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A Brief Survey of the Biblical Integration of Engineering and Missions with Emphasis on Appropriate Technologies

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Abstract

A Biblical foundation for the integration of engineering and missions, an overview of appropriate technology in a Christian context, a survey of projects at other Christian engineering programs, and proposed engineering projects are discussed for remote areas and developing countries. At the core of the Biblical integration of engineering and missions is the desire to use engineering skills and resources to assist others, especially those in the Christian family, improve their lives, help them obtain Biblical information, and encourage personal responsibility. Engineering topics are proposed that will help people gain access to information, improve agricultural methods, improve their health, and grow in the Word. Through engineering efforts, Godly relationships between engineers and others in developing countries can be fostered to help spread the Gospel. The specific categories of topics that are considered are electrical engineering focused and are in the areas of electrical power, instrumentation and data logging, telecommunications, remote sensing, radio, agriculture, medical equipment, and security systems. Emphasis is placed on appropriate technologies that are small-scale, can be fabricated with local inexpensive materials, and can be maintained locally by the people.

Introduction

Numerous opportunities exist, inspired by Scripture, to apply engineering skills and talents to improve the lives of others in our nation and around the world, which can result in relationships where the Gospel can be shared. Inspiration for the integration of Biblical principles, engineering, and missions can be found in Matthew 25:35-36 where Jesus says "For I was hungry and you gave me food, I was thirsty and you gave me drink, I was a stranger and you welcomed me, I was naked and you clothed me, I was sick and you visited me, I was in prison and you came to me." [1] Engineering talents and resources can be applied to help people improve their methods for growing and harvesting food, obtain water, and develop medical equipment. Inspiration for technologies such as radio equipment and smart phone apps that can be used to spread the Gospel can be obtained from Romans 10:14 that says, "How then will they call on him in whom they have not believed? And how are they to believe in him of whom they have never heard? And how are they to hear without someone preaching?" [1] Numerous opportunities are available for engineers to meet the needs of others, improve their lives, and in the process build relationships to share the Gospel and spread God's Word.

This brief survey paper includes material obtained from a literature search, insight into efforts at other Christian engineering programs, and feedback from discussions with missionaries and engineers working in the field. It discusses the Biblical foundation of missions-focused engineering and a concept, appropriate technology, from a Christian worldview. Emphasis is placed on surveying appropriate technologies (AT) that have been and could be developed to improve the lives of people and be used as a means to build relationships to share the

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Gospel. Missions-focused engineering projects that have been completed at several Christian university engineering programs will be summarized. Then technologies and topics are proposed that could be developed or taught in senior design projects, engineering electives, and other courses. Interdisciplinary technologies could also be developed with collaboration between departments such as engineering, biology, and business. In addition, possible collaboration opportunities with other Christian universities with engineering programs are proposed. The suggested topics emphasize that the development of the technology is to improve the lives of others, to develop God-honoring relationships, and not just to develop what could be considered a new "cheap" technology.

Biblical Integration of Engineering and Missions

The importance of missions-focused engineering will be highlighted with a few key Biblical concepts such as transformation (Romans 12:2), doing good to others (Galatians 6:9-10, Philippians 2:3-4), personal responsibility for a project (Leviticus 23:22), and the Great Commission (Matthew 28:16-20). These key concepts provide direction and insight into the importance of using our engineering skills and resources to help others and improve their lives.

Engineering conducted in the context of serving others and meeting their needs is one area where the engineering field can glorify God and reflect His transformative work in this world. Romans 12:2 declares "Do not be conformed to this world, but be transformed by the renewal of your mind, that by testing you may discern what is the will of God, what is good and acceptable and perfect." [1] Christ is the creator and redeemer of all Creation and is transforming us to be more like Him. Ashford, in his article about the relationship between Christianity and culture, says, "God's redemption and restoration transforms us in the totality of our being, across the entire fabric of our lives." [2] As Christian engineers, God can use us to transform our culture and He can utilize our creative abilities to help others flourish. We desire to glorify Him and be used as His light in the workplace and in the mission field. Christian engineers want to apply their engineering talents and skills to participate in His transformative work. We want to be transformed to be more like Christ allowing God to use us to reach others with His Word.

