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▶ Features, Use Cases, Requirements, Oh My!

by **Dean Leffingwell**
Senior Vice President of Process and Project Management
Rational Software

As a follower and proponent of object-oriented (OO) technology in the BU (Before UML) days, I must admit to a certain fascination with the various methods and notations spread by the industry thought leaders at the time. At about two to four years BU, if we had walked into a room full of OO advocates and asked the following question:

> I think this OO technology shows great promise; but tell me, since the object shares behavior and data, what do you call this thing an object does to fulfill its behavioral obligations?

We might have gotten the following answers:

> "It's a responsibility!" (Wirfs-Brock)

> "It's an operation!" (Booch)

> "It's a service!" (Coad/Yourdon)

> "It's a (virtual) function!" (Stroustrup)

> "It's a method!" (many others)

And if this array of answers seems confusing, don't even think about the range of responses we would have elicited by asking how you would graphically represent that thing we call an object and a class (e.g., "It's a rectangle," "It's a cloud," "It's a. . . whatever."). While these differences might seem inconsequential, the reality is that some of the most significant shared concepts among our software engineering leaders -- inheritance, relationships, encapsulation -- were obscured by minor differences in terminology and notation. In other words, neither the science of OO engineering nor the benefits to be gained could advance further because the language to describe the science had not yet been invented. Of course, gaining agreement among these authors, methodologists[1], and independent thinkers was not a trivial matter, but eventually, along came the UML, and the science of software

engineering marched forward again.

While it's perhaps not as bad as the Tower of Babel wrought by the pre-UML competing OO methodologies, the methodology of *requirements management* suffers from some of the same issues -- specifically, the prevalence of ambiguous, inconsistent, and overloaded usage of common terms. These terms, including such seminal constructs as "Use Cases," "Features," and "Requirements," we assume are common, everyday terms that "everyone understands." In truth, however, each individual attaches his or her own meaning to these terms within a given context. The result is often ineffective communication. And this occurs in a domain wherein success is defined simply by having *achieved* a common understanding.

Booch [Booch 1994] points out that Stepp observed:

> *. . .an omnipresent problem in science is to construct meaningful classifications of observed objects and situations. Such classifications facilitate human comprehension of the observations and subsequent development of a scientific theory.*

In order to advance the "scientific theory" of requirements, we have to come to terms with terms!

The purpose of this article is to take a small step forward in the discipline of software engineering by defining and describing some of the most common terms and concepts used in describing requirements for systems that contain software. In doing so, we hope to provide a basis for common understanding among the many stakeholders involved: users, managers, developers, and others. Certainly if we communicate more effectively and establish a common view, it will be possible to more quickly develop and deliver higher quality systems.

This article is not an overview of the requirements management discipline -- for that we refer you to a number of books on the topic listed under the heading "Suggested Reading." The goal of this article is simply to help practitioners in the field improve their ability to answer the following, fundamental question:

> *"What, exactly, is this system supposed to do?"*

The Problem Domain vs. the Solution Domain

Before we start describing specific terms, however, it's important to recognize that we will need to define terms from two quite different worlds -- the world of the problem and the world of the solution. We'll call these the *problem domain* and *solution domain*, respectively.

The Problem Domain

If we were to fly over the **problem domain** at a fairly low level, we would see things that look very much like the world around us. If we

flew over the HR department, we might see employees, payroll clerks, and paychecks. If we flew over a heavy equipment fabricator, we might see welders, welding controllers, welding robots, and electrodes. If we flew over the World Wide Web, we'd see routers and server farms, and users with browsers, telephones, and modems. In other words, in any particular problem domain we can most readily identify the things (entities) that we can see and touch. Occasionally, we can even see relationships among those things; for example, there seems to be a one-to-one relationship between Web users and browsers. We might even see messages being passed from thing to thing -- e.g., "That welder appears to be programming a sequence into a welding robot's 'brain.'"

If we were really observant, we might see things that look like *problems* just waiting to be resolved: "The welder seems really frustrated with his inability to get the sequence right," or "Notice that nasty time delay between the time that employee enters her payroll data and the day she receives her check!"

Some of the problems seem to just *beg* for a solution. So we say: "Perhaps we can build a system (a better programmable controller, a more efficient payroll processing) to help those poor users down there fix those problems."

