ARIZ 85-C
Algorithm of inventive problem solving – parts 1-3

The following text is based on the book of V. Philatov, A. Zusman, G. Altshuller, and B. Zlotin: Tools of Classical TRIZ. Tools of Classical TRIZ. Southfield: Ideation Intl Inc., 1999, ISBN 978-1928747024.

NOTE! *When this text was created, the analytical tools of TRIZ, like function analysis or CECA, were not as developed as they are today. Therefore, you will find concepts in the text that are no longer applicable today.*

ARIZ is the Russian acronym for **algorithm of inventive problem solving**, a comprehensive program based on the objective trends of engineering systems evolution. ARIZ was authored by Genrich Altshuller for the purpose of analyzing and solving inventive problems. The modifications to ARIZ made by Altshuller after 1977 adopted the experience, comments, and suggestions of other TRIZ scientists.

The following principles form the foundation of ARIZ:

1. ARIZ is a program of sequential procedures for transforming an inventive problem by identifying and resolving the technical contradiction causing the problem. ARIZ adopts a step-by-step approach, making it possible to convert a vague initial innovation situation to a simplified problem model, and then to an image of the ideal solution and, finally, the analysis and resolution of contradictions. The program, by way of its structure and rules for performing each step, reflects the trends of engineering systems evolution.

2. Since ARIZ is carried out by a human, it is imperative that certain psychological factors be controlled. For instance, it is desirable to suppress psychological inertia while stimulating imaginative work. To a certain degree, just by working with ARIZ the user is significantly influenced. For example, the predetermined sequence of procedures excludes certain types of otherwise common mistakes, increases the user's confidence in his/her problem-solving abilities, stimulates him to go beyond the boundaries of his area of specialization and, most importantly, steers his thinking toward the direction that is most promising for success.

   In addition to the above "built-in" features, ARIZ also includes specially-targeted psychological operators. One of these is the entreaty to avoid specialized terms, as these are "carriers" of psychological inertia related to the particular area of specialization. This operator includes rules that help identify and eliminate specialized terms and replace them with non-specialized terms that nonetheless reflect the „true" meaning. Another operator – the method of simulation with small smart people (SSP) – entails graphical representation of the conflict situation, where the primary action is carried out by the group of SSP.

3. ARIZ is supported by a comprehensive yet compact knowledge base that is updated frequently. The basic components of the knowledge base are libraries of physical, chemical, and geometric effects and phenomena.

   The ideal solution, i.e., one which achieves a positive effect without any "sacrifice", is, in reality, rarely attainable. Setting one's sight on the ideal, however, allows the most important principle of ARIZ to be realized; namely, the principle of making minimal changes to the initial system. The sole purpose of this principle is to ensure that the implementation phase is as smooth as possible.

   The first "cycle" of work with ARIZ might not produce results suitable to the problem-solver's expectations. Therefore, ARIZ was designed to support multiple cycles, with each successive cycle bringing new solutions.

Solving a problem by means of ARIZ is a research process, the results of which can be more significant than merely developing a solution to a particular problem. Nearly always, a solution will be complemented by, advanced, and used to solve other problems that have not yet been solved, or for which the solutions have long been forgotten – ARIZ incorporates special procedures to address these concerns as well.

Part 1. Analyzing the problem

The main purpose of part 1 is to facilitate the translation from a vague problem situation to a precisely formulated and extremely simplified model – the problem model.

1.1. Formulate the mini-problem

Formulate the *mini-problem* – without using specialized terms – according to the following template:

An **engineering system for** *(state the purpose of the system)* **includes** *(list the main parts of the system).*

Technical contradiction 1 (TC-1): *(identify)*

Technical contradiction 2 (TC-2): *(identify)*

It is necessary, with minimum changes to the system, to (*state the required result*).

Example:

- An engineering system for receiving radio waves includes a radio antenna, radio waves, lightning rods, and lightning.
- **TC-1:** If the system contains many lightning rods, the antenna is reliably protected against lightning. The rods absorb radio waves, however, and thus reduce the amount of radio waves received by the antenna.
- **TC-2:** If there are few lightning rods, they do not absorb a significant amount of radio waves. But in this case, the antenna is not protected against lightning.
- It is necessary, with minimum changes to the system, to protect the antenna against lightning without absorbing radio waves.

