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THE COHERENCE OF AN ENGINEERED WORLD

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ABSTRACT

Normally, scientific discoveries are funnelled into the development of engineered products that benefit humanity. But recently, a strange turnabout in the flow of practical information has occurred. Concepts from the field of engineering have been found extremely useful in areas of science. From the very large aspects of the universe (i.e., big bang cosmology and galactic and stellar evolution) to the very small (i.e., the fitness of the chemical elements and the coding of DNA for life), the cosmos is so readily and profitably reverse engineered by its human inhabitants as to suggest that the whole shebang was engineered from the beginning. The linking of extraordinarily complex, but stable and functional structures with the production of value provides the strong impression of a calculating intentionality, which is apparently able to operate in a transcendent fashion. The most coherent view of the universe is that of a system of interdependent subsystems that efficiently interact to prepare for, develop, and support advanced life, subject to various physical constraints. The quest for understanding our universe as a whole benefits from the integration of knowledge from all areas of study, including those that consider questions of purpose, such as design engineering. The synthesis of this knowledge that provides the most satisfying answers regarding human experience is one that admits the recognition of purpose and the existence of an (as yet, not-well-understood) engineering influence.

Keywords: Cosmogony, Cosmology, Design in Nature, Fine-tuning, Intelligent Design, Laws of Nature, Philosophy of Science, Reverse Engineering, Teleology, Transcendence.

1 INTRODUCTION

Throughout the ages, many great minds have expressed a profound appreciation for the beautiful functionality and incredible ingenuity of natural systems. Leonardo da Vinci, from his in-depth study of human anatomy, recorded in his notebook that "The human foot is a masterpiece of engineering and a work of art." He recognized that the intricate structures of the foot provide a synergy resulting in robust functionality without compromising aesthetic value. In a much more recent work, distinguished physicist Walter Thirring [1] writes in *Cosmic Impressions: Traces of God in the Laws of Nature*, "Chemical forces are able to create the most astounding things out of atoms as if by magic. Life continues this process and takes it to the extreme." Although science has progressed significantly since the days of da Vinci, there remains much to explain regarding the origin of such stable functional structures as the universe, galaxies, solar systems, atoms, and living organisms. The very laws of nature appear to work magically for the benefit of life. Perhaps in the face of such wonder and awe, it is appropriate to apply the Third Law of futurist and science writer Arthur C. Clarke [2]: "Any sufficiently advanced technology is indistinguishable from magic." Could it be that what we call "nature" is actually advanced technology resulting from a transcendent engineering influence?

Human-engineered systems are characterized by stability, predictability, reliability, transparency, controllability, efficiency, and (ideally) optimality [3]. These features are also prevalent throughout the natural systems that make up the cosmos. However, the level of engineering appears to be far above and beyond, or transcendent of, current human capabilities. Even so, there is a curious match between the comprehensibility of the universe and the ability of mankind to comprehend it. This unexplained matching is a prerequisite for any kind of reverse engineering activity to be even remotely successful. And yet, mankind seems to be drawn onward toward a potential wisdom, almost in tutorial fashion, by the puzzles of nature that are continually available for us to unravel. Indeed, the universe is so readily and profitably reverse engineered as to make a compelling argument that it

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was engineered in the first place, apparently with humanity in mind. The fact that the universe appears to be in an unfinished state does not seem to detract from its functionality in providing for and sustaining life. Various aspects of the cosmos are discussed in what follows in an effort to investigate the idea of a transcendently engineered universe.

2 THE ENGINEERING OF THE LAWS OF NATURE

When discussing the origins of the universe, a common question is “Why is there something rather than nothing?” One should not stop there. Explaining matter is one thing, but explaining matter’s behavior may be even more difficult. Science has come a long way in discovering the workings of the cosmos, but in some ways the growing confidence in science has become blinding. For example, Newton wondered why objects fall. Eventually, supposedly after seeing an apple fall, he developed the theory of gravity and his three laws of motion. Now, when asked why apples fall, most would be content to say that gravity is the cause. This answer is basically correct, but what is gravity? Why do masses attract each other? Why does matter or energy behave in any orderly manner at all? These are the questions that lead to the idea that the universe may be much more than matter and energy. There is a clear difference between describing and explaining. Something much more fundamental must be explained if a more complete understanding of the cosmos is to be achieved. Perhaps this is an area where engineers can play a part by helping to reverse engineer nature’s fundamental behavior and meaning.

Author Roy Abraham Varghese [4] refers to the predictable behavior of matter as “embedded intelligence.” He defines it as “Embedded intelligence describes intelligent systems like atoms that process information by following certain laws, but are not autonomous.” Intelligent systems receive input, process the input, and respond accordingly. There is no computer chip in a force field, yet this process still occurs.

Every great scientific mind has understood in his or her own way that there is great embedded intelligence superimposed on matter and energy. Albert Einstein is quoted as saying, “The most incomprehensible thing about the world is that it is comprehensible.” Indeed, the governing laws seem to display beautiful unity, symmetry, and simplicity, making comprehension and prediction possible. As a result, physicist Paul Dirac [5] felt awe for the intricate mathematical nature of physics, claiming “God is a mathematician of a very high order and He used advanced mathematics in constructing the universe.”

2.1 The search for the Theory of Everything

Some researchers hope to find a natural cause for the orderly laws underlying the universe. The search for a Theory of Everything (TOE) might be such an example. The ultimate goal of a TOE is to reduce the behavior of every event to a single function with one universal constant. Considering the large number of accepted universal constants, this is very ambitious. This universal constant could be used as the variable to model the behavior of other universes if one assumes the existence of a multiverse. Such fields of research may lead to valuable discoveries, but it would be vain to expect to explain the cause of every law in naturalistic terms. As was written above, to explain is much more difficult than to describe. A TOE may describe the output of a situation given an input, as mathematical functions do. However, it can never explain its own order, nor why what exists interacts in any manner at all.

Where some multiverse concepts fall short is that they merely postulate an infinite set of combinations of the universal constants without considering the actual equations represented. Even if all constants in this universe were reduced to a single TOE with just one universal constant, there is no reason why another universe should obey the same TOE. Otherwise, one would have to explain the origin of the order given by the TOE. Others have recognized the inadequacy of such explanations and have actually proposed that universes with very different behavior may exist. For example, Max Tegmark [6] proposes that some universes may obey mathematics based on fractals or non-Cantorian sets. Paul Davies [7] suggests that some universes might not even obey mathematics, but instead obey purely teleological principles. Do the possibilities stop? What would be the cause of such a strange variety of universes in which mankind is just one infinitesimal occasion? The situation quickly deteriorates into absurdity with no possible scientific test to determine truth from fairy tale. In the end, the assumption of a multiverse is purely hypothetical and seems to be proposed simply out of an attempt to reconcile the apparent life-supporting behavior of this universe.