On User and Stakeholder Needs

Before we build that new system, however, we need to make sure that we understand the *real needs* of the users in that problem domain. If we don't, then we may discover that the welder was grimacing only because he was suffering from a painful corn on his toe, so neither he nor his manager is interested in purchasing our brand new "SmartBot" automated welding control unit. We might also notice that when we try to sell the SmartBot, the manager seems to emerge as a key stakeholder in the purchasing decision. We don't remember seeing her in our fly-over. (Perhaps she was in the smoking lounge; our cameras don't work as well in there.) In other words, not all stakeholders are users, and we have to understand the needs of both communities (stakeholders and users) if we hope to have a chance to sell the SmartBot. To keep things simple, we call all of these needs *stakeholder needs*, but we'll constantly remind ourselves that the potential users of the system appear to represent a very important class of stakeholders indeed.

We'll define a stakeholder need as:

> . . .a reflection of the business, personal, or operational problem (or opportunity) that must be addressed to justify consideration, purchase, or use of a new system.

Stakeholder needs, then, are an expression of the issues associated with the problem domain. They don't define a solution, but they provide our first perspective on what any viable solution would need to accomplish. For example, if we interview the plant manager for a heavy

equipment fabricator, we may discover that welding large, repetitive weldments consumes a significant amount of manufacturing time and cost. In addition, welders don't seem to like these particular jobs, and they are constantly in danger of burnout. Worse still, the physical aspects of the job -- repetition, awkward manual positions, danger to eyesight, and so on -- present personal safety issues and long-term healthcare concerns.

With these insights, we could start defining some *stakeholder needs:*

> *We need an automated way to fabricate large, repetitive weldments without the welder having to manually control the electrode.*
>
> *We are happy to have a welder present, but we need to remove him to a safety zone outside of the welding area and away from any moving machinery.*
>
> *We need an easy-to-use "training mode" so that average welders can "train" the machine to do the majority of the welding for them.*
>
> *We need to allow more flexibility in the training mode and recognize that this may contradict some aspects of the need for user-friendliness.*

As we understand these various aspects of the system, we'll mentally "stack" these discoveries in a little pile called "stakeholder needs."

The Solution Domain

Fortunately, our fly-over of the problem domain doesn't take very long, and (usually) what we find there is not too complicated. We start to appreciate the problem when we leave the airplane, and set off to build a solution to the problems and needs we have observed. Yes, we've reached the beginning of the hard part: *forming a solution to the problem.* We consider the set of activities (system definition, design, and so on), the "things" we find and build to solve the problem (computers, robot arms, and the like), and the artifacts we create in the process (such as source code, use cases, and tests) part of the **solution domain**.

In the solution domain, there are many steps and activities we must successfully execute to define, build, and eventually deploy a successful solution to the problem. They include:

1. Understand the user's needs

2. Define the system

3. Manage the scope and manage change

4. Refine the system definition

5. Build the right system

In a nutshell, the steps above define a simplified process for requirements management. This paper won't discuss these steps in much detail; for this we refer you to the Bibliography and Suggested Reading, including the text, *Managing Software Requirements* [Leffingwell, 1999]. The ideas in this paper are consistent with those in that text, and most of the definitions provided here are taken from it.

The text defines requirements management as:

> *. . .a systematic approach to eliciting, organizing, and documenting the requirements of the system, and a process that establishes and maintains agreement between the customer and the project team on the changing requirements of the system.*

But let's move on to discovering and defining more of the requirements management terms we'll need to describe the system we are about to build.

Common Requirements Terms in the Solution Domain

Features of a Product or System

As we start thinking about solutions to the problems we've identified, it's very natural to start jotting down the *features* of a system. Features occupy an interesting place in the development of a system. They fit somewhere between an expression of the user's real needs and a detailed description of exactly how the system fulfills those needs. As such, they provide a handy construct -- a "shorthand", if you will -- for describing the system in an abstract way. Since there are many possible solutions for the problem that needs to be solved, in a sense features provide the initial bounds of a particular system solution; they describe what the system is going to do and, by omission, what it will not do.

