Yuri Salamatov

TRIZ: The Right Solution at the Right Time

A Guide To Innovative Problem Solving

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SAMPLE CHAPTER

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2. MONOPOLY OVER CREATIVITY DOESN'T EXIST

2.1 COMPETING WITH EDISON

The method used by most inventors of the 19th century can be characterized as ***the blind trial and error method***: possible solutions were chosen randomly. No rules of idea generating were used and, in principle, any idea could be accepted. No criteria were applied either, which forced the inventor into multiple experiments in order to evaluate each possibility. The inventive process was a *quid pro quo*, reciprocal exchange, where **ignorance was being exchanged for time** ("the less we know, the longer we search"). Thus Paul Ehrlich, originator of modern chemotherapy, was striving to "aim a chemical gun at the disease-causing microbe". His optimism kept him going after 300, 400, 500 failed attempts. He scored a triumph with a 606th medicine, the famous *Salvarsan*, and the 914th substance, *Neoarsphenamine*, turned out even more effective.

Thomas A. Edison took a similar path. In 1873 A.N. Lodygin invented a vacuum lamp that used carbon electrodes. Edison followed Lodygin in the endeavor to create the incandescent electric lamp. In his first experiments, a filament made of charred paper only lasted for 8 minutes and a platinum filament – 10 minutes. Subsequently, filaments from titanium-iridium alloy, boron, chromium, molybdenum, osmium and nickel were tried, but with poor results. The next series of tests using 1600 different materials led Edison nowhere. And finally, charred cotton filament was found that shone for 13,5 hours. Fourteen months later, filament from charred board shone for 170 hours, and filament of charred bamboo (constructed from a Japanese fan-case which Edison borrowed from a lady at a ball) shone as long as 1200 hours! This was in 1879, after more than 6,000 experiments. In 1880 Edison elaborated the entire electric lighting system that consisted of current generators, wires, switches, safety devices, lamp-holders, etc.

Many of Edison's 1093 inventions emerged as a result of an *exhaustive search for multiple variants* which is **the major disadvantage of trial and error method**. Such was the case with the alkaline cell, when Edison achieved positive results after 50 thousand experiments. And all this tremendous work was accomplished in a surprisingly short time! How did Edison manage to benefit from the exchange of knowledge for time? Because, most importantly, he invented *the research institute*. The total of 50 thousand tests were divided among 1000 employees. This idea, simple as it was, led to amazing efficiency; which gave the impression that the main drawback of trial and error method was done away with...

But in the 20th century, a vast number of ever more complex problems came into view. Because they could not be ignored, a mushroom expansion of research laboratories began both in the US (300 in 1920, 1600 in 1930, 2200 in 1940 and toward 15,000 in 1967) and worldwide. The *more-people-more-*

ideas approach sounded reasonable as long as human resources were available and the economy could cope with the unprecedented increase of money being spent on the development of science and technology. In 1970–80s, however, all industrialized countries faced the depletion of human and material resources. So, the rate of increase in expenditure for science and engineering began to slow down and finally stopped at its ceiling. i.e. the rate of national income growth.

As a conclusion, the only promising way to optimize engineering and scientific development can only be achieved by intensifying the process of creative problem solving.

Long ago the deficiencies of trial and error method became a source of constant concern to scientists and engineers: sometimes even large-scale research institutes would fail to solve 'million-test' problems. Therefore the **intensification of the trial and error method** developed in two directions: <u>*acceleration of idea generation*</u> (the more ideas are worked out prior to experimenting, the greater the probability that an idea will emerge by chance) and <u>*intensification of idea filtering*</u> (the more ideas are dismissed at preliminary discussions, the fewer experiments are needed). It seemed at first that both ways combined successfully in *mental experiments*, because, due to the enormous volume of knowledge accumulated by mankind, the majority of variants would have predictable results, and notably, mental experimenting required considerably less time and practically no costs. Yet, these ways turned out to have two major shortcomings which canceled out all their strong points: <u>*subjective selection of variants*</u> (the risk of errors) and <u>*the lack of unexpected side discoveries*</u> (no "Columbus effect": sailing to India Columbus discovered America).

There exists ample evidence suggesting that many major discoveries in science and technology were side-products of material experiments. Edison discovered the phonograph principle while experimenting with automatic telegraph machine. But on another occasion he made a serious mistake discarding the 'trifle' effect of motion of electrical charges in vacuum space and not patenting it (later studies of the effect led to the discovery of the electron, invention of the electron tube and explorations in radio engineering).

Below is another example. We offered the following problem to numerous teams of engineers and scientists for mental experimenting.

> <u>Problem 6.</u> While drilling deep boreholes in the earth it is essential to monitor the condition of the teeth of the instrument that digs into the rock, for the teeth will break off sometimes. Unaware of the condition of teeth, a technician has to work blindly, regularly replacing the working instrument with a new one (just in case). To do this, the entire column of pipes is pulled out of the borehole which is often a few miles deep. However, replacing consumes too much time and labor. It is necessary to find a simple way to control the condition of the working instrument.

Together with the problem, a number of possible search directions were suggested. They included a dozen stereotyped solutions (making teeth unbreakable or self-replaceable, creating a device to dismantle the pipes quickly, installing electronic sensors, etc.) and a few 'bizarre' ones (consult a perfumer, study the system of household gas supply, refer to the branch of chemistry that studies esters). Mental experiments would always go along the same path: the 'bizarre', absurd ideas were discarded offhand and gave way to dispute on microprocessors and micro-robots shuttling inside the pipes.