2.2 The "biofriendliness" of the universe

The universe is undoubtedly "biofriendly." Christian de Duve [8] (Biochemist, Nobel laureate in medicine) states just how obvious this concept has become among the scientific community:

> We live in a biofriendly world. Were it otherwise, we wouldn't be around. The question is, therefore, how biofriendly is it? Physicists have addressed this question and have come to the conclusion that if any of the fundamental physical constants were a little smaller or a little larger than they are, the universe would be very different from what it is and unable to produce or harbor living organisms.

So just how biofriendly are the physics and chemistry of the universe? Lawrence J. Henderson wrote a very relevant book to this question in 1913 entitled *The Fitness of the Environment*. A 1913 review called it a "logical sequel to the *Origin of Species*" [9]. A tribute to Henderson's work, entitled *Fitness of the Cosmos for Life*, was recently published in 2008. Henderson's overall point is that "Fitness there must be, in environment as well as in the organism" [10]. He claims that first of all life must be complex – physically, chemically, and physiologically. Also, life and its environment must be durable, especially chemically. Third, it must have metabolism, exchanging energy and matter to maintain an improbable shape [11]. The environment plays a critical role in allowing for the possibility of such an unlikely mechanism as a living organism. Indeed, some even claim that the environment is the engineer that designs life. Let us dig deeper into how chemistry and physics behave to see if this seems feasible or if the laws of nature actually appear to be engineered themselves.

2.2.1 The incredible properties of water and carbonic acid

Incredibly, most of Henderson's observations are still very important today despite writing *Fitness* before Rutherford's theory of the nuclear atom had been applied. Henderson primarily focuses on the life-supporting properties of carbonic acid (H_2CO_3) and water. Carbonic acid is to be appreciated for the constancy of the alkalinity of both blood and the oceans. The common but vital reaction of carbonic acid is fairly simple as seen in eqn. (1):

$$CO_2 + H_2O \rightarrow H_2CO_3 \rightarrow H^+ + HCO_3^- \tag{1}$$

This reaction can go either direction, forming a stable system. It acts as a great buffer against a fluctuating acidity by allowing excess acid to automatically be carried by the blood and then out of the lungs. Henderson [12] states that the chemist cannot rival its efficiency. Michael Denton [13] describes it as a "solution of breathtaking elegance and parsimony."

The remarkable properties of water are numerous. Its very high specific heat maintains relatively stable temperatures both in oceans and organisms. As a liquid, its thermal conductivity is four times any other common liquid, which makes it possible for cells to efficiently distribute heat. On the other hand, ice has a low thermal conductivity, making it a good thermal shield in high latitudes. A latent heat of fusion only surpassed by that of ammonia tends to keep water in liquid form and creates a natural thermostat at 0°C. Likewise, the highest latent heat of vaporization of any substance – more than five times the energy required to heat the same amount of water from 0°C–100°C – allows water vapor to store large amounts of heat in the atmosphere. This very high latent heat of vaporization is also vital biologically because at body temperature or above, the only way for a person to dissipate heat is to sweat it off [14].

Water's remarkable capabilities are definitely not only thermal. A high vapor tension allows air to hold more moisture, which enables precipitation. Water's great surface tension is necessary for good capillary effect for tall plants, and it allows soil to hold more water. Water's low viscosity makes it possible for blood to flow through small capillaries. A very well documented anomaly is that water expands into the solid state, which keeps ice on the surface of the oceans instead of accumulating on the ocean floor. Possibly the most important trait of water is its unrivaled solvency abilities, which allow it to transport great amounts of minerals to immobile organisms and also hold all of the contents of blood. It is also only mildly reactive, which keeps it from harmfully reacting as it dissolves substances [14]. Recent research has revealed how water acts as an efficient lubricator in many biological systems from snails to human digestion. By itself, water is not very effective in this role, but it works well with certain additives, such as some glycoproteins [15]. The sum of these traits makes water an ideal medium for life. Literally, every property of water is suited for supporting life. It is no wonder why liquid water is the first requirement in the search for extraterrestrial intelligence.

All these traits are contained in a simple molecule of only three atoms. One of the most difficult tasks for an engineer is to design for multiple criteria at once. As engineering professor Henry Petroski [16] notes, "All design involves conflicting objectives and hence compromise, and the best designs will always be those that come up with the best compromise." Satisfying all these criteria in one simple design is an engineering marvel. Also, the design process goes very deep since many characteristics would necessarily be changed if one were to alter fundamental physical properties such as the strong nuclear force or the size of the electron. Paul Davies [7] comments insightfully on the subject:

> It happens that water combines in one substance several key qualities (thermal, mechanical, chemical) that life exploits and indeed that are indispensable to life as we know it. What are we to make of this? Is it just a lucky fluke that the same stuff that has an anomalous expansion property when it freezes (enabling ice to float) also has superlative solvent properties or unusually high surface tension and/or efficient tectonic lubrication qualities, for example?

The molecular shape of water explains most of its incredible thermal properties. The molecule is a triangle at a 104°30′ angle. The electron of each hydrogen atom is pulled toward the oxygen atom, exposing the positive proton nucleus of the hydrogen atoms a bit. The nucleus of the oxygen atom is overcompensated, leaving its exposed shoulder with a negative charge. The water molecules are therefore able to become weakly coupled and re-coupled (a hydrogen bond). The lower density of ice is because the crystal structure opens up and the coupling effect is reduced in ice. Henderson did not know about hydrogen bonds, but they play other vital roles in organisms. For example, the strands of DNA are joined by hydrogen bonds, which are strong enough to hold together but weak enough to unzip when it is time for replication, a very beautiful design [17].

2.2.2 Hydrogen, oxygen, and carbon

Conveniently, the three elements in water and carbonic acid are the same ones that have the ability to create compounds with the incredible amount of variety and complexity necessary for life. Henderson [18] comments on this:

> That the very elements which make up water and carbonic acid, and apparently they alone, should posses this wonderful property [complexity, variety] is, when taken together with the physical properties of water and carbonic acid and their place in cosmic evolution as constituents of the atmosphere, a fact which cannot lightly be set aside.

Henderson could not have known why these elements occur in such abundance. Hydrogen, oxygen, and carbon rank one, three, and four, respectively, in prevalence in the universe (helium is the other). The explanation has to do with fusion within stars. Early reactions start with hydrogen atoms and then produce deuterium (mass 2), tritium (mass 3), and alpha particles (mass 4), but no stable mass 5 exists. This limits the creation of heavy elements and was considered one of "God's mistakes" until further investigation. In actuality, the lack of a stable mass 5 necessitates bigger jumps of four which lead to carbon (mass 12) and oxygen (mass 16). Otherwise, the reactions would have climbed right up the periodic table in mass steps of one (until iron, which is the cutoff above which fusion requires energy rather than creating it). The process would have left oxygen and carbon no more abundant than any other element.

