Su-Field Analysis

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The following is taken from an improved chapter in my book *Step-by-Step TRIZ*. I apologize for not having it in the first edition. The following format can be used for a power point presentation and notes pages. Thank you in advance for any comments for further improvement. Ellen Domb and Joe Miller have helped add the 76 Standard Solutions. This month the first of 5 parts of the Standard Solutions are in a reference article. Yes, this is all public domain in the spirit of Altshuller.
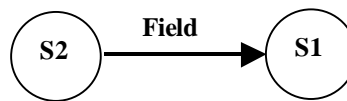

Figure G-1

The Substance-Field (Su-field) Model
Substance-Field (Su-field) Analysis is a TRIZ analytical tool for modeling problems related to existing technological systems. Every system is created to perform some functions. The desired function is the output from an object or substance (**S1**), caused by another object (**S2**) with the help of some means (types of energy, F). The general term, substance has been used in the classical TRIZ literature to refer to some object. Substances are objects of any level of complexity. They can be single items or complex systems. The action or means of accomplishing the action is called a field. Su-field Analysis provides a fast, simple model to use for considering different ideas drawn from the knowledge base.

Su-field Analysis was first used to describe the problem. Su-field Analysis works the best for well-formulated problems, like those developed with the formulation. Individuals starting to use TRIZ find it useful to use the models to present the Standard Solutions. A different format has been chosen to present the essence of the Standard Solutions. Also, this analytic instrument requires greater technical knowledge (information on how to perform the physical effects) than some of the other TRIZ tools.
When to Use Substance-Field Analysis

This analysis is used to zoom in on the zone of interest. However, the analysis can be applied to system as well as component levels of abstraction. This is often at the interface between the two substances. For complex systems there is a Su-field Model for all the zones of interest. Two substances and a field are necessary and sufficient to define a working technical system. The formation of this trilogy can be found in the early work of the mathematician Ouspensky.[28] The triangle is the smallest building block for trigonometry, as well as for technology.
There are four basic models:
1. Effective complete system.
2. Incomplete system (requires completion or a new system).
3. Ineffective complete system (requires improvement to create the desired effect).
4. Harmful complete system (requires elimination of the negative effect).
If there is a problem with an existing system and any of the three elements are missing, Su-field Analysis indicates where the model requires completion and offers directions for innovative thinking.
If there is an innovative problem and the system has the three required elements, Su-field Analysis can suggest ways to modify the system for better performance. This is particularly true if radical changes in the design are possible.
Following the analogous thinking of TRIZ, a triangular technical system should have its own set of rules within the geometry of problem solving. These few basic rules and the 76 Standard Solutions permit the quick modeling of simple structures for Su-field Analysis.[29]
Making a Model
The field, which is itself often some form of energy, provides some energy, force or reaction to guarantee an effect. The effect could be on **S1** or the output of the field information. The term field is used in the broadest sense,

including the fields of physics (that is, electromagnetism, gravity and strong or weak nuclear interactions). Other fields could be thermal, chemical, mechanical, acoustic, light, etc.

The two substances can be whole systems, subsystems or single objects. They can also be classified as tools or articles. A complete model is a triad of two substances and a field.

The innovative problem is modeled to show the relationships between the two substances and the field. Complex systems can be modeled by multiple, connected Su-field Models.

There are four steps to follow in making the Su-field Model:

    1. Identify the elements.

    The field is either acting upon both substances or is within substance 2 as a system.

    2. Construct the model.

    After completing these two steps, stop to evaluate the completeness and effectiveness of the system. If some element is missing, try to identify what it is.