Another important aspect of the integration of engineering and missions is that we are encouraged to do good to everyone. Galatians 6:9-10 commands "And let us not grow weary of doing good, for in due season we will reap, if we do not give up. So then, as we have opportunity, let us do good to everyone, and especially to those who are of the household of faith." [1] Philippians 2:3-4 complements this Scripture by commanding us to "Do nothing from selfish ambition or conceit, but in humility count others more significant than yourselves. Let each of you look not only to his own interests, but also to the interests of others." [1] Excellent statistics are available for topics where people can be helped: "Of the 5 billion people living in the developing world, one billion are illiterate, one billion lack access to safe drinking water, and 2.5 billion lack access to basic sanitation." [3] Fellow Christian brothers and sisters around the world can be assisted with our engineering skills in many ways. Ideally, we want to teach them about designing and building devices that will help meet their basic needs, but also show that as fellow Christians, we are serving them as members of the body of Christ.

As we help fellow believers in other countries, we also want to help build their confidence, responsibility, and independence. One important concept related to these character traits is found in Leviticus 23:22, "And when you reap the harvest of your land, you shall not reap your field right up to its edge, nor shall you gather the gleanings after your harvest. You shall leave them for the poor and for the sojourner: I am the Lord your God." [1] Based on this Scripture, the poor had to walk to a field to gather some of the gleanings, which illustrates that resources should not necessarily be given directly to the poor but the poor need to participate and supply labor and time to obtain the resources. Their participation gives them a sense of ownership and responsibility. Dale Harlan, from the organization Serving in Mission (SIM), and Gonzalo Fiorilo, from the BOL-CAN Foundation, emphasize three related concepts in their water supply ministries as they help those near Cochabamba, Bolivia. They refer to the concepts as self-led, self-financed, and self-propagating in the context of a Christian worldview, recognizing that God is providing for them [4]. With assistance from engineers and missionaries, the participants are expected to learn how to make the wells and hand-operated pumps, provide half of the funds, and supply labor toward the construction. In the process, they build confidence that they can construct a device and learn how to maintain and repair it. The water ministry based on Scriptural principles has resulted in a very successful outreach to help people obtain clean water and build their confidence, but also has developed numerous Godly relationships between engineers, missionaries, and local people.

Using our engineering abilities to serve others, help them learn new skills, and build their confidence are very important. However, the greatest reason for committing time and resources is the Great Commission (Matthew 28:16-20). The Great Commission commands Christians to witness to others near home but also in lands further away. Relationships with others and building bridges to share the Gospel should be a top priority as we engage in various engineering projects. Engineers and missionaries from SIM have been involved in water supply ministry. A hand-operated water pump has been developed by SIM and tested in rural areas in Bolivia. Cedarville University (CU) engineering teams have participated in some of the efforts. The successful trips that CU teams have taken to Bolivia to assist with water ministry and church encouragement have proven that God uses engineering efforts to help build Godly relationships and spread His Word. For example, a 2016 Bolivia engineering team helped install a water pump for a woman named Aurelia. The team decided to buy her a Bible and then many of her friends asked if the team could help them get Bibles. The local missionary has arranged for the team to help purchase approximately 75 Bibles for her friends, family, and other church members. The recipients of the Bibles each pay half of the cost and the team assists with the purchase of the rest. God used an engineering project to open up an opportunity to spread His Word. The proposed projects described later in this paper are intended to provide opportunities to build relationships to help spread God's Word in addition to improving people's lives and meeting basic needs.