One might wonder why beryllium (mass 8) is not more prevalent. This is because it too readily reacts with helium to create carbon. Stability is an important consideration here, and it is also a very important feature of most engineered systems. Energy resonance levels are the major determinant of stability. Resonance here refers to how beryllium and helium have a combined energy almost exactly equal to an excited carbon atom. Cosmologist Fred Hoyle actually predicted carbon's resonance level based solely on the anthropic assumption that it was necessary in large quantities for life. He was later proven correct. If the resonance level of carbon was 4% lower, essentially no carbon would form. If it was 0.5% higher, almost all carbon would react and become oxygen [17].

An interesting engineering analogy here would be LEGOs®. The reason why LEGOs are so enjoyable is because they stay together when assembled into a creation, but they also can be broken down and reassembled when desired. In order to make this possible, engineers in Denmark have carefully calculated and implemented the perfect "interference fit." If the fit is too tight, the pieces will have trouble going together or coming apart, while if it is too loose, they will have trouble staying together. Taking into account the average strength of children, engineers combined knowledge of material properties such as hardness and friction coefficient with creativity to shape interfacing parts to a very high degree of precision and reliability. LEGOs are actually manufactured to a tolerance of 2 μm [19]. In the same way, if the "fit" of carbon had been 4% "tighter," it would have rarely ever formed, and if it had been 0.5% "looser," it would have rarely stayed together. The forming and breaking of essential chemical bonds, as well as the synthesis of proteins, for biological structures and life processes also come to mind in this regard. The obvious implication is that chemical elements and resulting biological structures have somehow been engineered for the purpose of facilitating the foundational elements and processes of life.

Though he remained agnostic, Hoyle's prediction of carbon's resonance level must have surprised even him because it led to some interesting quotes:

> A commonsense interpretation of the facts suggests that a superintellect has monkeyed with physics, as well as with chemistry and biology, and that there are no blind forces worth speaking about in nature [20].

And also:

> I do not believe that any scientist who examined the evidence would fail to draw the inference that the laws of nuclear physics have been deliberately designed with regard to the consequences they produce inside the stars [20].

2.2.3 Physics

Physics, and not just chemistry, has played a part in the examples so far, but it has not yet been discussed directly. Several people have made lists of physical values that must be "fine-tuned" for life to exist as it does. Astronomer Hugh Ross [21] lists 154 such examples on his Web site. These optimalities suggest the influence of a calculating intentionality or some kind of transcendent cosmic engineer. Three instances of different types of fine-tuning of physics are listed below [22]:

1. The ratio of gravity to the electromagnetic force is nearly perfect for star variety and therefore element variety and also for long life spans of stars (the preciseness is on the order of $1{:}10^{40}$).
2. The ratio of electron mass to proton mass allows for long chains such as DNA.
3. Three space dimensions are the only possible dimensional space that allows for stable orbits, which are needed for atoms and solar systems.

Many more inferences of engineering can be drawn from physics. Some will be examined more closely in the section on cosmology.

2.3 Beauty and purpose

The concept of beauty is important in engineering. In most cases, it has been used above to describe a beautiful solution. Generally, in terms of engineering, a beautiful solution is one that optimally fulfills many constraints in the simplest and most efficient manner. Water is an excellent example. Beauty is also something that can be superimposed over a design with no apparent usefulness other than pure enjoyment. This concept is significant in the automotive industry, for example. It is difficult to deny that nature also contains immense beauty. An example that satisfies both of these types of beauty would be light. Light is useful for energy transfer and information transfer and is the speed limit of the universe, yet it also exhibits the beautiful array of colors that the human eye can perceive.

Another example is illustrated by the famous opening line of a poem by Joyce Kilmer, "I think that I shall never see a poem lovely as a tree." Many of the forms assumed by nature are not only pleasing to the eye but also exhibit a beautiful parsimony in achieving their purpose. This phenomenon has been largely captured for flowing systems by the research efforts of Adrian Bejan [23] of Duke University in the development of the Constructal theory, which he describes as follows:

> Constructal theory is a hierarchical way of thinking that accounts for organization, complexity, and diversity in nature, engineering, and management. It was first stated in the context of optimizing the access to flow between a point and an area … "For a finite-size open system to persist in time (to survive) it must evolve in such a way that it provides easier and easier access to the currents that flow through it."

This versatile theory has been used to successfully model a wide range of phenomena: from social dynamics [24], to scale effects in animal locomotion [25], to the shapes of tree roots, canopies, and forests [26]. Bejan takes what he calls an "integrative approach to understanding the emergence of 'designedness' in nature." Furthermore, the passage below demonstrates that he fully recognizes the key role that purpose plays in our scientific understanding:

> One way to construct a pure theory of structure in living systems is to treat them as energy systems with flows, constraints, and above all, global objective … It is sufficient to note that some of our contemporaries have difficulties with the concept of objective (or purpose, function, design, optimization), even though they themselves rely on it permanently, in thought and way of life. I believe, nevertheless, that we ought not to suffer ourselves to be daunted by these difficulties; but that on the contrary, we must look steadfastly into this theory.* I quoted Rudolf Clausius [directly above] because today we are facing a situation very similar to the one faced by him. To account for coupled thermomechanical behavior, he had to formulate a second principle, the second law, in addition to the conservation of energy. With this new principle came the concept of entropy, which was completely foreign to science. Today the new principle is the construction of geometric form, and the new concept is objective, or purpose.

If trees and animals can be successfully modeled as flow systems by applying the Constructal theory, perhaps it can also play a part in providing a better understanding of the human condition, not just with regard to form, but also with regard to human survival, purpose, and motivations.

Another researcher who takes an integrative approach to understanding nature is Enzo Tiezzi [27] at the University of Siena. In his book *Steps Towards an Evolutionary Physics*, he argues that integrative complexity, biodiversity, and biological beauty point to a metaphysical design of life, as described in the following passage:

> Geological, meteorological, ecological, oceanographic and biological studies demonstrate that the life of every organism is part of a large scale process that involves the metabolism of the whole planet. *Biological activity is a planetary property, a continuous interaction of atmospheres, oceans, plants, animals, microorganisms, molecules, electrons, energy and matter, all part of the whole.* The role of each of these components is essential for the maintenance of life … Biodiversity and the marvellous [*sic*] biological beauty are in favour [*sic*] of a metaphysical design in the evolution of life.

His research into "evolutionary physics" shows promise for assisting in the development of a currently non-existent "thermodynamics of organized complexity" that would apply to living systems. He suggests the need to "supersede the dichotomies of reductionism and antireductionism" since "materialist and creationist dogmas are merely two sides of the same scientific stupidity." He also emphasizes "working towards unification of the two cultures (science and humanities)." This effort to more fully involve the study of human constructs and concerns in the development of scientific explanations is seen as a positive development, which should lead to a more intimate and relevant understanding of nature.

There are many reasons to suspect that chemistry and physics show signs of being engineered at a transcendent level. These can be found from the subatomic level all the way up to the cosmic level. Currently, the most common way to refute this is not to deny that the behavior of the universe is improbably convenient for life, but to claim that there are nearly infinite other universes that were not so fortunate. This solution, however, makes very large assumptions and still must answer some of the crucial causal questions regarding matter and its behavior. Considering this, the hypothesis of a transcendent engineer may not be as improbable as it might originally seem.