Comment: In this wording we should change the specialized term *lightning rod* to *conducting rod* or even simply *conductor*.

Notes:

1. The *mini-problem* is obtained from the problem situation by introducing the restriction: *Everything in the system remains unchanged or becomes less complicated, while the required action (or property) appears, or a harmful action (or property) disappears.* Converting the problem situation to the mini-problem does not mean that we intend to solve this "smaller" problem. Rather, by introducing an additional requirement of obtaining the desired result without incurring changes to the system directs us to sharpen the conflict and, from the very beginning, block the path toward trade-offs.

2. While formulating step 1.1 you should indicate not only the technological parts of the system but also the „natural" ones that interact with the system. In the problem of protecting the telescope antenna we can consider lightning and received radio waves as natural objects (radio waves are emitted by objects in space).

3. The technical contradiction denotes the interaction in the system whereby the useful action also creates the harmful one: in other words, by introducing or improving a useful action, or by eliminating or reducing a harmful action, either all or part of the system degrades (sometimes intolerably) as a result.

   Technical contradictions are formulated by identifying (in writing) one state of a system element with an explanation of both the good and bad results of this state. Then the opposite state of the system element is identified, along with its associated explanations.

   Sometimes a problem situation contains only *the product*; the engineering system (*the tool*) is absent, and thus there is no clear technical contradiction. In this case, the technical contradiction can be obtained by considering two states of the product, even if one of the states is impossible to achieve. For example, consider the following problem situation:

   How can minute particles suspended in a clear liquid be observed with the naked eye, if the particles are so small that the light flows around them?

   TC-1: The liquid remains clear because the particles are small, but the particles cannot be seen by the naked eye.

   TC-2: Large particles are easy to observe, but result in the liquid being no longer clear, which is an unacceptable consequence.

   It seems as if the problem situation deliberately avoids considering TC-1: after all, we cannot change the product! So, we will consider only TC-1 here but noting that TC-2 gives us an additional requirement to impose on the product: small particles should remain small and should also become large.

4. To reduce psychological inertia, specialized terms associated with the tool and the environment should be substituted with easily-understood words. The reason for this is that specialized terms:

   - imprint a stereotypical image of the tool's working method: for example, “the ice-breaker breaks the ice” leads one to forget that it is also possible for the ice-breaker to move through ice without breaking it;
   - can hide certain features of the elements described in the problem situation;
   - narrow the range of possible states of a substance: using the term paint forces one to imagine a liquid or solid paint, although paint can be gaseous as well.

1.2. Define the conflicting elements

The conflicting elements include *a product* and *a tool*.

<u>Rule 1</u>: If the Tool can be in two states, in accordance with the description of the problem situation, indicate both of these states.

<u>Rule 2</u>: If the problem situation description deals with several similar pairs of interacting elements, considering only one pair is adequate.

<u>Example:</u>
Products: lightning and radio waves
Tool: conducting rod (many rods or a few rods)

Notes:

5. ***The product*** is the element that requires “processing” within the problem situation (by “processing” we mean manufactured, moved, modified, improved, protected against harmful action, detected, measured, etc.). Some elements, usually considered by their purpose to be tools, can be considered products in problems having to do with measurement and/or detection.

6. ***The tool*** is the element that directly interacts with the product, such as, for example, a mill rather than a milling machine, or a flame rather than a burner. A specific part of the environment can be considered as a tool. The standard parts from which the product is assembled can be considered as a tool, as well.

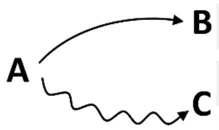
7. One of the elements in the conflicting pair can be doubled. For example, there can be two different tools simultaneously acting on the product, where one tool interferes with the other. Or there can be two products that should be processed with the same tool, where one product interferes with another.

1.3. Build graphical models for the technical contradictions

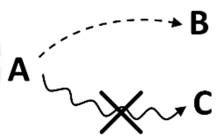
Build graphical models for the *technical contradictions*:

Example:

TC-1: many conducting rods



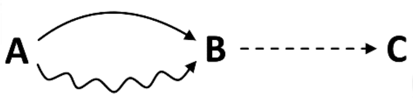
TC-2: a few conducting rods



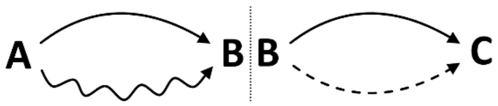
Notes:

8. Models of typical conflicts are shown in table below. Use of non-standard graphical models is permissible if they closely reflect the “essence” of the conflict.

