HU Goes There

New problem-solving tool **should have a place** in your quality arsenal

In 50 Words Or Less

- There are plenty of tools for identifying root causes of problems, but not many for solving them.
- A tool called the harmful/useful diagram, in the hands of innovative employees and with help from an effective knowledge management system, can find the answers you need.

TO DATE, MOST of the tools used by performance improvement professionals— including five whys, flowcharts and design of experiments—have been directed at defining and identifying root causes of problems. But after the cause has been identified, what tool do you use to fix it? Enter a problem-correcting tool called the harmful/useful (HU) diagram.

Sometimes called the contradiction diagram, a HU diagram is a graphic presentation of the positive (useful) and negative (harmful) effects related to a situation, problem or process. It is based on Newton's Third Law: For every action, there is always an equal and opposite reaction.

by H. James Harrington, Ron Fulbright and Alla Zusman

HU diagrams are used to solve problems, evaluate potential situations, and push products and processes to higher levels of performance. This approach is designed to motivate an individual or team to look at a situation from a different point of view and formulate out-of-the-box solutions.

The team assigned this project is often referred to as a performance improvement team (PIT). This is a group of six to 10 people assigned to analyze and design an innovative solution to a problem, situation or product. They may be assigned to the project part time or full time and usually hail from different organizational functions.

Regardless of what part of the organization in which you work, it's likely you attack challenging situations based on the field in which you were trained. And regardless of whether you expand your knowledge base in that specific field, sticking to that one area probably won't give you the best answer to your problem. To get the best results, the problem solver needs to use the best knowledge from many different scientific fields.

HU diagrams are designed to provide users with a different way of looking at situations and open their minds to different thought patterns.

HU diagrams are not designed to give you the perfect answer to all situations, but they help you ask the right questions. You still need innovative people and a good knowledge management system to come up with the very best solutions.

The good, the bad and the ugly

All too often, in our zeal to attack a situation, we make things worse or create new problems. For example, Coca-Cola decided to redesign its two-liter bottle to make it look more attractive, taking on the shape of its original glass bottle (good). But the new Coke bottles were taller and would not fit on standard refrigerator shelves (bad). As a result, some consumers bought Pepsi because its two-liter bottle fit into the refrigerator (ugly).

HU diagrams are designed around the concept that all systems have positive aspects (useful functions) and negative aspects (harmful functions). A function involves an aspect of a system, including an activity, state, process, condition or transformation.

HU diagrams use two symbols—harmful functions represented by rectangles with rounded corners and useful functions represented by rectangles with sharp edges. You can also make the two symbols stand out by using a different color for the two types of functions.

The arrows that connect one symbol to another indicate the first symbol established the relationship to the second. These arrows designate one of two relationships: The arrow without a vertical line through it indicates the first symbol or situation caused or produced the other symbol or situation to exist, while the arrow with the vertical line through it indicates the first symbol or situation counteracts or inhibits the second symbol or situation.

Sometimes, a useful function can cause another desirable function to occur. There are also times when a useful function has undesirable side effects and causes something harmful to happen. In addition, a harmful function can cause a harmful function to occur, or it could a cause a useful function to occur. A HU diagram is essentially a collection of these cause-and-effect relationships that describe various situations.

Constant contradiction

Contradictions occur when something useful has undesirable side effects and causes something harmful to happen, or when something harmful has desirable side effects and causes something useful to happen.

There are eight different ways harmful and useful functions interact, and four of them are contradictions. Examples 1, 4, 6 and 7 in Figure 1 are contradictions because they involve two connected but opposite functions.

There are three types of contradictions:

1. 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).
2. A function counteracts an opposite function but also produces another opposite function. For example, a useful function counteracts a harmful function (desirable) but also produces a harmful function (undesirable).
3. 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).

A process without any contradictions would be ideal, 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 ones—in other words, to maximize the value-added content while minimizing the nonvalue-added content.

