ARIZ:
theory and practice

Dmitry KUCHARAVY, dmitry.kucharavy@insa-strasbourg.fr

LGECO - Laboratory of Engineering Design
INSA Strasbourg - Graduate School of Science and Technology
24 boulevard de la Victoire, 67084 Strasbourg Cedex, France

April, 2006

objectives of the course

The release of atomic power has changed everything except our way of thinking... the solution to this problem lies in the heart of mankind.
(1945) Albert Einstein

- **To understand** the process of solving an inventive problem and to be able to follow this process for practical cases.
- **To practice** the Algorithm of Inventive Problem solving (Altshuller's ARIZ) and to be able to apply ARIZ partially for practical cases.
- **To understand** the scope of usage of ARIZ as well as the studied methods, techniques and knowledge from TRIZ.
- **To practice** the development of solution concepts for non-standard* inventive problems.

* problems, which cannot be solved by direct application of techniques like 76 Inventive Standards, or 40 Inventive Principles

course contents

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

1. **PROBLEM SOLVING PROCESS**
2. **PROBLEM ANALYSIS: Altshuller's ARIZ***
3. **PRACTICAL WORK on specific cases**

ARIZ: theory and practice

* ARIZ-85C

overview of the program

Day One: Example of analysis using Altshuller's ARIZ "Testing the parachute model"; Optional: Three riddles; Case example "Wire spool"; Learners' specific cases.

Day Two: PROBLEM SOLVING PROCESS: Analysis of the initial situation; PROBLEM ANALYSIS: Altshuller's ARIZ; Work on specific cases.

Day Three: PROBLEM ANALYSIS: Altshuller's ARIZ (case example); Work on specific cases.

Day Four: PROBLEM ANALYSIS: Altshuller's ARIZ (case example); Work on specific cases.

Day Five: Altshuller's ARIZ ; Presentation of results for working on specific cases; Summary of the course.

ARIZ: theory and practice

PROBLEM SOLVING PROCESS and it's particularities

You're either part of the solution or you're part of the problem.

Eldridge Cleaver

- ❑ **Historical overview**
- ❑ **Process of solving an inventive problem***
- ❑ **Analysis of the initial situation**
- ❑ **Practice: Contradiction formulation**

ARIZ: theory and practice

* Classical TRIZ

where does TRIZ come from?

Sources	❑ Available methods for inventive problem solving. ❑ Experience of inventors (contemporary and from antiquity) and scientists. ❑ Hundreds of thousands of patents. ❑ History of Technical Systems evolution.
Research	"..it is necessary to build a program that performs step by step systematic analysis of the problem, disclose, study and overcome technical contradiction*".
Systematization	❑ Extracted powerful solutions. Levels of innovative solutions. ❑ List of frequent (typical) contradictions and principles to resolve them. ❑ Idea of Contradiction model / Idea of Ideal Final Result model / Idea of Resource model. ❑ Techniques to overcome mental inertia. ❑ Preliminary knowledge about objective Laws of Technical systems evolution.
Analysis + Synthesis	❑ Multiple application for the first versions of ARIZ, Inventive principles, and Special organized information including selected scientific effects from physics, chemistry, geometry.. ❑ "..it is necessary to get a Theory of inventive problem solving. This theory gives ability to solve high level problems by a systematic way. This theory has to be based on the knowledge of objective Laws of Technical Systems Evolution*".
Results	❑ Theoretical basis: Laws of Technical systems evolution and trends of evolution for particular engineering systems. ❑ Set of methods for problem analysis including methods to overcome mental inertia. ❑ Set of techniques in order to resolve defined contradictions. ❑ Useful for Inventors practice Knowledge base, including thousands of effects from physics, chemistry, geometry, and other branches of science.

ARIZ: theory and practice

*© G.Altshuller, G.Filkovsky. Actual state of TRIZ. Baku. 1976

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.

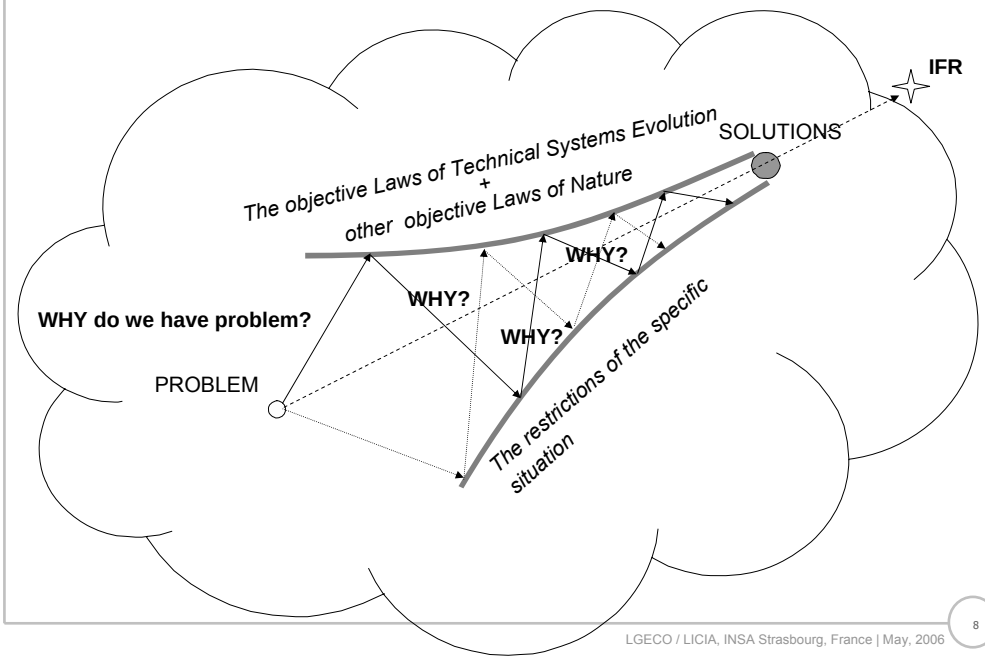
2. Idea of Contradiction as a problem cause

- 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.

how do we look for the solution to a problem?



structure of classical TRIZ

Theoretical basis	Methods	Techniques / Tools	Knowledge base
The Laws of Technical Systems Evolution	Algorithm of Inventive Problem Solving (ARIZ)	Principles for Physical Contradictions Elimination	Repository of descriptions the solutions obtained with TRIZ
	Contradictions analysis	Principles for Technical Contradiction Elimination (40 Inventive Principles + Altshuller's Matrix)	Collections of advanced inventions
	Su-Field Analysis	Standard Approaches to Solving Problem (76 Inventive Standards)	Pointers to effects: • physical • chemical • geometrical
	Function and Cost Analysis/TRIZ-enhanced	Function and Ideality Modeling (convergence)	Lists of substance-field resources most frequently used in inventive problem solving
	Methods for Creative Imagination Development (RTV)	- Modeling with Little Creatures; - Size-Time-Cost Operator (Dimensions-Time-Cost operator); - "Golden Fish" operator;	Repository of ideas drawn from science fiction literature
	Methods of Research problem analysis	Analysis of Inverse problem	TRIZ-based Software and database
	Multi screen scheme of strong thinking		

ARIZ: theory and practice

the history of ARIZ development

A PRE-PROGRAM ACHIEVEMENT

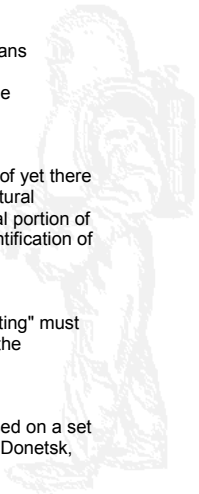
ARIZ-56 Strengths of ARIZ-56:
- It was precisely stated that solving a problem means revealing and resolving a technical contradiction;
- It incorporated the concept of reaching beyond the boundaries of the immediate subject.

THE SYNTHESIS OF A PROGRAM FOR PROBLEM-SOLVING BEGINS

ARIZ-59 The first steps, a chain of operations, appears. As of yet there is no system – the steps can be interchanged. "Natural prototypes" are moved to the end of the operational portion of ARIZ. A new and important step is introduced: identification of the Ultimate Final Result (Solution).

By the end of the 1950s it became obvious that a "method of inventing" must include, besides ARIZ, the patterns of technological evolution and the constantly growing knowledge base.

ARIZ-61 ARIZ-61 was an improved version of ARIZ-59, based on a set of seminars conducted in cities other than Baku in Donetsk, Tambov, Ryazan.



G.S.Altshuller, 1986. THE HISTORY OF ARIZ DEVELOPMENT

ARIZ: theory and practice

the history of ARIZ development

CLARIFICATION OF THE PROGRAM

ARIZ-64	ARIZ-64 introduces the section on "**Clarifying and verifying the problem statement**." This is a significant change and one that indicates a new direction in ARIZ development – as that of a tool for obtaining powerful solutions to difficult problems. The rules for fulfilling the recommendations have been introduced. The first **table of Innovation Principles** has been developed.
ARIZ-65	The first **limited contradiction table is introduced**. The word "ALGORITHM" has been introduced as an indication of the long-term objective for the development.
ARIZ-68	The first chapter of ARIZ-68 is divided into two parts: Selection of the problem and clarification of the problem statement. Special steps for handling psychological inertia are introduced. The knowledge base is significantly extended and structured…

During period from 1968 to 1971 – TRIZ seminars were organized in the following cities: Sverdlovsk, Kaunas, Moscow, Dzintary, Dushanbe, Baku, and Gomel... Altogether, more than 5,000 records related to 150 problems were available and provided for the transition to the next version: ARIZ-71…

ARIZ: theory and practice

G.S.Altshuller, 1986. THE HISTORY OF ARIZ DEVELOPMENT

the history of ARIZ development

THE PROGRAM BECOMES ONE OF THE ALGORITHMIC TYPE

ARIZ-71	…The program becomes more rigorous. In the process of analysis, the **operational zone** and its contradictory requirements have been identified (a prototype to the later physical contradiction). A **psychological operator** for modifying Dimensions, Time and Cost (DMC) has been introduced. The Contradiction Table has been brought to completion…
ARIZ-75	… is a logical continuation of ARIZ-71: more precise recommendations for each of the steps and stricter requirements for completing them. Continued analysis has revealed the existence of **physical contradictions**…
ARIZ-77	… the rigorousness of the program is significantly improved. The text includes multiple rules, notes and examples. A prototype of the physical contradiction on a micro-level (Micro-PhC) is introduced. Analysis of the solution process has been included as well…