3 THE ENGINEERING OF THE COSMOS

The universe is a multifaceted complex system with countless far-reaching subsystems that display many interesting phenomena. These phenomena are proving to be pertinent to a study of the human condition. The cosmos is so vast that it may be impossible for mankind to measure and comprehend all of its secrets, but an attempt can be made to extrapolate from current measurements and observations. By considering the possibility that the universe might be a transcendently engineered system, principles of reverse engineering can be applied to glean some aspects of the meaning and purpose of the universe and mankind's place within it.

3.1 Product teardown

One of the main steps in reverse engineering is the product teardown. Product teardown is the process of taking apart a product to understand it and to understand how the company making the product succeeds [28]. Applying this method to the universe allows one to think about "dismantling" it into its various galaxies, planets, and other subsystems in order to see how, and possibly why, it works the way it does.

Galaxies fall into three basic types: spirals, ellipticals, and irregulars. The best galaxies for observation come from what is known as "The Local Group" coined by Edwin Hubble in his book *The Realm of the Nebulae*. The Local Group refers to the small cluster of stellar systems surrounding our own galaxy. The Local Group contains examples of most major types of galaxies except giant ellipticals. This is actually a good thing because any giant elliptical galaxy even remotely near to our own galaxy would cause enough cosmological damage to prevent life on earth [29]. The Local Group is just a small portion of the approximately hundred thousand million galaxies that can be seen using modern telescopes, but their proximity has allowed for great developments in the study of galaxy composition and formation.

These galaxies in turn hold about a hundred thousand million stars. Our sun is an example of an average-sized, yellow star, near the outer edge of the spiral arms of the Milky Way galaxy. Around our sun are the planets of our solar system. Each one is unique yet contributes to the whole of the system. The most unique planet is earth since it is the only habitable planet known to mankind.

The *New York Times* in a February 2008 article cited that around 250 planets outside of our solar system have been found since 1995 [30]. The majority of these planets were found using the Doppler Detection method, with six of them being found through a new method called microlensing. The new planets could possibly form a solar system that is similar to our own although no life is believed to exist on the discovered planets.

The majority of the systems that have been found vary from our solar system in two important ways. First, some of the giant planets in these systems orbit very close to their host stars with periods as little as 3 days. Second, the planets with orbital periods longer than a few weeks generally have highly elongated orbits, changing drastically in their distance from host stars. This makes our solar system an oddity in comparison with most of the neighboring systems [31].

In looking at galaxies and planets as components of the whole universe, one must not forget to include the importance of universal constants and laws in the investigation. After all, these constants and laws act as the nuts and bolts. Without them there would be no order to hold the universe together, seemingly for the benefit of life. There are numerous constants that hold throughout the universe. Some of the more widely known constants include vacuum permittivity, vacuum permeability, the constant of gravitation, Planck's constant, and the speed of light in a vacuum. There are also many electromagnetic and chemical constants that appear to hold true throughout the entire universe. Along with these constants are the laws that govern our universe, such as Newton's laws, the laws of Thermodynamics, and Maxwell's equations. All these play an important role in the life-friendly structure and order of the universe.

3.2 Functionality

When it comes to galaxies, the bulk of knowledge comes from our own galaxy and the galaxies nearest to it. Looking at these galaxies alone, there seems to be no functional reason for their existence. Its importance becomes apparent when the galaxy is treated with respect to the whole. One of the greatest intellectual revolutions in the twentieth century comes from the discovery that the universe is expanding. The rate of this expansion can be determined by measuring the velocities at which other galaxies are moving away from us using the Doppler Effect [32]. This expansion rate is very specific in that it is based on the density of the universe and the gravitational pull caused by this density. With an increase in universal density on the order of just $1{:}10^{60}$, the gravitational pull would cause the universe to collapse on itself, while a density slightly lower by the same amount would cause the universe to expand at such a rate that galaxies would most likely never form at all, let alone contain life [22]. This evidence suggests the influence of a calculating intentionality that engineered the large-scale structure of the universe in accordance with the laws of nature to support one or more life sites.

Planets are important not for the universe as a whole, but as a home base for life. Therefore, planets could be called the "customer satisfaction" aspects of the universe. More than just being habitable itself, a planet can offer protection for other planets. One example of this is the protection Jupiter provides for us from flying debris. The gravitational pull of Jupiter keeps most asteroids, comets, etc. from ever reaching the inner solar system, thus protecting earth from life-threatening bombardments [31].

The universal constants keep the order in the universe. These constants ensure predictability and repeatability of what are considered the laws of the universe. For an engineered system, all these constants must be fine-tuned to ensure a proper working order and that is what the universe displays. Giuseppe Del Re [33] summarizes it well:

- *First premise:* Our present view of the history of the universe is based on the accepted general laws of nature.
- *Second premise:* Those laws involve precise universal constants, i.e., special values of certain physical quantities.
- *Third premise:* If any one of those universal constants had a value slightly different from the one it has, then (a) the processes which have produced the chemical elements necessary for life such as we know it would not have taken place, at least within the estimated life of the universe and (b) even if they had taken place, evolution wouldn't have had time to produce *Homo sapiens*.

Now that the functionality of the system has been considered, it is helpful to apply the concepts of reverse engineering to those aspects that create customer satisfaction. There are a wide array of phenomena in this universe that seem to work for the benefit of mankind, but they fit mostly into three categories in reference to an engineered system: (1) the "parts" that create the ability for human life; (2) the potential for discovery that allows humans to discern the workings of the universe; and (3) the aesthetic value of the universe.

3.3 Requirements for life

The requirements for life range from the macroscopic to the microscopic scale. On the universal scale, however, one can see that our planet is in a comparatively narrow region of space known as the "Galactic Habitable Zone" [34]. This zone allows for the right surface temperature, stable climate, metallicity, ability to hold liquid water, and many other conditions necessary for life. There is no practical reason why the universe has to contain life, but the fact that it does gives great importance to this zone for the benefit of our existence.

Not only does this zone satisfy the requirements of life but also it endowed humans with a prime position to view the wonders of the universe. There are many qualities that make the earth an excellent place from which to study the universe. First of all is the transparency of the atmosphere. Our atmosphere admits the radiation necessary for life while blocking most of its lethal energy. This transparency also allows humans to see into space without the distortions caused by a thick atmosphere as would be the case on Venus. Secondly, the regularity of our solar system's orbits makes time calculation of planetary events more predictable, even allowing for estimations of planetary orbits millions of years ago [31]. Finally, the gas and dust in our region of the Milky Way are diffuse compared to other regions in the local mid-plane. This allows humans to view 80% of the universe without blockage. If our solar system was moved farther away, perpendicularly to the mid-plane, we would be able to see the other 20%. However, this would cause a large percentage of our current view to be blocked by dust as well as the luminosity of stars in close proximity [29].

