Introduction to TRIZ

by Lev Shulyak

As can be learned from his biography, Genrich Altshuller analyzed thousands of worldwide patents from the leading engineering fields. He then analyzed solutions that were, in his judgment, most effective. This work provided the first understanding of the trends, or patterns, of evolution for technical systems. It also laid the foundation for the development of an analytical approach to solving inventive problems, later becoming the foundation for TRIZ, his theory of inventing problem solving, with its axiom:

> *The evolution of all technical systems is governed by objective laws.*

These laws reveal that, during the evolution of a technical system, improvement of any part of that system having already reached its pinnacle of functional performance will lead to conflict with another part. This conflict will lead to the eventual improvement of the less evolved part. This continuing, self-sustaining process pushes the system ever closer to its *ideal* state. Understanding this evolutionary process allows us to forecast future trends in the development of a technical system.

Over the past 40 years, TRIZ has developed into a set of practical tools for inventing and solving technical problems of varying complexity. Today, we can identify several basic TRIZ tools as well as other methods and techniques that combine to makeup what is known as Systematic Innovation. Students and followers of Altshuller developed these additional techniques over the past 15 years.

This section provides a short introduction to some basic TRIZ tools. It is here for two reasons:

First, it is important for new readers to first learn TRIZ terminology and its meaning so that they may effectively utilize the 40 Principles to solve problems.

Second, it is important for the reader to be familiar with the philosophy underlying TRIZ tools and techniques in order to be able to fully apply them.

THE FOUNDATION OF TRIZ

1. Technical Systems:

Everything that performs a function is a technical system. Examples of technical systems include cars, pens, books and knifes. Any technical system can consist of one or more subsystems. A car is composed of the subsystems engine, steering mechanism, brakes and so on. Each of these is also a technical system unto itself (with its own series of subsystems) — and each performs its own function. The hierarchy of technical systems spans from the least complex, with only two elements, to the most complex with many interacting elements.

The table below shows the hierarchy of the technical system called "Transportation." In the left column are names of technical systems. They are placed in descending order. Horizontal rows contain names of subsystems that belong to the technical system described on the left.

For example, the technical system "Brake" is a subsystem of the technical system "Car" — as well as a supersystem for the technical system "Pad."

When a technical system produces inadequate or harmful functions it may need to be improved. This

Technical Systems	Subsystems for Technical Systems				
Transportation	Cars	Roads	Maps	Drivers	Service Stations
Car	Power train	Brakes	Heating	Steering	Electrical
Brakes	Brake pedal	Hydraulic cylinders	Fluid	Brake pad assembly	
Brake pad Assembly	Pad	Mounting plate	Rivets		
Pad	Particles A	Particles B	Chemical bond		
Chemical Bond	Molecules A	Molecules B			

requires the imaginative reduction of the system to its simplest state. In TRIZ, the simplest technical system consists of two elements with energy passing from one element to the other.

Chalk and a blackboard are not, together, a technical system unless some energy (mechanical force) passes through the chalk causing it to interact with the chalkboard. The technical system "chalk, blackboard and applied force" can then become functional — a *chalkboard*. *Chalk* and *board*, as separate elements, are each independent technical systems. Chalk has a molecular structure. Interaction of different chemical elements within its structure produces a bond creating a material called "chalk." Should the quality of the bond require improvement, then the technical system of the molecular structure must be analyzed. At the same time, chalk is a subsystems of the supersystem *chalkboard*.

All subsystems are interconnected with each other within the bounds of the higher system. Changes in any one subsystem can produce changes in higher, supersystems. When solving a technical problem always consider interactions of the existing technical system with those systems above and below it.

In addition, technical systems are like biological systems. They are not immortal. They emerge, ripen to maturity, and die — only to be replaced with new systems.

2. Levels of Innovation

Analysis of a large number of patents reveals that not every invention is equal in its inventive value. Altshuller proposed five levels of innovation:

Level #1. A simple improvement of a technical system. Requires knowledge available within a trade relevant to that system.

Level #2. An invention that includes the resolution of a technical contradiction. Requires knowledge from different areas within an industry relevant to the system.

Level #3. An invention containing a resolution of a physical contradiction. Requires knowledge from other industries.

Level #1 is not really innovative. It provides only an improvement to an existing system without solving any technical problem. Levels #2 & #3 solve contradictions, and therefore are innovative by definition.

Level #4. A new technology is developed containing a breakthrough solution that requires knowledge from different fields of science.

This fourth level also improves upon a technical system, but without solving an existing technical problem. Instead, it solves the problem by replacing the original technology with a new technology.

Level #5. Discovery of new phenomena.

Here a new phenomenon is discovered that allows pushing the existing technology to a higher level.