Lawn care

To better understand how to develop a HU diagram, let's examine a gas-powered lawn mower as an example (see Figure 2). Start by defining its primary function: to cut grass. That's a useful function. So, to start constructing the HU diagram, place a sharp-edged rectangle on the paper or computer screen and label it "cuts grass" (function 1 in Figure 2).

Now, define what functions are required to allow the lawnmower to perform its primary function. The blade rotation is a useful function that causes the grass to be cut and is represented by a sharp-edged rectangle labeled "blades rotate" (function 2). Because the blade rotation cause the grass to be cut, the connection line is drawn from 2 to 1.

A sharp blade is a useful function when you're trying to cut grass, so this is added to the HU diagram as another sharp-edged rectangle labeled "blade is sharp" (function 3). There is also a connection line drawn from 3 to 1.

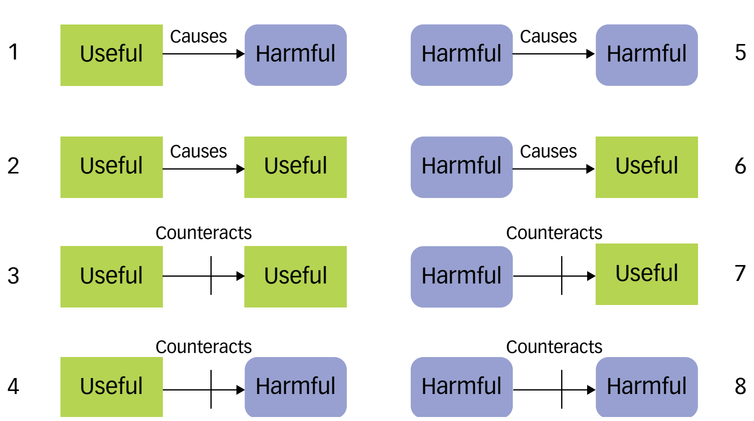
If the lawn mower were stationary and not moving, it would not perform its function, so another useful symbol labeled "lawn mower moves" (function 4) is added to the diagram. Because moving the lawn mower is required to cut the grass, there is a direct connection line from 4 to 1.

Now, there are four useful blocks on the HU diagram, and it's time to look at some of the harmful effects related to the useful functions (see Figure 3):

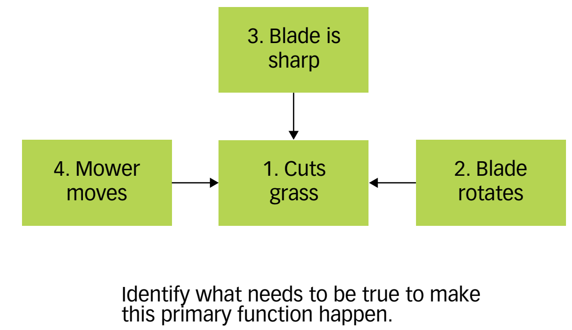
- **Function 5**—cuts fingers and toes. Because function 3, "blade is sharp," can cause fingers and toes to be cut, it creates function 5, so there is a connection line between 3 and 5.
- **Function 6**—thick grass. If the grass is thick, it prevents the lawn mower from moving. As a result, the connection line goes directly from 6 to 4, but it has a vertical line through it, indicating it counteracts or inhibits the lawn mower from moving.
- **Function 7**—clippings clog blade. Cutting the grass can cause clippings to clog the blade, so there is a connection line from function 1 to function 7. And because function 7 could inhibit the blade from rotating (function 2), there is a connection line with a vertical line through it from 7 to 2.
- **Function 8**—throws hard objects. Because the blade rotation can cause debris to be thrown, "throws hard objects" is added to the HU diagram. Because this can occur due to the blade rotation, a connection line is drawn from 2 to 8.