Humanity's place in the universe is amazingly unique when it comes to discovery. Planet earth is in prime position for the gleaning of knowledge from the stars. The only thing that makes the universe more amazing is its breathtaking beauty. Looking up into the night sky, one cannot help but wonder at the vast intricacy of the universe. In the words of Stephen M. Barr [35]:

> [if] the laws of nature are based on symmetries that are so sophisticated and so deep that while we may study them with the tools of modern mathematics they lie far above our mental powers to appreciate on an intuitive level, does that not suggest the mind of an artist [and engineer] at work that is far above the level of our own minds? When we contemplate this strange and beautiful universe, well may we ask, in the words of the poet Blake, "What immortal hand or eye could frame thy fearful symmetry?"

From its parts to its whole, the universe demonstrates that it is both precise and planned, strongly suggesting that it is specifically engineered to support life. In addition, this life support system readily lends itself to the reverse engineering process, which also confirms this perspective, assuming a working knowledge of the cosmos is of value to intelligent beings.

4 THE ENGINEERING OF LIFE

A lot of common engineering designs have come from looking at biological systems. A prime example of this is the propeller. However, it is a common error to overlook the importance of the fact that these biological systems exhibit clear evidence of being engineered systems. Biological systems are constantly undergoing processes that exhibit modularity, specificity, adaptability, durability, and many other aspects of engineered systems. In *The Design of Life*, William Dembski and Jonathon Wells [36] write:

> Many of the systems inside the cell represent nanotechnology at a scale and sophistication that dwarfs human engineering. Moreover, our ability to understand the structure and function of these systems depends directly on our facility with engineering principles.

For the sake of space, we will not break down every biological system and investigate the engineering principles they exhibit; therefore, it is important to note that these principles are not just applicable to the examples put forth, but apply to virtually all biological systems.

4.1 Construction of biological systems

All things that are engineered start out as a concept that is designed with the end in mind. What purpose will this serve? What will be needed to realize the functional structure? These are some of the common questions asked when in the first stages of engineering. After these questions have been answered, the next step is to acquire the materials needed and to start building, which in itself is a complex process, because if one thing is out of place, or not attainable, the whole system is compromised. In his book, *The Edge of Evolution*, Michael Behe [37] refers to this overall process as being a "bottom up-top down" design. He writes, "by bottom up I mean that of course the foundation of the building had to be poured first, the ground floor next, and so on, all the way to the zenith at the sixth floor," and "by top down I mean that the building was planned." The construction of a cilium appears to follow the same process. When a cell starts putting out a new cilium, it gathers the materials that it needs to start the process and stores them at its base until they are utilized.

4.2 Reverse engineering of biological systems

When the propeller was first engineered, the developers found the basis of their design by looking at a cell and analyzing a flagellum. Scientists and engineers then used reverse engineering to discover how the flagellum was able to produce movement of the cell and applied these principles to large-scale systems that we now use for transportation. The state of the flagellum is constantly monitored and maintained. Perhaps one of the best examples of engineering in a biological system is the flagellum, which is

> thought to be the only structure in nature that has a rotary motion, acting as a highly efficient propeller that drives a bacterium forward or backward. It is typically made up of about 50 proteins and builds itself from the inside out. Its precision motor is powered by the movement of protons, with a drive shaft equipped with a cylindrical bushing that pokes through the bacterium's membrane. It is like an outboard boat motor only much faster and more efficient, and if a single part were missing, it clearly would not work [38].

An interesting feature regarding the construction of the flagellum is that as the final piece of a section is being put in place, it brings a coded gene that initiates the next phase of the construction. This enables the flagellum to be built in an extremely efficient manner.

4.3 Modularity of life

Another engineering principle that is being recognized in biological systems more frequently is that of modularity. In his book, *System Modeling in Cellular Biology: From Concepts to Nuts and Bolts*, Zoltan Szallasi [39] talks about how biological systems show signs of being modular in design:

> Almost all artifacts of evolved human engineering are modular through and through: their entire architecture is composed of parts packaged within bigger parts with clear functional interfaces. This is true of electronics, it is true of houses, and it is true of software. In these systems, all parts are members of some module, and the entire architecture is modular. It would seem, based on this experience, that the way forward in simplifying the complex biochemistry of life is to encapsulate complexity in similar modules.

There are two common types of modularity: "function based" and "manufacturing based." Cells exhibit both types of modularity. First off, there are many different types of cells within all living creatures that have different functions. Red blood cells contain hemoglobin, which is used to transport oxygen to the various regions of the body. If it also had the function of the white blood cell, then pandemonium would ensue. If modularity did not exist, it would be extremely difficult for a system, in this case a cell, to be reconfigured. A group called El-Samad recently researched the bacterium *Escherichia coli*, or *E. coli*, viewing it as a modular system:

> In a top-down manner within this module, the authors have performed a systematic model reduction, and they have proposed the existence of certain functional submodules based on characteristics of the overall behavior of the entire system, such as robustness … or optimal performance. This approach closely follows the method of modular decomposition routinely used in system engineering, namely the identification of submodules or devices based on their dynamic functions [40].

The ability to breakdown biological systems into modules and submodules is nothing new since it is recognized that various organs and cells inside the body have modular characteristics. A common example is that of organ transplants. If body organs were not modular, it would be nearly, if not completely, impossible for transplants to be successful.

4.4 Adaptability

Another important principle is that of adaptability. If a system is to last in a changing environment for any period of time, it has to be able to adapt to its surroundings. One of the best examples of biological adaptability exists between malaria and the immune system of humans. Malaria gets into the bloodstream, attaches itself to a red blood cell, travels through the bloodstream until it reaches a prime organ, such as the liver, and then duplicates quickly to infect many more red blood cells. Over the years, it had to continuously adapt to changes of the immune system. Mutations in the cellular structure of the body have brought about certain changes that malaria had to overcome. The most common of these is known as sickle cell disease, characterized by irregularly shaped blood cells, which combat malaria by causing the red blood cells to stick together and sweep the infected red blood cells through to the spleen, which is a very effective filter for old cells.

When we look at the human body, we see that there are millions of complex systems working together to create and sustain growth and maturation. The fact that these cells work so well together is remarkable, especially considering the complexity involved with the DNA strand and genes. The human body and the bodies of other living organisms as well are functional systems that clearly exhibit evidence of not only being planned, but of being "stunningly well engineered" [41].

5 TECHNOLOGY DETECTION AND REVERSE ENGINEERING

Several recent works document the ever-strengthening convergence between the fields of biology and engineering [42–44]. Patterns of engineering design found in biological structures are described in *The Cell's Design* by Fuzale Rana [45]. Recent articles in the *International Journal of Design and Nature* illustrate the highly advanced engineering found in natural structures such as the multifunctioning and multioptimization of bird feathers [46]. Biologist E.O. Wilson [47] admits the great utility of engineering principles for elucidating complex biological structures, as well as the amazing efficiency of such structures in the following passage:

> The surest way to grasp complexity in the brain, as in any other biological system, is to think of it as an engineering problem. What are the broad principles needed to create a brain from scratch? Whether contrived by advance planning or by blind natural selection, the key features of architecture can be expected to be very broadly predictable. Researchers in biomechanics have

> discovered time and again that organic structures evolved by natural selection conform to high levels of efficiency when judged by engineering criteria.