Meanwhile, only the 'bizzare' ideas could furnish the clue (see Soviet patent # 163 559). They suggest supplying the teeth with micro-capsules containing fragrance (hence perfumery, ester) or some stinky substance (e.g. *Methylmercaptan*, a substance with foul smell at concentration as low as 1 mg in 10,000 m^3, which is admixed with town gas).

Therefore, *inventive problems can be of two kinds: simple and complex*. The former can be solved by everyone. Let us make sure they do:

> Problem 7. Everyone knows how the incubator works. But can incubation be carried out in space? Space station provides all the necessary conditions for incubation (atmosphere, heat), except one: gravity. That is why chickens simply won't hatch! An idea for the space incubator is wanted. What would you recommend for creating artificial gravity?

Most likely, the solution occurred to you before you finished reading the problem. Yes, one should make the incubator revolve around its axis. Isn't that too simple? Maybe, it is not an invention at all? Yes, it is. It is a *genuine invention* and it was granted Soviet patent 1 020 098 in 1983.

Let us try to solve another problem: Edison's problem.

> Problem 8. Edison used to offer 'tricky' technical problems to his would-be employees, especially theoreticians. Once he invited a mathematician into his lab, and asked him to calculate the volume of a bulb. For more than an hour the mathematician was busy doing measurements and intricate calculations. He dealt with the task successfully and proudly handed Edison a sheet of paper with the answer. To mathematician's bewilderment, in a few seconds Edison demonstrated an easier (and more reliable) way to measure the bulb.

Will you pass Edison's test? Incidentally, it only requires elementary knowledge of physics from an elementary school syllabus.

Middle school students tackled the problem in no time, high school students fared worse, and college students failed. A tendency was observed: the further the respondents were from the age at which Archimedes' principle was studied at school, the more difficulties they had. Nevertheless, in each team of engineers there were a couple of those who found the solution immediately. For some reason the principle lingered on in their memory from school physics.

To make sure this tendency really exists, try to solve another problem.

> Problem 9. The Dutch company advertises a device that provides rectilinear micro-displacements (measuring hundredths of micrometers) in microscopes. The device is very complex and contains an electric motor, a worm gear, a two-stage friction gear, all components being made of special hard steel with exceptional, precision, accuracy. The company emphasizes the advantages: no backlash, no lost motion, no lubricants used.

Design a primitive device that uses a principle known from elementary school physics, has no lost motion but greater accuracy.

The reader might ask: where is the border that separates between simple and complex problems, since school knowledge will be enough for both?

ZEBRA OR WAVES?

A town square was turned into a playground for children. At the same time it was impossible to bar the traffic in an adjoining street. This gave rise to a problem: is it possible to make motorists slow down while driving past the playground? Two proposals were put forth: covering a part of the street with a zebra crossing or giving this section of the road a zigzag profile. The first way was cheap but had a restricted effect, the second was safe but expensive. The desired solution should combine the advantages but be devoid of the disadvantages. What would you suggest?

FIRE OR ABASEMENT?

Lucas Cranach Junior, famous artist, was commissioned to paint a portrait of Cardinal Albrecht of Brandenburg, a notoriously cruel figure of those days. Cardinal was to be depicted in his own study, a Bible and a Crucifix in his hands. Showing the true character of Cardinal was out of question, but compromising would be immoral. What could be done?

TRIAL AND ERROR IN ARTS

"The seeker gropes in the dark, like a nightly air-raid in times of war" (E. Vinokurov, poet)

"Our profession demands a period of painstaking search; discovering, checking and rejecting hypotheses. You go to extremes, get into a dead end, run you head against a brick wall, feeling desperate about your stupidity and inaptitude... And suddenly, after a thousand failures, the thread of creative thought begins to weave" (G. Kozintsev, film director)

2.2. FORTUNE MAY NOT SPARK OFF A BRIGHT IDEA

The simple answer given by advocates of trial and error method to the question above (*i.e. the dividing line between simple and complex problems*) was: *the number of tests*. If so, then the process of solving complex problems can be accelerated by speeding up sequential search for variants. This principle was used in the computers of the first generation. Very soon, however, it became clear that the exhaustive search for variants wasn't effective enough even at enormous speeds.

G. Ivanitski, Russian scientist, points to the fact that this method is useless even in studying systems that are, from his viewpoint, relatively simple (chemical synthesis, development of new varieties of plants, machine-building, creating works of art). In biology, the difficulty to examine an enormous number of variants to accomplish a single task (e.g. modeling collagen (simple protein) requires 10^{120} attempts, a bacterial cell – $10^{20\,000}$ attempts) precludes us from using this method today or even in the near future.

In the 1960s, the idea of *heuristic programming* was proposed. Instead of examining all the possibilities, the computer uses certain rules to select as many of them as is sufficient to come up with a solution. Such programs were given pretentious names (e.g. General Problem Solver), but behind the new terminology there was the old formula: to use non-dialectic, i.e. rigid, logic as a basis for creating a problem solving tool.

According to Professor Yuri Shreider, the testing of such programs in the former USSR demonstrated their inapplicability even for solving problems that contained enough data to build a model. For instance, even when the structure and all necessary data on a chemical compound were given, it was impossible to predict the pharmaceutical properties of the compound.

Later, the exhaustive search as a main problem solving approach was used in the third and the fourth generations of computers. At this stage, the main ideas were: *mathematical modeling* and subdividing the 'ocean' of tests into separate 'rivers' and 'creeks' that are subsequently put under *parallel processing.* Mathematical models do not exclude, only complement, material experiments: computers calculate intermediate results or, given experimental data, process those variants that do not allow material experimenting (e.g. emergency operation of nuclear reactors, climatic and ecological change).

