The Simplicity Cycle

Simplicity And Complexity In Design

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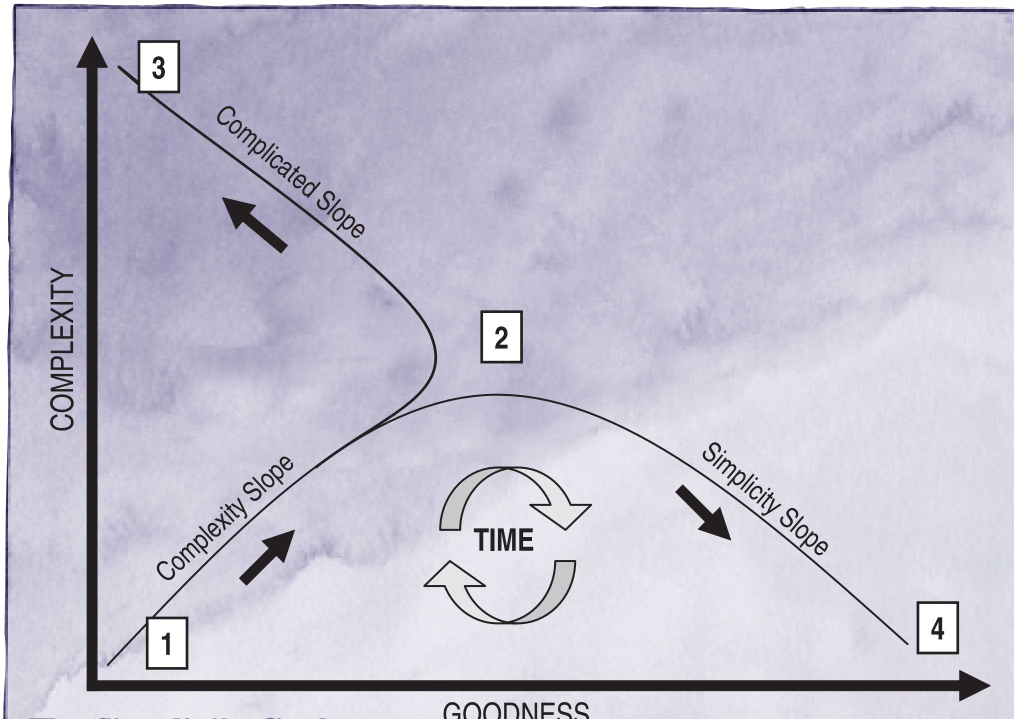
Albert Einstein and Henry David Thoreau were kindred spirits in many ways. They were both towering geniuses, each with the unique and intriguing eccentricities that tend to accompany people with such extreme mental gifts. They were both tremendously curious about the world around them; they both worked as teachers; and both left indelible marks on the world. And despite the vast scale and scope of their chosen fields of study, they both had a profound appreciation—and need—for simplicity in their lives as well as their work.



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Thoreau is famous for challenging his readers to "simplify, simplify, simplify." With slightly more nuance, Einstein opined that "everything should be made as simple as possible, but not simpler."

However, to simply say simplicity is important is rather … simplistic. There's a lot more to it than that, so we're going to take a tour of something I call "the simplicity cycle."

Simplicity 101

From naive simplicity we arrive at more profound simplicity. Albert Schweitzer

The simplicity cycle is a teaching tool I developed to illustrate the typical progress of a system design, academic discipline, or technology development program as it progresses from conception to maturity. The simplicity cycle highlights a typical path for any number of activities and illuminates a few key design myths and pitfalls on the way. We will examine it one piece at a time, then put the pieces together.

We begin with a blank x-y chart where *complexity* increases along the vertical y-axis and *goodness* along the horizontal x-axis. Goodness is a general term that means slightly different things depending on the application and context. If we are talking about a technology or a system, goodness represents operational functionality or utility; for an academic discipline, it represents increased understanding; and for system design, it reflects design maturity.

Region 1: The Region of the Simplistic

One, two, buckle my shoe. Traditional nursery rhyme

The journey begins in the lower left quadrant of our x-y chart above: the *Region of the Simplistic*. Here, complexity and goodness are both low. In mathematics, this is where we discover numbers and encounter things like 1 + 1 = 2. In aircraft design, it's where we make paper air-

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planes. In other words, this region is where a foundation is laid for all the progress and work that follows.

From the simplistic vantage point, it is sometimes difficult to tell the difference between subsequent regions because our understanding of the road ahead is too simplistic. Not to worry, we usually don't usually stay here for very long.