9. Some problems have multiple-step graphical conflict models, for example:



A model such as this can be converted into two, one-step graphical models (as shown below) if we consider element B as a modified product or extend the main property or state of element A to element B:



10. The conflict can be considered not only in space, but in time as well.

11. Steps 1.2 and 1.3 improve and refine the general problem situation description. Thus, it is necessary to return to step 1.1 after step 1.3 and check if there is any disparity in the line 1.1 - 1.2 - 1.3. If a disparity exists it should be eliminated, and the line should be corrected.

Typical graphical models of technical contradictions

1. **Counteraction**

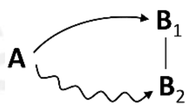
   A usefully acts upon **B** (regular arrow), however, in certain stages a reverse harmful action occurs (corrugated arrow). It is necessary to eliminate the harmful action and retain the useful one.

2. **Conjugated action**

   The useful action of **A** on **B** at the same time harmfully influences **B** (for example, in different stages of the process the same action may be useful or harmful). It is necessary to eliminate the harmful action and retain the useful one.

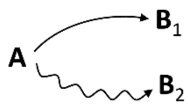
3. **Conjugated action**

   The useful action of **A** on one part of **B** causes a harmful action on another part of B. It is necessary to eliminate the harmful action on $\mathbf{B_2}$ and maintain the useful action on $\mathbf{B_1}$.



4. **Conjugated action**

   The useful action of **A** on **B** is harmful for **C** (**A**, **B** and **C** constitute a system). It is necessary to eliminate the harmful action and maintain the useful one without damaging the system.



5. **Conjugated action**

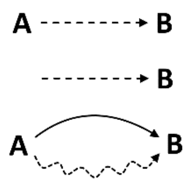
   The useful action of **A** on **B** is accompanied with the harmful action on **A** itself (in particular, making **A** more complex). It is necessary to eliminate the harmful action and maintain the useful one.

6. **Incompatible action**

   The useful action of **A** on **B** is incompatible with the useful action of **C** on **B** (for example, machining is incompatible with measurement). It is necessary to provide the action **C** on **B** (represented by the wavy line) without changing the action of **A** on **B**.

7. **Incomplete action or missing action**

   A provides one useful action on **B** while two different actions are required. Or, **A** does not act on **B** at all (represented by the corrugated line). Sometimes **A** is absent: an action on **B** is required, but it is not clear how this should be achieved. It is necessary to provide an action on **B** that is compatible with the „simplest" **A**.

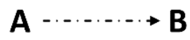


8. "Silence"

Information about **A**, **B** or their interaction is absent (represented by the corrugated arrow). Sometimes only **B** is given. It is necessary to obtain the required information.

9. Uncontrollable (in particular, excessive) action

A acts on **B** in an uncontrollable way (for example, constantly) while a controllable action (for example, an alternating action) is required. It is necessary to make the action of **A** on **B** controllable (represented by the punctured line).



1.4. Select a graphical model for further analysis

From the two graphical conflict models, choose the one that provides the best performance for the main manufacturing process (i.e., main function of the technological system as indicated in the problem description). State what this main manufacturing process is.

Example:

In the problem of protecting the radio telescope antenna, the main manufacturing process is receiving the radio waves. Thus, we should choose TC-2: in this case the conducting rods do not absorb the radio waves.

Notes:

12. When choosing one of the two graphical conflict models we choose one state of the tool from its two opposite states. Our subsequent problem-solving efforts should be related to this state. ARIZ prohibits converting *few conductors* into *some optimal number of conductors* – the goal is to sharpen the conflict rather than smooth it over. If we stick to the one state of the tool we should, later on, gain the required positive property for the tool in this state, even though this property is inherent in another state of the tool. There are few conductors and we won't increase their number, but as a result of solving the problem the lightening should be „caught" in the same manner as if there were many conductors.