Thus, in 1967, a new phenomenon in plasma physics, the so-called T-layer, was first calculated and later verified experimentally. This discovery demonstrated computer-based acquisition of new knowledge. However, is it correct to speak of *computer-based creative problem solving*? Says G. Pospelov, Chairman of Artificial Intelligence Scientific Committee, Russia: "It appears as if the computer worked creatively... in fact, it only follows the program imposed by man and is fully dependent on the program. We do not describe the components of the violin as 'sophisticated'. Why then should chips be sophisticated?"

The following is an example of a problem solved through a computational experiment:

> Problem 10. Theoretically, metals can be hardened in nitrogen using a laser beam. Due to high temperature, nitrogen penetrates into the surface layer of metal, forming nitrid, a high-tensile compound. Experiments have shown, however, that high temperature causes the metal to evaporate and 'fly away' from the hardening area before it enters a compound. The process starts at low evaporation rate, then the evaporation rate increases steadily and reaches peak values by the end of the hardening process. In other experiments, a pressure of 100 Bars has been created. Yet, such pressure is unacceptable for industrial hardening, so the application of this method is delayed. What is to be done?

Think of an inventive solution to this problem. The above-mentioned examples hint that there should be *a trick*: providing a normal hardening process at no extra pressure. That's right, this would be a creative solution. From later sections you will learn about specific evaluation criteria and the rules used to derive them. Let us now consider the solution given by a computer.

Two institutes within the framework of the USSR Academy of Sciences were busy solving the problem. The work was divided in two stages and involved complex mathematical modeling (with a system of 15 equations being solved at the first stage). Reportedly, "the work on this utterly complex task employed to the full the potential of contemporary computational mathematics". Despite the difficulties, the solution was obtained: the pressure should be kept at 30 Bars, the power of the laser beam should be at peak value at the very first moment and should be decreasing gradually towards one tenth of its initial value by the end of the process... Notably, it was concluded that technological tasks, usually involving multiple parameters, often turn out to be more complex than the tasks of nuclear physics, plasma physics and astronautics.

What makes computer-based solving of difficult problems so difficult? Is it only the tremendous number of variants? Not only that. The main problem is that computers are perfectly logical, whereas in many situations creative tasks demand either non-logical thinking or extra knowledge from a different area, that is not pre-programmed in the computer. In other words, dialectic logic should be at work, instead of traditional formal logic used now in the computers.

Dialectic logic possesses the power to expose and resolve contradictions: 100 Bars is good for hardening but impossible for industrial application, while 1 Bar (absence of excessive pressure) meets the industrial standards but makes hardening not possible. The computer chooses an intermediate value of 30 Bars, whereas the contradiction should be resolved in such a way that hardening may be performed at 1 Bar. Where traditional logic is used, there it is useless to bring on board a group of experts to model the task.

"Bringing the opinions of geniuses to an average, we get a mediocre opinion at best. Rejecting contradictory opinions we sap the strength of expert knowledge. There is only one road left: to seek the logic of tackling contradictions, which is, of course, far from easy." (Yu.A. Shreider, "Computers as a tool for knowledge representation", in: *Priroda*, Vol. 10, 1986, p. 20, in Russian).

In the USA the boom of computer creativity is now over, and 'new' ways are being sought of to galvanize the trial and error method. For example, IBM has hired 45 'free of duty agents': 'day-dreamers, heretics, rioters, oddballs and geniuses'. "We are fewer in number than there are vice-presidents in the corporation," says one of them. "A free of duty agent is free to do whatever he wants to do in the course of five years. His role is simple: to shatter the system. And that's precisely what we're doing."

The chance of catching a good idea is very low, so the main commandment of the inventor reads: "You should be prepared to failures... If you are not prepared to put up with mistakes, you cannot be an innovator." *True, trial and error method implies 99,99% mistakes and no one knows when* *the bright idea sparks off.* The wheel has gone full circle: 'free agents' are the 19th century 'free inventors' now being employed by large companies.

Trial and error method means tremendous material damage to society. The effectiveness of research and development work is very low. Up to 50 percent of all launched projects are closed down as having no future, one half of the other 50 percent does not meet production requirements. Only one fifth of the projects brings profit to companies.

Not only the waste of time and effort is entailed by trial and error method. *Trial and error method is detrimental in that it rules out the possibility of anticipating new objectives*. In this respect, entire decades and even centuries may be lost. For example, the meniscus telescope, admits D. D. Maksutov, its inventor, could have been invented in the days of Descartes and Newton. There was a need and every possibility to invent it. The task was simply overlooked until the mid-20th century. In the opinion of Charles H. Townes, lasers could have appeared in late 1920s, all the theoretical premises having been developed for this. V.A. Fabrikant, Soviet scientist, described the concept of a laser in 1939. In 1951, he was refused a Soviet patent because the commission of experts considered the idea impracticable. Their decision was reconsidered as late as in 1964. Though it may be argued whether or not the society really needs this or that technical system, there is no question about the acute demand for new medicines, such as penicillin, that help to save millions of human lives. The fact that penicillin, discovered by Sir Alexander Fleming in 1929, only started being widely put to use during WWII is even less shocking in the light of the entire history of penicillin, dramatic and full of absurdities. Penicillin had been studied and used long before Fleming: research results on penicillin were published first by Russian scientists V.A. Manasein and A.G. Polotebnov in 1871, then by S. Grigorov, Bulgarian scientist in 1906. More than that, the healing properties of molds had been known as early as in Ancient Greece.