Altshuller concluded from his research that a large number of patents (77%) belong only to Levels #1 and #2. The practical utilization of TRIZ methodology can help inventors elevate their innovative solutions to Levels #3 and #4.

3. Law of Ideality

The goal of any technical system is to provide some function. Conventional engineering thought states: "It is required to deliver *such and such* a function. Therefore, we must build *such and such* a mechanism or device." TRIZ thinks: "It is required to deliver *such and such* a function *without introducing a new mechanism or device into the system*."

The Law of Ideality states that any technical system, throughout its lifetime, tends to become more reliable, simple, effective — *more* ideal. Every time we improve a technical system, we nudge that system closer to Ideality. It costs less, requires less space, wastes less energy, etc.

Ideality always reflects the maximum utilization of existing resources, both internal and external to the system. The more free or readily available the resources utilized, the more ideal the system will be.

We can judge an inventive work by its degree of Ideality. The further an invention is from its Ideal state, the more complex the system will be — and *visa versa*.

What happens when a system reaches Ideality? The *mechanism* disappears, while the *function* is performed.

> Example: A meat plant in South America ships its product to the United States. Refrigeration is required during transport to keep the meat frozen. The meat is flown to the United States, so refrigeration systems were installed in cargo planes. When competition increased, the owner of the plant sought to reduce delivery cost. It became obvious that he

must increase the amount of product per air shipment. Analysis of the situation revealed that he could compete better if the weight of the refrigeration system were replaced with that of meat. He did exactly that. Flying at an altitude of 15,000 - 25,000 feet the air temperature is below 32 °F, so no refrigeration system was actually needed. Conclusion: Utilization of existing resources costing nothing brought the system closer to Ideality.

The art of inventing is the ability to remove barriers to Ideality in order to qualitatively improve a technical system. (In this book we are talking only about technical systems. Of course, this statement can be applied to any system.)

There are several ways to make a system more ideal:

A. Increase the amount of functions of the system.

Example: An entertainment center contains a radio, tape player, CD player, and amplifier.

B. Transfer as many functions as possible to that working element which produces the system's final action.

Example: A crimping tool also cuts wire, strips insulation, and crimps the terminal to the wire.

C. Transfer some functions of the system to a supersystem or to the outside environment.

Example: Usually, windows in a green house operated manually. When the outside temperature is low, the windows are closed. When it is hot, the windows are opened for better ventilation. A new, more ideal system can be developed when the windows open and close automatically. This is accomplished with a temperature sensitive bimetallic spiral mechanism.

D. Utilize internal and external resources that already exist and are available.

Example: Comtrad Industries, Inc. of Virginia recently developed its Spectrum Antenna™ that utilizes the existing wiring system of a house as an additional receptor.

4. Contradictions

As mentioned before, the most effective solutions are achieved when an inventor solves a technical problem that contains a contradiction. When and where does a contradiction occur? It occurs when we are trying to improve one characteristic, or parameter, of a technical system and cause another characteristic, or parameter, of the system to *deteriorate*. A compromise solution is then usually considered.

A technical system has several characteristics (parameters) — weight, size, color, speed, rigidity, and so on. These characteristics describe the physical state of a technical system. When solving technical problems, these characteristics help determine the technical contradictions residing in the problem.

Examples:

Increasing the power of an engine (positive improvement) requires an increase in the size of the engine (negative effect). So, an inventor considers increasing the power partially in order to reduce the negative effect (compromise solution).

To increase the speed of an airplane, a new and more powerful engine is installed. This increases the weight of the airplane so the wings can no longer support it during takeoff. Increasing the wing size produces more drag, slowing the airplane down.

These are some examples of how improvements can produce contradictions. The improvement goals were never fully achieved because the root technical contradictions were never resolved. These are called technical contradictions because they happen inside of technical systems. The 40 Principles are used to resolve technical contradictions.

There is another type of contradiction — physical contradiction — appearing when two opposite properties are required from the same element of a technical system or from the technical system itself. There are different methods for resolving physical contradictions (separation of contradictory requirements in time or space, changing the physical state of a substance, etc.).

Examples:

Landing gear must be present on an airplane in order to land and takeoff. It should not be present during flight because of an increase in air drag. The physical contradiction is that the landing gear must be both present and absent. This contradiction is resolved by separating the requirements in time — make the landing gear retractable.

For high water diving, water must be "hard" to support the diver and "soft" so as not to injure the diver. The physical contradiction: The water must be hard and soft at the same time. This contradiction is resolved by separating the requirements in space: Saturate the water with air bubbles — the pool contains both air and water.

