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HU Diagrams (Harmful / Useful Diagrams): A Different Way to Improve Products and Processes

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Abstract

HU Diagrams (Harmful/Useful Diagrams) is a new approach based upon Newton's Third Law – to every action there is always an equal and opposite reaction. HU Diagrams also focus on risk management to ensure the solution has minimized the potential risks related to the solution. HU Diagrams are used to solve problems, evaluate potential situations and to evolve products and processes to a higher level of performance. This performance improvement approach is designed to stimulate an individual or team into looking at a

situation from a different point of view, helping them to come up with “out of the box” solutions

Introduction

HU Diagrams were designed to provide the user with a different way of looking at situations in order to open his/her mind to different thought patterns. HU Diagrams are not designed to give you the perfect answer to all situations, but by combining them with an effective Knowledge Management System the individual or team can often define a better solution than they were able to do in the past. HU Diagrams only help you ask the right questions; they won't give you the right answer. You still need innovative people and a good Knowledge Management System to come up with the very best solutions.

How To Use HO Diagrams

HU Diagrams are designed around the concept that all systems have positive aspects (useful functions) and all systems have negative aspects (harmful functions). A function is defined as capturing some aspect of a system including function, activity, state, process, condition, transformation. See Figure 1.

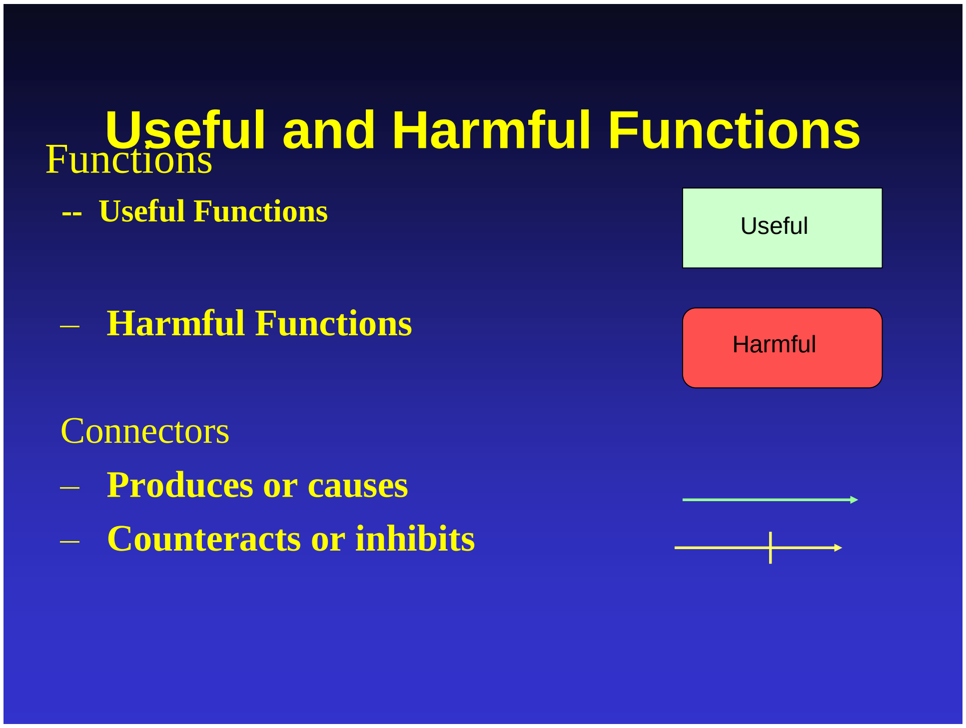

Figure 1. Useful and Harmful Symbols and the Two Types of Connectors

HU diagrams only use two symbols – harmful functions (negative/undesirable features) and useful functions (positive/desirable features). The harmful functions in a HU Diagram are represented by a rectangle with rounded corners. The useful functions are represented by a rectangle with sharp-edges. Often, to make the two differences standout, the background is a different color for each of the two types of functions.

The arrows that connect them can be designated as one of two relationships as shown in Figure 1. The arrow from one symbol to the other symbol indicates that the first symbol established the relationship to the other symbol. The arrow without a vertical line through it indicates that the first symbol (situation) caused or produced the other symbol (situation) to exist. The arrow with the vertical line through it indicates that the first symbol (situation) counteracts or inhibits the second symbol (situation). Sometimes a useful function can cause another function that is desirable to occur. However, sometimes a useful function has undesirable side affects and causes something harmful to happen. On the other hand, a harmful function can cause a harmful function to occur or it could a cause a useful function to occur. (See Figure 2.) A HU Diagram is essentially a collection of cause-and-effect relationships describing various situations.

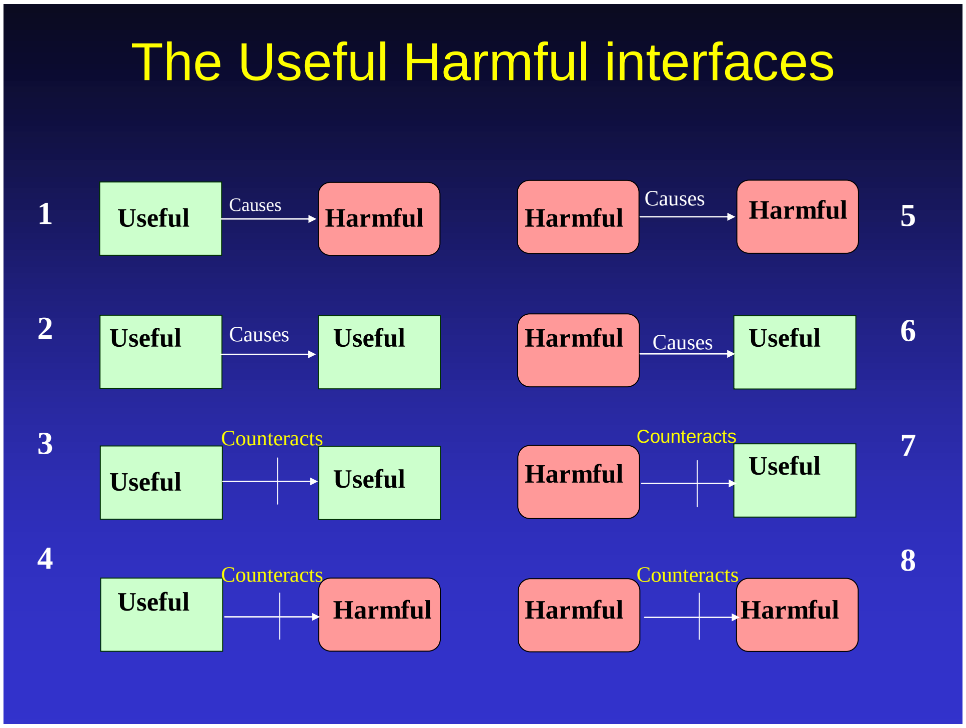

Figure 2. The Two functions can be related in Eight Different ways

Contradictions

Definition:

Contradiction – It is when something useful has undesirable side effects and causes something harmful to happen. It can also apply when something harmful has desirable side effects and causes something useful to happen.