Also, trial and error method is responsible for the lack of criteria of evaluating new ideas: almost every important invention was once given the verdict: "Impossible". It took years, even decades, until some major inventions of our time were recognized: *vacuum diffusion welding* (I.F. Kazakov, 1951), *the memory shape effect of alloys* (G. Kourdiumov, L.G. Khandros, 1948), *the electro-hydraulic effect* (L.A. Yutkin, L.I. Goltsova, 1950), *the hydro-extrusion processing of metals* (1958), etc.

A YEAR BEFORE THE TELEPHONE

In 1875 American newspaper reported: "A man was arrested yesterday while trying to get a bank loan under false pretext. He claims he can make a device that consists of two small apparatuses and a long wire. Using this device one person can speak to another person a few miles away. No doubt, the man is a charlatan and unashamed ramper who needs a lesson that Americans are clever enough not to be fooled by a trick. Even if this mad idea can be realized, it will be of no practical use, except for performing conjuring tricks in a circus".

SOFT WATER NEEDED

High diving is getting more and more complicated and demands virtuoso performance.

Accidents happen very often during drilling. What precautions can be taken against injuries occurring when the diver hits against the water surface?

Imagine that the diver is midway from the diving board to the water surface when the coach realizes that the dive is not successful...

What should be done?

EMBODYING FINNISH SOUL

Designing the Government House in Kuwait, Finnish architect Pietile was striving to "express the Finnish soul in this land". However, Finnish architecture uses straight lines, sharp angles that do not combine with the streamlined, well-rounded style of Arabian buildings. What could be done?

2.3. DREAMS THAT DIDN'T COME TRUE

When mere accumulation of knowledge was no longer viewed as valuable, primary importance was attached to renewing ideas and generating new ideas (in science, engineering, humanities and society). **New ideas are considered to be the main source of national wealth determining nation's economic,**

cultural and military potential. This became the reason for active search started towards finding ways to intensify the flow of new ideas. The idea to coordinate the inventive process thus easing the deadlock and creating a method of creative problem solving became dominant.

Gradually, creative processes became the object of keen inspection; the evolving scientific research gave inspiration to find universal rules of creative problem solving. Here, the previous progress of science was a source of encouragement: man had learnt to control the forces of nature, unveiled the secrets of matter, and reached out to far ends of the Universe. Why can't man clear the mystery of creativity and learn to control it?

At first, the researchers did not encounter many problems: there appeared a lot of works in psychology (*"On Early-Developing Intelligence of 300 Geniuses", "A Study of Genius", "The Psychology of Invention"*, etc.). Historians reconstructed in detail the situations in which geniuses gained insight into great discoveries, studied their personal accounts of such situations, their dreams of the eve of such great days. But no universal recipes of creative work were found and inventors continued to work in the old-fashion way.

Psychologists then proceeded to studying the finest mechanisms of human brain hoping to reveal the secrets of invention in the head of the inventor. Historians continued to collect meticulously the facts from the history of science and engineering, placing them on the time scale, analyzing epochs and technological revolutions in conjunction with social changes.

Undoubtedly, all these studies were not in vain. But their isolation caused by separation of these highly-specialized areas did not allow researchers to suggest valid practical recommendations. Psychologists ignored the tendencies from the history of technology, as well as of any other, social or creative, systems. At the same time, historians were unaware of the psychological peculiarities of the creative process. Meanwhile, a technological revolution brought on board millions of people: invention became a movement. The question "**how does one invent?"** became urgent. That is why, technology was the first to break through to the mystery of creative work: ***brainstorming*** became a pioneering technique of creative problem solving. As the term suggests, the emphasis was laid on the psychological side of invention. Despite its weak points and theoretical shortcomings (i.e. ignoring the objective character of systems development) the technique has played an important role in revealing some of the origins of creativity and also attracted attention to the problem of creative work theory.

As a technique, brainstorming is based on the assumption that the generation of ideas should be separated from evaluation. During discussions of a problem, people usually shun expressing bold, unexpected ideas for fear of ridicule, mistakes, or disapproval on the part of higher-ranking colleagues, etc. Once expressed, such ideas will often be castigated by other participants and will perish without further development.

In 1940s Alex Osborn suggested that ideas could be generated in a setting where criticism is banned and any idea, however odd or funny, is encouraged.

Six-eight idea-generators, analysts, and neutral with possibly diverse backgrounds, form a group without a leader. The group generates ideas in an informal setting. The ideas expressed are recorded or stenographed. Then the ideas are submitted to a group of experts for evaluation and selection based on promise or potential.

A favorable setting allows a group of 'day-dreamers' to collect as many as 50-100 ideas in half an hour. The totality of ideas is boiled down to a few that "sound reasonable". Peak experiences of the group give rise to agitation, hectic outburst of ideas, intuitive suppositions. It is these ideas that constitute the most valuable product of brainstorming work.

"Thoughts are pelting down like rain. The group is gaining a 'creative insight'... The task is to find a fast, simple and effective way of connecting two ends of a wire. "Just clutch them together with your teeth, that's it!" somebody shouts. However absurd, this suggestion gave the idea of the clamp for cold-welding of wires.[1]

Freudianism is a philosophical basis of brainstorming. According to Freud, absurd, irrational ideas break out of the restless domain of the unconscious penetrating the thin and weak layer of consciousness. Consciousness controls ordinary thinking, restraining illogical actions, imposing a multitude of taboos. But an invention is always an overcoming of conventional views on what is possible and what is impossible. Unhitched, freed from the power of consciousness, the brain is able to produce ingenious ideas.