We'll define a feature as:

> *. . .a service that the system provides to fulfill one or more stakeholder needs.*

Features are easily represented in natural language, using terms familiar to the user. For example:

> *The system runs off standard North American power.*

> *The tree browser provides a means to organize the defect information.*

> *The home lighting control system has interfaces to standard home automation systems.*
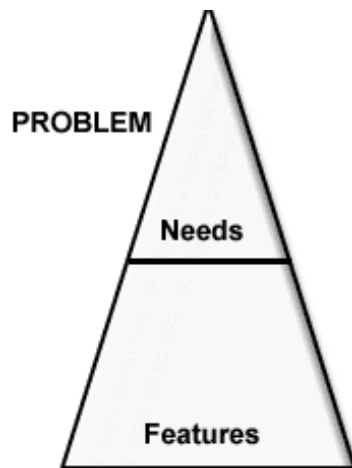
Since features are derived from stakeholder needs, we position them at the next layer of the pyramid, below needs. Note that we've also moved from the problem domain (needs) to the first level of the solution domain (features).

It's important to notice that features are NOT just a refinement (with increasing detail) of the stakeholder needs. Instead, they are a direct response to the *problem* offered by the user, and they provide us with a top-level *solution* to the problem.

Typically, we should be able to describe a system by defining 25-50 features that characterize the behavior of that system. If we find ourselves with more than 50 features on our hands, it's likely that we've insufficiently abstracted the true features of the system. Or the system may be too large to understand, and we may need to consider dividing it into smaller pieces.

Features are described in natural language so that any stakeholder who reads the list can immediately gain a basic understanding of what the system is going to do. A features list usually lacks fine-grained detail. That's all right. Its purpose is simply to communicate the intent and, since many stakeholders are likely to be non-technical, too much detail can be confusing and may even interfere with understanding. For example, a partial list of features for our SmartBot automated welding robot might include:

> *A "lead through path" training mode that allows the welder to teach the robot what paths will be welded.*

> *A "step-and-repeat" feature that supports repetitive welding sequences.*

Use Cases

As we think further about the way in which the system needs to do its job for the user, we might find it beneficial to employ the *Use Case Technique* for further describing system behavior. This technique has been well developed in a number of books [Jacobson 1992] and is also an integral technique in the industry-standard Unified Modeling Language (UML) [Booch 1999].

Technically, a use case:

> *. . .describes a sequence of actions, performed by a system, that yields a result of value to the user.*

In other words, the use case describes a series of user and system interactions that help users accomplish something they wanted to accomplish. Stated differently, the use case describes HOW users and

the system work together to realize the identified feature.