5. Evolution of Technical Systems

Altshuller established eight Patterns, or Lines, of technical systems evolution:

1. Life cycle.
2. Dynamization.
3. Multiplication cycle.
   (Transition to Bi- or Poly- system)
4. Transition from macro to micro level.
5. Synchronization.
6. Scaling up or down
7. Uneven development of parts
8. Replacement of human (Automation)

Here are some of these patterns:

The Pattern of Dynamization suggests that any technical system during its evolutionary process makes a transition from a rigid to a flexible structure. This transition can be summarized as follows: A solid system obtains one joint, then many joints, then the whole system becomes completely flexible. Dynamization also means that a ridged system may be divided into elements that can become moveable relative to each other.

Examples:

The steering column of a car has a joint allowing adjustment of its vertical position.

An antenna becomes collapsible.

The landing gear of an airplane folds and retracts.

A good example of complete Dynamization is a screwdriver whose stem is made of two springs, one inside the other, with opposite winding directions making it completely flexible.

The Pattern of Multiplication states that a technical system evolves first as a single system and then later multiplies itself.

When similar elements are added together, it is called a homogeneous system. This combination of elements acquires a whole new property.

Example: Two boats attached through a single frame (a catamaran) become more stable than two separate boats.

Different elements added together form a heterogeneous system. Such a system provides more functions while occupying less space.

Example: The pocketknife began its cycle with a single blade. Different types of blades were added, then scissors, screwdriver, a file and so on.

Another variation on the heterogeneous system involves the addition of an opposite function producing higher levels of innovation.

Examples:

A pencil and eraser are joined together.

A tape recorder can both record and erase.

The Pattern of Multiplication usually ends with the rejection of all extra elements that belong to the heterogeneous system — driving the system back to a mono system and thus beginning *a new cycle.*

The Pattern of Transition to Micro level states that elements of a technical system during its lifetime have a tendency to decrease in size, eventually collapsing into the micro level (molecules and atoms).

Examples:

1. A record playing device transitions from a mechanical needle (having mechanical contact with the surface grove of a record) into an optical system with a laser reading information on a digital disk.

2. A computer mouse has a ball that converts mechanical hand movement into an electrical signal. The next generation of mouse is a touch plate, where the mechanical motion of a finger is transformed

into an electrical signal.

THE MAIN TOOLS OF TRIZ: PRINCIPLES

The tools used to overcome technical contradictions are called Principles.

Principles are generic suggestions for performing an action to, and within, a technical system. For instance, Principle #1 (Segmentation) suggests finding a way to separate one element of a technical system into many small interconnected elements.

Example: How can we prevent a nail from making a flat tire? The Segmentation principle indicates we should separate all available internal space of the tire into many sections — hundreds , thousand, millions....

The Periodic Action principle means that a continuous action should be replaced with a periodic, or pulsating, action.

Example: Watering a lawn with a continuous stream of water can damage the soil. A pulsating sprinkler system eliminates this problem.

The 40 Principles described in this book allow the development of numerous solution concepts for every technical problem — without introducing a compromise. Implementing a chosen concept still remains the work of an engineer.

STANDARDS

Standards are structured rules for the synthesis and reconstruction of technical systems. Once understood — and with some experience in their implementation — Standards can help combat many complex problems.

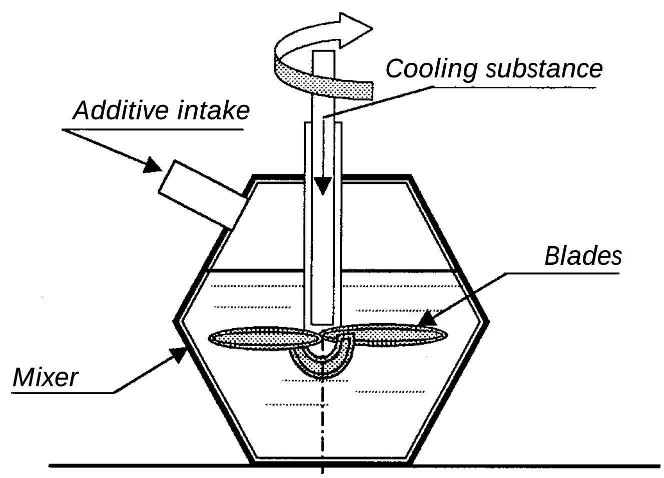
Standards provide two functions:

1. Standards help to improve an existing system or synthesize a new one.

Examples:
In order to improve a system, a certain substance should be introduced; however, its introduction is prohibited by conditions native to the problem.