Wilson's confidence in only blind, unguided processes to execute feats of unparalleled engineering skill is not shared by scientist Michael Polanyi [48], who, not long after the discovery of DNA, asked the relevant question: "Can the control of morphogenesis by DNA be likened to the designing and shaping of a machine by the engineer?" He answered this question in the affirmative, stressing that life is not reducible to physics and chemistry.

The idea of a great cosmic engineer is certainly not a novel concept. Even a half century before the time of Christ, Anaxagoras of Clazomenae posited that the obvious order in the universe was due to the larger plan or design of a mind. This was an early form of the eutaxiological argument, which recognizes the beneficial harmony found in natural systems. Socrates and Plato added the idea that this mind also acts to sustain the universe at all times. Aristotle made the jump to teleology, with detailed studies into causality and purpose [49]. Many famous scientists over the last few centuries have made use of teleological concepts to further our understanding and use of nature. Cosmologist Helge Kragh [50], in his book *Matter and Spirit in the Universe*, describes the impact these ideas had on the great scientist James Clerk Maxwell:

> He [Maxwell] was impressed by the fact, as revealed by the spectroscope, that molecules of the same chemical species were all alike and had not changed the slightest "since the time when nature began." Uniformity in time as well as uniformity one-to-another strongly indicated that atoms and molecules were created … Borrowing an expression from John Herschel, he famously (and with an allusion to natural theology) referred to the molecule as a "manufactured article."

In the last couple of decades, several researchers have attempted to better quantify our ability to detect the presence of an engineering influence [51]. This often takes the form of attempting to characterize various types of complexity. Michael Denton, in his book *Nature's Destiny*, uses the term "integrative complexity" in referring to subsystems that are integrated together to form a complex and functional unit that supports life. In *Darwin's Black Box*, Michael Behe introduces the idea of "irreducible complexity," in which a functional system is made up of multiple interacting parts that are all necessary for functionality and hence not easily obtained through natural selection. William Dembski [52], using the mathematical theories of probability and information, has defined a more precise tool known as "specified complexity." An object, event, or structure exhibits specified complexity if it is both complex (i.e., not easily reproducible by chance) and specified (i.e., displays an independently given pattern). Finally, David Seargent [53] asserts that one of the primary hallmarks of an engineering influence is a property he calls "transitive complexity," in which the suspected design points to a larger state of affairs beyond itself. An example of this would be a signal containing the prime number sequence emanating from a far-away planet. Such an engineered signal points beyond the mere complexity of the coded number sequence, in effect communicating the existence of intelligent alien life, which would presumably be the purpose for such a signal. All these researchers argue persuasively that our world is permeated with such incriminating forms of complexity. While it may be argued that natural processes will eventually be discovered to explain the origin of such complexity, even if this turns out to be true, it does nothing to explain the origin of those ingenious "natural" processes and the expert engineering that results.

In *The Design Matrix*, Mike Gene [54] attempts to synthesize many of these ideas into a set of four criteria that can be scored and combined to quantify an indication of design or non-design for any particular system. The four criteria are as follows:

1. *Analogy*: Does the system resemble entities that we know are engineered by humans, such as machines, codes, or other devices?

2. *Discontinuity*: Does the system exhibit irreducible complexity or is it possible to evolve via a series of gradual intermediate functional states?
3. *Rationality*: Does the system have a function that can be structurally decomposed? Does the working hypothesis of a "purpose" explain the system? How well do engineering criteria for good design map to the system?
4. *Foresight*: Does the system demonstrate Original Mature Design (design that has remained unchanged over long time periods and is robust in the face of disturbances)? Does the present state explain something about the past?

While it appears that Mike Gene intends mainly for the above criteria to be applied to biological systems, his criteria are similar in some respects to the more universal set of criteria suggested by philosopher Michael Corey [55] in his book, *The God Hypothesis*. He asserts that the following criteria can be used to judge if any given artifact has been deliberately engineered:

1. The existence of a coherent object that is comprised of a complex concatenation of interconnected parts that all work together toward achieving some practical end.
2. A complex degree of cooperative interaction between the various internal components toward a single functional end.
3. An Aristotelian "formal cause" or intelligible design that can be laid out in a logical coherent fashion.
4. The exploitation of well-known technological and engineering principles that are utilized for a common constructive end.

He continues with the following claims:

> By these criteria, it is evident that the universe has indeed been contrived in some fashion. For one thing, it is hard to question the assertion that the universe itself is a coherent mega-artifact which has the goal of supporting biological life as one of its "intended" functions. With the advent of modern physics, it has also become evident that there is a complex state of cooperation between the various structures of the universe and their resultant functions. The various cosmic "coincidences" themselves are perhaps the most exquisite illustration of this type of functional cooperation. Moreover, these "coincidences" are known to exploit a wide variety of technological and engineering principles in their mutual cooperation to produce a viable life-supporting universe.

Walter Bradley [56], a Professor of Mechanical Engineering at Baylor University, has produced several publications that provide insight into the idea of an engineered world. He delineates the three essential factors that are necessary to achieve design outcomes in engineering as follows:

1. The mathematical form that nature assumes
2. Values of the universal and local constants
3. Specification of boundary conditions

Human engineering consists of specifying the boundary conditions under which the laws of nature operate in order to produce a purposeful outcome. Cosmic engineering must involve specification of not only the conditions under which the laws of nature operate but also the very laws themselves and the universal constants that scale the "building blocks" of matter and energy and the fundamental forces in nature to provide the purposeful outcome of a habitable universe for life and life itself. Dr Bradley contends that for someone to choose to believe that there is a naturalistic explanation for the precise engineering of all these factors is to "believe in a miracle by another name."

Recent advances in quantum mechanics and cosmology suggest the possibility of additional dimensions beyond the four familiar space–time dimensions of human experience. If there really are extra dimensions, then a concept like the multiverse may turn out to be true, but additional dimensions also "makes space" for a realm in which a transcendent engineer can clandestinely "work humans out" on the "drawing board" of our four-dimensional universe. Consider the fact that human engineers instinctively resort to a fewer dimensional space (i.e., two-dimensional piece of paper or computer screen) to sketch out an engineering design, which typically culminates in a set of blueprints prior to the development of a three-dimensional prototype. (This probably originated when early humans began to scratch out a plan in the dirt, which still regularly occurs in the huddle during touch football games on playgrounds across the United States.) Perhaps humans have been endowed with some measure of the same creative capacities and inclinations as this transcendent engineer.