The Complexity Slope

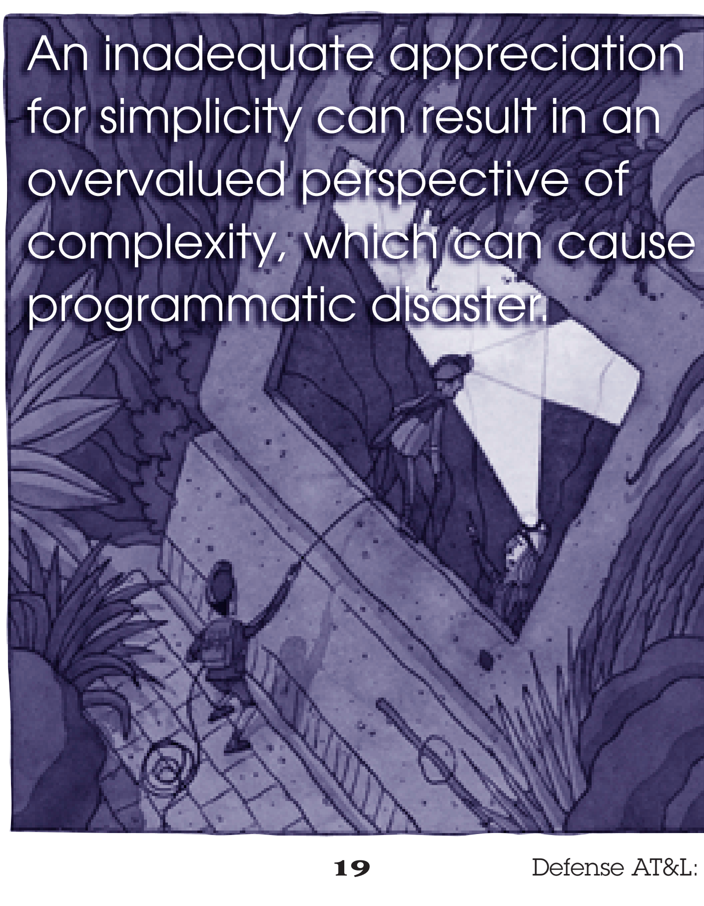
I have yet to see any problem, however complicated, which, when you looked at it in the right way, did not become still more complicated. Poul Anderson

As you learn and develop, new elements are introduced, and complexity increases. Fortunately, these new elements add utility, functionality, or maturity, so goodness also increases. This corresponds to movement from the bottom left quadrant towards the middle of the chart.

Progress along this slope—the *complexity slope*—can be described as learning and creating. In a word, the slope is about genesis. For mathematicians, our use of numbers and simple addition grows to include things like multiplication, division, and algebra. Now, rather than $1 + 1 = 2$, we are working with $Y = mX + b$, which requires (among other things) the introduction of elements beyond numbers. The complexity of our output has increased. And so has the goodness because we can do things with algebra that we can't easily do with arithmetic.

For system designers, travel along this path involves adding new pieces, parts, and functions. Aircraft designers leave paper airplanes behind and move on to scale models, wind tunnels, and operational prototypes. The transition from paper airplane to operational prototype results in the ability to do more, whether that be to fly longer and higher, to carry more weight, or simply to land without crumpling. It is reasonable to conclude the increased goodness/utility/maturity is largely the result of the increased complexity.

That brings us to one of the primary myths of complexity—a common but erroneous belief that complexity and goodness are always proportional, and an increase in one dimension equates to an increase in the other. More pointedly, there is a misperception that increased complexity actually *causes* increased goodness. As we have already seen, this is partially and initially true—but only to a point. Eventually we arrive at the second region, and our trajectory must change.