Use cases also introduce the construct of an actor, which is simply a label for someone who is using the system at a given time. In UML, a use case is represented by a simple oval; an actor is represented by a stick figure with a name. So we can illustrate both with a simple diagram like the one below.
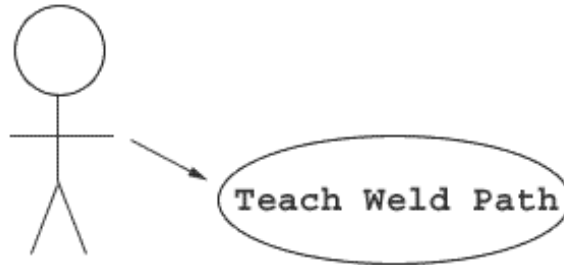
The use case technique prescribes a simple, step-by-step procedure for how the actor accomplishes the use case. For example, a use case for Step and Repeat might start out as follows:

```
Step 1: The welder presses the "Step and Repeat"
button to initiate the sequence.

Step 2: The welding system releases power to the
drive motors so that the robot's arms can be moved
manually.

Step 3: The welder grabs the trigger, moves the arm
to the weldment, and holds down the "Weld Here"
button for each path to be welded.
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The use case technique provides a number of other useful constructs, such as pre and post descriptions, alternate flows, and so on. We'll talk about these later as we examine the use case in more detail. For now, we simply need to know that use cases provide an excellent way to describe *how* the features of the system are achieved.

For planning purposes, it's likely that more than use cases will be necessary to describe how a particular feature is implemented. A small number of use cases (perhaps 3-10) may well be necessary for each feature. In describing the use cases, we are elaborating on the behavior of the system. Detail increases as we achieve additional specificity.

Vision Document

Many development projects use a Vision document that defines the problem, identifies key stakeholders and user needs, lists system features, and perhaps includes example use cases. This document may be called by a variety of other names: Project Charter, Product Requirements Document, Marketing Requirements Document, and so forth. No matter what it's called, the Vision document highlights the overall intent and purpose of the system being built. It captures the "gestalt" of the system, using *stakeholder needs, features*, and *use cases* to communicate the intent.

We cannot, however, simply dump features and initial use cases into the hands of the development team and expect them to rush off and develop a system that really satisfies stakeholder needs. We need to be a lot more definitive about what we want the system to do, and we'll probably have to add a lot of new stakeholders, including developers, testers, and the like. That's what happens in the next layer of the system definition -- the software requirements.

Software Requirements
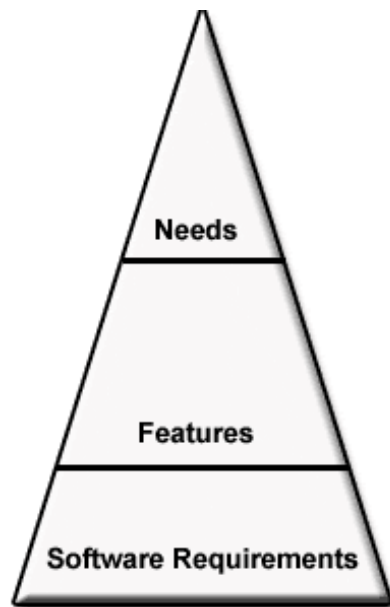
Software requirements provide the next level of specificity in the requirements definition process. At this level, we specify requirements and use cases sufficiently for developers to write code and testers to see whether the code meets the requirements. In our graphical representation, software requirements are at the base of our pyramid.

What is a software requirement? Although many definitions have been used throughout the years, we find the definition provided by requirements engineering authors Dorfmann and Thayer [Dorfmann 1990] to be quite workable. They say that a software requirement is:

. . .a software capability needed by the user to solve a problem that will achieve an objective

OR

a software capability that must be met or possessed by a system or system component to satisfy a contract, standard, specification or other formally imposed documentation.

Applying this definition, the team can develop a more specific set of requirements to refine, or elaborate, the features list discussed earlier. Each requirement serves some feature and vice versa. Notice the simplicity of this approach. We have a list of features, and we then elaborate those features by writing a set of requirements that serve those features. *We don't write any other requirements.* We avoid the

temptation to sit down, stare at the ceiling, and "think up some requirements for this system."

The process is straightforward but not necessarily easy. Each feature is reviewed, and then requirements are written to support it. Inevitably, writing the requirements for one feature will spur ideas for new requirements or revised requirements for a feature that has already been examined.

Of course, as we know, it's not easy to write down requirements -- and there may be a large number of them. It's helpful to think about three types or categories of software requirements: functional requirements, nonfunctional requirements, and design constraints.
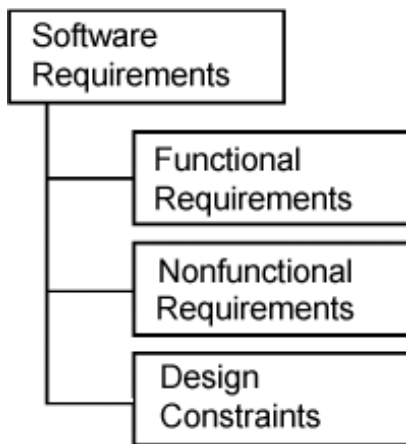
We find these three categories helpful in thinking about the requirement and what role we expect it to fill. Let's look at these different types of requirements and see how we can use them to define different aspects of the proposed system.

Functional Requirements
Functional requirements express what the system does. More specifically, they describe the inputs and outputs, and how it is that specific inputs are converted to specific outputs at various times. Most business software applications are rich with functional requirements. When specifying these requirements, it's important to strike a balance between being too vague ("When you push the 'On' button, the system turns on") and being too specific about the functionality. It's important to give designers and implementers as wide a range of design and implementation choices as possible. If we're too wishy-washy, the team won't know what the system is supposed to achieve; if we're too specific, we may impose too many constraints on them.