Appropriate Technology

Scripture clearly emphasizes that efforts be taken to use our skills and talents to meet the needs of others and help build independence and responsibility. One concept found in the literature that has several Biblical principles is "Appropriate Technology." Although not derived from Scripture, aspects of appropriate technology (AT) are beneficial from a Christian perspective to

assist others with their technological needs. Appropriate technology (AT) is characterized and defined by technologies that are "small-scale, energy efficient, environmentally sound, labor-intensive, and controlled by the local community." [5] Advantages of AT are summarized by Hazeltine and include the following: provides goods, services, and jobs that can't be provided otherwise, benefits a lot of people not just a few, is less disruptive to the social structure, can be adapted to local requirements, fosters self-reliance and responsibility, and encourages cooperation and frugality [5]. Developing these types of technologies have Biblical underpinnings since they help others as God commands, encourage participation by the people due to the small scale, use locally available resources that God has provided, and encourage self-reliance and responsibility as discussed in Leviticus 23.

The aspects of AT that have Biblical parallels will be emphasized in the rest of the paper. AT concepts can help guide ideas for engineering projects that can improve the lives of people in rural or remote areas. If the technology is small-scale and decentralized, then local residents can participate in the development, fabrication, and maintenance of the technologies and devices. If the materials are obtained locally, then the equipment will more likely be affordable to those in-country. The owners can pay for some of the costs and contribute labor to the assembly and maintenance following the principles of Leviticus 23:22. Long term, families could develop small businesses to manufacture and assemble devices or teach others to do the same.

Another objective of AT is to involve more members of an area in the economic activity. Biblically, this could be thought of as doing good to others. One critical aspect of AT is that instead of a large industry controlled by a few people, many people are involved in the productivity of items. Akubue stresses, "It goes without saying that using AT to stimulate productivity and employment in sectors outside the modern sector is such an important objective that it ought to be seen as a national imperative." [6] Evidence shows that getting more of the society involved in more of the production stimulates the economy. Helping more of the people in a country participate in manufacturing and developing beneficial technologies is doing good to others.

A few Biblical reasons for the support of developing AT have been given. If an engineer or missionary helps many people in a society be more productive and helps them develop self-reliance and responsibility, then this encourages more relationships to be developed and opens up the door for the Gospel and Christian discipleship. These are Biblical reasons for considering AT but criteria can also be specified to determine the possible success of a particular technology.

From the perspective of a Christian organization with limited resources, it is important that resources be used prudently. Therefore, the proposed AT projects must be judged using criteria. Some of the possible criteria to judge the appropriateness of technology is given by Wicklein and are listed below [7]:

1. Systems Independence: relates to the ability of a technology to stand alone or does it need supporting facilities, materials, and equipment. If it does need supporting materials and equipment, are they available locally?

2. Image of Modernity: people want to be perceived that they are modern and progressing in their society so the technology has to provide a positive image from the perspective of the local people.
3. Individual vs. Collective Technology: this criterion is related to the culture where the technology will be implemented and the type of culture will determine how well it will be successful.
4. Cost of Technology: a very important consideration and what may seem cheap to us may still be too expensive for another society so it must be determined if the people are willing to pay for the technology.
5. Single-Purpose vs Multi-Purpose Technology: certain technologies may be more successful if they can serve more than one purpose.

This is intended to be a brief overview of criteria to consider for any new technology. The proposed technologies listed later in the paper should be evaluated using criteria such as these depending on the location, materials available, and the culture that will use the technology.

The book by Bunch entitled "Two Ears of Corn" also lists some very relevant questions and some are summarized here. Many of the questions are similar to the criteria already provided [8]. The type of culture, intended application of the technology, cost, and other areas addressed below will also determine the success of the technology.