There are eight different way of how useful/harmful functions interface and four of them are contradictions. The numbers 1, 4, 6, and 7 relationships in Figure 3 are all contradictions as they have two opposite functions connected together.

There are three types of contradictions:

- Type 1 category is when a function produces a similar function but also produces an opposite function. For example, a useful function produces another useful function (desirable) but also produces a harmful function (undesirable). See Figure 3.
- Type 2 category is when a function counteracts an opposite function but also produces another opposite function. For example, a useful function counteracts a harmful function (desirable) but produces a harmful function (undesirable). See Figure 4.
- Type 3 category is when a function counteracts an opposite function, but also counteracts a similar function. For example, a useful function counteracts a harmful function (desirable) but also counteracts another useful function (undesirable). See Figure 4.

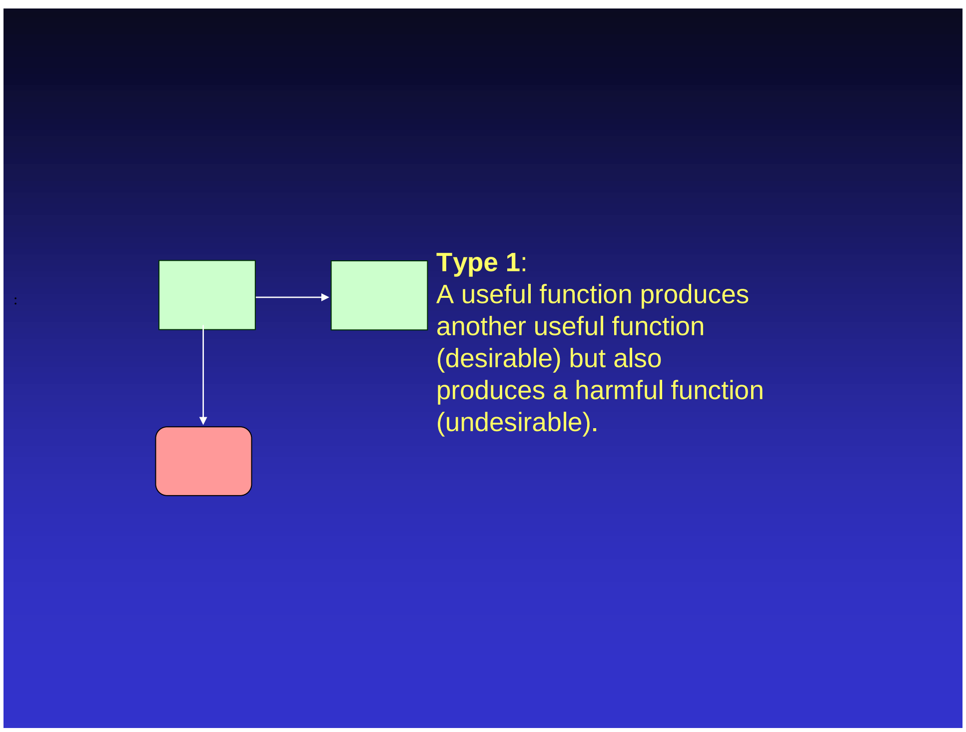

Figure 3. A useful function that produces another useful function and a harmful function (Type 1 relationship)

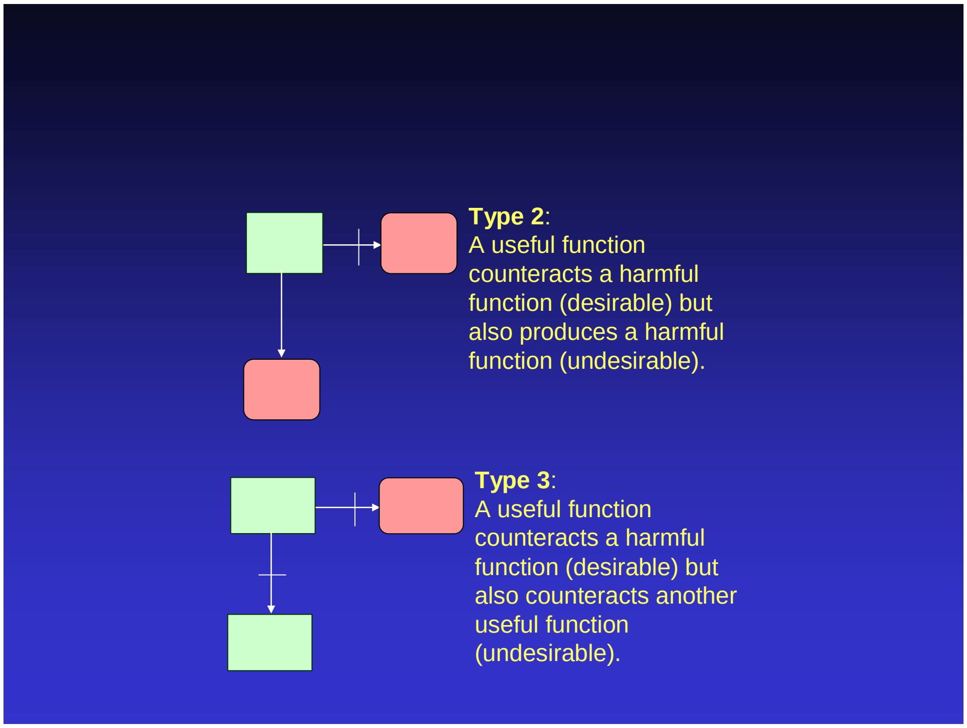

Figure 4. Example of Useful Functions That Produce Type 2 and Type 3 Relationships

A process without any contradictions would be the ideal process, but in reality, there is no such thing as a completely ideal process. All processes have at least one contradiction. In fact, the reason for analyzing a process is to maximize the useful functions and minimize the harmful functions – in other words, to maximize the real value-added content while minimizing the non-value-added content of the process.