Presumably, humans stand as the crowning achievement, but many resist the notion of an engineered world because of the extent of pain and suffering associated with the human condition. Admittedly, this is a major challenge, but human experience in general, and engineering research in particular, speak of the critical role that adversity and failure play in the acquisition of wisdom and the success of engineering design. Henry Petroski [57], author and professor of civil engineering and history at Duke University, investigates this concept in his most recent book, *Success through Failure: the Paradox of Design*, where he writes:

> Failure is thus a unifying principle in the design of things large and small, hard and soft, real and imagined … Whatever is being designed, success is achieved by properly anticipating and obviating failure.

Related to this is the idea that good engineers are often able to take something which appears to be bad and somehow "turn it around" and cause it to work for good. Sometimes this is referred to as "blessing in disguise" or "making the devil work for you." This concept is recognized as an important part of the inventive process of creative problem solving as described in Semyon Savransky's [58] book *Engineering of Creativity: Introduction to TRIZ Methodology of Inventive Problem Solving*. Converting harm into benefit is one of the 40 inventive principles selected by Genrich Altshuller after an extensive study of thousands of patents from around the world. Perhaps it is also an underlying theme that can help to explain the adversity associated with the human condition.

Others may question why such a transcendent engineer would not be more visible to humans during this process. Why the clandestine approach? This is where the social sciences may lend some insight. Humans are thought to be a crowning achievement, not just because they possess the most complex and capable hardware in the universe (the human brain) but also because they possess the very powerful and transforming capacity to love (the human heart, figuratively speaking). It therefore seems likely that the purposes of such a transcendent engineer might have something to do with the endowed ability to enter into love relationships, possibly to enter into an eternal love relationship with the maker. If this is the case, then, as is well known the world over, potential love must be treated with the utmost care and sensitivity. Here, Soren Kierkegaard's [59] parable of the king and the maiden is very apropos. The king seeks to win the love of a humble maiden, but if he appears to her as the king, he might elicit her devotion for the wrong reason. So he comes as a servant – not in disguise, for that would be deceptive, but really becomes a servant to win her love [60]. So this transcendent engineer must keep an "epistemic distance" in order to attain the desired outcome. Obviously, much remains to be investigated on this topic, but it is interesting to note that over the years, significant advances in science, engineering, and the humanities have not seemed to erode the coherence of an engineered world. On the contrary, the magnificent ingenuity displayed in nature continues to speak of a supreme competency and reliability that inspires curiosity and imitation in human minds and hope in human hearts.

6 CONCLUSION

An interdisciplinary study of the cosmos suggests that a transcendently engineered world may be the most coherent explanation for the reality we experience as human beings. E.O. Wilson [61] recently revived the term "consilience" in reference to the unity of knowledge; "literally a 'jumping together' of knowledge by the linking of facts and fact-based theory across disciplines to create a common groundwork of explanation." This phenomenon is currently being realized across the physical, life, and social sciences within the context of an engineering mindset. The universe displays a beautiful functionality that seems to automatically deploy for the benefit of life and mankind in particular. Even so, humans are largely able to comprehend the workings of the cosmos and recognize widespread technological attributes that dovetail into a consilience that is best explained by the wisdom of a transcendent engineer. The idea of transcendence indicates that we detect an engineering capability that is above and beyond the limits of our ordinary experience and possibly beyond our material existence. The discerned laws that govern the behavior of matter, energy, and information over space and time display a sublime ingenuity and intentionality that many (especially scientists and engineers) recognize as significant for worldview considerations [62]. Could it be that the realm of nature and the human mind were, in some sense, made for each other, possibly engineered to facilitate the communication of important truths leading to the impartation of vital wisdom and the consummation of the ultimate love relationship [63–65]. This idea goes a long way toward explaining the fine-tuning of the universe for life and the grand success humans have had in reverse engineering the cosmos.

REFERENCES

[1] Thirring, W., *Cosmic Impressions: Traces of God in the Laws of Nature*, Templeton Foundation Press: West Conshohocken, PA, p. 129, 2007.
[2] Clarke, A.C., *Profiles of the Future*, Macmillan: New York, p. 39, 1973.
[3] Braha, D., Minai, A.A., & Bar-Yam, Y. (eds.), *Complex Engineered Systems: Science Meets Technology*, Springer: New York, p. 7, 2006.
[4] Varghese, R.A., *The Wonder of the World*, Tyr Publishing: Fountain Hills, AZ, p. 27, 2003.
[5] Dirac, P.A.M., The evolution of the physicist's picture of nature, *Scientific American*, p. 53, May, 1963.
[6] Tegmark, M., Parallel universes (Chapter 21). *Science and Ultimate Reality: Quantum Theory, Cosmology, and Complexity*, eds J.D. Barrow, P.C.W. Davies, & C.L. Harper Jr., Cambridge University Press: Cambridge, UK, p. 459, 2004.
[7] Davies, P.C.W., Fitness of the cosmic environment (Chapter 6). *Fitness of the Cosmos for Life*, eds J.D. Barrow *et al*., Cambridge University Press: New York, pp. 100–110, 2008.
[8] de Duve, C., How biofriendly is the universe? (Chapter 10). *Fitness of the Cosmos for Life*, eds J.D. Barrow *et al*., Cambridge University Press: New York, p. 169, 2008.
[9] Mendelsohn, E., Locating "fitness" and L.J. Henderson (Chapter 1). *Fitness of the Cosmos for Life*, eds J.D. Barrow *et al*., Cambridge University Press: New York, p. 13, 2008.
[10] Henderson, L.J., *The Fitness of the Environment*, Macmillan: New York, p. 6, 1913.
[11] Henderson, L.J., *The Fitness of the Environment*, Macmillan: New York, pp. 267–69, 1913.
[12] Henderson, L.J., *The Fitness of the Environment*, Macmillan: New York, p. 147, 1913.
[13] Denton, M.J., *Nature's Destiny: How the Laws of Biology Reveal Purpose in the Universe*, Free Press: New York, pp. 132–33, 1998.

