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Foreward

Welcome to the 2015 Christian Engineering Conference! In this volume of proceedings you will find the 16 papers from the conference in the order they were presented. You may also find each paper individually along with the associated slide presentations at the proceedings website. Many thanks are due to the authors who did such a fine job of preparing them. The conference also featured a keynote address from Tom Lyster (“Developing the AED”), an invited talk from Philip Marston (“The Faith of James Clerk Maxwell”), a panel discussion on assessment, and numerous informal discussions with colleagues from industry, public universities, and other Christian institutions.

This is the second year the conference has been held as the “Christian Engineering Conference,” i.e., “CEC” instead of “CEEC.” The rebranding was intended to make the conference more open to those in secular institutions, whether industrial or academic. There were 19 submissions to the conference from 24 authors affiliated with 19 distinct institutions—two industrial, five secular colleges or universities, and twelve Christian colleges or universities from a wide variety of faith perspectives.

The next CEC will be June 28–30, 2017 at Cedarville University following the ASEE Annual Conference in Columbus, OH. As always, the Christian Engineering Society and the Christian Engineering Conference web pages will have full details as they become available. In 2016, we will meet for dinner and discussion during the ASEE conference in New Orleans, LA, June 26–29.

If you wish to be involved, informed, or to participate in discussions in the meantime, we have a Facebook group, a newsletter, and an email list.

Special thanks are due to Melani Plett (the conference general chair) and steering committee members Aaron Dingler, Steve VanderLeest, and George Roe. Thanks also to the 28 reviewers who reviewed papers and abstracts for the Conference.

Michael Foster

CEC 2015 Program Chair
A Biblical Model of God as Refiner, or Process Systems Engineer, with Implications for Theodicy and Special Divine Action

Dominic Halsmer

Abstract

A recurring theme in Scripture is of a God who refines his people in the furnace of affliction. Allowing the disciplines of science, engineering, technology, and history to interact with those of biblical literature, theology, and philosophy, this model of God as an early version of today’s process systems engineer is explored in hopes of shedding light on problems in the areas of special divine action and theodicy. This model differs from that of a divine craftsman since a process systems engineer maintains intimate involvement and interaction with the intended product throughout the refining process, in order to maximize the probability of achieving the desired results. Investigating metallurgical technology from the biblical era sheds light on who God is, and what He does. Although a model of God as process engineer has its limits, it may never-the-less be helpful. God has chosen to reveal Himself in categories and images to which humans can relate. Both Scripture and nature can assist in furthering our knowledge of God, and deepening our relationship with Him.

It appears that God allows humans beings to experience adversity because, when received with humility in a redemptive environment, it tends to produce certain positive affordances in the human system, which are necessary for an ongoing fruitful relationship with the Creator. Furthermore, the fruit of increasing faith, hope, and love in the midst of affliction affords testimony of God’s wisdom in allowing disharmony to persist for a season. Often, this is accomplished via God-ordained natural laws, but sometimes humans need special grace that is only realized through the unmistakable nature of special divine action.

Introduction

Problems in divine action deal with how God acts in the world, and especially in relating to human beings. In order to gain a better understanding of how God acts, or how God is likely to act in a particular situation, it is helpful to consider what kind of persons this triune Christian God is. In considering whether a given human being will respond to some stimulus in a particular way, one would certainly want to know what kind of person he or she is. People behave differently, depending not only on their background and capabilities, but also on their personalities.

Though not an incontrovertible law, scientists and engineers are often introverted, or drawn toward their own thoughts and inventions, as opposed to seeking out the company and conversations of others. Whereas those attracted to the fields of business and marketing, for example, are often found networking, or making connections with others that result in positive possibilities for the future. Thus, knowing whether someone is introverted or extroverted is important if one is trying to predict social behavior.

Now, all this would be quite useless in assisting our understanding of God and how he acts if he is not a personal being, and humans were not made in his image with some capacity for
apprehending his personalities. But, according to Christian theology, God is personal and we are made in his image. Furthermore, God has chosen to reveal himself in categories and images with which humans have first-hand and intimate understandings. Therefore, a fundamental thesis of this paper is: If one wants to know how God is predisposed to act, one should get to know him on a personal level. To this end, it seems that the special revelation of Scripture may be more helpful than the general revelation of nature. However, though creation may be less personal, what God has made also lends insight into his character and serves to corroborate conclusions from Scripture.

The Bible presents a rich and multifaceted portrait of God, whose depths may never be completely plumbed by mere mortals. But, one of humanity’s chief purposes is to know God, and believers can look forward to the bliss of pursuing this relationship for all eternity! One of the primary ways that God has already revealed himself to mankind is as Creator, including all of the ongoing implications of that role. Although God rested from his acts of creation on the “seventh day,” it is clear from Scripture that his involvement with creation, and mankind in particular, did not cease at that point. On the contrary, the Bible often speaks of God’s intimate involvement with his people through both good times and bad times. Even so, the precise manner and means of his involvement may not always be evident from a human perspective.

An example of God’s involvement at a difficult time in Israel’s history occurred during their long period of slavery and ensuing Exodus from Egypt. Three times in Scripture, God is described as one who brought his people out of Egypt, referring to that experience as an iron-smelting furnace (Deut 4:20, 1 Kings 8:51, Jer 11:4). It is interesting that the formation of Israel as a cohesive people occurred at about the same time in history as humans were discovering how to forge iron implements from iron ore through the use of these specialized heating devices.1

This kind of technological development is recognized as significant in the history of mankind, with ancient time periods being labeled as “stone age,” “bronze age,” and “iron age,” depending on the current prevailing technology. And the iron-smelting furnace was the high technology of the early Jewish era, comparable to smart phones or the computer internet of today. And the ancient smith played a similar role to the process engineer of today. Indeed, many places in Scripture refer to the image of metallurgy in describing how God interacts with his people. This image and its implications will be further explored in what follows in an effort to find meaning in adversity. But first, a quick look at the concept of models will prove helpful.

A Model is Worth a Thousand Words

The world is a very complex place. One of the biggest challenges for people in virtually every field of study is how to handle this complexity. Scientists and engineers want to understand how the world works so they can accurately predict what will happen when they attempt to manipulate things in the world. Consider the example of sending people to the moon and back. This ambitious project presented a tremendous challenge. Not only did engineers have to develop a rocket with enough punch to safely achieve escape velocity, but they also had to navigate the changing environmental conditions associated with a trip to the moon. This involved multiple vehicles and devices that could continue to function properly in the changing temperatures, pressures, and gravitational fields entailed by such a voyage. And all engineered
with enough accuracy and precision to afford a high level of confidence that a safe return to the earth would be achieved.

What was the key to accomplishing this incredible feat? At the most fundamental level, the key was having enough knowledge of rocket science, and our earth-moon system, to allow the development of the necessary models. These models were then used to predict what would happen if certain forces, devices, and procedures were to be applied. In the technical sense then, models are simplified representations, or pictures, of reality, that allow this reality to be simulated, better understood, and perhaps manipulated to achieve some purpose. A worldview is simply a comprehensive model of all that exists. In science and engineering, models are often mathematical since the language of mathematics has been found to be extremely (some would say unreasonably) effective in describing the physical world. For example, mathematical formulas are used to predict the varying gravitational forces that pull on a spacecraft, depending on whether it is near the earth, midway between the earth and moon, or near the moon.

Engineers are known for their ability to develop helpful models, even though they may only be approximations to reality. Modeling is the art of simplifying a complex system in a way that still captures important aspects, allowing our purposes to be achieved. It’s been said that, “You know you’re an engineer if…you’ll assume a horse is a sphere in order to make the math easier.” This sounds like an absurd assumption, but it can actually be quite useful if a quick calculation of how much heat is generated in a stable full of horses is needed. It should be clear then that a model need not be a perfect representation of reality to be helpful. In fact, if it was perfect, it probably wouldn’t be helpful at all because it would be too complex. Scientist E. P. Box put it succinctly when he wrote, “Essentially, all models are wrong, but some are useful.”

This is an important feature of models that holds true even beyond the fields of science and engineering.

Some models are mathematical, or quantitative, in nature, but some models are more qualitative. This is true of the use of analogies in theology to help in understanding the concept of God. These kind of models have a lot in common with models used in science and engineering. Philosopher Thomas J. Oord writes, “Theologians and scientists use models to explore the validity and fruitfulness of competing theories.” He explores several models of God’s providence in his forthcoming book, The Uncontrolling Love of God: An Open and Relational Account of Providence. He also offers an insightful definition of “model” originally articulated by Frederick Ferre; a model is “that which provides epistemological vividness or immediacy to a theory by offering as an interpretation of the abstract or unfamiliar theory structure something that fits the logical form of the theory and is well known.” In other words, a good model makes the theoretical understandable by relating it to something familiar.

In his book, Science and Religion: A New Introduction, Alister McGrath discusses the similarities and differences between models in science/engineering and theology. In neither area are these models literal depictions of reality. Models are approximate organizing images that allow us to structure and interpret events, ultimately relating to observational data (engineering) or personal experience (theology). However, theological models differ from scientific models in that they serve non-cognitive functions, and evoke more total personal involvement. Indeed, theological models appear to be more influential than the formal beliefs and doctrines which are
The model proposed in this paper is a combination of theological and technological ideas. A model of God as refiner, or process systems engineer, is a theological construct based on scientific principles and engineering applications.

**The Biblical Basis for God as Refiner**

The Bible employs a rich diversity of imagery in describing God. He is depicted as love, light, king, shepherd, lamb, friend, bridegroom, father, mother (see Isaiah 49:15), and refiner, among others. Philosopher of religion Ian Ramsey argued that these models are not to be viewed in isolation, but interact with and qualify each other. McGrath adds that each of these models illuminates certain aspects of our understanding of God and salvation. Although no model is exhaustive in itself, taken together, they provide a comprehensive and consistent understanding.

His use of the word “comprehensive” here should not be taken to mean “complete,” but rather, “broad in scope.” He provides the following example for further clarification,

> To speak of “God as shepherd” is thus to affirm that “God is like a shepherd.” In other words, the image of a shepherd helps us think about the nature of God, and allows us to gain insights into his nature. It does not mean that God is identical to a human shepherd. Rather, it means that some aspects of a human shepherd help us think about God more effectively.

In many ways, the models of shepherd and refiner (or process systems engineer) are similar. They both speak of an overseer who is intimately involved in caring for his/her charge. Indeed, the process systems engineer is often tasked with maintaining, or adjusting, operating conditions (such as various temperatures, pressures, and flow rates) so that the engineered product (such as gasoline or plastics) efficiently reaches its intended state. In a sense, the skilled process engineer successfully “shepherds” the product through the process. Though similar, the shepherdly image emphasizes a nurturing and caring relationship, while the engineering image emphasizes God’s wisdom and skill, in allowing us to pass through the “refining fires” of this life, and come through for the better. However, both images provide encouragement and reassurance in the midst of trials.

According to McGrath, the three main models of God as creator are emanation (an overflowing of creative energy), artistic expression, and construction (or engineering). In expounding on this third facet, McGrath writes,

> Many biblical passages portray God as a master builder [or engineer], deliberately constructing the world (for example, Psalm 127:1). The imagery is powerful, conveying the idea of purpose, planning, and a deliberate intention to create. The image is important, in that it draws attention to both the creator and the creation. In addition to bringing out the skill of the creator, it also allows the beauty and ordering of the resulting creation to be appreciated, both for what it is in itself, and for its testimony to the creativity and care of its creator.
Helping Christians appreciate the skill of the Creator, as seen in nature, plays an important role in the strengthening of their faith. Theologian Dennis William Cheek has recently engaged in an exploration of the interactions between theology and technology. His insights are also helpful in considering a model of God as process engineer. Along these lines, he writes:

The concept of technology is not foreign to the Bible; in its canonical form, it is replete with references to ancient technologies of many types. God is sometimes presented in the Old Testament in a manner that we would today call a systems engineer. He creates (designs) a universe and world and places within it creatures, including human beings… The New Testament continues this theme of technologies…The sacrificial death of Jesus is presented as an act that was designed (in modern parlance “engineered”) and sanctioned by God as a means to present a spotless “Lamb” who takes upon himself the sins of the world.

We may not normally think of God as one who “engineers” our redemption, as Cheek suggests, but in a general sense, engineers simply arrange things in order to accomplish their purposes. We see a hint of this in the wise woman of Tekoa’s messianic response to King David, “Like water spilled on the ground, which cannot be recovered, so we must die. But that is not what God desires; rather, he devises ways [or engineers a solution] so that a banished person does not remain estranged from him.” (II Samuel 14:14) How has God engineered the world to assist in his redemptive plan?

Of course, redemption immediately invokes images of the cross of Christ, and rightly so. But God has also engineered various facets of this universe to play important roles in our redemption. God appears to be using the universal experience of adversity to teach humans vital truths that, perhaps, may not be obtained by any other means. Scripture contains many examples of this idea, including Psalm 119:71 – “It was good for me to be afflicted, so that I might learn your decrees,” and Isaiah 38:17 – “Surely it was for my benefit that I suffered such anguish.” It seems likely that occasions of adversity, if received with humility, make us more receptive to God’s redemptive plan for our lives. And as a result of his redeeming power, we become useful tools in his hands. These ideas are repeatedly illustrated in the many verses that liken God’s work in our lives to a refining process:

Deut 4:20 The LORD took you and brought you out of the iron-smelting furnace, out of Egypt.  
1 Kg 8:51 your people, whom you brought out of Egypt, out of that iron-smelting furnace  
Jer 11:4 your ancestors when I brought them out of Egypt, out of the iron-smelting furnace  
Jer 9:7 I will refine and test them, for what else can I do because of the sin of my people?  
Is 1:25 I will thoroughly purge away your dross and remove all your impurities.  
Ps 66:10 For you, God, tested us; you refined us like silver.  
Ps 66:12 We went thru fire…but you brought us to a place of abundance.  
Is 48:10 See, I have refined you…I have tested you in the furnace of affliction.  
Mal 3:2 For he will be like a refiner’s fire or a launderer’s soap.  
Mal 3:3 He will sit as a refiner and purifier of silver…and refine them like gold & silver.  
Ez 22:20 As [metals] are gathered into a furnace to be melted…so will I gather and melt you.  
Ez 22: 22 As silver is melted in a furnace, so you’ll be melted.  
Pr 17:3 The crucible for silver and the furnace for gold, but the LORD tests the heart.
Pr 27:21 The crucible for silver and the furnace for gold, but people are tested by their praise.
Jer 6:27 I have made you a tester of metals and my people the ore, that you may...test them.
Jer 6:29 The bellows blows... to burn away the lead...but the refining goes on in vain.
Dan 11:35 Some of the wise will stumble, so they may be refined, purified and made spotless.
Dan 12:10 Many will be purified, made spotless and refined.
Zech 13:9 I will put them into the fire; I will refine them like silver and test them like gold.
Matt 3:11 He will baptize you with the Holy Spirit and fire.
John 15:2 He cuts off every fruitless branch, while every branch that does bear fruit he prunes.
Heb 12:29 for our “God is a consuming fire
1 Cor 3:13 It will be revealed with fire, and the fire will test the quality of each person’s work.

Many of the Old Testament passages refer to the use of specialized furnaces for iron smelting and purification of precious metals. As mentioned earlier, the forging of iron weapons and tools was new technology at the time of Israel’s forming as a nation. Expert knowledge and skill were necessary to produce these advanced implements that were used for the production of food and protection from enemies. Research into the early iron smelting process of that era reveals a very labor intensive activity, in which an early version of a process engineer was intimately involved in continually maintaining the right conditions. An extremely hot combustion chamber was necessary to exceed the melting point of iron (1537°C). Bellows were frequently employed to provide enough oxygen for the combustion process. Carbon was repeatedly added to draw the oxygen from the iron ore, and in the right amounts to produce iron and steel. A suitable flux was added during reheating and hammering processes to remove the impurities (dross). Quenching and tempering (reheating to lower temperatures) processes were employed to produce hard and durable iron alloys.\(^\text{15}\) The implication is that success in this metallurgical engineering venture required not only the skill and resources, but also the careful attention, of a wise and experienced smith who was familiar with the latest technologies.

Religious Studies Professor Paula McNutt provides insight into the biblical symbolism of the refining process in her book, *The Forging of Israel: Iron Technology, Symbolism, and Tradition in Ancient Society*. She describes the key image of a divine smith who accomplishes transformation in his creation, by allowing that creation to experience adversity with appropriate mediation.\(^\text{16}\) It is a vivid picture of a God who not only creates and maintains the right conditions in the universe to afford the opportunity for human transformation, but also enters into that universe to participate in the adversity and mediate an ultimate solution to the human condition. The next section will further explore this imagery by addressing concerns associated with theodicy (the problem of evil and suffering in the world) and divine action (how a spiritual being acts in the physical world).

**Refined for Relationship**

Notice that the first three verses from the above list (Deut 4:20, 1 Kg 8:51, and Jer 11:4) all refer to Israel’s time of slavery in Egypt as a period of refinement as in an “iron-smelting furnace.” But that is not the only thing these passages have in common. Upon closer inspection of the immediate context in each case, it becomes clear why God allows his people to experience such adversity. It is for the relationship they are to have with their Maker. This idea is expressed by many of the other verses as well. God refines us so that we are fit to experience the fullness of
an intimate relationship with him. We are still in process, and although we are saved by the death and resurrection of Christ, God somehow uses the difficult experiences of this life to refine, or sanctify us, preparing us for an eternity with our Maker.

Process engineers know that refining methods that produce valuable metal alloys make use of key relational aspects of creation to generate desirable characteristics such as hardness, durability, and toughness. These features, when present in a forged tool or weapon, afford the user increased efficiency and capability for the task at hand. In a similar way, our Creator allows us to experience adversity because it produces valuable, if not vital, affordances in human beings. According to 1 Corinthians 10:13, he will not test us beyond our ability to endure. When received with humility, in a redemptive environment (thanks to Jesus), we see how adversity often results in strength, resilience, endurance and a greater knowledge of the truth. In addition, philosopher of religion Richard Swinburne writes that difficult circumstances provide us with significant opportunities to show compassion and kindness to others that we might not have under any other circumstances. Again, we see how adversity brings opportunity for enhancing relationships.

Furthermore, strength, and even growth, in the midst of adversity appears to provide testimony that God knows what he’s doing. Paul writes to the Thessalonians,

We ought always to thank God for you, brothers and sisters, and rightly so, because your faith is growing more and more, and the love all of you have for one another is increasing. Therefore, among God’s churches we boast about your perseverance and faith in all the persecutions and trials you are enduring. All this is evidence that God’s judgment is right, and as a result you will be counted worthy of the kingdom of God, for which you are suffering. (2 Thessalonians 1:3-5)

The Thessalonians were experiencing persecutions and trials, and yet their faith and love was increasing. Paul claims that this shows that God’s calculations are correct, even justifying the Creator’s wisdom in allowing evil and suffering to persist for a season. Indeed, history shows that the early church, in Rome especially, grew rapidly during extreme persecution, largely because of the joyful testimony of the suffering faithful and the martyrs. It seems that adversity may play a key role in solidifying a believer’s trust in God, ultimately committing him/her to always choose the good, true and beautiful out of love for their Maker.

Finally, adversity appears to afford opportunities for God to break through (special divine action) and encourage his people when they really need it. In 2 Corinthians, Paul writes about his tormenting thorn in the flesh, which was so bad that he pleaded with God three times to remove it. It is interesting to note that God did not remove it, but instead spoke to Paul. He said, “My grace is sufficient for you, for my power is made perfect in weakness.” (2 Corinthians 12:9) I don’t know whether Paul heard an audible voice on that occasion, but somehow God broke through (from the supernatural to the natural) in a way that made all the difference, and provided an important lesson about adversity to benefit the church for the rest of time.

I’m not suggesting that special divine action such as this happens a lot, but testimonies abound within the church on how God somehow communicates with his children in
unmistakable ways. I’m also not suggesting that this is something that can easily be quantified or studied scientifically. But I know it when I see it, or when I experience it for myself. On at least two occasions in the last six years, I have found myself in very difficult places at critical points in my life. And God communicated profound and life-changing encouragement to me in the midst of those challenging circumstances. I didn’t hear an audible voice or experience a documented miracle. But in both situations, I knew beyond a reasonable doubt, that I had “heard” from God, even if in a somewhat mysterious way. The reason I say this is because of the good and ongoing fruit that resulted in both cases, due to my complete change in attitude and mental/emotional state.

Basically, due to unusual events, I surprisingly and immediately found myself with the joy, courage and power to carry on with the work to which I had been called. Due to the personal nature of these testimonies, it is with some hesitation that I share the details of one of them in the next section. But I think it is important to recount this experience as a witness to God’s intimate concern and involvement with us in the midst of the refinement process.

**Personal Experience of Special Divine Action**

About six years ago, I was beginning to spend more time conducting research in the area of science and faith, and less time in engineering. It seemed to me that the Lord was leading me in this direction, even though I continued to enjoy teaching engineering courses at my home institution. I was also beginning to see how the field of engineering might have important contributions to make to the science and theology conversation.

I was working on a PowerPoint presentation at home one evening on my laptop computer at our dining room table. The presentation was on science and faith to be delivered the following day at a seminar for which I had volunteered. I remember being somewhat overwhelmed with everything that was “on my plate” at that particular time in my career. And I began to wonder if I was doing the right thing by spending time researching in science and faith. I wasn’t getting much encouragement or support from any direction at this time, and I was beginning to doubt what I had thought was a call into this area.

On top of all that, I was struggling to use a piece of software that was supposed to easily capture video clips for insertion into PowerPoint presentations. But it was not working out very well. It captured the video fine, but an external microphone was needed to grab the audio, and the sound was not coming through loud and clear. I remember getting extremely frustrated with the whole project, sitting there at the table in a very dejected state of mind, wondering if I was just wasting my time.

It was about then that our youngest daughter, Josie, came in the front door from high school basketball practice. Partly to get a break from my unsuccessful attempts to craft an exciting presentation, I offered to make her some supper, remembering that there was some leftover rice in the refrigerator. She said she would eat some fried rice, so I pulled it out, along with an egg and some vegetables. I put a skillet on the stove top and turned on the heat.
I must not have been paying close attention to what I was doing. My mind was probably still fretting over all the things I had to do, including the pressing presentation for the next day. When I grabbed the bottle of olive oil, I shook it, for some unknown reason, like it was an oil and vinegar salad dressing that needed to be reconstituted before using. That was stupid because it was just olive oil, without the slightest need for shaking. And again, for some unknown reason, the cap on the bottle was loose, and olive oil went everywhere!

For an instant, this was like the straw that broke the camel’s back. Really God? This is what I get for trying to serve others? A big mess to clean up, meaning even less time to tend to all my urgent responsibilities. I stood there in the kitchen, my blood beginning to boil, wondering if a primal scream was next on the agenda. What a mess! Some of the oil fell on the floor. Some of it fell on the countertop. Some of it fell on the clean dishes, drying in the sink. Some of it actually fell in the pan. And some of the olive oil fell…on…my…head!…What a minute. All of a sudden, my frustration was arrested, and my volcano of rage immediately became inactive.

Why? Because I had been working on a Master’s Degree in Biblical Literature, and I understood the significance of having olive oil poured on one’s head. I smiled as I thought to myself, “I know what this means…It means that I am anointed.” I actually began to laugh at the completely ridiculous idea that through my own stupidity, God had somehow managed to anoint me with the bottle of olive oil from our kitchen cabinet. And yet, here I was, with a complete reversal of emotions, and newfound joy, energy, and enthusiasm to carry on my work.

I immediately thought of Jesus words in Luke 4:18-19, “The Spirit of the Lord is on me, because he has anointed me to proclaim good news to the poor. He has sent me to proclaim freedom for the prisoners and recovery of sight for the blind, to set the oppressed free, to proclaim the year of the Lord’s favor.” It was as if a new realization of how these verses could describe the impact of my work had suddenly been downloaded to my brain. I couldn’t stop laughing as I reveled in the thought that, even though no mentor or friend was available to anoint me, God himself had somehow pulled it off. I know it sounds silly, and perhaps it was all in my head, and God actually didn’t do anything. But that doesn’t really make sense when considering the fruit, or the outcome of the event. I went from deep depression to abundant joy; from paralyzing frustration to energized inspiration, virtually in an instant. That just doesn’t happen accidently, or through human will power.

After a while, I came to understand that this message of special anointing was not just for myself, but for the entire faculty at my home institution. I seized the opportunity at a subsequent University Faculty Assembly meeting to remind the faculty and administration that, even when we feel alone, inept, or unappreciated, we are anointed to complete the work to which God has called us. This message was received with gratitude and generally found to be very encouraging. The significance of these events for the larger community provides another reason to believe that God was indeed communicating something special to me through these weird circumstances. In addition, years of successful and fulfilling work in the area of science and faith since this event continue to confirm this understanding.
Conclusions

Since God is a personal being and humans are made in his image, he has enabled humans to know him to a significant degree, even in this life. God reveals himself, both in Scripture and in nature, using categories and images that humans can understand. A powerful image from Scripture is of a refiner, or process systems engineer. Experience with these technologies clarifies this image and helps in knowing God better. Though no image is perfect, a model of God as refiner, or process systems engineer, is a useful biblical and theological construct based on scientific principles and engineering applications. Characteristics of the ancient iron-smelting process indicate that the smith (or process engineer) was intimately involved in “shepherding” the product though the difficult refining process. The biblical picture is one of a divine Smith whose skill and wisdom are seen in a universe with just the right amount of built-in adversity, which affords the transformation of willing humans, with appropriate mediation through the incarnation, death, and resurrection of Christ.

This provides some measure of relief to the problem of theodicy since, as a result of this model, we can more easily see God’s wisdom and skill in turning evil and adversity around, and causing it to work for our good. In particular, we notice that God is refining us for a wonderful and eternal relationship with himself. Finally, the author’s experiences of divine communication and encouragement in the midst of the heat of refinement testify to the ongoing care and loving-kindness of our Maker during the process. Thus, God’s kindness assists us greatly during trials, and leads us to repentance (Romans 2:4). In this way, the universe seems to be engineered to woo us away from depending solely on our own resources, and instead, place trust in our Maker, and the wisdom of his redemptive plan.

8 McGrath, Science and Religion, 106.
10 Thanks to a conversation with David L. Wilcox, as a result of the following article, for helping me see this point: David L. Wilcox, “Three Models of Making: Prime Mover, Craftsman, and King – Alternate Theistic Frameworks for Teaching Origins,” Perspectives on Science and Christian Faith 39 (December 1987): 212.
11 Even so, the actions of a good shepherd may not always be obviously kind, as when a sheep’s leg may be intentionally broken to keep it from wandering. In such cases, caring is informed by wisdom. Thanks to an anonymous reviewer for this insight.
12 McGrath, Theology, 44.
Christian Learnings from Islamic Perspectives on Technology

Max Deffenbaugh

Abstract

The imperative to understand technology in the light of faith is felt deeply in both Christianity and Islam. Although the two faiths are clearly different in many respects, the questions posed and answers given about technology are remarkably similar. English language Islamic scholarship on technology occasionally cites Christian sources, though Christian scholars seem unaware of the work of Muslims. This paper suggests that there is a significant opportunity for Christians to evaluate methodologies, gain new insights, and challenge conclusions about technology by looking into the mirror of Islamic scholarship. Parasites between Christian and Islamic perspectives are noted in three areas. First, Christian efforts to prove the divine origin of the Bible by finding references to modern scientific concepts in its ancient text are compared to parallel efforts in the Islamic world with respect to the Qur’ān. Next, the shared belief in the oneness of God is explored—a doctrine which has received relatively little attention from Christian scholars recently, but one which some Muslim scholars consider foundational to an Islamic understanding of science and technology. Finally, the influence of religious law on civil government in the Islamic world is compared to the calls of many Christians for civil law to more closely resemble Biblical law. In each case, insights for Christians are suggested.

Introduction

Christianity and Islam are in some respects worlds apart. Nevertheless, there are certain fundamental similarities, including belief in the same eternal, all-powerful and all-knowing God—the God who created all things and revealed Himself through many of the same prophets. The words of these prophets are recorded in a written scripture (Bible or Qur’ān) which the faithful regard as the infallible Word of God. These scriptures reveal humankind as utterly dependent on God as both Creator and Sustainer. They reveal God as giving certain Laws governing how people are to treat each other and worship Him, but which people have a propensity to disregard. A Day is coming where all people will be resurrected and judged by God, who will grant to each either eternal life or eternity in Hell. While all have sinned and none can claim to deserve eternal life, the scripture reveals God as supremely merciful, such that He has made a way for us to gain eternal life (by virtue of Jesus having made atonement for our sin according to Christianity or by God’s forgiveness if our good deeds outweigh our sin according to Islam).
Christians and Muslims have a similar historical experience with science and technology. Both enjoyed periods of history where theirs was the dominant world view and where science and engineering flourished under its influence. For Muslims this period began about a century after the Prophet of Islam and withered over the centuries following the fall of Baghdad to Mongol invaders in 1258. For Christians, this period began with the scientific revolution of the 17th century in Europe and ended abruptly with the Darwinian revolution of the late 19th century.

…this [Darwinian] revolution was far more than a revolution in biological theory. It involved a profound change in the prevailing basic philosophical assumptions. The [Christian] fundamentalist outlook preserves essentially Enlightenment and pre-Kantian philosophical categories. Truth is fixed and eternal and something to be discovered either by scientific inquiry or by looking at some other reliable source such as the Bible. Much of the rest of modern thought, however, had gradually come to view the human mind as imposing its categories on reality. Perception itself in this view is an interpretive process. Truth, moreover, is relative to the observer and to the community or culture of the inquirer. Speculative theorizing is essential, since human thought in any case involves such imposing of one’s constructs on reality. Not only did this philosophical revolution undermine the concept of eternal truths generally, it also supplied a new model for explaining reality. Everything, including religion itself, could be explained by reducing it to natural causes in process of development. The proper locus of intellectual inquiry became, often by definition, to explain development in terms of observable natural forces. Appeals to the supernatural were hence a priori written out of fields of “scientific” knowledge. By this standard, of course, the Bible had to go.¹

This dominant world view in Western science today is fundamentally different from the world views of both Christianity and Islam, which often leads to a doublemindedness among Christians and Muslims who study those fields.

The committed Muslim student is presented with a problem: his education will be rooted in an intellectual tradition which is different and hostile to his basic religious beliefs. As he approaches graduation he will learn to cope with this by assigning the ‘secular’ and ‘religious’ knowledge he acquires into two separate mental compartments: of matter and spirit, of physics and metaphysics, of nature and supernature, of scientific method and mysticism, of science and religion. Sooner or later he will forget the early tensions in his mind which first forced reality to be divided in this way. The boundaries will become firmly established as natural rather than arbitrary demarcations. This is the trap to be avoided, for the start of the process of ‘de-Islamization’ is when one’s single, integrated world-view becomes compromised.²
The same spectrum of attitudes toward science and technology is found within both faiths. Many eagerly adopt new technology, but see a need to regulate certain uses. Others consider technology to be tainted by the secular values of those who created it, values they see infecting their society. Some feel a sense of disenfranchisement who the modern scientific and technological endeavor, a distrust of its motives, and a deep concern over its current direction. Some look back to their golden age of science and wish to reconnect science and technology to its roots within their religious tradition.

With many similarities in world view and a parallel historical and sociological experience with modern science, it is not surprising to discover that similar responses to science and technology are found today in both communities. The premise of this paper is that we can learn from each other’s responses to modern technology through insights that may be present in one religious tradition but not in the other and from the opportunity to look in the mirror by examining the other and thus regarding ourselves from an objective distance. In this paper we will look at several important doctrines in Islam and their similarity or difference from Christian doctrine. Then we will consider how these doctrines have shaped Islamic perspectives on technology and what Christians can learn from these perspectives.

*Ahlu al-Kitāb* (People of the Book)

Muslims see the written scriptures of Christians, Jews, Zoroastrians, and Sabiens as part of the Book of God’s revelation to humankind. They refer to people of these faiths together as *ahl al-kitāb* (“people of the Book”) and esteem their faiths as earlier revelations of Islam, though revelations which have become somewhat distorted over the years. Muslims consider the Qur’ān to be the final written revelation and to correct errors which were introduced over time into the other Books.

Christians consider the Bible to be “inspired by God” (2 Timothy 3:16) and written by authors who were “carried along by the Holy Spirit” (2 Peter 1:21) as they wrote. However, differences in literary ability, vocabulary, and style are apparent between the Biblical authors. Muslims consider the Qur’ān to have been dictated by the angel Gabriel to Muhammad, so that the literary creativity of the human author was not a factor in its composition. In Surah (chapter) 10:37-38, the Qur’ān reads:

> And this Qur’ān is not such as could ever be produced by other than Allah, but it is a confirmation of (the revelation) which was before it [i.e. the Taurat (Torah), and the Injeel (Gospel), etc.], and a full explanation of the Book (i.e. laws and orders, etc., decreed for mankind) - wherein there is no doubt from the Lord of the 'Alamin (mankind, jinns, and all that exists). Or do they say: "He (Muhammad) has forged it?" Say: "Bring then a Surah like unto it, and call upon whomsoever you can, besides Allah, if you are truthful!"
Muslims hold what Christian fundamentalists would call a “high view” of scripture: that every word of the Qur’ān is exactly as God intended (like the Christian doctrine of verbal inspiration) and that the Qur’ān contains no errors (like the Christian doctrine of inerrancy). Similar doctrines about divine inspiration lead to similar interpretive approaches when the text touches matters of science. Within Islam, some have searched the Qur’ān for references to modern science and technology. The study and interpretation of these references is known as al-tafsīr al-‘ilmī (“scientific exegesis”). This interpretive tradition began in the late 19th century and was originally used by certain Muslims to promote acceptance of discoveries and inventions from the West. An early practitioner was Said Nursi (1877-1960) who found, for example, foreshadowing of and endorsement for modern aircraft where God gives Prophet Sulayman (Solomon) control of the wind (Surah 34:12), and for modern drilling where Prophet Moses brings water out of the earth. (Surah 2:60). In recent decades, the scientific exegesis has taken on an apologetic focus, presenting prescient references to modern science as proof of the divine origin of the Qur’ān. An example of this literature available in English includes the work of Maurice Bucaille, a French physician who converted to Islam. Bucaille writes,

…it is inconceivable for a human being living in the Seventh century A.D. to have made statements in the Qur’ān on a great variety of subjects that do not belong to his period and for them to be in keeping with what was to be known only centuries later. For me, there can be no human explanation to the Qur’ān.

Within Christianity, there is a similar interpretive tradition. One of the most prolific writers in this tradition is Henry Morris, who says,

One of the most amazing evidences of the divine inspiration of the Bible is its scientific accuracy. There are many unexpected scientific truths that have lain hidden within its pages for thousands of years, only to be recognized and appreciated in recent times.

The scientific references identified in the Bible and Qur’ān are similar in character. For example, both contain references to the water cycle. Surah 39:21 reads,

Do you not see that Allah sends down rain from the sky and makes it flow as springs [and rivers] in the earth; then He produces thereby crops of varying colors; then they dry and you see them turned yellow; then He makes them [scattered] debris. Indeed in that is a reminder for those of understanding.
According to Zahir Naik, until the 19th century it was thought that springs were fed by sea water through an underground passage or by water vapor that condensed in cool underground caverns, while the Qur’ān here teaches correctly that spring water comes from rain water. In the Bible, Ecclesiastes 1:7 reads, “All the rivers run into the sea; yet the sea is not full; unto the place from whence the rivers come, thither they return again.” According to Ray Comfort, the complete water cycle was not fully understood until the 17th century, long after Ecclesiastes was written.

Most Christian practitioners of the scientific exegesis find that the Bible contradicts the big bang, biological evolution, and the geological history of the earth. At these the points of contradiction, some conduct alternative research to prove that the Bible is correct and the conclusions of the scientific community are wrong. In the area of applied science, some Christians have formed an oil exploration company based on a scientific exegesis of the Bible which points to the presence of oil in certain parts of the modern nation of Israel. Muslim practitioners of the scientific exegesis are divided on whether the Qur’ān teaches biological evolution. Some find support for it, while others find opposition to it.

Muslim practitioners of the scientific exegesis have extensive outreaches to popularize their views, including websites and radio programs.

Today, every Thursday evening when you turn on Cairo radio there are one or two very famous lecturers who are, in fact, very devout Muslims, loved by the people of Egypt, [and] the heart of their message is every single verse of the Quran which deals with either Ta’akul or Taffakur, that is intellection or knowledge or observation or mushahida. These [verses] are interpreted “scientifically”, that is, as an attempt to preserve Islam through scientific support for the Islamic revelation, for the Quran itself. And this is a very strong position in the Islamic world today. Therefore [the Muslim] thinks in fact there is no problem as far as Islam and modern science are concerned.

Christians also have ministries that promote scientific exegesis through popular radio broadcasts. One of these has a website which offers scientific exegesis resources for parents to share with their children:
Many Christian parents are concerned that such a secular environment [in college] may lead their children to walk away from the Church. This concern is justified, since studies have shown that around two out of three Christian students from conservative churches will leave the church when they become adults. First of all, our research shows that the problem starts much earlier than college. Nearly 90% of those students who leave the church have already begun to doubt God’s Word by the time they graduate from high school. Although they may continue to attend church with their parents, spiritually they are already gone. Most Christian teenagers do not understand how the Bible connects to the “real world.” They have been taught “Bible stories,” but they have not been shown how the Bible’s history explains the evidence around us—from biology and geology to astronomy.  

Some Christians from the scientific community have spoken out against the scientific exegesis of the Bible, particularly insofar as it opposes the discoveries of modern science. However, Christian theologians—those who train pastors—have generally remained silent on the issue, and the scientific exegesis is widely taught from conservative pulpits. As a result, many Christians are led to believe that if the Bible is inspired by God then its poetic imagery must be scientifically accurate, from Solomon’s natural metaphors for the futility of life in Ecclesiastes 1 to a poem about Sabbath-keeping in Genesis 1-2:3. Some scholars of the Qur’ān have opposed the scientific exegesis, including Amin al-Khuli, a professor of Qur’ān exegesis. One of Al-Khuli’s objections is that the Qur’ān was first addressed to contemporaries of the Prophet and cannot contain anything (like references to future inventions or undiscovered scientific processes) that they did not understand. 

Significant lessons for Christians can be drawn from considering the various ways Muslims interpret the Qur’ān. First, Christians who imagine that their scientific exegesis proves the Bible is uniquely inspired and safeguards the faith of their children should note well that the same method of scientific exegesis is used throughout the Islamic world to prove the divine origin of the Qur’ān. Either both books are inspired by God or the method of scientific exegesis does not prove as much as its practitioners suppose. It is worth noting that Muslims consider the Bible to have come from God (e.g., Surah 29:46), so those who subscribe to the scientific exegesis of the Qur’ān would not be surprised to find similar scientific references in the Bible. Second, it is worth noting that to at least some Muslim scholars, the verbal inspiration of the Qur’ān does not imply the kind of scientific inerrancy that some Christians teach—that the text contains divine revelation about every natural phenomenon it touches, regardless of the author’s intended meaning or message. Though they regard every word of the Qur’ān as dictated by God, these Muslim scholars reject a search for hidden meanings that would not have been understood by the original audience. Perhaps studying how Muslim scholars interpret the Qur’ān would provide some insight into how the Biblical authors would have expected their audience to interpret their writings. The modern Western mind has difficulty processing non-technical literary types, but Islamic scholarship provides a unique opportunity to see how a mindset and cultural perspective closer to that of the Biblical authors processes a revealed text.

* Al-Khuli’s objections are described by Muzaffar Iqbal in Islam and Science, p. 290-291.
Tawhid ("oneness") of God

Christianity and Islam both teach that there is only one God. The doctrine appears in the 225 word Nicene Creed “We believe in one God the Father Almighty…” but not explicitly in the more condensed 110 word Apostle’s Creed “I believe in God the Father Almighty…..” In the modern Western world, atheism seems a greater threat to faith than polytheism, and the doctrine of “one God” receives limited attention in Christian thought and homiletics. In contrast to its peripheral status in modern Christian thought, the oneness of God is front and center in Islam. It is first of the two points in the 12 word Shahada (testimony) “There is no god but God; Mohammed is the messenger of God.” The doctrine is alive and active today as a defining principle in modern Islamic perspectives on all aspects of life. The Islamic understanding of tawhid has three dimensions.

1. **Tawhid-al-Rububiyyah** (Oneness of Lordship),

   Say: ‘Who is it that provides you with sustenance out of heaven and earth, or who is it that has full power over hearing and sight? And who is it that brings forth the living out of that which is dead, and brings forth the dead out of that which is alive? And who is it that governs all that exists?’ And they will answer: ‘God.’ (Surah 10:31)

2. **Tawhid-al-Uluhiyyah** (Oneness of Worship),

   Say: ‘Behold, my prayer, and my acts of worship, and my living and my dying are for God [alone], the Sustainer of all the worlds, in whose divinity none has a share: for thus have I been bidden, and I shall be foremost among those who surrender themselves unto Him.’ (Surah 6:162-163)

3. **Tawhid-al-Asma’ wal-Sifat** (Oneness of Names and Attributes).

   The names or key attributes of God must never be attributed to anyone else.

   ‘And God's [alone] are the attributes of perfection; invoke Him, then, by these, and stand aloof from all who distort the meaning of His attributes: they shall be requited for all that they were wont to do!’ (Surah 7:180)

This understanding of tawhid has informed Islamic perspectives on science and technology from earliest times, and leads many Muslims today to call for development of “Islamic science” or “sacred science”, a reforming of science and engineering such that it is practiced as an essential part of Islam. This is a call for a fundamental unity which is very different from finding Qur’an passages that refer to science or even applying Islamic values to evaluate western technology. Muzaffar Iqbal writes,
As far as Islam is concerned, a *sine qua non* for any genuine discourse is that the “and” in the phrase “Islam and science” must always remain a unitive and never become a connector. This essential prerequisite of the discourse stems from the fact that it is inconceivable to think of an Islamic discourse in which there exist two orders of reality or two completely independent paths to Reality. … This unique aspect of the Islamic perspective on modern science renders many contemporary typologies irrelevant to the discourse.  

For example, Ian Barbour identified four kinds of relationship that may exist between science and religion: fundamental conflict, separate domains, science affirms divine guidance, or constructive dialogue. Iqbal rejects all four as incompatible with the Islamic view of the *tawhid* of God, as they all assume that science and religion can exist as distinct realities.

There is a sense among many Christians in technical fields that there must be some deeper relationship between faith and their work. Consideration of the doctrine of one God can provide Christians with some insight into that relationship as it has done for Muslims. Christians have not explored the doctrine of one God in recent years to the same extent as Muslims or looked at its application to science and technology. When polytheism or idolatry is mentioned in Christian sermons, the application is commonly to the matter of setting priorities. For example, “It is fine to own cars, it is even fine to like cars, but if cars become more important to you than things of God, the cars have become an idol.” But this application seems off the mark. It is hard to imagine the Old Testament prophets denouncing idolatry in ancient Israel by saying, “It is fine to own statues of Baal. It is even fine to worship those statues. Just don’t worship Baal more than you worship God.” Idolatry or polytheism has never been a question of degree. Rather, idolatry in the Old Testament (and at the time of the Prophet of Islam) was an expression of a world view that there are different domains, each of which has its own rules, its own approaches and methods, its own geographic region, its own origin, and its own rule giver. These domains were personified and portrayed as pagan deities of fertility, weather, war, etc. Domains could be controlled in isolation without interference into other areas of life.

Pagan idolatry was attractive to the ancients because, among other things, it was based on the assumption that frequency and generosity of worship (bringing a lot of food to an idol’s shrine) would establish a good relationship with one’s god or goddess. Ethical living was not required. Idolatry is not the sin of skewed priorities, rather it is the sin of a bifurcated world view that posits domains beyond the concern, the worship, or the sovereignty of the God of Scripture. Returning to the car example, the very idea that there are “things of God” and other things (like cars) that are not of God is polytheism. The division of life into “sacred” and “secular” is polytheism. Any view of engineering and science that makes them other than a dimension of Christian life and worship is polytheism. This is a very useful starting point in building a Christian perspective on engineering and science. It rejects questions about how to integrate faith with engineering and science and asks instead how a Christian should *practice* engineering and science. The benefits of framing the question in the second way include:
1. We find clear answers in the Bible. The Biblical authors knew nothing of modern science as a separate domain that would emerge to challenge the Biblical worldview, so they wrote nothing about it. However, they wrote a great deal about how Christians should do the things they do.

2. It embraces engineering and science as fully appropriate activities for Christians in God’s creation. The “integration” question suggests that the goals of science and engineering of understanding God’s creation and using that knowledge to serve mankind lack value in God’s site and must be augmented with some “spiritual” component.

*Ibadah (Worship)*

The Qur’an is quite clear as to the purpose of mankind. “And I did not create the jinn and mankind except to worship Me.” (Surah 51:56) The word ‘*ibadah* (act of worship) is derived from the Arabic word ‘*abd* (a slave)\(^{24}\), so worship means fully submitting to God, living to please God, and serving God. In fact, the word “Islam” means “surrender or submission (to God)”, and a “Muslim” is “one who submits (to God)”. For Muslims, worship is expressed by living according to *shari’a* (“The Way”), which is the way of life which God desires for mankind and which He will ultimately reward with eternal life. No aspect of life is outside the domain of *shari’a*, including the civil government. According to a recent survey, the majority of Muslims around the world want their governments to enforce *shari’a* law, a legal system based on the laws of the Qur’an and Hadith.\(^{25}\)

Christians are referred to as “slaves of Christ” (1 Corinthians 7:22), and the Islamic sense of worship as submission to God is very close to the Christian meaning of worship as self-sacrifice in Romans 12:1, “Therefore, I urge you, brothers and sisters, in view of God’s mercy, to offer yourselves as a living sacrifice, holy and pleasing to God—this is true and proper worship.” Many Christians have called for civil law to more closely reflect Biblical law. Former House Majority Leader Tom Delay (R-Texas) said, “I think we got off the track when we allowed our government to become a secular government. When we stopped realizing that God created this nation, that He wrote the Constitution, that it’s based on Biblical principles.”\(^{26}\) Pastor Ted Weiland takes a different view of the Constitution but a similar view of the law. His website states:

…the Constitution … defies Yahweh’s sovereignty and morality in nearly every article and amendment… It’s the reason America is teetering on the precipice (or, actually, already falling into the chasm) of moral depravity and national destruction… Every problem America faces today can be traced back to the fact that the framers failed to expressly establish a government upon Yahweh’s immutable morality as codified in His commandments, statutes, and judgments.\(^{27}\)
Whether the U.S. Constitution is or isn’t based on the Bible, DeLay and Weiland agree with many Christians that the laws of the nation ought to be based on Biblical law. Accordingly, many Christians would support restrictions on uses of technology and media content which are destructive to Christian values.

The laws of Saudi Arabia are clear as to the influence of Islam and the Qur’an. Chapter 1, Article 1 of the Basic Law of Governance of Saudi Arabia begins: “The Kingdom of Saudi Arabia is a sovereign Arab Islamic State. Its religion is Islam. Its constitution is Almighty God's Book, The Holy Qur’an, and the Sunna (Traditions) of the Prophet (PBUH).” Accordingly the government maintains a panel of scholars who advise them on matters of Islamic law. These scholars also take questions on the full range of practical matters concerning how Muslims should live, and they provide responses based on Islamic law via their website. These answers are posted on the website and provide many useful insights into the panel’s view of technology. For example:

Q 9: What is the ruling on listening to the Qur’an on the radio?
A: The radio is an instrument which in itself has no special ruling. The ruling is on the material broadcasted through it. If the radio broadcasts Qur’an, clarification of the Laws of Allah, heart-softening exhortations, authentic news by which people know the status of other nations and countries in the world to become more aware and can adopt a correct stance towards their friends and enemies, commercial news by which the people know what benefits them in life and other suchlike benefits, in such cases, listening to the radio will be a good thing, or even Wajib (obligatory) sometimes.

However, if the radio broadcasts immoral songs or false news whose purpose is to reverse the truth and deceive people, and in substance they are mere empty shows and provoke emotions by announcing falsehoods, and such vices, it will be falsehood which does not befit the Muslims to listen to or be silent about.