Gas-Powered Lawn Mower Example

To better understand how to develop a HU Diagram, let's take a gas-powered lawn mower as an example. We will start by defining its primary function. We can all agree that its primary function is to cut grass and that is a useful function. (See Figure 5.)

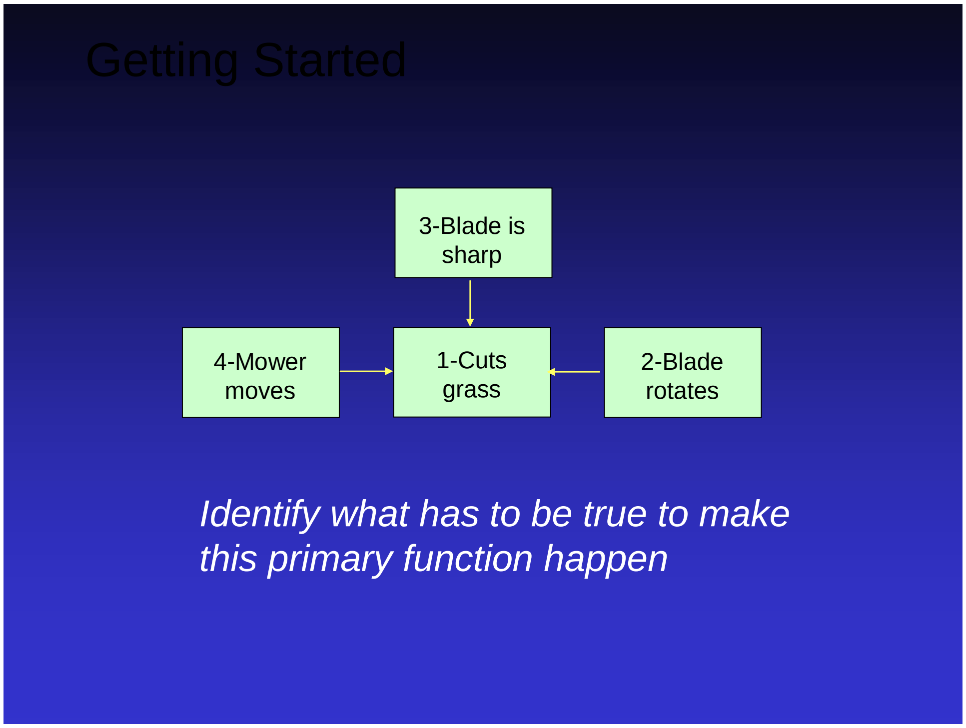

Figure 5: Start of a HU Diagram for a Gas-Powered Lawn Mower

To start our HU Diagram, place a sharp-edged rectangle on the paper or computer screen that the HU Diagram will be constructed on and label it "Cuts grass." (Function #1 in Figure 5). Now let's define what functions are required to allow the lawnmower to perform its primary function (cuts grass).

- The blade rotation is a useful function that causes the grass to be cut; it is represented by a sharp-edged rectangle labeled "Function #2 - blades rotate." Because the blades rotating cause the grass to be cut, the connection line is drawn from #2 to #1.
- A sharp blade is a useful function when you are trying to cut grass so this is added to the HU Diagram as another sharp-edged rectangle labeled "Function #3 - blade is sharp" and there is a connection line drawn from #3 to #1 because #3 causes #1.
- If the lawn mower was stationary and not moving, it would not perform its function, so another Useful Symbol labeled "Function #4 - lawn mower moves" is added to the HU Diagram. Because moving the lawn mower is required to cut the grass, there is a direct connection line shown from #4 to #1

We now have four useful blocks on our HU Diagram (Figure 5) and it is time to look at some of the harmful impacts related to the useful functions. (See Figure 6.)

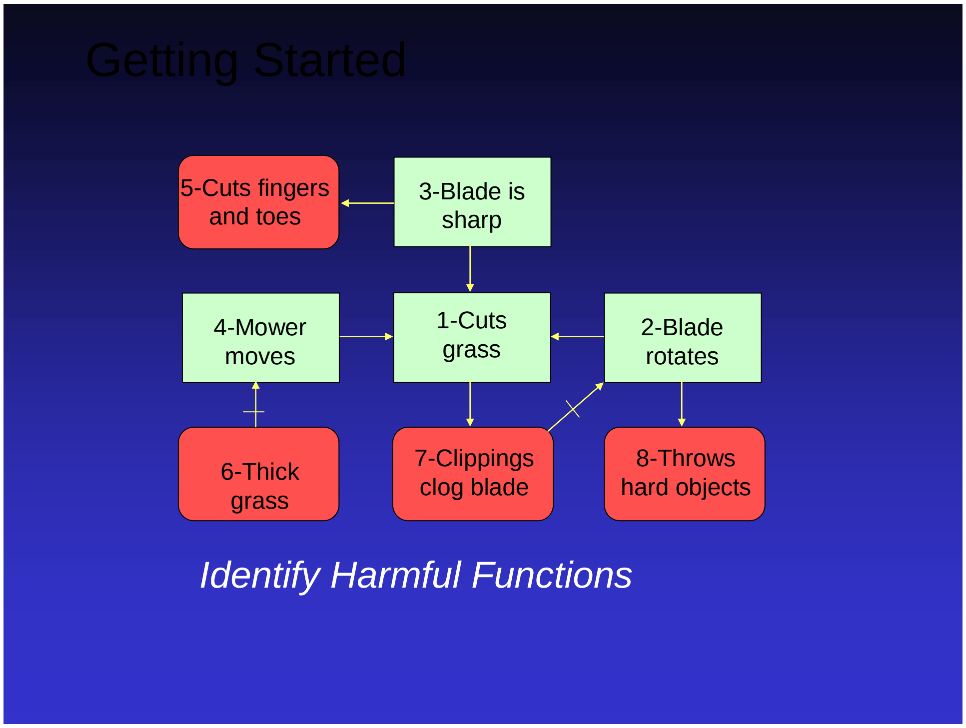

Figure 6. HU Diagram for a Gas-Powered Lawn Mower with Harmful and Useful Functions Presented