    3. Consider solutions from the 76 Standard Solutions.

    4. Develop a concept to support the solution.

In following Steps 3 and 4, activity shifts to other knowledge-based tools.

```
          ┌──────────────┐
          │ 1. Identify  │
          │ the Elements │
          └──────────────┘
                 │
                 ▼
          ┌──────────────┐
          │ 2. Construct │
          │  the Model   │
          └──────────────┘
                 │
                 ▼
    No        ◇ Complete
 ◄────────────  System? ◇
                 │
                Yes
                 ▼
    No        ◇ Useful? ◇
 ◄────────────
                 │
                Yes
                 ▼
 ┌───────────┐ No  ◇         ◇  Yes
 │ 3. Select │◄──── Effective? ────► Implement
 │ Standard  │     ◇         ◇
 │ Solutions │
 └───────────┘
       │
       ▼
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 │ 4. Develop│
 │  Concept  │
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       │
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 │ Use other │
 │ Knowledge │
 │   Based   │
 │   Tools   │
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 No  ◇         ◇  Yes  ◇        ◇  Yes
◄──── Effective? ────►  Simple? ────► Implement
     ◇         ◇       ◇        ◇
                           │
                          No
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                  │  Use Class 5   │
                  │ in 76 Standard │
                  │   Solutions    │
                  └────────────────┘
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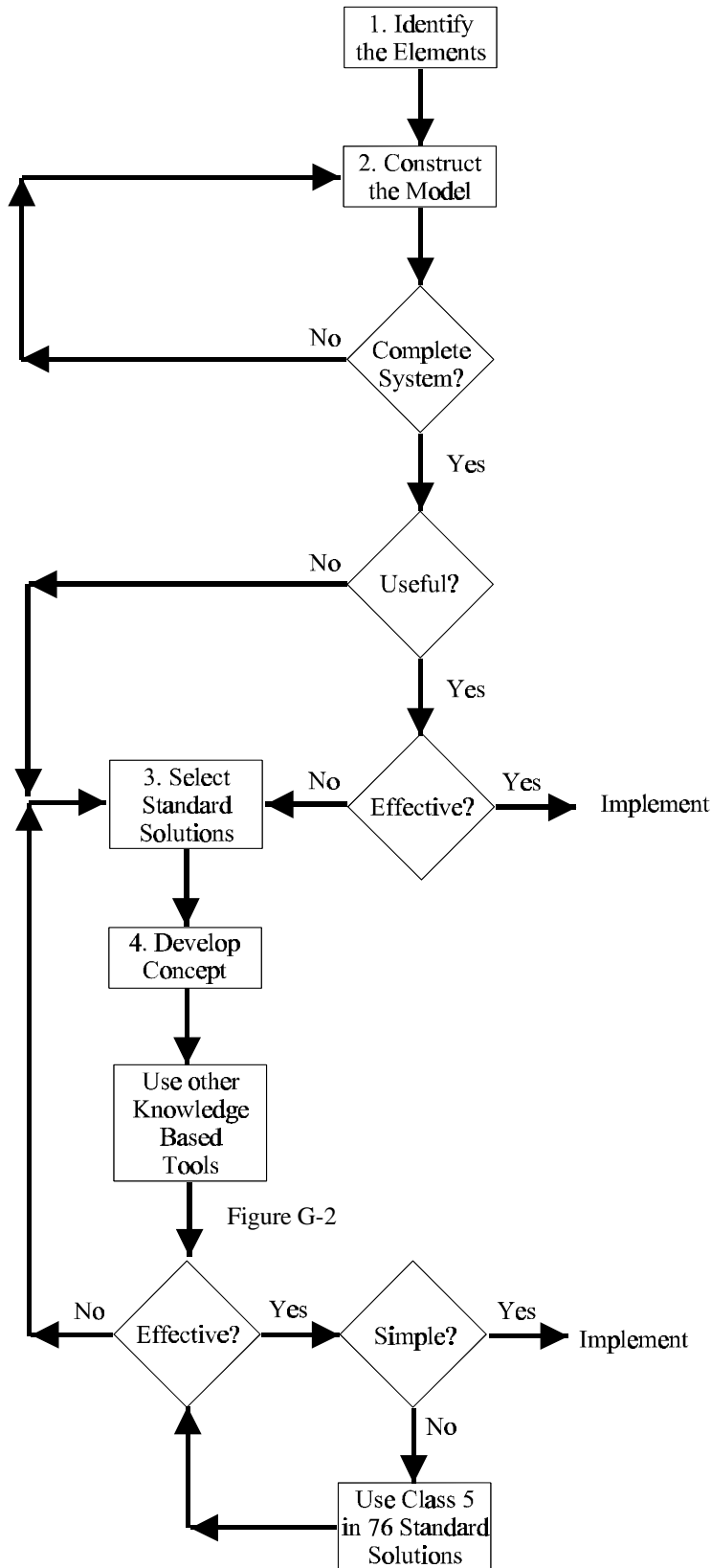
Figure G-2

A diagram showing how the problem solver would apply this TRIZ tool is seen in Figure G-2. You can see that there is a constant alternation between the analytic and the knowledge-based tool.