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

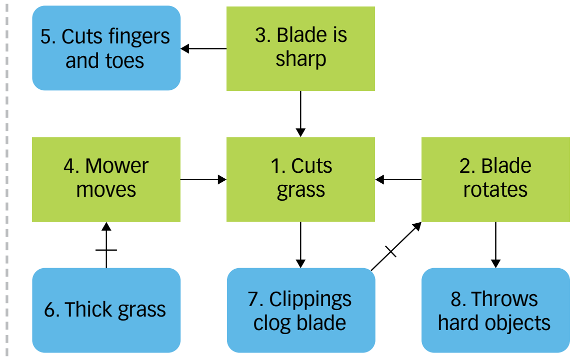
Relationships among functions / FIGURE 1



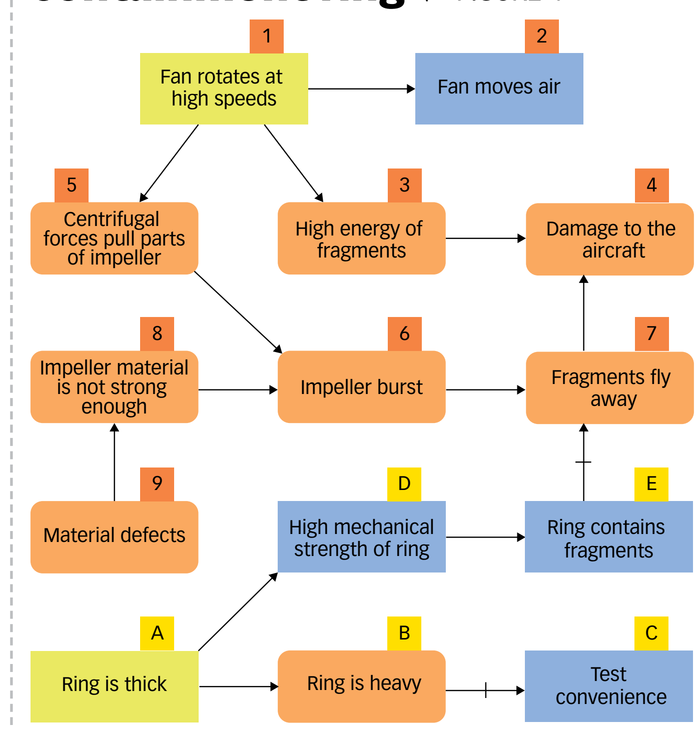
Initial harmful/useful diagram / FIGURE 2



Detailed harmful/useful diagram / FIGURE 3



Harmful/useful diagram for containment ring / FIGURE 4



Getting complex

Let's try something that isn't quite so simple. There are two problems related to an airplane's containment ring problem. The first problem is that the impellers can break, and without something to contain the fragments, the aircraft body and passengers can be damaged.

The second problem is that the rings currently used are heavy and, as a result, decrease the plane's overall efficiency. In addition, they need to be inspected regularly, and their weight and way they are mounted to the engines make them difficult to remove and inspect. Figure 4 (p. 43) is a simple HU diagram of the problem—the impellers in the jet engine breaking and causing damage to the airplane.

The impellers rotate at a high speed (function 1), causing a large quantity of air to move through the engine (function 2). Both of these are useful functions because they cause the airplane to move forward or backward. Because function 1 causes function 2, a connection line is drawn from 1 to 2.

The high-speed fan rotation can cause two harmful functions to occur:

1. It gives high energy to fragments of the impellers (function 3), which in turn can cause damage to the aircraft (function 4). As a result, connection lines need to be drawn from 1 to 3 and from 3 to 4.
2. It causes a centrifugal force to be applied to the impellers in the fan, which can cause parts of the impellers to break off (function 5). That, in turn, can cause the impeller to burst (function 6), which can result in fragments flying away (function 7) and possible damage to the aircraft (function 4). So, four connection lines need to drawn from 1 to 5, from 5 to 6, from 6 to 7 and from 7 to 4.