The following are some harmful functions:

- Harmful Function #5 –Cuts fingers and toes. Since Useful Function #3 – "Blade is sharp" can cause fingers and toes to be cut, it is creating Harmful Function #5 – "Cuts fingers and toes" to occur so there is a connection line between #3 to #5.
- Harmful Function #6 -— Thick grass: If the grass is thick, it prohibits the lawnmower from moving. Thick grass (Function #6) inhibits lawn mower from moving (Function#4). As a result, the connection line goes directly from #6 to #4 but it has a vertical line through it indicating that it counteracts or inhibits the lawn mower from moving.
- Harmful Function #7 – Clippings clog mower: Cutting the grass (Function #1) can cause Function #7 (Clippings clog the blade) to occur. Since Function #1 can cause Function #7 to occur, there is a connection line shown from Function #1 to

Function #7. And because Function #7 – “clippings clog the blade” could inhibit the blade from rotating (Function #2), there is a connection line with a vertical line through it from #7 to #2. This is a contradiction.

- Harmful Function #8 – Throws hard objects. Because Function #2 – “the blade rotates” can cause debris to be thrown, Harmful Function #8 – “Throws hard objects” is added to the HU diagram. Since this can occur because the blade is rotating, a connection line is shown from #2 to #8.

As you can see, this very simple example has generated a number of contradictions that would be addressed by the PIT when solving the problem.

Containment Ring Example

We will now look at a problem related to an airplane’s jet engine containment ring. See Figure 7.

Figure 7. Jet engine containment ring problem

There are two problems related to the containment ring problem. The first problem is the impellers can break and without something to contain the fragments, the aircraft body and passengers can be damaged. The second problem is the present rings are very heavy and as a result, they decrease the plane's overall efficiency. In addition, they need to be inspected on a regular basis and the weight and the way they are mounted in the engines makes them hard to remove and inspect. Figure 8 is a simple HU Diagram of the problem with the impellers in the jet engine breaking and causing damage to the airplane.

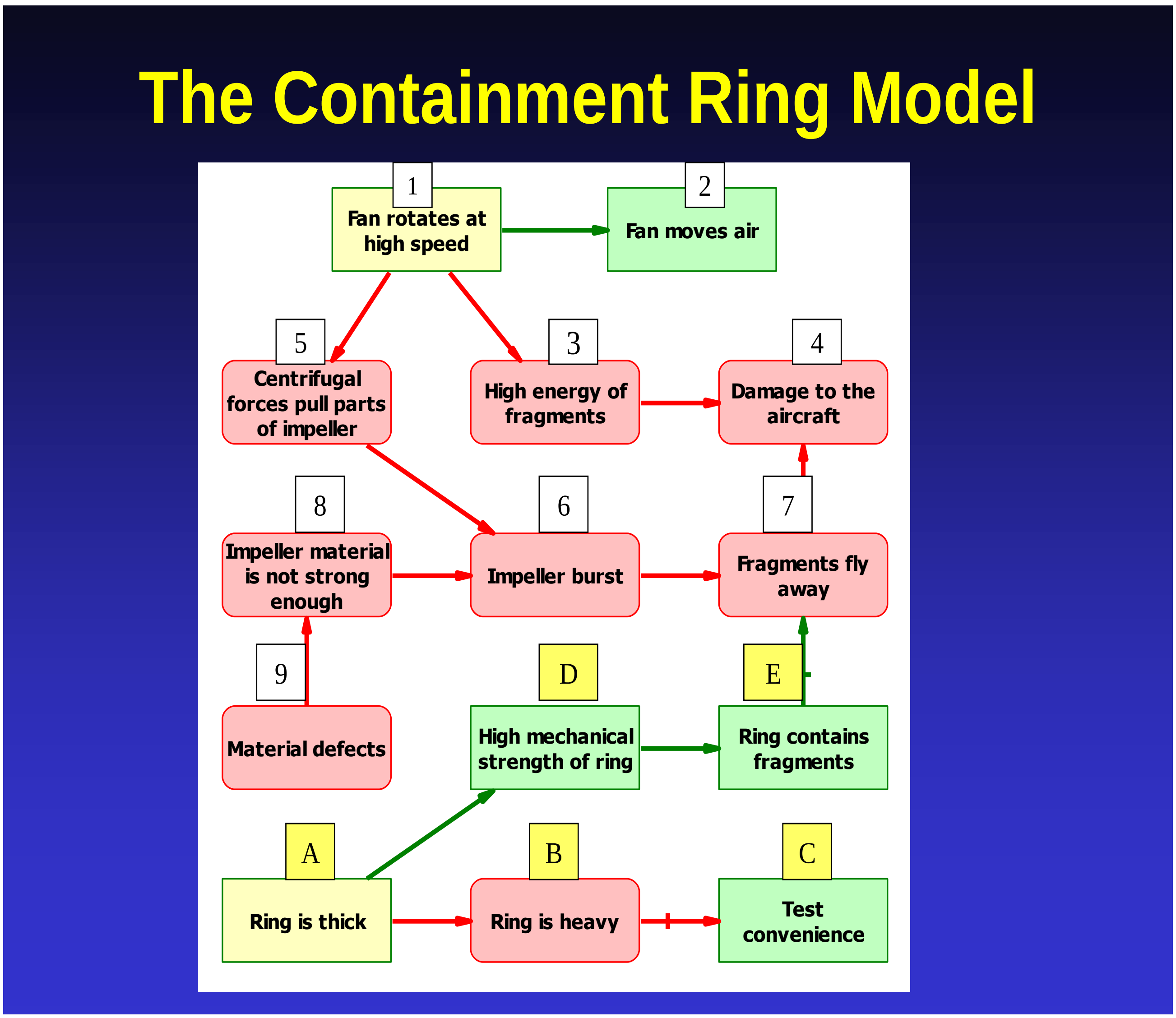

Figure 8- HU Diagram of the Containment Ring Problem

The impellers rotate at a high speed (Useful Function #1) causing a large quantity of air to move through the engine (Useful Function #2). These are both useful functions as they cause the airplane to move forward or backward. Because Function #1 causes Function #2 to occur, the connection line is from #1 to #2.