[14] Denton, M.J., *Nature's Destiny: How the Laws of Biology Reveal Purpose in the Universe*, Free Press: New York, pp. 19–46, 1998.
[15] Lee, S. & Spencer, N., Sweet, hairy, soft, and slippery. *Science*, **319(1)**, pp. 575–576, February, 2008.
[16] Petroski, H., *Invention by Design: How Engineers Get from Thought to Thing*, Harvard University Press: Cambridge, MA, p. 30, 1996.
[17] Gingerich, O., Revisiting the fitness of the environment (Chapter 2). *Fitness of the Cosmos for Life*, eds J.D. Barrow *et al*., Cambridge University Press: New York, pp. 20–30, 2008.
[18] Henderson, L.J., *The Fitness of the Environment*, Macmillan: New York, pp. 219–220, 1913.
[19] The LEGO Group, Company Profile 2007, p. 7, available from: http://www.lego.com/info/pdf/LEGO_company_profile_UK.pdf.
[20] Hoyle, F., The Universe – past and present reflections. *Annual Review of Astronomy and Astrophysics*, **20**, pp. 8–17, 1981.
[21] Ross, H., Fine-tuning for life on earth; reasons to believe, 2004, available from: http://www.reasons.org/resources/apologetics/design_evidences/200406_fine_tuning_for_life_on_earth.shtml.
[22] Holder, R.D., *God, the Multiverse and Everything*, Ashgate Publishing: Burlington, VT, pp. 33–39, 2004.
[23] Bejan, A., *Shape and Structure, From Engineering to Nature*, Cambridge University Press: Cambridge, pp. xvii–xix, 2000.
[24] Bejan, A. & Merkx, G.W. (eds), *Constructal Theory of Social Dynamics*, Springer: New York, 2007.
[25] Bejan, A. & Marden, J.H., Unifying constructal theory for scale effects in running, swimming, and flying. *Journal of Experimental Biology*, 209, pp. 238–248, 2006.
[26] Bejan, A., Lorente, S. & Lee, J., Unifying constructal theory of tree roots, canopies and forests. *Journal of Theoretical Biology*, **254(3)**, pp. 529–540, 2008.
[27] Tiezzi, E., *Steps Towards an Evolutionary Physics*, WIT Press: Southampton and Boston, pp. 11–13, 2006.
[28] Otto, K. & Wood, K., *Product Design Techniques in Reverse Engineering and New Product Development*, Prentice Hall: Upper Saddle River, NJ, p. 135, 2001.
[29] Bergh, S.V.D., *The Galaxies of the Local Group*, Cambridge University Press: New York, pp. 1, 46, 2000.
[30] Overbye, D., Smaller version of the solar system is discovered. *New York Times*, February 15, 2008.
[31] Gonzalez, G. & Richards, J.W., *The Privileged Planet*, Regnery Publishing: Washington, DC, pp. 66, 93–95, 2004.
[32] Hawking, S.W., *The Theory of Everything*, New Millennium Press: Beverly Hills, CA, p. 33, 2002.
[33] Del Re, G., *The Cosmic Dance*, Templeton Foundation Press: West Conshohocken, PA, p. 173, 2000.
[34] Gonzalez, G.D.B. & Ward, P.D., The galactic habitable zone. *Scientific American*, pp. 60–67, October 2001.
[35] Barr, S.M., *Modern Physics and Ancient Faith*, University of Notre Dame Press: Notre Dame, IN, p. 104, 2003.
[36] Dembski, W.A. & Wells, J., *The Design of Life*, The Foundation for Thought and Ethics: Dallas, p. 256, 2008.
[37] Behe, M., *The Edge of Evolution*, Free Press: New York, p. 85, 2007.

[38] Witham, L., *By Design: Science and the Search for God*, Encounter Books: Lanham, MD, 2002.
[39] Szallasi, Z., *System Modeling in Cellular Biology: From Concepts to Nuts and Bolts*, MIT Press: Cambridge, MA, p. 48, 2006.
[40] Szallasi, Z., *System Modeling in Cellular Biology: From Concepts to Nuts and Bolts*, MIT Press: Cambridge, MA, p. 42, 2006.
[41] Beckerman, M., *Molecular and Cellular Signaling*, Springer: New York, p. vii, 2005.
[42] Gene, M., *The Design Matrix: A Consilience of Clues*, Arbor Vitae Press, arborvitaepress.com, pp. 39–63, 2007.
[43] Alon, U., *An Introduction to Systems Biology: Design Principles of Biological Circuits*, CRC Press: Boca Raton, FL, 2006.
[44] IEEE, *IEEE Transactions on Automatic Control and Circuits and Systems: Special Joint Issue on Systems Biology*, January 2008.
[45] Rana, F., *The Cell's Design: How Chemistry Reveals the Creator's Artistry*, Baker Books: Dartmouth, MA, 2008.
[46] Burgess, S.C., Multi-functioning and multi-optimisation in feathers. *International Journal of Design and Nature*, **1(1)**, pp. 1–10, 2007.
[47] Wilson, E.O., *Consilience: The Unity of Knowledge*, Vintage Books: New York, p. 112, 1998.
[48] Polanyi, M., Life's irreducible structure, *Science*, **160**, June 21, 1968.
[49] Corey, M.A., *God and the New Cosmology*, Rowman and Littlefield: Lanham, MD, pp. 12–14, 1993.
[50] Kragh, H., *Matter and Spirit in the Universe: Scientific and Religious Preludes to Modern Cosmology*, Imperial College Press: London, p. 35, 2004.
[51] Ratzsch, D., *Nature, Design, and Science: The Status of Design in Natural Science*, State University of New York Press: Albany, NY, 2001.
[52] Dembski, W.A. & Wells, J., *The Design of Life: Discovering Signs of Intelligence in Biological Systems*, The Foundation for Thought and Ethics: Dallas, TX, p. 165, 2008.
[53] Seargent, D.A., *Planet Earth and the Design Hypothesis*, Hamilton Books: Lanham, MD, p. 39, 2007.
[54] Gene, M., *The Design Matrix: A Consilience of Clues*, Arbor Vitae Press, arborvitaepress.com, pp. 268–291, 2007.
[55] Corey, M.A., *The God Hypothesis: Discovering Design in our "Just Right" Goldilocks Universe*, Rowman & Littlefield: Lanham, MD, p. 167, 2001.
[56] Bradley, W.L., Is there scientific evidence for an intelligent creator of the universe? *Science: Christian Perspectives for the New Millennium*, eds S. Luley, P. Copan & S. Wallace, Christian Leadership Ministries: Woodstock, VA, pp. 159–204, 2003.
[57] Petroski, H., *Success through Failure: The Paradox of Design*, Princeton University Press: Princeton, NJ, p. 5, 2006.
[58] Savransky, S., *Engineering of Creativity: Introduction to TRIZ Methodology of Inventive Problem Solving*, CRC Press: Boca Raton, FL, p. 212, 2000.
[59] Kierkegaard, S., *Philosophical Fragments*, trans. D.F. Swanson, Princeton University Press: Princeton, NJ, Chapter 2, 1962.
[60] Swinburne, R., *The Resurrection of God Incarnate*, Oxford University Press: Oxford, p. 45, 2003.
[61] Wilson, E.O., *Consilience: The Unity of Knowledge*, Vintage Books: New York, p. 8, 1998.
[62] Halsmer, D., Application of the "engineering mindset" for worldview evaluation. *Proceedings of the 2008 ASEE Midwest Section Annual Meeting*, University of Tulsa, September 17–19, 2008.

[63] Halsmer, D., Halsmer, N., Johnson, R. & Wanjiku, J., The applicability of engineering design principles in formulating a coherent cosmology and worldview. *2008 ASEE Annual Conference Proceedings*, ASEE: Washington, DC, 2008.
[64] Halsmer, D., Why Engineers Make Good Apologists (Chapter 8). *Religion, Culture, Curriculum, and Diversity in 21st Century America*, eds M.A. Trent, T. Grizzle, M. Seahorn, A. Lang & E. Rogers, University Press of America; Lanham, MD, 2007.
[65] Ross, H., *Why the Universe Is the Way It Is*, Baker Books: Dartmouth, MA, 2008.