As reflected in this fatwa (opinion on the interpretation of Islamic Law from a qualified scholar), the panel generally takes the view that technology itself is value-neutral, but the purposes for which people use technology may be either good or bad. If a technology is usually used for bad purposes, then they will rule against it, as in this case:

Q: I work as an electronic engineer. My work involves fixing radios, TVs, VCRs and suchlike. I hope that you can advise me whether I should continue in this work. It should be noted that if I do not do this work, I will miss out a lot of experience and the profession for which I have been studying all my life, and I may suffer bad consequences if I abandon it.
A: The proofs of Shari’ah, from the Qur’an and the Sunnah, indicate that a Muslim must strive to find a good source of living. So you have to look for work where your earning is lawful. As for earning a living from the work that you mention, this is not lawful because these devices are usually used for unlawful purposes. May Allah grant us success. May peace and blessings be upon our Prophet Muhammad, his family, and Companions.

Accordingly, Saudi Arabia restricts uses of technology and media content which are destructive to Islamic values.

While government restrictions on messages that are destructive to Islamic values are consistent with many Islamic views of ‘ibadah and sharī’ah, we suggest that Christian calls for similar restrictions based on Biblical law are inconsistent with the teaching of the Bible about Biblical law. Imposing Biblical law can have two outcomes as illustrated in a story Jesus told:

Two men went up to the temple to pray, one a Pharisee and the other a tax collector. † The Pharisee stood by himself and prayed: ‘God, I thank you that I am not like other people—robbers, evildoers, adulterers—or even like this tax collector. I fast twice a week and give a tenth of all I get.’ But the tax collector stood at a distance. He would not even look up to heaven, but beat his breast and said, ‘God, have mercy on me, a sinner.’ I tell you that this man, rather than the other, went home justified before God.” (Luke 18:10-13)

The Pharisee in this story believed that keeping Biblical law made him righteous and justified in God’s sight and put him ahead of sinners like the tax collector. The tax collector, however, knew that he was a sinner. He called out to God for mercy and received forgiveness of all his sins so that he (and not the Pharisee) was justified before God. The Bible explains, “…no one will be declared righteous in God’s sight by observing the law; rather, through the law we become conscious of sin.” (Romans 3:20) A law which none are capable of obeying and one which serves only to make one conscious of sin by showing God’s perfect standard, is simply not practical as a civil law for a nation.

† The Pharisees were Jewish religious leaders who strictly obeyed all regulations of Biblical law. Tax collectors were Jewish employees of the hated Roman government who often charged more taxes than Rome required and kept the extra for themselves.
There is a second reason why Christians should not support implementing Biblical law as civil law. To Christians, one of God’s most important names is “Savior”. Consistent with the Islamic understanding of Tawhid-al-Asma’ wal-Sifat (oneness of the names and attributes of God), a name of God cannot be rightfully applied to any other. God, speaking through the Prophet Isaiah, says, “There is no other God besides Me, a righteous God and a Savior; There is none except Me. Turn to Me and be saved, all the ends of the earth; For I am God, and there is no other.” (Isaiah 45:22). For Christians, salvation has three aspects. Salvation begins when we believe that Jesus Christ paid the divine penalty for our sins so that we are guaranteed God’s full forgiveness of every sin past and future. Salvation continues as God’s Spirit transforms our hearts so that we begin to live lives of righteousness and self-sacrifice as worship to God (similar to the Islamic understanding of ‘ibadah). Salvation will be completed at the resurrection and day of judgement when God has promised that we will be saved from Hell and given eternal life with Him. Since to Christians “Savior” is a name only for God, it would be the sin of shirk (polytheism) for a Christian to imagine that he could contribute toward any of these three aspects of salvation. The Christian cannot contribute any good works toward earning forgiveness of his sins. He certainly cannot resurrect the dead and grant eternal life. Neither can he transform hearts to produce true righteousness and worship that is pleasing to God. All three aspects of salvation are described in God’s promise given through the prophet Ezekiel (36:24-28), and in each case, God is the one who acts to save.‡

For I will take you from the nations, gather you from all the lands and bring you into your own land. Then I will sprinkle clean water on you, and you will be clean; I will cleanse you from all your filthiness and from all your idols. Moreover, I will give you a new heart and put a new spirit within you; and I will remove the heart of stone from your flesh and give you a heart of flesh. I will put My Spirit within you and cause you to walk in My statutes, and you will be careful to observe My ordinances. You will live in the land that I gave to your forefathers; so you will be My people, and I will be your God.

To Christians, the lesson of the Old Testament is that the imposition of Biblical law cannot create a people that honors God. It can only drive sin below the surface where it is less visible, potentially turning tax collectors into Pharisees.

Conclusion

The views on technology found in Islamic scholarship and reflected in the policies of Islamic nations are similar to those found in the Christian community. This creates an opportunity for scholars of both faiths to look at the practices of the other and see from an objective distance their own beliefs and motivations in action. We considered three different perspectives on technology that exist within Islam today: first, that the Qur’ān contains prescient technical references which prove its divine origin and demonstrate the acceptability of modern technology; second, that science and engineering must be—and can be—reformed at their very foundations

‡ Christians believe that Old Testament prophecies about the promised “land” are ultimately not about a geographical region on earth, but rather are references to the Kingdom of God or heaven.
to take their rightful place within Islam; third, that technology itself is value-neutral, though the messages it delivers make it good or bad and should be regulated accordingly by the civil authorities to comply with God’s standards. In comparing these Islamic perspectives to Christian belief, we noted a similar tradition of “scientific exegesis” in both faiths, discovered that the doctrine of “one God” may shed significant light on the place of science and engineering within Christian faith, and suggested that the difference in Islamic and Christian understandings of the role of God’s law imply different national policies regarding the regulation of technology.

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Abstract

Integral Christian higher education is in vogue. Most Christian institutions of higher education who take their mission seriously make the claim that the education offered to students is one where faith and learning are not separate. It is a belief that their entire educational enterprise is inexorably tied in some way, shape, or form to our new life in Christ. Most engineering programs on Christian campuses are the outgrowth of this perspective.

Over the last fifty years, numerous philosophers, writers, scientists, and engineers have developed a solid foundation from which engineering can be understood as an essential calling in the kingdom of God. Central to this work has been a revival of the Biblical theme of creation, the mandate for culture formation, and the proclamation of the gospel through engineering work. The dialogue has often focused on developing a Christian motivation for our engineering work rooted in a Biblical understanding of Creation or on defining what constitutes “right” engineering action (ethics, responsibility, morality, witness…) from a Christian perspective.

While I applaud these efforts and find this work indispensible for our task in engineering education, our work to date has yet to plumb the depths of another theme that thoroughly pervades scripture. This Biblical theme is the unpredictable, indeterminate, and irrational grace that characterizes life in the kingdom of God. When it comes to engineering education (which seems at home in the systematic and rational environment of laws, rules, regulations, and responsibility), grace is often either relegated to a personal sphere or is conveniently left for elsewhere in the curriculum. If the epoxy of grace is so bound up in the fiber of the kingdom of God and we claim that faith and engineering are not separate, then the trajectories of engineering and grace must somehow intersect.

This paper will begin by establishing a biblical hermeneutic for understanding engineering in the light of scripture. It will illustrate from scripture that “grace” is not simply a theological concept or a mechanism for salvation. It is a way of life. Using the work of Christian philosopher Albert Borgmann on technology and grace as a starting point, the paper will explore how grace is woven into our work as engineers. An example of how “grace” might color a course in the engineering curriculum will be presented using an Instrumentation and Control Systems course as an example.

Grace: The Rosetta Stone of Scripture

There are certain concepts in physics or engineering that resist explanation. Instead, they beg for illustration or experience. The concept of force is an example. Attempts to create a definition, equation, or essay on force, will lead a person no further toward conceptualization than if you forego words altogether and simply lean on someone. The absence of words creates the most complete and most correct definition. This is what
force and grace have in common. Rational explanations often confuse rather than clarify. Just as force begs for experience, grace begs for story.

For example, this is what grace looks like.

The Parable of the Sower (Matthew 13:1-17, NRSV)

That same day Jesus went out of the house and sat beside the sea. 2 Such great crowds gathered around him that he got into a boat and sat there, while the whole crowd stood on the beach. 3 And he told them many things in parables, saying: “Listen! A sower went out to sow. 4 And as he sowed, some seeds fell on the path, and the birds came and ate them up. 5 Other seeds fell on rocky ground, where they did not have much soil, and they sprang up quickly, since they had no depth of soil. 6 But when the sun rose, they were scorched; and since they had no root, they withered away. 7 Other seeds fell among thorns, and the thorns grew up and choked them. 8 Other seeds fell on good soil and brought forth grain, some a hundredfold, some sixty, some thirty. 9 Let anyone with ears listen!"

10 Then the disciples came and asked him, “Why do you speak to them in parables?” 11 He answered, “To you it has been given to know the secrets of the kingdom of heaven, but to them it has not been given. 12 For to those who have, more will be given, and they will have an abundance; but from those who have nothing, even what they have will be taken away. 13 The reason I speak to them in parables is that ‘seeing they do not perceive, and hearing they do not listen, nor do they understand.’ 14 With them indeed is fulfilled the prophecy of Isaiah that says:

‘You will indeed listen, but never understand,
and you will indeed look, but never perceive.
15 For this people’s heart has grown dull,
and their ears are hard of hearing,
and they have shut their eyes;
so that they might not look with their eyes,
and listen with their ears,
and understand with their heart and turn—
and I would heal them.’

16 But blessed are your eyes, for they see, and your ears, for they hear. 17 Truly I tell you, many prophets and righteous people longed to see what you see, but did not see it, and to hear what you hear, but did not hear it.

There is a sense of mild angst when Jesus is pressured into turning this story into an explanation. The gospel of Mark (Mark 4:13) records that he said to his disciples “Don’t you understand this parable? How then will you understand any parable?” implying that an explanation is really not needed for those who are seeing with “kingdom vision” and without this “kingdom vision” resorting to explanation only depreciates the story’s power. As SparkNotes are to a novel, so is the explanation to the parable. Jesus knows this. The most frustrating part of having to explain the parable is that the Rosetta stone for understanding this parable is “in their face” (Luke 17:21). The key to understanding any and all parables is Jesus himself, the Word made flesh, the embodiment of grace.
(unfailing love) and truth (enduring faithfulness). As Jesus states, many prophets and righteous people longed to see this living Word present among them in the here and now.

As people of the living Word, our challenge is to resist further dissection of the explanation given, and look at the story itself in the light of the storyteller. First point. The story is about a farmer. We miss this point often. We so often want to make the story fundamentally about seed. Second point. This farmer is neither efficient nor smart. He is clearly not a science or engineering type familiar with cost-benefit analysis, optimization algorithms, or even basic agronomy. He irrationally and without proper planning recklessly wastes a large amount of seed in places that have little or no chance of growth. That is the main point. The follow-up explanation to the disciples is not intended to reiterate this main point. The disciples were puzzling over the details and Jesus was patient enough to address the specific questions on their minds. Even today, there is little need for explanation on the seeds. If we are listening to our lives, we are quite well versed at practicing a vast array of no-growth strategies in our day to day interactions. While this is an important reminder for disciples of any era, there is no hidden mystery about this facet of the parable.

When Jesus refers to the revealing of “secrets” and “mysteries” of the kingdom of heaven, he is referring to his presence among them. If as contemporary disciples we can finally see beyond ourselves long enough to see kingdom of God in our midst we will take the parable of the sower at face value and understand. It is the parable of the prodigal (i.e. reckless) farmer, not the parable for identifying common causes of insufficient germination. The story is one of radical grace. The Rosetta stone of Scripture is grace.

**Foundations for a Biblical Hermeneutic**

Before expounding on this thesis that the lens of grace is essential for understanding all of Scripture, it is helpful to establish a few principles of how Scripture lives and breathes through our daily lives, from our worship to our engineering. These are only considerations for a Scriptural hermeneutic, not an exhaustive how-to guide.

First, I am going to avoid the term Biblical fundamentalism even though it is part of my faith tradition. It is a term that has been so confused and misinterpreted inside and outside the church that it no longer helpful or valuable for clarification. It either carries the baggage of being too narrowly wrong for some, thus functioning as an ostracizing label. Or it is interpreted to narrowly right for others, thus functioning as a pharisaical label. More recently, it has evolved into a term used in popular media to define those who, fueled by religious beliefs of all types, take matters into their own hands and resort to violent extremes (physical or psychological) to assert their views. Ultimately, when a culture uses a term for too long, it tends to lose its ability to communicate anything beneficial. That said, if there is any thread of continuity in the various manifestations of Biblical fundamentalism essential to maintain a meaningful hermeneutic, it is as Roy Clouser observes that most fundamentalists “…have retained the idea that religious faith should guide the whole of life.” However, due to the confusing cultural baggage tied up in the term fundamentalism, this paper will use the term “radically Biblical”, a term that Roy Clouser has coined to describe an “essentially” or “strictly” Biblical position.
Basing his definition on underlying principles found in Psalms, the prophets, and the New Testament, Clouser states...

...there is no knowledge of truth that is neutral with respect to belief in God. The {Biblical} writers who assert this do not also specify exactly how belief in God impacts “knowledge of all kinds” or “all truth”, but they are clear that they regard beliefs in other (putative) divinities as partially falsifying all that is taken to be truth or knowledge, and that knowing God enables us, in principle, to avoid that partial falsehood.4

While being comprehensive on this score, the Bible is quite terse when it comes to theology and doctrine. It is also short on sociology, business, biology, chemistry, or any other discipline you might want to seek Christian wisdom on. More specifically, any discipline that has predominantly defined its modern identity in the last few centuries (i.e. engineering) will find perplexing the Scriptural ambivalence to its disciplinary concerns. Modern readers of Scripture have tried to compensate for this by either asserting that scripture only illumines the “spiritual” spheres of our existence, while knowledge in the disciplines are discovered through conventional methods of rational conjecture or empirical methodology. Well-meaning Christians loosely use terms such as general revelation or common grace to address this apparent silence of Scripture on the subjects. Others simply are content to shoulder the cost of sporting different outfits for each occasion, the every-day uniform for ordinary life, and the spiritual suit for more religious affairs.

None of these responses to Scripture’s ambivalence are satisfactory from a radically Biblical perspective. ALL knowing is guided and directed by religious belief. This religious belief comes from the creator God through the living word, Jesus Christ, as revealed to us in scripture through the power of the Holy Spirit.

Second, the only Biblical story is the whole Biblical story. In one sense, this is to say, context always matters in exegesis and hermeneutics5. But recognizing context is only one part of this assertion. The entire Scriptural narrative depends on all other Scriptural narrative regardless of its literary forms (i.e. early covenant story, wisdom, prophecy, gospel story, church letters, etc.). There is no complete creation story without the complete redemption, and reclamation story. For example, the most complete and accurate creation story comes not from Genesis, but rather from Colossians 1 and John 1. Standing where we are in the story of God’s people, it would be impossible to understand Genesis without the gospel of John and the subsequent letter to the Colossians. There is also no redemption or reclamation story without an all pervasive fall narrative and the experience of brokeness. Likewise, there is no understanding of the creation story that can circumvent our clouded lens of the fall. Without the Light who was before and in all things, there would be no seeing or hearing at all.

Which brings me back to my original thesis on Biblical hermeneutics. The Rosetta stone of Scripture is grace. The gospel on John says this best...

In the beginning was the Word, and the Word was with God, and the Word was God. 2 He was with God in the beginning. 3 Through him all things were made; without him nothing was made that has been made. 4 In him was life, and that life
was the light of all mankind. The light shines in the darkness, and the darkness has not overcome it.

The Word became flesh and made his dwelling among us. We have seen his glory, the glory of the one and only Son, who came from the Father, full of grace and truth.

Grace and truth are two sides to the same stone. Unfailing love and unending faithfulness are synonymous with grace and truth.

Reading scripture without the Rosetta stone of grace makes a substantial difference in our scientific and technological world. For example, a strong case could be made that both sides of the origins debate in the Christian community have been plagued by the absence of this interpretive key to scripture. The two predominant polarized views of the origins debate are products of the graceless technological secularized framework. One side reads scripture into a secularized framework, the other reads scripture out of a secularized framework. In contrast, the unlocked Genesis story is a rich gracious song of delight, in which the background chorus keeps ringing “it’s good” again and again, the musical pattern clearly is established to emphasize the key relationships. God is God. Creatures are creatures. The musical journey takes us through a cadenza of two other important creaturely relationships beyond the creator to creature distinction. These are the relationship of humans to the rest of creation, and the relationships of male to female. All of this comes together in the finale of goodness and celebrative rest.

The Genesis story is a primer on grace because it is fundamentally a story about relationships. It is a dynamic story that must continually change (unfold, develop, and grow) to stay alive. Predictable or “mechanical” music is bad music. To comment that someone is a “technically” good musician is a nice way of saying that they really are not a musician yet. Predictable and controlled relationships are always unhealthy relationships. Healthy relationships beg for contingency, dependency, mystery, and risk. Such are the relationships established in the creation story.

**Cultural Barriers to the Radically Biblical Hermeneutic**

The problem however does not reside in simply correcting misguided methodologies and assumptions about how to read scripture. The deeper problem is that from our modern cultural vantage point we have managed to find ourselves in a position from which it is impossible to see Scripture. Herman Dooyweerd refers to this as the secularization of science which as he says

“It is vain illusion to suppose that the Christian faith has only to do with the world beyond and nothing to do with science! Secularized science profoundly affects the human heart. From the very moment one accepts it, it accompanies him when he reads scripture and when he says his prayers.”

For Dooyweerd, secularization is not first realized in the rejection of belief, but rather in the declaration of autonomy and the absence of a contingency culture. Albert Borgmann describes this roadblock to the contemporary hearing of the Word, as follows…
“Many of us share the intuition that contemporary life is uniquely inhospitable to Christianity...Our culture seems indifferent to the real message of Christianity and at the same time is eroding the ground that Christianity needs to prosper. There are head-on attempts at bringing Christian doctrine to bear on the life of our society, such as branding our culture as materialist, trying to promote prayer in school through legislation, and seeking to outlaw abortion. But for all their directness, these attempts appear to have little purchase on the deeply underlying problem. Something less direct and more reflective is called for.

A first step in this direction is to recognize that the indifference of contemporary culture to Christianity is, theologically speaking, a problem of grace, of God's presence in our world...Grace is always undeserved and often unforethinkable, and a culture of transparency and control systematically reduces, if it does not occlude, the precinct of grace. A technical term for what lies beyond prediction and control is contingency. What we need to recover then as a condition of receiving grace is the realm of significant contingency.²

This is the problem. The fabric of modern techno-scientific life has created an environment in which we have no other alternative but to exclude the very interpretive heart of the gospel. Just as Neil Postman¹⁰ suggests that certain messages are either incompatible with or redefined by the technological medium used to communicate them, so we continue to try to share the gospel through a cultural medium incompatible with the message. Not only is the cultural medium incapable of conveying the message, the immersion in our techno-scientific culture slowly trains us by habit to engage the message in ways that will re-wire us unreceptive to the message, even if the medium was capable of communicating it. Our technological culture, with its new habits of doing and thinking, has stunted our Scriptural imaginations, analogous to what the internet culture does to our ability to read and know.¹¹ The frequencies of grace in our world have become nearly inaudible to our modern techno-scientific mindset.

**Modern Engineering as Antithetical to the Gospel**

As modern engineers who have been shaped by over a century of scientific hegemony in our field, Borgmann challenges the Christian in the field of engineering to respond to his assertion that modern technology forces a scientific agenda that demands that we pursue the transparency and control of all of life. Transparency as a problem solving practice assumes that all solutions begin with dissection, disassembly, removal of interconnections, and categorization of the parts. The problem solving practice of control assumes that knowledge of the parts leads directly to the independent control of the whole. In contrast, the culture of grace never embarks on a journey without dependency and contingency.

The modern manifestation of engineering in both education and profession is antithetical to the precinct of grace, which renders engineering (and modern science) foundationally incompatible to the gospel. A brief characterization of the last 100 years of engineering education suggests that Borgmann is correct. The nature of engineering (and STEM)
education is uniquely resistant to grace. Modern STEM education is defined by the following practices:

Analyzing (Transparency): The preponderance of early engineering education (despite valiant efforts to change) remains firmly in the grip of the analysis culture. We consciously and subconsciously train engineers that knowing is power and knowing in mathematical abstraction is the highest form of knowing. By our prerequisite traditions, we declare that before you can know anything else of significance, you need to know mathematically. Other methods of knowing, empirical, experiential, or imitational are but imperfect short-cuts needed to fill in the blanks until mathematical knowing can catch up to experience. A diet of calculus, physics, chemistry remains status quo for most college engineering freshman, and the majority of these courses (even at Christian institutions) are taught with the presupposition that to “see through” things, you need to look at them mathematically. As C.S. Lewis recognizes, there is a difference between looking at and looking along.

Modeling (Predicting): Reinforcing this notion of the power of math is the apparent success of mathematical reductionism as a means of taming our world. Fear is a creation of the unknown. Explaining or naming something is often a means of eradicating fear. Being able to predict, even if the predictions are dire, is a means of achieving temporal comfort. Asserting that math is describing the created world is not declaring anything new. As a creaturely language, math has nothing else to express other than what is created in our minds and in our day-to-day experiences of created order. Math cannot transcend creaturely limitations. Human experience can be depicted through math with its ability to bring out the rational hues in creation. Nonetheless, the very premise of the modern scientific engineering is that if you cannot model it, you cannot engineer it. This thesis does not find support either experientially or historically, but it remains the modus operandi of modern engineering.

Optimization (Controlling): Analyzing and modeling are not the property of engineering. Engineers are invited guests, but only if we promise to play by the local rules that lead to transparency and predictability. Optimization is the engineer’s original contribution. Optimization reduces all potential solutions to one right answer. Since the turn of the 20th century, underlying all scientific engineering and management systems is the belief that scientific methodology will yield the solution most consistent with “natural law” in all spheres of culture. Contrary to popular perception, optimization does not “find” the best answer. Optimization is only a means of reinforcing the currently trending notion of progress. In the process of optimization the limited range of right answers is already decided upon before any calculations begin. Optimization is a means of control. Optimization looks at the process, not along the process to the legitimate need. As a result, engineering solutions that circumvent mathematical methods of optimization are often derogatorily referred to as “blow-torch engineering” of “seat-of-the-pants” creations, even when the end result effectively meets a real need.

Efficiency (Valuing): Analyzing, modeling, and optimizing all find convergence in the modern gospel of efficiency. The quintessential modern engineer Fredrick W. Taylor aptly describes this new creation-fall-redemption motif that animates modern culture in his marquee work *Principles of Scientific Management* by declaring…
This paper has been written:

First. To point out, through a series of simple illustrations, the great loss which the whole country is suffering through inefficiency in almost all of our daily acts.

Second. To try to convince the reader that the remedy for this inefficiency lies in systematic management, rather than searching for some unusual or extraordinary man.

Third. To prove that the best management is a true science, resting upon clearly defined laws, rules, and principles as a foundation...principles [that] can be with equal force to all social activities: to the management of our homes; ...our farms;...our churches;...our universities, and our governmental departments. 13

Notice the Fall-Redemption-Creation motifs in points one, two and three respectively. The religious language of “suffering”, “neo-messianic redemption”, and “creational order” is no coincidence. All humans have a Creation-Fall-Redemption narrative. For Taylor, as for our modern culture, this narrative avoids traditional dualisms. The narrative applies to every square inch of human existence.

Until modern culture abandons its obsession with efficiency, their ears will never be open to the gospel. Christians and non-Christians alike find agreement on one point. God is inefficient. He completely abandons economies of scale and the efficacy of standardization. He is unapologetically wasteful in utilizing every potential color, shape, size, skill, ability as he creates and recreates. God loves diversity. The ridiculously overdesigned creation is a glaring testimony to his lack of optimization. He also entrusts the care of this creation to a group of inadequately trained caretakers, opening the door to a myriad of failures as this group tries to get their minds around the vast diversity of interrelationships and the dynamic potential in creation. He has been known to patiently take thousands of years to teach a story of redemption and outline a process of reclamation, leaning heavily on the work of temporary interns and student teachers to point the way.

This truth about God’s inefficiency culminates in the practice of worship, the very act that shapes the core identity of the people of God. As theologian and Jaques Ellul scholar Marva Dawn writes...

To worship the Lord is – in the world’s eyes – a waste of time. It is indeed a royal waste of time, but a waste nonetheless. By engaging in it, we don’t accomplish anything useful in our societies terms...To understand worship as a royal waste of time is good for us because it frees us to enter the poverty of Christ...Worship of such a God immerses us in such a way of life, empowered by a Spirit who does not equip us with a means of power or control...but with the ability and humility to waste time in love of the neighbor. 14

Sowing Seeds of Grace in an Engineering Profession

This puts Christian engineers in a predicament. If modern engineering in the contemporary shape and form that ABET and other accreditation bodies are seeking is foundationally antithetical to the message of the gospel, what place does an engineering
program have at a Christian institution? Or for that matter, on what basis can an engineer legitimately join the modern engineering profession? I would like to suggest that as the exiled people of God we are called to be a subversive presence in a Babylonian culture, so the engineer is called to service in a manner that will seek the prosperity of the culture around us, but do so in a way that does not bow to the local deities.

Right modeling: Modeling will look different for the Christian engineer in more than one way. Recognizing that all theory making is guided and directed by religious belief, not all prevalent theories or models will be embraced or endorsed by the Christian engineer. However, more importantly, a grace-driven engineer enters the act of modeling (mathematical or other form) with the objective of unearthing contingency, rather than predicting reality. The Christian engineer sees the values in modeling as establishing new boundaries of knowing and abstracting, rather than eliminating boundaries to knowing.

Right humility: With a clear recognition of boundaries and the potential for unresolvable mystery, that Christian engineer has allowed for humility to seek temporal solutions to temporal needs within temporal constraints. This frees the engineer from the utopian burdens all too often carried at great expense in the realm of scientific inquiry and technological development. Humility generated mystery is a powerful agent of emancipation.

Right design: The goal of any design should not to be to control, but rather to enable. As Andy Crouch discusses in his book on power12, the gift of power used well will result in a net power increase. The gift of power used to control, requires a net reduction in power as one creature (human or non-human) in creation must relinquish power to succumb to another creature. Design should always result in more net power transfer throughout the creation. This is the definition of designing for creational flourishing.

Right valuing: The Biblical concept of stewardship (of time, money, etc.) frequently gets confused with concepts of efficiency. This is unfortunate. The call to Biblical stewardship is a call to waste our time and energy in the tasks of creating, loving, and caring. The goal is rarely to make things cheaper, faster, or easier. In fact the goal in the Biblical concept of stewardship is to recklessly waste our time, money, and resources in the act of loving our world and all the creatures in it (humans and non-humans). This may mean cutting costs or time to better enable flourishing. But is also might mean embracing toil, suffering, and inefficiency in order to cultivate in the world around us a receptivity to grace. As Borgmann responds to those pursuing the technological promise of the eradication of trouble from the human condition, he states "Trouble is often the twin of grace, and if one cannot prosper, neither can the other"15. As hard as this may be for the modern engineering mindset to stomach, sometimes flourishing will involve a journey alongside pain, not a solution to the problem of pain. The motivations and designs of a Christian engineer should reflect this.

Preventing the Soil for Grace via an Engineering Curriculum

Grace by its very nature resists controlling, so to suggest pedagogical techniques designed to conjure up more grace in those who study engineering would undermine the
thesis of this paper. The goal of the Christian engineering instructor is not to teach grace, but rather to teach engineering in a manner that provides no barriers to grace. What does preparing the soil of our hearts to receive grace look like in the engineering curriculum?

First of all, no two classes should look the same. A course on design will approach this very different from a course on engineering economics, or a course on engineering analysis.

We recently piloted an example of grace cultivation in a technically abstract course taught in our program at Dordt College (Engineering 170: Programming for Instrumentation and Automation). The course was designed to teach structured programming to students in the context of instrumentation and automation components. It is a project-based class using tools such as Matlab and LabView. Initially, this course seems to be a poor candidate to explore overarching themes of grace receptivity. However, it is often in these abstract courses, that the unearthing of the theoretical presuppositions buried deeply in the course material provides a perfect stage for the surprise appearance of grace. Grace thrives on unexpected entries.

These two primary goals of the course are intended to develop of engineering habits that in many ways are independent of course content. Many students will not be aware that these objectives are designed specifically to cultivate grace receptivity. The first habit is the practice of embracing failure. Central to programming is the unexpected complication. Most of the time students spend in this course will be “wasted” time as they muddle around dead-end paths, patiently trouble-shoot, and experience unexpected results through tedious exploration. Practicing patient tenacity at any level is a preparation for grace receptivity. Secondly, an emphasis is placed on the development of technical empathy. Under the guise of effective GUI development is the more important recognition of an infinitely diverse human community being served by the developer’s program. This is a challenge, since a program that can only communicate in black and white, needs to accommodate a range of users with a spectrum of experiences, abilities, and assumptions.

On the content side of the course, the class explores through a series of scriptures reading, essays, and book excerpts the cultural concept of “Boolean thinking”. After a nearly a generation with computers, it is becoming evident that the proponents of a future with artificial intelligence have their primary thesis inverted. The artificial intelligence community claims that we will someday have computers that learn more like computers, what is disconcerting is that rather than computers becoming more like humans, our experience suggests that humans are becoming more like computers. We are becoming constrained by “Boolean thinking”.

It is good to first recognize that at the root of doing computer technology is Boolean thinking. While the complexity of today’s programs and applications mask this reality well, the reality has not changed. Computer technology has only a “1” or “0” to offer. Apart from the human interface, the “both-and” or the “maybe” results are not a possibility for digital machines. What is important to recognize, is that Boolean thinking is not an invention of our modern era. Boolean thinking is an ancient construct. It is a construct with the following characteristics:
1. The absence of any "maybe", "both/and", "almost there", "already here and yet to come" conclusions.
2. The rational assumption of "one best way" for everything.
3. An understanding of everything in black and white (either/or) categories.
4. The "predefined optimal process" and "generated results" are the only measures of importance (evaluated as "True/Win" or "False/Loss"). The journey is irrelevant.

As a whole, scriptural narrative is black and white. You are either in the light (Christ) or in darkness. In this sense the gospel is truly Boolean. Grey is not an option. However, while these two Boolean states prevail in and through scripture, the logical cause-effect paths of Boolean operators are conspicuously absent.

For this reason, the essays and readings of this class move through a series of readings intended to help students identify Boolean thinking in historical narrative and recognize how it emerges in conflict with the Biblical culture of grace. Each reading asked the students to reflect on how exposing absolutized Boolean thinking can make a difference in how they do their engineering design, analysis, or programming. It should also become evident to students that the key to understanding scripture is to understand grace. The all-of-life concept that is often foreign in the modern work and practice of engineering. An annotated summary of the semester assignments are provided in Appendix A.

The Conclusion of the Matter

The teacher in Ecclesiastes says it well, when he declares that we now have heard it all and concludes in chapter 3 and again in chapter 12, that there is an irrational mystery that trumps the chaotic irrationality of life. It is this. God picks up the pieces16. In one of the most graceless books of the Bible, the punch line can only be interpreted via grace. Not only the book, but meaning itself (i.e. life itself ) is nothing apart from this lens. Humans have nothing better than to eat, drink, work, and take existential pleasure in their engineering, but only because we know that God picks up the pieces. A grace full engineer will never forget this.

References

[1] Examples of foundational works in the philosophical-perspectival development of Christian engineering and technology:


[4] Ibid., p. 95.


[8] Ibid., p. 3.


Appendix A: Example of Engaging Grace frameworks in the Engineering Classroom

EGR 170: Programming for Instrumentation and Automation
Dordt College Engineering Department
Readings and Reflections on Boolean Thinking

Instructor’s Note: The planned rhythm of this reflection component is as follows. The students are asked to read the passage or excerpt before the next class. During the class we briefly reflect on the key points. The instructor suggests a particular hermeneutic related to the content of the class. Based on this commentary and their reading, students will submit an essay response before the following week.

Reading Response Essays: Students will be asked to write brief weekly response essays (approximately 100-300 words) following their reading of scripture, essays, or articles. To receive full credit, responses must be clearly communicated. These responses will be submitted electronically on Canvas@dordt. Students are asked to reflect on the following prompts:

Essays are evaluated on whether a thorough understanding of the reading is articulated and how well the arguments are communicated and supported.

WEEK 1 & 2 - READ - Psalm 115
Reflecting on the Boolean Culture: Professor Brue asserts that the way we think is influenced by the "Boolean mindset" more than we are aware of. Characteristics of the "Boolean Culture" are...

1. The absence of any "maybe", "both/and", "almost there", "already here and yet to come" conclusions essential to the Biblical narrative.
2. The assumption of "one best way" for everything
3. An understanding of everything in black and white (either/or) categories
4. The "predefined process" and "generated results" are the only measures of importance (evaluated as "True/Win" or "False/Loss"). The journey is irrelevant.

Boolean culture preceded (and gave birth to) the computer culture. However, the computer culture also shapes the way we think. Many technological futurists believe that computers will soon "think like humans". On the surface this may appear to be happening. However, it may be closer to the truth that humans are thinking more like computers and less like humans. This is a Biblical theme. We tend to worship what we make. When we worship what we make, we become more like what we make and less like who we were created to be.

1. Summarize the main point that the passage is trying to make?
2. How does the instructor connect this passage to this class? Do you think the argument has validity? Why or why not? Can you illustrate or refute with example?
3. How might programmers or engineers do their technical work differently after reading the assigned passage?

Instructor’s Note: The key theme to develop in this reading is how inanimate constructs of our own making, easily become idols. But this is not the end of the story, once a human-molded
creature has been idolized (e.g. such as in the absolutizing of Boolean thinking), we don’t simply worship it, we become like it. The goal is to have students recognize contemporary idolatry potential.

WEEK 3 & 4 - READ - II Kings 5 and Borgmann essay
1. Summarize the main point that the passage is trying to make?
2. What is the main point of the Borgmann reading? How is this related to II Kings 5?
3. How does the instructor connect this passage to this class? Do you think the argument has validity? Why or why not? Can you illustrate or refute with example?
4. How might programmers or engineers do their technical work differently after reading the assigned passage?

Instructor’s Note: The story of Naaman has a wonderfully rich cross-section of characters all who hold certain cultural “Boolean” conditionals as absolute. As a result, each tries to create a new God of Israel in their own image (Namaan, the kings of Aram and Israel, and Gehazi). This manufactured image prevents them from truly seeing the kingdom of grace. The only characters in the narrative who have their ears open to the irrationality of this kingdom are the most unlikely ones, a slave girl and a servant of Aram. The goal is to have students recognize that accepted contemporary practices and constructs (as mundane and ordinary as “how healing happens”) have the potential to occlude grace without a person seeing it. The answers that the digital age gives us to what it means to “know” occlude grace, as Borgmann asserts.

WEEK 5 & 6 - READ - Jonah
In the context of your previous reading of Borgmann and your re-reading of Jonah...
1. What strikes you anew about the story of Jonah as you read it again (and possibly as you place it in the context of your coursework and extra course readings) for this class?
2. What is it in the “worldview framework” of Jonah that places him in the category of our modern technology (re-read the first three paragraphs of the Borgmann article for review)?
3. How is Jonah a very “modern” or “boolean thinker” when it comes to his understanding of how the world works?
4. What is the Biblical concept of idolatry (as noted in class)...How can a deep seated belief in God be a form of idolatry...what types of idolatry are presented in the Jonah story?

Instructor’s Note: The story of Jonah is a powerful tragedy. A sometimes humorous, but always sad story of an idol created in a near likeness of the God of Israel – but without the characteristics that have always bothered us about God. The perfect God for a culture of transparency and control would stick to the prescribed operation. Disobedience = damnation.
To conclude otherwise would be analogous to getting a wrong answer in math class and opting to change the rules of addition to make it right.

WEEK 7 & 8 - READ - Philemon

1. What is the letter to Philemon about?
2. Why do you think the letter to Philemon is included in the canon of scripture that we include in our Bible?
3. Is the message of the book of historical interest only?
4. How does it speak to the world we live in today?

Instructor’s Note: It is good for students to ask why the church (led by the spirit) moved to include a book like Philemon in the Biblical canon. At first glance, it looks like we are reading someone else’s mail. However, the passage is not about a particular slavery incident. It is clearly a radical counter-cultural statement about the illegitimate hegemony Boolean thinking when it comes to place, station, and value of any human being (even Philemon). If the story unfolds as Paul hopes, it is Philemon who eventually gets his cultural chains broken. If this happens, receptivity to grace has again been realized.

WEEK 9 & 10 - READ - Colossians 1:1-14

READ: Colossians Remixed: Subverting the Empire, by Brian Walsh and Sylvia Keesmaat, Read Chapter 2 and Chapter 3.

You have read Albert Borgmann (in the excerpt from Power Failure) who discusses on a personal level how our culture of transparency and control (often the predominant culture of the digital technology industry) creates an environment hostile to the gospel way of life (which is a life of contingency and grace). In the book of Philemon, we read someone else’s mail from a culture that we are not entirely familiar with. In understanding the context of the Roman empire, we begin to understand the relevance of the letter for our time and place. Slavery was the machinery of the empire culture, it was the technological mechanism of control - the assumed way in which things get built and produced. Paul says that the gospel message of freedom trumps the cultural machinery of the day and continues to do the same for us today. The narratives and translations from Colossians Remixed help us to see the "new machinery" of our day.

1. How does this "re-telling" of Colossians relate to our information and technology culture today?
2. How might programming development and information system design look different for Christ followers when we recognize the prevailing "empire" assumptions in today's world?

Instructor’s Note: We scarcely recognize the cultural machines that surround us. The system assumptions are often the hardest uproot, because they often come with “natural law” baggage that declares them as “the way it works”...as sure as gravity. Recognizing these in the digital culture is not an easy task. The resurrected Christ changes everything. At this point in the semester we begin to design and develop feedback control systems, so the notion of control becomes real as a technical tool.
The following example passages are often used to reinforce the theme that the Rosetta stone of scripture is grace, since without that interpretive key, existential discontinuities and conflicts within Scripture itself will arise.

Examples: Ecclesiastes 3, the Beatitudes, many different “the kingdom is like…” parables, the prodigal God parable, Joshua and Jericho, along with many other stories often misapplied.
Biomimetics and Bio-Inspired Engineering  
from a Christian Perspective with an Emphasis on  
Optimization and Control Examples in God’s Creation  

Frederick G. Harmon

Introduction

Biomimetics, the mimicking of elements of nature and using the designs in engineering applications, and bio-inspired engineering, the learning of principles from nature and using them as inspiration for engineering designs, are relatively new research fields [1]. Because biomimetics (or biomimicry) and bio-inspired engineering involve studying elements of God’s Creation, then Christian engineers and scientists can gain insight into the handiwork and knowledge of God (Psalm 19:1, Colossians 2:2-3) [2]. Because God created everything in the universe in six days before the Fall and said that everything was “very good” (Genesis 1:31) [2], the original Creation was perfectly designed, optimized, and controlled. In other words, He was the perfect designer and engineer for everything in the universe. God’s designs did not stop after the Fall, for God revealed to Noah what could be considered an “optimal” design for the ark to withstand the extreme conditions of the Genesis Flood. After the Fall, the Curse, and the Genesis Flood, Christian engineers and scientists who study God’s Creation can still gain insight into His designs and creativity and apply the ideas and knowledge gained to various engineering challenges, albeit tainted by sin and a decaying universe (Romans 8:20-22) [2]. The Christian engineer’s responsibility is to give God the glory acknowledging the source of the wisdom and knowledge as they learn and apply the insight gained.

Examples are provided that illustrate how engineers have been able to learn and receive inspiration from God’s Creation, specifically biological creatures, and apply that knowledge to engineered systems, with an emphasis on optimization and control examples. In the area of optimization, several bio-inspired examples are provided that can be formulated as constrained nonlinear optimization problems such as human-engineered cochlea and the design of synthetic gene circuits. In addition to optimization, examples are provided for feedback control systems such as the nonlinear flight control of insects and birds, central pattern generators in the spinal cords of creatures such as lobsters, and artificial neural networks.

Finally, included in the paper are student assessment data obtained after providing biomimetic and bio-inspired examples in undergraduate engineering courses at Cedarville University. The feedback from the students was very positive and encouraging. This paper is intended to be an introduction to the topic of biomimetics and bio-inspired engineering from a Christian engineer’s perspective and forms the foundation for follow-on research and publications in this area.

God: The Perfect Designer and Engineer

The Biblical lens used in this paper is a literal interpretation of the Creation account in Genesis in which the heavens and the earth were created in six twenty-four hour days. God reveals in the first thirty-one verses of Genesis, Chapter 1, that everything in the heavens and universe was
created in six literal days [2]. Since the act of Creation was before the Fall, the Curse, and the Genesis Flood, that world is unknown to us except for the insight given to us in the Scriptures and possibly from other sources such as archeological discoveries. One key phrase that God reveals to us about the Creation was that everything was originally created “very good” (Genesis 1:31) [2]. More details concerning the term “very good” will help Christian engineers understand what the original Creation may have been like.

What is meant by the term “very good”? One researcher states:

God’s “very good” creation only occupies two chapters of the Bible before Satan and sin enter in Chapter 3 of Genesis, but the Hebrew word, towb (good), is used throughout the Old Testament. It is a word used to describe the “fair” and “beautiful” Esther (Esther 1:11; 2:7), the “best” men (II Kings 10:3), and the “better” of a host of comparisons (Genesis 29:19, et al.). “Bountiful,” “fine,” “joyful,” “pleasant,” “precious,” “prosperity,” and “sweet,” are just a few of the many other translations of the word which God had used to describe His creation before sin entered it.

God saw that His creation was “good” six times throughout the creation week (Genesis 1:4, 10, 12, 18, 21, 25), but at the end of the sixth day (Genesis 1:31), He pronounced it very good. If we could take all of the above adjectives and put them into one incredibly descriptive word and then add exceedingly to all of that, we might begin to have an idea of what God’s creation was like. [3]

The assumption is made that the term “very good” means the original Creation was perfectly designed and optimized. More specifically, from an engineering perspective, it was originally designed and optimized for a purpose, and then perfectly controlled. God was the perfect designer and engineer for everything in the universe. After the Fall, the original, perfect design will never be known, but the assumption can be made that the original design was perfect for its original purpose. Today, as engineers study the fallen Creation, insight into the original design can still be gained but the study and analysis requires a tremendous amount of effort.

If Christian engineers know that God originally created everything “very good,” what perspective should they have about Creation and what can they learn about it to apply to their engineering disciplines? They can know that the world that we see now was originally created by God to be “very good” but the Curse has caused it to be in a degraded state. The degraded state now includes “thorns and thistles” which causes difficulty in seeing the original design (Genesis 3:16-19) [2]. This does not mean that the designs should be ignored since there are many remnants of the original Creation that engineers can implement and apply to their disciplines. Through labor and increased effort, glimpses of the original design can be seen and the knowledge applied to various applications.

Optimal Designs Given to Man by God

Even after the global flood, God revealed and illustrated His optimal designs by providing an optimal design for the ark to Noah to withstand the turbulence and extreme conditions of the
Genesis Flood. Researchers have studied the design and have come to the following conclusion concerning the optimal structural design of the ark and its stability:

In conclusion, the Ark as a drifting ship, is thus believed to have had a reasonable-beam-draft ratio for the safety of the hull, crew and cargo in the high winds and waves imposed on it by the Genesis Flood. The voyage limit of the Ark, estimated from modern passenger ships' criteria reveals that it could have navigated sea conditions with waves higher than 30 metres. [4]

The researcher’s conclusion revealed that the ark was an optimal design to protect the crew and the animals during the sea conditions that God foreknew would occur during the Genesis Flood such as waves in excess of 30 m. If the conditions were not going to be as extreme, then God very likely would have given Noah a slightly different design that did not need to withstand such cataclysmic waves. God knew the exact structure and size that would be needed to safely carry all of the crew and animals and provided this optimal design to Noah.

For comparison, the 1991 perfect storm, a nor’easter that developed to the south of Nova Scotia, reportedly had a wave of approximately 30 m:

Aside from tidal flooding along rivers, the storm's effects were primarily concentrated along the coast. A buoy off the coast of Nova Scotia reported a wave height of 100.7 feet (30.7 m), the highest ever recorded in the province's offshore waters. In the middle of the storm, the Andrea Gail sank, killing its crew of six and inspiring the book, and later movie, The Perfect Storm. [5]

The design of many modern ships cannot withstand waves of 30 m since those conditions are typically not encountered. However, because God foreknew those conditions would occur during the flood, He provided a design to Noah that could survive in those sea conditions.

As given in Genesis, God has revealed His optimal or “very good” designs in Creation but also has given them directly to men such as Noah, when needed, to protect His remnant. Whether God has optimally designed an animal such as a bird or fish or has provided a design such as Noah’s ark, Christian engineers can mimic or learn from His designs. In addition, Christian engineers can acknowledge that the design is from Him. The rest of the paper will focus on optimal designs in biological creatures and how Christian engineers can learn from them.

**Christian Engineers can Learn from God’s Creation**

For Christian engineers, learning from biology and Creation with the perspective that God is the “perfect designer and engineer” and applying that knowledge to engineered systems is an exciting endeavor. God created the fish in the sea, the birds of the air, and the land animals and the study of them can reveal the Designer’s knowledge and understanding considering that the original design was “very good.” Since the Fall and the Curse, animals and the rest of Creation have been decaying (Romans 8:20-22) [2], but Christian engineers can still study and gain insight into God’s design. As engineers and scientists study God’s Creation, a better understanding can be gained of His excellent wisdom and knowledge and that insight can be
applied to problems in engineering. Christian engineers with a perspective that they are learning from God’s Creation is in contrast to the views of most engineers and scientists of today.

In general, evolutionists believe that random processes over millions of years resulted in the animals and plants that are observed today. Their logic is that we can learn from millions of years of evolution since it had a “head start.” One common concept in the evolution circles is the idea of uniformity which assumes that the conditions on the earth have been approximately the same for millions of years. God foreknew the extreme conditions of the global flood, but He also foreknew that scientists in the last days would believe in uniformity instead of cataclysmic events such as the global flood as predicted in 2 Peter 3:2-7:

that you should remember the predictions of the holy prophets and the commandment of the Lord and Savior through your apostles, knowing this first of all, that scoffers will come in the last days with scoffing, following their own sinful desires. They will say, “Where is the promise of his coming? For ever since the fathers fell asleep, all things are continuing as they were from the beginning of creation. For they deliberately overlook this fact, that the heavens existed long ago, and the earth was formed out of water and through water by the word of God, and that by means of these the world that then existed was deluged with water and perished. But by the same word the heavens and earth that now exist are stored up for fire, being kept until the day of judgment and destruction of the ungodly. [2]

For Christian engineers, there is comfort in knowing that God knew that many would believe in ideas such as evolution in the last days. This can give Christians confidence in the Scriptures and encourage them to trust His Word concerning matters of science and Creation. Christian engineers should have a strong motivation to learn from Creation such as designs in plants and animals. They were created by God for a purpose and we can learn about His designs by studying His Creation. It is encouraging to know that He is the source of all wisdom and knowledge (Colossians 2:2-3) [2], and that knowledge has been used in Creation, and not millions of years of random processes.

In the book of Job, God asks Job a number of questions about His Creation in chapters 38-41 [2]. Job was not present during the Creation of the world and God makes that point very clear (verse 38:4). It is clear from the dialogue in these chapters that Job does not understand everything about the Universe but since God was the Creator, He does completely understand His Creation. Another verse which clearly explains that God is the Creator of the details in the universe is Proverbs 20:12 which states “The hearing ear and the seeing eye, the Lord has made them both.” [2]. As engineers, we can study the design of the God-created sensors and other components of Creation to determine if the principles can be applied to engineered designs.

The terms that are currently used in the engineering community to describe copying or learning principles from Creation are biomimetics (i.e., biomimicry) and bio-inspiration [1]. Biomimetics is defined as:
the study of the formation, structure, or function of biologically produced substances and materials (as enzymes or silk) and biological mechanisms and processes (as protein synthesis or photosynthesis) especially for the purpose of synthesizing similar products by artificial mechanisms which mimic natural ones. [1]

A key word in the definition is to “mimic” or copy the natural design. Bio-inspired, however, means to gain insight or inspiration from the design to apply to the design of products, mechanisms, or processes. From a Christian engineering perspective, because biomimetics and biomimicry involve studying elements of God’s Creation, then Christians (and non-believers) are gaining insight into the handiwork and knowledge of God (Psalm 19:1, Colossians 2:2-3) [2].