- Perception: Is the technology recognized as being successful?
- Usefulness/Benefits: Does the technology meet a felt need? Will the technology benefit the user? Does it arouse enthusiasm with the potential users?
- Cost: Is the technology financially advantageous? This was mentioned in the criteria and the local people do not necessarily have to pay for all of a new technology but enough so that they have a sense of ownership and responsibility.
- Uses Local Resources: How does the technology use the resources that are locally available? This topic is related to the systems independence criteria described by Wicklein. A technology is more likely to have success if the users have local supplies to fabricate and repair the technology.
- Culture: Is the technology culturally acceptable? The type of culture being either collective or individual will help determine if the technology will be successful.
- Simplicity: Is the technology simple to understand? Can the technology be communicated efficiently? Does the technology require minimal on-site supervision?
- Education: Is it simple to teach? Missionaries involved in the water ministry of SIM teach the local people how to assemble the concrete rings for the well and PVC pipes for the pumps. The technology is simple enough to teach to make it successful in the culture.
- Number of Applications: Is the technology widely applicable? Just as Wicklein suggested multiple uses, if the technology can apply to multiple uses then that will encourage the success of the technology.

These criteria and questions need to be considered and are important for the success of a technology in a new society or culture. Organizations such as Practical Action, National Center for Appropriate Technology (United States), and Centre for Appropriate Technology (Australia) have many more resources where a Christian engineer could obtain ideas and judge them against

the appropriate criteria. Potential topics should be evaluated in light of the Scriptural topics listed above and also the cultural considerations, cost, and other criteria described.

Christian Engineering University Projects

Engineering teams from Cedarville University (CU) have worked on a number of missions-related projects in Romania, Liberia, and Bolivia. The teams that have traveled to Bolivia during the last three years have focused on clean water ministry supporting SIM and the BOL-CAN Foundation. A hand-operated PVC water pump has been developed by SIM, modified and tested during senior design projects, and tested in the field near Cochabamba, Bolivia. Prior to the involvement in Bolivia, CU took several missionary teams to Liberia. Teams worked with SIM in Liberia on a number of projects related to solar-powered lights, clean water ministry, and well-drilling machines. The projects in Liberia and Bolivia have been guided by Biblical principles and some of the AT concepts.

Other Christian engineering programs have also participated in several integrated engineering and missions projects. As a fellow Christian engineering program, much can be learned from them and a few of the projects are summarized in this section (the list is by no means all-inclusive). Other universities also have efforts in these areas but there is not sufficient room to include them all. In this survey paper, information from three other universities are included: Messiah College, Letourneau University, and Dordt College.

David Vader at Messiah College has established a well-run and financed collaboration center called "The Collaboratory for Strategic Partnerships and Applied Research" that supports a number of missions-related engineering projects [9]. Some of their work is in collaboration with SIM at Burkina Faso, Africa. Various groups in the Collaboratory focus on different technical areas. One group in the Collaboratory Center focuses on communications technology. One research topic related to the internet and telecommunications involves using VSATs for internet connectivity. Increased internet connectivity in a region can improve education and support local businesses. Another group at Messiah College assists disabled persons. They have developed a hand-operated tricycle that can be used by disabled people to travel around the terrain at Burkina Faso. A trike such as this can be maintained by the local people and can help people in their own community. In a letter from the Collaboratory to an SIM missionary, an engineering professor has the following goal in mind for the manufacturing of the wheel chair:

> "Our goal is to develop the manufacturing processes, supply chains, and local fabricators needed to make the 3-wheeled off-road wheel chair that we developed to become widely available. This technology brings new freedom and dignity to people who have previously lived much of their life on the ground. With mobility comes the ability to go to school, hold down a job, and have a family." [10]

In addition, students at Messiah in the Energy Group of the Collaboratory have installed solar electricity systems for clinics, mission stations, and rehabilitation centers in Africa." CU also has experience in this area and there is a possibility for collaboration on these types of solar electricity projects that are feasible for these developing areas.