13. With problems having to do with measurement and/or detection it is sometimes difficult to determine the main manufacturing process. Ultimately, measurements are almost always performed for the purpose of modification, i.e., processing a product, producing something, etc. Thus, in measurement problems the main manufacturing process is the main manufacturing process of the entire system, not just the part that has to do with measurement. Problems of measurement for scientific purposes can be considered exceptions to this, however.

1.5. Enforce the conflict

Enforce the conflict by indicating the limiting state (action) of elements.

Rule 3: Most problems involve the following types of conflict: *many elements* versus *few elements*, *strong element* versus *weak element*, etc. The conflict *few elements* should be converted into either the typo *no elements* or *absent element* only.

Example:

Let us consider that instead of *few conductors* there is an *absent conductor* in EC-2.

1.6. Formulate the problem model

Formulate the problem model to indicate the following:

- the conflicting elements;
- an enforced (i.e., emphasized, exaggerated) formula of conflict;
- what should be rendered by an additional element, referred to as the *X element*, to be introduced into the system to solve the problem (i.e., what the X element should hold, preserve, eliminate, improve, provide, etc.).

Example:

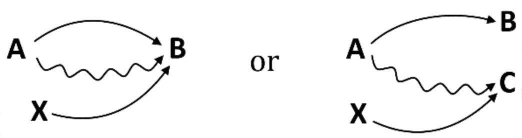
Given: An absent conductor and lightning: The absent conductor does not hinder the antenna's reception of the radio waves but does not provide protection against lightning.

Required: Find an X element that maintains the above feature of the absent conductor (i.e., does not hinder the antenna's reception) while also protecting the antenna from lightning.

Notes:

14. The problem model is a type of abstraction, artificially selecting only some of the elements of the technological system while putting other elements temporarily "out of scope". For example, in the problem of protecting the antenna we select only two of the four elements (these being the antenna, radio waves, conductor, and lightning); the other elements are ignored for now.

15. After step 1.6 you should return to step 1.1 and check the logic of the problem model you have created. Sometimes, the chosen graphical conflict model can be refined by indicating the action of the X element, for example.



16. The X element does not necessarily represent a substantial part of the system, but can be some change, modification, or variation in the system, or something unknown entirely. Examples are temperature change or a phase transformation of a system element or the environment.

1.7. Apply the system of standard inventive solutions

Consider solving the problem model using the system of standard inventive solutions. If this does not solve the problem go to Part 2 (i.e., steps 2.1-2.3). If it does solve the problem, you may go to Part 7, although it is still recommended that you continue your analysis through Part 2.

Notes:

17. The analysis performed in Part 1 and the building of the problem model results in significant clarification of the problem, and in many cases allows standard elements to be identified within non-standard problems. Thus, applying the standard inventive solutions at this stage of the problem-solving process is more effective than trying to apply them to the initial problem.

Part 2. Analyzing the problem model

The main purpose of Part 2 is to create an inventory of available resources (space, time, substance, and fields) that may be applied toward solving the problem.

2.1. Define the operating zone (OZ)

Example:

In the problem of protecting the antenna, the operating zone is the space previously occupied by the lightning conductor; i.e., mentally define the operating zone as the “empty” or “absent” rod (i.e., the place where the rod used to be).

Notes:

18. In the simplest case the operating zone is the space where the conflict indicated in the problem model appears.

2.2. Define the operating time (OT)

Notes:

19. Operating time is the available „time resource”, consisting of the time during which the conflict occurs (T1) and the time before the conflict (T2). Conflicts – especially if fleeting, momentary, or short-term – can often be prevented or eliminated during T2.

Example:

In the problem of protecting the antenna, the operating time consists of the time during lightning discharge (T1’) and the time between two occurrences of lightning (T1'). T2 is not considered here.

2.3. Define the substance and field resources

Define the substance and field resources (SFR) of the analyzed system, the environment, and the product. Create a list of resources.

Example:

If the problem is protecting the antenna, the “absent” lightning conductor is considered, and thus SFR include only substances and fields in the environment. In this case we can consider air as SFR.

Notes:

20. Substance and field resources are those substances and fields that already exist, or that can be easily obtained according to the problem description. There are three types of SFR:

    Internal SFR:

    - SFR of the tool,
    - SFR of the product.

    External SFR:

    - SFR of the environment that pertains to the given problem, for example, in the problem having to do with observing small particles in a clear liquid, water is an SFR,
    - SFR common to any environment, including background fields. Examples are gravity or the Earth's magnetic field.