Brainstorming originated in the US where its way had been paved by Freudianism. For the first 10-20 years it was viewed as very promising and seemed to have unlimited power. In the course of time, the brainstorming proved a very powerful aid in solving problems in the field of management, advertising, etc, but turned out hardly appropriate for present-day inventive problems.

Compare the following three problems:

> Problem 11. Below is a patent formula (Soviet patent 1 011 460) which describes "an innovative device for packaging rubber nipples. In order to improve the vendibility of production by securing the alignment of rubber nipples in a package, the device is equipped with a guiding mechanism. The mechanism consists of a conveyer with sockets, a 180^{o}-steerable positioner fixed over the conveyer and having open-bottom sockets and grips for holding misaligned rubber nipples straight, and a pusher located under the conveyer coaxially with the sockets of the positioner, allowing vertical reciprocating motion.

Never mind if the formula seems long-winded and you do not understand the principle of the mechanism: in this case you do not need to go into detail. Briefly, here is an expensive and bulky robot used for putting children's dummies into boxes in regular rows (to provide accurate packaging). How can

[1] B, Pekelis. Your Capabilities, Men! – Znanie, Moscow 1984. p.245

one simplify the system, increasing productivity and quickly aligning the dummies? A novel idea is needed.

So, what are your suggestions?

> <u>Problem 12.</u> A company producing potato-peeling knives ran into marketing difficulties. At first their knives became very popular: they were made of hard steel, had a convenient plastic handle and were of elegant design. But in a few years the sales fell: the knives didn't break and it took long time till they got blunt. Housewives did not need a second knife at home. In order to stay afloat in the market, the company commissioned specialists in creative problem-solving. What should be done to increase the demand for knives without reducing the quality or spending money on a new advertising campaign? Any solution will do, but it should preferably be free of cost...

> <u>Problem 13.</u> In a new company building, the employees began to complain about improper functioning of the lifts: it took long to wait for a lift to arrive, which was very irritating... The administration was faced with a problem, whether to install new lifts, replace the old ones with high-speed lifts, or create a computer center to monitor the lifts. Each solution seemed too expensive and a creative problem-solving adviser was commissioned to tackle the issue. Is there a simple way to work it out?

More or less original answers to problems like 12 and 13 are found in groups that have at least a short record of brainstorming work. Quite often, these solutions surpass in clarity those that were put into effect by companies. With respect to problem 12, it was suggested to make handles resembling potato peels in color (so that the knives are more likely to be thrown into waste bins). For problem 13, it was suggested to hang big mirrors near the lift entrances (because the actual reason behind complaints was not the waiting itself but to the *boredom* of waiting, so while standing by the lift doors people should be busy doing something enjoyable).

Problem 11 caused more difficulties. As a rule, no less complex and equally unreliable solutions were put forth: orienting the nipples by placing them on a vibrating conveyer, into water, or a stream of air, using vacuum pump, rolling them down an inclined plane, etc. At times it looked as if the group were getting close to a simple and effective solution: introducing a ferromagnetic (a tiny piece of magnet) into the nipple or its ring and thus orienting the nipple in the magnetic field, but at this moment another idea would crop up, and the discussion took another direction or started anew.

Offer this problem to a group of respondents and watch their pointless, irrational search which constitutes the core of this method.

2.4. INVENTIVE ADVERTISING

There are many ways to beat brand names into customers' heads. A German tobacco company published an ad: "Remember the name: *PILO*". The caption beneath the picture read: *POLO*.

A flood of letters to the editor followed pointing to the slip. The papers replied with an announcement: "We apologize for the mistype that occurred. Indeed, *PILO* was an error, the correct name is *POLI*". Consequently, other mistypes followed *PRZO*, *PAOLO* and so on. At last the papers reported that "the responsible typesetter has been fired, the new product's real name is *POLO"*. All mistakes corrected, the tobacco company paid a good commission to the advertising agency.

THE MAN WHO INVENTED BRAINSTORMING

Alex Osborn was born in New York. He worked successively as a builder, office boy, clerk to pay for his education. At the age of 21 Osborn became a police reporter in a newspaper, then worked as a shop assistant and at the same time as a teacher at an evening school. After that he was an assistant manager of a small plant and finally entered an advertising agency. Brainstorming was developed in 1937, but the first publications only came out in 1957, when Batten, Barton, Durstine & Osborn has been using the method effectively for 20 years. By the end of WWII the company was running 14 branches with 1800 employees.

At present, there is a score of varieties of brainstorming: individual, paired, multi-stage, stage methods, idea conferencing, cybersession, "pirate briefing" and etc. Each of them has a weaker effect than pure brainstorming, because the attempts to manage a spontaneous process invalidate the most valuable mechanism of brainstorming – providing a setting for free expression of irrational ideas.

2.5. UNVEILING THE MYSTERY

It seems strange now that in those days, some 50-100 years ago, students of the origins of creativity disregarded the most obvious circumstance: **the objective character of technological development.** Ample evidence such as archeological finds (e.g. similar, often identical, tools discovered all over the world), historical explorations, numerous instances of independent 'parallel' discoveries and inventions made in different epochs and different countries lead to an obvious conclusion that ***the development of technical systems, in the same way as of social, scientific, artistic and other systems, follows inherent rules that are independent of human will.*** But the overwhelming authority of old views on the nature of creativity, the domination of single possible problem-solving technique (trial and error method) were too powerful and it took decades to come to this basic postulate of the theory of creativity.