…Beginning with ARIZ-82, a paradoxical process of **specialization/generalization** begins. In technology, ARIZ is targeted specifically toward the solving of difficult non-typical problems and the development of new standard solutions…

ARIZ: theory and practice

G.S.Altshuller, 1986. THE HISTORY OF ARIZ DEVELOPMENT

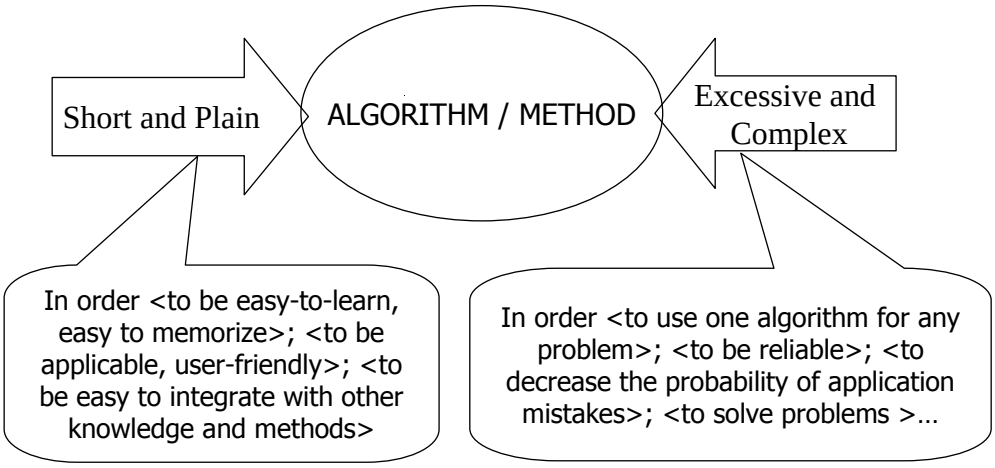
the history of ARIZ development

ARIZ-82 (modifications A, B, C and D) and ***ARIZ-85A***	…A new trend is in action: all recommendations and notes made by a teacher must be incorporated into the algorithm. All chapters of ARIZ (with the exception of the first) are improved, especially the operators having to do with transitioning from a physical contradiction to methods for eliminating it…
ARIZ-85B and C	… Significant changes in structure are introduced, including the second line of operations and the analysis of substance-field resources. The *former first chapter is no longer part of the algorithm as it is not rigorous enough compared to the other chapters.* The orientation towards ideality strongly increases as a void (empty space) is recognized as the most effective resource…

ARIZ: theory and practice

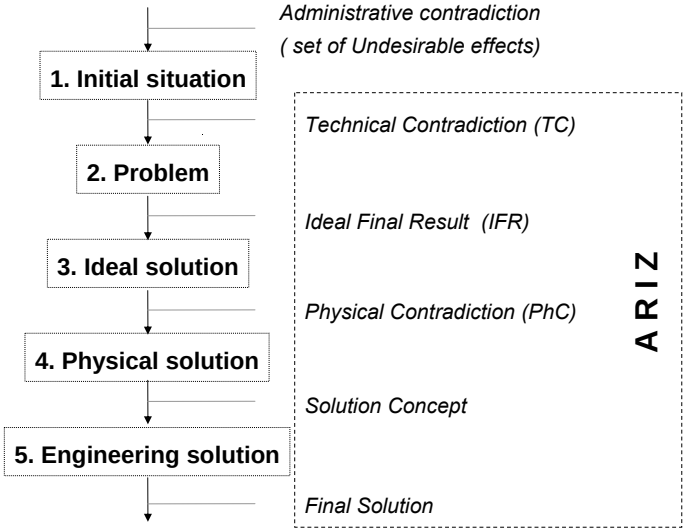
G.S.Altshuller, 1986. THE HISTORY OF ARIZ DEVELOPMENT

conflicting requirements from the algorithm



ARIZ: theory and practice

PROCESS OF SOLVING AN INVENTIVE PROBLEM



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

practice: avalanche

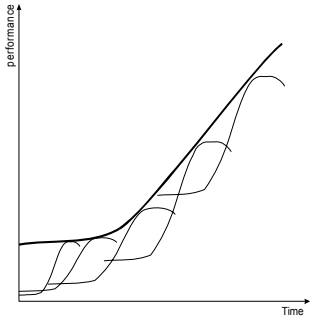
Source: http://www.fondation.maif.fr/

It is extremely difficult to find a person trapped under an avalanche. There exist various radio transmitters.

However, people do not like using such a transmitter "just in case"; the batteries of the transmitter need to be charged regularly, if an alarm switcher is installed it is impossible to switch it on at the right time.

What should be done?

ideal final result: why is it important?



increasing IDEALITY of technical systems:
During their evolution technical systems tend to improve the ratio between SYSTEM PERFORMANCE and the EXPENSES required to achieve this performance.

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

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

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

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

practice: power line support

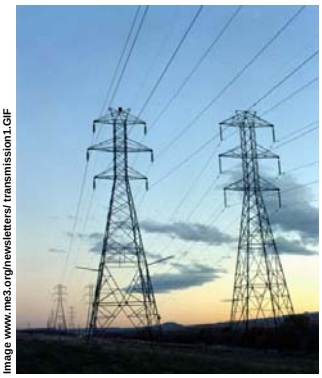


Image www.me3.org/newsletters/ transmission1.GIF

There are electricity pylons in the northern Russian tundra. The frozen ground is strong for most of the year but in summer, from time to time, the sunlight and increasing temperature creates a risk: the ground thaws out. The tall heavy pylon may fall down.

To reduce this risk helicopters patrol the power transmission line to evaluate the risk level. From time to time the helicopter takes ona specialist who detects the ground's strength. This method is unreliable, expensive and time-consuming.

It is necessary to propose a reliable easy method without landing the helicopter?

ideal final result - IFR

A definition of an IFR must describe what should be done in order to eliminate the undesirable effect whilst keeping the useful (positive) features.

Simplified definition of IFR:

The X-element, *itself, without harmful side effects*, eliminates

<*indicate the harmful action*>

whilst keeping the ability to provide

<*indicate the useful action*>.

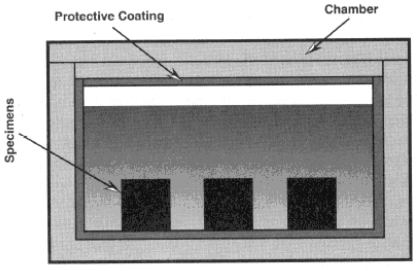
ARIZ: theory and practice

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?

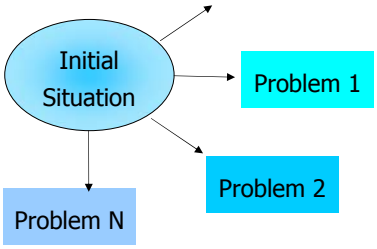


ARIZ: theory and practice

* 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

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*.

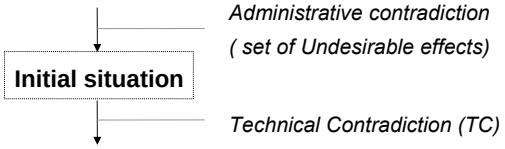
Initial situation - is any situation with chosen undesirable (harmful) feature(s) or properties.

ARIZ: theory and practice

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.

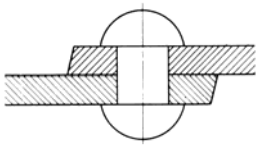


Known techniques and methods:

- 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)

ARIZ: theory and practice

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.

MAXI-problem:

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

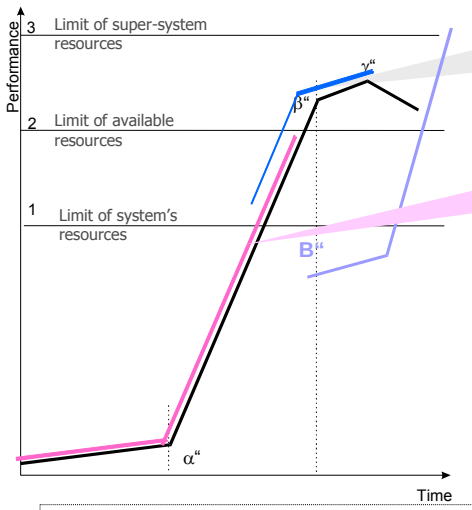
Riveted joint: The riveted joint makes a firm junction. The mobility of the junction is performed for the rivet joint.

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.

ARIZ: theory and practice

mini- OR maxi- problem?



maxi-problem Solution concepts are required

mini-problem Solution concepts are required

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

ARIZ: theory and practice

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)

practice: increase brightness of a LCD display

Initial situation:

To backlight liquid crystal displays fluorescent lamps are applied. For displays larger than 12", in order to improve the brightness of the display, two lamps are installed on both sides of the display. In order to improve the homogeneity of the backlight a set of special sheets are applied.

It is necessary to improve the brightness of the LCD display by 20%.

What should be done?

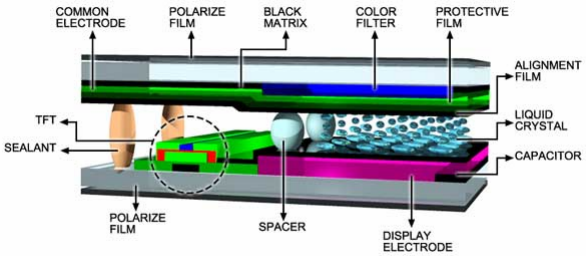
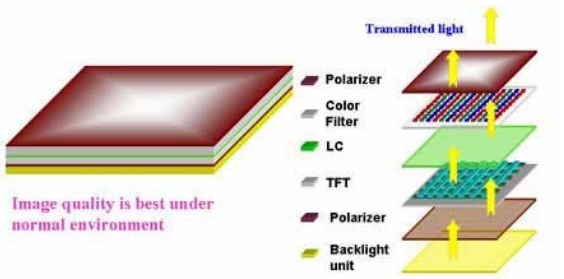


Figure A



Source: www.toppoly.com.tw.

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)?

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

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

d. What is the roughly acceptable expense?

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

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

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?

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.

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).

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).

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

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).

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

nine steps: 0.4. - 0.5

0.4. Determine the required quantitative characteristics:

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

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

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.

_____

_____

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

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 development of a technical solution. If the problem is still unsolved, go to 0.8.

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

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?

