Part 3

Man and Algorithm

We have shaken loose your mental filters,
and as a result, the answer appeared.

This method works, and it will always be effective.
What is necessary is to get rid of your excess load of prejudice
and petrified garbage in your head; change the tuning
of your mental filters in relationship to ways you're inclined
to act — and then, it will be possible to find the necessary
answer to any problem you may desire to investigate.

✍ *R. Johns*

Part 3-1

Psychological Barriers

In one of my seminars on the Theory of Inventiveness (TRIZ), the following problem was offered:

> *"Let's assume that 300 electrons, in several groups, must jump from one energetic level to another. However, a quantum transfer has already taken place by two groups less than were originally calculated; consequently, each group now has five more electrons. How many electron groups were there in total? This complex problem has not yet been solved."*

Participants in the seminar — all highly qualified engineers — declared that they were not going to tackle this problem. "This is Quantum Mechanics, but we just come from mechanical factories. Since others could not solve this problem, it would be impossible for us."

Then, I read them this algebra problem:

> *"To send 300 scouts to summer camp, several buses were reserved; however, two buses did not show up at the required time. Therefore, each bus took five scouts more than was planned. How many buses were sent?"*

The problem was solved immediately. Inventive problems always have an intimidating tinge. There is a clear subtext in any mathematical problem: "It is possible to solve me. Similar problems have been solved more than once before." If a mathematical problem is "undefeatable," then everybody believes that it cannot be solved. In an inventive problem the subtext is completely different: "People have tried to solve me, but nothing happened. It is not in vain that smart people believe nothing can be done here."

An article was published in *Inventor and Innovator* magazine about the problem of unloading frozen cargo. Its author explained this problem as follows:

> *"This is one of those eternal problems that have annoyed miners, steel workers, railroad workers and coke chemists for many years — the unloading of frozen cargo. Sometimes, the life and death of many a company depends upon this process."*

Furthermore, different suggestions were described without finding any useful applications ("There were many attempts to solve me, but nothing happened"). The article ended as follows:

> *"Time passes rapidly on. Secrets of the atomic nucleus are discovered. The sensitive ears of radio telescopes listen to the whispers of the farthest galaxies. Yet today, ore is still unloaded the old way, and the whole world still breaks it with pry-bars and sledge hammers."*

From the beginning, an inventor is warned that he is facing "one of the eternal problems." The problem was not even described, and nothing specifically said; however, the inventor is already intimidated in every respect. Not everyone can show the bravery needed to conquer an "eternal problem" — an undefeated problem, even in the time when "secrets of the atomic nucleus are discovered, and the sensitive ears of radio telescopes listen to the whispers of the farthest galaxies!"

The problem of unloading frozen cargo really is an "eternal" one. However, "eternal" does not mean difficult. It happens, of course, that for a long time the problem was not solved in spite of larger numbers of suitable attempts. These cases are very rare. An industry brings up only those problems for which conditions for solving them already exists. Marx wrote: "Society always raises only those problems for which the ability to solve them exists because, under closer scrutiny, it always happens that the problem only appears when the material conditions for its resolution exists — or, at any rate, exists in process of development"[1].

If, over a long time, the problem was still not solved, this means that the wrong search direction was chosen. In this case, even a simple problem may seem "eternal." The same thing happened, for instance, with the meniscus telescope. It could have been invented, as Maksutov mentioned, by contemporaries of Descartes and Newton; however, the invention was made only in that period when the "sensitive ears of the radio telescopes listen to the whispers of farthest galaxies . . . ."

The more eternal the problem, then usually the easier it is to solve. As a matter of fact, when the problem appears, the conditions to solve it already exist. Each unsuccessful attempt to solve it reduces the degree of uncertainty along with the search field.

Time passes by, and the degree of difficulty in solving the problem gets smaller — but, the arsenal of technology continuously grows. This means that the relationship between these powers has changed: the problem itself becomes easier, while the means to solve it increases, becoming more powerful. Rarely are there problems in industry that are impossible to solve — even in the future. It is impossible to break the basic laws of nature — the Law of Conservation and Law of Dialectics; for other types of problems, the impossibility is only temporary.