Due to the fact that around the world patenting offices registering technical inventions prescribe similar rules on how to report on new ideas, we have a unique opportunity to trace the history of any technical system from the moment or its conception. Usually, many inventors become equally concerned about the need to solve the task, but the patent is granted to the first-comer. Thus Alexander Bell, teacher at an oral school, filed an application to United States Patent Office on 14 February, 1876, and had the patent for the telephone issued in three weeks. Meanwhile, much the same application filed by Elisha Gray an hour later was rejected. Afterwards, A. Bell won about 600 cases against claimants to priority of invention.

Patent experts are the first to receive identical ideas coming from different parts of the country. Says N. Patrakhaltsev, "My experience of working as an expert (and I have examined over 400 applications) shows that quite often, identical solutions come in from several authors within a relatively short time. Inventive thought appears to be inspired by life itself, by science, industry and by product demand. In fact, it would be strange if no identical solutions were found in a long chain of applications.

State borders, differing social systems have little or no influence on the objective character of technological development. Academician V.V. Struminsky tells the story of a coincidence which seems amazing to an inexperienced person. When the US triggered the war in Korea, the USSR aided China with air fighters. The first missions of new Soviet MIG15 fighter was a shock to the American military. "After the MIGs started to be used successfully in the Korean air, Americans came up with F-86 Sabre, an innovative jet-fighter with swept-back wings. The two models came from two different countries; they were developed with absolute secrecy. But when missions began, the two models proved to have so much in common, their specifications being surprisingly similar... That's science! Scientists and engineers worked independently in the two countries only to achieve very similar results."[2]

This is to say, technology should be treated as material, and its development as dialectic. There seems to be no question about that. Clearly, technical systems are of material nature and therefore evolve, as any other systems, according to dialectic laws. What follows is the leading principle of inventive methodology: ***there exist objective evolution laws for technical systems. These laws can be studied and purposefully applied to inventive problem solving without resorting to a search for variants.***

Nevertheless, for the entire 20th century, ever since regular explorations into creativity started, research has focused on the psychological side of invention. Up to the present day it has been assumed that essential processes occur in the head of the inventor. To a certain extent, this approach was endorsed by inventors and scientists themselves, who all too often alluded to 'intuition', 'insight', 'revelation', 'instant flash amidst the darkness of thought' (Edison), 'free creation of mind' (Einstein), etc. in their biographical accounts. The wealth of annoyingly unconvincing statements has amounted to a "heap of rubbish, wherein we dump the mechanisms of intelligence we are unable to analyze or simply give name to, or don't care to name or analyze'.[3] Therefore, most present-day researchers into creativity agree that 'intuition', 'insight'

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[2] M. Arlazarov. *A Propeller and a Wing.* Znanie, Moscow, 1980.
[3] M. Bunge. *Intuition and Science.* Nauka, Moscow, 1967.

stem from idealistic thinking. On the other hand, derisive remarks about intuition as "the vain ambition of idlers... the credulous offspring of knowledge, whose prattle is senseless..."[4] are equally unconvincing.

A question arises: how did the numerous inventions appear, both in the past and the present, if they required searching through an enormous range (hundreds of thousands, millions) of variants? This paradox becomes clear when we consider the fact that each invention results from joint efforts: partly due to cooperation of contemporaries and partly due to borrowing from the heritage of past generations. Despite the illusion that they are perceived by geniuses, lucky solutions are, in reality, a product of *cooperation of contemporaries* and *the relay-race of generations.* The 90% or even 99% of tests appear to have been performed by others and the lucky one has to complete that job. The 'inventive marathon' suggests a competition of gold-miners: the field is divided among thousands of prospectors, each one mining a plot. Some, despite the difficulties, continue to dig laboriously, while others, tired of excavating barren rock, walk away and look for another spare plot. Finally, there are no spare plots left. At this moment somebody comes to occupy a lucky plot, either accidentally (simply because there aren't any more plots left) or purposefully, bearing in mind the previous attempts (which may have shown that gold grains are more likely to be found up (or down) the river). It still takes some effort and good luck to strike a vein of gold. And then journalists and psychologists come to the site shouting: "Extraordinary! How did you do it? What method did you use?"

Therefore, the role of individual in science and technology is proportional to individual's awareness of the social demand to solve a problem, and to individual's conscious/unconscious conformity with objective development of the scientific or technical system.

Here is a unique acknowledgment made by one of the inventors of Maglev (high-speed magnetic levitation rail): "You often hear a question: how does a new idea come into being? One might imagine a fascinating scenario in which the idea to reject the use of the wheel occurs to the author while he is somersaulting in his car that has had a wheel gone loose. But no. The decision to reject the wheel came as a result of long speculations about the ways to increase the vehicle speed". [5]

Does this mean that, in order to make a great discovery or invention it is enough to trace an objective tendency in the development of a system? Of course not. If you tell an inventor: "Look at the tendency and take one step forward", it won't work. It is not only the difficulty to project the development of a system, but also the difficulty to find a way to overcome an obstacle that stands in the way of its development (for otherwise there would be no problem at all). Therefore, alongside with **the strategy**, or the main tendencies of development, the theory of creativity should teach **the tactics,** *or* the methods

[4] A.C.Karmin. *Origins of Scientific Discovery.* Nauka, Moscow, 1986
[5] G. Zelenkin. *Flying Expresses.* Vysheishaya Shkola, Minsk, 1984.

and techniques to deal with obstacles. Additionally, it is necessary to take into account the peculiarities of using inventor's main tool: the human brain. *Traditional thinking is extremely conservative*, it is biased towards the only method used for millennia, the trial and error method. Only a small part of us is inclined to *dialectic thinking* that is always looking for new ideas. Dialectic thinking should be made available to everyone, hence there is the need to incorporate the *rules of using dialectics* into the theory of creativity. To avoid errors, proper organization of creative work should employ the best of human thinking (*imagination, fantasy*) and take heed of its weaknesses (*psychological inertia*). Finally, for solving present-day inventive problems there is a need for knowledge, i.e. inventor should have an *information database* at his fingertips.