In addition, water ministry is an important focus at Messiah:

> Clean, abundant water is one of the most pressing needs in the world today. Messiah Engineering students are working to develop and expand many water-related technologies, including well drilling, irrigation, water pumping, water purification, and sustainable agriculture. Several senior design projects have developed key water technologies, such as a low-cost, portable water filtration system, a percussion well drilling rig, and a redesigned hand pump for disabled persons. Work on these projects and more continues within the Water Group of the Collaboratory. [9]

LeTourneau University also has a number of senior design projects related to missions-focused engineering for developing nations and remote areas. The list on their website includes frontier wheelchairs, prosthetics, disaster relief solutions, and water relief solutions in sub-Saharan Africa (will be tested in Senegal in the summer of 2017) [11].

Dordt College is one of the few Christian colleges with degrees in agriculture and engineering, which opens up opportunities in agricultural missions. For example, Dordt College has collaborated with the ECHO organization on a solar power project: "The goal of this project is to design an off-grid solar power generation system for the Educational Concerns for Hunger Organization (ECHO) in North Fort Myers, Florida. The system will generate electricity for an office on the ECHO campus, and it will also be used as a demonstration to educate development workers and missionaries on solar power and its benefits for developing countries." [12] As discussed later in the paper, many opportunities exist at the intersection of engineering and agriculture and collaboration with Dordt College could be very beneficial.

Technologies

With a Biblical background, overview of appropriate technology and leveraging it in a Christian context, and survey of efforts at other Christian engineering colleges, an overview of possible future engineering topics will now be discussed. The emphasis will be on electrical engineering technologies that can help improve people's access to information, agricultural methods, health, and growth in the Word. Increasing cellular coverage and developing smart phone apps will increase education and knowledge of the Word. The following topics are intended to help build people's sense of ownership and responsibility as they participate in the design, development, assembly, and maintenance of devices. The categories of topics considered include electrical power, instrumentation and data logging, telecommunications, remote sensing, radio, agriculture, medical equipment, and security systems. Although emphasis is on appropriate technologies, some of the projects and devices may require assistance from engineers in more developed countries due to the electronics or training required.

Power

For many of the electrical-engineering focused projects that will be discussed, power is a critical factor and is not readily available in remote or rural areas of the U.S. or in developing nations. In many areas, distributed power generation can be the most feasible solution to power various

devices. In many parts of the world, including in Africa and Australia, there is a boom with cell phones but landlines are much less common due to the required infrastructure. The same trend appears to be occurring with off-the-grid power generation with possibilities such as solar, wind, and small hydro-electric plants. If sufficient fuel supplies are available, small generators that run on petroleum-based products such as gas, diesel, natural gas, or propane would also be feasible. For example, natural gas is used in many vehicles in Bolivia due to the abundant supply so small natural-gas powered generators could be feasible. The distributed nature of these solutions minimizes the amount of infrastructure needed. When the U.S. was being settled, the windmill was a very common way to generate mechanical power to obtain water. Leveraging technologies such as the windmill could be very beneficial in certain countries. Any topic related to distributed power generation to make it more efficient or which uses local supplies would be a worthwhile endeavor.

One potential project, suggested by Ray Hutchison of SIM who has spent many years on the mission field in Africa, is to develop solar-powered cell phone chargers [13]. Cell phones are becoming much more popular in areas such as in Africa and South America. There is a strong need for more effective and efficient ways of charging the phones. Based on the solar-powered lights developed and assembled by students at CU, possibly a solar-powered charger could be designed and fabricated for cellular phones. Experience and knowledge gained by Messiah College on their solar projects would also be of value and collaboration on this project is possible.

Other potential projects are small power generation or electrical storage devices for data loggers for instrumented water pumps, agricultural equipment, or medical devices. As technologies are developed to help in these areas, power generation and electrical storage solutions could be designed and assembled by local people. Resident people could be trained to maintain and repair the devices.