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[1] K. Marx, "Critique of Political Economy," *Gospolitisdat*, 1952, page 8.

"Whatever a human being can imagine, others can make reality." These words belong to Jules Verne. They are true. The history of science fiction gives vivid examples of the transformation from the "impossible" to the "possible."

In general, the following can serve as an illustration:

Science fiction authors	Total number of ideas	Fate of science fiction ideas					
		Came true, or will come true in the near future		Confirmed possibility of the general concept realization		Found erroneous or unrealizable	
		Numbers	%	Numbers	%	Numbers	%
Jules Verne	108	64	59	34	32	10	9
H. G. Wells	86	57	66	20	23	9	11
Alexander Beliaev	50	21	42	26	52	3	6

A hundred years of science fiction history has witnessed this:

The bold idea has a higher probability of realization than the conservative one.

Jules Verne's idea to shoot astronaut capsules by cannon is considered a classic example of the "impossible." Nevertheless, a young scientist, Gerald Gowll from Montreal University, announced the possibility to use a cannon for just such astronomical investigations.

In comparison with the achievements of space technology — placing multi-ton satellites in orbit, walking in space, landing on the Moon — the spaceship fired from Jules Verne's cannon does not seem so impressive. However, cannon space technology has a good future: for each manned spacecraft, dozens of pilotless crafts are built. It is simpler, and more effective, to launch by the Jules Verne method.

An article was published about the American and Canadian experts who started project *Harp*. This project aimed at utilizing cannons with barrel diameters of 127, 178 and 408 mm to probe the atmosphere.

The completed design has a cannon with a barrel 150 meters long. It weighs 3,000 tons, with a diameter of 814 mm. According to their calculations, this cannon can send a container, with apparatus weighing 7.5 tons, to a height of several hundred kilometers — or, it can deliver a half-ton satellite into Earth orbit. The cost of such a satellite delivery is only $50,000 — including the cost of the satellite.

In other words, had Jules Verne's idea not been considered impossible, there probably would have been satellites of several dozen kilograms sent into Earth orbit by the second decade of the 20th Century.

Here, it is worth remembering that rocket ships could have appeared much earlier. It is not without reason that the prominent Soviet researcher Yuri Vasilievich Kondratiuk wrote in 1928:

> *"Sorting through my mind the remarkable achievements of science and technology in the last few years, and asking the question of why the problem of interplanetary transport has so far not been solved, I come to this conclusion: because of a lack of audacity and initiative."*[1]

Lack of audacity and initiative held back the appearance of the quantum generator (laser). A directed thermal ray idea was expressed by Herbert George Wells in 1898. Twenty-one years later, Albert Einstein theoretically substantiated the physical process for developing the quantum generators. Lasers, in C. Town's opinion, could have appeared at the end of the second decade of the 20th Century. In 1951, the Soviet scientist V. Fabricant applied for a patent on the quantum generator and received a rejection: the patent expert considered the idea for his invention to be unfeasible. Later, the expert changed his decision, and the inventor got his Author's Certificate.

The "impossible" idea of science fiction author Alexander Beliaev — an amphibious human being — is now very close to realization. It is interesting to follow, step-by-step, the way the "rating" of his idea has changed. Here are three excerpts published at different times by the same person, who is an engineer and author of several inventions:

> **1958:** " . . . not an amphibious human, but people equipped with an apparatus for underwater diving and swimming, will conquer the unknown ocean depths."
>
> **1965:** "Amphibious humans do not exist yet, and maybe they will never appear at all . . . ."
>
> **1967:** "Today, man tries to dive very deep without any diving gear, breathing under water like whales do. Maybe someday, real "Echtianders" (the amphibious humans in Beliaev's SF story) will appear with the help of medicine, chemistry, and technology. The ocean will surrender itself to those people for whom water and air will become the same habitat element."

In less than ten years, the assessment of this "impossible" idea changed completely. Now its assessment is nearer reality.

