Thoughts on Substance-Field Models and 76 Standards
Do we need all of the Standards?

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The basic concepts in TRIZ are the Contradictions, 40 Principles, the Matrix, and the Laws of Evolution, the Substance-Field Analysis Modelling, Ideal Final Solution, Substance Field Resources, Scientific Effects and the Job Plan ARIZ. Further the Method includes additional tools for Problem Statement, like in the determination of the scope of the study the Mini Max choice, inventive and innovative Tricks, like Modelling with Miniature Dwarfs, and STC (Size Time Cost) operator. These have been described in the TRIZ text books in various ways, each of the authors have left their own marks on the topics. The main things are often similar, but often confusing variations occur. There has obviously been a dilemma: How to describe the established method once again with a reasonable newness to attract readers or to clarify the topics.

This article is a draft for further development. Any comments or suggestions are welcome.

Separation of basic concepts

I have studied the textbooks of TRIZ, namely [1], [2], [3], [4], [5] and [6]. From the reader's point of view there are however some confusing and apparently conflicting things. It seems that some basic concepts will reappear in other contexts. The Principles are mixed with Substance-Field modelling, the same applies to the Laws of Evolution, Effects are included in Standards, TRIZ and ARIZ have been intermingled, even in a recent study ARIZ was called a "method" [10], not to speak about apparent printing errors.

To make TRIZ more like a "scientific" approach requires clarification and separation of these concepts. This could mean that each of these would appear only once, although references can always be made within the concepts. Let me explain.

1. The Technical and Physical Contradiction should lead to the solutions via the Matrix (to some of 40 Principles) and to the solution of the latter via Separation principles, Phase transformation, and studying the Super or Sub System.

2. The 76 Standards should be made general, simplified and cleaned from excessive repetition of the previous and some detail design rules and Effects as pointed by Savransky [4].

3. The Standards, which cannot be modelled as Substance-Field's, should be written separately, joined to Laws of Evolution or given as other "Tricks", like Modelling with Miniature Dwarfs.

4. The search for solutions for established Functions should have a separate Route and use the data base, Effects [8]. See later explanations and propositions. See also my article [7] where some preliminary thoughts were presented.

5. The Job Plan, ARIZ, should be simplified and restructured. Instead of a consequent (serial) order of execution, there should be separate simultaneous or optional routes for different Problem Statements. If we have a clear Technical Contradiction we should follow the relevant Route that will use the Matrix. If we have e.g. a not properly working system, we will follow the Substance-Field Route. If we are after a function and would like to find new phenomenon, we should refer to Effects Route. See [7].

6. The correct timing of Substance-Field-Resource Analysis should be rethought.

Quantity does not necessary breed quality

Substance - Field Model is one of the corner stones in TRIZ. However the numerous models with the explanatory Standards create a high threshold for newcomers to adapt this powerful tool for technical system and product development. I have tried to question the 76 Standards and refer to other ideas within TRIZ. One of the Laws of Evolution [2] states that "Increased Complexity [is] followed by Simplification". Bearing this in mind we might greatly reduce the number of Substance-Field drawings referring to Standards, extract from them unnecessary and repeated or associate concepts and find to them their proper location and thus make **the learning of TRIZ simpler**. This complies with the rules of cognitive theories.

The Standard Solutions

Some General Principles concerning Substance-Field Models and Standard Solutions

Standard solutions involve the presence of additional Substances or Fields.
Some basic things from [1],[2],[3],[4]:
1. Substances or Fields is at the best found in the system, or as variants of system components
2. Substances or Fields can be obtained from or by environment, its decomposition or introducing additives into it.
3. "Substances" denote anything from a single material to complex devices, processes etc.
4. A void is a modification of a Substance (replacing it)
5. The main elements are Field, Tool and Object. The terms "Tool" and "Object" are also found as "Instrument" and "Artefact" or "Workpiece" and even "raw object" respectively. I think that for the simplicity Tool and Object will do very well if we will define them for our purposes.
6. Substances or fields can be changed.
7. In the following I use "Rules" instead of established "Standards".