_____

_____

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

nine steps: 0.9

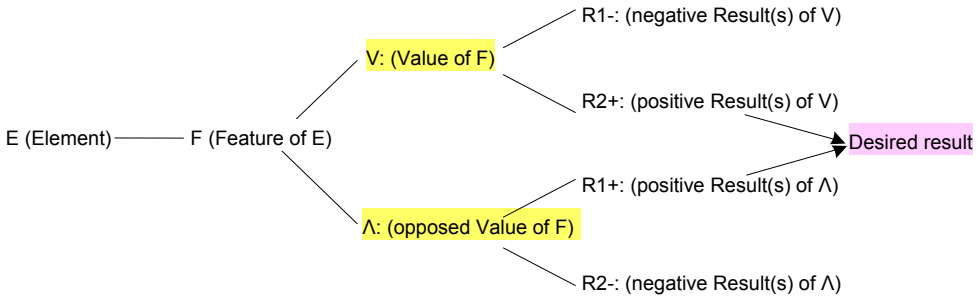
Use STC (Size, Time, Cost) operator.

PROCEDURES	CHANGING THE OBJECT OR PROCESS	HOW CHANGED PROBLEM IS SOLVED	PRINCIPLE USED IN THE SOLUTION
S → 0 (bit by bit)			
S → ∞ (bit by bit)			
T → 0 (bit by bit)			
T → ∞ (bit by bit)			
C → 0 (bit by bit)			
C → ∞ (bit by bit)			

* Altshuller G.S. ALGORITHM OF INVENTION. Moscow: Moscowskiy Rabochy. (1st ed.-1969; 2nd ed.-1973) p.p. 120-138

CONTRADICTION

…The main act of inventing to be the discovery of a contradiction…

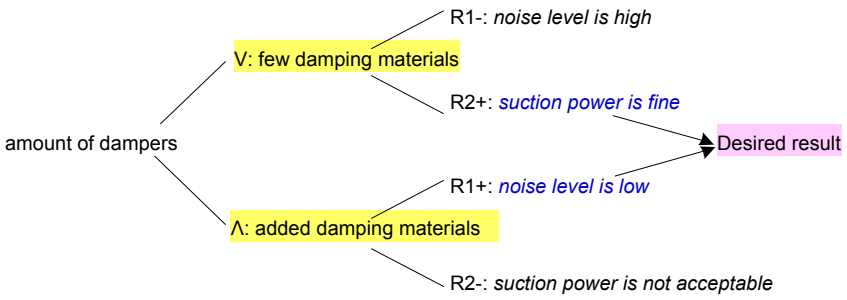


- It is recommended to start constructing such a description from the **Right side** (from the Desired result).
- Result(s) 1 and 2 for opposed Values of F (Feature of E) should be **inverse**. *If R1 is negative for V it should become positive for Λ.*
- Values of F (Feature of E) should be opposed. Feature and Element are disclosed to the complete model. The model should be logically **harmonized** in accordance with the initial situation.

ARIZ: theory and practice

contradiction formulation

Source: http://www.appliancepros.com/miele/inside.jpg



ARIZ: theory and practice

contradiction formulation (2)

Pattern:
TC-1: *If there is <**V**>, then <**R2+**>, but <**R1-**>*
TC-2: *If there is <**Λ**>, then <**R1+**>, but <**R2-**>*

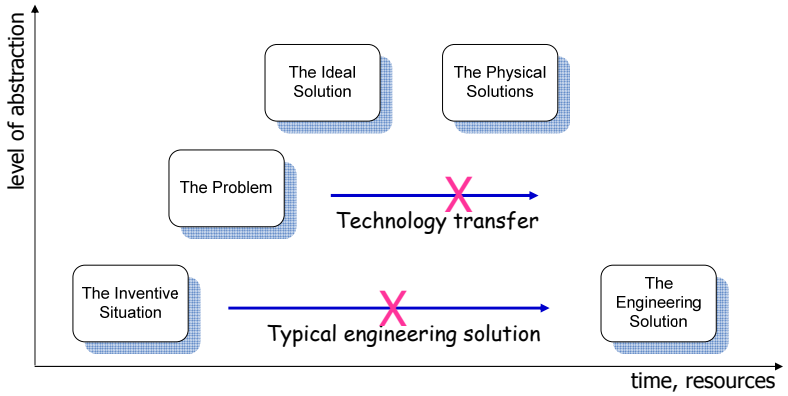
TC-1: If there are <a few damping materials>, then <the *suction power is fine*>, but <*the noise level is high*>.

TC-2: If there are <additional damping materials>, then <*the noise level is low*>, but <*the suction power is not acceptable; the dimensions of the vacuum cleaner are large, the temperature of the fan-motor increases*>.

Desired result: It is necessary with minimal changes of the system to <*reduce VC noise*> without degrading <*suction power*>

ARIZ: theory and practice

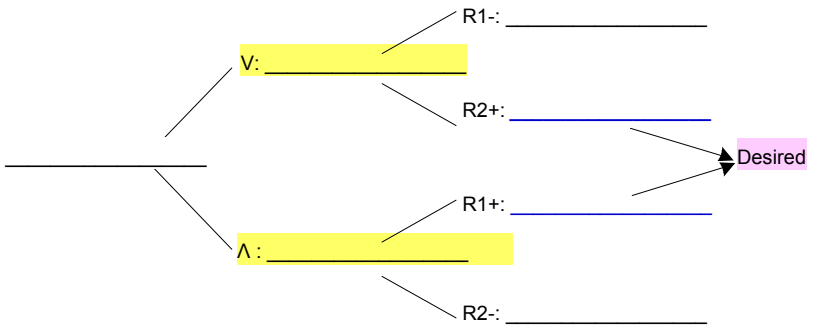
line of problem analysis and contradiction



ARIZ: theory and practice

practice: contradiction formulation

AVALANCHE:



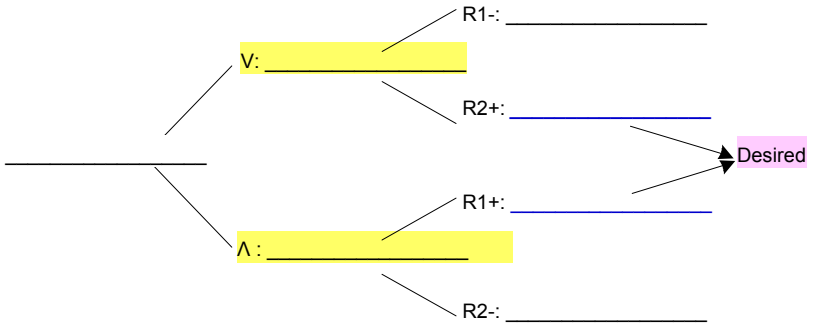
ARIZ: theory and practice

LGECO / LICIA, INSA Strasbourg, France | May, 2006

39

practice: contradiction formulation

POWER LINE SUPPORT:



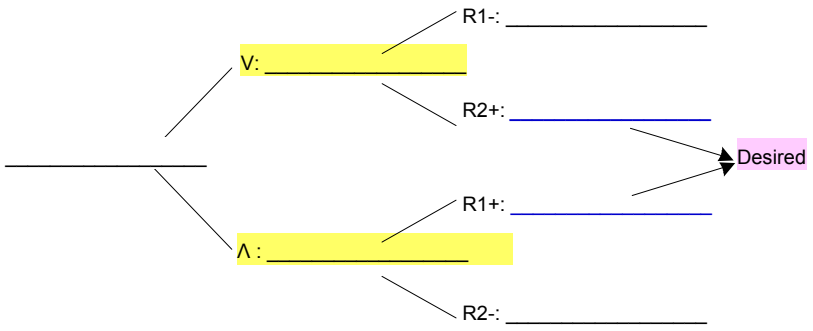
ARIZ: theory and practice

LGECO / LICIA, INSA Strasbourg, France | May, 2006

40

practice: contradiction formulation

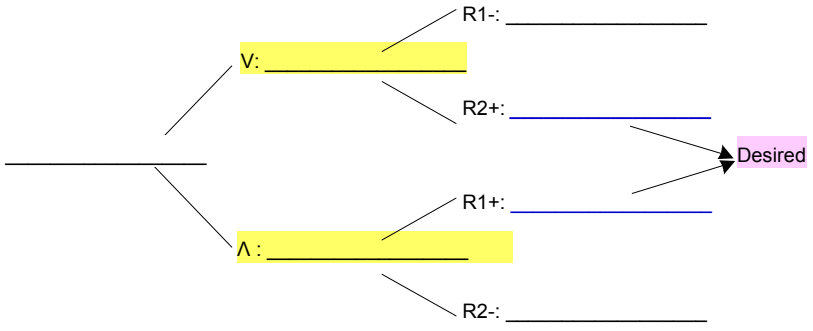
STUDYING EFFECTS OF ACIDS ON METAL ALLOYS:



ARIZ: theory and practice

practice: contradiction formulation

RIVETED JOINT:



ARIZ: theory and practice

PROBLEM ANALYSIS: Altshuller's ARIZ

- **Logic of problem processing**
- **Types of contradictions**
- **Useful models and definitions**
- **Structure of ARIZ**
- **Case example**
- **Practice on case example**

ARIZ: theory and practice

* Classical TRIZ

LOGIC OF PROBLEM PROCESSING

Initial situation consists of many Problems (Conflicts and Conflicting Pairs)

ARIZ

Model of problem = Intensified Contradiction + Product and Tool + Requirements of X-element

Ideal Final Result (IFR) = Intensified Conflict + Resources (Time, Space, Substances+Fields)

Physical Contradiction (PhC) = Resources(Physical States) + Intensified Conflicting requirements

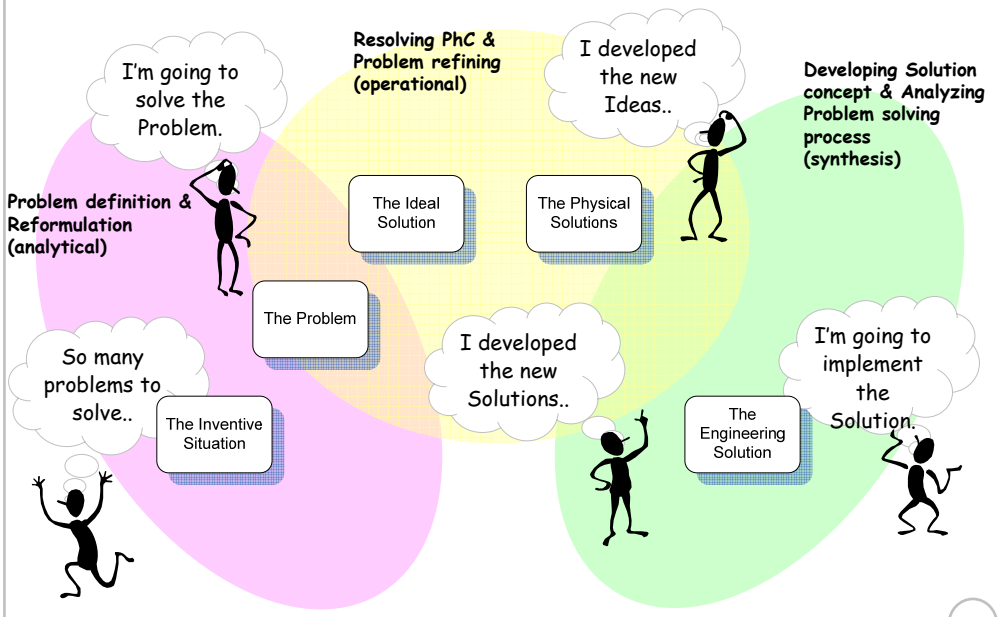
Solution Concept = Primary Set of (Features + Specific Values) + Principal Resources list