There are no unsolvable problems; however, the history of an invention often begins with someone proclaiming, "Impossible!"

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1. Kibalchik, Tciolkovski, Tcander, Kondratiuk, *Selected Works*, M., Science, 1964, page 539.

The reasons that force people to proclaim "impossible" and proof of impossibility are different. Sometimes, simple ignorance is responsible. This is how, in the second decade of the last Century, when scores of locomotives were built, the influential British magazine *Quarterly Review* was able to flatly assert:

> *"There is nothing more funny and foolish, than to promise to build a locomotive that will move twice as fast as a postal carriage. It is also less probable that English people will entrust their lives to such machines, and allow themselves voluntarily to be blown out in a rocket."*

Soon after, the Stephenson locomotive "rocket" ran passenger trains at speeds of 40 km/hour.

When inventor Alexander Graham Bell began to sell his devices, one American newspaper requested that police stop this "charlatan cheating trusting citizens." The newspaper said:

> *"The statement that a human voice can be transmitted though conventional metal wire from one place to another should be considered highly humorous."*

In spite of this, ignorance is not the major cause behind people saying, "Impossible." More often, this is said by people who cannot really be suspected of ignorance. In O. Picard's memoirs, the inventor of the stratospheric balloon and the bathysphere wrote the following lines:

> *"Experts at the time found my concepts impossible. Things that are elementary for us today, in previous times appeared Utopian. The single objection brought up against me was that my concept did not yet exist. How many times I have heard this objection!"*

◆

What forces knowledgeable and non-conservative persons to not believe in a new development?

Here is a typical example. Several years ago, one of the leading experts in the automotive industry wrote:

> *"Suppose it is necessary to determine the diameter of a wheel for a future automobile. It is a known fact that, from year to year, a reduction of wheel diameters can be observed when considering the wheels of different automobiles during the past 50 years. However, this reduction becomes less and less pronounced, and the moment arrives when it stops completely. Meanwhile, there was a short period during which wheel diameter was sharply reduced. If the study is limited to only this period, it is possible to arrive at a wrong conclusion — that, within 20 years, the diameter of the wheel will reach zero."*[1]

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[1] Y. Dolmatovski, *Novel About an Automobile*, 1968, page 214.

Let’s closely follow this thought process. The basic idea is absolutely correct: the diameter of an automobile wheel keeps getting smaller from year to year. Knowing this tendency, it is possible to look into the future. Then the logical conclusion follows that a moment will come when an automobile will loose its wheels. Here, the “impossible” appears. First of all, how can there be an automobile without wheels — if such a vehicle “does not exist yet?” Second, the actual wheel diameter reduction becomes, over time, less pronounced. This means it’s also “impossible” for the diameter to reach zero.

Now, let’s try to sort through these conclusions.

In reality, wheeless automobiles have never existed. We are so accustomed to this that it is difficult to imagine an automobile suspended in air over a road without “anything” supporting it. But that is not the bases for the categorical word “impossible.” We simply do not know how to do this. However, getting rid of the wheels is very intriguing. They only play a service role. Therefore, the tendency toward wheel-diameter reduction is not accidental, and we should not expect this tendency to go away. It is true that wheels cannot, practically, be reduced after reaching a certain limited size. The concept itself, inherited from automobile wheel design, enters into conflict with the tendency of automobile evolution.

The history of technology has many examples of one or another design that “did not want” to continue its development. The outcome was always the same — the design was rejected. Besides, if an automobile’s wheels contradict the progression of a technological tendency, this means the time has came to think about wheel-less automobiles.

This conclusion is completely supported by real life. Wheel diameter, “impossible” as it may have seemed, did reach zero size: new automobiles moving on an air suspension (hovercrafts) appeared.