The process cycles within Steps 1 and 2 until a complete model is found. The standard solutions in Step 3 offer breakthroughs in thinking. Alternative structures to the completed system are considered. For each structure, alternatives to the basic building blocks are considered through the use of knowledge- based tools. Su-field Analysis was created during 1974 - 1977. The four models are presented in this material. Each cycle of improvement increases the number of models and options available. Today, there are 76 Standard Solutions. The 76 Standard Solutions are refinements of the original solutions.

Lev Shulyak the deceased President of the Technical Innovation Center has used a hammer breaking of a rock to introduce Su-field Analysis. This simple example has been modified and will be used to present some of the standard solutions.
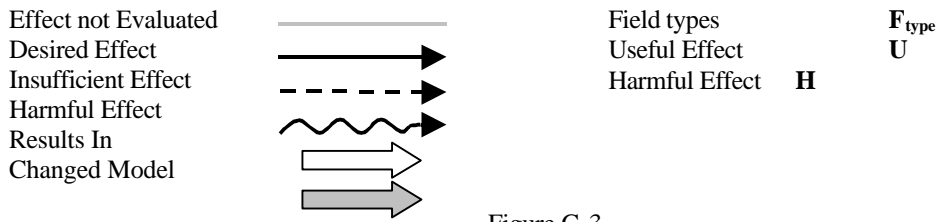
Effect not Evaluated		Field types	F_{type}
Desired Effect		Useful Effect	U
Insufficient Effect		Harmful Effect	H
Harmful Effect			
Results In			
Changed Model			

Figure G-3

Analysis Nomenclature

The identification of substances (**S1** and **S2**) depends upon the application. Either substance could be a material, tool, part, person or environment. **S1** is the recipient of the systems action. **S2** is the means by which some source of energy is applied to **S1**.

The source of energy, or field (**F**), which acts upon the substances, is often:

(Me) — Mechanical
(Th) — Thermal
(Ch) — Chemical
(E) — Electrical
(M) — Magnetic
(G) — Gravitational

The letter(s) associated with the applied field will be used in the Su-field Model of the different systems.

Relationships between the elements in the Su-field Model are depicted by five different connecting lines shown in Figure G-3

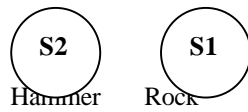Pulsed Air

S2   **S1**

Hammer Rock

Figure G-4

There is a hydraulic hammer, in which a metal piston can be moved by the power of pulses of compressed air. And there is a rock. If the air pressure is turned off, or if the hammer is not in contact with the rock, nothing will happen. This could be the reason for Altshuller's insistence on good physical drawings, as well as the models!

Analysis

Apply the four modeling steps to the four basic models.

1. *Identify the elements*

Our task is to break a rock.

Function = Break Rock

Rock = **S1**

Hammer = **S2** or tool