Final Solution = Complete Set of (Features + Specific Values) + Exhaustive Resources list

Analysis of Problem Solving Process

ARIZ: theory and practice

phases of the problem solving process



ARIZ: theory and practice

TYPES OF CONTRADICTIONS

Administrative contradiction *(Initial situation) = Undesirable Effect + Demands*

RIVETED JOINT:

Technical contradiction = *Two opposite states of Tool + (Positive + Negative)consequences*

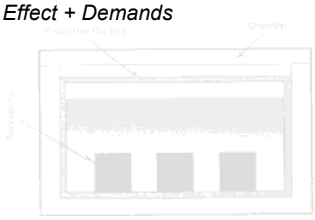
Physical Contradiction *(PhC) = Resources(Physical States) + Intensified Conflicting requirements*

ARIZ: theory and practice

TYPES OF CONTRADICTIONS (2)

STUDYING EFFECTS OF ACIDS ON METAL ALLOYS:

Administrative contradiction *(Initial situation) = Undesirable Effect + Demands*



Technical contradiction = *Two opposite states of Tool + (Positive + Negative)consequences*

Physical Contradiction *(PhC) = Resources(Physical States) + Intensified Conflicting requirements*

USEFUL MODELS AND DEFINITIONS

- **Law of Ideality increase & Ideal Final Result**
- **Initial situation: mini-problem and maxi-problem**
- **How to handle the special terms?**
- **Conflicting pair:** Product and Tool
- **Model of problem =** Conflicting Pair + Intensified Conflict + Requirements to X-element
- Resources: **Operational zone, Operational Time, Substance and Fields**

Law of Ideality increase & Ideal Final Result

increasing IDEALITY of technical systems:

During their evolution technical systems tend to improve the ratio between the SYSTEM PERFORMANCES and the EXPENSES required to perform these performances.

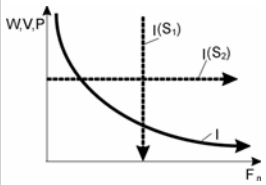


Fig. 1

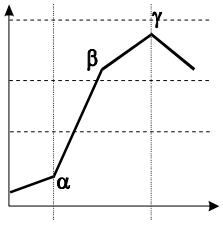


Fig. 2

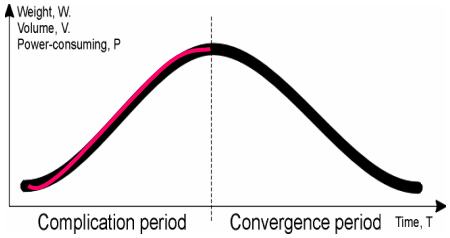


Fig. 3

ARIZ: theory and practice

special terms: how to handle them?

- Instead of specific terms it is necessary to use functional or feature "names" in accordance with the context of the problem analysis.

- *WHY? "…To reduce mental inertia, special terms associated with the tool and environment should be replaced with easy words, because special terms:*
  - *impose old concepts about working principles of the tool;*
  - *can hide certain properties of the elements described in the problem situation;*
  - *narrow the range of possible states of a substance…"*

Special term	⇨ Function / feature	⇨ "new name"
Electric Battery		
Ampoule		
Backlight		

ARIZ: theory and practice

definition of the function

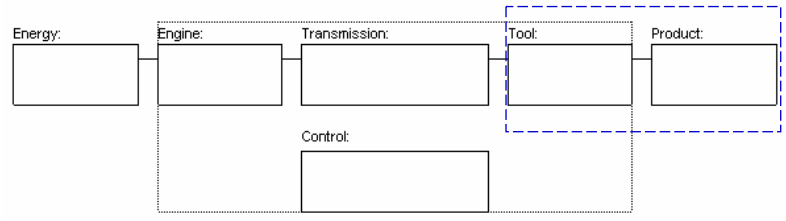
How do we define the function?

1. Describe a function using common words and expressions:
   pencil: to write, to draw
2. Reformulate the defined function in accordance with pattern:
   <verb> + <subject/noun> + <..additives/object..>
   <draw> <letters>; <supply> <ink>
3. Reformulate redefined function according to pattern:
   <change> + <features (values)>
   <change> <color> <of base (e.g. paper)>

ARIZ: theory and practice

conflicting pair: Product and Tool

- The **PRODUCT** is the element that needs to be processed (manufactured, moved, changed, improved, protected from a harmful influence, revealed, measured etc.) according to the problem conditions.
- The **TOOL** is the element that directly interacts with the product (e.g., mill rather than a milling machine; fire rather than a burner).



ARIZ: theory and practice

Intensified Conflict

- Within intensification it is necessary to consider circumstances of conflict intensification for **both**: *negative* and *positive* after-effects as well.
- It is recommended to apply *Size-Time-Cost operator* in order to intensify the conflict systematically.

Practice: *Intensified conflict*

Vacuum Cleaner noise:

_____

_____

Test metal alloys:

_____

_____

Brightness of LCD display:

_____

_____

Operational Zone, Time, and Su-Field Resources

The **Operational Zone (OZ)** – this is the space where the conflict indicated in the Problem Model appears.

The **Operational Time (OT)** – this is the available resource of time: the time when conflict occurs - T_1 and the time before the conflict - T_2.

The **Substance and Field Resources (SFR)** – there are substances and fields that already exist or may be easily obtained according to the problem conditions.

There are **three types of SFR**:

1. System (internal) resources:
   a) SFR of the tool; b) SFR of the product.
2. Available (external) resources;
3. SFR of super-system.

reference data: *frequently used substances**

Substances with change of phase:

- easy-to-evaporate (gas generators)
- easy-to-dissolve (etching)
- easy-to-burn-out (low temperature of inflammation)
- easy-to-melt (low melting temperature)
- exothermal & endothermic (heat generation & heat-absorption)
- Substances with shape-memory effect (metallic, plastics)

Usually cheap substances:

- "void"
- foam
- air, water
- loose (granular) materials
- waste materials

Other substances:

- ferromagnetic substances (monolith, powder, liquid)
- capillary-porous substances
- viscous / sticky substances
- luminophors substances
- substances with salient taste and smell

*I.L.Vikentiev, I.K.Kaikov. LADDER TO IDEAS. 1992. Novosibirsk. (in Russian)

summary for substance-field resources

	System resources (internal)	**Available** resources (external)	Resources from **Super-System**
Space void, empty space, areas			
Time before, during, after			
Substances solid, liquid, gas, plasma			
Fields (M A Th Ch E M)			
Information measurement, detection, signals			
Functional additional function for existing part			

STRUCTURE OF ARIZ

Analytical Stage	**PART 1. ANALYZING THE PROBLEM (7 steps)**
	PART 2. ANALYZING THE PROBLEM MODEL (3 steps)
Operational Stage	**PART 3. DEFINING IDEAL FINAL RESULT (IFR) AND PHYSICAL CONTRADICTION (PhC) (6 steps)**
	PART 4. MOBILIZING AND UTILIZING OF SUBSTANCE-FIELD RESOURCES (SFR) (7 steps)
	PART 5. APPLYING THE KNOWLEDGE BASE (4 steps)
Evaluation & Engineering (Synthetic) stage	**PART 6. CHANGING OR SUBSTITUTING THE PROBLEM (4 steps)**
	PART 7. ANALYZING THE METHOD OF RESOLVING THE PHYSICAL CONTRADICTION (4 steps)
	PART 8. APPLYING THE OBTAINED SOLUTION (3 steps)
	PART 9. ANALYZING THE PROBLEM SOLVING PROCESS (2 steps)
Appendix	**Table 1. Typical Graphic Models of Technical Contradictions (9 models)**
	Table 2. Principles for resolving the Physical Contradictions (11 principles)

ARIZ: theory and practice

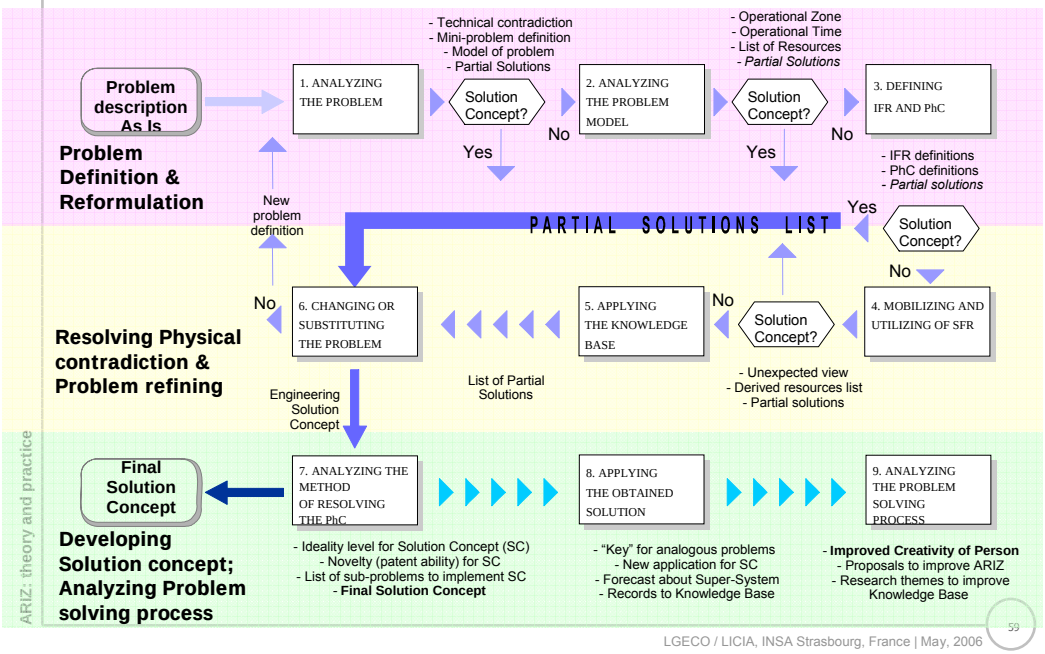
structure of ARIZ (2)