    SFR of the super-system:

    - waste materials of some other system, if available according to the problem description,
    - inexpensive resources, i.e., "foreign" elements of negligible cost.

    When solving a mini-problem it is desirable to achieve the required result with minimum expenditure of resources. Thus, the utilization of "internal" SFR should first be considered. However, when developing solution concepts and/or predict, (i.e., maxi-problems) the widest range of possible resources should be considered.

21. The product is considered an unchangeable element – so, what kinds of resources can it have? Indeed, the product cannot be changed, or rather, it would be inappropriate to change it while solving the mini-problem. However, sometimes the product can:

    - change itself,
    - allow for modification of a part, where this part is present in large quantities (such as water in a river, wind, etc.),
    - allow for the transition to the super-system (for example, bricks are unchangeable, but the house can be changed),
    - allow for the involvement of micro-level structures,
    - tolerate being combined with „nothing" (empty space),
    - allow temporary modification.

    Thus, the product can be considered an SFR, but only in these somewhat rare cases where it can be easily modified without undergoing modification.

22. SFR are available resources and thus should be utilized first. If there are no available resources, other substances and fields can be considered. In other words, the analysis of SFR in step 2.3 constitutes a preliminary analysis.

Part 3. Formulating the ideal final result and physical contradiction

Working through Part 3 should result in the development of an image of the ideal final result (IFR). The physical contradiction hindering the achievement or IFR is identified as well. Although the ideal solution is not always achievable, it does, however, indicate the direction in which the most powerful solution can be obtained.

3.1. Identify the formula for IFR-1

Identify and document the formula for IFR-1 using the following template:

The introduction of the X element does not complicate the system in any way, does not create any harmful effects, and eliminates (*indicate the harmful action*) **during the operating time inside the operating zone, while maintaining the ability of the tool to perform** (*indicate the useful action*).

> **Example:**
>
> The X element does not complicate the system at all, does not create any harmful effects, eliminates the "non-attraction" of lightning during the operating time through the absent lightening conductor, while maintaining the conductor's ability to not hinder the antenna's reception.

Notes:

23. With the exception of the conflict "a harmful action is associated with a useful one", other types of conflicts are possible, such as: "introducing a new useful action results in complicating the system", and "one useful action is incompatible with another". Thus, the formula for IFR-1 identified in step 3.1 is only a pattern (that is, it should apply to other IFR formulas as well).

    Any IFR formula means the following:

    Obtaining a new useful feature, or eliminating a harmful one, should not be accompanied by either the degradation of other features or the appearance of new harmful features.

3.2. Enforce the formula for IFR-1

Enforce the formula of IFR-1 by introducing an additional requirement.

The introduction of new substances and fields in the system is prohibited - only the SFR should be utilized:

> **Example:**
>
> There is no tool (i.e., there is an absent tool) in the problem model related to antenna protection. According to Note 23, the formula for IFR-1 should incorporate the environment, thus the X element should be substituted by "air" (or, more precisely „the volume air occupying the space where the absent lightning-conductor was").

Notes:

24. According to Notes 20 and 21, substance-field resources should be considered in the following order when solving the mini-problem:

    - SFR of the tool
    - SFR of the environment
    - foreign SFR
    - SFR of the product, if not prohibited by Note 21

    Four "lines" of further analysis are determined by the above types of resources. The problem situation, on the other hand, cuts off the availability of some of these lines. When solving the mini-problem, analyzing these lines is only necessary up to the point where a solution concept is obtained; if an idea is found on the "tool line" (the first line, above) then the other lines need not be considered. When solving the maxi-problem, however, all available lines should be considered. Thus, if you have found an idea on the tool line, the lines having to do with the environment, with foreign resources, and with the product should be considered as well.

When mastering ARIZ, a sequential, linear analysis is gradually being substituted by a parallel one, as the problem-solver cultivates the ability to transfer ideas from one line to another. In other words, he/she develops a "multi-faceted" way of thinking: the ability to simultaneously consider changes in the super-system, system, and sub-systems.

ATTENTION! Problem solving is accompanied by the breaking down of outdated concepts and the appearance of new ones – which often cannot be adequately described in words. How, for example, can one describe a feature of paint wherein it is dissolved without dissolving, or colors without coloring?