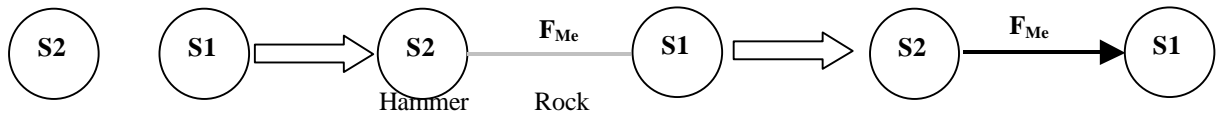
Figure G-5

2. Construct the model

Incomplete system

If there is only the rock, it will not break, and therefore the model is incomplete. The model is also incomplete if only the rock and a hammer (**S2**) exist. In the same way, the model is incomplete if some field (gravity) and the rock are the only elements of the system.

In these incomplete models, the desired effect does not occur. Completing the system will, at the very least, make the useful function possible. One complete system is a pneumatic hammer, which provides pulsed mechanical force upon the rock with the hammer. The performance of the system is not considered at this time. The incomplete Model b is completed by the application of the mechanical field (F_{Me}) by the hammer (**S2**) to the rock (**S1**).

Once a complete system has been defined, performance can be analyzed. The unevaluated performance is shown with a simple gray line. The evaluation of a completed system's performance gives three possible answers.

      1. Effective complete system

            If the system provides the desired effect, analysis is complete.

            Pulsed air is to be used for the Mechanical Field.

            If this system provides the desired effect then the link between

               S2 and **S1** is a solid arrow.

      2. A harmful effect occurs.

            Consider 76 Standard Solutions

      3. The results are ineffective

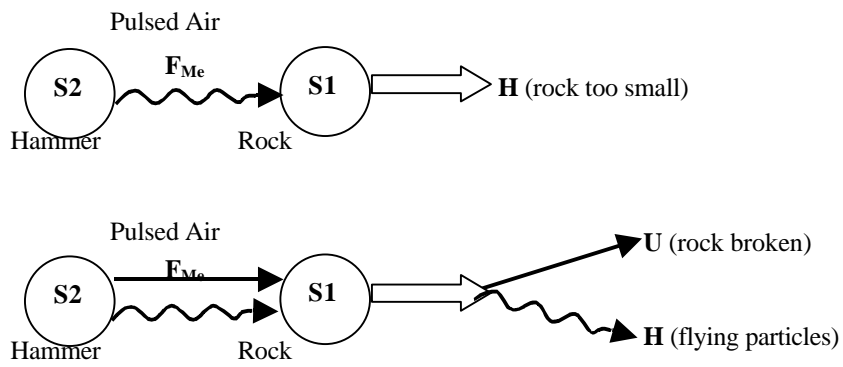   Consider 76 Standard Solutions

Harmful Complete System

Figure G-6[1]

[1] The branching to a harmful and useful event is stimulated my Zinovy Royzen.

1.2.1
S1= rock
S2= hammer
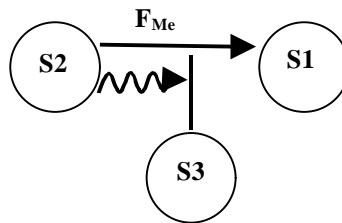**S3= ????**
F$_{Me}$ = Pulsed Air

Figure G-7

3. Consider solutions from the 76 Standard Solutions

Depending upon the application there may be the option of a new system by replacing **S2** by **S3** and/or using a different Field. For example **S2** could be a large vise still using a **F$_{Me}$** but the mechanical field is created by a human while in the example above the is created by pulsed air.