Altshuller's algorithmic program consists of:

- Nine (9) interconnected Parts;
- Forty (40) interconnected Steps;
- Forty-four (44) interlinked Comments to perform steps;
- Eleven (11) Rules to perform steps;
- Seven (7) Attentions to prevent frequently occurring mistakes;
- Two (2) appendices to facilitate a problem formulation and solving process;
- Five (5) case examples to illustrate the particularities of applying ARIZ + 1 case example in the body of ARIZ's text

ARIZ: theory and practice

ARIZ flowchart



analytical stage

*... **When solving a problem, do it as if you will get a score not for the right answer, but for the process of attaining the answer.** Consider it most important to build a ladder of answers to all the questions. This ladder has to have two special characteristics: the first is the absence of a breakdown in the logical process, the second is the presence of some sort of sudden twist...*

PART 1. ANALYZING THE PROBLEM

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

PART 2. ANALYZING THE PROBLEM MODEL

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

ARIZ: theory and practice

operational Stage

PART 3. DEFINING THE IDEAL FINAL RESULT (IFR) AND PHYSICAL CONTRADICTION (PhC)

As a result of applying Part 3 the image of the Ideal Final Result (IFR) should be formulated . The Physical Contradiction (PhC) that stands in the way of achieving the IFR should be identified too.

PART 4. MOBILIZING AND USING SUBSTANCE-FIELD RESOURCES (SFR)

Part 4 of ARIZ includes systematic procedures to increase availability of resources. It considers the derivative SFR that can be obtained almost free of charge through slight modification of the already available resources. Steps 3.3-3.5 began the transition from the problem to the solution based on the application of physics; Part 4 continues in this direction.

PART 5. APPLYING THE KNOWLEDGE BASE

In many cases, Part 4 of ARIZ helps to achieve a solution concept, so it is possible to go to Part 7 of ARIZ. If no solution is achieved after step 4.7, Part 5 is recommended.
The purpose of Part 5 of ARIZ is to mobilize all experience accumulated in the TRIZ knowledge base.

ARIZ: theory and practice

synthetic stage

PART 6. CHANGING OR SUBSTITUTING THE PROBLEM

Simple problems can be solved through direct elimination of the Physical Contradiction… Complex (non-typical) problem solving is usually associated with changing the problem statement, that is, with removing the initial restrictions created by mental inertia – those that seem obvious from the beginning.

…inventive problems can not be precisely formulated at the beginning.
***The process of problem solving is the process of correcting (reformulating) the problem statement**.*

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. The Physical Contradiction should be resolved almost ideally, "without nothing".

PART 8. APPLYING THE OBTAINED SOLUTION

The real innovative idea not only solves the particular problem, but also provides a universal "key" to many other analogous problems. The purpose of Part 8 of ARIZ is to maximize utilization of resources unveiled by the obtained solution concept.

ARIZ: theory and practice

perfection stage

PART 9. ANALYZING THE PROBLEM SOLVING PROCESS

Every problem solved using ARIZ has to increase the creative potential of the person. To achieve that, however, a thorough analysis of the solution process is required. This is the main purpose of the final Part 9 of ARIZ.

case example:
simulator of meteorite collision*

A steel ball of 3 to 5 millimeters is injected into a high speed jet and accelerated to collide with a sample of spacecraft shell. The traces and damage on the sample of spacecraft shell should be examined.

When the speed of the ball was 8 kilometers per second the installation performed adequately. The explosion chamber can provide a high speed jet of up to 50 kilometers per second.

However, at 16 kilometers per second the balls disintegrated when entering the jet due to the stress induced by high acceleration.

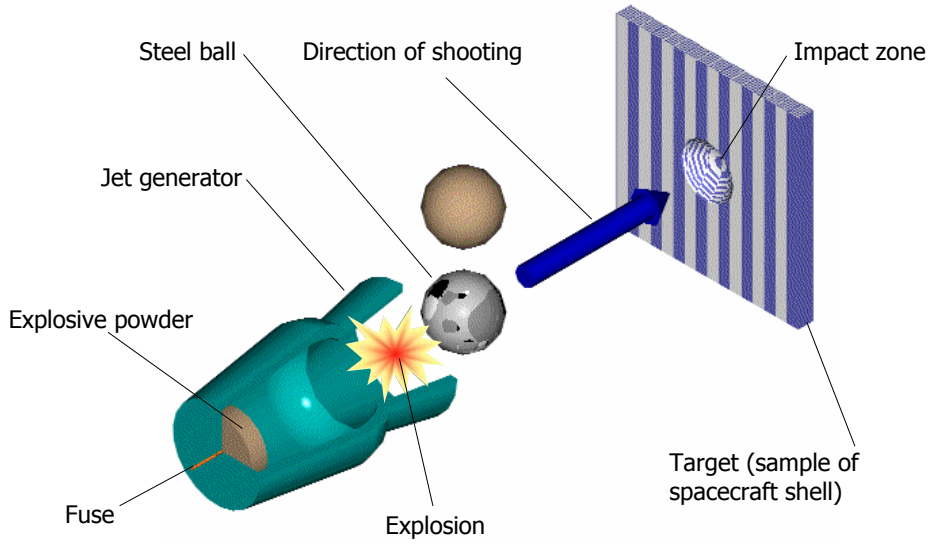
1. Attempts to use stronger or softer materials for the ball failed. 2. Attempts to use a bigger ball failed as well. 3. Trials to change the speed of the ball on introduction into the high speed jet or accelerating the ball step-by-step were not successful. 4.Accelerating the sample so that it collides into the ball leads to immense energy consumption and sample disintegration.

It is required to test the spacecraft shell at a speed of at least 16 kilometers per second.

What should be done?

* Source: G.S.Altshuller, 1986

simulator of meteorite collision (2)



Pictures: Denis Cavallucci, 2000

ARIZ: theory and practice

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

1.2. define the conflicting elements

1.3. describe graphic models for technical contradictions

1.4. select a graphic model for further analysis

1.5. intensify the conflict

1.6. describe the problem model

1.7. apply the inventive standards

ARIZ: theory and practice

1.1. formulate the mini-problem

Description: a system for <accelerate a steel ball> consists of <an explosion chamber, hyper jet, and steel ball>.

***TC#1**: If there is <a high speed (16km/s) hyper jet>, then <it provides the required acceleration>, but <it destroys the ball>.*

***TC#2**: If there is <a "low speed" (8km/s) hyper jet>, then <it does not destroy the ball>, but <it does not provide the required acceleration>.*

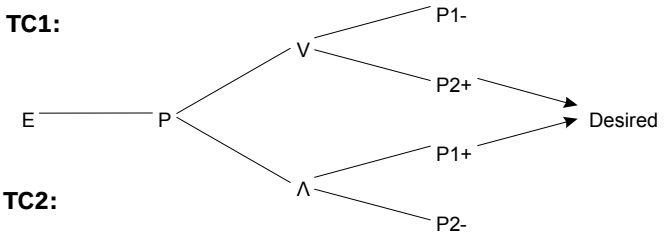
The desired result:

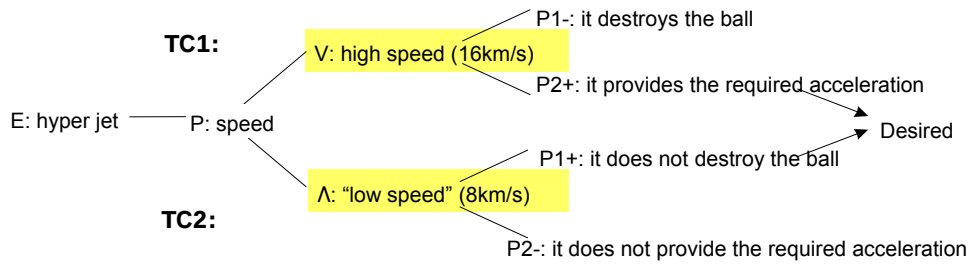
It is necessary, with minimum changes to the system, <to provide the required acceleration while keeping the ball whole>.

ARIZ: theory and practice

comments for problem description

ENV model*





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

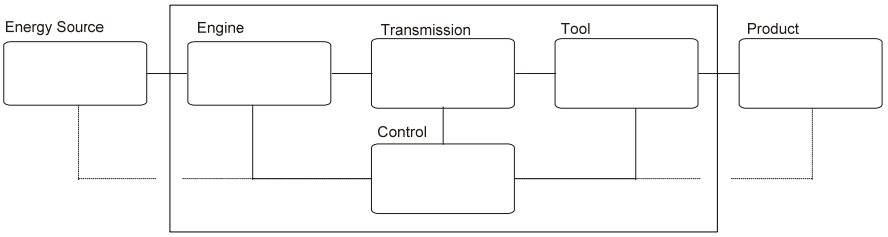
ARIZ: theory and practice

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:

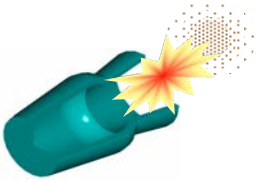


Conflicting pair:
Product - *ball*
Tool – *hyper jet (high speed, "low speed")*

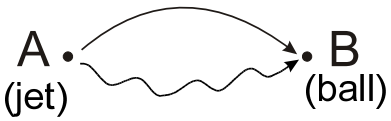
ARIZ: theory and practice

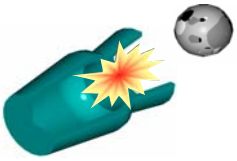
1.3. describe graphic models …

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

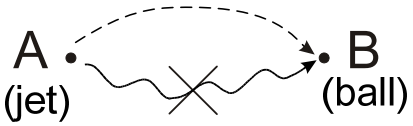


TC #1:
high speed jet





TC #2:
"low speed" jet



Pictures: Denis Cavallucci, 2000

ARIZ: theory and practice

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 accelerate a steel ball>

Chosen contradiction:

***TC #1**: If there is <a high speed (16km/s) jet>, then <it provides the required acceleration>, but <it destroys the ball>.*

* 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 "high speed" jet (16km/s) there is a "super-high-speed jet (>> 16km/s)" for TC#1.