As you work with ARIZ you should document your notes using simple, non-technical, even "childish" words, avoiding specialized terms, as they enforce psychological inertia.

3.3. Formulate the physical contradiction for the macro-level

Formulate the physical contradiction for macro-level according to the following template:

The operating zone during the operating time should be (*indicate the physical macro-state, for example, „hot"*) **in order to perform** (*indicate one of the conflicting actions*), **and should be** (*indicate the opposite physical macro-state, for example, „cold"*) **to perform** (*indicate another conflicting action or requirement*).

<u>**Example:**</u>

The volume of air should be electrically conductive during the operating time to „remove" the lightning and should be electrically non-conductive to prevent absorption of the radio waves.

This formula suggests to us that the column of air should be electrically conductive when lightning discharges and electrically non-conductive all the rest of the time. Lightning discharge occurs relatively infrequently, and when it does it acts quickly. The subtrend of rhythms coordination suggests to us that the lightning-conductor should appear at exactly the same time that the lightning strikes. This obviously is not a complete solution concept since, for example, the following secondary problems must be solved: *How can the air column be transformed into a conductor when lightning discharges? How can the conductor be made to disappear immediately after the lightening has discharged?*

<u>**Notes:**</u>

25. The physical contradiction (PhC) denotes opposite requirement to those of the physical state of the operating zone.

26. If creating a complete formula for the physical contradiction is difficult, try formulating a brief physical contradiction according to the following template:

    The element (or part of it) **should be in the operating zone in order to perform** (*indicate*) **and should not be there to prevent** (*indicate*).

    ATTENTION! When solving a problem using ARIZ, the solution concept develops slowly, similar to the way a photograph develops. Never stop the problem-solving process when an idea first appears, or you may later find yourself fixing a half-developed idea. Instead, carry the process through to the end of ARIZ!

3.4. Formulate the physical contradiction for the micro-level

Formulate the physical contradiction for the micro-level according to the following template:

The particles of a substance (*indicate their physical state or action*) **should be in the operating zone in order to provide** (*indicate the required macro-state according to step 3.3*) **and should not be there** (*or should have the opposite state or action*) **in order to provide** (*indicate another macro-state according to step 3.3*).

> **Example:**
>
> The free charges should be in the air column when lightning strikes to provide electrical conductivity to "remove" the lightning and should not be there the rest of the time to eliminate electrical conductivity to prevent the absorption of radio waves.

Notes:

27. It is not necessary in step 3.4 to precisely define the notion of "particles" – domains, molecules, atoms, ions, etc. can all be considered to be particles.
28. The particles may be a part of a:
    - substance
    - substance together with a field
    - field (although very seldom)
29. If the problem can be solved only on the macro-level, there may be no way to formulate step 3.4. Still, attempting to formulate the physical contradiction for the micro-level can prove beneficial, if only because it provides us with the additional information that the problem must be solved at the macro-level.

    ATTENTION! The first three parts of ARIZ essentially change the initial mini-problem; step 3.5 will summarize this change. By formulating the ideal final result IFR-2, we obtain an entirely new problem, a "physical" one.

    From this point on we should focus on this new problem!

3.5. Formulate the ideal final result (IFR-2)

Formulate the ideal final result (IFR-2) according to the following template:

The operating zone (*indicate*) **during the operating time** (*indicate*) **should, on its own, provide** (*indicate the opposite macro- or micro-state*).

Example:

The neutral molecules in the air column should, on their own, be transformed into free charges when the lightning strikes. After the lightning has discharged the free charges should, on their own, be transformed into neutral molecules.

The meaning of this new problem is as follows: for the duration of the lightning discharge the free charges should appear on their own inside the air column; in this case the column of ionized air acts as the lightning-conductor and "attracts" the lightning. Immediately after discharge the free charges in the air column should, on their own, become neutral molecules again. To solve this problem a knowledge of middle-school physics is needed.

3.6. Consider solving the new problem using the system of standard inventive solutions

Consider solving the now physical problem using the system or standard inventive solutions. If after doing this the problem is still unsolved, go to Part 4. If using the system of standard inventive solutions does solve the problem, you may go to Part 7, however, it is recommended that you continue your analysis through Part 4 anyway.