It is hard? It is not harder than learning to drive. One may head off towards the destination on foot, hoping that some 'heavenly fire' will at last show the way to the weary traveler. But wouldn't it be more practical (and more up to date!) to whiz down the newly-discovered road at a breath-taking speed!

HAD THEY NOT BEEN BORN:

Sir Isaac Newton, James C. Maxwell, Max Planck, Dmitri Mendeleev... These questions could start an interesting discussion on the role of individuals in science (there are many interesting materials devoted to this topic). The following quotation from Albert Einstein can be used to open the discussion: "I don't understand all these eulogies to myself as the creator of the theory of relativity. Had it not been for me, Poincare would have done the same a year later, or, Minkovsky would have done it in two years. After all, Lorentz did half of the job. My services are exaggerated." (K. Seling. *Albert Einstein*, Moscow, Nauka, 1964). A no less thought-provoking discussion could be organized that focuses on the originators of great inventions: the laser, the nuclear reactor, holography, spacecrafts, etc. What about artistic inventions? What would have happened, if the originators of science fiction (Jules Verne), symphony (Joseph Haydn), landscape painting (Brueghel), air perspective (da Vinci), artistic documentary, the opera, the comedy, the musical comedy and etc., had never been born?

2.6. A TABOO ON POOR SOLUTIONS

There is always an abundance of inventive problems to be solved, since the development and practical application of technology is accompanied by continuous problem solving in every area of study. As a rule, problem solving begins with using familiar technical knowledge and technical means. It happens too often, however, that this knowledge and these means appear non-applicable.

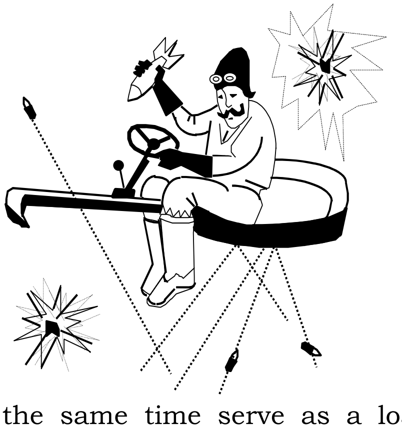
> Problem 14. When tanks appeared at the start of our century, there was an acute need to counteract them. What could be used against tanks? Aircraft? But in a duel between a tank and an aircraft the latter was obviously weaker, for it could easily be destroyed by the tank's machine-guns. What could be done? Designers in many countries attempted to construct armor-plated aircraft (such as German U-1 designed by Junkers) but these were heavy and slow and

might be easily shot down from below. Many pilots during the World War II put cast-iron pans under their seats! After the war Americans tried to solve this problem. Many variants were examined: using powerful engines, avoiding extra weight, bearing fewer weapons on board. Similar research was carried in Russia by development laboratories of Tupolev and Polyakov, but with poor results.

The problem contained a paradox: the armature is vitally important only at certain short moments during the fight; and for the rest of time it is dead weight. In other words, the armature should be present to shield the aircraft and its crew from being shot down, but at the same time it should not be present, because it adds extra weight to the aircraft.

The problem acquired primary importance when the Great Patriotic War started: the situation did not allow poor solutions. What could be done?

In summary, in the 'aircraft-armature' system, better defense results in lower speed of the aircraft. And *vice versa*, higher speed requires thinner armature and consequently weaker defense. Such conflicts found between parts or properties of a system are called **technical contradictions.**



A problem containing technical contradictions can be solved either by seeking a compromise between the conflicting properties (*to what extent is it appropriate to lose in certain properties in order to gain in other properties?*), or by trying to resolve the contradiction (obtaining the desired result without much sacrifice). The first way is typical of ***engineering solutions***, the second way characterizes ***inventive solutions.***

Soviet aircraft designer Iliushin came to a brilliant solution to the 'aircraft – armature' system: he realized that armature should at the same time serve as a load-carrying structure of the aircraft, not only defending it, but also bearing the forces that occur when the plane is air-borne. Armature should strengthen the aircraft and thus there will be no 'dead weight'. The famous IL-2 attack plane (IL-10 since 1944), known as 'the flying tank' is recognized as the best in its class. The benefit of Iliushin's invention was great (the advantage of these planes over enemy's planes, more chances of victory) whereas the sacrifice was incommensurably small (alterations in the construction of the plane and in the production technology).

The essence of inventive creativity is to find a technical solution where the sacrifice for the result is either zero or nil as compared to the benefit achieved.

This proportion should be borne in mind while solving inventive problems. Let us compare two solutions to the problem described below.

<u>Problem 15.</u> When shells and bullets penetrate the gasoline tank of the aircraft, it looks as if explosion is imminent. But combustion can only occur in the mix of fuel and air, when part of the fuel has been discharged and the fuel vapor is present in the empty part of the tank. Can formation of gasoline-air mix be avoided, and the chance of explosion reduced?