The fan rotating at high speeds can cause two harmful functions to occur. The high speed rotation of the fan (Function #1) gives high energy to fragments of the impellers (Harmful Function #3). Because the high speed rotation of the fan (Function #1) causes Function #3 to occur, therefore there is a connection line from #1 to #3.

The high energy of the fragments (Function #3) can cause damage to the aircraft (Harmful Function #4). Because Function #3 causes Function #4 to occur, the connection line is from #3 to #4.

A second harmful function occurs because the impellers rotate at high speed (Function #1); this causes a centrifugal force to be applied to the impellers in the fan which can cause parts of the impellers to come off (Harmful Function #5). Because Useful Function #1 causes Harmful Function #5 to occur, the connection is from #1 to #5.

Harmful Function #5 can cause the impellers to burst (Harmful Function #6). Because Harmful Function #5 causes Harmful Function #6 to occur, there is a connection from #5 to #6.

When Harmful Function #6 occurs, it causes fragments to fly away, creating Harmful Function #7. The fragments flying away (Harmful Function #7) can cause damage to the aircraft (Harmful Function #4), so there is a connection line from #7 to #4.

Because Harmful Function #6 (Impellers burst) is a key function, we will look at it in more detail. Let's start by asking the question: "What could cause this to happen?" If the impeller material is not strong enough (Harmful Function #8), it could cause the impellers to burst. Harmful Function #8 can create Harmful Function #6 to occur, so there is a connection line from #8 to #6. When asked the question, "What could cause the impeller material not to be strong enough," the answer might be that there could be defects in the material (Harmful Function #9). Harmful Function #9 causes Harmful Function #8 to occur, so the connection is from #9 to #8.

The second part of the problem relates to the containment ring itself. The containment ring at the present time is thick (Useful Function A). The ring is thick which causes the ring to be heavy (Harmful Function B). Since Useful Function A causes Harmful Function B to occur, there is a connection shown from A to B.

Test convenience (Function C) is a useful function. As a result of the ring being heavy, it has a negative affect on the convenience of testing the ring (Useful Function C). Because the ring is heavy, it counteracts or inhibits convenient testing. As a result, the connection line from B to C has a vertical line through it indicating that Function B counteracts/inhibits Function C.

Function A (Ring is thick) also creates a useful function because the thickness provides high mechanical strength. As a result, Function A causes Useful Function D (High mechanical strength of ring) to be generated. The high mechanical strength of the ring allows the ring to contain the fragments (Useful Function E.) The ring containing the fragments counteracts the fragments flying away (Harmful Function #7). Therefore, the connection line from E to 7 has a vertical line through it indicating that it is offsetting some of the negative impacts of the fragments flying away.

Often the individual conditions are further analyzed by constructing a HU Diagram of their own. This analysis is then connected back into the main HU Diagram.

The four circled areas in Figure 9 indicate conditions that should be resolved to offset the harmful parts of the HU Diagram and bring into better balance the ratio of harmful and useful functions.

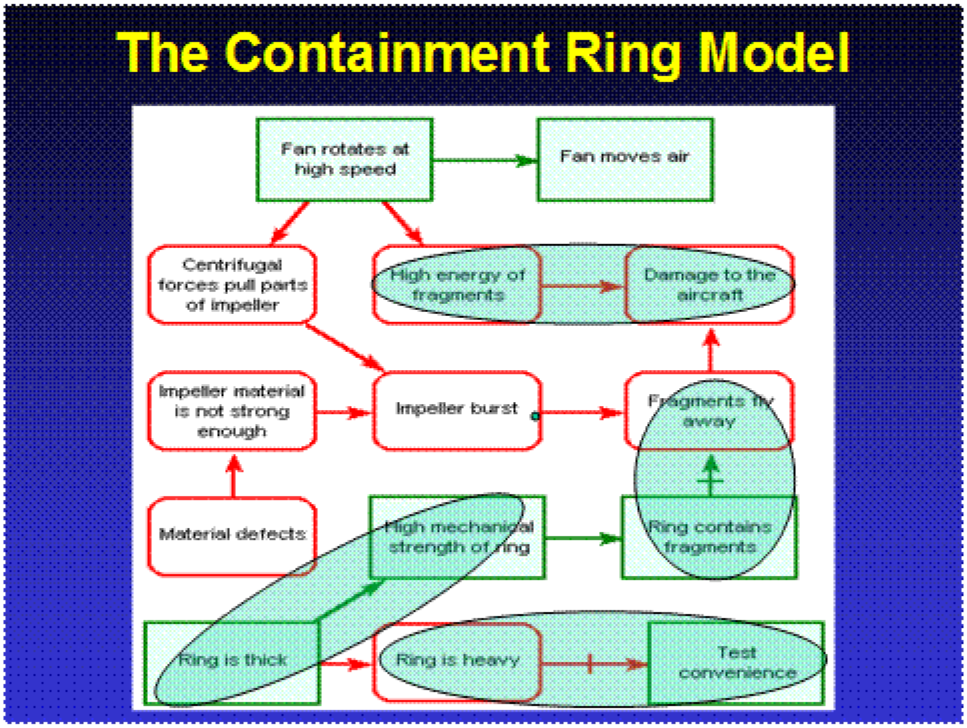

Figure 9. Jet Engine Fan Problem Detailed HU Diagram with Four Focus Improvement Areas Identified

Using a HU Diagram to solve a Problem

This is where the individual innovation and the organization's Knowledge Management System kick in to high gear. HU Diagrams have defined the conditions. Now the excellence of the results rests in the hands of your people and your Knowledge Management System. What sets apart the final results is the experience and creativity of your people; however, that is not enough, because if left on their own, they will fall into the old trap of playing it safe and not venturing outside of the scientific box they have been limiting themselves for years. We strongly believe that every problem, situation, or solution and opportunity you face has a golden nugget embedded in it as a result of experience. Sharing these golden nuggets with the rest of the organization is critical to the success of the whole organization. Just think of the time and effort that would go into recreating the information used in the calculus class you took during your Freshman year. Knowledge sharing, not knowledge hording, is key to be successful today. This means that these golden nuggets of past solutions and best practices need to be documented and categorized so that the best concepts can be applied to today's situation. They serve as a starting point in our quest for perfection. Although we will never be perfect, it is only through our continuous quest for perfection that we will reach the standards of excellence needed to be successful today. Although we find that some of our best concepts come from the experience within our organization, there is a lot of well-defined and documented hard (explicit) knowledge available in the public domain related to the problems we are facing. In most organizations it is the soft (tacit) knowledge that is not disseminated well throughout the organization. It is this soft knowledge that is the key to success today. It is almost as though every time a person dies, we have lost a whole library of knowledge.