Because function 6 (impellers burst) is a key function, let's look at it in more detail. Start by asking, "What could cause this to happen?" If the impeller material is not strong enough (function 8), it could cause the impellers to burst. Function 8 can create function 6 to occur, so there is a connection line from 8 to 6.

When asked, "What could cause the impeller material not to be strong enough," the answer might be defects in the material (function 9). That could cause function 8 to occur, so the connection is drawn 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 (function A), which causes the ring to be heavy (function B), so a connection is drawn from A to B.

Test convenience (function C) is a useful function. But because the ring is heavy, it has a negative effect on the convenience of testing the ring. As a result, the connection line from B to C has a vertical line through it, indicating function B counteracts or inhibits function C.

Function A also creates a useful function because the thickness provides high mechanical strength (Function D), which in turn allows the ring to contain the fragments (Function E). The ring containing the fragments counteracts the fragments flying away (function 7). Therefore, the connection line from E to 7 has a vertical line through it, indicating it offsets some of the negative effects of the fragments flying away.

Often, individual conditions are further analyzed by creating their own HU diagram, which is connected back to the main HU diagram.

The circled areas in Figure 5 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. This is when individual innovation and the organization's knowledge management system come into play.

Nuggets of wisdom

What sets final results apart is the experience and creativity of an organization's people. But that isn't enough because, if left on their own, they will fall into the trap of playing it safe and not venturing outside the scientific box in which they limit themselves. An effective knowledge management system can counteract this.

Every situation you face has a golden nugget embedded into it as a result of experience. Sharing these golden nuggets with the rest of the organization is critical to the success of the entire organization. That's why these golden nuggets of past solutions and best practices need to be documented and categorized—so the best concepts can be applied to any situation. They serve as a starting point in the quest for perfection.

Although some of the best concepts come from the experience within the organization, there's plenty of well-defined, explicit knowledge available in the public domain related to the problem you might be facing. In most organizations, it's the soft or tacit knowledge that is not disseminated effectively. It is almost as though every time a person leaves an organization, it loses a library of knowledge. That soft knowledge is the key to success.

Set aside one part of your knowledge management system as the problem or situation improvement knowledge base. Each time a problem or situation is corrected, data related to how it was solved should be added to the database. Well-documented examples are one of the best ways to share experiences—good and bad.

A good way to get this database started is to input the 40 TRIZ Principles[1] and the 39 Engineering Parameters for Expressing Technical Contradictions.[2]

The knowledge management systems that contain these golden nuggets of wisdom trigger you to think about how to solve a problem or to improve a process under evaluation. These golden nuggets, sometimes called "operators," are drawn from successful results of previous actions that resolve different technology or process problems.

To date, about 1,000 golden nuggets have been defined. But in our experience, solving most problems a PIT will encounter requires knowing only 200 to 400 of these nuggets.

Using a knowledge management system filled with organized examples of how situations have been addressed in the past is the most effective way to find the best solutions. But some organizations will stick with the brainstorming approach because they feel comfortable with it or because they don't have a problem or situation improvement knowledge base. There's little wrong with this approach, and it does provide acceptable solutions, but it might not be the most efficient strategy.

Elimination round

There are three other ways to define a solution to a problem. Their complexity falls somewhere between the knowledge management system and the brainstorming method to problem solving. These three fundamental approaches are:

1. **Eliminate approach.** Remove the harmful or mitigate the negative effect.
2. **Alternatives approach.** Find a different way of doing or enhancing the condition.
3. **Resolution approach.** Separate or isolate the cause of the negative condition or byproduct.