There are two directions in the evolution of technology — *evo*lutionary (inside one level), and *revo*lutionary (a transition from one level to another). Schematically, this development can be shown by a complex line with a large number of turns. Experts in a narrow field sees those directions within one section of the line very clearly. Thinking about the future, they tends to see that future develop out from the present — as if, in their mind, a continuation of the last section of line. Understanding the limitations of an existing technology, experts clearly see unsolved problems as a wall into which their mental extension line abates. However, the dialectics of technological evolution are such that “unsolvable problems” are solved with the help of a by-pass method — in principle, by a new technological means. This is exactly why some experts consider those problems which cannot be solved by any means known within an industry to be unsolvable.

The “impossible” appears so only because people do not know *how it* *can happen*; therefore, they say beforehand that this *generally cannot be*. But, we must assume that it can be — we just do not yet know exactly how.

The inventor must overstep the word “impossible,” and temporarily forget about it. Sometimes this is enough to almost automatically reach a new technological idea. Of course, it may happen that the road to the solution will be long and difficult. But, any long journey always begins with the first step.

* * *

Theoretically, all this is simple: just don’t be afraid of the word “impossible.” In practice, bravery accumulates gradually during the process of solving problems that seem unsolvable.

Let’s remember the problem about winding wire on a ferrite ring. This problem was solved during seminars at the Institute of Mathematics at SO Academy of Science, USSR. Analysis led to the conclusion that the problem contained the contradiction “Productivity vs. Accuracy.” The winding is actually done by hand. If we want to increase the winding speed, we sacrifice the quality or accuracy of the winding process: the wires will be positioned improperly. The Matrix[1] contains the contradiction type “Productivity vs. Accuracy of manufacturing,” correlating to Principles #18, #10, #32, and #1. Principle #1 (Segmentation) is excluded by the conditions of the problem — cutting the ring is prohibited. Principle #10 (Prior Action) is also excluded because it is impossible to perform the winding before, or during, the process of making the ring. Principle #13 (Do it in Reverse): don’t wind the wire, but unwind it? This is also no good. Principle #31 (Utilization of Magnets and Electromagnets) is also unworkable.

The following dialog then occurred between the instructor (**I**), and the student (**S**) attempting to solve the problem:

S: Maybe I stated the wrong contradiction?

I: Well, try to state it differently.

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[1] *Lev Shulyak comments:* While translating this section of the book, a discrepancy was found while matching suggested Principles with those printed in the Matrix. Two principles were not listed — #13 and #31. When contacted, Altshuller revealed that this was an example with historical significance. It was the first problem solved with the original ARIZ-68 Matrix. Later, ARIZ-68 showed that the Matrix can, and must, be flexibly modified. In Altshuller’s words, “just like the Nautilus is mobile and immobile in Jules Verne’s *Twenty Thousand Leagues Under the Sea*.” What is important in this example is the logic of the thought process. We have translated and published this part exactly as it first appeared in the original edition.

S: We can say: "The smaller the diameter of the ring, the lower its productivity. The contradiction now is 'Length vs. Productivity.' The Matrix suggests Principles #13 and #28. We can try another contradiction: 'Length vs. Speed' — Principles #13, #14, #34."

I: So what?

S: (*Unresolutely*): The Matrix suggests Principle #13, which means "Do it in Reverse." But that's impossible.

I: Why?

S: We have to wind a wire, but "Do it in Reverse" means, in this case, to unwind it. To unwind requires making extra loops. Where do they come from?

I: You have to think how to get the extra loops.

S: It is impossible without winding the wire first.

I: Please, think some more. Maybe this is just the *Predawn Effect*. You need a ferrite ring with windings. How can this be done?

S: If winding is excluded . . . I don't know.

I: Think.[1] Imagine a toroid with extra loops.

S: That is simple.

I: What does it look like?

S: A ferrite ring with wire windings. I would say, with extra windings.

I: What does it mean with *extra* windings? Imagine that visually.

S: With *extra* means with many loops. Loop placed next to loop without any gap. Maybe like this: All of the ring is covered with a thin layer of metal. This is like an infinite number of loops.

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[1] In the beginning of mastering ARIZ, similar situations are often found. A person solves a problem by themself; however, it is necessary to repeat: "Please, think; please, do not stop halfway through."