There are a number of knowledge principles that we all should be familiar with and using including the following:

- Thomas J. Edison and his approach to innovation
- Genrich Altshuller's work in defining the 40 TRIZ principles
- Osborn's direction decreasing of psychological inertia, activation of human motivation, organization of effective team work
- The 39 engineering parameters for expressing technical contradictions.

Thomas J. Edison was one of America's most creative problem-solvers. He used a Solution-Centered Mindset to help come up with new solutions. Once an opportunity was identified, he approached it with the belief that success was inevitable. He mentally prepared for the hunt and he was not deterred by formidable obstacles ~~and~~ or when results proved elusive. Edison would look at each problem from many different angles. This allowed him to come up with many different possible solutions. Each possible solution was tested to determine its merits and then set aside while another one was evaluated. This allowed him to come up with a number of options of which he could select the very best one. He looked for the most simple way of accomplishing a task breaking down a complex problem into simple and clear terms that eliminated ambiguity. He established a set of common goals that his fellow workers believed in and were committed to, thereby greatly increasing their efforts and creativity. Edison's philosophy of value creation was to bring out the secrets of nature and apply them for the happiness and enjoyment of mankind.

Alex Faickney Osborn (May 24, 1888 – May 13, 1966) is best known for being the father of brainstorming. Brainstorming is a group creativity technique designed to generate a large number of ideas for the solution of a problem. In 1953 he popularized the method in his book called *Applied Imagination*. Osborn proposed that groups could double their creative output with brainstorming. He found that when these rules were followed, a lot more ideas were created and that a greater quantity of original ideas gave rise to a greater quantity of useful ideas. He described brainstorming as "a conference technique by which a group attempts to find a solution for a specific problem by amassing all the ideas spontaneously by its members". He came up with the following rules:

- No criticism of ideas
- Go for large quantities of ideas
- Build on each others ideas
- Encourage wild and exaggerated ideas

In 1952, Osborn published *Wake Up Your Mind: 101 Ways to Develop Creativeness*, and subsequently published the book under the title *How to Become More Creative* in 1964. Osborn describes "as a term, imagination covers a field so wide and so hazy that a leading educator has called it an area which psychologists fear to tread".

The Creative Problem Solving Process (CPS), also known as the Osborn-Parnes CPS process, was developed by Osborn and Dr. Sidney J. Parnes in the 1950s. CPS is a structured method for generating novel and useful solutions to problems. CPS follows three process stages, which match a person's natural creative process, and six explicit steps:

Process Stage	Steps
Explore the Challenge	Objective Finding (identify the goal, wish or challenge)
	Fact Finding (gather the relevant data)
	Problem Finding (clarify the problems that need to be solved in order to achieve the goal)
Generate Ideas	Idea Finding (generate ideas to solve the identified problem)
Prepare for Action	Solution Finding (move from idea to implementable solution)
	Acceptance Finding (plan for action)

CPS is flexible, and its use depends on the situation. The steps can be (and often are) used in a linear fashion, from start to finish, but it is not necessary to use all the steps. For example, if one already has a clearly-defined problem, the process would begin at Idea Finding.

Source: Wikipedia

We recommend that you set aside one part of your Knowledge Management System as your "Problem/Situation Improvement Knowledge Base." Each time a problem/situation is corrected, data related to how it was solved should be added to this data base. Good examples are one of the best ways to share experiences both good and bad. A good way to get your “Problem/Situation Improvement Knowledge Base” started is to input into it the 40 TRIZ Principles (See Figure 10) and the 39 Engineering Parameters for Expressing Technical Contradictions (See Figure 11).

Altshuller’s 40 TRIZ Principles for Conflict Resolution

1	*Segmentation*	21	*Rushing through*
2	*Extraction*	22	*Convert a harm into a benefit*
3	*Local conditions*	23	*Feedback*
4	*Asymmetry*	24	*Mediator*
5	*Combining*	25	*Self-service*
6	*Universality*	26	*Copying*
7	*Nesting*	27	*Disposable object*
8	*Anti-weight*	28	*Replacement of a mechanical system*
9	*Prior counter-action*	29	*Use a pneumatic or hydraulic construction*
10	*Prior Action*	30	*Flexible film or thin membranes*
11	*Cushion in advance*	31	*Use of porous material*
12	*Equipotentiality*	32	*Changing the color*
13	*Inversion*	33	*Homogeneity*
14	*Spheroidality*	34	*Rejecting and regenerating parts*
15	*Dynamicity*	35	*Transformation of physical and chemical states*
16	*Partial-excessive action*	36	*Phase transition*
17	*Shift to a new dimension*	37	*Thermal expansion*
18	*Mechanical vibration*	38	*Use strong oxidizers*
19	*Periodic action*	39	*Inert environment*
20	*Continuity of a useful action*	40	*Composite materials*

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Figure 10-The 40 TRIZ Principles