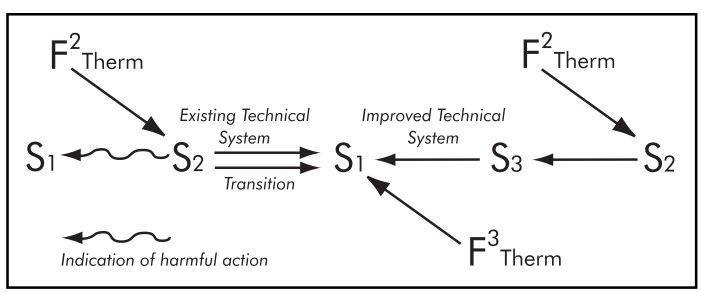
A factory produces a new type of steel. Different additives are added into the mix of molten steel. In order to prevent the blade of the mixer from melting away during the mixing process, the blade must have a protective *coating*. However, this coating may pollute the mixture of molten steel.

2. Standards are the most effective method for providing a graphical model of a problem. This is called S-Field modeling.



A molten steel mixer.

S-Field modeling of a technical system is performed in the Operating Zone, the area where the core of the problem — the actual contradiction — occurs. In this area, two substances *(elements)* and a field *(energy)* must be present. Analysis of the S-Field model helps determine changes necessary within the technical system in order to improve it.



The diagram above shows a graphical model of the molten steel mixer problem. S_1 is the blade, S_2 is the molten steel, and F_2 is the thermal energy of the steel that melts blade S_1. The wavy arrow represents a harmful interaction between the hot molten steel (S_2) and the blade (S_1). To protect the blade, a third substance, S_3, must be introduced. In this case, S_3 is a modification of S_2. By providing cold (F_3) to blade S_1, a crust from the molten material will develop on the blade's surface and protect it from melting.

Altshuller offered 72 Standards divided into five classes:

- Class #1: Build or destroy an S-Field.
- Class #2: Develop an S-Field.
- Class #3: Transition from the base system to a supersystem or to the micro-level.
- Class #4: Measure or detect anything within a technical system.
- Class #5: Describes how to introduce sub stances or fields into the technical system.

ARIZ
(Algorithm to Solve an Inventive Problem)

ARIZ is the central analytical tool of TRIZ. It provides specific sequential steps for developing a solution for complex problems.

The first version of ARIZ was developed in 1968 and many modifications during the next 20 years received. Over the years, it has become a precise tool for solving a wide variety of technical problems.

The most recent version, ARIZ- 85C, was published in 1985 and contains nine steps. Each step includes many sub-steps. Below is brief description of the nine steps.

Step #1. Analysis of the problem.

Begin by making the transition from vaguely defined statements of the problem to a simply stated (without jargon or terminology specific to any industry) mini-problem.

Example: "A technical system consisting of elements A, B, and C has technical contradiction *TC* (state the contradiction). It is necessary to provide required function *F* (state the function) while incurring minimal changes to the system."

It is not important that such a result is achievable; however, it is important to state that the system should stay the same — or become even simpler.

Step #1 also provides for an analysis of conflicting situations; i.e., technical contradictions. Here a decision has to be made as to which contradiction should be considered for further resolution. Once decided, a model of the problem is formulated.

Step #2. Analysis of the problem's model.

A simplified diagram modeling the conflict in the Operating Zone is drawn. (The Operating Zone is a specified narrow area of the conflict). Then an assessment of all available resources is made.

Step #3. Formulation of the Ideal Final Result (IFR).

Usually, the statement of the IFR reveals contradictory requirements to the critical component of the system in the Operating Zone. This is the Physical Contradiction.

As a result of these first three steps, a *vague* problem is transformed into a *specific* physical problem — the Physical Contradiction.

In many cases the problem is solved by the end of Step #3. If so, you can proceed to steps 7, 8 and 9. There are several additional steps in ARIZ that provide more recommendations for resolving a contradiction.

Step #4. Utilization of outside substances and field resources.

If the problem remains unclear, the "Small Miniature Man" model from Step #4 is imaginatively applied in order to better understand the problem.

Step #5. Utilization of informational data bank.

Consider solving the problem by applying Standards in conjunction with a database of physical effects.

Step 6. Change or reformulate the problem.

If the problem has still not been solved, ARIZ recommends returning to the starting point and reformulating the problem in respect to the supersystem. This looping process can be done several times.

The following steps apply once a solution has been found:

Step 7. Analysis of the method that removed the Physical Contradiction.

The main goal of this step is to check out the quality of a solution: Has the Physical Contradiction been removed most ideally?

Step 8. Utilization of found solution.

This step guides you through an analysis of effects the new system may have on adjacent systems. It also forces the search for applications to other technical problems.

Step 9. Analysis of steps that lead to the solution.

This is a check point where the real process used to solve a problem is compared with that suggested by ARIZ. Deviations are analyzed for possible future use.

Mastering the powerful TRIZ tools requires many hours of study, along with working many practice problems. We hope that other books in this series will help you accomplish this task.