Scientists have published many papers on biomimetic topics in recent years and a word cloud published by Lepora is given in Figure 1 [6]. The data in the word cloud is taken from approximately 18,000 publications and the size of the word corresponds to the relative number of uses of the term in the publications. The term “biomimetic” occurs in about 17.5% of the publications. The terms design and control occur in about 6.8% and 6.7% of the papers, respectively.

![Figure 1: Common Topics in Biomimetics - The size of the word in the word cloud corresponds to the relative number of papers that included the word in the title (note the relatively large size of the words design and control; the terms neural network and optimization are also in the word cloud) [6].](image)

Christian engineers can learn from God’s Creation since He was the supreme engineer. Even though God may not be given credit in the publications, design optimization and controls examples will now be provided that illustrate that engineers are learning from God’s Creation and either are copying the designs or developing applications that are inspired from the Creation.

**Optimization Examples from God’s Creation**

Optimized designs can be found in God’s Creation which reflect His handiwork. The optimization examples from the literature emphasized in this section are those that can be formulated as constrained nonlinear optimization problems (i.e., nonlinear programming). However, before examples are given, some discussion concerning the lack of biomimetic examples in the literature involving optimization is warranted.
Many scientists believe that due to evolution, there are not necessarily optimized designs in nature. In fact, it can be difficult to find optimization papers in the literature concerning the optimal design of animals because it may hint at an intelligent Creator. Alexander explains this in his paper entitled “Design by Numbers” which was published in the Nature magazine:

The suspicious attitude of many biologists to optimization theory is exemplified by one of the anonymous reviewers of my proposal for a book that I am currently writing. He or she complained that my outline emphasized optimization of design, “whereas evolution by natural selection often yields suboptimal but adequate design.” A comparison of squid and fish might be used to support this view. Squid swim more slowly than typical fish of similar size, but use more energy in the process. The point that has to be understood here is that evolution is constrained by ancestry. A squid is clearly not the best possible swimmer, but it may be close to the best that can be evolved from a mollusk ancestor. … In mathematical language, the squid has failed to reach the global optimum, but it may well be near to a local optimum. [7]

The reviewer for Alexander’s paper did state that “‘this is not to suggest that optimal design does not apply in some cases’” [7]. To paraphrase, the concept is that the end result has been constrained by evolutionary processes and the resulting design is not an optimized design but it is adequate. From a Christian perspective, if God has created everything, He did create everything for a purpose and could have placed constraints on the design as He saw best. The decay and groaning of the universe since the Fall has placed different constraints on the design and the designs now could definitely be suboptimal. This can be viewed from a mathematical perspective of designs satisfying local minima as compared to global minima. Just as Job did not understand all of the details about Creation, engineers today never will either, but God knows exactly how everything was originally designed and how it has decayed after the Fall. The Christian engineer’s responsibility is to study the different designs and gain insight into possible optimization formulations to subsequently determine the best application of the principles.

Alexander, in his paper, highly recommends the work by Parker and Smith entitled “Principles of Animal Design: The Optimization and Symmorphosis Debate” published in 1998. The Dictionary of Biology defines symmorphosis as:

A hypothesis, proposed by Ewald Weibel and Charles Richard Taylor in 1981, postulating that biological systems adhere to an ‘economy of design’ giving a close match between their various structural and functional parameters. Hence, no single parameter in the system has unnecessary excess capacity, beyond the requirements of the system. The hypothesis was tested initially by analyzing the mammalian respiratory system. Here it was found that, except for the lungs, the structures of the oxygen-transfer system, including blood, heart, muscle capillaries, and mitochondria, are well matched to the functional capacity of the system. However, components often serve in more than one physiological system; for example, the blood and blood vessels are also parts of the excretory
system. Therefore, apparent spare capacity in one system might be needed for another system. [8]

Concepts such as symmorphosis point toward a Creator due to the complexity of design and the efficient use of components for multiple systems. God knew how to design components which could be used for the oxygen-transfer system but also the excretory system. Do we know how to design a single system that can be used to supply water to a house but also can remove waste from a house? Typically, the systems are separate and could be argued not as well designed or efficient as God’s designs.

A bio-inspired design and optimization example that involves nonlinear programming is the design of a silicon cochlea circuit. Kirk describes the circuit as a “biologically-motivated analog VLSI circuit” [9]. The researchers used nonlinear programming to design a cochlea which was a cascade of lowpass second-order filters. The search direction technique primarily used for the constrained optimization problem was a gradient descent technique. The parameters determined from the optimization were the bias settings for each of the filter stages. As a result, optimization was used successfully to design a circuit that closely matched a biological design that was originally created by God.

Another example in the literature using optimization methods based on a bio-inspired design of synthetic gene circuits uses mixed integer nonlinear programming:

Current optimization methods for synthetic gene design rely on heuristic algorithms that are usually not deterministic, deliver sub-optimal solutions, and provide no guaranties on convergence or error bounds. Here, we introduce an optimization framework for the problem of part selection in synthetic gene circuits that is based on mixed integer non-linear programming (MINLP), which is a deterministic method that finds the globally optimal solution and guarantees convergence in finite time. Given a synthetic gene circuit, a library of characterized parts, and user-defined constraints, our method can find the optimal selection of parts that satisfy the constraints and best approximates the objective function given by the user. We evaluated the proposed method in the design of three synthetic circuits (a toggle switch, a transcriptional cascade, and a band detector), with both experimentally constructed and synthetic promoter libraries. [10]

It is clear from these examples that engineers are learning from God’s design and applying principles to the design of circuits and components for human-engineered systems.

Optimization and using specific programming techniques such as nonlinear programming to analyze the designs in God’s creation could be used in many situations. Leonhard Euler, a Swiss mathematician and physicist, stated in his famous 1744 quote referred to as the principle of least action or the fundamental variational principle, “For since the fabric of the universe is most perfect and the work of a most wise Creator, nothing at all takes place in the universe in which some rule of maximum or minimum does not appear.” [11] Since wisdom, knowledge, and creativity were used by God in the design of the universe, Christian engineers can learn from previous scientists such as Euler to understand how more can be learned from God’s Creation.
In addition to using optimization to study God’s design, Christian engineers can learn about feedback control systems in God’s created beings.

**Feedback Control Examples in God’s Creation**

God created the universe including the insects, land animals, birds, and fish. The study of these creatures reveals intricately-designed feedback control mechanisms. Feedback control and control design has been taught for decades in colleges and universities and used in industry, but researchers are gaining insight into other feedback control approaches by studying His Creation. Recent examples include nonlinear flight control in flapping insect wings [12] [6], hierarchical control in the form of central pattern generators [13], and intelligent control such as neural network control [14].

**Nonlinear flight control:** To advance the field of nonlinear flight control and obtain bio-inspired ideas, novel methods to understand and learn from God’s designs are critical. Researchers from the University of Oxford “have demonstrated the practicality of making measurements of the rigid body motions of a free-flying bird simultaneously with measuring the control inputs the bird applies through motions of its tail” [15]. They are attempting to obtain a systems-level understanding of the dynamics of flight control with possible application to engineered systems [16]. They have concluded “that a small bio-inspired aircraft with flexible wings and a variable-geometry horizontal tail might successfully execute flight manoeuvres in a rather different fashion to today’s fixed-wing unmanned air vehicles” [15]. Researchers at Harvard University proposed a single-loop adaptive flight control suite inspired by the agility of flying insects [17]. A prototype of their bio-inspired robotic fly is shown in Figure 2.

**Central Pattern Generators (CPGs):** Flapping flight for small micro aerial vehicles is being investigated by numerous researchers. Chung has investigated the use of coupled limit cycle oscillators to model CPGs which are found in numerous animals to govern rhythmic motion such as flapping wings or the coordinated motion of tails such as in lobsters [13]. The CPGs are not found in the brain but in the spinal cord. Chung states:

> The central pattern generators of animals are neural networks that can endogenously (i.e., without rhythmic sensory or central input) produce coordinated patterns of rhythmic outputs. Hence, CPGs are believed to reduce the computation burden of the brain. [13]
God’s design reveals that in order to control rhythmic motion, controllers apart from the brain would be the best approach to minimize the computational burden of the brain. Figure 3 shows a control structure utilizing a CPG to reduce the computations required in the controller for the outer loop.

![Control Structure Utilizing a CPG Network to Reduce the Computational Burden of the Brain](image)

**Figure 3: Control Structure Utilizing a CPG Network to Reduce the Computational Burden of the Brain /13/**

**Spiking Neural Networks (SNNs):** Inspiration can be obtained from the brain architectures of insects and mammals designed by God and applied to the control of more advanced engineered systems. Scientists, biologists, and engineers are learning more in the areas of computational neuroscience, neuromorphology, and biomimetics and have discovered that insects, birds, and mammals have numerous sensors and actuators that are controlled efficiently by the brain. The creatures are equipped with numerous sensory channels that receive data that are integrated and used to make decisions. The sensory channels include vision, acoustic, and touch. This type of architecture with numerous sensors, controllers, and few actuators is in contrast to current engineered systems that have a few sensors, complex controllers, and actuators [18]. For example, flies have 338,000 neurons in their brain (98% are used for sensor processing) and receive sensory inputs from 80,000 receptor axons [18]. The current architecture of modern engineered systems typically involves few sensors, significant computations; whereas, God’s design in flies appears to be numerous sensors, extensive signal processing and relatively few computations for the command signals. As nonlinear systems such as sensor networks and robots more closely mimic God’s design in the area of structures (e.g., morphing wings) and aerodynamics (e.g., flapping wings), control systems will be required that more closely mimic biological systems.

Another control example of learning from God’s Creation and potentially applying the gained knowledge to the design of engineered systems is intelligent control such as neural networks. Artificial neural networks (ANNs) are very beneficial and suitable as controllers for highly
nonlinear systems operating in uncertain conditions since they do not rely on a system model and have excellent learning and adaptive capabilities. In the literature, there are three generations of ANNs [19]. The first generation of ANNs are based on McCulloch-Pitts threshold neurons. The second generation uses continuous activation functions to compute the output. The third generation are spiking neural networks (SNNs). SNNs resemble biological neurons much more closely than the previous two generations and permit spatial-temporal information to be encoded. Real neuron networks exhibit numerous behaviors due to the nonlinear dynamical elements (spiking neurons) and the timing delays. SNNs use the timing of short electrical pulses (spikes or action potentials) to transmit information. The spikes travel along synapses that connect two neurons referred to as the pre-synaptic neuron and the post-synaptic neuron. The post-synaptic neuron will generate a spike if enough pulses arrive in a short amount of time or if a specific threshold is reached. SNNs have a relatively short research history and much more research needs to be conducted.

One of the most recent extensions to SNNs is the concept of polychronization as defined by Izhikevich [14]. Polychronization is seen in SNNs when groups of cells are time-locked but are not synchronized. Izhikevich has demonstrated that polychromous groups [14] exist in the human brain and the number of groups can far exceed the number of neurons in the network. Spiking neural networks (SNNs) that use concepts such as polychronization could open up new avenues in the field of control in areas such as sensor networks, autonomous navigation, robotics, and distributed power networks.

Learning from animals in areas such as nonlinear flight control, CPGs, and SNNs in God’s Creation and applying the principles to engineered systems will inspire young engineers, improve engineered systems, and glorify God in the process.

**Student Assessment Data**

Student assessment data was collected concerning biomimetic and bio-inspired engineering examples discussed in controls and optimization courses from the perspective of God as the Designer and Creator. The examples were typically given at the beginning of class and discussed for several minutes. Five multiple-choice questions were included in the survey along with one short answer question (see Figure 4). Please note that for Questions 1-4, the more “positive” responses are the first two choices. For Question 5, the students were asked about the number of details desired for the examples which does not have a “positive” or “negative” answer. The survey results for the first four questions from a Systems Optimization elective class of six mechanical engineering students are shown in Figure 5. The same students were in a previous controls course taught by the author in which bio-inspired controls examples were given but the survey was not given to the students in the controls course. Five out of the six students responded to the anonymous survey. The average score for Questions 1 and 2 is 4.8 indicating the students enjoyed hearing about the different examples. The maximum score of 5 corresponds to the first answer in each question. The scores for Questions 3 and 4 averaged about 4. For Question 5, most of the students (4 out of 5) preferred “Some details” when biomimetic and bio-inspired engineering examples are given in class.
Survey: Bio-Inspired Engineering/Biomimetics/Creation Examples in Courses
* Required

1. Do you enjoy the instructor providing bio-inspired engineering/biomimetic/Creation examples in class if they relate to the class material? *
   - Mark only one oval.
     - Strongly Agree
     - Agree
     - Neutral
     - Disagree
     - Strongly Disagree

2. Do you think we can learn from God's Creation in ways that will help engineers in their field (for example, control systems or structures in animals)?
   - Mark only one oval.
     - Strongly Agree
     - Agree
     - Neutral
     - Disagree
     - Strongly Disagree

3. Do bio-inspired engineering/biomimetic/Creation examples help strengthen your Christian faith?
   - Mark only one oval.
     - Strongly Agree
     - Agree
     - Neutral
     - Disagree
     - Strongly Disagree

4. Do you think learning about God's design and His Creation can help us be a good witness to others (e.g., help others view nature as God's design vs. a result of random processes)?
   - Mark only one oval.
     - Strongly agree
     - Agree
     - Neutral
     - Disagree
     - Strongly Disagree

5. When biomimetic/bio-inspired engineering examples are given, do you prefer a top-level explanation or many details?
   - Mark only one oval.
     - Top-level description
     - Very few details
     - Some details
     - Many details including equations

6. Please provide additional comments related to using bio-inspired engineering/biomimetic/Creation examples in class.

Figure 4: Survey for Bio-Inspired Engineering/Biomimetic/Creation Examples

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The feedback from the students was very positive and encouraging including comments such as “Just want to say thank you! These have been great examples of optimization that relate very well to my faith and are a good way to connect to others who may be struggling with the idea of a Creator. Please keep giving them!” Based on the results of the survey, additional time is justified learning from God’s Creation, obtaining research results from others on God’s design and Creation, and presenting those examples in courses.

**Made in His Image**

Before concluding, a final note will be discussed concerning man being made in the image of God and how it relates to Christian engineers. Because man was made in the image of God, He has given engineers (Christian and non-believers) a “portion” of His creative ability and they can use that creative ability to design (e.g., optimized systems). However, the Gospel is the means by which a believer is transformed into the image of their Creator (Colossians 3:10; 2 Corinthians 3:18) [2]. Thus, the Christian engineer or scientist is best equipped to reflect this creative work given by God. As a believer conforms more and more to be like Christ, then God increasingly provides knowledge and creativity to become more like Him.
Man is made in the image of God and the engineering abilities that He gives man mirrors God's creative work. The human race is a part of His Creation so they can reflect that creative ability via engineering or another creative endeavor. Man may or may not give God the credit and the glory for the creative talents that He has given to them. It pleases God when man gives him the glory and praise for the talents, skills, and creative abilities that He has given.

Next Steps

There are numerous potential opportunities to learn from God’s Creation to apply to engineering. One potential next step is to explore more areas of optimization in God’s design. Learning from the research that has already been conducted on God’s Creation for nonlinear flight control and intelligent control is also another possibility. Research efforts at numerous universities by brilliant researchers can be leveraged where the control systems of insects and birds are being studied. Another option is to form an inter-disciplinary team of engineers and biologists to study God’s Creation in the areas of optimization and feedback controls. Plans could be written to develop technologies inspired from God’s Creation and collaborate with the business department to market the technologies. Engineering electives courses could be offered on topics such as biomimetics and bio-inspired engineering. The topics learned and technologies developed could be demonstrated to students in high schools or other colleges to inspire them to learn more about God’s Creation and apply the principles to human-engineered systems.

Conclusion

Optimal designs and feedback control systems in Creation were originally from God, but have become tainted by the Fall and the Curse, and Christian engineers and scientists must pray for guidance and wisdom to study and find the principles that can be applied to specific applications. Lepora states that “Biomimetics is a research field that is achieving particular prominence through an explosion of new discoveries in biology and engineering” with several thousand papers published per year in the first decade of this century [6]. God, the Designer and Creator of all things, should receive the credit and glory for these biomimetic and bio-inspired designs since they originated with Him. Out of thousands of papers, how many researchers have given God the glory for His wonderful designs? As Christian engineers and scientists, we can give God the glory and acknowledge the source of the design and knowledge (Colossians 2:2-3) [2].

The universe was created by God in six literal days and Christian engineers should learn from it in addition to helping take care of it and manage it. Christian engineers and scientists understand that everything was originally created “very good,” but now due to the Curse, it takes effort to gain insight into the designs because the original Creation is decaying and “thorns” have been introduced. It may take extra effort to learn from His Creation, but He has revealed a tremendous amount of knowledge and insight with His Creation. As Christian engineers learn about God’s designs from His Creation, they can apply the knowledge to engineered systems or use their God-given creative ability to wisely use the information in various designs.

Eventually Jesus will return, and helping build God’s kingdom is a key priority for Christians. But until He returns, Christian engineers can continue to learn from His Creation and apply the knowledge to engineered systems to help improve the lives of many. Before He returns,
Christian engineers can work as if working for the Lord (1 Corinthians 15:31) [2], learn from His Creation by studying the designs in birds, fish, and other animals and apply what they learn to engineering problems.

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Bibliography


Abstract

The concept of vocation has been largely lost in our modern culture. Many people think it only means a career in full time Christian ministry or an education obtained at a vocational/technical school. However, vocation for the Christian engineer should mean much more. In his excellent paper in Christian Scholars Review, Dr. Byron Newberry writes that vocation refers to a “divine call or summons to live a life of transcendent purpose-to use one’s distinct gifts in the service of God’s people and for the stewardship of God’s creation.” Dr. Newberry’s paper discusses the difficulties in trying to install this concept of vocation in contemporary engineering education. This paper expands upon Newberry’s work by discussing some specific things God may be calling the 21st century engineer to do. It also expands upon an earlier paper by the author that describes the narrower topic of calling and motivation for Christian engineers to work on international projects.

Introduction

The question of what God’s calling might look like for a Christian engineer requires an understanding about the nature of technology and how it can be used to better society. In a world with large numbers of very poor people, does our calling require us to use our engineering skills to better the lives of the poor? Some engineers believe that by making a substantial income and giving some of it to good causes they have done enough. Other engineers believe they have been called to work full time in the developing world with groups like Living Water or Bridge to Rwanda. Other engineers may donate a few weeks of their time each year helping out groups like Engineers without Borders or Engineering Ministries International. Frequently Christian engineers help out with international service projects because it feels like a nice thing to do. This paper will go beyond this superficial perspective to help Christian engineers understand their calling.

This paper will have the following sections. The first section is The Nature of Engineering. Before the understanding the concept of calling for Christian engineers there is the need to understand what the Bible says (or doesn’t say) about engineering. The second section is The Concept of Vocation. Many people in our culture today do not understand the rich meaning that vocation can have within the Christian Community.

Only after some understanding of vocation, can the Calling of the Christian Engineer be understood. The final two sections deal with specific calling of some Christian engineers. Some are called to become Christian Academic Engineers. Others may be called to a life of Humanitarian Engineering.

1 Baylor University, Waco, TX
A Christian Perspective on Engineering

Before the issue of the calling of a Christian engineer can be addressed, this paper will examine what the Bible does or does not say about engineering. What follows is a Christian perspective on engineering, not the Christian perspective on engineering. Related to this will be the discussion about culture that is in the Humanitarian Engineering section of this paper.

Science based engineering as exists today did not exist in Biblical times. On a trial and error basis some engineering skills had been developed. Examples of this are the Great Pyramids at Giza, and Roman aqueducts. Even in ancient times governments recognized the difference between competent and incompetent engineering. One fracture mechanics textbook by Hertzberg reports on a clever way to ensure quality bridge designs. Whenever a new bridge was built the designer of the bridge had to stand under it while a team of chariots rode over it. There is therefore a need to infer a Biblical perspective on engineering based on what the Bible says about things such as building. The author has discussed some aspects of this in two earlier conference papers. Building things is praised in the Bible. An example of this is in the building of the ark of the covenant. It is written in Exodus 31:1-7:

Then the LORD said to Moses, “See, I have chosen Bezalel son of Uri, the son of Hur, of the tribe of Judah, and I have filled him with the Spirit of God, with skill, ability and knowledge in all kinds of crafts—to make artistic designs for work in gold, silver and bronze, to cut and set stones, to work in wood, and to engage in all kinds of craftsmanship. Moreover, I have appointed Oholiab son of Ahisamach, of the tribe of Dan, to help him. Also I have given skill to all the craftsmen to make everything I have commanded you: the Tent of Meeting, the ark of the Testimony with the atonement cover on it, and all the other furnishings of the tent.

It appears from this Exodus passage that the interest and skill in doing this work were gifts from God. Similarly, our interest in engineering, and our ability to solve engineering problems are gifts from God. This does not mean that hard work is not required for us to able to use our skills to their fullest potential. The competent practice of engineering is hard work. However, we do need to recognize that our engineering interests and abilities come from God.

While God commends building and creating, engineers to recognize that what they build is not going to last forever. This is pointed out in Ecclesiastes 2:4-6, 10-11, where the teacher states:

I undertook great projects: I built houses for myself and planted vineyards. I made gardens and parks and planted all kinds of fruit trees in them. I made reservoirs to water groves of flourishing trees. I bought male and female slaves and had other slaves who were born in my house. I also owned more herds and flocks than anyone in Jerusalem before me. I amassed silver and gold for myself, and the treasure of kings and provinces. I acquired men and women singers, and a harem as well—the delights of the heart of man. I became greater by far than anyone in Jerusalem before me. In all this my wisdom stayed with me.

I denied myself nothing my eyes desired; I refused my heart no pleasure. My heart took delight in all my work, and this was the reward for all my labor.

Yet when I surveyed all that my hands had done

58
and what I had toiled to achieve,  
everything was meaningless, a chasing after the wind;  
nothing was gained under the sun.

Fortunately the above quotation is not a final statement about building. However, it makes the point, that if engineers only care about the things they create, they will inevitably be disappointed. This does not mean that building great structures is bad, only that this cannot completely satisfy your life.

While an engineer works, she needs to do what she can while she can. Our current world, and our personal lives will not last forever, and the engineer needs to accomplish all she can in the limited time she has. Paul makes this point in Ephesians 5:15-16.

15 Be very careful, then, how you live—not as unwise but as wise,  
16 making the most of every opportunity, because the days are evil.

Engineers do not have unlimited time, so they need to be wise in how they choose to use it. They also need to strive for excellence, even if no one is watching. Paul makes this point in Col 3:23.

23 Whatever you do, work at it with all your heart, as working for the Lord, not for men,

These two passages make the point that all of our work has God for an audience. Even if no one else appears to be watching, God is. It is therefore God’s opinion about our work that really matters. Guinness refers to this as working for an “audience of one”. Guinness writes:

When asked why he was not stung by a vicious attack from a fellow Member of Parliament, Winston Churchill replied: “If I respected him, I would care about his opinion. But I don’t, so I don’t.” Similarly we who live before the Audience of One can say to the world: “I have only one audience. Before you I have nothing to prove, nothing to gain, nothing to lose.”

All the engineer’s work should be done so that his Audience of One is pleased with what he does.

This paper is based on the conclusion that God wants engineers to work in a productive manner that helps meet real peoples real needs. For most engineers, this work will be “secular”, the fact that they are working to please God and not just other people should never be ignored. Engineers need to recognize that the things they create will not last.

**The concept of Vocation**

The term vocation is much misunderstood today. For many people it has one of two meanings:

- Career in full-time ministry
- Technician type training that can be obtained at a vocational/technical college.

In some circles it is taught that this call to ministry (or to anything else) is a mystical experience that you either have or do not have. This paper will not attempt to deal with personal calling of that sort. The paper will discuss how God calls Christian engineers in general. How this relates to a specific individual is a more complex undertaking.
In his excellent paper in Christian Scholars Review, Dr. Byron Newberry writes that vocation refers to a “divine call or summons to live a life of transcendent purpose-to use one’s distinct gifts in the service of God’s people and for the stewardship of God’s creation.” Dr. Newberry’s paper discusses the difficulties in trying to install this concept of vocation in contemporary engineering education. Dr. Newberry makes the point that this call “applies to all facets of one’s life, regardless of the nature of one’s paid occupation”.

One of the greatest threats to the concept of vocation is to lose sight of it. Someone cannot strive to achieve an unrecognized goal. This leads to whether this call can be taught to engineering students.

Vocational calling may be more easily understood in the context of a liberal arts education. It is more difficult when dealing with professional education, such as engineering. In these areas there is a concentration upon scientific and technical education. There is less room for discussion of major life issues such as purpose. Meaning and purpose can be discussed in the context of an engineering program within a Christian university. Van Treuren and Eisenbarth discussed this in their 2008 paper. They discuss the role of faith and professionalism within an engineering program at a Christian university. They write:

“Technology is the product of the engineering design process. Monsma, et al. define technology as “a distinct human cultural activity in which human beings exercise freedom and responsibility ... by forming and transforming the natural creation, with the aid of tools and procedures, for practical ends or purposes.” These authors further assert that “doing technology [engineering] is not a [morally or ethically] neutral activity but one that involves valuing of a profound, fundamental nature.” The philosophical basis for asserting that valuing is inherent in the engineering design process [technology] is that “any set of standards for determining what does or does not constitute a solution to a problem must clearly lie outside the problem itself.” In other words, the evaluation of whether a particular design is a “good” or “bad” solution is not self-determined by a particular solution. Therefore, the presuppositions and pre-commitments of the designer [engineer] must play the central role in alternative design evaluation. In particular, one’s personal perspectives, ethics and moral commitments become important factors in determining the final design solution.”

A student’s ability to deal with these issues is related to her worldview. How it is applied in engineering education is not simple. Much of what is learned is done in non-engineering classes. Van Treuren and Eisenbarth write:

“is it possible to help students develop a worldview that is compatible with their engineering profession? To this question we must answer in the affirmative, however, in a much broader manner than might be expected. Let us assume for the sake of argument, that many entering undergraduate students are only at the pre-philosophical level with respect of a worldview; they possess the materials out of which a worldview can be constructed; but they have not reflected, analyzed or integrated this material using Biblically informed philosophical processes. If worldview construction is a desired outcome, then the curriculum, in some part, must provide the setting, opportunities and encouragement for students to begin the process. In typical undergraduate programs, it is the liberal arts component of a curriculum where these opportunities are most often
encountered; particularly in courses that deal with human values, e.g. literature, philosophy and ethics, art, religion, anthropology, etc. Much of the balance of the curriculum either expands the pre-philosophical building material or might be considered minimally worldview oriented, e.g. mathematics, physics, chemistry and many engineering topics.

On the other hand, if worldview construction is possible, is it possible for worldview formation to be explicitly directed by the engineering education process to the end that a coherent Christian worldview is the ultimate result? The answer to this question must be carefully crafted, but in general, the answer is negative. Typical engineering curricula provide few opportunities for the reflection and analysis needed for the worldview generation process to be successful. “

Van Treuren and Eisbarth are more hopeful that the above quote might imply. They write: “From a Biblically-based Christian worldview we understand that “all knowledge is God’s knowledge” and that our quest to understand God’s creation (his general revelation) is also a quest to understand Him more completely. Therefore, even though there may not be a specific application of the Christian faith principles in every engineering problem, students can often be reminded to take a step back and look at the big picture of His presence and sustaining activity in the world. As an engineer works through the extrinsic elements of a design artifact, a Christian worldview can provide a basis on which to consider and make the necessary value judgments and choices required by the engineering design process.”

Christian engineers (and engineering students) can learn to be more reflective about why they do what they do. As they think through their Christian world view they can gain insight as to how they can organize their professional life.

**Changing perspectives on Calling and Vocation**

The concept of calling of Christian engineers and scientists has changed over the last 30 years. There has been further refinement of the concept of calling to a vocation being much broader than just a calling to full-time ministry. This is seen to some extent by assessing three different books written over the last 30 years. In 1986 Monsma published his book *Responsible Technology*. This book is about the use of technology and how technology affects society. While it is not directly about calling, it has some implications for calling. One of them is its emphasis that technology is not morally neutral, but it is value laden. On page 44 of his book Monsma writes: “Doing technology is a cultural activity. Therefore, if we are to analyze and understand technology and our responsibilities in regard to it, we must understand the nature of the broader culture within which technological culture formation is done and our technological responsibilities are fulfilled.”

According to Monsma, if Christian engineers are to fulfill their calling, they must understand how the technology they develop affects the society around them.
In 1990 Lee Hardy published his book *The Fabric of this World*. The subtitle of this book is *Inquiries into Calling, Career Choice, and the Design of Human Work*. This book is explicitly about calling of Christians into their careers. He discusses how the concept of calling has changed in Western Civilization since the time of the Greeks. He discusses the work of Luther and Calvin, as well as that of modern philosophers. He emphasizes that all Christians should be called to their vocation. He makes the following points on pages 84 and 93.

“An initial attempt to formulate the principles of vocational choice was made by the Protestant reformers of the sixteenth and seventeenth centuries. They were firmly convinced that all of life, even the life of everyday work, out to be lived to the glory of God….The second step in vocational decision-making is locating the place where our native abilities and acquired skills can be put at the disposal of those who need them.”

According to Monsma engineers should not decide upon their careers only based on what benefits them. They also need to think who needs help from the skills that they have. In her book *Kingdom Calling*, Amy Sherman looks at the issue of vocational stewardship for the common good. The theme verse of her book is Proverbs 11:10, “When the righteous prosper, the city rejoices.” Professionals should strive to practice engineering in a righteous manner that helps others. People should not just choose careers that benefit themselves. While she does not use this term, the author believes she would be supportive of the concept of seeing engineering as a helping profession. In her discussion of pathways to vocational stewardship, she outlines four ways this can be done:

- Bloom where you are planted
- Donate your skills
- Launch your own social enterprise
- Participate in your church’s targeted initiative

Embedded in all these is the need for the professional person to use his skills to benefit others. She also makes the point that discovering these vocational options will involve receiving feedback and mentoring from others.

Over the last 30 years there has been much work on the issue of God calling Christians into vocational service that appears on the surface to be secular, but which serves His goals for the word. The three books discussed above show how these concepts have been developed. However, they have not dealt with another major issue facing Christian engineers trying to discern their calling. That is how technology itself affects the decision making process. Exploring this in detail is the task of a future paper. However the author will make several points about these issues.

Most concepts of calling have some sort of community interaction or mentorship. Some of this can now be done at a distance. An engineer’s mentor does not have to live in the same area anymore. However, if this mentorship is to be meaningful there needs to be some personal relationship between the two people. This implies that the relationship probably already needs to be there for this long distance relationship to work.

The development of the internet has a profound impact upon how someone can sort out important concepts related to calling. The large amount of information available is both a
blessing and a curse. The author will use as an example his interest in doing research that also
helps poor people in developing countries. He has begun to work on the mechanical properties
of polymeric composites that have been reinforced with natural fibers from the pseudo-stem of
banana plants. The motive is to help poor people in developing countries by developing a
market for something they now just throw away. There has been much useful information on the
internet to help him discern some issues relating to working in this area. However, there is so
much information, it is difficult to discern what is important from what is not important. When
looking for advice it is sometimes hard to discern what is good advice, what is time wasting
advice, and what is bad advice. How to use the internet to help Christians sort out their calling is
a complex study that needs much more work.

Calling of the Christian Engineer

Calling is related to vocation in the sense that a Christian engineer is called by God to become an
engineer for a reason. Insight can be gained from the excellent book by Os Guinness, The Call6.
Os Guinness suggests that each Christian has two callings. The primary one is to become a
disciple. The secondary one is to our work. We need to balance them so that neither one gets
overwhelmed by the other one. Guinness writes:

“Calling is the truth that God calls us to himself so decisively that everything we are,
everything we do, and everything we have is invested with a special devotion, dynamism,
and direction lived out as a response to his summons and service.”

As we think about our calling as engineers, we need to recognize that work itself was created
before the fall of man, and not a result of the fall. This is seen in Genesis 1:28

God said to them, “Be fruitful and multiply, and fill the earth, and subdue it; and rule
over the fish of the sea and over the birds of the sky and over every living thing that
moves on the earth.”

Work is important to us as it predates the fall. Work is more important than just providing for
the needs of our families. We do need to work to provide for our families, but there is more to
work than just this. While we work, we need to recognize that we are always working for God.
Paul writes in Eph 6:7

With good will render service, as to the Lord and not to men.

God expects Christian engineers to use their skills to benefit society. Jesus speaks in Matthew
25: “Then the righteous will answer him, “Lord, when did we see you hungry and feed you, or
thirsty and give you something to drink? When did we see you a stranger and invite you in, or
needing clothes and clothe you? When did we see you sick or in prison and go to visit you?”
“The King will reply, “I tell you the truth, whatever you did for one of the least of these brothers
of mine, you did for me.”

As engineers we have been given great talents, and God expects us to use them appropriately.
Jesus speaks in Luke 12: 48, “From everyone who has been given much, much will be
demanded; and from the one who has been entrusted with much, much more will be asked.”
The above comments do not mean the every engineer needs to work full time to help poor people. It does mean that every engineer should think about how her work benefits the society at large, and not just her immediate employer or client.

This Christian calling for an engineer to use her skills to help others is consistent with how professional societies see engineering. For example the ASME code of ethics includes as its Fundament Canon\textsuperscript{11} “Engineers shall hold paramount the safety, health and welfare of the public in performance of their professional duties.” The National Society of Professional Engineers states in their code\textsuperscript{12} “Engineers, in the fulfillment of their professional duties, shall hold paramount the safety, health and welfare of the public”. The IEEE has the following statement as an introduction to their ethics code\textsuperscript{13} “We, the members of the IEEE, in recognition of the importance of our technologies in affecting the quality of life throughout the world, and in accepting a personal obligation to our profession, its members, and the communities we serve, do hereby commit ourselves to the highest ethical and professional conduct and agree…”

Modern engineering codes of conduct are secular documents that are changed from time to time to reflect changes in our engineering culture. For example there is now more emphasis on sustainable engineering that there was 25 years ago. An interesting exception to these secular documents is the Engineer’s Creed that was adapted by the National Society of Professional Engineers in 1954. It is still on their website\textsuperscript{14}

**Engineers’ Creed**

As a Professional Engineer, I dedicate my professional knowledge and skill to the advancement and betterment of human welfare.

I pledge:

To give the utmost of performance;
To participate in none but honest enterprise;
To live and work according to the laws of man and the highest standards of professional conduct;
To place service before profit, the honor and standing of the profession before personal advantage, and the public welfare above all other considerations.

In humility and with need for Divine Guidance,
I make this pledge.

While the spirituality of this creed is rather vague, it does reflect the opinions of post-World War II engineers that engineering practice was not totally separated from a spiritual world view.

In view of the idealistic statements that are in engineering codes of conduct, it would be useful to examine whether or not they are really put into practice. Byron Newberry looks at this issue in his essay, The Dialectrics of Engineering\textsuperscript{15}. There is not a simple answer to this question. Newberry writes:

“This same overarching idealism—pursuing the benefit of humanity/society—is common rhetoric for engineering organizations and institutions worldwide. This is not surprising
One aspect of this discussion is whether practicing engineers really think in these terms of helping society. In another paper Newberry writes:\(^1\):

“A common key phrase is many such statements is for the benefit of mankind. Is this really the case? Is working for the benefit of humanity a foundational element of the engineering ethos? If so, we might expect engineers to devote considerable time to, and to be quite vocal on, the subject of what does or does not constitute a benefit of humanity, particularly with respect to technology. But this is generally not the case.”

While Newberry makes a relevant point in his comment above, the author is not sure that this is necessarily the case. From the author’s experience, many engineers are not very reflective people. They fact that they do not write about the need to benefit society in their work does not necessarily mean they don’t want to benefit society. They may think that society’s benefits from the work are obvious by the nature of the new products they create.

One way to reconcile the idealistic statements with the reality of engineering practice is to consider what it means to benefit humanity in our engineering work. Newberry writes that using a utilitarian ethics approach, “benefit, therefore comes to mean on balance”\(^1\). Does the good produced by the engineer outweigh the negative consequences of the work? While this is a reasonable way to interpret the codes, there is still the complex issue of how to measure the good and bad produced in a given project. This complexity is beyond the scope of this paper. So while engineers may not always live up to the ideals expressed by their professional societies, these statements provide an aspirational target for practicing engineers in their daily work.

**Calling of Christian Academic Engineers**

The calling of a Christian engineering professor has some differences from the calling of a Christian engineer who works in industry. The academic enterprise has some unique aspects to it. In addition to teaching students, and activities such as engineering mission trips, the Christian engineering professor also has scholarship as a big part of her professional life.

This author has learned a great deal from the work of Stephen Evans\(^1\). The author has discussed some of these concepts in his 2009 paper\(^1\). Evans’ essay brings out several important points. This section of this paper is adapted by the author from Evans’ work. As a Christian who works in a Christian university, the author is concerned with how relate Christian faith and scholarship. This paper attempts to expand on what Evans has done and apply it to Christian engineers working on service projects in developing countries.

Christian engineers need to engage our culture and participate in its common life. Evans makes the point that a Christian in academia is a “kind of double missionary. On one hand the educated Christian is a representative of Christ’s church in the spheres of life where intellectual issues are important…the Christian scholar is also a missionary for the life of the mind within the church…”

coming from a discipline that aims to be a profession in the fullest sense. But is there substance to these claims? Against them is the reality that the benefits proffered by engineering accomplishments are almost always attended by some measure of undesirable side effects or unintended consequences.”
The calling of the Christian teacher-scholar forms the heart and soul of Christian higher education.”

Evans groups Christian scholarship into three basic types:

- **Purely vocational Christian scholarship.** This is scholarship that is motivated by the Christian faith of the scholar, but whose outward appearance is not any different from what would be done by a non-Christian scholar.

- **Implicit Christian scholarship.** In this situation the Christian faith of the scholar has shaped the choice of research topics as well as the hypothesis he/she is testing.

- **Explicit Christian scholarship.** This is where the Christian faith of the scholar is an integral and direct part of the entire scholarly activity.

Evans offers some cautionary thoughts. One key issue is which type of scholarship should a Christian scholar pursue. Evans’ response is “all of them.” Any one of them is not inherently better than another one. Depending on the context, all of the above approaches can and should be done by Christian scholars. All of them can be legitimate with some qualification as to the perspective of the viewer, be it the promotion and tenure committee or the editor/reviewers for a journal or conference. The author has done scholarship of all three types depending upon the specific situation.

The author agrees with Evans when he says that Christian scholarship should not be done in an intellectual Christian ghetto. While this paper is presented at a Christian conference, the author has presented papers at other locations that deal with many of these same topics.

When the types of Christian scholarship are analyzed in the context of different academic fields, it becomes clear that explicit Christian scholarship will be easier in some disciplines than others. For example, there are many areas within engineering where it is not obvious to say there is a Christian perspective on that topic. For example, the author would never claim that there is a truly Christian perspective on fracture mechanics. However, it is much easier to say that there are Christian perspectives on engineering ethics. This does not make work on fracture mechanics any less Christian. It just means that scholarship in that area will be more likely to be vocational Christian scholarship. If we do an excellent job on vocational Christian scholarship, then others in our academic community will be more willing to listen to us when Christian topics do come up for discussion.

When engineers conduct Christian-related scholarship, they need to recognize another caution from Evans. Evans writes: “In a pluralistic community Christians must model respect and tolerance, even while they show that intellectual humility can coexist with committed conviction and action.”

**Calling of some engineers into Humanitarian Engineering**

Some engineers will feel called to work directly on behalf of poor people. This leads to the concept of Humanitarian Engineering. If the engineer’s projects in the developing world are to impact the local people there needs to be rethinking as to how and why they are done. For these projects to really work well there needs to be involvement of the local community.
In traditional design the engineers try to design what the customer wants. When working with local communities, it is not obvious whom are the real customers. Local non-profits are frequently acting in the name of the local community. An important question to ask is if the local community really wants what the non-profit is asking the engineer to do. In their book *Service Learning: Engineering in Your Community*, William Oakes and Marybeth Lima raise several issues that need to be addressed when working in poor communities, whether in the United States or in the developing world. They make the point that engineers and engineering students frequently do not seriously think about how their design might impact a community. The social implications of their designs are not one of the criteria used to assess its success. Oakes and Lima make the point that engineering in poor communities needs to be done in a democratic way. This does not require that everyone votes on every proposal. It does mean that the local community needs to be involved in the decision making process concerning the project. This issue has been addressed in an ASEE paper by William Frey. He writes:

> “technology is *appropriate* in the sense that it mitigates the harmful social consequences of moving too quickly from indigenous, labor intensive technology to high capital intensive technology. Technology appropriate to orderly, sustainable or even humane development (a) gives “special consideration…to context of use, including environmental, ethical, cultural, social, political, and economical aspects”; (b) seeks *simplicity* (as opposed to what Langdon Winner terms manifest and latent complexity); (c) chooses *decentralization* over authoritarian centralization; (d) employs labor intensive as opposed to capital intensive strategies; and (e) addresses itself to the *unique characteristics* of the surrounding community. Working with the marginalized and the poor does not imply charity. Rather, a true partnership with the community that is being served must be forged through a model where the community is involved in decision-making and management of projects. We understand this to be true for our broader view of appropriate technology, and note that this applies, not only to engineers or engineering projects, but to all who develop, sell, manage, and otherwise proliferate technology.”

For the solution to be sustainable the solution must meet a felt need. The local community must be interested in maintaining the equipment (and know how to do so). However, the local community may not know enough to make specific design related decisions. This is because the engineers know a lot more about what does not work than what does work. This has led to some rethinking about what is meant by doing engineering in the developing world. The author has been greatly impressed with the book *Humanitarian Engineering* by Carl Mitcham and David Munoz. This book described many of the things that the author has had to learn by practice. They wrote humanitarian engineering “is the artful drawing on science to direct the resources of nature with active compassion to meet the basic needs of all – especially the powerless, poor, or otherwise marginalized.” They made the point that humanitarianism is not humanism, though humanists can be humanitarians. Humanitarians can also come with a religious motivation. This makes the point that the students are not just doing engineering in a poor country, but are doing it with the explicit goal of making a difference in the lives of the poor and marginalized.

Mitcham and Munoz go over the history of the development of Humanitarian Engineering. Some of the key people include Maurice Albertson who as an engineering professor who contributed greatly to the founding of the U.S. Peace Corps. Another key person is the civil
engineering professor Bernard Amadei who is the founder of Engineers Without Borders USA. With respect to how engineering should be practiced Albertson writes (quoted in Mitcham and Munoz):

“We need to be motivated by service as well as profit. We serve best by finding out what people want and helping them work to realize their dreams, not by going into a country and telling villagers what they need.”

This is very consistent with the recommendations of Oakes and Lima in their book Service Learning: Engineering in Your Community.

Bernard Amadei makes the important point (also in Mitcham and Munoz):

“I’m not going to dump another technology on the poor people of the world. That is a crime against humanity and we do it all the time. It is not about technology; it is about empowering the poorest people in the world to get back on their feet. It is about teaching them to fish and ensuring a market for their fish.”

It is unfortunate that many attempts to help poor people have not worked, or have not been sustainable. It is even more unfortunate that many of these projects have actually hurt the people they were intended to help. It is not enough just to have good motives. The excellent book by Steve Corbett and Brian Fikkert make some important points about working in the developing world. Their book, When Helping Hurts, makes the point that many things well-meaning people do to help those in the developing world only make things worse. For example after the earthquake in Haiti several years ago many people and organizations gave food to help the people survive. Giving such aid freely in times of disaster is very appropriate. However, in this situation people continued to give free rice after the emergency began to subside. The result was that the local rice farmers were devastated. Then when the food gifts eventually slowed down, there was no local agricultural industry left that could help them.

A concept related to humanitarian engineering is service learning. In service learning the students learn aspects of engineering while actually doing the engineering. This can be done from a humanitarian perspective, though it does not have to be done in this way. Ohio State University has an active engineering service learning program. They embed sustainable concepts into their service learning course. They describe their course:

“An important part of the project proposal is a statement of sustainability and local ownership. Being able to fabricate projects from locally available parts is paramount to sustainability. The teams must also consider ways to involve the people/community in the construction, care and maintenance of the project. Methods of community education must be delineated. Although the course does not follow a social enterprise model specifically, the teams are asked to speculate on possible entrepreneurial opportunities that may be associated with their projects.”

The Christian engineer and culture

How a Christian engineer views culture will affect how she practices engineering. The author has found the work by Richard Niebuhr in his book Christ and Culture to be very helpful. He has presented portions of this material at two different conferences. Niebuhr has used Christ
and culture to explain several different ways Christians look at culture. He categorizes the responses into five general categories:

- Christ Against Culture
- The Christ of Culture
- Christ Above Culture
- Christ and Culture in Paradox
- Christ the Transformer of Culture

How a Christian engineer interprets her calling will depend largely upon her view of culture. The Christ against culture approach sees a fundamental opposition between Christ and culture. One example of this is the monastic movement, as well as the new monastic movement as exemplified by people like Shane Claiborne. Some modern fundamentalists are also in this group.

The Christ of Culture approach sees Jesus as the hero of human culture. To be in your culture and to be a Christian are largely the same things. The “wide church” view of some Anglicans are an example of this perspective. They believed that being an Anglican and being English was substantially the same thing.

The Christ above Culture approach sees Christ as separate from culture, but which enters into it in many ways. An example proponent of this is Thomas Aquinas. Many modern Catholics also adopt this view.

The Christ and Culture in Paradox approach sees Christ and culture as different and in tension with each other in many ways. An example of this perspective is Martin Luther. Niehbuhr writes of this perspective24: “Life must be lived precariously and sinfully in the hope of a justification which lies beyond history.”

Christ the Transformer of Culture approach sees the need to change culture. This can partially be done by worldwide evangelism. We can also change culture by being actively involved within it. Examples of this perspective are Augustine and John Calvin. Many modern evangelicals would be in this tradition.

How a modern engineer views culture will shape how she sees her calling as engineer. If you are in the Christ against culture perspective, you may feel a need to be honest and ethical, but have no real calling to use engineering to change the lives of poor people. If you are in the Christ of culture perspective you also many not see any need to change the way your culture deals with poor people.

If you are in the Christ and culture in paradox you may wish to help poor people or you may not care because you are hoping to do your job with the least amount of daily sin in your life. The Christ above culture engineer sees Christ sitting in judgment on a culture that does not always help poor people. You will likely feel a need to do so.

If you are in the Christ transforming culture, you may be one of two very different perspectives. If your view of transforming culture is evangelism, you may only work to help poor people as a
means to an end (successful evangelism). If you see your engineering skills as capable of helping to improve lives you will be motivated to help poor people as this is intrinsically the right thing to do. Evangelism will also result, but it is not the only goal.

The Christ transforming culture approach is very consistent with Christian Humanitarian Engineering. This engineer wishes to help poor people because it is intrinsically the right thing to do. This can also lead to other good things, such as evangelism, discipleship, and church growth. The engineer is willing to do this type of engineering, even if these other things do not result.

**Conclusions**

The calling of the Christian engineer is not simple. First the engineer needs to respond to God’s call to become a disciple of Christ. She then needs to understand the nature of engineering and believe she is called to a life of engineering. This may have many different applications, such as working in industry, working in academia and practicing Humanitarian Engineering. Sorting out the specifics of this calling can be helped in several ways:

- Understanding more of a Christian perspective on engineering.
- Understanding the nature of God’s call to a particular activity. This can be assisted by reading in books on the subject, such as those by Monsma and Sherman.
- Personal mentoring by others who are also engaged in this process. Ideally this would be done in person, but long distance mentoring can be of some use.

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Finding Your Path
Michael Foster¹ and Justin Vander Werff²

Introduction

Each of us has a desire to do good, fulfilling work. How do we find this work? Do we discover it or is it something we create for ourselves? If we believe there is a particular area in which we should work, then work decisions can become even more burdensome. Since there are so many areas in which we could work, and many more we may not even know about, how do we know if we have chosen the right path?

These questions are particularly acute for college students. From first-year students through seniors, some aspect of their journey toward the working world looms.