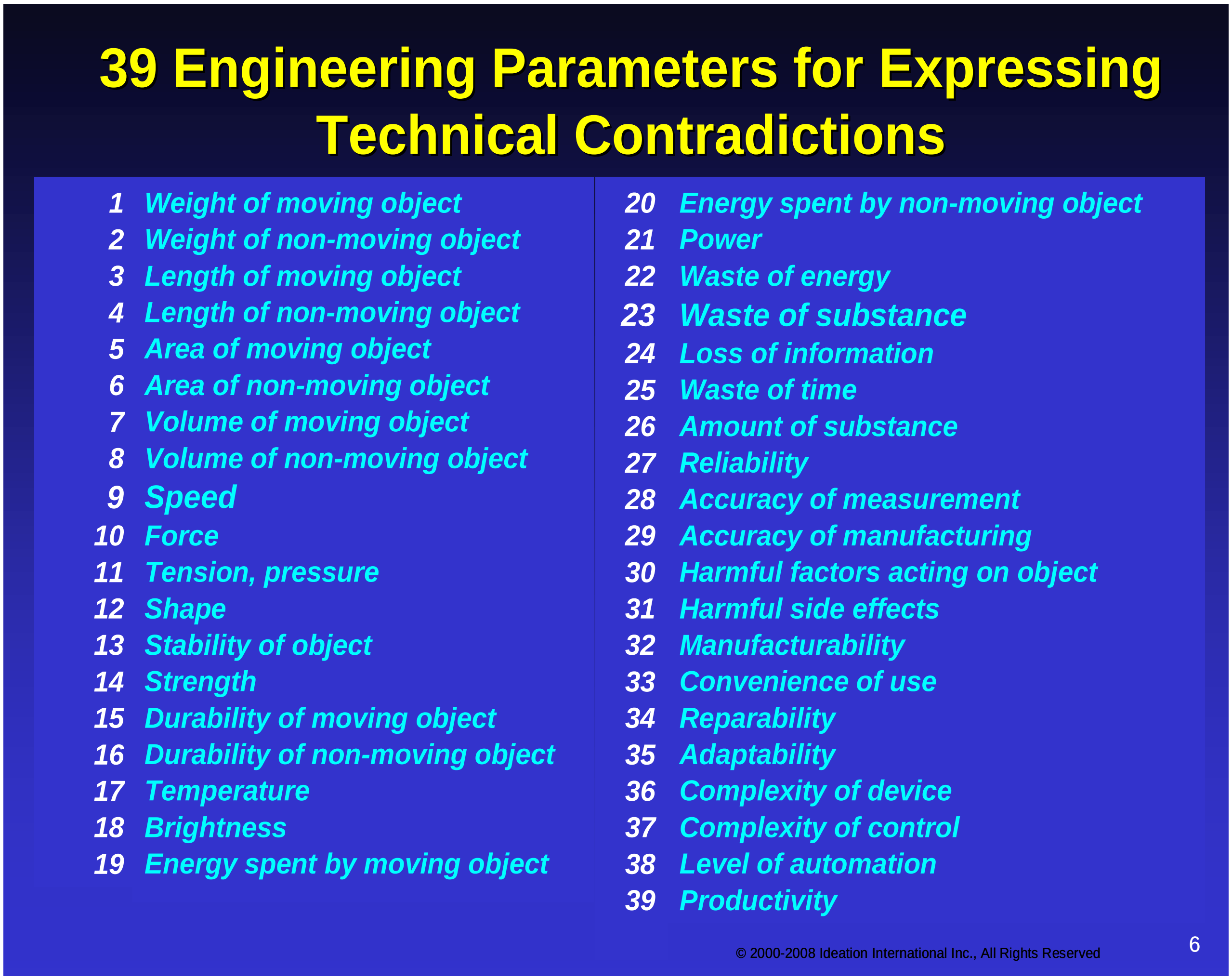

Figure 11- The 39 Engineering Parameters for Expressing Technical Contradictions

The Knowledge Management Systems that contain these little golden nuggets of wisdom (recommendation, suggestion) are used to trigger you into thinking how to solve the problem or to improve the process under evaluation. These golden nuggets, sometimes called "operators," are drawn from successful results of previous action that resolve different technology problems and/or process problems. To date, there are approximately 1000 of these golden nuggets that have been defined. However, it is our experience that by using 200-400 of these golden nuggets is all that is really needed to solve most problems a PIT will encounter.

We believe that using a Knowledge Management System that is full of organized examples of how situations have been addressed in the past is the most effective way to finding the best solutions. However, some organizations will stick with the brainstorming approach because they feel comfortable with it to find solutions to the conditions revealed by HU Diagrams. Or, they continue to use the brainstorming approach because they don’t have a Problem/Situation Improvement knowledge base. Of course, there is nothing wrong with this approach and it does provide acceptable solutions.

Figure 12 is a typical HU diagram generated by a computer program along with the comments related to key elements on the diagram.