The speed of gas is so high that acceleration is multiplied by N, our ball becomes a fine powder and does not impact the target anymore.

* see Size-Time-Cost operator (STC)

1.6. describe the problem model

Formulate the Problem Model to indicate the following:

1) the conflicting pair (from 1.2);
2) the intensified conflict definition (from 1.5);
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:
‹ ball › and ‹ hyper jet ›.

(2) Intensified Conflict:
‹The super-high-speed jet› accelerates ‹ the ball › adequately, but ‹the ball disintegrates when entering the jet›.

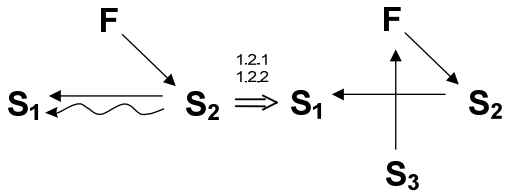
(3) Problem:
It is necessary to find an X-element which keeps the ability of ‹the super-high-speed jet to accelerate the ball› and prevents ‹the ball from disintegrating ›.

* compare with the Initial situation description

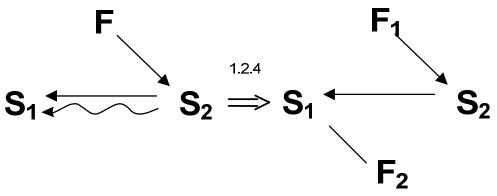
ARIZ: theory and practice

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 – ball;
S_2 – hyper jet;
F – mechanical (aerodynamic)
S_3 - ??, F_2 - ??



ARIZ: theory and practice

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 .

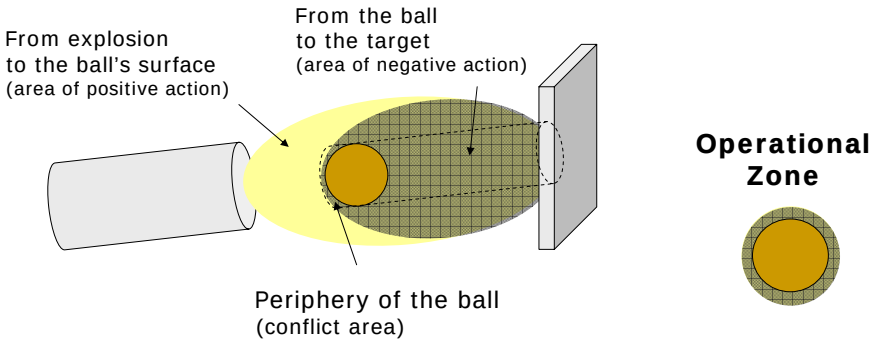
2.1. define the operational zone (OZ)

2.2. define the operational time (OT)

2.3. define the substance-field resources (SFR)

2.1. define the operational zone (oz)

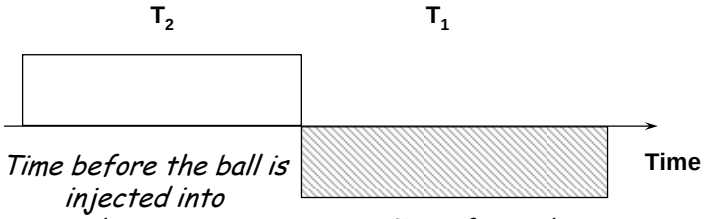
Analyze and describe the **Operational Zone** (OZ).



Definition of the Operational Zone:
surface layer of the ball + the layer of the jet in the vicinity of the ball
= **periphery of the ball.**

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.



Time before the ball is injected into a hyper jet

Time from when the ball starts to interact with the hyper jet until impact with the target (very short time <0.001s) = **Acceleration time**

ARIZ: theory and practice

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:
Hyper jet (Gases at high-speed);
Ball (Material, Shape);
Mechanical Field (Aerodynamic).

Available (external) resources:
Thermal field of hyper jet; Sample (target);
_____.
_____.

SFR of the super-system
Gravity; Air pressure, humidity, temperature;
_____
_____.

ARIZ: theory and practice

* see Multi-screen analysis and Summary for substance-field resources

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
3.2. intensify the definition of IFR-1
3.3. identify the physical contradiction for the macro-level
3.4. identify the physical contradiction for the micro-level
3.5. formulate IFR-2
3.6. apply the inventive standards to resolve the physical contradiction

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> (1.6)
within the <Operational Time> (2.2)
inside the <Operational Zone>, (2.1)
and keeps the tool's (1.6) ability to provide
<indicate the useful action> (1.6).

The X-element, without complicating the system and without harmful side effects, eliminates
‹*disintegration of the ball*›
within ‹*the Acceleration time*›
inside the ‹*Periphery of the ball*› and keeps the ‹*hyper jet's*›
ability ‹*to accelerate the ball*›.

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> eliminates
<the negative effect>
inside the <Operational Zone>
within the <Operational Time> and provides
<a useful effect> without complicating the system and without harmful side effects.

‹***Gases at high-speed***› eliminate
‹*disintegration of the ball*›
inside the ‹*periphery of the ball*›
within ‹*the acceleration time*› and provides
‹*acceleration of the ball*› without complicating the system and without harmful side effects.

ARIZ: theory and practice

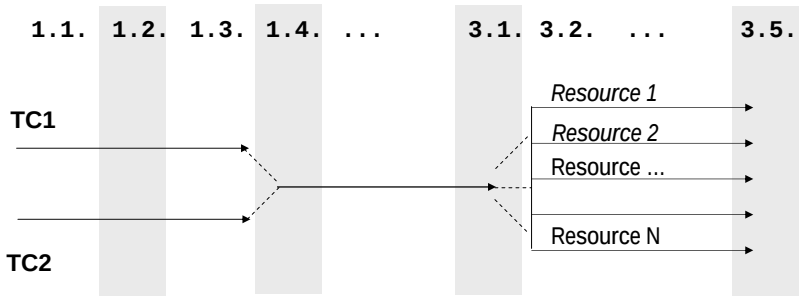
3.2. intensify the definition of ifr-1 (2)

‹***A metallic ball***› eliminates
‹*disintegration of the ball*›
inside the ‹*periphery of the ball*›
within ‹*the acceleration time*› and provides
‹*acceleration of the ball*› without complicating the system and without harmful side effects.

‹A ***mechanical field (Aerodynamic)***› eliminates
‹*disintegration of the ball*›
inside the ‹*periphery of the ball*›
within ‹*the acceleration time*› and provides
‹*acceleration of the ball*› without complicating the system and without harmful side effects.

ARIZ: theory and practice

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 <Resource in 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
has to… <indicate the opposite physical macro-state>
to perform <indicate another conflicting action or requirement>.

the <*gases inside the periphery of the ball*>,
within the <*acceleration time*>,
have to… <be high-speed flow "gas-proof" (do not transmit hyper jet)>
to <*prevent disintegration of the ball*> and
have to <be low-speed flow "gas-leak" (transmit hyper jet)>
to <*accelerate the ball*>.

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 ‹"*force" particles/molecules of gas*›
in the ‹*periphery of the ball*› within the ‹*acceleration time*›
in order to ‹not transmit the hyper jet›
and there should be ‹"weak" particles of *gas* or nor particles at all›
in order ‹*to transmit hyper jet forces to the ball*›.

ARIZ: theory and practice

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 ‹*periphery of the ball*›
has to provide ‹"*force" particles of gas (to preserve the ball)* and/or
no particles of gas (to transmit gas forces to the ball)› itself
within the ‹*acceleration time* (‹0.001s) ›.

Comment:

"Force" particles should disappear at the end of T_1 – acceleration time.

Partial solution concept:

_____

_____

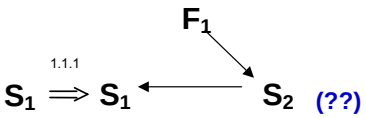
_____

_____

ARIZ: theory and practice

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.



When,
S_1 – periphery of the ball;
S_2 – ?? "force" / "weak" particles ;
F_1 – mechanical (aerodynamic?)

PART 4. mobilizing and utilizing substance-field resources (SFR)

At the step 2.3, the available resources, which can be used "free of charge", were identified. **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
4.2. to take a "step back" from the IFR
4.3. using a combination of substance resources
4.4. using "voids"
4.5. using derived resources
4.6. using an electrical field (passed through)
4.7. using a field and field-sensitive substances

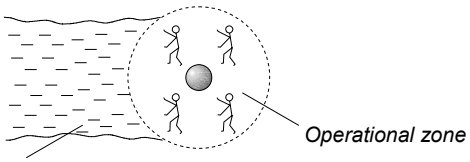
4.1. simulation with little creatures

Method of Simulation with Little Creatures (LC):

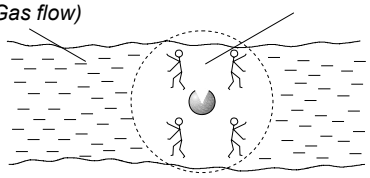
a) describe graphic model of conflict using the Simulation with Little Creatures (SLC);

b) modify this graphic model so that "Little Creatures" act without conflict.

1.



2.



One group of LC
(preserve ball)

There is no disintegration, but there is no acceleration as well.

Another group of LC
(transmit gas flow)

There is acceleration, but there is disintegration as well.

ARIZ: theory and practice

* Source: G.S.Altshuller, 1986

4.1. simulation with little creatures (2)

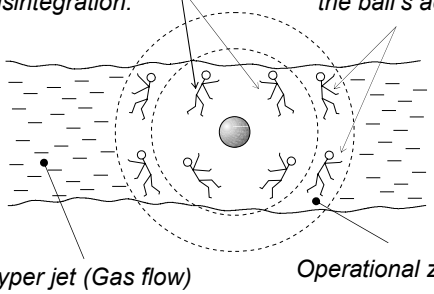
a) describe the graphic model of conflict using the Simulation with Little Creatures (SLC);

b) modify this graphic model so that the "Little Creatures" act without conflict.

The first team of LC compresses the ball to prevent its disintegration.

The second team of LC compensates (neutralizes) each other, in order to allow the ball's acceleration.

3.



Both groups of LC work together.
Eureka!
There is acceleration, but there is no disintegration.

ARIZ: theory and practice

* Source: G.S.Altshuller, 1986

4.1. simulation with little creatures (3)

Corollaries:

1. There should be the “force particles” in the Operational zone (periphery of the ball – diameter 5-8mm) within Operational time T_1 (acceleration time <0.001s) in order to compress the ball from all sides: it will protect the ball from disintegration and it will allow the ball’s acceleration.

2. There should be a substance, which will effect forces of compression from all sides for a very short time (a pulse-like impact).