- First-year students: Which major should I pursue? If I fail a class, what do I do (or not do) next? What if I find I don’t like the classes I’m taking, but I'm already a couple semesters in?
- Sophomores and Juniors: What aspect of engineering should I focus on? What should my concentration be? Where should I get an internship? Can I get an internship?
- Seniors: What do I want to do? Should I take a job near college/home/friends/etc.? How choosy can I afford to be about which job I pursue? What if I’m burnt out and do not want to do this any more? If I do something different now/later, will these past few years have been a waste?

Students are not the only ones asking these questions; engineers in the academy and industry may ask similar questions about what their work should look like in the future.

- Faculty members: Should I maintain a full schedule of teaching/research or should I move partially or completely to administration? Should/Can I move to a new research area? Should I consider accepting a new class prep? In which university or non-university service activities should I participate? Should I consider working at another institution?
- Industry professionals: Should I continue pursuing this work or should I look to move into something else? If I want to make a move, should I do it within the same company or look at other opportunities elsewhere? What is the value of my work? Should I pursue something with higher value?

These questions typically arise when people lack clarity about the meaning for their lives. If our mission, our focus, is known, then the opportunities and challenges that come before us can more easily (though maybe not simply) be put into perspective. The purpose of wading through difficult challenges is for a greater end.

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The question that therefore arises is how do we achieve this clarity—can we determine what work we are to do, and if so, how? We propose that primary principles related to the search for our work include striving for biblical obedience; seeking to discern how our passion, calling, and skill development mesh; and finding an avenue of service that meets a legitimate need. In this paper we seek to review the main tenets of “how should I choose what to do” or “what should I do” advice to determine if they work in concert with each other, or if they can only be followed exclusively. As we conclude, we will provide some mentoring guidelines for helping others (and yourself!) find good and fulfilling work.

**Approaches to Work**

*Modernity: Approaches to Finding Work*

When looking for ways to approach thinking about the choice of a career path, two options quickly come to mind: passion and calling. A third, the craftsman approach, has more recently been highlighted by Cal Newport in the book *So Good They Can’t Ignore You*. In this section we seek to briefly summarize each approach.

The passion approach was most likely popularized by the book *What Color is Your Parachute?*, which came out in 1970 and has over six million copies in print. It prompted people to “Follow your passion.” It reasoned that if you are going to do something for the next several years (more than 40 years for college graduates), then you should pursue something that you will enjoy doing. Once you figure out what you enjoy doing, you can focus your job search to areas that will provide you the greatest happiness.

While the passion approach is much more inward oriented (what do I like?), the calling approach is more outward focused (what does God want me to do?). The calling approach presupposes that each person has a unique calling from God. For some this could mean a specific job. For others, understanding God’s calling means they recognize their design and then can look for jobs that they will fit. While there are different ways of finding and interpreting your calling, the result is expected to be the same---fulfillment will come once I am doing what God wants me to do.

For the craftsman approach, the core idea is that “Working right trumps finding the right work.” Newport describes how workers can look at existing needs in society and then pursue the skills necessary to meet one of those needs. In addition, to create a fulfilling work experience, the skills chosen should be rare and valuable. These “special” skills allow the worker to build career capital, which can then be exchanged to craft a fulfilling work experience. An example of a key exchange would be for opportunities to pursue a compelling mission in the field you have chosen. Since you have spent significant obtaining rare and valuable skills in a field, you are able
to see what lies at the edges of knowledge in that field, the “adjacent possible,” which Newport claims is where compelling missions come from.

**Antiquity: The Value of Work and Approaches to Finding Work**

We have touched briefly on the idea of work as calling. This idea is certainly not new, and often the term “vocation” is used to refer to work in this regard. Two of the most prominent figures in the Protestant Reformation, Martin Luther and John Calvin, taught strongly vocational views of work. Both Luther and Calvin formulated their concepts of vocation largely in response to the dualistic mindset that came from the Greeks. The Greek belief system clearly devalued physical aspects of the creation such as body and materials as opposed to spiritual aspects such as soul and the afterlife. Consequently, daily work that deals with physical realities was viewed as much lower and more menial than religious contemplation and meditation. The Christian manifestation of this belief system was that pietistic pastimes such as priesthood and monasticism were far more valuable than occupations such as farming or artisanship. Many in our current society, including many Christians, still view work through a lens clouded by this worldview.

However, both Luther and Calvin articulated viewpoints of work that contrasted starkly with such a dualistic framework. Luther reportedly “declared that a father washing diapers pleases God,” clearly offering an illustration of the meaning of physical labor. Luther viewed our particular vocation as “the specific call to love one’s neighbor which comes to us through the duties which attach to our social place or ‘station.’” While he drew a distinction between the kingdom of heaven (loving God) and the kingdom of earth (loving neighbor), he felt strongly that work in the earthly kingdom is a divine vocation. In fact, Luther wrote that “all the duties of Christians, such as loving one’s wife, rearing one’s children, governing one’s family, obeying the magistrate, etc., … are fruits of the Spirit.”

Calvin strongly articulated the value of work, wholeheartedly agreeing with the worth Luther gave to our daily activities. In his *Institutes of the Christian Religion*, Calvin claims, “no task will be so sordid and base, provided you obey your calling in it, that it will not shine and be reckoned very precious in God’s sight.” In his commentary on the Gospels, taking particular aim at those who he felt severely distorted Jesus’ criticism of Martha in Luke 10:38-42, Calvin writes, “[W]e know that men were created for the express purpose of being employed in labour of various kinds, and that no sacrifice is more pleasing to God than when every man applies diligently to his own calling, and endeavors to live in such a manner as to contribute to the general advantage.”

Puritan thinkers such as John Cotton, Thomas Gataker, and William Perkins followed closely in Calvin’s footsteps by continuing to articulate the inherent value of work. In fact, in Perkins’ “A Treatise of the Vocations,” a discourse based on 1 Cor. 7:20, we find ideas that in many ways are parallel to the contemporary approaches of passion, craftsman, and calling that we have
highlighted above. Perkins, a Puritan minister in England around the turn of the 17th century, taught that as Christians we have a general calling to be a child of God and to be a witness for Christ, but we also have a personal calling which is “the execution of some particular office arising from that distinction which God makes between man and man in every society.”

Perkins strongly articulated the calling of the layperson to do work, not simply to survive and provide means but to serve a purpose and make a difference. He writes, “It is a miserable and damnable estate for those who, being enriched with great livings and revenues, spend their days in eating and drinking, in sports and pastimes, not employing themselves in service for Church or Commonwealth.”

(To clarify, what Perkins means by “in service to the Commonwealth” is what we would consider normal vocations that advance society and provide goods and services to the general public.) Isn’t it remarkable that already in the 1600s, in a time when subsistence living was much more the norm than in our current society, Perkins so clearly recognized the biblical mandate of calling in work and the inherent value of work?

Perkins even provided insight on how to choose a particular calling. He taught that an appropriate calling will be one that touches the person’s affection (the passion approach) and one that matches the person’s gifts (the craftsman approach). Focusing on these two aspects will help us find God’s calling for us personally. Perkins pointed out many biblical examples of how God calls us to particular vocational tasks, including Adam’s task of tending the Garden (Gen 2:15), Moses’ call to lead Israel, Philip’s call to be an evangelist (Acts 8:26), and the apostles’ call by the Holy Spirit (Acts 20:28). He taught that carefully examining one’s affections and gifts will lead us to discern God’s particular calling for us.

**Integrating the Approaches**

As Christians, there may be an assumption that we must default to the calling approach. Unfortunately, many people have been stumped trying to figure out what God wants them to do. To remedy this, they find moving to the passion approach helpful after considering Psalm 37:4, "Delight yourself in The Lord, and he will give you the desires of your heart." Assuming the passion or excitement we have toward something to be arising from the "desires of [our] heart" we may find ourselves moving into our area of calling. Finally, if the other two approaches cause frustration, the craftsman approach can seem like a last ditch effort as you craft your own career, building up career capital to eventually exchange for a fulfilling work experience. In this approach, if we can develop rare and valuable skills, we may be able to develop (or find) a mission at the "adjacent possible."

Digging deeper, we seek to find if these approaches are somehow parts of a whole, which seems to be in line with Perkins’ ideas from a few hundred years ago. Can each of the approaches described above actually come together to create a better whole than the parts?
Of the three approaches, only Calling has an aspect of looking at the past. (Passion looks at what I like right now and Craftsman purports that I can craft a career of my choosing.) In his book *Let Your Life Speak*, Parker Palmer admonishes the reader to consider what things have grabbed his or her attention in the past.\(^9\) What activities have you been involved with or what events have occurred that have shaped who you are? However, be careful to not let any aspect of your life dominate in isolation of the other parts. Be sure to consider vocations that would integrate the different highlights that you have noted. Let these answers help direct you in making decisions about the opportunities being offered to you right now.

Next, you must commit to starting your chosen work. It does not have to be a "right" path, which we will discuss more below. But, be aware that a desire to get it right the first time may creep in. Boldly and courageously move forward in your decision. Once you have made that crucial decision to start, commit to the work of deliberate practice that will make you "so good you can't be ignored." Acknowledge and keep a record of the career capital that you are gaining as you grow in your work. Be sure to also acknowledge the value you are providing to your work. As you continue on this journey, remember that you have only started, you are not committed indefinitely to this specific path. You can always move to something else, but you will probably need to build up career capital before you can expect valuable returns.

Now that you have looked to the past to see where you can start, committed to an initial path, and built some career capital, you may expect to begin feeling a passion for your work. Because of the initial work you did in reviewing significant aspects of your past, your work may already have some meaning to you. Spending the time in deliberate practice, you have become more of an expert and may be able to see more of the nuances of your work and are able to adjust the focus of your pursuits to better achieve a meaningful mission, which just might turn out to be the calling that God has for you after all.

**A Biblical Approach to Finding Work**

We propose that a balanced biblical approach to finding work will recognize that passion, skills, and calling are all involved in discerning God’s direction for our vocation. If we eliminate passion from the equation, we neglect biblical principles such as delight (Ps. 37:4) and contentment (1 Tim. 6:6). If we downplay skills, we neglect the biblical principles of God-given talents and abilities (Matt. 25:14-21, 1 Cor. 12). If we ignore work as a calling from God, we completely miss the holistic nature of our Christian walk and the all-encompassing effect that Christ’s salvation and the Spirit’s work should have on our daily walk.

It is interesting to note that, after considering modern approaches to choosing a career and looking back at approaches from antiquity, what we have surmised as a biblical approach, holistically integrating these ideas, looks very similar to what Perkins wrote in 1605.\(^7\) Perkins began with the biblical foundation of work as a calling from God, and then he applied the
biblical principles of delight and talent to conclude that these two personal facets should both be used to discern God’s particular calling for our lives. But perhaps this similarity to our three-fold approach of integrating passion, skills, and calling should not be surprising. Although our 21st-century culture (and work within our culture) is considerably different than in Perkins’ time, God’s call to glorify him and love our neighbor by diligently stewarding his creation remains unchanged. Faithfulness to his mandate, and the biblical principles that guide us in what this obedience looks like, should look similar as well.

**Guidelines for Mentoring Students**

We now propose some guidelines in mentoring others in a biblical approach to choosing a vocation. For those of us who regularly mentor college students, it seems that students just beginning college in particular should be encouraged to recognize work as calling, given that this understanding of work seems to be quite counter-cultural. If a student’s primary motive in choosing a particular field of study is that it is a route to a “cushy job” and “easy money,” we want to redirect this student as soon as possible! This student needs a more holistic understanding of work to make a wise decision. Recognizing the tendency of our students to not have a holistic vocational perspective, it seems appropriate during the first year or two of college to require readings and reflections on a biblical understanding of vocation to help nurture students in this direction. In addition, employing the resources of the campus career center can help students process their personality, values, skills, and interests they have demonstrated in the past and how those might direct where their calling may lie.

As students develop an understanding of biblical vocation and continue to progress in a curriculum, then it will be helpful to guide their focus towards how their passions and skills align with the path they are pursuing. They will be developing a deeper understanding of engineering, and they will begin to determine if they really see it as a possible source of “delight” and also if it is something that they have the ability to do. This process of discovery will not be easy, so as mentors it may be helpful for us to remind the students that they will continue to see more application and likely more “delight” later in the curriculum. It is also helpful to remind students that every career has its “weeds” on this side of eternity as a result of the fall. However, recognizing that passion, skills, and commitment should play a role in their career decisions may provide helpful guidance.

**Guidelines for Faculty and Professionals**

If we find ourselves as faculty members in the university setting, the particular circumstances and decisions might be different than those of students. The decisions might also be different for practicing engineers in a professional setting. However, we feel that the three-fold framework of calling, passion, and skills can be readily applied to these circumstances as well. While incorporating this framework provides no promise of an easy answer, it does introduce a fuller
set of questions to be pondered when making possibly career-altering decisions. For example, if one feels their passion leading them strongly in a certain direction, but they are not able to point to anything from their background or experience that provides them with “skill-set capital,” considering both passion and skills may indeed prevent them from making a poor decision. Similarly, if an opportunity comes up that seems to be a natural progression from a current position given one’s experience and background, but they feel very little desire for this particular opportunity, a holistic consideration of passion along with skills and calling will again be helpful in making a decision.

Words of Caution

As was briefly mentioned above, the worry about perfection can easily creep into this process: what if I don't pick the right work for me to do? In trying to discern the path forward from the (potentially) disconnected parts of our past, the sway of false passions and misguided advice can steer us in many an errant way. But take heart! Our God is a god of grace, love, and forgiveness, but for grace, love, and forgiveness to be relevant, sin has to exist. For people to experience the blessed feeling and healing that comes from offered grace, love, and forgiveness, they need to have blown it. They need to have sinned.

In Eric Metaxas’ bibliography of Dietrich Bonhoeffer, he recounts a conversation Bonhoeffer had with a colleague about his involvement in the conspiracy to assassinate Hitler. The following is Metaxas’ assessment of this conversation:

Bonhoeffer knew that to live in fear of incurring “guilt” was itself sinful. God wanted his beloved children to operate out of freedom and joy to do what was right and good, not out of fear of making a mistake. To live in fear and guilt was to be “religious” in the pejorative sense that Bonhoeffer so often talked and preached about. He knew that to act freely could mean inadvertently doing wrong and incurring guilt. In fact, he felt that living this way meant that it was impossible to avoid incurring guilt, but if one wished to live responsibly and fully, one would be willing to do so.

Applying Bonhoeffer’s wisdom to choosing a career, we could say that to live in fear of choosing the wrong career and potentially disappointing God is, in itself, sinful, especially if that fear prevents us from making a decision. We do not need to, and should not, dread the consequences of our career decisions. We can make the necessary corrections as we pursue the direction God has for us and he more fully reveals his will for our lives.

A brief reminder of God’s grace in the sanctification process can provide reassurance as well. In Extravagant Grace, Barbara Duguid relies heavily on the writings of John Newton to point out how our continual growth as Christians is totally in God’s hands. Although from our perspective it feels like we need to make the right decisions in order to grow in obedience and
serve God effectively, in actuality God uses our poor decisions as well as our good decisions to accomplish his purposes. Can our gratitude to Christ for his saving work in our lives drive us to strive for obedience and strive to make wise decisions that further his kingdom? Absolutely! But we need not have a crippling fear that making the wrong decision will bring God’s plan to a screeching halt. God uses us, warts and all, to accomplish his purposes in our lives and to use us for his kingdom purposes.

Conclusion

We recognize that determining the direction that God would have for us can be a confusing and potentially scary task. For people that find this to be true we hope that some of the above discussion helps them move to a place of better clarity.

Ultimately, we showed a remarkable tie between the current popular approaches to finding work and what was advocated centuries ago. Reviewing what Calvin, Luther, and others said about the value of work, we then noted how the integrated version of the modern approaches, as well as the approach advocated by Perkins, have a strong tie to a biblical approach.

We then provided some guidelines for readers and mentors of people who are at this juncture in their career. Throughout this process, we know that God will love us and offer us the grace and forgiveness we need to boldly pursue a God-directed career.

References

Abstract

The alignment of engineering professional functions with biblical calling and purpose will be explored by mapping engineering functions to major biblical themes. There is a human tendency to delineate aspects of life as either “sacred” (dedicated to God) or “secular” (independent of God). This leads to thinking errors and wrong conclusions about one’s purpose and opportunity to serve God. The typical thinking is that a Christian Engineer should simply be a moral engineer or practice engineering “Christianly”. Rather, a fuller understanding is that Engineering is a holy calling in which God calls some of His beloved to serve Him, by serving the needs of mankind. Engineering is not merely a career choice, but rather a divine calling from a God who loves us and will empower us to use the material resources that He has provided, in such a way as to improve the lives of people (all of whom He loves) and bring Him glory. What a magnificent opportunity! Could not God use engineers who thought this way and depended on Him to enable them to greatly improve the world? As Christian engineers and engineering educators it is our privilege to draw out this thinking in our colleagues and students so that we help them fulfill their calling. An Ishikawa (AKA “fishbone” or “cause and effect”) diagram will be used to map aspects of the engineering profession to the biblical themes of 1) Creation, 2) The Fall, 3) Redemption, and 4) The Second Coming (Restoration).

Introduction

In Dorothy Sayers’ seminal essay, ironically titled “Why Work?” she examines the valid reasons for work in what was a soon pending post World War II world. During the war, work had become a means to supply war preparations, and for a season, the reasons for work were self-evident; chiefly, the preservation of life and liberty. She ponders the past frivolities of not mending pre-war nylon stockings, but rather discarding and replacing worn specimens. During World War II, DuPont had reallocated all nylon from stockings to parachutes, tire cords and rope production. In the end Dorothy postulates that much of our economy and consumption is based on wasteful greed and striving.

“And, so that those wheels may turn, the consumer – that is, you and I, including the workers, who are consumers also – will again be urged to consume and waste; and unless...
we change our attitude – or rather unless we keep hold of the new attitude forced upon us by the logic of war – we shall again be bamboozled by our vanity, indolence, and greed into keeping the squirrel cage of wasteful economy turning.”

Sayers further suggests that the work should be for the beauty, efficacy and excellence of the work and in fact, the work itself is a way in which mankind honors God.

“And it is very possible that we cannot deal with economics at all, unless we can see economy from outside the (squirrel) cage; that we cannot begin to settle the relative values without considering absolute values. And if so, this may give a very precise and practical meaning to the words: “Seek ye first the kingdom of God, and His righteousness; and all these things shall be added to you.”…. I am persuaded that the reason why the Churches are in so much difficulty about giving a lead in the economic sphere is because they are trying to fit a Christian standard of economic to a wholly false and pagan understanding of work.

What is the Christian understanding of work? .... I should like to put before you two or three propositions arising out of the doctrinal position which I stated at the beginning: namely, that work is the natural exercise and function of man – the creature who is made in the image of his Creator. You will find that any of them if given in effect everyday practice, is so revolutionary (as compared with the habits of thinking into which we have fallen), as to make all political revolutions look like conformity.”

In brief summary the three propositions that Sayers put forth are:

1) Work is not the thing one does to live but should be the thing one lives to do and the way in which mankind offers himself to God;
2) Secular work is sacred for the Christian because God has called a person to it; and
3) The workers chief duty is to serve the work heartily as unto the lord.

Having seen Sayer’s analysis of the question “Why Work?” as asked from a predominately Christian perspective, the goal is to address the question of “Why would a person who lives in fellowship with Christ, invest their lives in the vocation of engineering?”; or simply put, “Why Engineer?”. This question will be approached from a biblical perspective by mapping engineering functions to major biblical themes.

**Secular – Sacred Divide**

There is a perhaps human tendency to break life into compartments: work vs. play; teaching vs. learning; responsibility vs. opportunity; Christian vs. Non-Christian; vocation vs. ministry; and perhaps worst of all, secular vs. sacred. Concern over this last compartmentalization is longstanding in the Christian church and perhaps inadvertently entrenched in church culture. Consider that we pray for Sunday School teachers who teach 1 hour a week and often neglect to pray for the same people, some of whom are vocational teachers who are engaged in teaching 40+ hours per week. God is surely as concerned for the effectiveness of the 40+ hours as He is for the 1 hour.
This longstanding misgiving that some things are sacred (dedicated to God) and others are secular (independent of God) is pervasive, persistent and problematic. This level of compartmentalization leads to legalism, hypocrisy and cynicism both in the Christian church and as seen by those outside the Christian church. A more biblical view is that everything is just Christian living. That is, a part of our life that God chooses to be involved in out of love for us. Scripture teaches that the Holy Spirit is in us and therefore with us at all times.

“As you therefore have received Christ Jesus the Lord, so walk in him, 2 pretending to God. 3 For you were bought at a price; therefore honor God with your bodies.” 1 Corinthians 6:19-20

In addition to His constant presence, this verse teaches that we were bought at a price, the implicit and precious blood of Jesus! Our sense of duty to vocational ministry is partly valid in that all Christians are “bought at a price” and called to live and work in fellowship with Christ through His indwelling Holy Spirit, but only some will derive a vocational living from their work, and most are not called to be pastors or missionaries. What we are missing is that secular work is sacred to God because His Holy Spirit indwells us as a comforting companion and we have wrongly assumed that He is disinterested in our non-church vocations. This problem is longstanding and has not been adequately dealt with by simply continuing to state that there is not a sacred vs. secular divide between church/service and other activities (work, play, recreation). Rather than continue to reiterate that there is no secular vs. sacred divide, we need to cast an inspiring vision of God’s intimate interest and involvement in all aspects of the lives of Christians, including their work, and most specifically in this case; the work of engineering.

Typical Thinking

Conventional wisdom is that a Christian engineer should simply live better in terms of honesty, sobriety, fairness, faithfulness and other character traits. These virtues, while essential, seem vastly insufficient for a person who has been called into fellowship with God through faith in Christ’s redemptive work on the cross. There is a sense that a Christian engineer is just supposed to engineer pleasantly, or ‘Christianly’. A dominant theme of the Christian faith is that individuals have a personal and interactive faith in God as He relates to them as individuals, each dear to His heart. It seems that a Christian Engineer should have a sense of calling from God to be an engineer and use God given skills for God’s glory! While engineering has meritorious qualities such as creativity, prestige, stability, higher than average wages and it is understandable that one might desire them, they are not sufficient for one who lives in fellowship with Christ. However, they do not need to be sufficient, because the engineering profession allows an effective and unique outlet for living out biblical themes and being used by God to implement his loving plan for people.

Alternative View

In response to these realities, what if Christian engineering students and engineers were exhorted to pray and determine whether they sensed that God has called them individually to be engineers? There seems to be three options:

1) Believe that you are not called to be an engineer and do it anyway – this is a double minded and delusional life;
2) Believe that you not called to be an engineer and change course of study or profession; or
3) See engineering as your divine calling from God and engineer to His glory.

Option 1 is wholly unacceptable. Option 2 does not seem very desirable, but is much more desirable than reaching the end of life and regretting your career choice, as the late Stephen Covey would describe as climbing the ladder of success, only to reach the top and suddenly realize that your ladder was leaning against the wrong wall. Option 3 is to see engineering as a calling from a God who knows you and loves you.

Mapping of Engineering Functions to Major Biblical Themes

The alignment of engineering professional functions with biblical calling and purpose will be explored by mapping engineering functions to major biblical themes. The typical church position is that a Christian engineer should simply be a moral engineer or practice engineering “Christianly”. Rather a fuller understanding is that engineering is a holy calling in which the triune God calls some of His beloved to serve Him by serving the needs of mankind. Engineering is not merely a career choice, but rather a divine calling from a God who loves people and will empower them to use the material resources that He has provided, in such a way as to improve the lives of people (all of whom He loves) and bring Him glory. What a magnificent opportunity! Could not God use engineers who thought this way and depended on Him to greatly improve the world?

A pictorial and conceptual mapping of engineering functions (and since engineers are human, this will implicitly include human functions) to major Biblical themes of 1) Creation, 2) The Fall, 3) Redemption, and 4) The Second Coming, as shown in Figure 1. A combination of scriptural references and illustrations will be put forth in mapping and illustrating these concepts.

Figure 1: Fishbone Mapping of Engineering Functions to Major Biblical Themes
1) Creation

A Biblical discussion of the work of engineering must begin in the book of beginnings, Genesis.

A) Divinely Provided Raw Materials

Genesis 1:1 states “In the beginning God created the heavens and the earth.” As Creator of the earth, God provided all materials that are in the earth: atoms, minerals, metals, oil, and all elements. Consider steel is a crafted combination of carbon and iron atoms, and the addition of modifying elements creates special alloys with unique properties (corrosion resistance, hardness, high temperature resistance, etc.). The diversity of what is currently known in steel alloy development and production allows a metallurgical engineer to spend an entire career maximizing the usefulness of God given carbon, iron and additional elements. God also provided all plant resources for our use.

Genesis 1:29a “Then God said, “I give you every seed-bearing plant on the face of the whole earth and every tree that has fruit with seed in it”.

At a minimum, agricultural engineering, paper and pulp engineering, wood science and engineering have their roots in seed-bearing plants that engineers modify for the benefit of mankind. God provided the earth and everything in it (mineral, oil, elements, plants, etc.); all material resources that we have access to. It is our privilege to steward these resources and discover their inherent usefulness in solving mankind’s problems. Christian engineers have the added benefit of deeply held convictions that God provided the raw materials, God cares about the physical needs of mankind, and that God indwells the individual Christian and can empower them for successful discovery and application of inherent properties.

B) Meaningful Work

Adam had a job tending the Garden of Eden and he did it in fellowship with God.

“The Lord God took the man and put him in the Garden of Eden to work it and take care of it.” (Genesis 2:15).

This provided a sense of purpose, responsibility, creativity, problem solving, intellectual engagement, as well as accountability to God for his faithful service. Work was intended to be enjoyable and fulfilling in the perfect world of the Garden of Eden. God’s fundamental expectation was that we would enjoy our work and find purpose and vitality in it, while enjoying fellowship with Him and each other. Some of us will find work as engineers, in accordance with the temperament and gifts God has given us. Work was not originally intended to be toil and suffering but rather enjoyment and by way of inference, both physical and mental exercise.

C) Emulation of God Given Design

Biomimicry is taking designs found in nature and using them to solve engineering problems. Biomimicry has provided technical adaptation from snakes teeth to hypodermic needles, bat and dolphin acoustic “sight” to sonar, burdocks to Velcro, and ant colony optimization (pheromone trails) to elegant solutions to the traveling salesman problem in operations research.4,5
Biomimicry has lead to numerous new designs as engineers emulate the Creator’s designs, though some scholars of biomimicry do not acknowledge the Creator.

D) Emulation of God’s Creativity in Design

The triune God has created mankind in his image and as Creator, He is inherently creative (thinking up new ideas and implementing them).

“All God said, “Let us make mankind in our image, in our likeness, so that they may rule over the fish in the sea and the birds in the sky, over the livestock and all the wild animals, and over all the creatures that move along the ground.” (Genesis 1:26).

It flows from being created in His image that mankind has an inherent tendency to be creative. Engineering allows a technically minded Christian to modify materials and energy for mankind’s benefit.

As an aside: Similarly, an artistically minded Christian can create artistic works of beauty and for engineers to make jest of their efforts is not far from making jest of a beautiful sunset or a field of wild flowers, which God created. The artistic among us are manifesting a non-technical aspect of being created in God’s image as they emulate the beauty He has created.

2) The Fall

In The Fall, Adam and Eve sinned against God and lost fellowship with Him (Genesis 3).

A) Work Became Toil

Genesis 3:17-19 states “To Adam he said, ‘Because you listened to your wife and ate fruit from the tree about which I commanded you, ‘You must not eat from it,’ “Cursed is the ground because of you; through painful toil you will eat food from it all the days of your life. It will produce thorns and thistles for you, and you will eat the plants of the field. By the sweat of your brow you will eat your food until you return to the ground, since from it you were taken; for dust you are and to dust you will return.”

Adam’s former meaningful work of managing the Garden in fellowship with God became toil – long strenuous fatiguing labor. As a result of this broken fellowship with God, separation from God (hiding in the Garden), fear, death and hard work appeared.

Genesis 3:21-24 ”The Lord God made garments of skin for Adam and his wife and clothed them. 22 And the Lord God said, ‘The man has now become like one of us, knowing good and evil. He must not be allowed to reach out his hand and take also from the tree of life and eat, and live forever.’ 23 So the Lord God banished him from the Garden of Eden to work the ground from which he had been taken. 24 After he drove the man out, he placed on the east side of the Garden of Eden cherubim and a flaming sword flashing back and forth to guard the way to the tree of life.”

B) Entropy and Decay Prevailed
After the Fall, creation was in “bondage to decay” as expressed in Romans 8:20-22 “For the creation was subjected to frustration, not by its own choice, but by the will of the one who subjected it, in hope that the creation itself will be liberated from its bondage to decay and brought into the freedom and glory of the children of God.” (Emphasis added)

A great deal of engineering effort goes into preventing decay of materials, for example:

i. Developing the process of pressure treating wood,
ii. Adding ultraviolet inhibitors to polymers to prevent photonic breaking of molecular bonds,
iii. Antioxidants to prevent metals from tarnishing,
iv. Paint and coating technology to preserve buildings and automobiles,
v. Sacrificial anodes to protect ocean going vessels from corrosion, and
vi. Oxygen barriers on food bags (e.g. potato chips) to keep fats from going rancid.

It could be reasoned that The Fall, set in motion the Second Law of Thermodynamics, which simply stated is, if a system is left alone entropy increases and things break down or decay. Not only does this apply to what are commonly thought of as engineering problems but to health problems as well, such as aging, skin disease from sun exposure, joint deterioration, memory loss and all health conditions. There is risk in this assertion in that all of our experience is in a fallen world, making it extremely difficult to imagine life in Eden or in the New Earth.

3) Redemption

A) Work Can Be Done in Fellowship with Christ

After redemption (accepting Christ’s sacrifice for our forgiveness) work can be done in fellowship with Christ as stated in I Corinthians1:9 “God is faithful, who has called you into fellowship with his Son, Jesus Christ our Lord.” In fact, in speaking of Christ, the Old Testament refers to him as “…friend who sticks closer than a brother” (Proverbs 18:24). Now the toil of work is once again done in the company of God.

B) Work Can Be Done in Fellowship with Others

The possibility of fellowship with other Christian’s in the workplace is self-evident and hopefully successful. John 13:34-35 states “A new command I give you: Love one another. As I have loved you, so you must love one another. By this everyone will know that you are my disciples, if you love one another.”

In addition to fellowship and love for Christians, there is a phenomenal opportunity in the engineering workplace to love those who are yet to be Christians and directives to do so. When Jesus was questioned as to what was the most important commandment He replied with two commingled commandments “ ‘The most important one,’ answered Jesus, ‘is this: ‘Hear, O Israel: The Lord our God, the Lord is one. Love the Lord your God with all your heart and with all your soul and with all your mind and with all your strength.’ The second is this: ‘Love your neighbor as yourself.’ There is no commandment greater than these.” (Mark 12:29-31).
10:25-37, the story of the Good Samaritan, Jesus established that anyone who needs our help, protection, kindness or mercy is our biblical neighbor. For some of us, this was nearly the totality of how we imagined God could be involved in our engineering profession.

C) Restoration of Order/Ministry of Reconciliation

In much the same way that health professionals apply skills to meet the health needs that resulted from sin entering mankind in Eden, so also, engineers apply their technical skills meeting the manifold physical needs that exist outside of Eden. Collectively these are a physical manifestation of restoration of order or what the Bible refers to as the ministry of reconciliation.

The biblical ministry of reconciliation applies primarily to the souls of mankind but also to the whole creation itself, which is now subjected to frustration (Romans 8:20). Engineers fight the disorder and chaos that exists outside of the Garden of Eden. Consider, in Eden there was no need for clothes so there must have been no need for heating and cooling systems, which some engineers make their living designing. Similarly food production was a non-issue in Eden, so agricultural equipment had no purpose. Since all needs were met in Eden, transportation was an utter non-issue; there was no place better to go. Yet, it is plausible that mankind would have engineered in Eden, since we are created in God’s image, which includes mimicking His creativity. Fuller discussion of this possibility will be left for those that are theologians firstly and perhaps engineers secondly.

2 Corinthians 5:17-21 states “Therefore, if anyone is in Christ, the new creation has come: The old has gone, the new is here! All this is from God, who reconciled us to himself through Christ and gave us the ministry of reconciliation: that God was reconciling the world to himself in Christ, not counting people’s sins against them. And he has committed to us the message of reconciliation. We are therefore Christ’s ambassadors, as though God were making his appeal through us. We implore you on Christ’s behalf: Be reconciled to God. God made him who had no sin to be sin for us, so that in him we might become the righteousness of God.” (Emphasis added)

In The Fall, both the souls of mankind and the living conditions of mankind suffered tragic loss. In Christ, the souls of mankind are restored and God involves us in the “ministry of reconciliation” as we are given the privilege of telling people about our confident faith in Christ. While the spiritual reconciliation is complete upon trusting Christ for forgiveness, the living conditions of mankind are not directly affected by their faith in Christ. As engineers it is incontestable that much of our effort is invested in improving living conditions outside of Eden; in this, there is a general and physical “ministry of reconciliation”.

D) Engineering Designs Decrease Toil

A traditional and common definition of engineering is –“the application of science and mathematics by which the properties of matter and the sources of energy in nature are made useful to people” 7 The term “useful” implies meeting a need but in Eden there were no needs that required an engineered solution. Much, if not all, of engineering provides accommodation
to meet needs that only exist outside of Eden and decrease toil. Figure 2 shows some example of sources of toil and engineering solutions.

<table>
<thead>
<tr>
<th>Source of Toil (Long Strenuous Fatiguing Labor)</th>
<th>Engineering Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Human waste removal and treatment</td>
<td>Design of a garbage truck to compress and contain trash; Sewage treatment plant</td>
</tr>
<tr>
<td>Food preparation/Cooking</td>
<td>Natural gas distribution systems and measurement meters for gas billing, Design of a stove and oven that avoids manual fuel collection</td>
</tr>
<tr>
<td>Lawn mowing</td>
<td>Gas powered riding mower/ zero turn</td>
</tr>
<tr>
<td>Snow removal</td>
<td>Gas powered snow blower</td>
</tr>
<tr>
<td>Hunting for meat</td>
<td>Firearm</td>
</tr>
<tr>
<td>Collecting food</td>
<td>Automobile for frequent runs to the grocery store</td>
</tr>
<tr>
<td>Digging a post hole for shop construction</td>
<td>Skid steer and power auger</td>
</tr>
</tbody>
</table>

Figure 2: Sources of Toil and Engineering Solutions

E) The Great Commission/Transportation

The Great Commission was stated by Jesus to the eleven disciples.

Matthew 28:19-20. “Therefore go and make disciples of all nations, baptizing them in the name of the Father and of the Son and of the Holy Spirit, and teaching them to obey everything I have commanded you. And surely I am with you always, to the very end of the age.” After Jesus’s death and resurrection, and in the last moment before his body ascension to heaven, Jesus stated “But you will receive power when the Holy Spirit comes on you; and you will be my witnesses in Jerusalem, and in all Judea and Samaria, and to the ends of the earth.” (Matthew 28:19-20).

The Great Commission “go and make disciples” was originally carried out by foot, riding animals, rowboats and sailboats. Were it not for engineering development in carriages, bicycles, automobiles, steamships, trains and airplanes, the “going” would be both slower and more difficult. Consider a transatlantic trip from England to New York used to take months by sailing vessel and today can be completed in about 10 hours by airplane. Not only have engineering innovations in transportation technology facilitated progression of the Great Commission but today, email and video conference further enable a virtual ‘going and telling’.

4) Second Coming/Restoration

Whether the Christian passes from this life and goes to Christ, or Christ first returns bodily to the earth, there will be a time of accountability for the Christian, not for sin as that is covered when they trust Christ’s sacrifice for their sin, but rather accountability for we did with the opportunities we had in life. This perhaps is a major factor in the Christian’s conflict over a life of “vocational ministry” (pastorate, missionary, etc.) or a life of “secular (non-church) work”.

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Again the issue is what the individual is called by God to do and how faithful they are at their individual calling, not whether they seek vocational ministry out of a sense of obligation. God had created us each with a proclivity for certain things and that includes certain types of work. For some of us that is the work of engineering.

A) Stewardship

Biblically a steward is one who takes care of something that belongs to another. For example, a steward often functioned as a household operations manager in a wealthy household. The homeowner was in charge of the decisions, but the steward was in charge of executing the homeowner’s wishes.

I Peter 4:10 “Each of you should use whatever gift you have received to serve others, as faithful stewards of God’s grace in its various forms.”

God being our Creator is in charge of how he created each of us, and we are stewards of our gifts, abilities and opportunities in all aspects of life. We must use them well for His glory and mankind’s benefit. If God created us with a desire/interest/aptitude for engineering and we chose vocational ministry not out of a healthy sense of calling, but rather out of a forced sense of responsibility, we will have been unfaithful stewards of the very lives He gave us in that we suppressed how He made us.

B) Rewards

2 Corinthians 5:10 states “For we must all appear before the judgment seat of Christ, so that each of us may receive what is due us for the things done while in the body, whether good or bad.” The text “what is due us” implies rewards or payment. Since sin is atoned for by trusting in Christ’s sacrificial death, the rewards for “good and bad” cannot refer to forgiveness and judgment, as that has been settled by trusting Christ. The rewards seem to be in the context of how faithful was our stewardship.

Conclusion

God calls some of his beloved and forgiven children to a career of engineering. This is an opportunity to manifest many of his attributes (creativity, problem solving, concern for others), while working in fellowship with God and man, and utilizing the material resources that He has provided in such a way that we help mankind, whom He loves, while stewarding our own God given desires, strengths and calling in such a way as to bring Him glory. For those called to engineering, it is not just a vocation to be endured, but it is a calling to be embraced, enjoyed, and stewarded. In this context, engineering is not merely a career choice, but rather a calling from a God who loves you and will empower you to use the material resources that He has provided, in such a way as to improve the lives of people (all of whom He loves) and bring Him glory. What a magnificent opportunity! Could not God use engineers who thought this way and depended on Him to greatly improve the world? It is time we advocate for this mindset of being ‘called of God to engineering’; it is needed in ourselves and colleagues as engineers, and in our students as engineering faculty. Could not God use us to bless this generation if we saw it as He sees it; engineering is a holy calling in accordance with how he created us? In closing,
“So whether you eat or drink or whatever you do, do it all for the glory of God.”
(I Corinthians 10:31); let us be found faithful to our calling as engineers!

Epilogue: A Historical Example

Christians have long felt a sense of duty or higher value to live a life of vocational ministry such as the pastorate or missionary work. R.G. LeTourneau felt the same sense of duty to dedicate his life’s work to full time vocational ministry; that is to say, ministry that provided a living. Eventually, he became convinced that God needed businessmen as much as God needed pastors and missionaries and entered into a partnership with God, wherein he pursued God’s priorities rather than asking God to support his priorities.\(^8\) Out of the partnership, God used R.G.’s means of making a living, namely engineering and business of earth moving and heavy equipment, as platform for ministry to limited access countries and a way to bless the people of the earth. Seventy percent of the earth moving equipment used in combat by the allied forces in World War II was manufactured by the LeTourneau Corporation.\(^9,10\) It is arguable that America and freedom might both have suffered a death blow were it not for R.G. answering God’s calling on his life to be a faithful engineer and businessman.

\(^1\) Sayers, Dorothy, “Why Work?” and essay in Creed or Chaos?, Sophia Institute Press, 1949. (First published as an essay or lecture pamphlet prior to the end of World War II, which spanned from 1939-September 2, 1945)

\(^2\) Smithsonian Magazine Online “Stocking Series, Part 1: Wartime Rationing and Nylon Riots”


A Christian Perspective on Artificial Intelligence: How Should Christians Think about Thinking Machines?

Steve VanderLeest¹ and Derek Schuurman²

Abstract

Artificial Intelligence (AI) is a topic that deserves attention and careful thought from Christians working in technology. The technology of AI has shifted from the subject of science fiction literature to become the goal of serious engineering development. Recent developments have led to more machine-like humans with repairs and augmentation of our physical bodies through artificial limbs, artificial hearts, and replacement hips. More ambitious research plans are underway to study the brain with the goal of replicating it. Ray Kurzweil, director of engineering at Google, has publicly declared his goal to live long enough that technology will have developed far enough to allow him to download his brain into a computer and thereby achieve immortality. Accompanying recent technological developments in AI have been calls for caution, warning society that AI is different than earlier technology inventions in ways that could bring unforeseen consequences or irreversible harm. In order to understand whether it may be possible to build a human-like machine, we must first understand what it means to be human. This paper will not presume to fully answer this age-old question, but will pose some relevant questions and attempt to catalog some of the attributes that might be key to the definition. Having identified some candidate attributes of the human identity, we then turn to the scriptures, identifying some biblical principles that may be helpful in considering AI and what it means to be human, organized into the themes of creation, fall, and redemption. The paper concludes with a call to responsibility and humility.

1. Introduction

Artificial Intelligence (AI) is the idea of developing computers that can think, performing tasks that have normally required human intelligence. While AI arose as a possibility quite early in the history of computing, the concept of a machine that could mimic a human has a much longer history, going back hundreds of years to the idea of automatons. Science fiction literature and film has a rich tradition of exploring the ideas of AI and their implications. For example, the classic 1982 sci-fi film Blade Runner depicted human-looking androids called “replicants” which could think as well as humans and were physically stronger. One of the officers on the starship Enterprise in the 1990s television series Star Trek: The Next Generation was Lt. Cdr. Data, a human-looking android with great physical strength and great computing capability. Both the movie and television series depicted machines that were surprisingly human-like – exhibiting physical characteristics, but often poignantly displaying human emotions and values. However, these are simply stories played out by human actors and not possible in real life. Or is it

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possible? For another perspective, consider the converse. Science fiction has not only imagined human-like machines, but also machine-like humans. Consider the 1970s television series *The Six Million Dollar Man*, where fictional character Steve Austin suffers a terrible accident resulting in an extensive surgery to rebuild the injured parts of his body with artificial parts, resulting in augmented abilities for his legs, right arm, and one eye. What seemed visionary 40 years ago has partly slipped into reality, with substantial advances in the technology and science of artificial limbs, though an artificial eye with the capabilities imagined by the TV show has yet to be realized.

In this paper, we explore the topic of AI from a Christian perspective. We have divided our discussion into three sections. First, we make the argument that the topic of artificial intelligence is worthy of consideration by Christian scholars. Technological advances in AI are hinting at some incredible opportunities, but also warrant significant caution. Christians can and should be part of this debate. Second, we explore one of the key questions that underlie many of the issues that AI raises: what does it mean to be human? We dare not claim to answer this question that has perplexed philosophers, poets, and theologians throughout the ages. Rather, we’ll mention a few interesting features of the human landscape, surveying and evaluating some of the potential litmus tests that have been suggested for our self-identification problem. Third, we explore a number of relevant scriptural themes that apply to AI as well as to our broader technological developments.

2. Artificial Intelligence is a Worthy Question

Artificial intelligence is a timely and important topic for Christians to consider as the gap between machine and human shrinks. Although we do not traditionally consider humans adding technology to themselves (machine-like humans) as a type of AI, we’ll briefly consider it in this section to set the stage for exploring the more traditional concept of AI, machines with human-like attributes.

2.1. Machine-Like Humans
Humans have been augmenting themselves with technology since the beginning. Marshall McLuhan suggests that technology and media are “extensions” of ourselves.¹ Tools are, by definition, an augmentation of some ability, from hammers that help us pound harder to telescopes that help us see further. Sometimes we use technology to repair, such as using a splint to guide the healing of a broken bone. Despite this close relationship with our tools, until recently the line between ourselves and our technology was fairly clear. When the technology becomes an integral part of our bodies, the line is a bit more ambiguous. For a person with an artificial hip or heart, most would agree on which part of the person was human and which part was technology. It gets a bit fuzzier if we modify someone’s cells using gene therapy. A machine of cold metal is easily identified as technology, but warm, supple artificial skin might fool us. Today’s artificial limbs are surprisingly sophisticated, and current research is already experimenting with artificial limbs controlled directly by a person’s nervous system.
The Christian philosopher Henk Geertsema writes that “the development and use of technical devices to heal or improve certain functions of the human body does not invalidate the difference between human beings and machines.”² But how much of ourselves can we replace and still remain human? What if I replace an amputated leg with an artificial limb? Surely, I am still human. What if I replace a faulty heart with an artificial organ? Although in ancient times the heart might be considered the seat of emotion and central to my humanity, in modern times my artificial heart would not disqualify me as being human. What if I start augmenting my brain? Would a “brain prosthesis” ever be possible? Nanotechnology enhancements might still be years away, but one could consider cochlear implants for the profoundly deaf to be a forerunner of brain augmentation. Suppose a microscopic computer is developed which can replace the function of a single neuron. Furthermore, suppose we begin using this to replace neurons in the brain. Replacing one neuron would have little or no effect, but replacing every neuron would essentially replace the brain with a computer. How much of our biological brain could I replace before I am no longer human?³

2.2. Human-Like Machines
While the previous section considered whether adding technology to ourselves might make us less than human, the question of this section is whether it is possible that technology might become more than machine, to be sentient. From the early days of computing, entertaining examples of software pretending to be a person have arisen, such as the ELIZA program written in the 1960s that responded in natural language using scripted pattern matching.⁴ Today’s expert systems can be surprisingly humanlike, such as computerized call center operators that understand a wide variety of spoken phrases, or the IBM Watson supercomputer that can defeat even the best humans on Jeopardy!, the popular TV game show. Even our smartphones are getting smart with us, with Siri providing helpful and sometimes entertaining answers to our queries. The Google autonomous car has demonstrated the ability for intelligent software to navigate a vehicle in complex environments. Web search engines routinely provide relevant results with both accuracy and speed.

A recent survey of current research in AI begins by noting how far the state of the art has advanced.⁵ The author notes that “[s]ome forms of computer vision and natural language processing can currently be done quite well.... The current generation of autonomous vehicles do quite well on the much more challenging problem of off-road driving. For certain kinds of technical image analysis, (e.g. in medical applications), computers do as well or better than human experts.” Despite these notable examples, AI still faces many fundamental challenges. The author concludes that even for simple narrowly defined tasks, AI still generally lags behind human abilities.⁶ It was also observed that AI capabilities often reach a plateau and that any incremental improvements typically require tremendous efforts and computing power. One area that presents particular challenges for AI is the area of common sense reasoning. A category of questions called “Winograd schemas” can be used to test such reasoning. An example is the following: “The man couldn’t lift his son because he was so heavy. Who was heavy?”⁷ Statements like these simply require identifying who the pronoun “he” refers to, yet they rely on
broader knowledge to infer that heavy items are more difficult to lift. Nevertheless, researchers remain busy trying to tackle problems such as these.

Ray Kurzweil, the inventor now working at Google on natural language processing, is famous for his publicly stated aim of transferring his consciousness into a computer and thereby becoming immortal. If Kurzweil tried it and the machine then said “I am Ray,” would we consider it to be human? Could we ethically turn it off or destroy it, saying it is simply a computer and therefore we can do what we wish with it? How certain would we be? What if it (he?) cried out for help and mercy? What role does humility play in considering such a technical marvel – or perhaps monstrosity? Does humility say humans should never dare to develop such devices? Kurzweil is not the only computer scientist imagining such a development. Danny Hillis, in a famous essay on AI, thought similarly: “Of course, I understand that this is just a dream. And I will admit that I am more propelled by hope than by the probability of success. But if, within this artificial mind, the seed of human knowledge begins to sustain itself and grow of its own accord, then for the first time human thought will live free of bones and flesh, giving this child of mind an earthly immortality denied to us.”