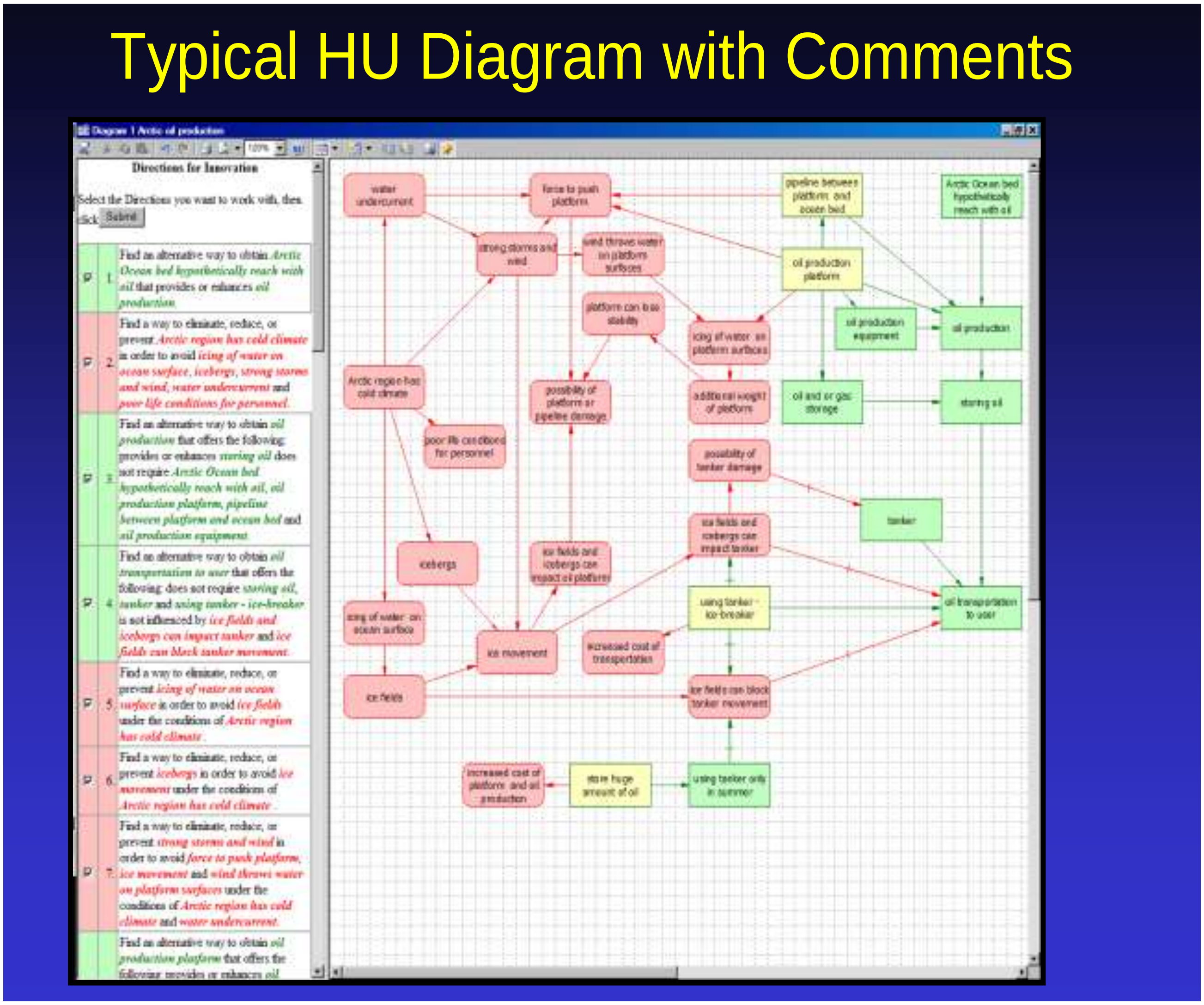

Figure 12. Typical HU Diagram with Comments

Summary

I have found HU diagrams very effective in helping PITs generate very innovative solutions, in particularly when it is combined with a knowledge-based system like I-TRIZ. The I-TRIZ system contains a world of experience from problems that have been solved in the past and whose approaches continuously repeat themselves in being useful in solving future problems. It is an effective approach for defining the operator that relates to the problem the PIT is addressing with practical examples of how to use each of the operators.

I-TRIZ is a software system sold by 20-20 Innovation and Ideation Inc. It is made up of four software packages. See Figure 13.

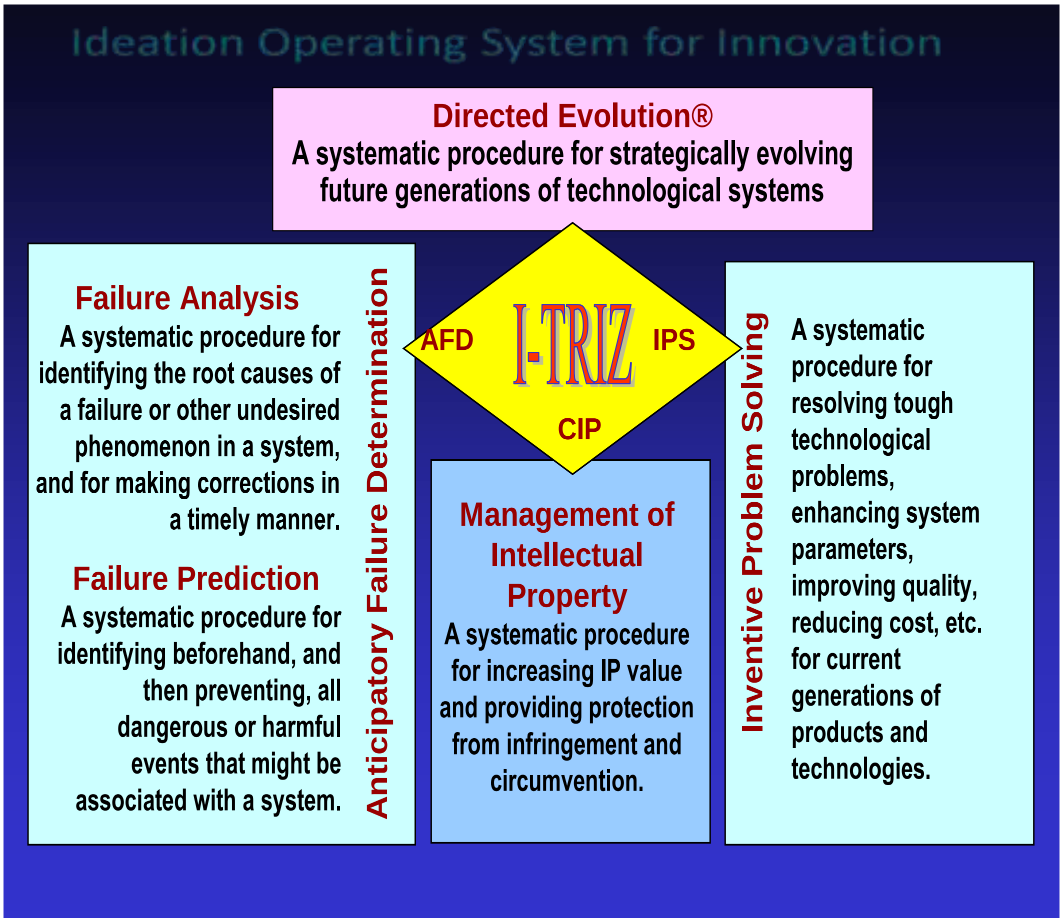

Figure 13. The Four Software Packages that Make-Up I-TRIZ

The I-TRIZ packages use HU diagrams as their analysis tool. It will construct the HU diagram using its computer program. We suggest that you start with Inventive Problem Solving software package, although the Directed Evolution software package is a better but more complex methodology. Once the future-state solution is defined, we suggest you use the Failure Prediction software package to define the major risks related to the new process.