3. Particles should disappear or became indistinguishable from gas flow particles (in accordance with Rule 7) at the end of Operational time (T_1).

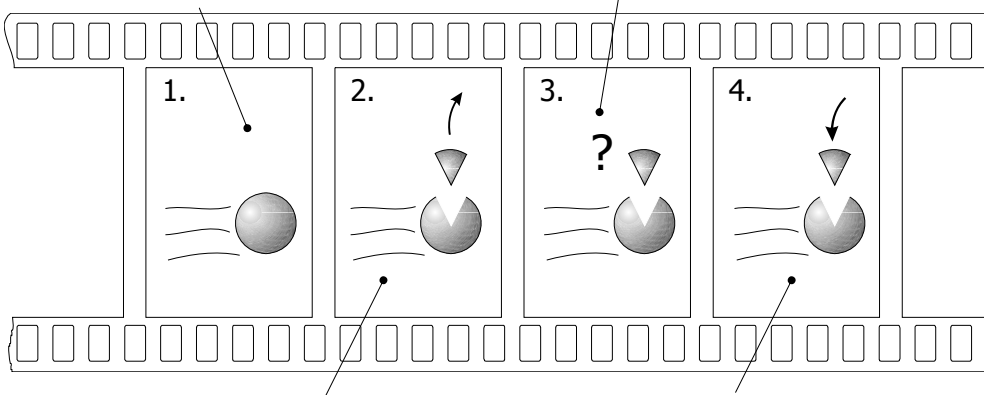
ARIZ: theory and practice

* Source: G.S.Altshuller, 1986

4.2. to take a "step back" from the IFR

1. **IFR:** The speed of the gas jet is 20km/s, but the whole ball arrives at its target.

3. **Micro-problem:** How to put back the lost particle?



2. **A Step back from the IFR:** One small particle lost contact with the ball during acceleration.

4. **Solution for the micro-problem:** Radial-force (“backmoving”) is applied to the lost particle.

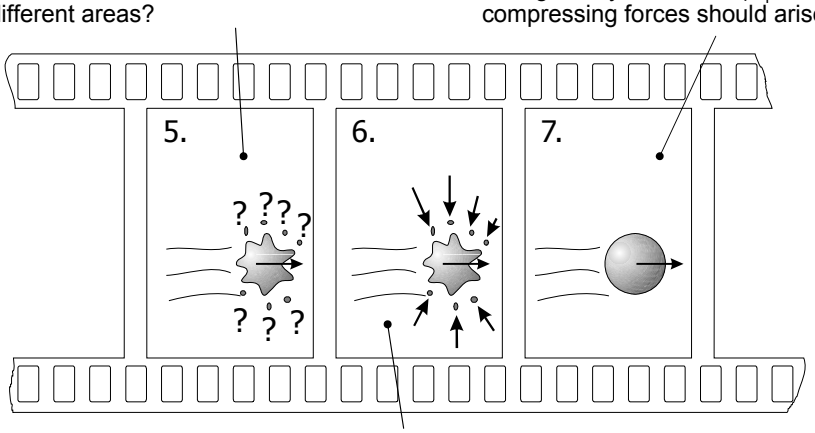
ARIZ: theory and practice

* Source: G.S.Altshuller, 1986

4.2. to take a "step back" from the IFR (2)

5. **Intensification of the micro-problem:** How to put back a lot of lost particles? All of them lost contact with the ball in different areas?

7. **Transition from the micro-problem to the real one:** In the Operational zone during a very short time (T_1 <0.001s) compressing forces should arise .



6. **Solution of the intensified micro-problem:** Radial-forces (“backmoving”) are applied to all lost particles simultaneously.

* Source: G.S.Altshuller, 1986

ARIZ: theory and practice

4.3. using a combination of substance resources

Consider the possibility of using a mixture of the substance resources.

Partial Solution concept:

ARIZ: theory and practice

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:

_____

_____

_____

_____

ARIZ: theory and practice

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.

Partial Solution concept:

_____

_____

New problem:

_____

ARIZ: theory and practice

4.7. using a field and field-sensitive substances

Consider the possibility of solving the problem using a pair:
"field + substance additive that is responsive to this field".

Preliminary solution concepts:

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

5.3. applying the principles for resolving physical contradictions

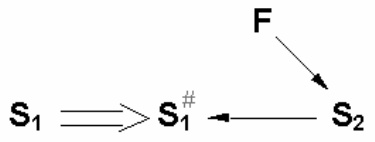
5.4. applying the pointer to physical effects and phenomena (passed through)

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 <periphery of the ball>
has to provide <"force" particles of gas (to preserve the ball) and/or no particles of gas (to transmit gas forces to the ball)> itself
within the <acceleration time>.



When,
S_1 - ball;
S_2 - _____;
F - very short time (T1 <0.001s) compressing forces should arise (4.2);
S_1# - particles of the ball;

ARIZ: theory and practice

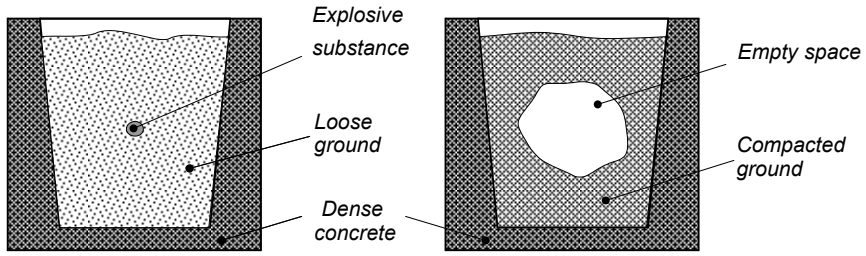
5.2. applying the problem-analogues

Consider the possibility of solving the problem (formulated as IFR-2, keeping in mind the SFRs considered in Part 4) by applying solution concepts to non-standard problems, that have already been solved using ARIZ.

Are there any known problem-analogues?

There is no direct analogue. The novelty of the proposed concept is to perform, for a short period of time, a superdense substance state (beyond the limits of elasticity) by implosion (supercompression).

Inverse analogue: making empty space inside an object by volumetric decontraction using the energy of an explosion. It was done for the same reason: to reinforce or to capsulate an object.



* Source: G.S.Altshuller, 1986

ARIZ: theory and practice

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).

9. Phase transition 3: using phenomena associated with phase transitions.

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

Partial 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

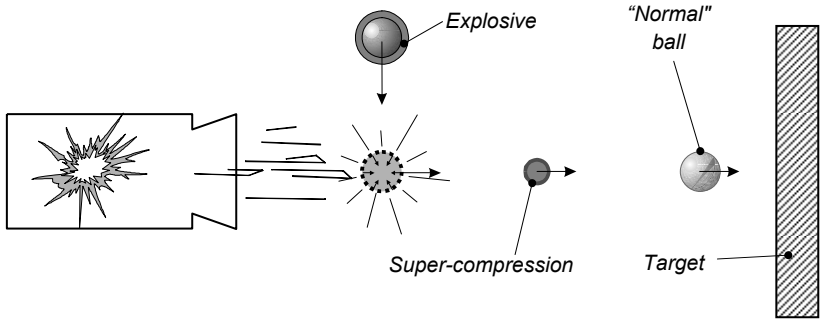
6.2. checking the problem formulation for combinations of several problems (passed through)

6.3. changing the problem (passed through)

6.4. reformulation of the mini-problem (passed through)

6.1. transition to the technical solution

The ball is covered with an explosive. The same explosive powder that is applied for the jet generator can be applied for covering the steel ball. Due to implosion, when the ball enters the hyper jet, its fragments do not fly away, but behave as a concentrated mass impacting the target with the required speed (16 km/s).
In fact, the steel ball is compressed and released (like a spring), however the time is enough to reach the target as a "normal" ball.



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

7.2. preliminary estimation of the solution concept

7.3. checking the priority of the solution concept through patent funds (passed through)

7.4. estimation of sub-problems to implement the obtained solution concept (passed through)

7.1. checking the solution concept

Consider each **introduced substance** and **field**.

Is it possible to apply available or derived SFRs instead of introducing substances / fields?

Can self-controlled substances be applied?

Correct obtained technical solution accordingly.

Self-controlling substances are substances that modify their state in a specific way in response to changes in environmental conditions (e.g., lose their magnetic properties when heated above the Curie point). Applying the self-controlling substances allows the system to be changed or its state modified without any additional devices.

7.2. preliminary estimation of the solution concept

Questioner:

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

Application of the explosive eliminates disintegration of the ball and keeps the ability to accelerate the ball.

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

The ‹gases inside the periphery of the ball› have to ‹restrain the high-speed jet›, in order to ‹prevent disintegration of the ball›, BUT
the ‹gases inside the periphery of the ball› have to ‹transmit a high-speed jet›, in order to ‹accelerate the ball›.

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 – amount and ignition speed of explosive powder. The properties of explosive powder enables control of the "integration" of ball speed.

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

The solution concept fits the limitations of testing a sample of spacecraft shell.

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

8.1. estimation of changes in the super-system

Define how the super-system that includes the changed system should be changed.

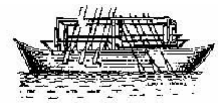


Fig 1. First steam-engine boat

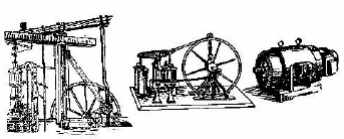


Fig 3. Evolution of electric motor

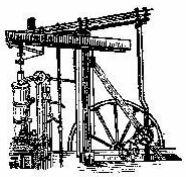


Fig 2. First electric motor design (as a steam engine)

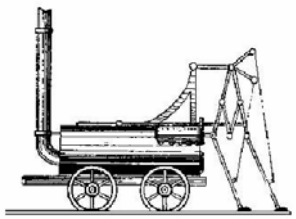


Fig 4. First steam-engine locomotive

* Source of pictures: Petrov V. 1999 Algorithm of inventive problem solving. Textbook. Tel-Aviv (in Russian)

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: _____

Inventive Standards: _____

_____

_____

_____

_____

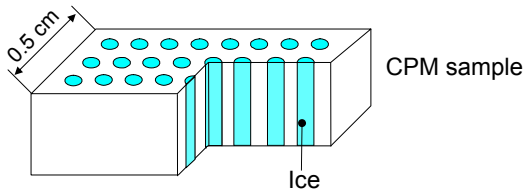
_____

summary (1)

What is useful?	What is strange?	What are the strong points of ARIZ?