2.3. Caution: Dangerous Curves Ahead

Futurists like Kurzweil look forward with nearly unbridled optimism towards the time when computers surpass us. “Before the next century is over, human beings will no longer be the most intelligent or capable type of entity on the planet.” But not all technology experts are so sanguine. Tom Dietterich and Eric Horvitz, the current president and a former president of the Association for the Advancement of Artificial Intelligence, highlight several risks and warn of the dangers of software errors in AI software. The growing complexity of AI software presents numerous challenges, especially when it is used to control automobiles, surgical robots, and weapon systems. It is a particular challenge to verify systems which rely on “machine learning” techniques. Another risk is the possibility of cyber-attacks, and AI systems which control safety-critical systems are also vulnerable to such attacks. Finally, the authors identify the risk illustrated in the tale of the “sorcerer’s apprentice.” What happens if a super-intelligent AI program runs amok and out of control? Others have voiced similar fears. Bill Joy, Sun Microsystems chief scientist at the time, wrote a famous article for Wired magazine shortly after a thought-provoking encounter with Ray Kurzweil. He writes about AI that “Thus we have the possibility not just of weapons of mass destruction but of knowledge-enabled mass destruction (KMD), this destructiveness hugely amplified by the power of self-replication. I think it is no exaggeration to say we are on the cusp of the further perfection of extreme evil, an evil whose possibility spreads well beyond that which weapons of mass destruction bequeathed to the nation-states, on to a surprising and terrible empowerment of extreme individuals.” Others are even more frank about these concerns. Stephen Hawking warns in a BBC interview that the “development of full artificial intelligence could spell the end of the human race.” The entrepreneur and engineer Elon Musk says “I think we should be very careful about artificial intelligence. If I had to guess at what our biggest existential threat is, it’s probably that.”
3. What Does it Mean to be Human?

As we develop technology to provide some amazing capabilities, does there ever come a point where we have crossed a line, where machines have become human in some sense? Or is that impossible? To answer that question, we need to understand what it means to be human.

Humans have always had an identity crisis. For much of our recorded history, we have used rather specious definitions of humanness or personhood that granted power to some, while granting few or no rights to others. At times some have thought our gender or the color of our skin formed a key part of that definition. If we have erred too narrowly in the past, do we now risk erring too widely? In this section, we first consider the classical division of a person into mind and body. Second, we identify a few human attributes that might be considered essential to our self identity. Third, we describe the Turing test for intelligence and one example critique of the test.

3.1. Mind, Body, Soul

What makes up the human person? Different schools of thought in ontology (the philosophy that explores the nature of being or existence) have suggested anthropologies that affirm or deny the existence of at least three different parts: the body, mind, and soul. The body is composed of our physical self, including our neurons and brain. The mind consists of our thoughts and consciousness. The soul is “that part of us that might be said to be eternal or to transcend in some way the mortal body.”

Most anthropological views can be categorized as either monism or dualism. Monism asserts that humans are made of one substance. Thomas Hobbes was an early supporter of monism by arguing that consciousness and souls arise from the functions of the body alone. In contrast, dualism holds that humans are somehow made up of two parts, often identified as the body and the soul. Dualism includes many theories about how the body and soul are separate but related. Platonic dualism saw the body as an earthly package for the spirit, something to be eventually discarded. René Descartes, an early modern philosopher who promoted a form of dualism, suggested the body was like a machine that interacted with the mind. Although the Bible is not a philosophical anthropology textbook, there are many verses indicating that we are more than our bodies. For example, Paul says that we “are confident, I say, and would prefer to be away from the body and at home with the Lord” (2 Corinthians 5:8, NIV). The view of “holistic dualism” acknowledges both the wholeness of body and soul as well as affirming the notion that one continues to exist after death without an earthly body.

A third view which is far less common is trichotomy, the notion that humans are comprised of three components: body, soul, and spirit. The spirit is the human self, where the soul mediates the spirit and the body. Trichotomists could appeal to literal interpretations of New Testament verses such as 1 Thessalonians 5:23 “May your whole spirit, soul and body be kept blameless at the coming of our Lord Jesus Christ.” However, care should be used when using the scriptures in
this way. The point of this verse does not appear to be a lesson on anthropology, but rather that our whole person be preserved and kept.  

More recently, many modern western philosophers have embraced materialism, which is a form of monism that denies the presence of a soul and holds that reality is made up of only the physical stuff around us. In his book, *The Concept of Mind*, Gilbert Ryle rejects dualism and ridicules it as “the myth of the ghost in the machine.” More recently, a materialist view has been promoted by Ray Kurzweil in a series of books such as *The Age of Spiritual Machines* and *How to Create a Mind*. This perspective dismisses the notion of a soul, concluding that our mind and consciousness arise entirely from the physical brain. Some materialists account for the complexity of the mind by attributing it to the interactions of many simple entities, like an ant colony. Although each ant appears to act at random, more complex behavior emerges at the level of the colony. “The notion of emergence would suggest that such a network, once it reached some critical mass, would spontaneously begin to think.”

Our view of human personhood has profound implications. For instance, a materialist view applied to the mind (sometimes referred to as physicalism) will conclude that all illnesses of the mind or spirit are reducible to an illness of the body which can be treated by pharmaceuticals. Matthew Dickerson argues that physicalism has significant implications for areas like creativity, heroism, ecology, as well as for reason and science. Despite its rejection of the spiritual aspect, materialism itself has religious aspects. The belief that there is nothing but the physical is itself a religious belief since it identifies the physical as an unconditional reality that is the ultimate explainer of our existence. For a physicalist, being human simply reduces to the interactions of basic particles. However, if we consider ourselves as more than simply a physical body, how does that shape our view of what it means to be human?

### 3.2. Which Attributes are Essentially Human?
In this section we inventory a number of the characteristics that some have suggested are essential human qualities, i.e., attributes that define us as human. We do not claim the list is exhaustive. Rather, it demonstrates the range of ideas thought to be core to our identity.

#### 3.2.1. Intelligence
Some technologists working in AI have not aimed for replication of humans, but rather for intelligence. Is intelligence, the ability to learn and to apply that learning, an essential quality of humanness? Is it a unique talent of humans alone, unattainable by any other natural or artificial creature? Could a machine have excellent logic and rationality, surpassing humans at deductive reasoning? The IBM supercomputer Deep Blue was able to beat the world chess champion Garry Kasparov in 1997. If a machine can play chess better than the very best human player, does that make it intelligent?

#### 3.2.2. Sentience
Closely related to intelligence, sentience is the ability to perceive. Is perception an essential human quality? Is consciousness, self-awareness, the key ingredient to personhood? The AI
community has long struggled with what self-awareness means. Douglas Hofstadter, in his famous 1979 book *Gödel, Escher, Bach*, explored ideas of recursion, self-reference, and the idea of the “strange loop” as possible layers that might allow the whole to be greater than the sum of its parts. This is the idea of emergence, that simple components can interact so that a more sophisticated, perhaps intelligent, behavior emerges.

### 3.2.3. Emotion

Emotion is often considered a part of our intellect, but a peculiar component that is not logical or calculating, even though it can often be predicted. Emotion seems to be connected both to our state of mind and to our bodies. Emotion makes our hearts race and our hands sweat. It puts the bounce in our step or the frown on our face. In order to feel emotions, one must have both intelligence and self-awareness. For example, someone becomes angry after a barrage of insults only because they both understand the meaning of the insults and they perceive the insult as directed at them personally.

### 3.2.4. Soul

As Christians, we consider the soul an essential part of our being, in fact, the one part that survives our death. In addition, this is often the attribute that many believe uniquely defines us as human, particularly when other attributes do not seem sufficiently unique because we find them at least partially in other creatures. For instance, we observe emotion in chimpanzees or dolphins and might perceive intelligence in a chess-playing computer. By contrast, the soul seems to be confined to humans. However, one cannot measure for the presence of a soul as a test of humanity. The computer scientist Matthew Dickerson makes the astute point that assuming we can scientifically test for the spiritual assumes that the spiritual is reducible to the material, which is equivalent to saying that the spiritual does not exist.  

### 3.2.5. Living being

If our body is an essential part of our humanity, then it seems biology is a necessary component of humanity. This is the part of our humanity that we share with other living creatures. However, having a natural biological birth does not appear to be part of that qualification, since we do not see any distinction for test-tube babies. It remains to be seen how we would treat human clones, or humans with significant alterations to their genetic makeup.

### 3.2.6. Creativity, Use of tools

Rather than distinguishing humans by how they think, as *homo sapiens*, many point to our ability to make tools as what distinguishes us from other creatures. Thus we are *homo faber*, humans as makers. Inventing novel devices, composing new music, and innovating in business are all examples of creativity that may also be hints of an essential quality of our humanity. Humor is a type of creativity required to banter about with one another, and laughter is sometimes considered uniquely human.

### 3.2.7. Free will

Do humans have free will, the ability to choose? Or do our circumstances, genetics, and state of mind determine our course of action? Vaclav Havel pointed to this attribute as essential: “The
secret of man is the secret of his responsibility.” We cannot be held morally responsible for an act unless we have a choice (to act or not to act). Moral agency, the ability to choose, and to be held morally accountable for our choice, is perhaps uniquely human. While some would argue that a computer can never be human because it cannot truly make a free will choice, others counter that humans cannot make a free choice either, thus subscribing to some version of determinism.

3.3. Implications of Materialism
Taking a materialist view to its logical conclusions would deny the very possibility of many of the attributes listed above. Physicalism applies the principles of materialism to the brain such that “our brains are natural phenomena and this must follow the cause-and-effect laws manifest in machines.” A strict physicalist view would deny the presence of a soul, suggesting we are just bodies operating under physical laws. In addition, it would reject the notion of free will. Kurzweil notes that “if human decision making is based on such predictable interactions of basic particles, our decisions must also be predetermined. That would contradict human freedom to choose.” Furthermore, if our thoughts are merely the “interactions of basic particles” then true creativity is also an illusion. Matthew Dickerson argues that “to the extent that creativity is defined in terms of originality … physical automata, whether the digital computer variety or the biochemical human variety, are not capable of originating anything.” According to this view, emotions would also be simply reduced to the interactions of basic particles.

Materialism and physicalism are highly reductionistic with profound implications on how we view our humanity. Human attributes such as souls, free will, creativity, and emotions are essentially an illusion reducible to the laws of physics. Furthermore, it has implications for our understanding of knowing and truth. Materialism is a type of naturalism, and C.S. Lewis observes that naturalism “offers what professes to be a full account of our mental behaviour, but this account, on inspection, leaves no room for the acts of knowing or insight on which the whole value of our thinking, as a means to truth, depends.” Ironically, a physicalist view of reality even leads to devaluing of our physical bodies, potentially leading to a new kind of gnosticism. Kurzweil suggests that “We don’t always need real bodies. If we happen to be in a virtual environment, then a virtual body will do just fine.”

What are the attributes that define our humanity? Even if one rejects a physicalist view, it is not clear that any of these attributes, or any other proposed characteristics can definitively categorize humans and nonhumans. Not only is it difficult to conclusively identify those attributes that are sufficient, it is also difficult to simply list which ones are necessary. Perhaps the value of such a list is not as a tool to determine who is in the human “club,” but rather to encourage and challenge each other to flourish and grow towards the best humans we can be. In order to determine what is best, we must identify our purpose. However, before we turn to that subject through the lens of Scripture, let’s look at one other proposed test, a rather well-known one within the AI community.
3.4. The Turing Test

Rather than attempting to catalog the attributes necessary to demonstrate intelligence, in a famous 1950 paper titled “Computing Machinery and Intelligence,” the computing pioneer Alan Turing suggested a test he called the “imitation game” that could be used to answer the question “Can machines think?” The proposed test would have a human interrogator send messages remotely to both a human and a computer (not knowing which was which), and get responses back. If the interrogator could not tell the difference between the human and the machine, Turing suggested that the computer could be said to be thinking. This test has since become known as the “Turing test.” Turing’s prediction was that the test he proposed would be passed by about the year 2000. A recent computer program which simulated a 13-year-old Ukrainian boy purportedly passed the the Turing test in 2014, but it passed by only a slim margin.

There have been many challenges to the presuppositions inherent in the Turing test. The validity of the Turing test rests on a philosophical notion called functionalism which suggests that mental states can be reduced to mapping sensory inputs to behavioral outputs. The philosopher John Searle challenges this idea by describing a thought experiment called the Chinese room experiment. Searle first considers a computer that passes the Turing test, but he adds the stipulation that the test is conducted in Chinese. He now conducts a second experiment, in which a person who only understands English is placed in a room. Messages in Chinese are passed into the room. Following an elaborate set of English instructions which are based on the program of the computer which passed the Chinese Turing test, the English-speaking person matches the Chinese symbols with instructions on how to return a message by arranging other symbols. To a person fluent in Chinese on the outside, it would appear that the English-speaking person in the room understands Chinese. However, as this experiment demonstrates, the English-speaking person in the room does not have any understanding of Chinese. Searle argues that the computer is comparable in that it is essentially a symbol processing machine and it cannot be said to think. He distinguishes between “weak AI” and “strong AI.” Strong AI holds that machines running the right software could become a mind, whereas weak AI holds that machines can only simulate thinking.

If a machine can play chess better than the very best human player, does that make it intelligent? Searle would claim no, that it is merely the human programmers that are intelligent, who have programmed the machine to implement their ideas. However, how is this different than a human mentor that teaches a student to play chess? Do we say the mentor is intelligent and the student is merely deterministically following the rules she was taught? We now turn to the Bible for further insight into that question, looking beyond our self-identified attributes and focusing rather on our purpose, as determined by our Creator.

4. Human Identity in Scripture

The previous section explored a few approaches that philosophers and sometimes scientists have taken in distinguishing what makes us human, or what constitutes thinking. Christians should find these questions particularly important, since our identity as humans should be closely tied to
our created purpose. In this section, we thus explore some scriptural concepts and references that help us understand our identity as humans and the role of technology. We will explore these concepts in categories corresponding to the three part narrative of creation, fall, and redemption.

4.1. Created Human

Genesis 1:27 recounts the creation of man, and in comparison to all the prior acts of creation, we are unique: the only creatures God created that he also endowed with his image. As the *imago Dei*, we reflect the creator. The Genesis passage offers scant explanation for what it means to be created in God’s likeness, though the immediately succeeding sentence indicates God created humans male and female. Many have taken this adjacent statement to imply relationship is a part of that reflection. Richard Mouw suggests as much, observing that “we are social beings because God created us with deep communal longings and needs.” He goes further to suggest that the image does not find its fullness in any single individual human, but only in “rich diversity of humankind spread over many places and times.” Like Mouw, Gunton also argues that part of our essential being is our placement in relation: “[that] the Platonic view is with us still in deep-seated assumptions of our culture is shown, for example, by the widespread belief that if a computer could be made to think, it would be a kind of person, as if relationality and especially love were not also essentials of our being.” These twin ideas of relationship and love are concisely seen in our Lord’s instructions to his disciples as he is preparing them for his impending death, commanding them to “love one another” (John 15:17). Perhaps we are the most human when we reflect God’s likeness in these twin ideas.

Another reflection of God’s likeness is our ability to create. Although all humans have creativity to some extent, the Bible tells of an extra dose of creativity that God gives Bezalel, the craftsman tasked with building the tabernacle.

> Then the Lord spoke to Moses. He said, “I have chosen Bezalel, the son of Uri. Uri is the son of Hur. Bezalel is from the tribe of Judah. I have filled him with the Spirit of God. I have filled Bezalel with wisdom, with understanding, with knowledge and with all kinds of skill. He can make beautiful patterns in gold, silver and bronze. He can cut and set stones. He can work with wood. In fact, he can work in all kinds of crafts.

Exodus 31:1-5 (NIRV)

Matthew Dickerson argues that creativity is the ability to make something original and “to bring into being something new, which does not proceed entirely from what has gone before or what already exists.” He argues that machines are controlled by physical causes (predictable or unpredictable) and therefore, by this definition, cannot be creative. Aesthetic ways of knowing cannot be simply reduced to physical processes. In contrast, a materialist view of humans would suggest that creativity is just an illusion.

Regardless of how we understand our status as created beings in the likeness of our Creator, there is a danger to defining a line too tightly around our humanity. If we define ourselves as
intelligent beings, then what does that say of people of below average intelligence? If we define ourselves as having a natural, biological birth, then what does that say of test tube babies or human clones (should they ever occur)? If we require emotion or creativity, what does that say of the person lying in a coma? Thus the danger in circumscribing our humanity too tightly is that we consider certain people as somehow less human, whether they are a fetus, a senile elderly person, a man in a coma, or a child with a severe brain injury. It would be a mistake to define some kind of litmus test for what it means to be human based on attributes such as intelligence or creativity. Instead we should affirm the clear biblical teaching that God has made humankind in his image. Our ontological status as humans seems to be distinct from the rest of the creation (including machines). This implies that human personhood needs to be attributed even when certain human attributes are less evident due to age, capacity or infirmities.

A materialist would reject the notion of a soul, free will, and creativity since this viewpoint sees everything as determined by natural laws. In contrast, a Christian view acknowledges the diversity as well as the irreducible complexity of reality. Geertsema concludes that “[f]or a responsible implementation of all kinds of technology it is of crucial importance that the distinct nature of human personhood be taken into account.”40 A Christian perspective is shaped by the understanding that God created us with the ability to respond to him, and with that ability comes freedom and responsibility. Part of that responsibility is given in the cultural mandate (Genesis 1:28) where humans are called to take care of the earth and unfold all the latent possibilities in creation. Freedom and responsibility imply we have a choice. The ability to choose (and especially to make a moral decision) is perhaps the most difficult attribute to understand about ourselves. How can the creator give the thing he creates the ability to do something other than what the creator intends? And yet that is what God gave us. This ability touches on the paradox between election and free will. This ability makes us human, and perhaps more than any other ability makes us distinct from machines, but this ability also allowed us to fall.
4.2. Fallen Human
Views such as materialism elevate “one aspect of human being to be the ultimate, apart from any
dependence or responsibility to God the creator.” Anthony Hoekema identifies this as a type of
idolatry: worshiping an aspect of creation rather than the creator. Others (such as Kurzweil) place
their trust in the hope that one day we will be able to download our brains into a computer and
dependence or responsibility to God the creator.” Anthony Hoekema identifies this as a type of
idolatry: worshiping an aspect of creation rather than the creator. Others (such as Kurzweil) place
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idolatry: worshiping an aspect of creation rather than the creator. Others (such as Kurzweil) place
their trust in the hope that one day we will be able to download our brains into a computer and
thereby achieve a kind of immortality. This is an example of technicism, placing our trust in
technology as savior of the human condition. Fred Brooks observes that the rhetoric in the field
of AI has “echoed the builders of the Tower of Babel: ‘We will make machines that think; we
will make Giant Brains.’” Brooks suggests that these goals, “although glamorous and
motivating, sent the discipline off in the wrong direction.” We are responsible for the direction
of our technology, also in the area of AI.

As Brooks observes, this posture is not new. The story of the Tower of Babel describes people
who use technology to build a name for themselves (Genesis 11:4). Other examples in Scripture
include King Uzziah. He built towers and invented devices for military use, which made him
powerful. “But after Uzziah became powerful, his pride led to his downfall” (2 Chron. 26:16).
The technology of AI, like many other technologies, makes the user more powerful. That power
can make us proud and lead to our own downfall. In response to technicism, we affirm with the
psalmist: “Some trust in chariots. Some trust in horses. But we trust in the Lord our God” (Psalm
20:7 NIRV).

Our intent is not to suggest that technology itself is inherently evil. Rather, it is corrupted by sin
just like all of creation. Following ideas from Wolters, we believe that God created inherent
structures as originally good, including marriage, government, music, math, technology, and
more. However, sin affects the direction of these structures, turning them away from God. Thus,
just as examples of bad marriages or governments should not lead us to conclude that marriage
or government themselves are evil, neither should examples of bad technology lead us to avoid
all technology.

All humans are fallen by virtue of the choice made by our first parents. Romans 8:22 tells us that
not only we, but the entire creation now groans under the weight of sin. So do we pass on that
sinful nature not only to our biological children, but also to our technical creations? If all
creation is tainted, then yes, our technical inventions are also affected by sin. It is notable that
although AI and robots are affected by sin, if they do not have moral agency, then they cannot
initiate sin on their own. Being held morally responsible for an act implies freedom and choice,
and AI programs simply follow a program. Thus sin becomes evident in machines when humans
develop and employ them in ways that go against God’s intent for his creation. Those that hope
AI will somehow enable us to surpass ourselves, producing an intelligent, yet sinless creature,
are mistaken. The whole creation is groaning, including our machines, and no human effort can
erase that taint. Our redemption does not lie in our technology.
4.3. Redeemed Human

As Christians, we believe that God created all things good, including humans. We believe that with our first parents, we fell into sin, tainting all creation in the act. Only through Christ do we have redemption: it is by grace we have been saved. As Christians, we are called to be Christ's redemptive agents in the world. As engineers, we are especially called to use our creative gifts to develop redemptive technology. What would such tools look like? Such tools would enable us to fulfill our purpose better. They would aid us towards shalom. Following his work with ELIZA, Joseph Weizenbaum reflected on the appropriate role for computers. He concluded that computers ought not to be used for tasks that require wisdom. Weizenbaum goes on to conclude that “there are limits to what computers ought to be put to do.”

Our purpose is to love God and our neighbor, to fill the earth and steward it, to act justly, love mercy, and walk humbly with our God. These are things that we ought not offload to machines. Why? Regardless of the question of whether machines could actually do these things, humans ought not delegate those tasks that form our very purpose. Tools that aid us in our purpose are commendable, but tools that purportedly perform our purpose instead of us are condemnable. Imagine inventing a machine that rather than helping us pray or worship, instead did our praying or worshiping for us, so that we no longer felt the need to do it ourselves. Such a machine would be completely misguided, and the users of such a machine would be truly deluded. For the remainder of this section we thus explore how AI could aid (but not replace) us in pursuing our purpose. Micah 6:8 (NIV) can be a helpful guide for engineers to ensure our project requirements conform with God's requirements:

He has shown you, O mortal, what is good.
And what does the Lord require of you?
To act justly and to love mercy
and to walk humbly with your God.

We could use AI technology to help us seek justice by enabling an attorney to help less fortunate members of society at a reasonable cost, by using an expert AI system as a first contact “help desk.” However, it would be important that the attorney does not simply sit back and let the expert system provide the only advice to the client. Rather, the attorney ought to use the expert system as an assistant to do a first interview, so that her or his in-person follow-up meeting with clients is more effective. Such combination of humans and machines could help the rural poor get at least initial legal advice remotely over the Internet or phone. A negative example related to justice would be handing over life and death decisions on the battlefield to AI programs. One principle of just war is that someone should be held justly responsible for any deaths that occur, an ethical requirement that cannot be offloaded to machines. We have faced the moral question of machines replacing humans to do physical labor for many years. Some might argue that manual labor is drudgery and the machines free us to do more creative work. Now with AI, we have a new variation of this dilemma as expert systems are developed in order to replace experts such as doctors, lawyers, or perhaps even engineers. But does freeing us from labour free us from the very activity that makes us human? Work is not a result of the fall; both manual work
and knowledge work are a legitimate part of our creational calling in this world. In his book *The Glass Cage*, Nicholas Carr provides a nuanced discussion on the many effects of automation illustrating that it is an ethical choice since it shapes our lives and our place in the world.\(^{48}\)

We could use AI technology to help us love *mercy*. For example, AI image processing systems already exist today that can detect certain types of breast cancer in mammogram images better than human doctors can alone.\(^{49}\) As another example of mercy, we could enable caring by providing a first contact for call centers with AI natural voice recognition so that trivial tasks could be completed routinely, while ensuring a human operator smoothly steps in for more creative and service-oriented needs. Home automation systems could enable the elderly to maintain independence longer by assisting them with everyday tasks such as cleaning and meal preparations. However, it is important that such systems do not entirely replace humans. For instance, the design of AI programs and robots should recognize social norms and not be employed to replace human care and companionship. Sherry Turkle observes that any relationship with a robot is a relationship only about one person.\(^{50}\)

We could use AI technology with *humility* by recognizing our own human limitations. If we are uncertain of the status of our AI creations, then in humility, perhaps we should avoid such pursuits. That is, perhaps there is a line beyond which we may develop technologies for which we no longer fully comprehend the implications. We have a long history of letting the genie out of the bottle, and we know you can never put him back in. This is the risk illustrated in the tale of the “sorcerer’s apprentice.” However, even if some or even most agreed to be prudent with research and development, a few might continue these developments. As we consider the AI tools we build, we need to keep in mind our purpose. All technology is utilitarian: we develop tools as means towards ends. But technology has a bias, and this bias shapes us as we use our tools. How can AI help us fulfill our purpose without the means distorting our ends? For one thing, we should not aim to develop thinking machines that replace us, but rather to develop thinking machines that aid us in thinking ourselves, that augment and extend our abilities. On the topic of AI, Fred Brooks suggest that we should explore intelligence amplifying software to work together with humans rather than focusing on building “giant brains.”\(^{51}\) In a paper on the benefits and risks of AI, the authors conclude that “Some of the most exciting opportunities ahead for AI bring together the complementary talents of people and computing systems.”\(^{52}\)

As a final thought regarding redemption as humans, we look forward to restoration. In contrast, consider that Ray Kurzweil looks forward to a day when we can download our brains into computers and thus shed the fragile “hardware” of our brains and bodies.\(^{53}\) Kurzweil goes on to quote Yeats who reflects on our physical self as “but a paltry thing, a tattered coat upon a stick.” We reject this thesis – the biblical story affirms the value of our physical bodies and the physical world. Although our body and soul are temporarily separated at death, God’s redemption plan involves a new heaven and new earth and a bodily resurrection for believers.\(^{54}\) We will not be disembodied souls floating in the ether, but rather we look forward to a day when God will renew his creation, which will include both our souls and bodies.
5. Conclusion

The computer scientist Edsger Dijkstra once wrote that the question of whether machines can think is about as relevant as the question of whether “submarines can swim.” Regardless of where one stands on this question, it is clear that AI raises many fundamental questions about what it means to be human. These questions include issues of philosophical anthropology and the notion of the body, soul, and mind. It includes questions about what makes us uniquely human and whether a machine could ever replicate that. Many attributes are associated with being human such as intelligence, emotion, creativity and free will. Views that suggest computers can completely replicate humans are largely based on a materialistic view of humans. We have argued that the implications of materialism lead to a denial of many of these attributes, such as free will, creativity, and the soul. In fact, materialism can lead to a rejection of the body as people seek to shed their mortal bodies and look forward to downloading their brains into virtual environments.

Instead, we have described a view of what it means to be human shaped by the story of Scripture. The creation story describes who we are as image bearers of God who have been granted freedom and responsibility. We acknowledge the fall into sin, which has led to many distortions in the use and application of technology, including AI. In fact, some make an idol out of AI, putting their faith in it as an eventual pathway to immortality. Thankfully there is hope through Christ’s redemption, and we are called to participate in bringing renewal, also in the work of AI and technology.

The question of how should Christians think about thinking machines is not just an academic exercise nor is it just fodder for science fiction movies. This question leads to fundamental beliefs about what it means to be human. As we better understand a biblical view of ourselves we will also better understand our relationship to our machines and technology. We are called to use AI in responsible ways that lead to human flourishing and exercising humility to avoid possible harm. We also recognize that there are some things for which AI ought not to be used and which may require limits. Differing philosophical presuppositions lead to very different conclusions about the place and use of AI. These technologies are not neutral, not only in the presuppositions behind them, but also in their increasing impact on our work, our culture and our world. In humility and in recognition of our fallen state, we should aim to develop tools that ameliorate the effects of sin, that enhance justice, that show mercy. In short, our tools should aid us in working as redemptive agents.

6. Endnotes

3 This question is not unlike the “Theseus' paradox” - a thought experiment which asks whether an object remains the same object if all of its individual components are replaced.
6 ibid, pp.3-4.
10 Tom Dietterich and Eric Horvitz, “Benefits and Risks of Artificial Intelligence”.
14 Note that the term dualism has different meanings in different contexts. In this context we are referring to the general notion that human beings are somehow comprised of two parts.
16 ibid., p. 120.
17 ibid., p. 9.
21 Hillis, p. 175.
22 Dickerson, pp. xxi-xxii.
23 Dickerson, Chapters 2-4.
24 It should be noted that physicalism does not necessarily imply determinism. Some physicalists suggest that quantum effects could account for randomness which cannot be predetermined.
25 Dickerson, p. 27.
26 Kurzweil, p. 57.
27 ibid., p. 58.
30 Kurzweil, p. 142.
35 Mouv, p. 265.
37 Dickerson, pp. 43-44.
38 ibid., p. 56.
42 ibid., p. 64.
44 Weizenbaum, pp. 8, 227.
ibid. p. 11.


ibid. p.17.

http://www.breastcancer.org/research-news/20130425-4


Brooks, p. 64.

Dietterich.

Kurweil, p. 129.

For a good discussion of this, see: J. Richard Middleton, A New Heaven and a New Earth, Baker Academic, 2014.
Christian Perspective on Neural Engineering

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Abstract

Neural Engineering is a fast growing field where new engineering solutions are applied to problematic areas of the brain in the hope that technology can provide a solution, and indeed has provided solutions to many individuals. With the Brain Research through Advancing Innovative Neurotechnologies (BRAIN) initiative in 2013, to map the human brain, neural engineering will have the spotlight for a while. Like any fast developing field, it is important that Christian scientists and thinkers come together to offer a Christian perspective. This will help us to envision the field of neural engineering from a biblical perspective, and also help us to deeply root ourselves in scripture as new neuroscientific findings challenge our perception of the human brain.

With this in mind we explore some topics related to neural engineering. We look at Biblical foundations for studying engineering and neuroscience through a Biblical framework. Next, we briefly introduce the concept of consciousness since the view of consciousness impacts how we make ethical decisions about neuro-research. We discuss in detail a Christian response to two areas of neural engineering: neural prosthetics and brain imaging. In neural prosthetics we look at the three main categories: motor, sensory and cognitive neural prosthetics. We introduce each of the categories mentioning the conditions it applies to and critique it from a Christian perspective. Finally we look at the discussion about free-will from a neuroscientific perspective and how our understanding may change with the use of brain imaging. While these topics can be discussed in length, our purpose is to introduce the topics and raise the reader's awareness of the principal problems at hand and therefore kept brief.

Introduction

While neuroscience is physical in nature (the study of neurons in the brain), there is also a non-physical aspect when explaining the nature of behavior caused by these neurons on a psychological level. For ages, humans have dealt with questions such as who we are and why we behave as we behave. Before today’s imaging techniques, philosophers and psychologists, were ‘soft’ scientists. These would become ‘hard’ sciences, with the possibility of recording and quantifying brain activity. We live in a society that values cognitive capacities, like thinking, memory and concentration, and society seeks to know the underlying biological mechanisms of these cognitive capacities. Technological developments boost the societal interest in neuroscience.

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Neural engineering (or neuroengineering) attempts to improve health and quality of life through replacement, restoration and enhancement of the functions of the nervous system. Today, the possibilities to monitor and manipulate brain activity seem to be endless. Neural imaging is used to understand the mechanisms of how dysfunctional nervous systems work. Neuroprosthetics alone have a predicted growth of $11.61 billion in 2021 [1]. Neurolaw and neuromarketing also have strong links to neural engineering.

We will explore what a Christian worldview looks like in engineering and neuroscience. Since consciousness has implications for how we do research, the topic of consciousness is briefly introduced. Two areas of neural engineering are discussed in this paper. First, neural prosthetics; where we introduce the technical aspects and formulate a Christian response. Second is the area of brain imaging and how this impacts the way we understand free-will.

A Biblical Framework

When coming up with a theological foundation for neural engineering, the primary problem is the definition of humanity. Unlike in traditional fields of engineering, here we deal with concept of who/what a human is and this definition makes a difference on how we apply engineering principles in to studies dealing with the brain, because the brain influences consciousness. Contemporary thinkers often base their theory on a reductionistic definition of what humans are. When humans are defined as material, technical structure, the step to transhumanity (an intermediary form between human and posthuman) is a small one. The mind is both naturalized and computerized, and the brain can now be described as an incredibly powerful microprocessor, the mother of all motherboards [2]." The widespread tendency to describe all interactions in terms of engineering lead to impoverishment of science and our society in general. In Christianity, human as image of God is central. The human exists in his relation to a Creator-God. In other words, humans do not exist in themselves, (‘in him we live and move and exist’ - Acts 17) and are not owners of their existence. All of reality is defined by this ‘origin-relationship’. In Christian philosophy, three fundamental assumptions are central according to Glaas: 1) diversity and coherency of aspects (like physical and spiritual), 2) the fundamental unity of being a person, 3) and the origin, namely the relation of Creator-creation [3]. Given the idea of a person, and its capacity to communicate with God, there is a sum equal greater than the physics and chemistry in the brain. Therefore, Christians are critical of technological developments and scenarios based on a reductionistic worldview which reduces the human from the God-given capacity to communicate at a higher level. It clashes with the in-freedom-responsible human, as described in the Bible [4]. A reductionistic worldview can be accepted in most traditional fields of engineering as they are in a physical domain. However, since the brain being in a physical domain, can influence consciousness in a non-physical domain, and by engineering manipulations of the brain, the consciousness (and through that free will) of a person can be manipulated, we as Christian engineers are critical of any reductionistic approach to neural engineering that does not incorporate the holistic approach.

When we consider our Christian understanding of engineering; God created the heavens and the earth in its vast array (Genesis 2:1) and entrusted humans to work it further and take care of it (Gen 2:15) and in doing so, we enter into a partnership with God. Engineering begins with the God-issued mandate of development and preservation of the vast creation. Engineering is a
creational task in unfolding God’s creation and glory. However, due to “the fall”, much of the engineering work involves alleviating the effects of sin in creation [5]. As we do this, we wait in anticipation along with all creation, for the day when all of creation will be redeemed (Romans 8). We understand that this salvation can and will only come through the redemptive work of Jesus on the cross. The age to come that Jesus inaugurated on the cross is one in which, all effects of the fall will be dealt with. We wait in hope as we live in the period of the ‘already-and-not-yet’, for that day when the kingdom is fully established (Rev 21:24-26).

One of the fundamental things that arise out of our Biblical framework, is our status as created beings. Humans have the capacity to make choices and are accountable for those choices. Academia is dominated by naturalists, like Daniël Dennett and Richard Dawkins, who present their worldview as if it follows from science, indeed, as if it is itself science. They extrapolate methodological reductionism in science to philosophical and atheistic materialism. As a consequence many Christians cannot resist the temptation to reject science [6, 7], even though they have no Biblical background to do so.

In matters where the Bible seems silent, the Christian worldview adopts a Biblical framework based on the character of God. Individual morality is derived from God and social ethics are often centered around the concept of morality derived from God. We are image bearers of God and the work we do has intrinsic value.

**Consciousness**

We humans, pride ourselves in superior intelligence, which beget human achievements like language, art, and last but not least, consciousness. Our specie distinguishes ourselves by the ability of self-consciousness. The mystery of consciousness is fascinating: we are familiar with being conscious, but it is a vague concept. Our view on consciousness will determine the way we make decisions on what to do with the brain; we need to think holistically.

To study consciousness, we are surrendered to introspection. The mystery of consciousness is interesting because of the gap between mind and body. Most scientists agree the brain is necessary in having consciousness. The experience of consciousness can be described as perspectivistic (experienced from first-person-perspective) and total (meaningful coherence with my memories and desires). Transparancy is another characteristic: When I look outside, I’m conscious of my garden, not of the representation on my retina. This reflexivity describes that we are conscious of our consciousness and stream of consciousness, meaning consciousness is not static. This way of describing consciousness is a reason for some scientists, like Susan Blackmore, to state that consciousness is not a personal, rather a cosmological experience [8].

It is fascinating to compare the Bible verses about consciousness, mind and reason. In the Old Testament the idea of the present day ‘mind’ is complex and understood in three forms; heart (leb, lebab), spirit (ruah) and soul (nepes). The way the Old Testament talks about the mind reflects the Oriental view on humans in a holistic manner: the intellectual and emotional dimensions of human life are considered from the perspective of the whole person: heart, soul, and spirit are not separate parts of the inner person, but each is a reference to the whole inner
person [9]. Nancy Murphy, a theologian and philosopher, shows that there is no single teaching about the metaphysics of human beings in the Bible, and humans remain morally responsible, independent of which theory you follow [10].

The definition of consciousness itself is something that is being evolved and naturalism and idealism have failed to give satisfying answers as yet. For the purpose of this paper, we resolve for a simple definition of consciousness as something we are aware of and that which influences decisions we make. Consciousness emerges from the operations of the brain and consciousness in turn influences the circuitry of the brain [11].

**Neural Prosthetics/ Neuroprosthetics/ Neurodevices**

One of the newest weapons in the struggle for improvement and enhancement is neural prosthetics (also known as neurodevices). A neuroprosthetic is a prosthetic which communicates with the nervous system to repair or replace impaired areas of the nervous system, resulting in modification of behavior or cognition. Neuroprosthetics are categorized into three broad classes: motor, sensory and cognitive. Motor neuroprosthetics use the signals from the brain and convert these into actions while sensory neuroprosthetics is an artificial sensor that converts mechanical signals into electrical signals which can be understood by the brain. Cognitive neuroprosthetics is a class of prosthetics that relate to higher level cognitive processes that organize behavior. We wish to describe briefly the working principles of each of these, their applications and the concerns as we apply neuroprosthetics in daily lives.

**Technology of Neuroprosthetics**

*Motor Neuroprosthetics:* These ‘thought controlled robots’ attempt to restore motor function to amputees or those with conditions such as paralysis, tetraplegia, spinal cord injuries (SCI), multiple sclerosis (MS) and amyotrophic lateral sclerosis (ALS). These prosthetics are often referred to as brain-computer interfaces (BCI) or brain-machine interfaces (BMI). The signals are acquired by inserting electrodes a few millimeters in to the brain for invasive signals (spikes or local field potentials (LFP)), or by placing electrodes on the surface of the brain (electrocorticography (ECoG) or intracranial electroencephalography (iEEG)), or non-invasively by placing electrodes on the scalp (electroencephalography (EEG)). The tasks are carried out by the actuator which can be a robot, a computer cursor or even a paralyzed limb through a technique called functional electrode stimulation (FES). BMIs are also used to aid rehabilitation.

*Sensory Neuroprosthetics:* Most of us may have been moved by seeing videos of infants respond to sound for the first time via cochlear implants, a type of sensory neuroprosthetic that is the most widely used. Cochlear Implants, visual implants, prosthetics for pain relief and bladder control implants are in use at present. The brain perceives the information coming from the organ, enabling the person to hear or see what was intended. Spinal cord stimulators use a pulse generator and an electrode to send electrical pulses to stimulate the nervous system to control chronic pain for conditions such as ischemia.
Cognitive Neuroprosthetics: This class of neuroprosthetics, is perhaps the least understood in engineering circles. The most common is brain stimulation; passing a magnetic (Transcranial magnetic stimulation (TMS)) or electrical current (transcranial direct current stimulation (tDCS)) through different areas of the brain which affects the disease area either directly or indirectly. Studies show cognitive enhancement after using these techniques [14, 15]. Deep brain stimulation (DBS) is the best known form of invasive neurotherapy, where electrodes are placed inside the brain in order to alter brain function. The electrodes are regulated by a pulse generator, which is implanted in the body (very similar to a cardiac pacemaker). Another promising technique is optogenetics: neurons are made photosensitive using genetic manipulation and not optimal for clinical use at preent [16, 17]. Cognitive Neuroprosthetics finds applications in Post-traumatic Stress Disorder (PTSD), Attention Deficit Hyperactivity Disorder (ADHD), Parkinson’s disease (PD), Obsessive Compulsive Disorder (OCD) and related disorders like misophonia [18, 19]. It is also used as a diagnostic tool for depression.

Figure 1: (A) A possible outcome: How a fully-implantable BMI could restore limb mobility in paralyzed subjects or amputees [12]. (B) hemiplegic patient walking with hybrid assistive limb (HAL) during an experiment [13]

Figure 2: (A) Cochlear Implant Device [20]. (B) DBS electrode implanted intracranially with wires connecting to pulse generators [21].
A Christian Response to Neural Prosthetics

With EEG, several groups have shown the ability to control wheelchairs and even control small robotic devices such as toy helicopters. With invasive signals paralyzed patients have been able to type emails and control robotic arms to feed themselves. Will this lead us to becoming mindless cyborgs or trans-human species? Probably not because of the present technological limitations. However, there are other concerns which need to be addressed.

Privacy & Autonomy: Autonomy here is defined as a person’s right for self-government and the right to be free from external control or influence. Research has shown how behavior and actions of animals can be controlled by the use of a BMI remotely. Ethical concerns have prevented such experiments being conducted in humans; even though this is possible. The idea of BMIs is to have a system that can learn from its environment and make decisions independently, foreseeing the needs of the person. With this technology, the needs of the person can be re-wired and the BMI which was to be a slave, becomes the master, which we are often cautioned to by science fiction. If this were so, can a person’s mind go back to its former state after completion of one’s duties? EEG controlled cyborgs and super-soldiers might one day become a reality. Our concerns as Christians and scientists, arise from the perspective of preserving the God-given freedom to both rationalize and to respond to our situations. Given our fallen nature, BMIs in the wrong hands can have this influence on otherwise helpless people.

Cultural Aspects: Sensory prosthetics have enhanced lives for decades since the first cochlear implant in 1970s, the benefits possibly far outweigh the risks involved. The majority of the world which is ‘hearing’ would consider deafness as a disability or as a tremendous disadvantage to society. Are deafness and blindness sicknesses, and if so, is it not the responsibility of Christian doctors and engineers to find a cure for them? The Gospels record Jesus healing several deaf and blind persons, almost always giving them the choice of being healed. Technology at present is not even able to come close to restoring vision or hearing to this level. Are we saying no to cochlear implants? Not at all: Given that deafness and blindness by itself does not cause death and most individuals of the deaf community do not consider deafness to be an impairment to live a happy life and would opt out of neurosurgery if offered the chance to hear. This does not mean that the deaf community is against technological advancement but simply that as a society, we need to respect the choice of the deaf community.

Controllability and Limiting Access: The fast growing popularity of cognitive neuroprosthetics is accompanied by many ethical questions. EEG, TMS and tDCS devices are easily available online, portable, can be used at home, and show significant effects on cognitive function. This results in its use for “cosmetic” neurology: the use of tDCS to enhance normal cognitive function [22, 23]. The devices not bound to the clinic, and commercial applications, without professional supervision, become more and more common, like the Emotiv EPOC (www.emotiv.com) and MindWave Mobile (www.neurosky.com). In the wrong hands, this technology can also do physical damage to brain and body areas it controls (i.e. the whole body).

Cognitive Side Effects: It is important to notice that DBS only treats symptoms of the disease and does not cure the illness. Human enhancement is not something for science fiction: in
today’s academia, methylphenidate and beta blockers are already used to boost concentration and relaxation. How much more influence can targeted stimulation with these neuroprosthesis do to cognitive processes? More research is needed to find out the mechanisms of working in these treatments and identifying their side effects, for example, in the gaming industry [24] and social enhancement, such as improving productivity and rehabilitation of criminals [25, 26].

Behavior Manipulation: Since by altering brain activity, consciousness and memory can be manipulated, proper controlling of these medical devices and technology needs to take place. The application of DBS has led to interesting findings. A famous example is a man who became manic during DBS-treatment; started an affair, spent his savings and bought multiple houses [27]. When the devices were switched off, the man agreed to stay at a mental hospital while on stimulation. DBS can lead to cognitive side-effects, and change in mood and memory [28]. These developments raise concerns about the extent to which mood and cognition can and should be manipulated. “Will the use of neurodevices for human enhancement pressure other people to enhance themselves too? If the government would like civil servants, or other groups, to use neurotechnologies, are they able to refuse this? Should we consider the use of neurodevices for social enhancement a valid option, or an undesirable technology fix for social problems [29]?” Biblically, we have responsibility for the creation and ourselves, but who is responsible for accidents caused by the use of neurodevices? The manufacturer, the physician or the user?

Neural Engineering Sheds Light on Free-Will

Brain defects are often the underlying cause for aggressive behavior. A 40-yr old schoolteacher who previously had no psychiatric conditions showed altered sexual behavior and sociopathy; unable to inhibit sexual urges despite preserved moral knowledge. The condition was identified as arising from right prefrontal lobe dysfunction by an MRI scan and was resolved following tumor resection [30]. If this man acted upon his impulses would he be to blame, or would his nervous system be blamed? The federal insanity reform act of 1984 states that as a result of severe mental disease or defect, a person may be unable to comprehend and appreciate the nature and quality of a wrongful act. In these cases arguments can be made that the defendant was unable to resist impulses [31]. In cases of chronic mental disorders, an argument can be made that the person can know that killing is wrong, but have no moral gravity of the act of killing to refrain from killing. Brain images are used to show that indeed, the psychopathic brain, processes information differently. However in most cases such brain images are not accepted as evidence in court. Legally, a person can be found blameworthy as long as their rational capacities remain largely intact [31].
Brain imaging can be produced by different techniques: magnetic resonance imaging (MRI), functional MRI (fMRI), computed axial tomography (CAT/CT) scans, positron emission tomography (PET) and Magnetoencephalography (MEG) are the most commonly used. Brain imaging influences how we understand free-will. Using fMRI one study was able to predict sixty percent accurately if a person would use the left or right hand to push a button 7 seconds before the person was aware of it themselves [33-35]. This raises the issue about free will: do we really have a choice if we are not even aware of the choices we are making? We did not make the choice, our brain did. Would not punishment be wrong in a world where people cannot choose to do right or wrong? [31]. Mentally intact adults are morally responsible as they have the ability to engage in conscious deliberation, follow rules and generally control themselves [36]. However, we are not able yet to distinguish those who could not control vs those who did not control themselves. People respond to knowledge, sanctions and rewards making it possible to be ruled by law. We often think of our dispositions or habits as those that are wired in our biology, but often these ‘virtues’ (good habits) or ‘vices’ (bad habits) are learned and they become intricately woven in to the fiber of our being and become as if they were natural or biological [37]. As Ramachandra wrote: “Is it not hypocritical of people to accept academic awards and book royalties for work that was all pre-programmed in their neural circuitry and over which they had no choice? But since all moral arguments, too, including outrage at hypocrisy and double-standards, are presumed to be neural reflexes or hangovers from our Stone Age past, I suppose they can be safely ignored. Until, of course, pseudo-sciences like evolutionary psychology are thrown out of our universities. The cries of moral outrage, then, will be deafening [38].”

Saying “we are our brain” raises some misunderstandings; we are also the other parts of our body. We became who we are by interacting with other people as a whole person. Another point to take in mind is about responsibility. According to some neuroscientists, like Dick Swaab, our behavior is caused by genetics factors and early-life experiences. During life, change should not be possible [39]. This is incorrect; the brain develops throughout our whole life. Even genetic factors depend on our environment, which is called epigenetics. Indeed, our behavior is influenced by unconscious processes, but still plays an important role in training programs that minimize racial prejudices. So, behavior is influenced by unconscious and conscious processes. As said by Martin Luther: “we have an enslaved will.”
Conclusion

Each of the topics discussed in this paper can be expanded at length, but our aim was to give an introduction to the field and make Christian engineers interested in this field. Our mind is rooted in the most complex organ in the cosmos. Our brain, containing 100 billion neurons, is still a mystery. We are thankful that this has not prevented engineers from inventing methodologies and devices to enhance life for humans in relation to our brains. Many people benefit from these technological advancements. However, the main concern lies in the mind-brain interface; brain belongs to the physical level, consciousness does not. According to Libet consciousness is a non-physical phenomenon [40]. Mind and body are one, but not just physical, and as Christians we think of this in a holistic manner of the coherency of the spiritual and the physical [3]. Therefore, neural engineers must keep in mind the immediate effects to the non-physical (consciousness and free-will) aspects of the human brain, as they seek to provide solutions and enhance physical brain functions.

As we discuss concerns to privacy, autonomy and God-given freedom of choice, one of the common themes is that the field of ethics has not been carefully thought out and developed to keep with the pace of the developing field of neural engineering. Another theme that arose from this paper is the issue of enhancing human life, not creating super-humans. Ramachandra’s quote captures our argument well: “The biblical message of Incarnation:…the Word embraces human flesh, affirming our creaturely finitude and temporal nature. It is in frailty and vulnerability that God chooses to reveal his power… Christians share with posthumanists the belief that humans should be transformed. But we profoundly disagree over the purpose and source of that transformation. [41].” As engineers, we wholeheartedly support application of engineering principles to the field of neuroscience to restore and transform the effects brought by fallen nature and improve functions of the brain to make us more human. However, we draw the line where the engineering improvements make us less human (for example, removing the God-given free-will). We also tread with caution as we ourselves, who apply these principles are fallen in nature and can only be redeemed by Jesus’ salvaging work on the cross.