Let's apply the eliminate approach to the container ring problem as an example. This approach should be the starting point to finding a solution for most problems. The eliminate approach involves the following basic questions:

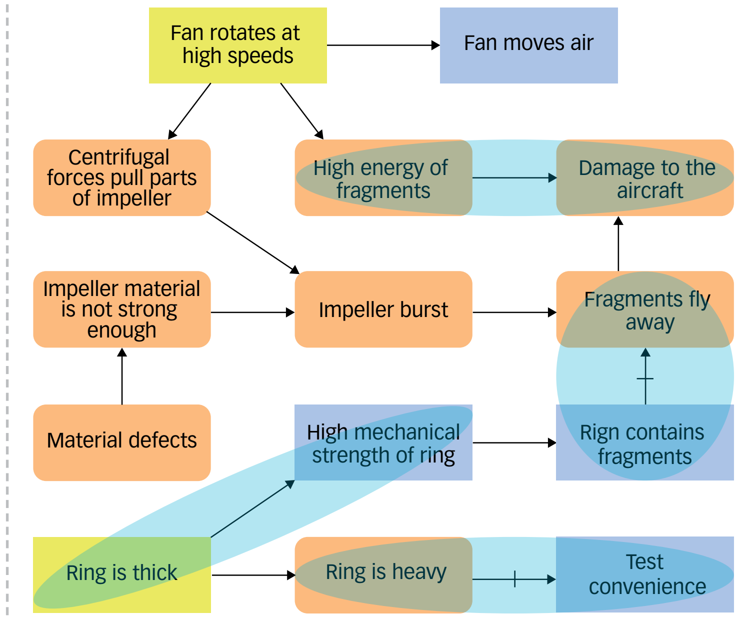
- Can you do without the object?
- Can you remove the thing causing the harm?
- Can you counteract the harm?
- Can you protect the system from the harm?
- Can you mitigate or reduce the harmful effects?
- Can you use the harm to do something good?

If you apply the eliminate approach to the containment ring problem, ask yourself, "Can I eliminate the possibility of the impellers bursting?" and "Can I eliminate the ring?" If the PIT can find a way to stop the impellers from bursting, the ring also could be eliminated.

In reality, there's no way to be 100% sure the impellers will not burst. And if they do burst, there must be something that will keep the fragments from hitting the body of the plane. Based on this analysis, it appears as though the eliminate approach can't be used to solve the problem.

But there are more opportunities for applying the eliminate approach than simply eliminating the potential impeller breakage or the ring. Let's look at function B (ring is heavy) and function C (test convenience) in

Detailed harmful/useful diagram for containment ring / FIGURE 5



Functions from containment ring's harmful/useful diagram / FIGURE 6

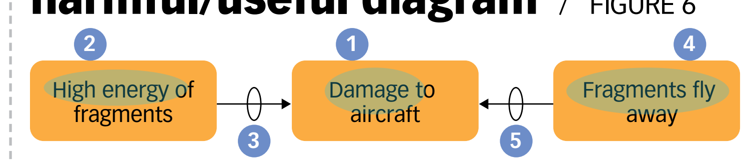


Figure 4 (p. 43). In this case, the eliminate approach can be applied inside five areas:

1. **Ring**—Can you eliminate the ring?
2. **Heavy**—Can you eliminate the heaviness?
3. **Connection between functions B and C**—Can you eliminate its impact on the test?
4. **Test**—Can you eliminate the need to have a test?
5. **Convenience**—Can you eliminate the need for the test to be convenient?

Now, let's look at another part of the containment ring's HU diagram in Figure 4—the three harmful functions:

1. Function 3—high energy of fragments.
2. Function 4—damage to aircraft.
3. Function 7—fragments flying away.

Note that in Figure 6 (p. 45), five individual points are highlighted. The following are typical questions the PIT should ask related to these five points as they are triggered by the eliminate approach:

1. Can you protect the plane from fragments?
2. Can you reduce the energy of the fragments?
3. Can you absorb the energy in some manner?
4. Can you prevent the fragments from flying away?
5. Can you use the fragment energy in some way?

While the eliminate approach was used in this situation, under normal circumstances, the PIT would use all three fundamental approaches and apply them to the different functions within the HU diagram to formulate an effective solution.