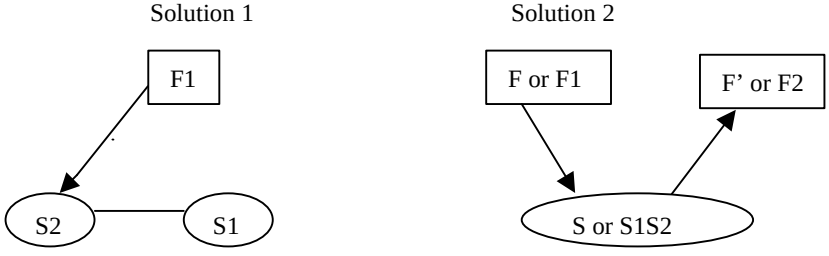
Standard Solutions Class 1. Building Substance-Field Models

Altshuller [1] had altogether 18 typical models of inventive problems and their Substance-Field transformations. Some of these are still valid and play an introductory role to those created thereafter. However there is a major fault, almost all related examples are missing. This fault has been corrected in [2] and [3].

1.1. One Element given, S or F

1. **Standard Solution with one element**:
Rule 1: Complement the drawing to a triangle: F-S-S or F-S-F. "If the substance or field lends itself poorly to control (inspection, measurement, change)"[1]. (Solution 1&2)
Notes:

1. F-S-S Explanation: S-S denotes S1-S2
2. F-S-F' or F1-S-F2 or F-S1S2-F' or F1-S1S2-F2. Explanation: S1S2 denotes Internal, External or Environmental complex link. S or S2 is an additive. F' is a variant from F. F2 is a different Field.
3. The scheme is valid for inspection, change, detection or measurement.



If there is a situation with just one Substance S1, then the solutions requires a Substance S2 to act on it and a Field as the means of action. The same applies to problem with a Field: it requires a Substance or Substances S1 and S2.

1.2. Two Elements given, S-F or S-S or F-F

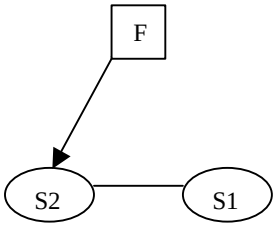
1. **Standard Solution with two elements**:
Rule 2: Complement the drawing to a triangle: F-S-S or F-S-F. "If two substances [1] do not interact… or problems with two fields… or problem with field and substance… " Problem (inadequate or surplus interaction; surplus field; interconnection of fields; measurement) with S1-S2 or F-S1 or F-F (Solution 3 & 4)
(It seems that in most of the books e.g. [2],[3] the cases in [1] with F-F have vanished.)

The drawing lines connecting F and S's (in the Problem Stating Phase) could be
1. Solid, indicating no problem
2. Dotted, indicating inadequate field or interaction
3. Corrugated indicating excess or problem in Field or interaction.

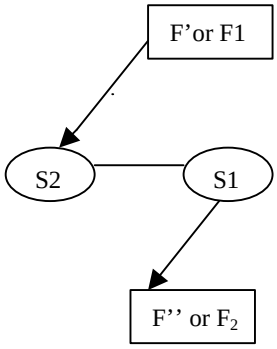
Note:

0. The Explanations 1&2 of F-S-S etc. in previous chapter are valid.
Corollaries:
1. If there is a harmful or inadequate interaction between the components, try also Technical or Physical Contradiction and the solutions from there.
2. Processing of fragile objects: join the objects temporarily together with either similar or different objects etc.(=mono>bi>poly?)
3. Field removes the excess of Substance; the excess of Field is removed by Substance (Minimum Mode)
4. If there is an excess of Field on Substance that is required, the Field should act on a second Substance in interconnection with the previous (Maximum Mode)

Solution 3



Solution 4

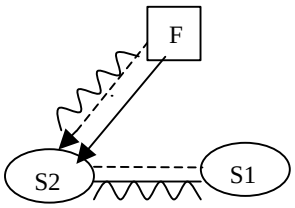


Standard Solutions Class 2. Enhancing Substance-Field Models and Problem Solving with three elements

When we have a Substance-Field Model of an existing technical system which either is subject to further development or bears some harmful characteristics the drawing gives a starting point to Substance-Field solution finding.