I: See, this is good. It seems that an infinite number of loops can be made without winding. All that's left is to remove the extra loops.

S: Spiral thread . . . .

I: (*Without antagonism*): Is this possible?

S: Of course. There are different methods other than just mechanical ones. We remove metal, making "empty" windings over each layer of metal. This is much easier than winding the wire. It is possible to cover this ring in advance with a thin layer of photo-sensitive film, and then project on the top and the bottom of the ring an optical image of loops.

I: This means that Principle #10 ("Do it in advance") can be applied, as well as Principle #28 ("Replacement of Mechanical System with an Optical System").

S: Possibly. However, the Principle "Do it in Reverse" fits better. This is a typical example of how to do it in reverse.

You begin to solve a problem. The first step is not yet finished, but you think that everything will come together later. You think that any direction may be chosen. However, this is a delusion. Even in the case of "stripping away" the conditions of the problem from the *evident* tendency, inertia forces one to take the direction of a *non-evident* (but existing) tendency of the problem.

The problem is initially stated through known terminology. These terms are not neutral, they preserve the contents belonging to them. The real invention an come only when old terms, or their combinations, are given new contents.

The inertia belonging to technical terminology can at first be explained through the inertia of our thinking process. An inventor "thinks by way of words," and these words — invisible to the inventor — push him in a certain direction. More often, this is a direction belonging to previously known technical ideas for which this terminology was devised. It is no accident that Engels wrote, "In science, each new point of view brings a revolution in its technical terms."[1]

Let's recall the winding problem. From the very beginning, the statement of the problem forces the inventor to choose a specific search direction. It is required *to wind* a wire— as stated in the conditions of the problem. Why

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[1] K. Marks and F. Engels, *Collected Works,* Book 23, page 31.

to wind? Only because of a tendency in terminology: originally, all known methods were based precisely on the winding process. A new problem was formulated in old terms. Meanwhile, the winding is in itself not necessary, only a ring with a spiral is required. Why should we complicate the problem by introducing the additional requirement of getting a ring having spirals made only by winding?

Of course, if we had asked this question at the beginning, we would have said: "The *windings* are unnecessary — it is only required that we have a ring with a wire spiral . It is unfortunate, however, that this dangerous tendency of terminology only becomes visible after the problem is solved. In the beginning, everything seems natural: the winding must be required — what else?

At one of the seminars, the problem of bringing an oil pipeline over a canyon was analyzed. Conditions of the task stated that the presence of pillars and a suspension support were excluded. Usually, in this case, the pipeline takes the form of an arch (with upward curvature, or, for long spans, downward curvature). However, the condition of the problem also stated that the pipeline must span the canyon without curvature.

The solution was trivial: "The cross-section of the pipeline must be increased."

Next time, the same problem was formulated differently: "An oil line has to be installed 'without anything' and 'without curvatures.'" Therefore, only one word was replaced: instead of "pipeline," "oil line" was mentioned.

Now, this was among the solutions:

> *"The strength depends on the area and shape of the oil line's cross-section. The cross-section area is prohibited from increasing under the stated conditions of the problem (*weight increase*). We can change the line's cross-sectional shape. Let's have a hollow I-beam. Then, with the same metal consumption for one unit of length, the carrying capacity of the oil line increases. However, this shape is difficult to manufacture. The I-beam shape in this part of the line can be made out of two pipes (smaller in diameter than the main line) positioned one over the other, and connected with vertical ties."*

Here is the result of the replacement of only one technical term with a common word! In the first case, the word "pipe" was present in the formulation of the problem. Although it is not necessary for an oil pipeline to be shaped as a pipe, engineering train of thought is such that it has difficulty "derailing," in spite of the less prospective solution direction chosen. As soon as the word "pipe" disappears from the formulation of the problem, the inertia of the thinking process is extinguished. In the inventor's field of vision, it's now easy to find a simple — and, in this case, new thought — **an oil line may not have to be shaped like a pipe.**

An inventor must consider the tendencies of terminology in order to direct thought through a conventional channel. It is necessary to have control over all the stages of ARIZ; when following through a process, prevent the "seepage" of special terminology. The formulations of every step must be simple, and free from technical terminology.