Obviously, one should prevent air from getting into the tank when fuel is being discharged. However, gasoline will not flow out of the tank without air input. Hence the technical contradiction: *the air should be present in the tank to make gasoline flow out, and it should not be in the tank to avoid the formation of gasoline-air mix*. Solution: in 1942 it was suggested to fill the empty space in the tank with inert gas nitrogen (which constitutes the four fifths of the earth atmosphere). Thus, the air *is* and *is not* present in the tank at the same time. The price paid for this solution was enormous: the weight of the cylinders with nitrogen, the valves, pipes, the operating system that weighted dozens of kilograms. But in those days this was the only possible way out (by 1942 another solution had been found: filling the tank with exhaust fumes of the engine). And below is a present-day solution, where the technical contradiction is viewed from the other side: *there should be gasoline in the tank to supply the engine with fuel, but at the same time it shouldn't be in the tank to avoid the formation of air-gasoline mix.* Yes, gasoline *is* in the tank (to secure the useful function of the system) but it is in gel-like form. The process of transforming fuel (in modern aircraft – kerosene) into a safe substance is called 'fuel stabilization'. It is enough to admix a small amount (0,3-3%) of certain polymer for the fuel to stop evaporating. Other properties of the fuel (such as fluidity) will be retained. Stable fuel will not combust during a clumsy landing and in racing cars a light bag may be used instead of a tank. A handful of polymer powder replaced the bulky system of nitrogen supply. In this case it was the working substance of the system (the fuel) that acquired the necessary property without using additional devices. Of course, the effect was first discovered scientifically and only later put into practice. Once discovered, each effect can be used endlessly and finally the wide use of the effect is a part of everyday reality. But the first application of the effect is always an invention, it empowers technology with a new idea. For example, the effect of the demagnetization of substances in heating above the Curie temperature was discovered long ago, but it is still actively used in inventive practice.

> Problem 16. Cereal often contains germs and eggs of pests that should be killed before packing. The best way to do it is by heating the cereal accurately up to 65^0 C, for cereals cannot be heated above $68\text{-}70^0$ C. During experiments, it was impossible to provide accurate temperature regime and high production rate at the same time: a thick layer of cereal did not get heated all through, and the lower layer burned. Using a thinner layer of cereal led to lower production rate. Other ways to heat cereal were tried: placing the cereal on a sieve and blowing it through with a stream of hot air coming from below. But due to excessive heating the cereal would deteriorate all the same. An utterly safe method is needed to secure high production rate.

Absolute accuracy of temperature regime was conditioned with the help to ferromagnetic pellets, admixed in cereals. The pellets have Curie temperature at 65^0C. Getting into alternating magnetic field, pellets, as ferromagnetics, are heated and lose their magnetic properties and stop being heating. When the temperature of ferromagnetic drops under 65^0 C, the pellets 'switch on' again. Pellets could be easily separated from cereal afterwards, for they are magnetic.

How can the technical contradiction be formulated for this problem? *Cereal should be processed in big quantities for high production rate, and in low quantities for temperature accuracy.*

> Therefore, an inventive problem is a problem that contains a technical contradiction, which cannot be solved using familiar knowledge and common technical means. The conditions of the problem do not allow a compromising solution.

Once the technical contradiction is overcome, the inventive problem is solved and an invention is obtained.

The technical contradictions are sometimes on the surface of the problem. Such are the problems presented in this chapter. However, sometimes the contradiction is hidden, or dissolved in the formulation of the problem. Nevertheless, the inventor should bear in mind the technical contradiction that needs to be resolved. It is relatively easy to reveal the contradiction in problems that read: "Improve object X obtaining result Y….". If only one part of this formula is presented in the task, i.e. "improve object X", or "obtain results Y and Z…", the problem is more difficult to solve.

YABLOCHKOV'S INVENTION

The technical contradiction underlying problem 5 can be formulated as follows: the gap between the carbon electrodes should be adjustable so that the electrodes are burning out at a constant distance between one another, and it shouldn't be adjustable to avoid using complex mechanisms. P. Yablochkov found an ingenious solution: he placed the electrodes vertically, one running parallel to another, and filled the gap with kaolin (or China clay). The electrodes burned out, but the gap remained did not change during the burning process.

LUCAS CRANACH JUNIOR faced a very complex contradiction, but managed to resolve it. Cardinal's face is normal. He is looking at the Cross. But the figure of Christ on the Cross looks so scared, intimidated, so miserable that it becomes clear that the man looking at Him is very cruel.

ZEBRA OR WAVE? BOTH!

Such was the solution to the problem about the road profile. A zebra crossing is painted on the flat road in the way it would look on a wavy road. Before realizing that it is an optical illusion, the driver will slow down almost instinctively.

IN ORDER TO EXPRESS HIS FINNISH SOUL the architect refused to compromise (giving the building neither streamlined form, nor straight lines and sharp angles), for this would have been a defeat. He used straight lines and sharp angles (the 'Finnish' way to build) that are arranged in a zigzag pattern, making the silhouette of the building look streamlined and very 'Arabian'.

FORMULATE A CONTRADICTION TO GET AN INVENTIVE PROBLEM.

For example, what contradiction was resolved in designing Chameleon sunglasses (sunglasses that change transparency when exposed to light)? Any item that comes at hand can be improved. Formulate technical contradictions for the pencil, the needle, the scissors, etc.