The general drawing is simply of type F-S2-S1, where S2 denotes the Tool and S1 the Object.

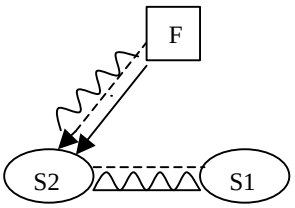
Problem Drawing



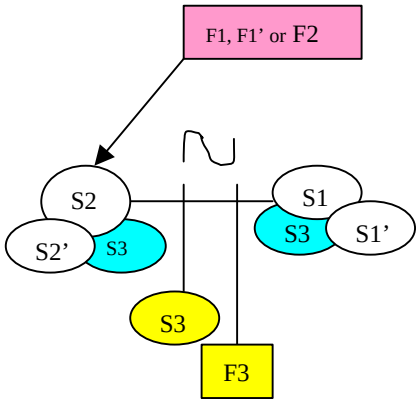
Standard solution with three elements
If in a system there are harmful field or interaction between substances; inadequate field or substance interaction, the solution is found according to following rules:

Rule 3: Add a new substance or field between the Tool and Object. If there is both a useful and harmful action between the Substances S2 and S1 or need to improve the interconnection, the problem is solved by adding between the Substances either a new Field or a new Substance (F3 or S3). (Solution 5)
Rule 4: Add a new substance either to the Tool or Object. As its best the new substance is the variant of the Tool or the Object. The new addition can be either complex internal, external or environmental. The solution is to add a modified Substance S2' or S1' to the relevant Substance, or a new Substance S3 to either S2 or S1. Both addition could be complex internal, external or environmental. (Solution 5)
Rule 5: Change the Field. The Field can be simply reduced (in measure e.g. halved) or changed to its variant (F1') (visible light to ultra violet).
Rule 6: Change the Field and the Tool. If there is a harmful or inadequate action towards the Object from the Tool (and Field), the solution is to change either the Tool or both the Field and Tool.(F2, S3) If the Field and Tool do not correspond to advanced needs (customer needs, competition response) the Field -Tool pair should be replaced by a more controllable pair. According to the Law of Evolution these should follow the sequence: Mechanical >Thermal >Chemical >Electrical > Magnetic >Electromagnetic.
Rule 7: TheTool and the Object can be fragmented. If the Tool should be enhanced, it can be done through the Fragmentation (grains >shots > pulverizing) or the use of Capillary and Porous Substances (solid substance> cavities>capillary or porous). A special case: added substance in capillary or porous substances is Ferromagnetic.
Rule 8: Use ferromagnetic substances and ferro-fields. A special case: ferromagnetic Substance or additives (granules, powder, finely grained particles, liquid) in conjunction with magnetic field.
Rule 9: The Field and the Substances can be made dynamic. The Tool and the Field can be made more dynamic. The Tool: Single hinge > multiple hinges > flexible. The Field: from permanent action to a pulse action.
Rule 10: Match (mismatch) the rhythms in the system. Simple matching: the other uses pause of the other Field. The frequencies of the Field(s) can be matched (or mismatched on purpose) with the Substances.
Rule 11: Compensate the harmful action of the Field by an additional counteracting system or field. If there are both useful and harmful action between the Tool and the Object, the solution is to create either a complete double Substance-Field or add a Field to counteract the system. (Solution 6)
Rule 12: The Object can be converted to a new system, which is linked to the other elements. If it is not possible to solve the problem by adding substances or fields, the object should be converted to a new system drawing, which is linked to the Field and Substance. Chain of systems. (Solution 7)