Solving the problem

The shaded area in Figure 5 (p. 45) that includes the useful symbol labeled "test convenience" (function C) and the harmful symbol labeled "ring is heavy" (function B) presents improvement opportunities to reduce the weight of the containment ring.

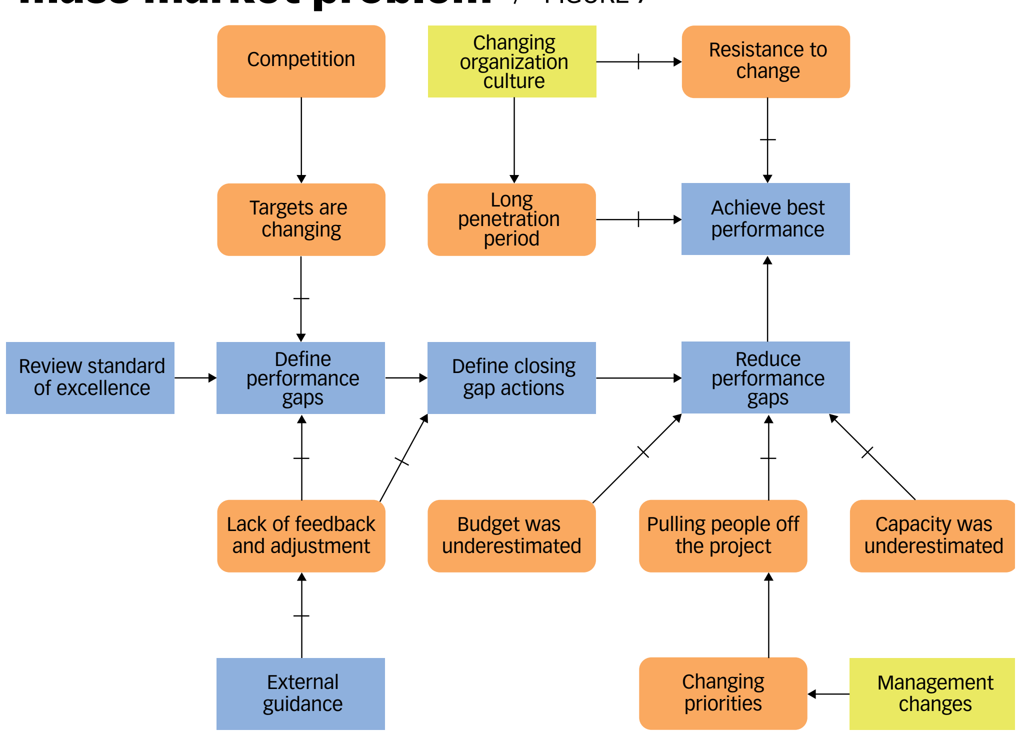
In this case, one of the operating principles the PIT could use is changing an object's structure from uniform to non-uniform and changing an external environment or influence from uniform to non-uniform. Using this golden nugget or operator as a starting point, the PIT will adapt it to the conditions set up in the shaded area.

A typical idea that could emerge from this analysis is to change the ring thickness over its length and width, making the ring denser closer to the blades and directly in line with the blades' motion, but less dense everywhere else.

Another operating principle that could be applied is changing an object's shape from symmetrical to asymmetrical. For example, this might lead the PIT to suggest that only the side of the ring closest to the body of the airplane needs to be thicker to give maximum protection. There would be little damage if the fragments hit the side away from the body of the plane.