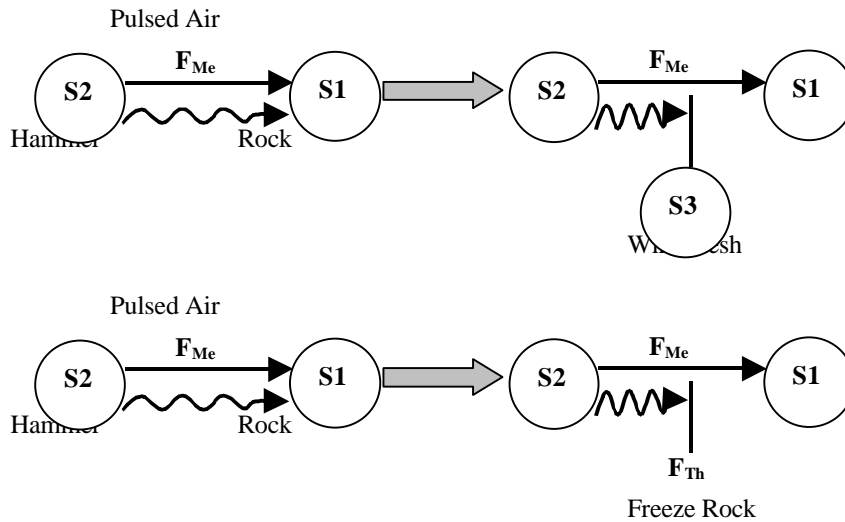Harmful complete systems are in subgroup 1.2 of the 76 Standard Solutions.

Pulsed Air

$$S2 \xrightarrow{F_{Me}} S1 \implies S2 \xrightarrow{F_{Me}} S1$$

Hammer   Rock

S3

Wire Mesh

Pulsed Air

$$S2 \xrightarrow{F_{Me}} S1 \implies S2 \xrightarrow{F_{Me}} S1$$

Hammer   Rock

F_{Th}

Freeze Rock

Figure G-8

4. Develop a concept to support the solution

The structural changes identified in step 3 direct the search for a means to support the change. Because the changes made are based only on the original form of the problem, new directions to search for design solutions are presented. Some of the directions may not be fruitful, but the important function of the model is to create global concepts. The challenging task is to supply detail to the global concept. Other TRIZ tools can be used to support this search. Looking for resources within the system and in the super-system is the least expensive start.

Harmful complete system— Two ways of applying a standard solution are introduction of another substance or introduction of another field. Insights come from considering different substances for **S** and different fields for **F**.

The harmful effect in our example is flying pieces, a metal cap or wire mesh covering the rock could be an added substance (**S3**) used to eliminate the harmful effect. Look at all the fields that are available when adding a field to a system. If the rock contains moisture, freezing (F_{Th}) could cause cracks produced by the expansion of the moisture when it freezes. If time is not an issue and winter was very cold, the project could be delayed until winter for no additional cost to the system. The breaking will occur as these cracks gradually expand, reducing the explosive release of fragments. This result may also be considered a "super effect," as it reduces the mechanical effort required to achieve the function.
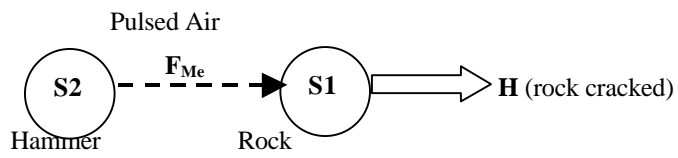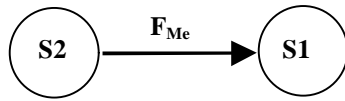
Ineffective Complete System

Figure G-9

3. Consider solutions from the 76 Standard Solutions