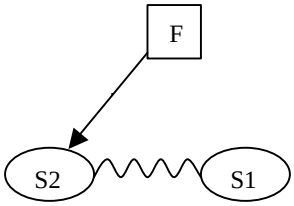
Problem Drawing



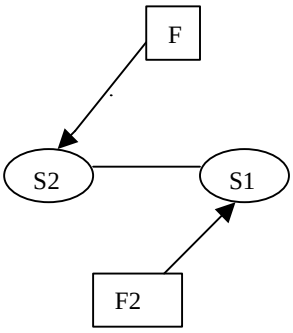
Solution 5



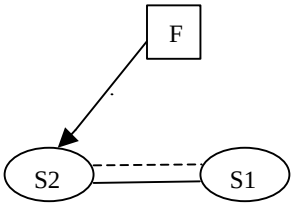
Problem Drawing



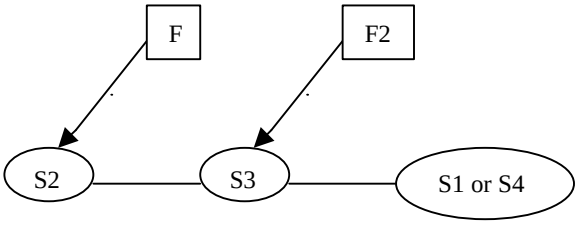
Solution 6



Problem Drawing



Solution 7



(The problem drawing above and the subsequent Solution drawing refer also to a problem with On-Off interaction between the substances. Hence it is a design task type mechanical coupling, or electrical

switch-on, switch- off, and only a simple technical task and should not be included. (But there exists, too, a thermal clutch (working “all by itself”) used in engine cooling system. Should that be included?))

Standard Solutions Class 3. Transition to the Super-System and Sub-System.

This Class refers to the Laws of Evolutions and is not necessary.
It also leads to the idea that the **Function of the Field-Tool-Object System** should be considered. This means that we should search for additional means of fulfilling the **Function**, at the best we should find a new (scientific) Effect to do the job.

(There is also a confusing terminology stating Super System v. Sub System, on the other hand Macro v. Micro System. My proposition is to dedicate “Super System - Sub System” to various levels of Tool and Object compositions or assemblies. Hence a car is a Super System, the engine a Sub System and a piston further as well a Sub System. All the previous systems are on Macro level.
Micro level refers to ions, molecules, atoms, or effects e.g. with no visible difference in the Substance, but first after certain conditions (in conjunction with a field). Thus, what is a nanotechnology gear?)

Standard Solutions Class 4. Standard Solutions for Detection and Measurement

This Class could be omitted and has been explained in Class 1 &2. Further many of the cases can be solved through Technical Contradictions and the Matrix.

Rule 13: In measurement or detection type of problems, one should consider the substance (to be measured etc.) in question as the Tool and the solution as an Object that reacts. The same applies to Field where we are seeking some substance(s) that react to the Field by either modifying or changing the field or an other field (F2>F2’) acting on the other substance, S2.
Corollaries:
1. Instead of measuring, change the system to avoid the need for measuring.
2. Measure the copies (a copy is a visual variant).
3. Measure the changes, derivates. Use effects that react to changes in the properties.
4. Measure the changes in the Environment. Use effects that react to changes.

Standard Solutions Class 5. Standards for Applying the Standards Solutions

Standard: Introducing Substances and Fields (if there are problems with addition) see also e.g.[2] or [3]

Rule 14: Introducing Substance

Corollaries:
1. Indirect Methods

If it is not allowed to add Substances, the following indirect ways should be utilized:
1. Apply void
2. Apply a Field instead of Substance
3. Apply external additive instead of internal
4. Add a small amount of very active additive
5. Introduce the additives in concentrated form in specific places
6. Use additives temporarily
7. Use the model or copy of the Object instead of the Object itself, allowing the introduction of additives.
8. Obtain the required additives via decomposition of the introduced additives (chemicals).
9. Obtain the required additives through decomposition or either the environment or the Object itself, by electrolysis or phase transition, for example.

2. Splitting the Substance

If the system is unresponsive to changes, and both changing the Tool and introducing additives is prohibited, interacting parts of the Object can be utilized instead the Tool.