Experience with solving inventive problems during seminars shows that the best results are obtained when common words are used instead of jargon. Then, after a new idea is found, it is possible (and necessary) to return to precise terminology.

◆

It was noticed long ago that many inventions were made in three steps. First, an inventor intensely and unsuccessfully searches for a solution. Then, having not solved the problem, he stops thinking about it. Some time passes, and suddenly, as if a delayed-action mechanism goes off — "as if by itself" — the required solution appears. Here is what Helmgoltz said:

> *"Each time, I first have to turn my problem over on all sides, examining it in such a way that all its turns and intertwining are strongly stored in my memory and could be again recalled by heart, without the help of notes. To reach that state is usually impossible without long preliminary work. Then, when my tiredness is gone, it is necessary for one hour of complete physical refreshment and feelings of wellness — and only then the good ideas come. Often, they come in the morning, after awakening, as mentioned by Gauss (who established the Induction Law in the morning, before arising)."*

We can offer another typical example. The prominent Russian bacteriologist, S. N. Vinogradski, for a long time tried learning the physiology of sulfur bacteria when there was little known about it. "I learn," wrote Vinogradski, "how to feed them with hydrogen sulfide, watch how fast they fill with sulfur, and then how fast the sulfur disappears without the presence of hydrogen sulfide." However, the working function of sulfur bacteria was not revealed for a long time. "There was no progress. I felt tired from that. Then, as a relaxation, I spent more time in the chemical laboratory, were I did analytical exercises. One day, I was walking home for dinner and, while reaching an embankment, I recalled the hydrogen sulfide water that remained in a glass on the table. It became cloudy from the precipitated sulfur, and then cleared up due to oxidation by the same sulfur. At that moment, as if tipped by this trivial fact, suddenly, vividly and brightly, the thought sparked in my head: My bacteria burns the sulfur into sulfuric acid. Then, their entire physiology opened-up in my mind. Furthermore, everything now went smoothly, and in several days the work was finished."

The three phases of an inventor's creativity (search, waiting period, illumination) are revealed very clearly. This is the only characteristic of creativity that can be seen from the outside. It’s no accident that this three-phase process serves (obviously, or not) as the basic point for all those explanations of creativity that focus the whole process down to one thing. Usually, only the last phase is highlighted: “*suddenly an idea appears*.” Others, on the contrary, see only the first phase: “you must search, try, test. . . .” Finally, there is one more “explanation” — stressing the second phase: “You must observe, look into surroundings, keep the problem constantly in your mind — and something will trigger a solution . . . .”

Now, having learned about inertia of the thinking process, we can objectively examine the mechanics of the creative process.

A problem is formulated with terminology possessing inertia, and secretly forces thought into the direction opposite to where new ideas are present. This is why the first phase of the creative process (if done unsystematically) usually does not lead to the solution.

Let’s show the conditions of the problem as follow:

$$A \leftrightarrows B \leftrightarrows C \leftrightarrows D$$

Each letter can represent, for example, a part of a system, while the arrows between them symbolically show an existing interaction. As a result of the first phase of the creative process, the basic structure is not yet broken. The interaction between the parts of a system is slightly reduced, or loosened. New conditions can be written, like:

$$A \leftrightarrow B \leftrightarrow C \leftrightarrow D$$

The second phase starts. The inventor almost doesn’t even think about the problem. Here, the positive role of inertia appears. A weakened interaction between the parts continue to get weaker, until they are broken completely:

$$A \quad B \quad C \quad D$$

Now the inventor can easily reposition the parts, change the character of the interaction between them, and so on. As a result, (without difficulty) a new formation of the system appears:

$$C \leftrightarrows A \leftrightarrows D \leftrightarrows B$$

When an inventor works at random, a lot of time is needed to break the habitual “bonds.” ARIZ does the breaking process deliberately and systematically.