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References


Robotics and the Creation of Man

Matthew Rueben*

Introduction to robotics issues for Christian engineers

Humans use tools. For millennia our dealings with the rest of the created world have been mediated by technology. We have tilled fields using plows, spread ideas using books, and now we do all sorts of things using digital computers. Recently, some technologies even seem to be intelligent. This artificial intelligence (AI) could change the way we design, build, and use technology, and is therefore of primary concern to Christian engineers. My area of study is robots, which are machines that can sense, think, act, and perhaps even learn. A robot might consist of an artificial intelligence written in software that is embodied with physical sensors and actuators. Robots raise major concerns about whether AIs can have agency or deserve rights, and about the tendency of people to treat AIs like living things. In order to begin dealing with robotics from a Christian perspective, this paper replaces three mistaken assumptions about robotics with principles from the Genesis creation account.

Christian thinkers, even those outside of technical fields, should care about robotics. Like stem cell research and climate change research, robotics is a new and relevant field with tricky ethical questions. Robots garner a lot of publicity. This is a clarion call for Christian thinkers to search for good answers to these questions and fight for good outcomes as God's ambassadors and servants. Also, robotics forces us to ask difficult questions about what it means to be human – especially our authority, calling, and work practices – as well as about the rest of creation – especially the status of animals, the purpose of art, and how the creation glorifies God.

There are many technical questions in robotics that are still open to Christian influence. Ought we to make artificial intelligences in the first place, or would this be “playing God”? If we do decide to make robots (or continue making them, at this point), how ought we to make them? What should they look like (robot morphology), and how should they act (robot behavior)? I would argue that most commercial and research robots are designed to fit a certain application without developing any sort of framework for how robots ought to be in general. A general ethical framework for robots might answer questions not unlike the following. First, should we design robots to imitate a template species like humans or dogs? Second, what ought the robot's role to be? We can imagine helper robots, soldier robots, friend robots, tradesman robots, worker robots, expert robots, and robots that, for all intents and purposes, function just like an ordinary person. Finally, what about robot personality? Should robots be honest or dishonest, confident or careful, silly or serious, social or independent? These are just a few of the open questions that Christian thinkers could address.

Related technologies

Perhaps it would be useful to address these questions by way of analogy. An analogy begins with something we understand and builds a bridge of similarity to something new; we then carry bits of understanding from the known entity across the bridge to the unknown entity. I am often

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reminded of the diversity of known entities that are analogous to robots, each representing a
different facet. Painting and sculpture are like robots in that they depict the shapes of living
beings. Animation and computer-generated imagery (CGI) do the same thing with the addition of
motion, as does animatronics and even live theater. Machines called *automata* were common in
the Middle Ages; they were puppet-like machines that moved at the strike of a clock, or to spice
up a play or church service. Also, AIs are already among us: expert systems, search engines, and
even non-player characters (NPCs) in video games. If we understand any of these areas, we could
apply that understanding to some facet of robotics.

*Three mistaken assumptions about robots*

This paper replaces three mistaken assumptions about robotics with principles from the Genesis
creation account. These mistaken assumptions – summarized below – lead to misguided and
destructive practices in robotics technology.

M1. Man is the creator of robots
M2. Human-like robots could share the image of God
M3. Man is the highest authority over creation

These are not the only assumptions about robots in circulation, nor is this the only applicable
scripture, but I deem it a good starting point for a larger conversation. All three mistakes are easy
to commit, perhaps even from a Christian worldview; this is because of a chasm between what *is*
the case with robotics technology and what *appears to be the case* on the surface. First, since
robots so often look or act like living beings, it can be easy to think of them as such.

Furthermore, since we design and build robots, it seems natural to think of us as their *creators*.
This is harmful to the extent that it encourages a sort of God complex. Second, if robots are made
to be sufficiently similar to humans, it is asked whether they might also share in the essential
nature of humanity. This nature includes having a spirit, being self-conscious and rational,
holding God-given authority, and relating to God in all the ways that humans do as revealed by
the Bible. To summarize this point, if humans make robots like themselves, could robots share
the image of God? Third, our increasingly deep and broad understanding of natural processes
tempts us with a humanistic and utopian worldview. We see technological triumphs in the past,
combine them with technological progress in the present, and, by extension, imagine a
progressively happier world in the future. This false picture of the world discourages recourse to
God for power or purpose, and thus sets up man as the highest authority over the natural creation,
including robots.

*Outline*

This paper will focus on the Genesis creation account to draw conclusions about robotics. Entire
volumes could be written drawing analogies between Scripture and robotics – just as voluminous
theologies **have** been written for almost every other area of life – but this discussion is limited to
just a few basic conclusions from the text. Reading any text involves interpretation, so I limit
myself to what I think are obvious conclusions so as to avoid divisive disagreements, and I quote
a few respected commentators and theologians to anchor the discussion in authority and
tradition. I am no theologian myself, and do not pretend to be comprehensive either in my
coverage of the text or of the relevant scholarship. I do hope, however, that this discussion will serve as a useful starting place.

The creation of mankind
Our discussion will be based around the following passage from Genesis:

26 Then God said, “Let Us make man in Our image, according to Our likeness; and let them rule over the fish of the sea and over the birds of the sky and over the cattle and over all the earth, and over every creeping thing that creeps on the earth.” 27 God created man in His own image, in the image of God He created him; male and female He created them. 28 God blessed them; and God said to them, “Be fruitful and multiply, and fill the earth, and subdue it; and rule over the fish of the sea and over the birds of the sky and over every living thing that moves on the earth.” 29 Then God said, “Behold, I have given you every plant yielding seed that is on the surface of all the earth, and every tree which has fruit yielding seed; it shall be food for you; 30 and to every beast of the earth and to every bird of the sky and to every thing that moves on the earth which has life, I have given every green plant for food”; and it was so. 31 God saw all that He had made, and behold, it was very good. And there was evening and there was morning, the sixth day. (Gen 1:26-31, NASB)

Conclusions from the passage
(a) God creates.
(b) God created man³.
(c) God created man as different from the rest of creation; namely, “in His own image”.
(d) God set man as ruler over all other life on the earth.
(e) God commanded man to multiply himself over the whole earth.
(f) God says that all of the above is “very good”.

Creation
We begin with conclusion (a), which says that God creates. With regard to robotics, we are wondering if man can create in a similar way; if so, we could draw some analogies from this passage to help us understand robotics. Does man create robots? Is man the creator of robots? No, not exactly. Roman Catholic theology, inspired by the Church Fathers, defines creation as causing something to come into existence without any preexisting materials – that is, ex nihilo or out of nothing – such that the creator himself is the sole, independent source of the creative act⁴. In this sense of the word creation, we do not create a sandwich but rather assemble it from preexisting materials, and we do not create a sketch but rather craft it from paper and ink. Furthermore, we do not create even our own children, but rather they are generated by our bodies out of biological materials.

St. Thomas Aquinas has a very good discussion of creation in his Summa Theologica, First Part, Question 45, Articles 1-5 and 8⁵. He uses the same, strict definition of creation discussed above. Article 1 says that to create is to make something from nothing. Article 2 says that it is possible
for God to create, and that only God can create. Article 3 says that creation is a relation between the Creator and the created things. Article 4 says that God created complete, composite things, and not just matter as a building block. Article 5 says again that only God can create, and that created beings cannot create even as ministers or instruments of God. Skipping ahead, Article 8 says that natural processes and human craftsmanship do not create anything, and the things they do make depend upon God's original creative act. We can conclude that, using this theological definition of *creation*, man does not *create* robots, nor any technology for that matter. Therefore, no man holds the office of *creator* over a machine, strictly speaking.

But only strictly speaking. This technicality is perhaps offensive to the more casual way that we use the words *create* and *creator* in everyday life. In this narrow sense of *creation*, “there is nothing new under the sun” (Eccl 1:9c, NASB), but it is commonly held that humans have *creativity* and that the creativity that goes into their works has value. The reason I have cited Aquinas's ideas here is out of concern that, if we consider ourselves the *creators* of robots, we might forget that our dealings with robots are subject to God's authority and must follow His commandments. Instead of making broad statements about *creating* robots, then, let us be more exact: we *design* and *build* robots. These acts rely on God's original creative act for materials and also on our God-given faculties and gifts. Considering the extent to which our relationships with robots can or should imitate God's relationships with humans deserves treatment in another paper.

*The image of God*

Conclusion (c) mentions the image of God in which man has been made. Briefly, what does this mean, and how might it relate to robotics? In his commentary on Genesis, Matthew Henry divides the image of God into three parts: (1) soul, which includes understanding and willpower, (2) status and authority, and (3) purity, which includes the complete subjection of man's thoughts and actions to righteousness and holiness. This image, writes Henry, is now largely ruined, with only scraps of it remaining. Similarly, theologian Karl Barth writes about God's image by comparing us with Christ:

> Allowing for the differences between Jesus and us, we may yet affirm that real man is to be seen as conditioned by his relation to God, his deliverance by God, his determination to God's glory, his standing under God's lordship, his being in history and freedom, and his service of God and being for him.

Perhaps the two most important ideas here for robotics are that man is especially close to God and also in a position of special authority. Since these ideas are both *relational*, it does not seem like they would necessarily transfer to man-made machines, even to very human-like robots. In fact, it is difficult to imagine even a very sophisticated robot being relationally close to God at all.
St. Augustine's idea of the image of God is more clear-cut. He makes a fine distinction: whereas all creation is made "through the likeness" of God (the Son), only humans are made “to the likeness” as well. The key difference for St. Augustine is the “rational soul,” or our faculty of higher reasoning. This highlights the distinction between humanity and the rest of creation, which includes inanimate things, plant life, and non-human animal life. Unlike the ideas of Henry and Barth (above), however, St. Augustine's theology as described here is rather simple and, since it appeals mostly to the rational faculty, could group artificial intelligences with humans. If the image of God is the ability to think rationally, a devil's advocate could say, then what is keeping robots and other computerized systems from qualifying? Therefore, I don't think the “rational soul” rule is a complete description of the image of God, but what Augustine says is still a clear reminder that we need to carefully draw a boundary around what is a human person bearing this image and what is not. Issues like abortion have already raised similar questions, and artificial intelligence will raise new ones soon.

**Man as priest of creation**

Theologians in the Orthodox tradition interpret Adam's role in the Garden of Eden as that of high priest. Some note that Rabbinic interpreters compare Genesis 1-2 to the tabernacle in Exodus 26-39, which might make Adam the first priest. Whether or not that is true, the Revelation of John foretold that we would all be priests in God's Kingdom (Rev. 1:5-6, 5:9-10, 20:6; NASB). C.S. Lewis defines a priest as someone who represents God before mankind and mankind before God. To cite a similar perspective from the Orthodox tradition, the priest's role is to present God's created things (sacraments) back to God (sacrifice).

The Psalms in particular teach that the created things – even things we call inanimate – praise God and His deeds (Ps. 69:34, 89:5; NASB). Another Orthodox author writes as if this is literally true: “all the trees of the forest are rejoicing today; their nature has been sanctified because the Body of Christ was stretched upon a tree”. With this in mind, Orthodox theology teaches that man serves as priest of creation. We, like Christ, lift up the created world to God, Who in turn blesses it for us. Taken at face value, this way of thinking about priesthood would say it is proper for technology, which is ultimately part of God's creation, to be offered to God in praise by man, or else God might not bless it.
Defining our role in robotics

Now that we have examined the creation account in Genesis for clues, we can begin to piece together a picture of how humans will relate to robotics technology. This replaces the three mistaken assumptions we are considering –

M1. Man is the creator of robots
M2. Human-like robots could share the image of God
M3. Man is the highest authority over creation

– with three sound conclusions from Genesis:

C1. Man is the designer and builder of robots
C2. Human-like robots are made in the image of man
C3. Man has delegated authority over creation, and serves as its priest.

These conclusions are explained as follows.

C1. Man is the designer and builder of robots

Man is often trying to name himself the god and creator of his technology, and the advent of robotics is a tempting opportunity to make this mistake afresh. As Christians, we are more like caretakers than creators. God is the Creator, and that means two things. First, regarding His intention, He dictates the intended meaning and purpose of the creation. Second, regarding His action, He makes the original substance of the world, and in reality He made it to be good. In fact, “all good things come from God” (James 1:17, NASB). I would say that our role with respect to technology is closer to that of a designer or a builder than to a creator. The list goes on; we are also maintainers and repairers, but the key point is that we can only manipulate what God has already created. This means two things. First, regarding our intention, we get to decide on the meaning and purpose of our technologies and what we do with them. But this is futile if not aligned with God's revealed will; we can't think up better purposes than His purposes, and even if we could we wouldn't fare well working against God! Second, regarding our action, we can work to make our technologies the way we intend them to be. But this is futile without God's power, without which we are thwarted by sin from its three canonical sources: the world, the flesh, and the devil. Therefore, robots should not relate to humans as a creature does to its creator, since we by ourselves have neither the wisdom nor the power to play the part of the Creator.

C2. Human-like robots are made in the image of man

It is in two senses that robots are made in the image of man. First is the superficial sense: some robots actually look and act like humans. Second is the deeper sense: all robots are designed by humans, and therefore according to human categories. Human categories are limited and conflicting, while God's categories are absolutes because they come from complete knowledge, perfect wisdom, and the highest authority. Let's examine this more specifically. If we try to make robots to be like a certain animal, say a dog, it will always be from an external perspective; we will really make them like a dog-according-to-humans. This is because we only know what dogs are like from the outside, and don't really experience it. If we try to make robots in the image of God, then, it seems like we could do it, since we have experienced this reality as humans. Recall,
however, what was stated earlier: only scraps of the image of God remain as part of human experience. Christ is the prototype of this reality, and we are only like Him. Perhaps, though, insofar as we know God by the Holy Spirit and “have the mind of Christ,” we could imbue robots with some fragments of God's likeness (1 Cor 2:16, NASB). This still leaves the question of what parts of His likeness it is even possible for robots, by their nature, to bear. Not all parts, I would argue. In conclusion, robots are not made in the image of God as previously defined, but rather are made in the image of man. This is a necessary result of the fact that man, not God, is the immediate designer and builder of robots. To put it another way, one must be made by God Himself in order to be made in His image; man alone cannot do the trick.

C3. Man has delegated authority over creation, and serves as its priest
We have established that man is placed by God as “ruler” over lower creation (Gen 1:26, NASB). We must understand this act as a delegation of authority, which has several implications. First, delegated authority is contingent on the delegator's good favor. For example, there are consequences when God's people break their end of a covenant. God remains faithful, but man's authority could be revoked as a punishment. The account of the fall of man in Genesis 3 is a poignant example; as punishment for disobedience, man's dominance over nature is decreased and he is banished from the Garden. This only makes sense if man's authority over nature is delegated to him by God. This does not mean the authority is not real; in scripture we often see God allowing man's authority to continue, even in foolishness. Also, delegated authority is intimately connected to the purposes of the delegator. One cannot use delegated authority for one's own purposes, at least without consequences. It is in this sense that we say that man has delegated authority over nature, and therefore over technology. This authority is real, but is intended to be wielded to accomplish God's purposes, and could conceivably be revoked at any time. We have no authority of ourselves.

I also think there is some truth in the Orthodox view that man is meant to be priest of creation. In some sense, I think creation is meant to be caught up in human endeavors and used to glorify God, and that this might be an analog of sanctification for inanimate things, including robots. I also think this perspective is new to the conversation about technology within Christendom.

How might this inform the way we think about robots? What does it look like to “offer” robots (and their services) to God? However we might describe this, it might be crucial to securing God's blessing on our work as engineers. Also, is there some way in which robotics technology can be made to “worship” God? The medieval automata mentioned earlier were often religious figures, including Christ Himself, engaging in acts of worship and prayer. How can we, as “priests,” guide robots towards honoring God? Furthermore, how can we do this in seemingly mundane and secular applications, wherein robotic saints and angels are not needed so much as are robotic workers, caretakers, and toys?
Design Recommendations

This paper has applied lessons from the Genesis creation account to correct three mistaken assumptions about robots. In addition to having a clearer perspective on robotics technology, we can also take away some practical design principles from this discussion, mostly regarding the intentions we have for our technology. "Because we can" is never valid as a standalone reason for building something. Our purposes must trickle down from God's – be inherited, in a sense – or they're not just immoral but also doomed to failure in the long run. We also know that robotics, like all technologies, only provides a means to an end. By this we can know a priori that robots designed for certain purposes should simply not be built, whereas others most certainly should. Robots we should not build include dangerous robots, robots as a means to adultery (e.g., sex robots), to murder, to stealing, or robots that undermine or replace the loving community between humans. Robots we should build include robots as a means to good work (e.g., helping to lift, remember, assemble), to staying safe, to good play (e.g., toys, games), as beautiful art that pleases and glorifies God (e.g., kinetic sculpture, theater), and as a means of care (e.g., therapy for autistic children). These are sound albeit general principles for what our robots should actually do.

If we align our intentions with the Lord's, what about the actions by which we accomplish them? How do we go about designing and building good robots? Here we already know the right methods: sound engineering practices applied in the right contexts, the intellectual virtues, a Christian conscience, the guidance of the Holy Spirit, the teachings of Scripture, the oversight of the church, and so on. These methods are neither new nor restricted to robotics. Using robotics to restore society to the way it should be – that is, to usher in God's Kingdom – is the task of the Christian roboticist. That restoration must have its source in Christ's death and resurrection. Again, we do not create anything ourselves, but rather serve as representatives of Christ's restorative message and power.
Acknowledgments
I would like to thank Kory Kraft and James Roberts for their help with refining these ideas. I am also indebted to the two anonymous reviewers for providing key caveats and concerns that I think made this a more careful and balanced paper.

References and notes
3. Throughout this paper I refer to humans, both male and female, as “man.” This is to echo the language of Genesis 1 in the NASB, and also for brevity. “Mankind,” “humankind,” and “the human race” are all valid substitutes.
6. St. Augustine of Hippo, “On the Literal Interpretation of Genesis,” in On Genesis. New City Press. Augustine seems to amend his argument in the same section; he writes that man is made in the image of all three persons of the Trinity, which interprets the text, “...in Our Image, according to Our Likeness”.
8. Karl Barth, Church Dogmatics, Ch. X, Sec. 44, p. 73f.
10. Lewis, C. S. (1970). “Priestesses in the Church,” in God in the Dock. Wm. B. Eerdmans Publishing. Lewis describes this office as being worn externally by the priest, and that we are called to, “Salute the uniform, not the wearer”.
13. Lewis, C. S. (1944). The Problem of Pain, Ch. 9, Zondervan. C.S. Lewis speculates that this is true in the case of our dominion over animals, that animals might live on in the Kingdom in the “context” of their various relationships to humanity.
14. God also sustains His creation, but this is left for future discussion.
15. Lewis, C. S. (1970). “Meditation in a Toolshed,” in God in the Dock. Wm. B. Eerdmans Publishing. See C.S. Lewis's distinction between looking at (i.e., by external analysis) and looking along (i.e., by involvement).
16. This claim is based on my limited experience interacting mostly with evangelical Protestants.
17. Lewis, C. S. (1952). “Social Morality,” in Mere Christianity, Bk. 3. Zondervan. C.S. Lewis says that it isn't the job of the church as an institution to solve society's problems, nor even the job of the church as a body of individual believers, but rather the job of those believers called to be “Christian trade unionists and Christian schoolmasters” and “Christian novelists and dramatists” – and, I add, Christian engineers and especially Christian roboticists – to solve those problems.
At Christian universities, engineering programs seem to stay out of the critical notice of church leadership. Engineering is not like religion and theology programs, where church leadership has a vested interest in what is being taught and the teaching methods involved. Engineering isn’t like biology programs that get caught up in the creation vs. evolution debates and curriculum choices, which attract the attention of church leadership. Business programs in Christian universities sometimes get faulted for ethics, and medical programs for their lack of service emphasis and the drive for high incomes. There isn’t much criticism or attention given to the engineering programs at Christian universities by church leadership, though. Engineering programs in Christian settings hopefully deal with ethics, but the ethical issues in engineering typically don’t rise to the level of scrutiny from leadership. Engineering, even on a Christian campus, seems to be immune from divisive church politics, and so seemingly removed from religion that nothing could be done to offend the religious.

This seemingly distant stance of engineering from religious relevance was somewhat troubling to me. After all, wasn’t I teaching at a Christian university because my Christianity was important for me to express in all aspects of my life? The apparent disconnect sent me on a mission to make God more relevant in my career and in my classes. This journey led down many different paths, as there are many good ways to address this disconnect. One path that was particularly meaningful to me was the discovery that we have a rich religious heritage preceding us in our careers as engineers. If this heritage is embraced, it would give our work a much richer religious context.

The religious heritage of engineering starts in the beginning of the Bible, continues throughout its pages, and includes promises of engineering applications in heaven. The early Christian church spurred technology development with their quest to distribute the Bible. Christians of the middle ages and renaissance kept alive a worldview that would allow science and engineering to explode into what it is today. Engineering has a rich Christian heritage!

**Biblical Roots of Engineering**

In Gen. 1:26, 27, God says “Let us make man in our image, after our likeness; and let them have dominion over … all the earth…. So God created man in His own image.” From the very inception of man, we were designed to be creative beings, patterned after a creative, inventive God. This creativity is manifest in many ways, and engineering creativity is one of them. Man’s tendencies toward creativity are a manifestation of being created in God’s image, and man’s
evident thirst for knowledge and instinctive creativity honors our Creator. The fact that we’re given dominion over the earth, should give direction for our creative engineering talents.

Not only were we created to be creative, but also very early on in the Bible, God appoints human engineers to accomplish His missions on earth. After the work appointed in the Garden of Eden, engineering is the next occupation appointed by God. The Bible illustrates that our work can be used for good and for evil, and guidance is given as to the type of work we should take on. The technology of our engineering trade was also used as illustrations in the Bible, even by Christ Himself. The rich spiritual heritage of our occupation stems from the beginnings of the Bible.

**Noah** was appointed as a construction manager, a civil engineer, for the ark (Gen. 4:14-16). Although the ark was designed by God, Noah had to figure out how to craft it all. He had to harvest and transport gopher wood, configure it into construction materials and figure out how to fit and fasten all the pieces together. I would imagine that he fashioned sawmills, tools and fastener systems to make all these tasks easier – after all, it was a very large construction contract.

**Bezalel** was also appointed as a construction manager by God (Ex. 31:1-6 & Ex. 35:20-36:1). The building of the Sanctuary was entrusted to the skill of man, even though God could have created it himself with just a word. God filled Bezalel, His appointed construction manager, “with the Spirit of God, with ability and intelligence, with knowledge and all craftsmanship.” He was to devote these gifts to “devise artistic designs: in the mediums of gold, silver, bronze, stonework, wood carving and every craft.” God also appointed Oholiab as an assistant construction manager for the temple, and gave “to all men ability that they may make all that I have commanded you.” God did not dictate exactly how to accomplish His design, but entrusted man to use his God given ability, intelligence and knowledge to develop the technology to accomplish the task at hand. I can extrapolate from this that all mankind that works in technology development does so with the God given gifts of ability, intelligence and knowledge. And we are exhorted, as the sanctuary engineers were, to “work in accordance with all the Lord has commanded.” As engineering educators, there is another gem in this passage of scripture. God “inspired” Bezalel and Oholiab to teach. An engineering educator is a career ordained by God Himself, the One that has filled you with “ability, intelligence, knowledge and all craftsmanship.” Let Him also fill you with the Spirit of God so you can emulate Bezalel and Oholiab and be “inspired” to teach and practice engineering.

**The tower of Babel** (Gen. 11:1-9) is an example of not using technology “in accordance with all the Lord has commanded” (Ex. 36:1). God acknowledged mans’ technical abilities. “And the Lord came down to see the city and the tower, which the sons of men had built. And the Lord said, ‘… this is only the beginning of what they will do; and nothing that they propose to do will now be impossible for them’” (Gen. 11:5-6). God’s gift of ability, intelligence, knowledge and all craftsmanship, isn’t tied to a requirement to use it in accordance with all He has commanded. These God-given gifts are subject to our freewill, and we must decide how we are going to use them – a responsibility we carry as Christian Engineers. Our work is not neutral, it is either in service to the Lord or it is not. The direction of our work as engineers should bring glory to God.
Metallurgy was an early occupation, as Tubalcain was named as a forger of all instruments of bronze and iron in Genesis (Gen. 4:22). Metallurgy is used as an illustration through the Old Testament for preparing for war or peace. Joel 3:10 admonished pounding plowshares into swords and pruning hooks into spears to prepare for war. Isaiah 2:4 and Micah 4:3 speak of pounding swords into plowshares, and spears into pruning hooks in preparation for the coming Kingdom of God – a time of peace symbolized by metallurgical technology. Malachi 3:2 compares the metallurgist’s refiner’s fire to the purification God is accomplishing in our lives. But once again, like the tower of Babel, metallurgy skills could be used contrary to God’s purposes, as in Aaron forming the golden calf (Ex. 32:1-6). There is also an interesting New Testament story about metallurgists that started a town riot because Paul and his associates are going to put them out of their lucrative idol business (Acts 19:23-41).

Structures are a big part of technology use in the Bible. The early Israelite laws gave safety instructions for building homes – putting a parapet around the roof to protect from a fall (Duet. 22:8). This is an early demonstration of how Christian values are embedded in our work as engineers. Putting a parapet indicates that we place high value on the care and safety of others. Structures are also highlighted in the Bible when God chose to dwell amongst the Israelites in a structure – the sanctuary. Christ used buildings as illustrations during His earthly teachings. He contrasted a house built on a rock and a house built on the sand to illustrate foundational issues (Matt. 7:24-27, Lk. 6:47-49). He also used the illustrations of structural failure (Lk. 13:4) and structural planning (Lk 14:28-30) to illuminate His points. In the prophesies of Isaiah, we are told our technological skills will be needed in heaven, also! In Isaiah’s description of the new heavens and new earth (Isa. 65:21-22), he says “They shall build houses and inhabit them. … They shall not build and another inhabit.” We will all be structural engineers in heaven!

The Bible gives a rich heritage to our engineering careers. Engineers were direct appointees of God on large construction projects. We’re given direct advice from God, including the precedent of being “inspired” to teach our trade. Christ has used our technology as illustrations of truth throughout the Bible. Our career has close ties to the Bible – from its very beginning, and will carry on through to heaven, where everyone will build houses.

Early Christian Purveyors of Technology Development

The very early Christian church had a vested interest in engineering methods for dissemination of knowledge. In their zeal to distribute the Bible, they were front-runners in developments in written communications. Although there is no way to tell who invented the codex form of manuscript, which is similar to our current book form, it is very clear that early Christians were the promoters of it. All the Christian manuscripts that have been found from the first and second centuries have been in the codex form. Meanwhile, contemporary polite society acknowledged one form and one form only for a book – the scroll. The codex was not legally accepted as a book estate settlements until 223 AD1, instead it was lumped in with personal notes. The shift from the scroll to codex for non-Christian literature was a slow, irreversible drift that took several centuries to complete. It wasn’t until the 5th century that most of non-Christian literature
was in codex form. Meanwhile, the Christian adoption of the codex seems to have been instant and universal.

In the mid-4th century, persecution of the Christians ceased when Constantine converted to Christianity. It is around this time that Biblical manuscripts switched from mainly papyrus to mostly parchment. Proselytizing Christians were deeply involved in parchment making and did much to widen parchment use and develop better technology for its production.

Under the same zeal to circulate Scripture, Johannes Gutenberg invented the movable type printing press in 1450. The number of books 50 years after this invention was equal to European scribes previous 1000 years of work. Francis Bacon declared in 1620 that Guttenberg’s press had the biggest effect of any invention, only equaled by gun powder and the compass. This milestone change in our civilization is credited to a humble, Christian goldsmith – who we would call an engineer today!

This early Christian emphasis on dissemination of knowledge had profound effects on our society, not just in improving how written matter gets disseminated, but it also encouraged literacy. Historians estimate that the literacy rate in Protestant England was approaching 50% in the 1580’s, increasing from a 1% literacy rate at the beginning of the Reformation 70 years prior. This is compared with a government survey around 1685 in Catholic France which indicated less than 25% of the population could do something as simple as signing their name.

Early Christians took up technology development in their zeal to proselytize. Their work was so significant that it changed society.

**Christian Worldview leads to Scientific Revolution**

Even in post-Biblical times, progress in our trade is closely tied to a Christian worldview. Engineering and the technology we design are very much science based today, and the worldview of our Christian forerunners opened up the way for our craft as we know it today.

Despite science taking all the credit for the Scientific Revolution, realize that there was no division at the time between theoretical science and applied science, which engineering is. Many of the great Christian scientists of the time practiced applied science. They created instruments to do experimentation and in their own right were engineers before the term was coined.

Christianity gave a worldview in which scientific discovery could flourish in Christian Europe, while scientific discovery was hampered in other technologically advanced cultures by their respective worldviews. There were many forms of brilliant technology before science was developed, but technical progress was based on empiricism – the product of observation and of trial and error, but lacking in explanations and an understanding of physics. Development of science utilized organized efforts, not random discovery, to formulate explanations of nature through systematic observations. The Christian scholars of the scientific revolution believed in God as the Intelligent Designer of a rational universe, a universe created in accordance with rational rules by a perfect, rational Creator. They pursued the secrets of this rational creation,
confident that they existed, believing that reason and observation would yield those secrets. Most religions outside the Judeo-Christian tradition did not postulate a creation. To them the universe was a supreme mystery, inconsistent, unpredictable and perhaps arbitrary. In their worldview, there was not a rational system to be discovered.

In order to understand how this shaping of the Christian worldview was different than other cultures, and illustrate that it wasn’t the technological superiority of Europe that caused scientific discovery to develop there, let’s look at a little history from some of the major cultures. And I would stress that these are historical worldviews, and do not reflect the current status of these cultures.

**Primitive Religions** held that the events of the natural world were coordinated by a host of uncoordinated gods and spirits of uncertain behavior. There was no rationality, regularity or consistency in the natural world, no “laws of nature,” no room for science.

**Ancient Greece**, although mired in Greek mythology, developed a group of independent thinkers starting in the 6th century BC, who began to look at the world more objectively, attempting to understand the natural phenomena by rational speculation. The answers they came up with may have been mistaken, but this was a start. Some of these notable Greeks include names we still recognize today – Pythagoras, Socrates, Plato, Aristotle, Euclid and Archimedes. These independent ancient Greek thinkers took on astronomy, mathematics, mechanics, biology, architecture, harnessing of steam power, theory and practice of machines – a wide array of subjects. Flawed theology, wrong ideas about the nature of God and reality, stymied the brilliant Greek achievements from developing further into science.

There were two major worldview beliefs that stymied progression of their rational thinking from advancing into experimentation and further development of science.

1. **Earth** was considered a diminished, degraded place, and thus observation and experimentation had little value. The only exception to this seems to have been in medicine. Because of its degraded status, involvement in the physical world was only fit for slaves, and the pronounced class division between the ruling elite and slaves led to the mechanical arts carrying a social stigma. Thus the basis of the worldview that the truth about the natural world could only be discovered or risen above through reason and mental processes.

2. The sun and other heavenly bodies were regarded as divine beings and thus had to be made from different materials than the degraded earth, and had to be perfect. A fallen meteorite, predicted by a Greek astronomer and worshiped through at least the first century AD⁴, could have been inspected to refute their theories, but the ancient Greeks clung to these beliefs.

Thus, their conclusions were based solely on speculative, rational, deductive philosophies. Aristotle declared that heavy objects fell faster than light objects, and that things float because of
their flat shape - based solely on rational speculation and deductive reasoning, not on experimentation.

Ptolemy, a Greco Roman mathematician, geographer, astronomer and astrologer, seems to be an exception. He actually created instruments for observation of the heavens, despite the low value given to observation and experimentation. He developed an astronomical model, however, astronomers have for centuries suspected that his models’ parameters were adopted independently of observations. Ptolemy believed that the heavenly bodies were animated, intelligent, perfect and eternal divine beings, and therefore had to move in a perfect circular fashion. His observations were interpreted to fit the theory and his model in a sense was applied theology and the theology was wrong.

India had early developments of clever technology that prepared the way for the development of science. There was reasoning and observation in astronomy, mathematics and medical treatment systems. An example of their advanced early technology is the 7 meter high, 6 ton Iron Pillar of Delhi. The composition of this pillar indicates that India’s metallurgy was more advanced than the rest of the world. It was erected in the 4th century AD, in honor of the hindu god, Vishnu, and is still attracting modern metallurgists because of the rust-resistant composition of the iron used in its construction. There are still questions today over how this resistance and durability was accomplished. One research group is trying to determine its composition and production process to devise better, more durable nuclear storage waste containers. The pillar has been called a testament to the skill of ancient Indian blacksmiths.

The drawback to scientific discovery in India was the lack of experimentation to go along with their scientific reasoning and observation. The only scientific experimentation was in psychology and psychosomatic techniques of mastering body and mind. Their underlying belief was that the world was intrinsically evil, the source of suffering, and a chaos of random events. Enlightenment required the closing their eyes to the world outside and withdrawal from the physical senses. Indian contemplative practices, such as yoga, attempted to attain the cessation of perturbations of the mind as the necessary condition for transcending discursive knowledge and to be one with the divinely understood “spirit.” This withdrawal and belief in earthly chaos kept them from studying the world around them. Also the influences of Hinduism and Buddhism held back the development of science, as these religions emphasized the unreality of the physical world.

China has a notable technological record, starting way before Europe’s. The earliest ship lock is credited to the Chinese, and dated at AD 950. Europe’s first ship lock system was developed by Leonardo da Vinci in 1500 – quite a time lag behind the Chinese. The early Chinese developed water-power for industry, iron and steel technology, suspension bridges, hydraulic engineering, mechanical clockwork, mathematics, optics, acoustics and magnetism. There was the careful observation and recording that are essential to science, but it did not proceed into scientific theory.

The Chinese philosophy of Yin and Yang was no doubt a barrier to the development of science. It was first referenced in approximately 700 BC, and has served as a heuristic mechanism for
formulating a coherent view of the world throughout Chinese intellectual and religious history. It was the basis for Chinese science, philosophy, medicine and martial arts. The Yin and Yang philosophy reduced all phenomena to opposite pairs which controlled everything. Natural dualities (such as light and dark, high and low, hot and cold, fire and water, life and death, and so on) are thought of as physical manifestations of the concept – 2 phrases in a constant cyclic change. The Yin-Yang duality also describes the coherent fabric of nature and mind exhibited in all existence, the interaction between waxing and waning of cosmic and human realms and a process of harmonization ensuring a constant, dynamic balance of all things. A sampling of corresponding pairs classified to Yin and Yang are given below.

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<td>Moon</td>
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<td>Decapitation</td>
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The groupings under these dualities have no intelligible order and no empirical relationships can be found in this arbitrary jumble of concepts. There is no room for scientific associations. There is no scientific mystery to be solved with this worldview. In fact, an Oxford historian of Chinese technology says the Chinese would have scorned the idea that that nature could be understood as “too naïve for the subtlety and complexity of the universe as they intuited it.”

The Muslim Arabs, established in the 7th century, are known for their purposeful early development of scholarly study and translation of scholarly texts into Arabic. The House of Wisdom was established in Bagdad in the early 9th century and by the middle of that century, it was the largest repository of books in the world. A similar Arab scholarly academy was established in Spain, extending their influence into Europe. Wisdom was so valuable that books and ancient texts were sometimes preferred as war booty to other riches. Drawing on Indian, Greek and Persian texts, scholars accumulated a great collection of world knowledge and built on it through their own discoveries. The center was unrivaled in medieval Islam for the study of mathematics, astronomy, medicine, alchemy, chemistry, engineering, zoology, geography and cartography. These centers also left a legacy of technologies – land irrigation, advanced industries in pottery, textiles, sugar refining, leather and paper-making. Postage stamps have been issued in Iraq commemorating the three Banū Musa brothers who were educated and worked in the House of Wisdom, engineers that published the Book of Ingenious Devices in 850, which described about 100 automatic machines and mechanical devices. Academic life at the House of Wisdom was a symbol of status and it was easy to make a living as a scholar. The
centers attracted European and Jewish scholars, thus widely disseminating the theory and practices developed there. The House of Wisdom was ultimately destroyed by the Mongol invasion in the 13th century, but the invasion was not the sole cause of the decline of Arab scholarship.

The house of Wisdom declined under the reign of al-Mutawakkil (847-861), who endorsed a more literal interpretation of the Qur’an than his predecessors, and thus moved away from rationalism and science. He saw the spread of Greek philosophy as anti-Islamic. Orthodox Islam stressed the free will of Allah as to make it absolute, unqualified by the constraints of a rationality shared by both God and humans. It was impossible to hold the notion of natural laws, as that would impose constraints on the infinite power of Allah. Everything was to be fatalistically determined by the will of Allah. The conservative Islam worldview shut down their dynamic scientific community.

Hebrews believed in a world made by a kind, good, rational creator, and thus believed the world itself to be good, rational and consistently ordered. They believed that we were created in the likeness of God with rational, consistent minds. The Jewish conception of God was as suitable to sustaining science as the Christian conception, but being a pastoral, poor group of people with few resources, they lacked the commercial products to trade that would have stimulated interaction with other societies. Thus, they did not make large contributions to the development of technology or science, but their religious beliefs gave the basis for a worldview in which modern science could develop.

Christianity provided the philosophical worldview that resulted in the climate necessary for science to develop in the manner it did in the 16th century. Christianity inherited the idea of a rational Creator creating a rational, consistently ordered world from the Hebrews. But Christians also accepted that because Jesus came to earth in human form, there is no conflict between the spiritual ideal realm and the material, earthly realm. The earthly realm in not a diminished realm, it is not detrimental as the ancient Greeks thought. Christ came to this earth and lived among us. Thus it is not “unholy” or detrimental to spiritual well-being for humans to deal with real material things like dirt and labor.

In the latter part of the fourth century, Cappadocian theologians set forth four fundamental principles opposing the prevailing Greek views. These principles are:

1. Because the cosmos is the creation of a rational God who has also made us in His image, it follows that the cosmos is in principle comprehensible by the human mind. It is a coherent cosmos, not a chaos of random events.
2. Because the cosmos is a creation by God as a free act of His will and not an emanation of God, the cosmos has a relative autonomy. Not everything that happens is the direct will of God.
3. Because Scripture says that God created the heavens and the earth, it follows that the “heavenly bodies” are not made of substance different from the elements that comprise the earth, but are, on the contrary, of the same substance.
4. Because of the work of Christ in the incarnation, we may use material means for the advancement of human salvation.

These principles set the groundwork for the development of science. Early Christian scientists made bold declarations contrary to the established Greek doctrines. Philoponum (490-570) introduced a new period of scientific thought based heavily on three premises: 1) The universe is a product of one single God, 2) the heavens and the earth have the same physical properties, and 3) the stars are not divine. He stated that based on observation, planets don’t move in circular orbits and heavy objects don’t fall faster than light objects. These conclusions were reached a thousand years before Galileo was reviled by the church for the same anti-Aristotle conclusions.

The Scientific Revolution began in Europe during the Renaissance and lasted through the eighteenth century. Its pioneers were scholars of deep Christian faith, notable for their piety. Copernicus is often cited as beginning the scientific revolution with his 1543 publication. For Copernicus, God was personally responsible for all the activity in the heavens and the regularity he was discovering in the movements of the planets was the manifestation of the faithfulness of a loving creator. He was followed by Galileo, Kepler and Newton, all of whom proclaimed God to be the originator of the marvelous world and the scientific laws they were discovering. We don’t understand how bold these declarations were in their time. These early scientists were labeled heretics by even the church for the conclusions their observations and worldview brought them to.

In 1592 Galileo published his universal law of acceleration, following which his teaching contract at University of Pisa was not renewed. In 1612, Galileo refuted Aristotle’s premise that objects float in water because of their flat shape, but instead because of the weight of water they displace. In 1613 he declared that there were sunspots, insinuating that the sun was not perfect – once again refuting Aristotle’s premise of the sun being divine and therefore perfect. In 1616 the church ordered Galileo not to hold, teach or defend Copernican theory. His subsequent publication of a book got him a summons to Rome, where he was convicted of heresy and sentenced to house arrest for the rest of his life. It was not until 1758 that the Roman Catholic Church lifted its ban on Copernican theory, and in 1835 it dropped its opposition altogether.

Although not an easy path, these early Christian scientists and engineers proclaimed the God that created a world with patterns and predictable laws. They celebrated the earth that Christ created and came to live amongst us in, rather than eschewing it as an evil, dirty place. They built instruments, experimented and observed, looking for the scientific patterns to the orderly world God created – those scientific patterns and predictable laws that we use every day in our engineering careers.

What a rich path these early Christian scientists and engineers laid for the Christians to follow. What a rich heritage for us who use their science daily.

**Leading Christian Scientists and Engineers in the Post-Scientific Revolution Era**

The end of the scientific revolution is often cited as Newton’s publication of *Principia* in 1687. Even after the explosion of science in Europe, spear-headed by Godly Christian men, with a
worldview of God, earth and the heavenly beings that made the explosion possible, Christians continued opening up new frontiers in science and engineering. D. James Kennedy in his book *What if Jesus Had Never Been Born,* presents a substantial list of some outstanding Bible-believing scientists who gave the lead in founding branches of science and engineering.

Although Christianity was essential for the development of science, unfortunately that dependency no longer exists. Rodney Stark in his book *The Triumph of Christianity* states that “the majority of American scientists still report themselves to be religious and the more scientific their field, the higher the proportion that do so. That is, substantial majorities of mathematicians and physical scientists say they are religious, while only a minority of social scientists make that claim.”10 As engineers, we are deeply steeped in mathematics and physical sciences, and perhaps that substantial majority claiming to be religious translates into our sphere also.

**Conclusions**

The Christian foundations for engineering and the technology we create come from several facets. God created us in His creative image, to do creative things. The Bible shows engineering work as being appointed by God and implies principles for its use today. Christ used our engineering technology as illustrations in His teachings. Early Christian theologians gave a worldview where science could flourish and thus give engineers better tools to work from. Christians have carried on the work of expanding the base of science and engineering.

Our careers have close ties to Christianity. Embrace that relationship in your daily work. Realize that your creativity comes from God, and that he has blessed you with “ability, intelligence, knowledge and all craftsmanship.” Remember that God inspired the early engineering educators – Bezalel and Oholiab. Ask for that same inspiration – whether teaching in a classroom or mentoring younger engineers. Realize that you are following in the footsteps of the early Christians who developed technology in order to proclaim Christ better. And realize that your occupation is grounded in the Christian worldview that brought about the development of science that our occupation is based on. Add your name to the growing list of faithful Christians who are opening up frontiers in science and engineering.

Take on the name Bezalel when you approach your trade. Be filled with the Spirit of God to accomplish your work, and realize the “ability, intelligence, knowledge and all craftsmanship” is bestowed by God. Beat your swords into plowshares and spears into pruning hooks to actively prepare for the coming Kingdom of God. And practice building structures, in preparation for building your very own in the New Earth.

**References**


**Other Resources**

Abstract
In 2013-14 I had a 13 month sabbatical from our engineering program with 500 primarily-undergraduate students and roughly 20 faculty. My family of four relocated so I could re-join my alma-mater, a large state research university with over 7,000 engineering students and over 300 engineering faculty. During this time I worked on a web-accessible automatic 3D printing station for the engineering lobby, conducted human subjects research on crowdsourcing the identification of innovation, supervised graduate students, re-developed and taught design classes, and built as many friendships as possible. The experience was life-changing for me and my family in three ways: professionally, personally, and spiritually. This paper will provide encouragement for those considering sabbatical, ideas for those planning such an ambitious undertaking, and a value proposition to those considering funding sabbaticals.

Introduction
Someone said to me, “You call it sabbatical, but I call it a vacation!” This misconception is very understandable - I often struggled to explain, even to myself, what my sabbatical was all about. Sabbaticals seem to be as unique as individuals, and mine was much different than I expected. I have been given a personality that treasures making the most of our time. My sabbatical was providentially a rich blend of some of the most delightful and painful experiences of my entire life - far beyond what I could ever have asked for or imagined. In God’s good providence, the experience was as transformational as my intensive first year of teaching at LeTourneau or my first year of graduate school. My entire family of four was changed by the experience. We re-invented our individual and collective lives when relocating, and again when returning home. Moving close to extended family was no small part of the transformational experience as we walked through aging, death, and other major life events with those close to us. The purpose of this paper is to highlight aspects valuable to any who may undertake such a potentially life altering experience, or those supporting others in taking a sabbatical. I believe these insights will be enriching and useful, but I also hope to be clear that the events and transformation we experienced are not something I could have planned, and are not something I could repeat with any amount of planning or effort (as in James 4:13-15.)

Investing in Faculty Sabbaticals: The Value Proposition
My generous home university provided 50% of my normal yearly compensation, and the remaining funds were arranged over time through my host with teaching, research, and mentoring appointments. From my perspective, I was entrusted with 50% of my normal annual compensation without providing any immediate service to my home institution in return. From a strictly financial perspective, my university saved 50% of my normal compensation, while my usual responsibilities were covered through the sacrifices of my co-workers and the generosity of a few cost-effective adjuncts. From a monetary perspective, we as an institution saved money;

1 LeTourneau University, Longview, TX
and from a long-term holistic perspective, I am now able to make far more net contribution than if my service had been un-interrupted by a sabbatical.

True to the name “sabbatical,” the productivity increase from this trusting investment is similar to what we may experience when we “sacrifice” working one day a week for Sabbath-like rest, worship, and other growth activities. Sabbatical is a substantial investment (in personal growth and the reputation of the sending institution) for a future payoff, which is fittingly much like the investment we ask our students to make in a four-year college degree. This sabbatical investment is made both by the faculty family that pulls up roots for a season, and also by the sending department which foregoes a valuable team member.

**Sending as a Team Effort**

In my lean department, a performance drop by one person is felt and compensated for by the team. This interdependence made the support of my colleagues critical in taking the sabbatical plunge. My good Dean said to me “Don’t even think about [how we will cover your responsibilities] while you’re gone, or you won’t go.” Later in the year when I expressed concern that we had not yet filled an open faculty position, my now-department-chair said, “Don’t even think about [backing out of this … you have to go now so others can go in future years.]” My other closest colleagues gave similar encouragement. An experienced colleague exhorted me not to entangle myself with the department while I was away. Colleagues and friends hosted a sending-off meal for my family, including a sending-off prayer time. I believe God answered those prayers.

**Cleaning My Plate, Detox, and Re-booting Service Responsibilities**

I had no idea how many responsibilities I had accumulated in 7 years until it came time to hand them off, in much the same way that an office or house never seems so full and cluttered as when moving time comes. Handing off work to others had the same effect as physically moving a household – prompting decluttering, updating, and streamlining.

My wise Dean, concerned about my workload, encouraged me not to resume all my prior responsibilities when returning from sabbatical. Much like moving helps us pass on items which do not fit well in our homes, being away on sabbatical allowed me to “reboot” my departmental service. This has been life-giving for recovery from burn-out. I had no idea how burned out I was until I was away from the heavy responsibilities of caring for the technical and spiritual needs of our students, and from frustrations seemingly plaguing many large organizations. Detoxifying from the burdens I had internalized over a period of years required more time and freedom than a normal summer affords.

**Stepping Out in Faith**

My home institution generously provided 50% of my annual compensation, and I needed to earn the balance through funded work. I was humbled to realize how much this small step stretched my faith. I have a network of contacts at my sabbatical institution and in surrounding industries, and yet I had no way of knowing what our expenses and income would actually be. The phrase that repeatedly came to mind in prayer over the months was, “Don’t worry about money. You will have plenty of money.” And we did. Month by month, additional opportunities and funding pieces fell into place, such that by the end of the year we had almost exactly the remaining 50%.
Visiting Churches
My mission at my home institution is to train the next generation of engineers technically and spiritually, through both mentoring and modeling with my own life. For this reason broadening my experience with denominations and congregational practices is valuable for my individual growth and professional work as a mentor/model. Although my family and I were very eager to find a stable spiritual community to call “home-away-from-home” in our new metropolitan setting, we also savored the nourishment of each different church visit like sampling an international food buffet. We visited widely varied gospel-loving churches recommended by friends. Each congregation had some unfamiliar practices, helping me see how uncomfortable visitors might feel with church expectations that are invisible to me due to my years of familiarity.