There isn't one right way to specify requirements. One technique is simply to take a declarative approach and write down each detailed thing the system needs to do. For example:

> During the time in which the "Weld Here" input is active, the system digitizes the position of the electrode tip by reading the optical encoders every 100 msec.

Elaborating the Use Case
In many systems, it's helpful to organize the specification activity by refining the use cases defined earlier and developing additional use cases to fully elaborate the system. Using this technique, we refine the steps of the use case into more and more detailed system interactions. We'll also need to define pre-conditions and post-conditions (states the system assumes before and after the use case), alternative actions due to exception conditions, and so on.

Since use cases are semantically well defined, they provide a structure

into which we can organize and capture the system behavior. Here is a representative use case for the Smartbot.

Use Case Name	Teach Weld Path
Actor	Welder
Brief Description	This use case prescribes the way in which the welder teaches the robot a single weldment path operation.
Flow of Events	Basic flow for the use case begins when the welder presses the "Teach" button on the control console. The system turns off the power to the robot arms. The welder grabs the teaching electrode and positions the teaching tip at the start of the first weld. The welder presses the "Weld Here" trigger and simultaneously moves the teaching tip across the exact path to be welded. At the end of the path, the welder releases the "Weld Here" trigger and then returns the robot's arm to the rest position.
Alternative Flow of Events	At any time during the motion, the welder can press the "Pause" button; then the robot will turn on power to the motors and hold the arms and teaching tip in the last known position.
Pre-conditions	The robot must have performed a successful auto-calibrate procedure.
Post-conditions	The traverse path and weld paths are remembered by the system.
Special Requirements	The welder cannot move the tip at a rate faster than 10cm/second. If faster motion is detected, the system will add resistance to the arms until the welder returns to the acceptable lead-through speed.

Nonfunctional Requirements
In addition to functional requirements such as inputs translating to

outputs, most systems also require the definition of a set of nonfunctional requirements that focus on specifying additional system "attributes," such as performance requirements, throughput, usability, reliability, and supportability. These requirements are just as important as the input-output oriented functional requirements. Typically, nonfunctional requirements are stated declaratively, using expressions such as "The system should have a mean time between failure of 2,000 hours;" "The system shall have a mean time to repair of 0.5 hours;" and "The Smartbot shall be able to store and retrieve a maximum of 100 weld paths."

Design Constraints

As opposed to defining the behaviors of the system, this third class of requirements typically imposes limitations on the design of the system or process we use to build the system. We'll define a design constraint as:

> . . .a restriction upon the design of a system, or the process by which a system is developed, that does not affect the external behavior of the system, but must be fulfilled to meet technical, business, or contractual obligations.

A typical design constraint might be expressed as "Program the welder control unit in Java." In general, we should treat any reasonable design constraints just like any other requirements, although testing compliance to such constraints may require different techniques. Just like functional and nonfunctional requirements, these constraints can play an integral role in designing and testing the system.

Hierarchical Requirements

Many projects benefit from expressing requirements in a hierarchical or parent-child structure. A parent-child requirement amplifies the specificity expressed in a parent requirement. Parent-child requirements give us both a flexible way to enhance and augment a specification, and a means to organize levels of detail. The parent, or top-level specification, is easily understandable to all users; implementers can inspect the more detailed "child" specification to make sure that they understand all of the implementation details. Note that hierarchical requirements consist of the standard three types of requirements: functional, non-functional, and design constraints. The hierarchical approach simply defines the *elaboration relationship* among requirements.

Traceability

In addition to defining the terms we use for things that describe system requirements, we should now turn to a key *relationship*, traceability, which may exist among these things.

A significant factor in quality software is the ability to understand, or trace, requirements through the stages of specification, architecture, design, implementation, and test. Historical data shows that the impact of change is often missed, and small changes to a system can create

significant reliability problems. Therefore, the ability to track relationships, and relate these relationships when change occurs, is key in software quality assurance processes. This is particularly the case for mission critical activities, including safety-critical systems (medical and transportation products), systems with high economic costs of failure (online trading), and so on. Here's how we define requirements traceability:

> *A traceability relationship is a dependency in which the entity (feature, use case, requirement) "traced to" is in some way dependent on the entity it is "traced from."*

For example, we've described how one or more Software Requirements are created to support a given feature or use case specified in the Vision document. Therefore, we can say that these Software Requirements have a *traceability relationship* with one or more Features.

Impact Analysis and Suspectness

A traceability relationship goes beyond a simple dependency relationship because it provides the ability to do impact analysis using a concept that we call "suspectness." A traceability relationship goes "suspect" whenever a change occurs in the "traced from" (independent) requirement, and therefore the "traced to" (dependent requirement) must be checked to ensure that it remains consistent with the requirement from which it is traced.

For example, if we use traceability to relate requirements to specific tests, and if a requirement such as "The Smartbot shall be able to store and retrieve a maximum of 100 weld paths" becomes "The Smartbot shall be able to store *and* retrieve a maximum of 200 weld paths," then the test traced from this requirement is suspect. It is unlikely any test devised for the first requirement will be adequate to test the second one.

Change Requests and the Change Management System

Finally, change is inevitable. For a project to have any hope of succeeding, a process for managing all changes -- including requests that affect features and requirements -- in an orderly manner is essential. The key element of any change management system is the Change Request itself. We'll define a Change Request as:

> *. . .an official request to make a revision or addition to the features and/or requirements of a system.*

Change Requests need to enter the system as structured, formalized statements of proposed changes and any particulars surrounding those changes. In order to manage these changes, it's important that each one have its own identity in the system. A simple Change Request form might look something like this:

Change Request	
Change Request Item	`Value`
Change Request ID	`CR001`
Change Request Name	`Safety Feature on "Power On" Button`
Brief Description of Change	`Add hold time to "Power On" button that requires user to hold button for xx seconds before system turns on.`
Requested by...	`Safety Supervisor`

A change management system should be used to capture *all* inputs and transmit them to the authority of a Change Control Board (CCB) for resolution. The CCB should consist of no more than three to five people who represent the key stakeholders for the project (customers, marketing, and project management). They administer and control changes to the system, and thereby play a key role in helping the project succeed.

Summary

At the beginning, we noted that a goal of this article was to help practitioners in the field improve their ability to answer the fundamental question:

"What, exactly, is this system supposed to do?"

As a step toward this goal, we defined and described some of the common terms -- such as stakeholder needs, features, use cases, software requirements, and more -- used by analysts and others who have responsibility for describing issues in the problem domain, and for expressing the requirements to be imposed upon any prospective solution. In so doing, we also illustrated some of the key concepts of effective requirements management. By using the terms and approaches outlined in this article, you can better understand your user's needs and communicate requirements for proposed solutions to developers, testers, and other technical team members.

The Unified Modeling Language (UML) is an important technique for further defining and communicating additional key aspects of software solutions. A language for visualizing, specifying, and documenting the artifacts of a software-intensive system, it provides a means for expressing these technical constructs in a more semantically precise manner. The *User Guide* and *Reference Manual* for UML listed below provide practical advice on its use.

Suggested Reading

Leffingwell, Dean, and Don Widrig. *Managing Software Requirements: A Unified Approach.* Reading, MA: Addison Wesley Longman, 1999.

Weigers, Karl. *Software Requirements*. Redmond, WA: Microsoft Press, 1999.

Bibliography

Booch, Grady. *Object-Oriented Analysis and Design with Applications*, 2nd ed. Redwood City, CA: Benjamin Cummings, 1994.

Booch, Grady, James Rumbaugh, and Ivar Jacobson. *The Unified Modeling Language User Guide.* Reading, MA: Addison Wesley Longman, 1999.

Dorfmann, Merlin, and Richard H. Thayer. *Standards, Guidelines, and Examples of System and Software Requirements Engineering.* Los Alamitos, CA: IEEE Computer Society Press, 1990.

Jacobson, Ivar, Magnus Christerson, Patrik Jonsson, and Gunnar Övergaard. *Object-Oriented Software Engineering: A Use Case Driven Approach.* Harlow, Essex, England: Addison Wesley Longman, 1992.

Rumbaugh, James, Ivar Jacobson, and Grady Booch. *The Unified Modeling Language Reference Manual.* Reading, MA: Addison Wesley Longman, 1999.

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[1]At Rational Software, it has been my privilege to work with some of the industry's leading methodologists -- Grady Booch, Ivar Jacobson, Jim Rumbaugh, Philippe Kruchten, Bran Selic, and others. While this has been a rewarding and fascinating part of my career, it's not something I could recommend for everybody. In other words, please do NOT try this at home.

For more information on the products or services discussed in this article, please click [here](#) and follow the instructions provided. Thank you!