Practice:
TESTING A CAPILLARY-POROUS SAMPLE

For a laboratory strength test the capillary-porous sample has to be saturated with water and be frozen. For the next stage of the test it is required to eliminate ice from the porous sample without heating. After this operation, another strength test is performed.
However, to eliminate the ice from the sample without heating takes a long time. It is required to eliminate the ice from the sample completely within an hour or faster.
What should be done?



ARIZ: theory and practice

1.1. formulate the mini-problem

Description: a system for <_____> consists of <_____, _____, _____, _____>.

***TC#1**: If there is <_____>, then <_____>, but <_____>.*

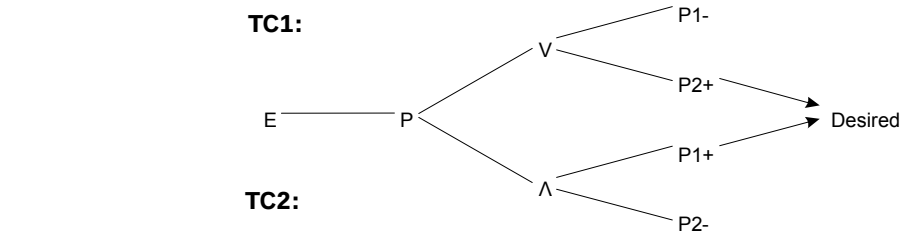
***TC#2**: If there is <_____>, then <_____>, but <_____>.*

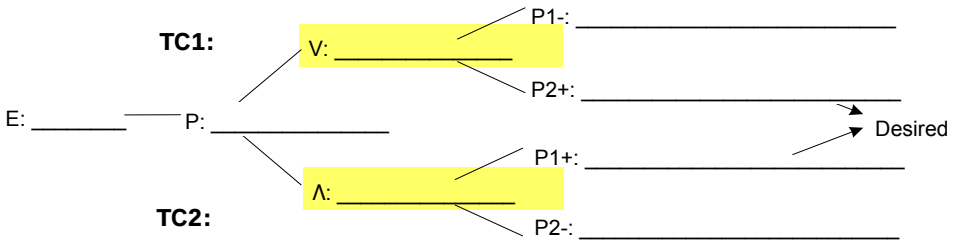
The desired result:

It is necessary, with minimum changes to the system, <_____>.

ARIZ: theory and practice

help for contradiction formulation





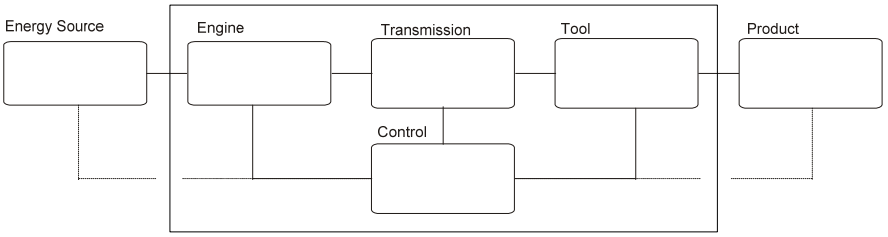
ARIZ: theory and practice

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: _____
Tool: _____

ARIZ: theory and practice

1.3. describe graphic models …

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

TC #1:
_____

TC #2:
_____

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:
<_____>

Chosen contradiction:

***TC #1**: If there is <_____>, then*
<_____>, but
<_____>.

* see Multi-screen analysis

1.5. intensify the conflict

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

_____
_____ *for TC#__.*

* it is recommended to perform Size-Time-Cost operator (STC)

1.6. describe the problem model

Formulate the Problem Model to indicate the following:

1) the conflicting pair (from 1.2);
2) the intensified conflict definition (from 1.5);
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:
< _____> and < _____>.

(2) Intensified Conflict:
_____
_____

(3) Problem:
It is necessary to find an X-element which
keeps the ability of <_____>
and prevents <_____>.

* 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.

2.1. define the operational zone (OZ)

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

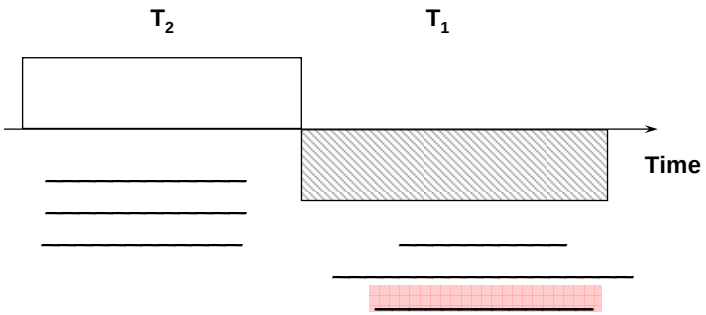
Definition of the Operational Zone:

_____

_____.

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.



ARIZ: theory and practice

LGECO / LICIA, INSA Strasbourg, France | May, 2006 121

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:

_____
_____
_____.

Available (external) resources:

_____
_____
_____

SFR of the super-system

_____
_____
_____.

ARIZ: theory and practice

LGECO / LICIA, INSA Strasbourg, France | May, 2006 122

2.3. define the substance-field resources (2)

	System resources (internal)	**Available** resources (external)	Resources from **Super-system**
SPACE void, empty space, areas			
TIME before, during, after			
SUBSTANCES solid, liquid, gas, plasma substance			
FIELDS (M A Th Ch E M)			
INFORMATION measurement, detection, signals			
FUNCTIONAL additional function for existing part			

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> (1.6)
within the <Operational Time> (2.2)
inside the <Operational Zone>, (2.1)
and keeps the tool's (1.6) ability to provide
<indicate the useful action> (1.6).

The X-element, without complicating the system and without harmful side effects, eliminates
<_____>
within <_____>
inside the <_____> and keeps the <_____>
ability <_____>.

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> eliminates
<the negative effect>
inside the <Operational Zone>
within the <Operational Time> and provides
<a useful effect> without complicating the system and without harmful side effects.

<_____> eliminates
<_____>
inside the <_____>
within <_____> and provides
<_____> without complicating the system and without harmful side effects.

ARIZ: theory and practice

3.3. identify the physical contradiction for the macro-level

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

the <Resource in 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 <_____>,
within the <_____>,
has to… <_____>
in order to <_____> and
does not have to <_____>
in order to <_____>.

ARIZ: theory and practice

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 <_____>
in the <_____> within the <_____>
in order <_____>
and there should not be the <_____>
in order <_____>.

ARIZ: theory and practice

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 <_____>
has to provide <_____> itself
within the <_____>.

Partial solution concept:

_____
_____
_____
_____

ARIZ: theory and practice

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.

4.1. simulation with little creatures

Method of Simulation with Little Creatures (LC):

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

1.

One group of LC

_____

_____

_____

2.

Another group of LC

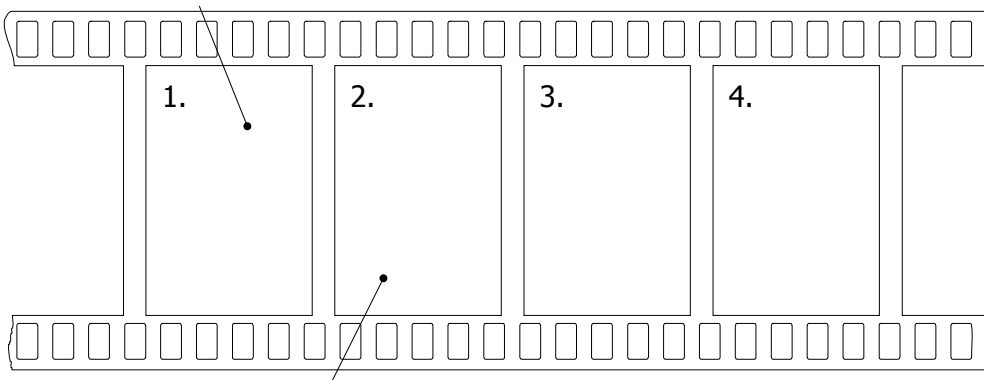
_____

_____

_____

4.2. take a "step back" from the IFR

1. **IFR:** _____



2. **Step back from IFR:**

_____

4.3. using a combination of substance resources

Consider the possibility of using a mixture of substance resources.

Partial Solution concept:

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:

_____

_____

_____

_____

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.

Partial Solution concept:

_____

_____

New problem:

_____

4.7. using a field and field-sensitive substances

Consider the possibility of solving the problem using the pair:
"field + substance additive that is responsive to this field".

_____
_____
_____

Preliminary solution concepts:

_____
_____
_____
_____

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 <_____>
has to provide <_____> itself
within the <_____>.

When,
S_1 - _____;
S_2 - _____;
F - _____

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).

_____

_____

_____

_____

Partial 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

6.2. checking the problem formulation for combinations of several problems

6.3. changing the problem

6.4. reformulation of the mini-problem

6.1. transition to the technical solution

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

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

7.1. checking the solution concept

Consider each **introduced substance** and **field**.

Is it possible to apply available or derived SFRs instead of introducing the substances / fields?

Can self-controlled substances be applied?

Correct the obtained technical solution accordingly.

7.2. preliminary estimation of the solution concept

Questioner:

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

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

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

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

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

8.1. estimation of changes in the super-system

Define how the super-system that includes the changed system should be changed.

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: _____

Inventive Standards: _____

_____

_____

_____

_____

_____

SUMMARY (2)

Strong points of ARIZ	Weak points of ARIZ	Comments:

References:

1. G.S.Altshuller: 1969, 1973. ALGORITHM OF INVENTION, Moscowskiy Rabochy, Moscow.
2. G.S.Altshuller: 1979. CREATIVITY AS AN EXACT SCIENCE. Sovietskoe radio, Moscow.
3. G.S.Altshuller: 1986; 1991, TO FIND AN IDEA: introduction to the theory of inventive problem solving, Nauka, Novosibirsk.
4. G.Altshuller: 1999, THE INNOVATION ALGORITHM: TRIZ, systematic innovation, and tech-nical creativity. Worchester, Massachusetts: Technical Innovation Center. 312 pages, ISBN 0964074044
5. RULES OF A GAME WITHOUT RULES, Karelia, Petrozavodsk, 1989.
6. N.Khomenko: 1997-2002. Materials for seminars: OTSM-TRIZ: Main technologies of problem solving, "Jonathan Livingston" Project.
7. D.Kucharavy: 1998-2004. Materials for seminars: TRIZ Techniques, OTSM-TRIZ Technologies Center.

The End

…The problems that exist in the world today cannot be solved by the level of thinking that created them…

attributed to Albert Einstein

;-)