Visiting churches on sabbatical was so enriching that we repeated the process after returning home. This time, however, we selected churches representing large percentages of my students and faculty colleagues. This experience was similar to visiting good friends in the context of their own home and family. Seeing the different emphasis each congregation placed on common themes of the historic Christian faith and practice gives me more context for working and communicating with my diverse colleagues and students.

Every church we visited was an amazing and enriching experience to be eternally treasured, perhaps a hint of the beautiful diversity of worship spoken of in Revelation 7:9. Three favorite touches from our visits are the church which gave us a free jar of bread, the church which gave us free books, and the church which had a city map of home groups linked to a stack of group information cards. The richness of visiting was deepest and broadest by committing to one church home-away-from-home. Much like living with a host family for a year, we were stretched and grown by the strengths and pitfalls of this particular congregation which became our local spiritual family for that city. Participating in a home group was helpful to integrate into the faith community and the local Christian sub-culture.

Teaching in a Different Context
One of my responsibilities and great privileges during sabbatical was to lead a senior-level design methods class with approximately 85 students in two lecture sections. I taught the lecture sections and coached the teaching assistants who taught labs and graded design memos. Ten years earlier I taught the same class as a graduate student. Coming to my current home institution 9 years ago was a major cultural adjustment as I learned to open class with a devotional and highlight spiritual tie-ins when the lecture content calls for it. My return to a state school was reverse culture shock. Thankfully, the years of experience and guidance from my mentors at LeTourneau prepared me well to provide an excellent student experience. In addition, a friend and colleague at my host institution allowed me to play a background role in her identical fall course, thus setting me up for success in the spring. The course evaluations from this class are among the highest I have ever received.

I taught this design methodology class in very similar ways at both my home institution (which has a Christian mission statement) and my host institution (a state university.) The largest differences were logistics (such as class size), and my relationship with the students. At my
home institution faculty and students feel much more freedom to share our backgrounds, beliefs, and prayer concerns. Almost all of the course content could be considered a “common grace” domain of knowledge which can be learned and applied without explicit reference to the metaphysical.

My daily prayer on sabbatical included that students would be blessed both through my service to them and through God’s personal work in their lives. I prayed for wisdom to live out my intense desire to serve students technically and beyond, and to avoid ending my opportunity by unnecessarily offending my students or my temporary employer. In our first class meeting I shared my interest in ultimate questions: Where did we come from? Why are we here? Where are we going? I invited students to feel free to bring these up in my office if they shared my interest, since the class would of course focus on specific technical objectives.

Some students detected my background more readily than I expected, and one asked me in the hallway if I was a pastor’s kid. He came to see me several times during office hours and one of his purposes was to thank me for teaching and being an example, and he asked, “How can I be praying for you?”

After my “socially responsible engineering” lecture, three students directly responded via email. One to say, “thank you so much …”, another wanting to chat about public policy graduate school, and a third stated “I believe this is the most important lecture I have ever heard.” The resonance these students felt with my talk was not due to alignment in our worldviews. One of them was an officer in a “religious freedom” organization seeking to outlaw prayer in schools; another told me he was from an “all-Muslim” country but he didn’t personally believe it and was in the process of assembling his own customized world-view.

I had considerably more freedom with graduate students since I was not their instructor, and once they saw I had very little sway in the department, they were comfortable talking freely with me. Although the days were filled with work tasks, we found many spare moments to chat about school, life, and occasionally faith. I hosted a seminar for graduate students interested in “teaching schools.” About 25 highly-inquisitive students attended, many of whom had no information about “teaching schools,” much less faith-based teaching schools.

**What Helped Me not Waste My Sabbatical**
The extensive freedom of sabbatical was a huge blessing which could also become a curse. I would not want to live with the regret of a sabbatical characterized by missed opportunities. Maintaining a regular professional and family routine was essential to reap rewards from the experience and maintain physical and mental health.

The need to earn 50% funding from my host institution helped focus my direction and gave my host incentive and authority to ensure my contributions were valuable.

My family found incredibly freeing the financially-necessary steps of renting out our house (to students), downsizing our temporary living space, and living “light” (by US standards.) I was surprised how little we missed the only home my children (ages 6 and 8) have ever known, and how quickly our family dynamics took advantage of our radically changed surroundings. *Had we*
imposed higher financial and lifestyle expectations on ourselves, we could have missed many or all of the opportunities sabbatical held.

Apartment living presented a whole new set of opportunities far beyond no lawn-mowing. We advertised and hosted a “Children’s Reading + Robotics Hour,” facilitated children’s gatherings (with “Soccer”, jump rope, and duck-duck-goose), and shared relationships, play, and meals with apartment families from Beijing, Israel, South Korea, Japan, and the US. Temporarily relocated families were the most responsive to our gentle offers.

Clearer Thinking when Distanced from Urgency
Sabbatical forced me to answer questions such as, “What am I about? What do I value? What should I be investing myself in?” Partial freedom from the pressing requirements of supporting my family and my students forced me to face questions of meaning and purpose at a whole new level. I knew for years I was spending too little time in growth and development for both myself and my family, but I had the ever-present excuse of urgent necessities. When this excuse significantly faded during sabbatical, I was forced to face the deep (and painful) question of how and why I decide to invest my time. This changed how I organize my work and life. I now try to restrain myself from tackling so many different projects, which has increased the quality of my professional contributions, my long-term investments, and my well-being. If there was ever any doubt in my mind whether my home university could survive without me, my one-year absence should remind me that I am only needed for what God calls me to.

Distance can Minimize Discontentment and Amplify Love
Sabbatical reminded me of things I love about my home institution: smaller class sizes, a closer-knit community, a highly-relational culture including moral and spiritual connections, a smaller and more-accessible campus, more explicit acceptance of faculty as coaches and role models, higher average student motivation levels, longitudinal relationships across multiple classes, lower student tolerance of academic dishonesty, a more-thoroughly residential campus, a smaller student body, lower costs of living, and more faculty interaction with students within the surrounding community. Even parking has major implications. My daily commute on sabbatical was a 45 minute trip by bus and foot or a 30 minute drive-park-pay-walk trip, whereas my home institution is 7 minutes away by foot or 5 minutes by car, including free parking.

On the other hand, the list of advantages of my sabbatical host - such as financial compensation, prestige, and access to resources - could be as long as the list above. But in this case distance helped soothe the discontentment I struggled with regarding my home community, in no small part due to a year’s rest from the weighty responsibilities of caring for students and the distance from campus dissension. Much like a good vacation, I was delighted to leave for sabbatical and delighted to return home.

Investments with a Good Return
I have been given a personality that treasures making the most of our time. Sabbatical presented an unusual opportunity to invest in relationships within a crisply defined 12-month window. Some of my opportunities had an immediate payoff: working/playing with 3D printers, access to TechShop – the maker’s dream, accomplishing research objectives and publications, and the sites and attractions of a major metropolitan area and research university.
Other opportunities presented a less-obvious and longer-term payoff: training students technically, building relationships with students and faculty, fostering intentional family time, and investing in personal and spiritual development. Near the end of sabbatical with only a few days left on campus, I was faced far more brutally than I anticipated with seeing what had or had not taken place in 12 months as a result of my choices. I worked nearby many people whom I had been with but did not know, with our cumulative interactions ranging from a few minutes to several hours. The emotional impact of this realization is hard to describe, and I suppose a small glimpse of what the days or weeks near death might be filled with. As scenes from the year flashed through my mind, I saw that where I had “sacrificed” the most attractive and immediate payoffs in order to care for people, I received in return the enduring reward of significance. Thus these “sacrifices” of interruption were really an “investment” for both me and those I served. This causes me to question my own mental categories and wonder why these interruptions felt like a “sacrifice” in the moment. This also increased my gratefulness to be in the teaching profession, a “sacrifice” with a huge future payoff.

How Current and Future Students Benefit from My Sabbatical
Sabbatical was an enormous and expensive undertaking, motivated in large part by the value added for my current and future students. Like many of my colleagues, I directly teach approximately 200 students per year, and influence many more through creating and enhancing courses, facilitating mentoring, and contributing towards an environment conducive to flourishing of both faculty and students. My particular sabbatical experience was providentially transformational professionally, personally, and spiritually. The transformative experiences of my sabbatical are appreciably benefiting large numbers of students over time since my mission at my home institution is training the next generation of engineers technically and spiritually - through both mentoring and modeling with my own life.

Conclusions
This paper provides encouragement for those considering sabbatical, ideas for those planning such an ambitious undertaking, and a value proposition to those considering funding sabbaticals. As seen in the preceding narrative, context is a major factor in sabbaticals such that broad generalizations may not apply. Despite this, below are fifteen overarching practices which helped make sabbatical a success in my particular context.
Guidance that Helped in my Particular Sabbatical Context:
1. Network with faculty from other universities
2. Plan and prepare early
3. Prioritize family
4. Pray and have faith
5. Promote sabbatical-sending as a team effort with team rewards
6. Hand-off home responsibilities cleanly
7. Fully leave home to be fully present elsewhere
8. Be flexible with work and lifestyle expectations
9. Establish healthy physical, professional, and family schedules
10. Explore local churches and commit to one
11. Learn the host institution culture
12. Stay accountable
13. Invest in personal growth with long-term payoffs
14. Invest in people and relationships
15. Share the fruits with colleagues and students

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Offer
I welcome contact if you or someone you know is planning a sabbatical and has further questions.
Useable Water for the Developing Regions of the World

William E. Medcalf, Jr.¹ and Robin J. McDaniel²

Abstract

The essential ingredient of life, water has presented and still presents challenges with which Christian engineers ought to be concerned. Throughout history access to water has often been the driver behind the establishment of settlements, feats of engineering, and the cause of wars. In recent history the salient challenge has been the sourcing and provision of “safe” water in the developing world. Water contamination, by biologics and heavy metals, affect sourcing. Local culture, economics, and political realities often exacerbate the challenge. Interpretation of the term “safe water” has resulted in focus on potable water, to the neglect of other uses. The pressing challenge is to develop low-cost, low-maintenance methods of sourcing and decontaminating water for populations that lack usable water and to work within the local culture to assure sustainability.

Definitions

“Usable water” is a term that is generally unfamiliar. It is used because water has a multiplicity of uses and only a fraction must be “potable.” Other uses include ordinary and universal tasks for which "polished" (disinfected) water is not required: washing clothes, showers, lawns, and golf courses.¹ It is estimated that only about one percent of the freshwater withdrawn from groundwater sources is used for drinking. Agriculture accounts for 70 percent of water usage.

The term “improved” in this paper and in relation to water supply means that one or more of the following conditions are met: a household connection; public standpipe; a protected dug well; a protected spring; or rainwater collection.²

The term “potable water” includes only the water actually used in activities that involve human consumption, i.e., cooking, drinking, and oral hygiene.

The term “usable water” therefore includes water for all beneficial uses to which extracted water can be applied: agriculture, livestock; household cleaning (showers, laundry, and more); lawns, gardens, golf courses, and, of course, drinking.

Water in History

Water, the ‘stuff of life’ has long been the catalyst for engineering feats. Circa 700 BC the Citizens of Erbil (in what is now northern Iraq) made gently sloping tunnels to bring groundwater a distance of about 20 kilometers to their city.³ The first systems for distributing water to the citizens of a city are believed to have been developed by the Romans about 300 BC.² After the fall of the Roman Empire, aqueducts and water distribution systems disappeared and people, even in cities, depended on water wells and bulk transport until about 1400 AD.⁴

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² Nibor Institute, Lake Villa, IL
In early societies it was common to use water as it was found, with spring water being a preferred source. Streams tend to be seasonal in their flow and, therefore, somewhat unreliable during portions of the year whereas springs are the result of underground reservoirs breaking through to the surface. It is, perhaps, because springs do not occur naturally in great abundance that mankind first began establishing wells, on occasion by taking advantage of a natural spring flow.\(^5\)

**Water for Life**

Water provides the transport of energy for sustaining life in our earthly bodies. There is a ‘water’ which sustains our spirits in this and eternal life. This is clearly evidenced in the discussion between Jesus and the Samaritan woman at the well.

“Jesus answered and said to her, “Whoever drinks of this water will thirst again, but whoever drinks of the water that I shall give him will never thirst. But the water that I shall give him will become in him a fountain of water springing up into everlasting life.”” The woman said to Him, “Sir, give me this water, that I may not thirst, nor come here to draw.” \(^6\)

The woman who met Jesus at the well recognized the human need for water. Water has always been important to human life. From Jacob’s well to the California State Water Project, safe usable water has always been essential to community development. Even so, it was not until the mid-1948 that the USA began to address, as a matter of national policy, the quality of water.\(^7\) It was even later, 1977, when the UN held its “Water Conference” to address the basic human needs and growing demands on the world’s water supplies.\(^8\)

As civilization has developed, people have clustered around sources of water.\(^9\) Hamlets have become villages and villages grown into cities. Many people also lived with, or very near, their animals. In many parts of the developing world these living conditions are still practiced.

**Extraction**

Sources of water have varied little throughout history. Today water is obtained from rivers and streams, lakes, springs, rainfall, and wells. A few locales, which are blessed with the resources and access to brackish or salt water, are able to obtain usable water by desalination. Each source type has both advantages and disadvantages and the impact of these pros and cons has significant effect on providing usable water in developing regions.

Rivers, lakes, and streams are often thought of as sources of pure “cool, clear, water.” Such is rarely the case. The environment through which these sources flow can contribute mineral and biological contamination.

Spring water varies greatly in quality and flow. Its contaminant content is dependent on the character of the flow replenishing the groundwater reservoir and the dwell time in the reservoir.\(^10\) Long supply paths increase the filtration of the replenishing water but the removal of biologic pathogens is not assured. Long dwell time, associated with the character of the reservoir environment may result in the colloidal dispersion of minerals in the water. Spring water is usually free of biological contaminants but may contain any of a number of minerals.
Rainfall has long been an important source of water and remains so today in many rural areas. Rain, as the condensate of water vapor, may be pure water or contain contaminants picked up during its fall to the surface. Rain is collected, often after it has flowed across a roof, and stored in a cistern (large) or barrel (small). Collection and storage are well-known as sources of biological contamination. Rainwater is most often transported manually in buckets, therefore, the costs relate to the provision of the storage system and societal impact.

Wells are a primary water source throughout the world. Wells for water extraction come in a variety of types and sizes. Wells were, and are, often hand-dug, therefore, shallow. (The world’s deepest hand-dug well, the Woodingdean Well in the UK, went to 1285 feet to reach the water table.) Driven wells are, typically, deeper and faster to complete than dug wells. Drilling is the most modern approach and can be completed to depths ranging from three to 900 meters.

Much more water is extracted than is consumed in each of three general sectors: agriculture; domestic; and industry. Global extraction of water, in 2000 AD, was an estimated 3700 million km$^3$. Consumption, as a fraction of the total extraction, is estimated to have been: 1) Agricultural – 48.6 percent; 2) Residential – 2.7 percent; and, 3) Industrial – 1.5 percent. The percentages are heavily affected by the developing world. As a contrast, consider that 2005 data for the USA show: agricultural extraction at 25.2 percent; domestic extraction at 0.3 percent; and, industrial extraction at 47.9 percent. The remaining extraction is indentified as for “public supply.”

**Contamination**

Shallow wells can be contaminated by any or all of several sources. Such wells are fed by surface water which may be, and often is, contaminated by biologicals, animal and human waste, vegetative decay and, in many locales, the detritus of various industries. Even the fast-flowing streams and rivers are not free of the risk of contamination, particularly when under the pressure of human population.

The fecal waste of animals and people has long presented mankind with a challenge: how to manage the ‘stuff.’ Even today untreated or minimally treated “sewage” – both animal and human fecal waste – is being used to fertilize crops. As local population densities rise, the challenge becomes much greater because of the volume of waste.

Deep wells may be, but are not always, free of biological pathogens because the soil through which groundwater must percolate acts as a filter. However, the depth brings with it an increased risk of mineral contamination by metals such as arsenic, iron, magnesium, and sodium. The removal of these metals has proved difficult and/or costly.

During the last two centuries, anthropogenic pollution hazards, often from industrial processes, have compounded the threat of heavy metals and synthesized organic compounds. In surveying the on-line literature for “industrial pollution rivers” the ‘hits’ indicated the problem to be spread over most of the world. Locations and rivers indentified ranged from Vietnam, through India, Africa, and Europe – and included the USA.
Decontamination

The removal of undesirable contaminants, sometimes no more than an unacceptable taste, from extracted water has been of interest for millennia. “Fresh water” may contain oils from vegetation, minute particles of soil which, although not injurious may be unacceptable to the consumer. Distilled water has a ‘flat’ taste and, if to be used for drinking, will find improved acceptability when aerated.

Methods of removing contaminants from water date back to about 2000 BC. Techniques ranged from boiling, or significantly raising the temperature, to filtration using crude filters of sand and/or charcoal. These techniques continued, with little revision, for nearly four millennia.

The first municipal water filter, a sand filter, was installed in Paisley, Scotland, in 1804. Sand filters required frequent cleaning, and grew in size and capacity through the years. Sand remained the sole decontaminant media until the addition of chlorine, a known poison and objected to by many, in 1850. Even today, municipal water systems are unable to supply pure chemical-free water.

There are techniques that are able to be, and are, used in the home. As noted earlier, water is often boiled to kill the pathogenic contamination before drinking or using for cooking. However, boiling alone does not address the problem of inorganic or metal contamination. Capturing water using the distillation process is an improved, but not risk-free, method. Some volatile organic compounds (VOCs) are difficult to separate by distillation because they have liquid-gas phase transition (“boiling”) temperatures close to that of water.

One of the most common methods for removing minerals, including arsenic, from water is the reverse osmosis (RO) water softener. Unfortunately, other technologies replace the removed ions with sodium (Na), not the healthiest of choices. Required back-flushing, to rejuvenate the filtering media, releasing Na and calcium (Ca) into the waste water stream where it enters a septic or municipal sewage system - either of which is less than optimum as a long-term solution.

The technologies available for water treatment (“decontamination”) are many and varied – varied as to type, complexity, and cost. The fundamental principles are little different from the foregoing discussion.

Experience to Date

Although documentation to support our suspicions was not found, we have reason to believe that WW-II significantly increased awareness of global water conditions. Millions of citizens of the industrialized world were exposed to the living conditions in much less developed regions of the globe. Since the end of WW-II, the USA has taken a different posture toward the quality of water within its borders and the UN has, more recently, identified ‘safe’ water as of major significance to all peoples.

Most of the developing areas of the world have never benefited from adequate sanitation and water distribution systems. Although improvements are being made, water contamination continues to arise because of man’s need for proximity to water. In many of the world’s developing countries, and especially in rural regions, citizens often do not have access to the
means for the sanitary disposal of human (and animal) sewage. The sewage is simply dumped – on the ground, or in the river.

Sanitation, in the form of the management of fecal waste, is a continuing global challenge. Most rural and semi-rural areas in developing regions lag behind the larger urban centers. Water treatment systems are not now available in sufficiently large scale to meet even the needs of larger cities the developing world. Between 2.1\textsuperscript{23} and 2.4\textsuperscript{24} billion of Earth’s people lack basic sanitation services.

Shallow wells that initially produced potable quality water have been found to yield water contaminated with biological organisms, usually due to poor sanitary conditions. An apparent solution, deep wells, may provide longer filtration pathways for biologicals but often introduce inorganic contamination. Deep wells (>60 m) have been found, not infrequently, to be contaminated with heavy metals.

In regard to using deeper wells, which allow greater ground water percolation, they are not a panacea. Deep wells may reduce, but not eliminate, the risk of biological contaminants but, dependent upon geographical factors, may increase the risk of contamination by toxic metals.

Experience has also shown that, in order to sustain water quality, separation of the water source of water and sanitation facilities is a “need,” not a “want.” Many, if not most, projects to date have been either water or sanitation, rarely both. A principal cause for shallow wells to become contaminated is animal and human waste deposited on the ground in close proximity to the well.

Physical separation of sanitary facilities and water sources permits percolation of the surface water as it travels through the soil into the water table, which is a recognized, albeit not always effective, method of pathogen removal.\textsuperscript{25} It has been found that, dependent upon the effectiveness of the soil, pathogenic organisms can migrate as far as 480 meters.\textsuperscript{26}

In 1990, about 25 years ago, it was estimated that about 24 percent of the global population did not have an “improved source” of water.\textsuperscript{27} That was reduced to about 19 percent in 2000. The same UN report now estimates that, in 2010, the percentage of global population lacking access to an improved source of drinking water had declined to 11 percent.\textsuperscript{28} However, most of the improvement is coming in population centers and the rural developing world is still in need as more than 19 percent of the global rural population lacks an improved water supply.\textsuperscript{29}

‘Modern’ systems for sourcing, transporting, and treating water have been developed over the past 200 years. In many places, even in the “developed world,” many families are still dependent upon wells and personal septic systems to provide both their drinking (“potable”) and other useable water and waste disposal. Even so, the systems in use in the developed regions of the world are neither economically nor sustainably transferrable to the rural third world.

What has been learned is as important as what has been accomplished. We have learned, for example, that in many third world countries:\textsuperscript{30,31}

- Rural and small village wells frequently become contaminated or fail, because of minor maintenance issues, within a few years of installation;
• Most citizens in developing countries lack the expertise and funds to maintain the systems;
• Corruption is rampant, having an adverse effect on system operation and maintenance;
• Many cities are unwilling to extend water distribution beyond their limits, where population growth is rapid;
• There is an absence of political commitment and accountability;
• Systems to permit billing for water use are usually absent; and,
• The cost of improving sanitation is about three times that of addressing water and both costs are, often, not recovered.

Defining the Problem

Providing usable water continues to remain a problem. The problem of water quality impacts the modern developed world in many ways but the challenges – and opportunities – are much greater in the developing regions of the globe. Data support the connection between poor water quality and health problems, even death.32 33 The majority of people without access to “improved” sources of water are in Africa and Asia.34

It is appropriate to ask “How extensive is the water problem today. Unfortunately, much of the information that has become public is dated by at least a decade. Nevertheless -

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Source: Markandya, Anil, “Water Quality Issues in Developing Countries,” 2004

Table 1. Portion of population without access to “safe” water

Work in Progress

In 2000, many heads of state endorsed the UN “Millennium Development Goals” for water quality, formalizing a program begun less formally in the 1990s.35 In addition to the several Christian mission organizations that have long worked to improve sanitary and water systems in
the developing world, many US colleges and universities are engaged in projects addressing the decontamination of water.

Consequently, there are a few research projects underway to address the challenge of removing minerals, especially the heavy metals, from extracted water. To serve in the underdeveloped regions of the world will require that any systems have ‘reasonable’ installation and operating costs and be sustainable within the culture being served.

Many Christian organizations have sponsored and/or conducted water projects. A few have sponsored or conducted sanitation projects. These projects range from raising funds to “boots on the ground” projects. Listing all and citing their areas of project service is not important. However, it is instructive to know that the service range is very broad. Calvin College (www.calvin.edu) through their “Water 2 Ecuador” project is striving to improve pump-storage spring-sourced gravity fed water systems originally built by Reach Global (formerly HCJB) personnel. On the more complex side, Engineering Ministries International (www.emiusa.org) provides design and build management services, including for water and sanitary systems throughout the world.36

Much of the research focus has been on the development of filters for the removal of biologic contamination. The on-going efforts have produced filter configurations which are simple, easy to make, easy to change media, and having various levels of efficacy.

PureMadi filters, a University of Virginia non-profit, has developed filters of a porous ceramic matrix, made of clay, sawdust, and water. Used in a five-gallon container and using gravity feed, the filter will treat 1 to 3 liters per hour of water.37 The developers of the PureMadi filter have established a factory in Limpopo province, South Africa, employing local workers. FilterPure is employing a similar technology using indigenous pottery factories in the Dominican Republic and Haiti.38

In a similar project to remove pathogens, Gonzaga University has designed a ceramic filter system that uses terracotta fired clay technologies, which can usually be manufactured locally.39 The limited flow rates are believed able to supply sufficient supply for potable human needs.

Both the PureMadi and Gonzaga filter designs are suitable for removal of biological contaminants but, in their current form, will serve only very small population centers. Neither addresses the removal of heavy metals. Both are amenable to manufacture using simple processes and, usually available indigenous materials.

There are also promising developments in efforts to find low cost ways for the removal of metals from water. A Tribhuvan University (Nepal) graduate student’s ME Thesis project40 has evaluated the low-cost adsorption of arsenic from water. Using a combination of “Bio-sand” and iron nails, arsenic and coliform bacterial were removed to a level approaching that of the local municipal water supplier. MIT has reported that its students have developed a similar multi-layer (sand, pebbles, and rusty nails) filter for arsenic removal without electricity, pressure (pumping), or addition of heat.41 A subsequent US patent application42 seeks to enhance the technology by applying an electrical differential across the layer of nails.
Fine filters and ion exchange and absorption technologies have advanced to the point that smaller portable filters utilizing activated carbon to absorb undesired contaminants have been deployed for low water volume applications in the field and for emergency conditions. However, these technologies are presently available only as short-term solutions, have significant capital requirements, and require operation and maintenance skill sets frequently not locally available.

The main concern about most of these newer systems is that they have been focused on western approaches to the supply of potable water for tourist travelers, campers, or relief workers. These systems rely on technology solutions which tend to be cost prohibitive because of the use of rare metals and complex machined parts. They are also unsustainable by the local population in the developing world.

**Recommendations**

It is the opinion of the authors that the emphasis on “improved” and “potable” water has slowed the efforts at addressing the water problem, in both the developing and developed areas of the world. The fraction of water that must be of sufficient purity for human consumption is small yet the complexity, size, and the cost of providing the systems necessary to deliver such is greater than would be necessary for many uses.

The provision of water for most rural residents and small communities poses the greater challenge because of scale. Treatment systems that are small, easily manufactured, and durable are required to remove contaminants. All engineers, but especially Christian engineers, are made in the image of God and are creating within His creation. As designers, consultants, and mentors to engineering students Christian engineers have a vital role to play in advancing the research and development of such systems.

It has been said that “the rich nations of the world share a “moral obligation” to help people in need.” In this statement, Professor Haddad reminds the Christian engineer of the Biblical admonition to provide water in His name.

It is recommended that Christian engineers engage in projects that include the people being served and address, simultaneously, both water and sanitation. Although most of the focus has been on the less costly work of providing potable water, it is apparent that providing usable water will be sustainable only when both water sourcing and sanitation are developed, implemented using equipment, tools and techniques that are compatible with the culture, economics, environment, and with early and long-term participation of the communities being served.

Not all extracted water needs to be potable. The relatively small portion of water that must be potable will facilitate smaller treatment systems, reducing cost and maintenance concerns. In most cultures potable water comprises no more than a few percent of water extracted. Thus it is reasonable to conclude that multiple stages of contaminant removal may be used to obtain water for agricultural, general household, and human consumption.

By designing, building, and implementing a water treatment system – with appropriate sanitary system considerations – the processed water need only be usable for agricultural and industrial systems. The usable water delivered for domestic consumption may then be further purified to
potable quality using a Point-of-Use (POU) technology. By post-treating only a fraction of the usable water for human consumption, a community will be able to provide less costly water for all applications.

The preceding clearly indicates that there is need to address the interwoven challenges of sanitary and water management provisions to rural areas of the developing world. The problem of water contamination by biological pathogens and toxic materials calls for integrating the engineering activities for both water and sanitary systems. At the same time, the cultural mores of those served must be integrated in any such project.

Clearly, this will require no less than a multi-year commitment to each community, including:

- developing knowledge of the cultural behaviors;
- pre-planning projects to address both sanitation and water, by working with local leadership able to provide continuity and accountability; and,
- Extended residency and working with the local churches to educate, exemplify, and train the necessary systems management.

**Challenge**

The need is clear. The challenge is clear.

Christian engineers ought to be aware of and support the research, design, development, and installation efforts that will provide affordable, economical, and useable water to people in all regions of the world, including the developing nations.

Clearly, as engineers, God has provided us with a set of valuable talents. Scripture admonishes us to use our talents to serve our Lord by being of service to his creation, which includes the peoples who lack usable water.46

The challenge of removing both biological and colloidal heavy metal content will prove especially difficult – and rewarding.

The need is clear. The challenge is clear. The water must be (cool) clear.

Let’s get to work!

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Heat Transfer in Biblical Miracles

Charles Baukal

Abstract

Mechanical and chemical engineering students usually take heat transfer as part of their required coursework. They solve many textbook problems that are well-defined and have a specific answer. However, such problems are not representative of many real-world problems that are often ill-defined and don’t have an answer in the back of the book. One method that could be used to expose Christian students to such ill-defined problems is to analyze biblical miracles. This paper discusses several different potential types of analyses including qualitative, quantitative, and mechanism type. Some example miracles that could be analyzed are presented including the fire on Mount Carmel, the crossing of the Red Sea, and the fiery furnace. The results are also reported for a survey of Christian engineering students in a heat transfer class where biblical miracles were analyzed.

Introduction

ABET Criteria 3 (Student Outcomes) and 5 (Curriculum) include the application of engineering science to real world problems. The latest edition of a popular heat transfer text is designed “for a practically-oriented heat transfer course for engineering students.”¹ The text is filled with many applications in the modern world such as the heat loss from heating ducts, convective cooling of an egg, and radiant heating of a chicken cooking in an oven. Application problems are important not only because practicing engineers may need to calculate heat transfer as part of their employment, but also because they help motivate engineering students on the importance of their coursework.

Another potential “application” of heat transfer is to analyze some of the miracles in the Bible. This could be particularly motivating for Christian engineering students to see how their engineering coursework might be applied to the Scriptures. For example, there are many fire miracles in the Bible such as the fire and brimstone that rained down on Sodom and Gomorrah, the burning bush, the pillar of fire, Elijah calling fire down from heaven on Mount Carmel, and the fiery furnace. While not enough details are provided in the biblical accounts to make precise calculations, some assumptions can be made to estimate the heat transfer that might have occurred in those miracles. These assumptions make the analyses more difficult, but the uncertainty is more representative of real-world problems which are also often ill-structured and complex.² Real-world problems may be missing data and may be subject to interpretation.³ This is in comparison to textbook problems that are well-defined, contain all the needed information, and have a definitive solution. Research has shown that different cognitive processes are used to solve well-defined (e.g., textbook) problems compared to ill-defined problems.⁴ Engineering students get lots of practice solving the former but not very much solving the latter, except in capstone and other types of design courses.

The purpose of this paper is to discuss an alternative type of application problem for heat transfer analysis for Christian engineering students. These students are likely very familiar with biblical miracles, but probably never considered analyzing them from a heat transfer perspective. As an example, the heat transfer that may have occurred in the fiery furnace was likely very high; enough to kill elite soldiers who never even entered the furnace. Although the purpose here is not

¹Oral Roberts University, Tulsa, OK

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to prove or disprove biblical miracles, potential outcomes of heat transfer analyses for Christian engineering students include increasing their appreciation for God’s sovereignty and giving them a new perspective on these miracles.

**Potential Analysis Types**

There are several ways that biblical miracles involving heat transfer might be used in a heat transfer course.

**Qualitative Analysis**

The first potential type of analysis is qualitative where few if any calculations are made. Rather, students discuss some of the important elements of heat transfer that might have been involved in a miracle. For example, students might discuss:

- what types of heat transfer (conduction, convection, radiation, condensation, and boiling) would have been significant,
- whether the analysis would need to be steady-state or transient,
- how many dimensions (1-D, 2-D, or 3-D) would be needed to adequately analyze the heat transfer,
- what information would be needed for the analysis such as dimensions and temperatures,
- what assumptions could be made in the analysis,
- what simplifications could be made, and
- what thermophysical properties would be needed and where they could be obtained.

**Quantitative Analysis**

For some miracles it is possible to do a quantitative analysis. Since the details needed for quantitative calculations are not provided in the biblical text, students could make their own assumptions or the instructor could provide some or all of the missing information such as temperatures, velocities, and dimensions.

**Mechanism Type**

A third type of analysis could focus on a particular mechanism of heat transfer. For example, convection and radiation were both likely significant in many of the fire miracles, so an analysis could be limited to just one of them. The heat transfer miracles were transient in nature which significantly complicates the analysis, so they could be simplified to assume they were steady-state over a given time period.

**Example Miracles**

Not all biblical miracles would be appropriate for heat transfer analysis. For example, healing miracles typically do not include significant heat transfer and would not be suitable for this exercise. Other miracles may involve heat transfer, but may be less useful for an analysis. For example, the rain sent down after Elijah’s fervent prayers on Mount Carmel in 2 Kings 18 would likely have involved some forced convection heat transfer when the likely cooler rain fell on the
warmer people. However, many assumptions would have to be made and such convective cooling was not an important aspect of that miracle, so it may not be a good candidate for heat transfer analysis. Some example miracles involving heat transfer that was a significant aspect of the miracle are discussed next.

Fire on Mount Carmel

An example biblical miracle that could be used for heat transfer analysis is the fire Elijah called down from heaven on Mount Carmel to evaporate the water from a water-soaked bull and altar, incinerate the bull, and destroy the stones used to make the altar (1 Kings 18:1-46). Fire from heaven on Mount Carmel is one of the most stunning and impressive miracles in the Old Testament. This confrontation “was one of the most dramatic acts in the whole history of Israel.” Herrmann noted, “the greatest and most triumphant event of his (Elijah’s) life seems to have been the contest on Carmel.” Zannoni argued, “The description of the contest between the Baal prophets and the solitary prophet of Yahweh is one of the most dramatic accounts in the Bible.” Nelson wrote, “This is one of the most dramatic stories in biblical literature, the contest between Yahweh and Baal on Mount Carmel.”

Elijah called for God to send fire to consume a bull on a pile of wood that had been saturated with twelve jars of water, laid on top of an altar with at least twelve stones. This is the only recorded instance in the Bible where Elijah made a sacrifice. The fire not only burned up the offering, but also the wood, the stones, and the soil and evaporated the water that had been poured on the altar. The fire literally “ate” or “devoured” the offering, wood, stones, and soil. The winning god only needed to send fire to burn up the offering, but Yahweh far exceeded that. “That day Carmel witnessed one of the grandest scenes in the history of Israel.” The altar was completely obliterated, possibly so that it could not become a shrine that could be worshipped instead of worshipping Yahweh. The fire came down from above, which made it supernatural as fire naturally travels upward due to buoyancy since hot gases rise rather than fall. Another aspect of the miracle often overlooked is that the onlookers and surrounding flora were not burned up by the fire which was apparently very directed.

God’s use of fire in this miracle is particularly significant, “The veneration of fire by most nations is not surprising if we consider that there is probably no agency more powerful for good or ill in the universe, than fire.” The fire that consumed the altar on Mount Horeb “provides stunning confirmation that YHWH is G-d.” This was a unique fire, “Fire that consumes stones and dirt cannot be kindled by human hand.” Leithart wrote, “Yahweh manifests his glory in fire and Israel confesses Yahweh as Lord and king.” Roper noted, “Carmel is one of those brief moments in history when God steps out of his unseen realm and makes his presence known.” Fritz argued, “The fire from heaven shows not only that Yahweh is the more powerful god, but that he himself is the only living God.”

For the purposes of heat transfer analysis, assumptions can be made about the sizes of the bull and altar and the conditions of the fire such as the fuel and flame length. This is actually a very complicated transient analysis involving multiple modes of heat transfer including convection, conduction, radiation, and boiling. The instructor has some options to break the problem into
multiple smaller problems and/or to simplify the problem, for example, by making it steady-state or focusing on one particular mode of heat transfer.

A homework assignment was given to a heat transfer class with 25 mechanical engineering students at a Christian college to analyze the heat transfer in this miracle. At the point in the course the assignment was given, conduction heat transfer had just been completed, so the assignment was limited to just considering the conduction heat transfer through the wood, bull, stones, and water. This was the first such assignment to analyze a biblical miracle, so it was a qualitative analysis. Students were asked to discuss what type of conduction heat transfer (e.g., steady-stage or transient; 1-, 2-, or 3-dimensional; lumped system analysis; semi-infinite solid, etc.) would be needed. They were not required to make any calculations.

Students first discussed what would be needed to calculate the conduction heat transfer through the various materials in this miracle such as the dimensions of the objects and their properties. Most students noted this was a transient problem, but that a lumped system analysis would probably not be applicable. Some argued steady-state could be assumed to simplify the calculations. The wood and bull could be analyzed as cylinders and the stones as spheres. Some argued the soil around the altar could be analyzed as a 1-dimensional infinite solid. The recommended analyses were generally 3-dimensional but might be simplified to 1-dimensional (e.g., radius of a sphere) given the number of assumptions that would already have to be made. In general in this assignment, the students spent too much time talking about the miracle and not enough about the heat transfer.

Red Sea Crossing

One of the more famous miracles in the Old Testament is Moses leading the Israelites across the Red (Reed) Sea (Ex. 14) and drowning the entire Egyptian army pursuing them. The pillar of cloud/fire was in-between the Israelites and Egyptians to give the nation of Israel time to cross. The waters of the Red Sea were temporarily held back by a “strong east wind” that dried up the river bed while the Israelites crossed. Once the Israelites crossed, the pillar of cloud/fire was removed and the Egyptians resumed their pursuit of the Israelites. However, their progress was impeded by God as their chariots got stuck in the riverbed. Once the army was entirely on the riverbed, the waters that were being held back were released and drowned the entire army.

A homework assignment was given to the class to analyze the convection heat transfer that might have taken place at the miracle of the Red Sea crossing. Two aspects of convection were to be considered: the forced convection of the wind used to hold back the water that flowed past the soldiers and the forced convection of the water that flowed over the soldiers when they were drowned. Students were told to approximate the soldiers as cylinders.

Most students calculated the heat transfer to a single soldier but a few assumed the flow through the Egyptian army could be approximated by staggered cylinders as in a heat exchanger. All students calculated turbulent flow for both the wind and the water cases. Knowing the flow was turbulent and calculating the Reynolds number, students then calculated the Nusselt number using the appropriate correlation so they could determine the convection heat transfer coefficient and then the convection heat transfer. Table 1 shows the results of students’ assumptions and calculations for this miracle. Some of the assumptions, such as the soldier height and
temperature, were fairly consistent. Other assumptions, such as the soldier diameter, air temperature and velocity, and water temperature and velocity, were less consistent.

Table 1. Sample heat transfer calculation assumptions and results for the parting of the Red Sea miracle.

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<td>42</td>
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<td>23</td>
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<td>0.146</td>
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<td>1.02</td>
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<td>38</td>
<td>17</td>
<td>60</td>
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<td>ND</td>
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<td>5.7</td>
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<td>3.4</td>
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<td>0.943</td>
<td>15</td>
<td>NR</td>
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<tr>
<td>14</td>
<td>NR</td>
<td>0.27</td>
<td>37</td>
<td>NR</td>
<td>29.1</td>
<td>0.051</td>
<td>27</td>
<td>29.1</td>
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<td>18</td>
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<td>37</td>
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<td>242.0</td>
<td>22</td>
<td>28</td>
<td>1610</td>
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</tr>
<tr>
<td>Maximum</td>
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<td>0.8</td>
<td>38.0</td>
<td>32.0</td>
<td>60.0</td>
<td>242.0</td>
<td>30.0</td>
<td>100.0</td>
<td>1910.0</td>
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<tr>
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<td>0.4</td>
<td>36.8</td>
<td>22.6</td>
<td>29.0</td>
<td>22.8</td>
<td>22.6</td>
<td>26.7</td>
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<td></td>
</tr>
<tr>
<td>Minimum</td>
<td>1.3</td>
<td>0.1</td>
<td>33.0</td>
<td>15.6</td>
<td>4.5</td>
<td>0.1</td>
<td>15.0</td>
<td>2.7</td>
<td>1.1</td>
<td></td>
</tr>
</tbody>
</table>

NR = not reported
ND = not done
a = did not calculate for water cooling
b = used wrong surface area (much too small)

The calculated heat transfer from the wind ranged from 0.1 to 242 kW, which is over a four order of magnitude difference. However, there were four answers considerably higher than most: 242 (student # 18), 64.5 (student #6), 34 (student #8), and 17.4 kW (student #5). The other 14 students had answers under 10 kW. Removing those four values, along with the exceptionally low value of 0.051, reduces the average to 4.1 kW, with a range of 0.9 to 9.7 kW.

The calculated heat transfer for the water ranged from 1.1 to 1910 kW, which is over a four order of magnitude difference. In those calculations, there were three results that appeared to be unusually low: 1.13 (student #7), 25.4 (student #14), and 40.5 (student #3). Removing those
three low values increased the average to 769 kW with a range of 154 to 1910 kW. As expected, the water produced more convective cooling than the wind.

Fiery Furnace

The miracle of the fiery furnace in Dan. 3:23 is another potential biblical miracle that could be used for heat transfer analysis. Regarding this miracle, Wharton wrote,

> You see the miracle that God does not leave the martyrs alone in the fire, that God spares the faithful ones and gives them life that no holocaust can destroy, that God’s power is greater than any earthly power, and that ultimately even the anti-godly tyrant is forced to his knees in wonder before a God who has such power and who has servants so faithful that they trust and obey God even if their obedience should cost them their lives.24

Lockyer commented that,

> . . . the miracle consisted in the divine suspension of natural laws. The human frame is naturally fuel for fire, as thousands of martyrs have proved when their bodies were reduced to ashes. For His glory, God arrested the normal processes of fire for His own, but allowed the intense heat to destroy the strong men who had cast the Hebrew youths into the flames. The terrible end they had designed for God’s children overtook the executioners. The miracle is made more impressive by the fact that not “an [sic] hair of their head was singed, neither were their coats changed, nor the smell of fire had passed on them” (3.27). Not only did God arrest the action of the intense heat in the hour of trial, He condescended to become their Companion in the furnace.25

Shadrach, Meshach and Abednego were tied up and “thrown like logs into the furnace”26 by king Nebuchadnezzar for failing to bow down and worship a golden image (Dan. 3:19-27). They were bound in their clothes which would have been another source of fuel that normally would have made them burn even faster. The three were not burned, however, and in fact were not even singed. The soldiers who threw them into the fire were killed by the heat. The irony is that the tormentors experienced the torment planned for their prisoners who were not delivered from the fire but in the fire.27 The fire burned through the ropes that bound the three boys without burning them. Nebuchadnezzar and his officials were amazed that the three Hebrews did not even smell of fire. Apparently, God did not alter the fire since the soldiers were burned, but somehow protected the three conscientious objectors. Did their bodies and clothes temporarily become flame retardant? How did they even breathe in a hot smoky furnace which would normally not have enough oxygen in it for people to survive?

It is unclear exactly what Dan. 3:19 refers to where King Nebuchadnezzar ordered the furnace to be heated seven times hotter. Three explanations may be given as to what “seven times hotter” refers to if it is to be taken literally.28 The temperature to melt pure copper and pure gold is 1085°C (1985°F) and 1064°C (1947°F), respectively.29 In the presence of tin, the melting point of copper is reduced to about 950°C (1742°F) where copper alloyed primarily with tin is used to make bronze.30 The furnace temperature must be hotter than the required melting temperature because heat transfers only from hotter materials to colder materials,31 requiring a furnace operating temperature of approximately 1100°C (2012°F).32 As another point of reference, brick
kilns from that time period operated at temperatures around 850-950°C (1560-1740°F).\textsuperscript{33} Seven times a furnace temperature of 1373K\textsuperscript{34} would be 9611K (9338°C = 16840°F), which is much hotter than the sun’s surface temperature and was not possible using technology available at that time.\textsuperscript{35} Besides that, no materials were available to make a furnace that would have been able to withstand those temperatures without being destroyed.\textsuperscript{36} Therefore seven times hotter cannot be understood literally as referring to temperature.

A second possibility is that it referred to seven times more heat flux. There are three common forms of heat transfer: conduction, convection, and radiation.\textsuperscript{37} In furnaces, the predominant form of heat transfer is usually thermal radiation.\textsuperscript{38} The heat flux by radiation is dependent on the fourth power of the absolute temperature of the source. In a furnace, the two primary heat sources are the flames and the hot walls. Assume the flame and furnace walls are at the above estimated temperature of 1373K (1100°C = 2012°F). The thermal radiation inside a furnace is a complicated calculation, but in this case the parameter of interest is the change in temperature necessary to produce seven times more heat flux. All other parameters, such as emissivity and view factor, can be assumed to be the same and therefore cancel out when calculating the absolute temperature before and after the radiant heat flux is increased by seven times. An absolute temperature of 2233K (1960°C = 3560°F) would be needed to increase the radiant heat flux by seven times, assuming all other variables remained the same. This is challenging but possible with today’s technology, but would not have been possible with the technology available at the time of this narrative. This makes the literal “seven times” unlikely with reference to heat flux.

A third possibility refers to the type and/or amount of fuel used. One variant of this possibility is that the soldiers could have used seven times more fuel than normal.\textsuperscript{39} This would not have been a trivial modification to the typical routine because the fuel would have taken up much more room. However, this is the most likely meaning of the phrase “seven times hotter” if it is to be taken literally. This would have increased the energy density (e.g., kJ/m\textsuperscript{3} or Btu/ft\textsuperscript{3} of furnace volume) by approximately seven times as the energy in the form of heat would have been increased by seven times while the volume of the furnace would have remained the same. However, it is unlikely the existing furnace was constructed in such a way as to be able to handle seven times the normal amount of fuel. Given that the furnace was probably already hot and that Nebuchadnezzar was very impatient, there would not have been time to modify the furnace to handle that much additional fuel. Another variation of this possibility is that other fuels with higher energy density could have been used to either supplement or replace the normal fuel which was probably charcoal. Sanders suggested pitch, naphtha, and brushwood;\textsuperscript{40} however, that is very unlikely as these fuels were not normally used in furnaces at that time and would not likely have been readily available near the furnace.\textsuperscript{23} Therefore it does not seem likely seven times more fuel could have been used.

The command to heat the furnace seven times hotter is most likely hyperbole. Baldwin believed this is a proverbial expression (cf. Prov. 24:16; 26:16) and should not be taken literally.\textsuperscript{41} Some argue this is an idiomatic way of saying “as hot as possible.”\textsuperscript{42} However, even if this were hyperbole, the furnace was almost certainly much hotter than normal as it killed the soldiers commanded to throw the three boys into the furnace.
Radiation heat transfer was likely the most significant mode of heat transfer in this miracle. There would have been natural convection and could possibly have been some forced convection if human-powered bellows were used to supply air to the furnace to increase the heating rate. The furnace was most likely a large directly-fired furnace where the fuel was burned in a separate chamber and the combustion products flowed into the main heating chamber. This type of furnace was probably used to re-melt the metals such as the bronze and gold that were used to make the statue of Nebuchadnezzar in the plain of Dura.

A heat transfer analysis for this miracle could assume the shape of the furnace, approximate the three Jewish boys as cylinders, and estimate the furnace temperature at some level above that required for melting gold for a furnace that was heated much hotter than normal. A steady-state analysis would greatly simplify the calculations.

The heat flux to the boys could be estimated and then compared against levels detrimental to humans. Research has been done to investigate the levels of thermal radiation produced by fires and the injuries to humans at various radiation levels. Hymes and others presented a table of incident radiation heat fluxes, exposure times, and the consequences to humans. Some examples illustrate the data: 16.9 kW/m² (5360 Btu/hr-ft²) radiation for one minute or 5 kW/m² (1600 Btu/hr-ft²) for five minutes will cause third-degree burns, while 21-53 kW/m² (6700-17000 Btu/hr-ft²) for one minute will cause clothing to auto-ignite. Eisenberg and others estimated the radiation from the atomic bombs dropped on Nagasaki and Hiroshima in World War II. They estimated that 99% of the population was killed when exposed to radiation at 586 kW/m² (186,000 Btu/hr-ft²) for 1.43 seconds in the open air (i.e., with no protection such as being located inside a building). This radiation level is at least 434 times more than from the sun on a bright sunny day. According to the U.K. Health and Safety Executive, thermal radiation levels of 37.5 kW/m² (11900 Btu/hr-ft²) would cause a human fatality.

An in-class small group problem was given to analyze the radiation heat transfer in this miracle. Self-selected groups of up to five students were asked to estimate the heat flux to the three boys so it could compared against thermal radiation levels known to be dangerous to humans. This miracle likely involved both radiation and natural convection, although radiation was likely by far the more dominant. Therefore, to simplify the analysis for hand calculations, the students were told to ignore natural convection.