Region 2: The Region of the Complex

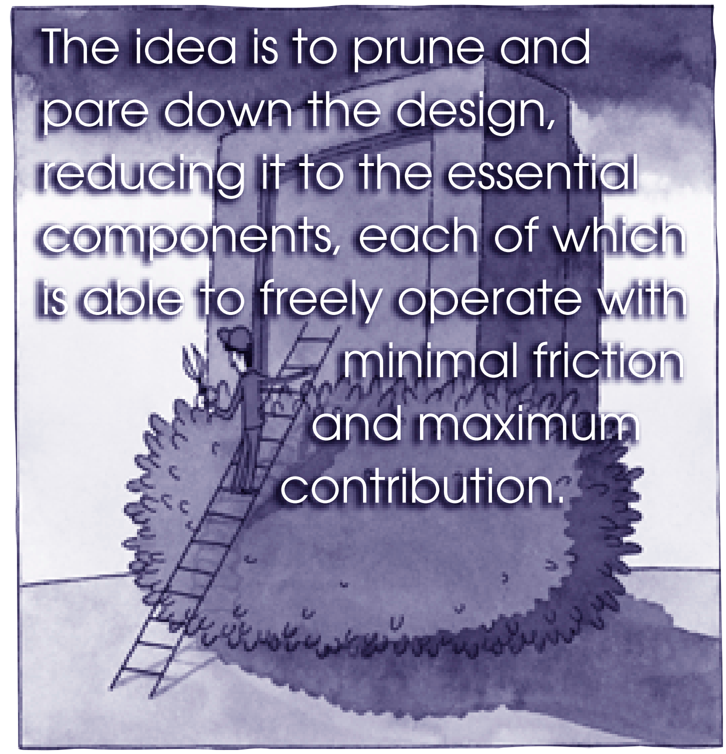
A complex system that works is invariably found to have evolved from a simple system that works. John Gaule

In the second region (located in the center of the graph), complexity and goodness have achieved a critical mass. This is the *Region of the Complex*. In practical terms, the number of elements involved have substantially increased beyond the original simplistic situation, and a meaningful degree of functionality and maturity (a.k.a. goodness) has been demonstrated.

To continue building on the aircraft example, the Wright Flyer fits in this category quite nicely. It was a rather complex machine and required a fair amount of effort and maintenance to keep it aloft. Its creation was primarily the product of genesis and learning as new information was produced and new functions and elements were added to earlier designs. It also demonstrated a wholly new ability: manned flight in a heavier-than-air vehicle. Thus, it can be said to have a moderate degree of both complexity and goodness. For that matter, the current fleet of NASA's space shuttles probably resides in this region or perhaps slightly up and to the left of center.

Operations in Region 2 typically involve a nontrivial amount of effort and strain. Significant resources, either mental or physical, are usually required. If you are working hard to create a design, solve a mathematical problem, or perform a similar task, chances are you're here.

As we enter this region, we have reached a crucial point where complexity and goodness are no longer proportional. Any substantial *in*crease in goodness actually requires a *de*crease in complexity. That is, improved utility or increased understanding requires some amount of *simplification*—represented by downward movement along the y-axis.



There are actually two paths out of this region, and neither follows the earlier trajectory of increases to both complexity *and* goodness. From this point on, the two axes have become inversely proportional, so an increase in one drives a decrease in the other. One pitfall that designers, engineers, and academicians may fall prey to in this region is the belief that continuing to increase complexity automatically leads to increases in goodness. That view leads us to the upper left quadrant of the chart.

Region 3: The Region of the Complicated

Something of true value does not become more valuable because it becomes complicated. Donald Curtis

"Complex" and "complicated" may sound similar, but they are in fact two very different beasts. Complexity is often essential. Certain topics, issues, and missions are inherently complex—and there's nothing wrong with that. But complicatedness involves *unnecessary* complexity. It's caused by the addition of non-value-added parts, of gears that turn without reason or grind against other gears. Generating new-and-necessary elements moved us to Region 2. Generating too many parts leads to Region 3: the *Region of the Complicated*.

Increasing complexity beyond that required to reach Region 2 actually represents a decrease in understanding, design maturity, and functional utility. It's a step backwards along the x-axis, though some people may take misguided comfort in the positive movement along the y-axis. Think of it as achieving "the complexity on the other side of understanding," often caused by overthinking a problem.

A brilliant young lady of my acquaintance described this region as "the smarter you are, the dumber you get." That absolutely nails it because it highlights the illusion that complexity and goodness are always directly proportional. Moving in this direction (toward the upper-left quadrant of our chart) is not a question of getting smarter—it is a question of simply producing a more complicated output. Here we find the learned academician who everyone assumes is brilliant because nobody can understand a word he says. In fact, his academics may simply be complicated and have very limited goodness.

I suspect many of the problems faced by beleaguered aircraft like the B-1 and V-22 were at least partly caused by the fact that their complexity exceeded their goodness, so they floundered around in the Region of the Complicated. That is precisely why this cycle matters to program managers and technology developers. An inadequate appreciation for simplicity can result in an overvalued perspective of complexity, which can cause programmatic disaster.

Incidentally, the B-1's operational goodness improved substantially once it moved towards increased simplicity, and the V-22 appears to be moving in that direction as well, according to an article in a recent issue of *WIRED* magazine. Movement toward the lower right quadrant is precisely the path one should take when leaving the Region of the Complex.