Depending upon the application there may be the option of a new system by replacing **S2** by **S3** and/or using a different Field.
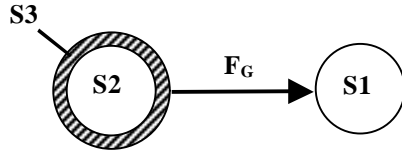Ineffective complete systems are in subgroup 1.1 of the 76 Standard Solutions.

1.1.3
S1= rock
S2= hammer
S3= vise
$\mathbf{F_{Me}}$

S2 →$\mathbf{F_{Me}}$→ S1

1.1.3
S1= ski
S2= snow
S3= wax
$\mathbf{F_G}$

S3

S2 →$\mathbf{F_G}$→ S1

2.1.1
S1 = rock
S2 = hammer
S3 = chisel
F1= Mechanical
F2 = Mechanical

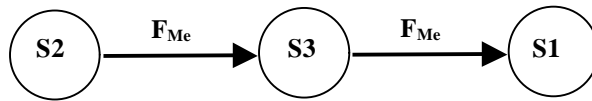S2 →$\mathbf{F_{Me}}$→ S3 →$\mathbf{F_{Me}}$→ S1

Figure G-10

3. Consider solutions from the 76 Standard Solutions

Depending upon the application there may be the option of a new system by replacing **S2** by **S3** and/or using a different Field. For example could be a large vise still using a $\mathbf{F_{Me}}$ but from a different source, a human. Ineffective complete systems are in subgroup 1.1 and 2.1.1 of the 76 Standard Solutions.

S2 --F_Me1--> **S1** ⟹ **S3** --F_Me2--> **S1**
Hammer   Rock Hammer   Rock

S2 --F_Me--> **S1** ⟹ **S2** --F_Me--> **S1**
                                          F_Ch

S2 --F_Me--> **S1** ⟹ **S2** --F_Me--> **S3** --F_Me--> **S1**
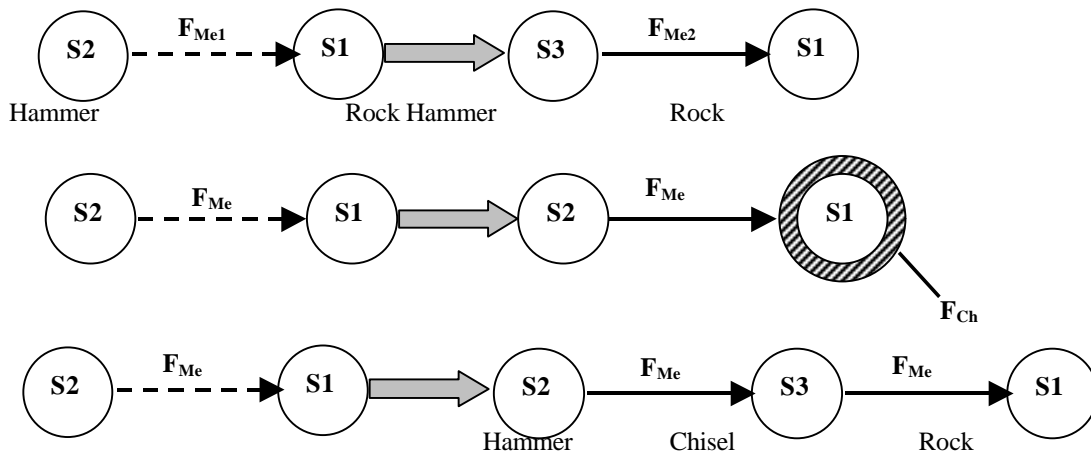   Hammer   Chisel   Rock

Figure G-11

4. Develop a concept to support the solution
Ineffective complete systemBreaking of the rock may not be efficient or as effective as desired.

One possibility for changing the substance (**S3**) is to replace the original hammer head with a rock hammer head (**S3**).

One way to change the field and substance is to use a gas fired thermal field (F_{Th}) and water (**S3**) to produce steam. The rapid temperature change could crack the rock. The added field may be chemical (F_{Ch}) to make the rock (**S1**) more brittle.

To add a substance and a field in, a chisel (**S3**) can be placed between the hammer and the rock. There are now two systems with three elements. The air pressure (F_{Me1}) acts on the hammer (**S2**), transferring energy to the chisel (**S3**). The hammer provides the energy (F_{Me2}) to the chisel (**S3**), which transfers the energy to the rock (**S1**).