Calculating the radiation view factor would be challenging because of the geometry of three humans inside of a furnace. The humans could be approximated as cylinders and the furnace could be idealized as rectangular. However, since virtually all of the radiation from the furnace would have been seen by each boy, a reasonable estimate could be made by assuming a view factor of one. A steady-state analysis would be reasonable as the furnace would already have been heated. Then, the most important assumption affecting the estimated heat flux was the furnace wall temperature.

The proper heat flux estimate for this problem can be calculated using the following equation (which was not given to the students who had to determine what equation to use):

\[ \dot{q} = \varepsilon_{\text{boy}} \sigma F_{\text{boy-furnace}} (T_{\text{furnace}}^4 - T_{\text{boy}}^4) \]  

(1)
where,

\[ q = \text{radiant heat flux (kW/m}^2\text{)} \]

\[ \varepsilon_{\text{boy}} = \text{emissivity of a boy} \]

\[ \sigma = \text{Stefan-Boltzmann constant} = 5.67 \times 10^{-8} \text{ W/m}^2\text{-K}^4 \]

\[ T_{\text{furnace}} = \text{furnace temperature (K)} \]

\[ T_{\text{boy}} = \text{temperature of a boy (K)} \]

The calculations for the eight groups with one to four students in a group are summarized in Table 2. One group actually looked up the estimated temperature in the ovens used at Auschwitz to incinerate the Jews in the Nazi concentration camps. This was an interesting choice given that Nebuchadnezzar was trying to incinerate three Jewish boys in a fiery furnace. All but one of the eight groups predicted heat flux rates well above the 37.5 kW/m² that would cause a human fatality according to the U.K. Health and Safety Executive. The average prediction was an order of magnitude higher than that for a fatal level. This gave the students a better idea of just how hot the fiery furnace may have been and how miraculous it was that the Hebrew boys were not even singed let alone incinerated.

Table 2. Sample heat transfer calculation assumptions and results for the parting of the Red Sea miracle.

<table>
<thead>
<tr>
<th>Group #</th>
<th>(T_{\text{furnace}}) (degC)</th>
<th>(T_{\text{boys}}) (degC)</th>
<th>Emissivity</th>
<th>(Q) (kW/m²)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1500</td>
<td>37</td>
<td>0.8</td>
<td>448</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>1300</td>
<td>37</td>
<td>1</td>
<td>347</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>1100</td>
<td>27</td>
<td>1</td>
<td>201</td>
<td>Used temp. of furnace at Auschwitz</td>
</tr>
<tr>
<td>4</td>
<td>649</td>
<td>30</td>
<td>1</td>
<td>40.5</td>
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</tr>
<tr>
<td>5</td>
<td>627</td>
<td>37</td>
<td>1</td>
<td>32</td>
<td>Ignored temp. of the boys</td>
</tr>
<tr>
<td>6</td>
<td>1727</td>
<td>37</td>
<td>0.3</td>
<td>272</td>
<td></td>
</tr>
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<td>7</td>
<td>1500</td>
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<td>0.8</td>
<td>448</td>
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<tr>
<td>8</td>
<td>1800</td>
<td>36</td>
<td>1</td>
<td>1047</td>
<td></td>
</tr>
<tr>
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<td>1</td>
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</tr>
<tr>
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<td>0.3</td>
<td>32</td>
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</tr>
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</table>

Student Survey

A one page anonymous survey was given to the class at the end of the course that was completed by 22 out of the 25 students (3 were absent the day of the survey). The survey consisted of four short-answer questions with the responses summarized below.

\textit{How do the biblical miracle heat transfer analyses compare to the textbook problems?}

The Red Sea assignment was closer to the textbook problems than the Mt. Carmel assignment. More assumptions are needed which is probably closer to the types of problems students may
solve as practicing engineers. Biblical problems are more involved, but are more “colorful and fun to do.” Several felt the biblical problems require more critical thinking. One student felt the textbook problems were more helpful and another felt the miracles were too abstract. Too many unknowns make the results very subjective. One student commented, “They also serve as a reminder that incomplete data results in incomplete results.” Another wrote, “Tougher, more vague, requires more thought and assumptions.” One wrote, “Helps to understand if problem passes the ‘realness’ test.” Another felt the biblical problems were relevant. A student wrote, “I think the biblical miracles are cool practical applications of the textbook problems.” One felt the analysis of biblical miracles offered a new perspective on those miracles that the student had not previously considered.

How do the biblical miracle heat transfer analyses homework help your understanding of heat transfer?

They give students a more practical application of the equations. The stories help solidify concepts and get a better feeling for the process. Helps students see heat transfer applies to more than just engineering but also to “everyday stuff.” The biblical problems are good to help students think through problems and better grasp concepts more fully. One student commented “It helps stretch my brain to apply the concepts of HT.” One student would have liked it if an answer were shown or a specific methodology was discussed. One felt the biblical miracle analyses didn’t help as much in understanding heat transfer as in helping better understand the miracles. Creativity is required in analyzing biblical miracles compared to textbook problems.

Any suggestions for how to improve these assignments?

Make them more descriptive if possible. Provide more detailed instructions for the assignments and some of the variables or at least a range of values. It was also suggested the instructor show his analysis of the miracles. One suggested giving students choices among several miracles to analyze.

Any suggestions for other biblical miracles to analyze?

Sodom and Gomorrah, Elijah calling down fire on the soldiers, turning water into wine to study the heat transfer in any reactions that took place, Jonah in the whale (heat transfer from stomach acid), fire above the heads in the upper room, and the burning bush. One student, who admitted they were struggling in the class, felt the biblical problems were just busy work. Another commented they would rather do more labs than analyze biblical miracles.

Conclusions

Heat transfer analyses of Biblical miracles can provide unique insight into God’s providence and sovereignty, while providing engineering students the opportunity to apply the knowledge gained from their heat transfer courses to their Christian faith. Certain miracles such as those involving fire are more amenable to heat transfer analysis compared to other miracles such as those involving healing. There are a variety of ways the analysis of biblical miracles can be worked into a heat transfer course to provide students with the opportunity to apply their knowledge to less well defined problems, which are the type they may encounter while employed as degreed engineers.
References


34. Absolute temperature should be used when comparing radiation heat transfer.

35. A plasma today can reach those temperatures.

36. The maximum temperature for furnace linings in the ancient Near East was estimated to be 1200°C (M.S. Tite, Y. Maniatis, N.D. Meeks, M. Bimson, M.J. Hughes, and S.C. Leppard, “Technological Studies of Ancient Ceramics from the Near East, Aegean, and Southeast Europe,” in *The Evolution of the First Fire-Using*
40. B.G. Sanders, *The Burning Fiery Furnace*, *Theology*, 58, 1955, p. 343. (Though not stated, this suggestion was likely prompted by the additional verses in the Septuagint.)
Abstract

At Dordt College, we work to make our motto, Soli Deo gloria (glory to God alone), the organizing principle for all activities. In the Engineering Department, it is our responsibility to continue to shape our program to be holistic and Christ-centered in order to equip our students to serve the Lord obediently in engineering. To direct the development and modification of our engineering curriculum, we established a set of five distinctively Christian guiding principles for engineering. Setting the direction for this work required a grounding point. Therefore, in a subsequent manuscript we evaluated the extent to which these principles were already emphasized in our civil engineering curriculum. This evaluation found opportunities for curriculum improvements, the most pressing of which was developing our students’ understanding that that the world and everything in it was created for God’s glory.

In this paper, we report on and critique our implementation of course activities that addressed the identified opportunities for curriculum improvement. This implementation included a common survey and targeted course activities. The survey provided an assessment of whether the guiding principles resonated with students at various points in their education. The activities were both linked to specific principles and course objectives and built upon activities in prior courses. Our critique of these early implementation steps provided evidence that the course activities helped our students understand and appreciate the guiding principles. However, further work needs to be done to translate this knowledge into a lifestyle where the principles guide all of our students’ engineering work.

Introduction and background

Guiding principles for engineering

As Christians, we recognize that God made us “for his own glory” and therefore seek to honor him in everything that we do [1]. Like many others who attend this conference, we feel the Lord’s call to serve in engineering education. There are many days that we find this calling daunting, but we trust that the Lord walks before us and leads us along a path that advances His plan for creation. As we seek to discern the Lord’s direction for our work in engineering education, we recognize that it is our responsibility to continue to shape our program to be holistic and Christ-centered in order to equip our students to serve the Lord obediently in engineering. As we try to avoid straying from His path, we are continually reminded that shaping and refining a program is hard work! It requires thoughtful reflection to continually discern the Spirit’s leading. It requires collaborative work to make plans envisioning what Christian engineering education could be. It requires focus

1 Dordt College, Sioux Center, Iowa
to hold ourselves accountable to these plans. It requires practice to ensure that every class and every day point towards guiding principles for our curriculum.

In our 2013 paper, we took time to discern the Spirit’s leading from God’s Word as we considered what it means to do engineering for God’s glory alone [2]. This thoughtful reflection led to a set of five distinctively Christian guiding principles for engineering (Figure 1). While the figure presents the principles in detail, we will refer to them briefly as: (1) God’s Glory, (2) Develop e/Keep, (3) Creaturely, (4) Human/Non-human, (5) Already/Not Yet. These principles attempt to create a framework we can use to serve in our imperfect world while recognizing that engineering is just one part of a broader interdependent creation. Underlying these principles was a recognition that although the suffering introduced by humanity’s fall impacted all of creation (Romans 8), through Christ’s blood all things (both humankind and all other parts of creation) are being reconciled (Colossians 1:20). We know that sin permeates our work as well; therefore, we also recognize that these principles are not the one and only approach to Christ-centered engineering education. Instead, we characterize our work as an attempt to discern God’s Word by finite sinful creatures.
Guiding Principles for Engineering

Serving the Lord in His World

1. The world (and everything in it) was created for God’s glory.
   - “For from him and through him and for him are all things” (Rom. 11:36).
   - “God’s goal at every stage of creation and salvation is to magnify his glory” (J. Piper).

2. God gave us dominion over creation and instructs us to develop and conserve it (at the same time).
   - We give creation its proper due by treating it with care that brings healing and renewal and enables it to unfold and grow (L. Kalsbeek, Gen. 1:28, 2:15).

3. We are creatures ... always finite, currently sinful.
   - Humans are the crown of creation, we have a unique role ... but salvation does not come from the work of our hands (Ps. 8:4-6, Eph. 2:8,9).
   - We are not saviors. We are finite, sinful, and corrupted.

4. Our sin caused creation’s suffering. We have a responsibility to ease suffering by engaging the human and non-human creation.
   - “For the creation was subjected to frustration, not by its own choice, but by the will of the one who subjected it ... the whole creation has been groaning” (Rom. 8:20-22)

5. We live in the already and not yet of Christ’s kingdom.
   - Christ’s kingdom is already here, and one day it will be fully consummated!
   - We work out of gratefulness for Christ’s saving work, and we trust Christ to use our work as He wills to fulfill His perfect plan
   - We work to continue the Spirit’s sanctifying work in our lives.

Figure 1. Summary of distinctively Christian guiding principles for an engineering curriculum.

Evaluating the emphasis of the principles in our current civil engineering curriculum
Developing the five guiding principles for engineering had an immediate impact on the courses we teach. It gave us a framework that helped us show our students how everything they do (engineering, work, life, etc.) is part of Christ’s creation-fall-redemption story. However, we seek to use these principles to direct the development of an engineering curriculum. Facilitating changes at this larger-scale represents a substantial challenge and requires thoughtful coordination between faculty members. Coordination on this level cannot occur unless those involved can agree on a starting point. We established this grounding point in a subsequent manuscript that evaluated the extent to which the five principles were already emphasized in our civil engineering curriculum [3].

The method used to evaluate the emphasis of the principles was quantitative [3]. We began by using a course scorecard to gauge (on a 0–4 scale) the emphasis placed on each principle within a
particular course. This scorecard was applied to all courses (both engineering and other requirements) featured in the civil engineering curriculum. We aggregated the course scorecards into an appropriately-weighted curriculum scorecard using a method similar to calculating a student’s grade-point average. Finally, we compared the curriculum scorecard to benchmark emphasis scores for each principle. The benchmark scores, while admittedly subjective, have been initially established based on our comparisons of the principles and best guesses as to what satisfactory scores will be. However, as we gather additional data, especially data from different subsets of students, we may refine the benchmarks as we feel is necessary.

Table 1 presents the comparison of our curriculum benchmarks to the civil engineering curriculum emphasis scores. In this comparison, a curriculum emphasis score that met or exceeded its benchmark was considered to indicate adequate emphasis of a principle in the program. As we used this method, we recognized that it had limitations, the most prevalent being the fact that we reduced the principles to a 0–4 emphasis score. Although a notable limitation, we reminded ourselves that it was our overall goal to create a starting point for implementation of the principles throughout the curriculum. For this purpose the method was sufficient and did not warrant additional modification because it would have drawn time away from the implementation work.

Table 1. Comparison of Dordt College civil-concentration curriculum benchmarks to principle emphasis scores [3].

<table>
<thead>
<tr>
<th>Principle</th>
<th>Curriculum benchmark (0–4)</th>
<th>Curriculum principle emphasis score (0–4)</th>
<th>Difference between score and benchmark</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (God’s Glory)</td>
<td>3</td>
<td>1.8</td>
<td>-1.2</td>
</tr>
<tr>
<td>2 (Develop/Keep)</td>
<td>2.5</td>
<td>2.2</td>
<td>-0.3</td>
</tr>
<tr>
<td>3 (Creaturely)</td>
<td>2.5</td>
<td>1.6</td>
<td>-0.9</td>
</tr>
<tr>
<td>4 (Human/Non-human)</td>
<td>2.5</td>
<td>1.8</td>
<td>-0.7</td>
</tr>
<tr>
<td>5 (Already/Not Yet)</td>
<td>1.5</td>
<td>0.9</td>
<td>-0.6</td>
</tr>
<tr>
<td>Average</td>
<td>2.4</td>
<td>1.7</td>
<td>-0.7</td>
</tr>
</tbody>
</table>

The results presented in Table 1 provided a method for us to compare the actual emphasis of a principle in our curriculum to our overall goals. As we reflected on these results, we proposed actions that we should take to elevate the emphasis of the principles within the curriculum. Table 2 summarizes these proposed actions. Primary objections were linked to the greatest needs identified by the results. The sequence of these events does sound rather robotic, but recognize that this was an initial rating and an initial proposal for actions that are part of an ongoing process to continually improve the curriculum in the years ahead.
Table 2. Primary and secondary objectives to increase emphasis of guiding principles identified by evaluating civil engineering curriculum [3].

**Primary objectives:**
- All principles: increase exposure
- Principle 1 (God’s Glory): increase emphasis
  
  **Recommended actions:** Readings, in-class discussion, personal reflections, develop closer ties between cohorts in which our older students help to mentor those who are joining our program.

**Secondary objectives:**
- Principle 2 (Develop/Keep): Help our engineers recognize conservation—the second part of our task.
  
  **Recommended actions:** Project- or problem-based activities that put engineering in context and consider broader impact on the natural creation.
- Principle 3 (Creaturely): Use targeted efforts to help students recognize that ‘we are creatures’ (finite and currently sinful).
  
  **Recommended actions:** When students have appropriate maturity and confidence, use case studies that demonstrate and reinforce the fact that our sinful nature becomes embedded in the things we create.
- Principle 4 (Human/Non-human): Leverage close ties to principle 2; recognizing a call to develop and conserve, it follows that efforts should be directed to easing suffering within creation caused by sin.
  
  **Recommended actions:** Demonstrate this principle alongside the project- or problem-based activities that emphasize principle 2.
- Principle 5 (Already/Not Yet): Carefully convey its relevance when students are likely to have needed maturity (e.g., the 7th or 8th semester).
  
  **Recommended actions:** Use reflective essays and class discussions because the principle is difficult to connect directly with engineering activities.

**Methods**

Flowing from the conclusions in Sikkema et al. [3], this paper reports on and critiques our efforts to address these identified needs by implementing a variety of course activities. To describe the approaches we used, this portion of the work features the following sections: (1) course activity selection and description and (2) course activity evaluation. The selection and description section documents the activities that were constructed and implemented in our efforts to address the conclusions from Sikkema et al. [3]. The evaluation section outlines how we evaluated whether the activities met their objectives.

**Course activity selection and description**

Our manuscript, which evaluated the emphasis of our principles in the civil curriculum, recommended increased exposure to all principles and an increased emphasis of principle 1 (God’s glory) [3]. In concept, the activities we selected should primarily work towards these two goals. In practice, choice of activities was influenced by other factors as well (e.g., course content, current...
events, opportunities to build on existing material). These activities and their relationship to the principles are summarized in Table 3.

Table 3. Course activities selected to improve civil curriculum emphasis of guiding principles.

<table>
<thead>
<tr>
<th>Activity</th>
<th>Description</th>
<th>Reason</th>
<th>Principle(s) emphasized</th>
<th>Course(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perspectives essay response</td>
<td>Students read short essays written by our department founder. Following the reading, students wrote a response.</td>
<td>These essays connected engineering and faith and shared themes with our principles.</td>
<td>1-5</td>
<td>EGR 115 (Introductory Engineering Statics &amp; Structures)</td>
</tr>
<tr>
<td>Christian Renewal article response</td>
<td>Students read and wrote a written response on an article.</td>
<td>The article recognized the unfolding potential of technology and how it manifests God’s glory.</td>
<td>1-3</td>
<td>EGR 212 (Mechanics of Materials)</td>
</tr>
<tr>
<td>Principles reflection</td>
<td>Students wrote reflections on the principles.</td>
<td>By reflection, the students became aware and developed an understanding of the principles.</td>
<td>1-5</td>
<td>EGR 317 (Structural Analysis)</td>
</tr>
<tr>
<td>Earthwise discussion</td>
<td>Students read and discussed chapters that related the cultural mandate to our place in creation.</td>
<td>The reading connected the principles to the care of creation and was relevant to course topics (environmental engineering).</td>
<td>1-5</td>
<td>EGR 319 (Environmental Engineering)</td>
</tr>
<tr>
<td>Lab activity project in context</td>
<td>Students designed lab activities and were challenged to connect this seemingly technical work to serving God.</td>
<td>This project developed the understanding that all of life is informed by our faith.</td>
<td>1, 2</td>
<td>EGR 319 (Environmental Engineering)</td>
</tr>
<tr>
<td>Principles survey</td>
<td>Students responded to a survey which gauged their understanding of the principles.</td>
<td>Completing the survey raised principle awareness and also a means to elevate.</td>
<td>1-5</td>
<td>EGR 115 (Introductory Engineering Statics &amp; Structures)</td>
</tr>
</tbody>
</table>

Activity evaluation
As we considered appropriate means to evaluate the activities, we were presented with a variety of challenges. Overall, we sought an approach that evaluated each activity with a similar set of metrics. We looked for a means to keep the conclusions from Sikkema et al. [3] at the forefront of our minds to ensure that we did not stray from the prevailing needs in our curriculum. We also recognized that our effectiveness at implementing the guiding principles in our civil curriculum is not simply a matter of developing relevant activities; the activities must be both pedagogically effective and placed at an appropriate point in the curriculum.
As we thought through these considerations, we decided to use a standard set of guiding questions that encouraged us to step back and thoughtfully reflect on the impact of our efforts. The questions we used for this evaluation are displayed in Table 4.

### Table 4. Guiding questions for activity evaluation.

<table>
<thead>
<tr>
<th>Evaluation type</th>
<th>Guiding questions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Relevance</td>
<td>1. How did this activity work towards the primary objectives?</td>
</tr>
<tr>
<td></td>
<td>2. How (if at all) did this activity work towards the secondary objectives?</td>
</tr>
<tr>
<td></td>
<td>3. What ties does this activity have to the recommended actions?</td>
</tr>
<tr>
<td></td>
<td>4. How could you strengthen the ties between this activity and the principles?</td>
</tr>
<tr>
<td>Effectiveness</td>
<td>1. Did students’ responses indicate that they understood activity’s relevance?</td>
</tr>
<tr>
<td></td>
<td>2. How deep of an understanding was demonstrated? Did they simply paraphrase the</td>
</tr>
<tr>
<td></td>
<td>activity’s prompts or did they develop unique insights?</td>
</tr>
<tr>
<td>Curricular impact</td>
<td>1. Was the activity placed at a point in the curriculum that allowed it to both</td>
</tr>
<tr>
<td></td>
<td>build upon prior learning activities and serve as a stepping stone to future</td>
</tr>
<tr>
<td></td>
<td>activities?</td>
</tr>
<tr>
<td>Summary</td>
<td>1. Should this activity be retained, improved, or replaced?</td>
</tr>
<tr>
<td></td>
<td>2. If the activity should be improved, how could you make it more effective?</td>
</tr>
</tbody>
</table>

### Results

The guiding questions provided a useful means to evaluate the activities we implemented in our curriculum. The results of this evaluation are provided in Table 5. This table includes the class activities (presented previously in Table 3) with responses to each of the guiding questions presented in Table 4. Discussion of these results is provided in the following section.
Table 5. Evaluation of Implemented Class Activities

<table>
<thead>
<tr>
<th>Evaluation type</th>
<th>Essay response</th>
<th>Christian Renewal article response</th>
<th>Principles reflection</th>
<th>Earthwise discussion</th>
<th>Lab activity project in context</th>
<th>Principles survey</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Relevance</strong></td>
<td>1. Engaged students in reading that reinforces how God’s glory shines through both the natural and developed creation.</td>
<td>2. Related to Principle 2…natural and developed creation.</td>
<td>3. Includes reading and personal reflection.</td>
<td>4. Could possibly provide the principles as background to the essay, or even have students reflect on principles 1 and 2 after reading the essay.</td>
<td>5. Increased exposure to the principles by asking one anonymous question related to each principle.</td>
<td>6. It asked questions related to Principles 2-5.</td>
</tr>
<tr>
<td><strong>Effectiveness</strong></td>
<td>1. Mostly.</td>
<td>2. Widely varying among the students (28% didn’t get it, 54% got it, 18% owned it)</td>
<td>3. Provide principles before reading as ask students to show where agreement or disagreement occur.</td>
<td>4. It is tied directly to the principles.</td>
<td>5. Increased exposure to the principles by asking one anonymous question related to each principle.</td>
<td>6. It asked questions related to Principles 2-5.</td>
</tr>
<tr>
<td><strong>Curricular impact</strong></td>
<td>1. Yes. (Primarily an introductory exercise, but that is the intention.)</td>
<td>2. Yes. (Built on freshman year and increased focus on God’s glory in technology.)</td>
<td>3. Yes. Applied principles in specific area of engineering.</td>
<td>4. Yes</td>
<td>5. Not really, more of an introductory assessment exercise.</td>
<td>6. Marginally.</td>
</tr>
<tr>
<td><strong>Summary</strong></td>
<td>1. Retained.</td>
<td>2. Perhaps improved by tying it directly to the principles.</td>
<td>1. Retained.</td>
<td>2. Good as is.</td>
<td>3. Improved.</td>
<td>2. Should be improved by thinking carefully about the questions and modifying as needed.</td>
</tr>
</tbody>
</table>
Discussion

Relevance to primary and secondary objectives from our curriculum evaluation

We found that we were fairly successful in developing activities that worked towards the primary objectives from our curriculum evaluation (see Table 2). These primary objectives included increasing students’ exposure to all five of the guiding principles and especially emphasizing the first principle (God’s glory). However, our reflection also found that some of the activities we used would likely be a part of our courses even if we were not working to implement changes that increased the guiding principles’ emphasis. This result should have been expected. When we developed the principles, we were not attempting to redefine what it means to serve as engineers who are Christians. Rather, the framework presented flows from the theological perspectives that have guided our department from its inception. This framework was helpful as we used the activities and discerned their usefulness. In some cases, explicit ties to the principles are not necessary, but we should take time to consider how to share this framework with the students so that they can also use it to discern the impact of their current and future work.

The activities were also helpful in working towards most of our secondary objectives (Table 2), particularly the objectives related to principles 2-4 (develop/keep, creaturely, and human/non-human). However, while a few of the activities touched on principle 5 (already/not yet) the evaluation process did reveal that these activities did little to really be formative or explicit.

Effectiveness of evaluation process

There are useful highlights to point out from the evaluation process. First, we discovered that even though we lacked a systematic rubric for rating the effectiveness of the activities, for most of the activities it was relatively simple to gauge the activities’ effectiveness on the basis of the students’ responses. For example, consider the first activity, “Perspectives Essay Response.” This activity asked students to read an essay discussing the beauty of the natural creation, such as mountains, rivers, and trees and the beauty of developed creation, such as poetry, computer programming, or technological artifacts. The essay pointed out how the beauty of both nature and development point to God’s glory, directly emphasizing one of our primary objectives. For the most part, it was surprising how easy it was to quickly skim a student’s response and see if they “got it” or not. As Table 5 shows, we divided the student responses into three categories: “didn’t get it,” “got it,” and “owned it.” These ratings were made simply on the basis of a quick review of the written responses from the students. While upon first thought it may seem like this exercise is very subjective and relative, a quick read was all that was necessary to clearly see if students responded by recognizing God’s glory in all things (getting it), passionately declaring God’s glory in all things (owning it), or missing the point entirely and just talking about vacation or human endeavors and not reflecting on God’s glory at all (not getting it). Since these categorizations of student responses felt meaningful and manageable, it reinforces to us that it is valuable to conduct such evaluations. Beyond simply providing data for assessment purposes, processing student responses in this way gives us a better picture of whether they truly are “getting it.”

Deviations from curriculum evaluation conclusions

We did not carefully regiment the activities we discussed in this paper. Consequently, as we reflected on the implemented activities, and then went back and reviewed the conclusions from our curriculum evaluation [3], we discovered that we did not necessarily work towards this work’s conclusions. While we indeed implemented new activities, many of which were quite effective,
these activities were not all directed to the objectives summarized in Table 2. For example, the readings from *Earthwise* were worthwhile and related to the principles. However, the activities constructed made no mention of the guiding principles. Creating a connection to the principles represents an easy opportunity to work towards the primary objectives in future years.

This apparent lack of focus in the activities we implemented may signify a need for greater planning on our part. However, on the flip side we can certainly see some benefit in activities like these not being carefully pre-planned and regimented. Oftentimes, the most valuable perspectival reflection activities are those which happen spontaneously based on current events or particular student interests. It is valuable to be able to take advantage of such opportunities and not feel so tied down to some preconceived plan. In fact, the relevance, effectiveness, curricular impact, and summary questions may show their true value in such situations, because they can be as readily applied to a pre-planned assignment as they can to a spontaneous one. As such, they serve as a good tool for evaluating student understanding of the guiding principles while still providing the freedom to change up the activities as the situation dictates.

**Conclusion**

As we reflected on this work, we found that the structure the guiding principles provided has helped us significantly in recognizing whether students are trying (and even desiring) to think Christianly about engineering. The principles provide a tangible framework that helps us see if students understand what integrally Christian engineering is really about. Perhaps even more importantly, the principles have helped us, as engineers ourselves, think more clearly and articulate more carefully what it means to do integrally Christian engineering. The guiding questions for activity evaluation were helpful in assessing the effectiveness of implemented activities, both carefully-planned activities and spontaneous ones.

In some cases we did get side-tracked. Since we did not carefully preplan the entire list of activities that we have implemented over the past academic year, when we went back and evaluated our activities we discovered that our activities were not evenly distributed in terms of addressing our primary and secondary objectives. However, we appreciate the flexibility that not carefully preplanning the entire gamut of activities provided, because it allowed us occasionally to incorporate timely current events that would have not been possible if we restricted ourselves only to a carefully regimented list.

By going through this process, we reaffirmed that these principles serve as a useful framework as we work to equip our students to serve the Lord obediently in engineering. We find real joy in using these principles because they offer clarity and direction to our work. We need to work harder to share this joy with our students. We need to describe these principles specifically and provide examples of how they guide our work. These principles have positively impacted our lives. We hope that they can help our students as they leave Dordt College and serve in a world clouded by sin but in anticipation of Christ’s final reconciliation and consummation of his kingdom.
References


Many Christian universities and colleges in the United States are rooted in the Christian liberal arts tradition with its distinctive missions fairly well articulated in the context of today’s higher education. This paper examines the identity and role of an engineering school in the biblical and the contemporary contexts and suggests that a well-designed engineering school should help fulfill the mission of Christian higher education in the liberal arts tradition in a more comprehensive way.

I. Introduction

Traditionally, Christian higher education has been one of the important missions of Christianity as numerous universities and colleges have been established with Christian goals and perspectives, especially in the context of liberal arts education. However, as they grow both in numbers and in scholarship, many of them have gradually given up their distinctive Christian mission and turned themselves into secular institutions.¹

My belief presented in this paper is that having a well-designed engineering school in a Christian higher education institution can help achieve its mission better, rather than diminishing the Christian nature of the institution.

After reviewing the larger contexts of both Christian higher education and secular education today, I will explore a biblical theology appropriate for Christian engineering education. I will then suggest important goals of an engineering school as an integral part of Christian higher education in the liberal arts tradition.

II. Engineering in the context of Christian higher education

With significant institutional and collaborative efforts, many Christian universities have managed to maintain their Christian missions. They strive to continue implementing Christian views and missions in all they do.² However, there seem to be a few dangers Christian higher education institutions are faced with almost in perpetuity. Let me list here three of them:

Firstly, in pursuit of academic excellent, many Christian universities tend to become “copycats” of secular institutions as the standards of excellence are often set by trend-setting secular institutions. “Mission drifts” occur -- albeit gradually and slowly-- as it did with so many schools who started with great and lofty Christian missions.

¹Greenville College, Greenville, IL
Secondly, on the other end of the spectrum, there are institutions that have set over-protective policies and over-extended curriculum that often impinges on the quality of education. These Christian institutions are rarely able to adapt themselves to changing environments and tend to suffer gradual declination.

Thirdly, there are Christian institutions that provide relatively good quality education without overly protective policies and curriculum. However, their influence is often limited to Christian circles. It is very rare to find Christian institutions that would be considered to be doing the role of “the light of the world” or “a city on a hill.” I am particularly concerned with this issue of how we might be restored to do this role in the contemporary context. To do this, I would first like to re-examine our prevailing ideas of “integration of faith and disciplines” in the larger historical context.

Greek and Hebraic ideas of truth and knowledge

The Apostles and the early church fathers contended that all truth is God’s truth wherever it may be found. Arthur Holmes, in his *The Idea of Christian College* and *All Truth is God’s Truth*, emphasizes two aspects concerning the idea of the unity of truth: all truth is God’s truth and the unity of all truth.

For Greeks, truth and knowledge belong to the world of “idea.” For Hebrews, they were more experiential. (1 Corinthians 1:22 “Jews demand signs and Greeks look for wisdom.”) Western philosophical and theological worlds have been dominated by Greek thoughts. It is well recognized that the two greatest theologians in Christian history, St. Augustine and Thomas Aquinas, owe their philosophical frameworks heavily to neo-Platonic and Aristotelian thoughts. Subsequently, most of biblical narratives are interpreted through the dualistic view of Greek philosophy.

For instance, the ideas about logos (λόγος) in the Gospel of John were interpreted differently in the Eastern and the Western Christianity. While the Western Church, under the heavy influence of Hellenistic philosophies, regarded it as somewhat close to the mind of God (thus translated it into an abstract term “word”), the Eastern Church regarded the word logos as representing more dynamic reality. In the Eastern Church, experiential knowledge and lived-out truth were considered real. We come to know truth not by contemplating it, but by practicing it. We know trees by their fruits. So is the case of Christian theology of creation. A central thesis of Western theology of creation is *creation ex nihilo* (“creation out of nothing”) – the idea that emphasizes God’s “supernatural-ness.” But it often ignores many other biblical testimonies that clearly tell us that God created the world in his detailed knowledge, wisdom, and with work of his own hands (Psalms 92:4-5, Isaiah 66:2, Proverbs 8, Job 26, 28, 37-39). We even forget that God labored hard that he needed to rest after six days’ creation! The Bible says that the most *spiritual* is the most *practical*. As Paul said in Romans 12:1, giving our *bodies* as a living sacrifice is our *spiritual* worship. All aspects of Christian life must be harmonized and practiced coherently as the Christian truth is not limited in the intellectual realm but encompasses our whole being and practice of living.
Christians are called to be doers, not just to be believers of truth. We are justified not just by our faith, but by our works as well (James 2:24). For Christians, doing has a higher priority over teaching. (Acts 1:1 “Jesus began to do and to teach.” Matthew 5:19 “… whosoever shall do and teach them, the same shall be called great in the kingdom of heaven.”) The point is that, in order for us to have a proper biblical theology for engineers, who are creative doers, we must first reexamine our existing theological frameworks and free it from the Hellenistic presumptions that regards the works of our hands less important than the works of our mind.

III. Christian engineering in the larger secular educational context

We also need to look at the status of Christian engineering education in the context of the larger public and secular education. We observe that the following key characteristics are prevalent in public education today:

1. Education without Truth and Value: Higher education today is done largely without regards to truth and value. The schools only transmit “fact” and “how to” but not truth and value. Stemming partly from pluralism, which has become a fact of contemporary public life, relativism is pervasive in the academic community.

2. Materialistic or Naturalistic Implications: Science and engineering education today tends to promote materialism and naturalism by not providing students with the opportunity to critically examine and reflect on the limits, assumptions, and applicability of science and engineering. Because material well-being seems to be the only common value among modern humans, our public life operates mainly on materialistic principles.

3. Extreme Compartmentalization of Knowledge: Though specialization of knowledge is both important and necessary in the contemporary world, we observe that communication between different disciplines or even within a discipline is becoming increasingly difficult. Unless a proper interdisciplinary perspective is developed, this extreme compartmentalization poses a crisis in which even the learned leaders of a society do not understand the implications of a development in one discipline for other disciplines.

4. Utilitarian Tendency and Human Alienation: We must be practical in all we do. We need to learn how to act in a more effective manner in accomplishing our goals. However, if our ideas of truth and value are focused only on the end results, they can be destructive. The absence of principles and values and materialistic implications tend to make our society utilitarian. This often can result in human alienation in which humans become only a means to accomplish various societal goals.

5. The Loss of Proper World-views: World-views were abandoned when many philosophers pronounced that metaphysics is neither possible nor acceptable. Kant posted an epistemological objection to metaphysics arguing that we are screened from the noumenal world by the human a priori; Nietzsche claimed that we are screened from the true world by human historicity; Wittgenstein pronounced that meaning stops with social
horizons. Derrida posed a moral objection that we should not attempt to have an objective world-view since it dehumanizes and tyrannizes.

6. Whatever We Can Do!: In science and technology, the world often rewards those who achieve things for the first time. The assumption behind this is often that science, technology, and engineering are value-neutral. In the name of creativity, discovery, and efficiency, we tend to do whatever we can do without even thinking twice about long-term or broad consequences.

IV. Erroneous Christian responses to public higher education

Through the course of my life as a Christian scholar and educator in the reformed and evangelical tradition, I have observed the following general errors in various Christian responses to higher education.

1. Dichotomizing Life into the “Sacred” and the “Secular”: The adoption of dualism in Christian thought has had far reaching results in Christian perspectives of the world. While the Scripture says that all of creation was pronounced good (Gen. 1, 1 Tim. 4:1-5) and that we are to do all things for the glory of God (Col. 3:23), many Christians have been misled by the dualistic idea of two worlds: the “sacred” and the “secular”. (For example, some scientists confess that they take off their Christian “hats” as they enter their science labs.) In the New Testament tradition, it is understood that all believers are called to be followers of Christ in all their being and actions. There is no such division between the “sacred” and the “secular” in Christian life.

2. Yielding to the subject-object division: By setting religious experience in an utterly separated realm from the physical one, some Christians tried to hide their faith commitment within the subjective world. According to positivistic modern thought, religious ideas, including many truth claims of Christianity, are unfalsifiable and therefore pronounced “irrational.” As a consequence, our life is torn into the mutually incommunicable world of facts and the world of value and meaning. In the current academic world, there is a wide communication gap, or rather a separation between scientific and technological disciplines and the studies in humanities. C.P. Snow eloquently identified this chasm in his influential work, The Two Cultures. In this false scheme, the world is divided into pieces: internal and external, subjective and objective, sacred and secular, mental and physical, moral and factual, private and public.

3. The Loss of Spirituality: While intellectualizing Christianity, Christian scholarship has lost the true meaning of spirituality. Spirituality is often identified as being “mystical” or “emotional.” Spirituality has been placed in a position opposite to practicality. This dualism has brought severe contrariety and discord between our inner life and the practicalities of our daily lives. Genuine spirituality, in the Biblical tradition, is always firmly grounded in our day-to-day life and activities, always addresses real life, and always has genuine effects upon one’s practice and behavior.
V. Biblical perspectives on engineering

I would like to examine a few important aspects of biblical narratives pertaining to our systematic discussion of theology for engineering.

1. More than Stewards: Christians rightly regard their relationship to God’s creation as that of stewards. However, we should also be reminded of the fact that the primary biblical identity of humanity is the image of God -- that we are made in God’s likeness – and that we are given the dominion over “all the earth.” The Hebrew word for dominion, “radah,” does not imply an abusive relationship, but it still means much more than just being a steward, but to “reign,” “rule,” and “subjugate.” The same word is also used in Nehemiah 9:28, Psalm 49:14, 72:8, etc. In today’s society, the word “dominion” may not be a politically correct one, but it is the word that was used in the Bible. The responsibility of the one who has dominion over others is much greater than that of a steward.

   (Genesis 1:26-28) And God said, Let us make man in our image, after our likeness: and let them have dominion over the fish of the sea, and over the fowl of the air, and over the cattle, and over all the earth, and over every creeping thing that creep upon the earth. So God created man in his own image, in the image of God created he him: male and female created he them. And God blessed them, and God said unto them, be fruitful, and multiply, and replenish the earth, and subdue it: and have dominion over the fish of the sea, and over the fowl of the air, and over every living thing that move upon the earth.

2. Created Co-creator: We often state that engineers see and appreciate God’s designs and materials in nature (Psalm 8, 19, Job 28, Proverbs 3, etc.), and adopt them in their designs. We don’t create the natural things like God did, but, we should note that we can create something truly new as we are created in the likeness of the Creator. Humans are not just imitators of what are already present in nature. We are, as Philip Hefner has said, in some sense, “created co-creators” of God. In my view, one of the most remarkable statements in the Bible appears in Genesis 2:

   (Genesis 2:18) And the Lord God took the man, and put him into the garden of Eden to dress it and to keep it. And out of the ground the Lord God formed every beast of the field, and every fowl of the air; and brought them unto Adam to see what he would call them: and whatsoever Adam called every living creature, that was the name thereof.

Adam was about to come up with names that never existed, and God wanted to see how he would do it! God could have named them all and taken them to Adam, but God did not do that. God also could have renamed once Adam did (something wrong or imperfect), but God did not do that either! God left rooms in His creation so that we may also be truly creative. He also allows things to remain the way we have created!
God created the birds that fly in the air. We learn from them and further created airplanes and rockets. God created our brains. We then created computers and supercomputers. Nature has electromagnetic phenomena. But we learn from it and have conceived electric power grids that supply energies to huge cities. We often hear that engineering is not doing something original (unlike new scientific discoveries) but is just an application of scientific knowledge. However, the biblical perspective is different. Engineers create something truly original that never existed before in our universe!

We have both an incredible privilege and incredible responsibility in conceiving ideas and being able to exercise control over God’s creation! This will bring us to the third aspect of God’s creation pertaining to engineering.

3. Developmental Worldview of the Bible: We often mess up what God has created. So, we often say that “the natural” is good and “the artificial” (what humans have created) is bad. But is it a proper biblical view? Yes, God created all things natural and pronounced them “good.” However, we also need to note that nature is not given to us in a maintenance-free state, but was entrusted to us in a state that needs to be tended, continually cared for, and to be further developed.

God also allowed us many natural challenges that we need to overcome. What do we think of natural disasters like floods, tornadoes, volcanoes, tsunamis, earthquakes, and asteroid strikes? Did God intend them to strike us? This should not be the case. Humans are given the potential to develop the world wisely so that the impacts of such natural disasters may be minimized. A Chinese legend has it that its civilization started with the successful control of the great flood by Yu with civil engineering projects (construction of dams, dikes, and canals) at the time of the “Emperor” Yao who started Xia Dynasty.

The Bible starts with the Garden of Eden and ends with the City of God. The biblical view of the world is neither static nor cyclical. There is a clear sense of historical development (albeit not always gradual) in the narratives in the Bible. The Bible starts with the natural state that God has first created, but ends with the city full of people living in it. The truly ideal place, according to the Bible, is not a garden but a city!

4. The Idea of Kenosis in Theology of Creation: The Greek word “kenosis” means “emptying.” The word is used in Philippians 2:7. There we note that God “emptied himself” to become a human. The idea of kenosis may be applied to the theology of creation. Perhaps, God, who is capable of making the world completely determined, by emptying His powers and rights, has left rooms for humans so that we may have true freedom and creativity?

5. Equipped for the Tasks: We are not only given commissions to have dominion over the creation, but also are properly equipped for the task. Humans are given God’s breath (therefore I assume that we have a potential to care about God’s creation), creativity, wisdom, hands that are freed to use (unlike dolphins, for instance), and enough intelligence (unlike squids, for instance). We are given abilities to change, rearrange, utilize, manipulate, and optimize the created order.
6. *Keeping the Greatest Commandment – Be the Doers:* Engineers are creative and skillful doers. While the focus of Christian liberal arts education is often concerned with Christian “mind,” engineers use all aspects of their life to glorify God. Mark 12:30 says: “Love the Lord your God with all your heart and with all your soul and with all your mind and all your strength.” Engineers can help fulfill our Christian duties to the fullest.

7. *Knowing God more through Engineering:* Engineers recognize that God has given us specific skills, talents and interests to utilize for serving Him and helping others. As doers, engineers meet the needs of others with purposeful labors. In the Bible, laboring for others is the surest sign of true love. Paul wrote to Thessalonians:

> “We give thanks to God always for you all, making mention of you in our prayers; remembering without ceasing your work of faith, and labor of love, and patience of hope in our Lord Jesus Christ …” (Thessalonians 1:2-3).

Jesus labored all the way to the cross because he loved us. “God so loved the world” and labored so much in creating the world. We ought to love others in truth and in action. Only in our labor of love, we come to know the depth of God’s love for us and for the creation. Jesus was a master carpenter with numerous scars in his hands – I presume. God is surely “the ultimate engineer” who dreamed, designed, developed, and delivered the creation through His labor of love.

VI. Light on the hill: a model for Christian engineering

With these biblical foundations in mind, how, then, may Christian higher education in engineering be directed? In what follows, I summarize my current thoughts pertaining to this important question.

1. *Engineering as a Calling:* Faith is our life’s response to God’s calling. Without faith, our best actions can only be futile if not destructive. “Deeds without faith” is a distinctive characteristic of engineering today. Financial needs or security (Jobs, jobs, jobs!) are often the reason to choose engineering rather than God’s calling. Responding to someone else’s dream (the case of the Tower of Babel in Genesis 11, for example), or responding to the national security’s “need” (the case of the Manhattan Project, for example) may not end up with the results that God would appreciate.

When we understand our calling to prepare for what God is about to do (the case of Noah’s Ark, for example), the calling to meet the needs of God’s people (the case of Nehemiah’s rebuilding the city wall, for instance), and the calling to participate in God’s vision (the case of Belzalel and Aholiab in building the Tabernacle, for example), our work will bear much fruit. We need to raise our future engineers with visions and callings from God. With the true sense of purpose and value, they will be able to discern what they need to do as they need to make important decisions.
2. **Building Christian Characters and Attitudes**: Christian education should help students to cultivate characters and attitudes that are suitable for mature and responsible Christian engineers who are not of the world but are still actively living in the world in order that they may transform the world. Such qualities as creativity and freedom may be developed fully only through the liberation of minds from the distortions of human-centeredness. It is only when we return to the knowledge and will of God, by which we are created in Divine image, that we find our true freedom and creativity. We also need to teach students how to be lovers, seekers, and doers of truth, and help them to remain humble before God’s unlimited knowledge. We need to inspire them to learn everywhere, encourage them to be open to greater truth, and help them to strengthen their honesty, humility, and integrity.

3. **Christian Perspectives of the World & Interdisciplinary Approaches**: Christian education needs to provide a general interdisciplinary perspective that encompasses both spiritual experiences and the contemporary scientific world-view. An integrated knowledge, its unity and diversity, must be coherently presented in a Christian perspective so that students may acquire a broad and coherent perspective of the world and their positions in it. If we don’t offer a persuasive Christian view of the world, this generation and the generations to come will look elsewhere for their guidance and world-view. They may well be lost either in material reductionism, or in occult spiritualism, or in riddles of the middle.

4. **Competence in Understanding and Actions**: Christians are not only called to be pure and holy, but are also called to be wise, truthful, and practical in this world. We are to love God not only with all of our heart and mind, but also with all our strength. In order for Christians to be God’s witnesses as the light and the salt of the world, we must be competent in our understanding and action.

Fruitfulness is a proof that we are in God who is the source of all creativity, life, power, and energy. Christianity is not a conceptual religion. It is a way of life. Practicality and fruitfulness must be emphasized in all areas of Christian education. In every area of study, the effectiveness of an education may be judged primarily by students’ ability to apply what they have learned to real-life situations. It is essential for a future leader to understand the realities of this rapidly changing world and be able to use the acquired knowledge effectively.

5. **Understanding One’s General and Particular Callings**: Christians are called out of the world by God to enjoy, share and show God’s love, righteousness, and eternal purpose. We are also called to release the captives, heal the sick, and mend the brokenhearted. In addition to this general calling as God’s ambassadors and epistles to the world, each one of us has a special calling with particular gifts and capacities. Helping students become clearly aware of their identity and specific vocational callings should be one of the primary objectives of Christian higher education.

Engineers recognize that God has given us specific skills, talents and interests. Engineers utilize them to serve God and others, and tend the creation. We are often called to be a
leader or a team member or as a specialist. As educators and mentors, we need to guide and help our students to grow into the persons God has intended them to be.

6. Awareness of the Global Community: In this age of rapid globalization in almost all areas of life, the awareness of different cultures, traditions, and ways of understanding is essential. We are to carry the gospel to every tribe, nation, kindred, and tongue. Christians today have, in some sense, unprecedented opportunity to preach the gospel to all people on this global community. It is not sufficient to seek a Christian perspective only within the Western tradition. Our world is already global and multi-cultural. Everywhere we meet people from different cultures and traditions. In order for us to serve the people in the world, we must learn to understand their particular views of the world, heritages, ways of thinking, and cultural traditions. Engineers have particular advantages here -- as the “language” of engineering is almost universal.

VII. Challenges

What I have tried to suggest in this paper is the idea that an engineering school can help fulfill the mission of Christian higher education more fully, rather than diminishing it. We also note that, Christian engineering education is basically no different from other Christian higher education. Therefore, we need to equip our engineering students with the highest quality Christian education possible.

However, the scope of engineering education is often more extensive than many other areas of higher education as it needs to include the details of “how to solve problems and meet the needs of a society.” Engineers need to (1) know the larger context of a particular problem, (2) understand the scientific principles, (3) have wisdom and creativity to design the “solution,” (4) have detailed knowledge of how to develop and implement the process, and (5) work with others to actually deliver the project/solution/product. Furthermore, all these need to be done in Christian perspectives.

There are many challenges with which Christian educators in engineering are faced. Just to mention one of those challenges – how one may design a curriculum that does justice to both the mission of Christian higher education and the quality of the professional program. We note that the goals of Christian engineering education stated in the previous sections cannot be achieved by sporadic efforts of isolated individuals. It requires careful, patient, cooperative work of many whose minds have been genuinely renewed by the Spirit.

I believe that Christianity needs this ministry of higher education more than ever. As the future of humanity depends on new generations being raised in this new global culture, reclaiming these new generations for Christ must be one of the top priorities of Christianity today.

So, how may we raise next generations of engineers equipped with Christian perspectives, ethics, creative mind, competent skills and caring heart?
Acknowledgments

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4 There are some Christian traditions that have kept the more balanced approaches to spirituality. They tend to, in my opinion, rightly emphasize “Christian practices” in everyday life. See, for example, Smith D. & Smith. J. (2011). *Teaching and Christian Practices: Reshaping Faith and Learning*. Eerdmans.