It should be noted that the upper right quadrant of the x-y chart is unreachable. An extremely high level of complexity and an optimized degree of goodness are simply not compatible. A system, process, design, or discipline that appears to be in this fairy-tale region actually resides in the Region of the Complex (center of the chart), and has the potential to increase its goodness only by decreasing its complexity.

The Other Side of the Mountain: The Simplicity Slope

Making the simple complicated is commonplace; making the complicated simple, awesomely simple, that's creativity. Charles Mingus

The ideal path out of the Region of the Complex is down and to the right, in the direction of increased goodness and decreased complexity. However, to begin moving in this direction requires us to learn some new tools … and forget some old ones. In place of learning and genesis, which served us well on the trip between Simplisticness and Complexity, we must now master a toolset that includes things like *unlearning* and *synthesis*.

At this point in the journey, the necessary tasks do not involve creation of new elements, but rather the integration of existing elements or even the removal of some elements. The process requires the abandonment of certain behaviors, principles, and activities that brought the current level of goodness because to continue using them has become counterproductive.

The idea is to prune and pare down the design, reducing it to the essential components, each of which is able to freely operate with minimal friction and maximum contribution. As software guru Eric Raymond explains in *The Cathedral And The Bazaar*, "Perfection [in design] is achieved not when there is nothing more to add, but rather when there is nothing more to take away."

One of the laws identified in Genrich Altshuller's *Theory of Inventive Problem Solving* (a.k.a. TRIZ) is the Law of Ideality. This law states that as systems mature, they tend to become more reliable, simpler, and more effective—more ideal. Further, the amount of complexity in a system is a measure of how far away it is from its ideal state. In fact, upon reaching perfect ideality, the mechanism itself no longer exists. Only the *function* remains. This path to maturity describes movement towards Region 4.

Region 4: The Region of the Simple

Out of intense complexities, intense simplicities emerge. Winston Churchill

Elegant, graceful, streamlined solutions are to be found in the bottom right quadrant of our graph, the *Region of the Simple*. Einstein's famous $E = mc^2$ equation is an example of life in the fourth region. There is tremendous complexity behind it, but the equation itself is at once profound and breathtakingly simple. There is something profoundly Zen-like about the goings-on in this region, and the individuals who abide here tend to have many attributes of Jedi masters.

In terms of aircraft, the streamlined, high-performance F-16 really takes the cake (notwithstanding the inevitable attempts, throughout the years, at gold-plating the initially minimalist design). In the world of consumer electronics, the ubiquitous Apple iPod combines extremely low complexity with an equally high goodness quotient, placing it squarely in this area.

This is the region most good system designers aspire to enter. However, the simplicity in this region is built upon an essential foundation of earlier complexity. One cannot often jump directly from simplistic to simple, skipping the complex entirely. The initial increase in complexity established a foundation and is as crucial to maximizing goodness as the later decrease in complexity.

What Comes Around, Goes Around

Complexity is another word for simplicity unfolding in time. Cliff Crego

There is an old Zen koan that poses the following question: "How do you proceed from the top of a 100-foot pole?" That is the question we must ask upon reaching Region 4. The optimal path out of this region involves yet another trajectory change, and we find ourselves traveling along a slope that runs parallel to the earlier complexity slope. This means increasing complexity once more as a means of establishing a corresponding increase in goodness. However, we must avoid the orthogonal *complicatedness* slope, which would take us up and to the left.

This means increasing complexity—once again using the opposite of the activities that moved us along the previous slope. The trick is to avoid complexity for complexity's sake and to accept only those additional elements that provide a corresponding bump in goodness. We might picture a sinewave leaving the region of the simple and extending out to the right. Where does it stop? I'm not sure it ever does.

Elementary, My Dear Watson!

Seek simplicity, and distrust it. Alfred North Whitehead

Mere simplicity, defined as a state of low complexity, is seldom adequate for the academic, systemic, operational, and organizational activities we pursue each day. And yet simplicity in speech, in design, in understanding, and in operations is essential to optimal performance. This is no paradox, once we are able to see the distinctions between simplisticness and simplicity and the ways both relate to complexity and complicatedness.

The journey of design, like any journey of discovery, involves both genesis and synthesis, learning and unlearning. True mastery comes from discovering "the simplicity on the other side of complexity" and then understanding that forward progress requires complexity to increase once again.

It's just that simple.

The author welcomes comments and questions at daniel.ward@rl.af.mil. He also recommends that readers visit poet Cliff Crego's "On Simplicity, Complexity and Human Design" at <http://picture-poems.com/week4/complexity.html> for further reading.