3. Self-Elimination of Substances

After carrying the work, an introduced substance should disappear or become identical to substances already existing in either the system or the environment.

4. Introducing substances in large amounts
   If conditions do not allow the introduction of large amounts of a substance, “emptiness” such as inflatable structures or foam can be utilized.

Rule 15: Introducing Fields
If it is necessary to introduce a field, you should first and foremost apply existing fields whose carriers are the substances involved.
Secondly: Introduce fields from the Environment
Thirdly: Utilize substances capable of originating fields.

Rule 16: Phase Transitions

Make use of the various phase states of materials
1. Changing the phase
2. Use dynamic phase state
3. Utilize associate phenomena
4. Use transition to a dual phase state
5. Phase interaction

Peculiarities of Applying Physical Effects and Phenomena.

These should be presented in the Effects Route.

Discussion

My aim was to reduce the number of various Substance-Field drawings representing the Standard solutions. From above we can find only 7 Substance-Field solution models and 16 Rules.

Some advantages:

1. What are left are only five models to remember. The solutions 1 & 3 are similar, but the problem drawings differ. The same applies to Solutions 2 & 4.

2. Solution 5 is the most useful of all, because it replaces most of the “old” standard models. Here also we can utilize the true cognitive principles. **The capacity of human working memory is limited to a number of a few units (five plus minus two?), see Miller [11]. So the solution is to group the various different standards to a larger and a more general one. This is easier to remember although it is a paradox: the capacity of human working memory concerns the number of units, not the unit size, see Engelkamp and Zimmer [12].** Hence actually you need to remember only the basic solutions, Solution 1 & 5 (and maybe the additional three others), which conform the Miller rule. Additional verbal “Rules” and “Corollaries” should also support the Solution drawings; these two together make the things easier to remember. Hence “Standards” or “Rules” which do not have point in common with the Substance-Field drawings should be kept in minimum (as problems with introducing of substances or fields).

3. Those former Standards, which cannot be presented as Substance-Field drawings, are relocated. They could be placed either amongst Laws of Evolutions, Effects or “Tricks”.

4. The Substance-Field-Resource Analysis (and Ideal Final Result pondering?) should be made first after each solution drawing.

5. The proposed enhancements are however only “incremental” because actually anything “new” is not found. It leaves also quite a number verbal descriptions as in the 76 Standards.

6. The Substance-Field model can also used in Anticipatory Failure Detection type problems. One should use the Principle "Do it in reverse" where the problem drawing and the solution drawing change places. So the question is: how can we spoil the correctly working system to create the (actual) problem drawing with the help (or rather the harm) of the substances and fields in the system, Super system or Environment?

7. The reducing of the number of Standards by 75% simplifies the things to be remembered. Further it gives room for new additional future rules.

8. The time aspect in Substance-Field needs also rethinking. The question is how to present various problems with time axis? A simple solution: cartoon like serial presentation. There have been several recent articles on the need to include time in the analysis of functions (one by Joe Miller and Ellen Domb in the December 2002 TRIZ Journal, several in the ETRIA proceedings.)

9. By eliminating some old standards springs up a need to list various "Tricks" in TRIZ. Such could be e.g. Minimum Mode, joining together temporarily fragile objects, dynamisation, matching rhythms between systems, use of magnetic liquids etc.

10. Some strong solution might even be found through the definition of Ideal Final Solution: how to keep the temperature in specific range "all by itself". This might be solved by the use of e.g. Curie point. There exists additional these type of effects. Are these merely Effects or simply "Tricks"?

11. Thousands of scientific effects could be useful. In the present Standards there are, however, only some. This causes additional questions. Why just these ones? The apparent solution is to separate them to another Route [7] and use the relevant software [8]. The effects give the answer to the Functional Problem Statement [9]. In Value Analysis the function definition and idea generation based on that is the key idea.

12. To include most of the scientific effects means that TRIZ is getting closer or equals Physics? How far should we go? Is it enough to include phase transitions of first and second level?

13. Next: some thoughts about ARIZ 2000?

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