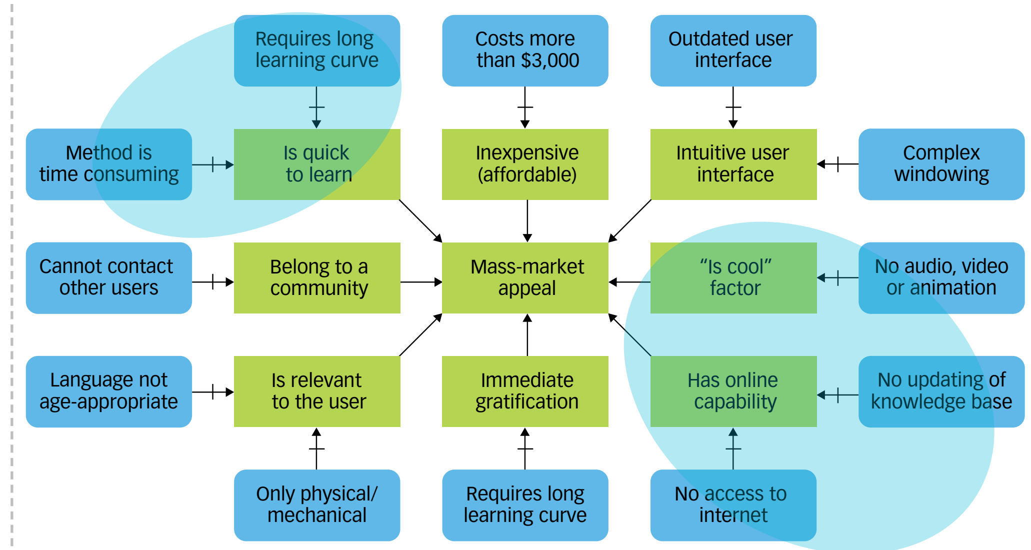
The shaded area that includes the useful symbol "ring contains fragments" (function E) and the harmful symbol labeled "fragments fly away" (function 7) presents another opportunity for improvement. In this case, the PIT could use an operating principle called "porous materials"—making an object porous or adding porous elements. Using this principle, the PIT might suggest using a honeycomb structure because the sharp edges of the structure would act like knives to shred the fragments.

Harmful/useful diagram of mass-market problem / FIGURE 7



The shaded area that includes the harmful symbols labeled "high energy of fragments" (function 3) and "damage to the aircraft" (function 4) also presents an opportunity for improvement. In this case, the PIT might focus on reducing the energy of the fragments. To accomplish this, the PIT could use two operating principles—porous materials and composite materials, the latter of which involves changing from uniform to composite or multiple materials.

Detailed harmful/useful diagram of mass-market problem / FIGURE 8



Based upon the concepts in these two operating principles, the PIT could suggest using multiple lightweight rings. The first ring could be thin and stiff but porous, and will shred the blade fragments without stopping them. The second ring could be made from carbon fiber, which is strong and lightweight, and would stop the fragments.

There is another opportunity for improvement available, even though it includes two useful symbols—the shaded area that includes "ring is thick" (function A) and "high mechanical strength of ring" (function D). In this case, the PIT could use an operating principle called "nested doll"—place one object inside another. Applying this operator to the situation involves using two containment rings, one inside the other. The inside ring would be thicker than the outside one, but together they will be lighter than one big ring.

More applications

The containment ring situation was a design solution, but HU diagrams work equally well for process solutions. For example, Figure 7 is a HU diagram for the impact of change on an organization, and Figure 8 is a HU diagram of a mass-market problem highlighting two areas in which additional actions need to be taken to offset the harmful effects.

Regardless of the setting, HU diagrams are effective in helping PITs generate solutions, particularly when the diagrams are used by well-trained, innovative people aided by an effective knowledge management system with information from past situations that have been solved. In addition, HU diagrams minimize the risk of implementing solutions that create other problems.

This approach definitely requires some practice, but after you get used to constructing and using them, you will find them to be a major asset. QP

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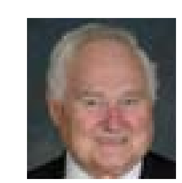

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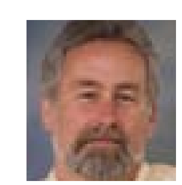

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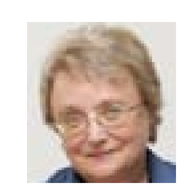

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