Another power generation option with potential is micro hydro-electric power. An excellent survey on this topic and the innovative technologies being considered for rural Africa is given by Kusakana [14]. Micro hydro-electric power is considered a very viable option in Africa and other areas such as Canada that has many rural residents. Designing a micro hydro-power system for a specific area needs to consider the penstock, turbine, generator, and electrical storage options [14]. One creative solution that includes hydro-electric power is hydro-aero power, which includes a windmill, water storage, and power generation as shown in Figure 1. The windmill powers a pump to draw water up to the storage tank where it can be used for drinking water or drains through a pipe to operate an electricity generator. This solution is finding success in Africa since many of the farmers already have a windmill. Various designs

Figure 1: Hydro-Aero Power *[14]*

of the hydro-aero power system could be evaluated for other areas taking into consideration available wind, resources available, and power requirements for a household.

Instrumentation/Data Logging

Small microcontroller-based systems for data logging have been investigated and partially developed for several applications. One system includes instrumentation, analog circuitry, a microcontroller, an SD card, and a Bluetooth module [15]. A version of the system was designed and tested by a CU senior design team to log data for a SonSet Solutions radio transmitter. Similar systems could permit data for a radio transmitter, water pumps, agricultural equipment, or medical devices to be logged and uploaded to a smart phone or the internet. For areas without internet, data can be sent via SMS or satellite connectivity to analysts in another location. Other design details could be leveraged from another data monitoring system that was briefly tested to monitor and analyze AC circuits [16]. Due to the electronics and software programming required, this technology may not completely satisfy the AT principles. However, as local people receive more education and training, this type of technology could be very beneficial to the people. Missionaries and engineers can collaborate with the local people to develop these types of systems to monitor various devices.

Telecommunications

Many areas in the world such as in Australia, Africa, and South America have a telecommunications network available to them but not infrastructure to access the internet. Via cell phones, residents are able to download and listen to Bible podcasts, download educational material, and data concerning their areas (for example, imagery for fields). One 2015 Centre for Appropriate Technology (CAT) report states that the focus of the report is on "a particular area of interest to our constituents, namely the adequacy of cellular mobile services for communities of remote indigenous residents, noting that mobile services are their telecommunications medium of choice." [17]. The CAT organization is developing mobile phone hotspots for parts of Australia that amplify the signal so that users who are more than 10-15 km from the base station still have access to cell phone signals. The mobile phone hotspots developed by CAT use unpowered passive parabolic dish antennas to focus and amplify the received and transmitted signals.

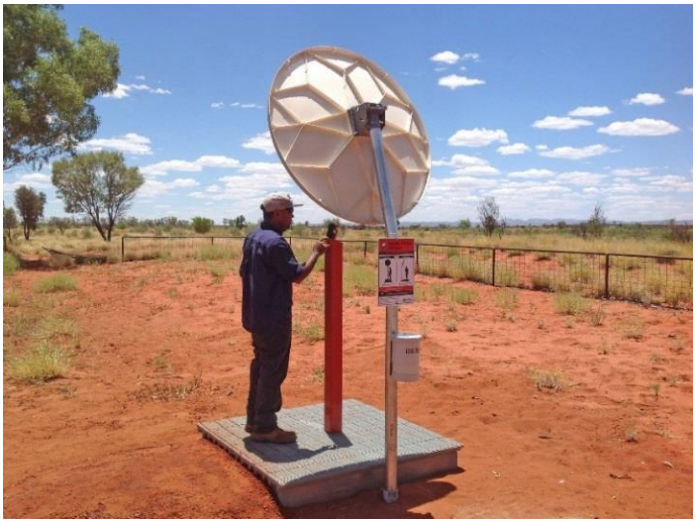

Figure 2: Mobile Phone Hotspot (photo from *[17]*)

The CAT mobile phone hotspot was designed for Australia (see Figure 2) but a potential project could be to investigate types of antennas and hardware configurations that could be used in remote areas of South America and other locations to amplify cell phone signals. In the Vacas area in Bolivia, there can be limited cell phone

coverage. A possible study would be to determine the size and types of antennas that would be appropriate to assist rural communities to be able to have cell phone coverage to receive Biblical educational material and other important information. Possible additional information could be field information such as the health of crops. Any project related to telecommunications that would assist small business operations would be of significant value.

Re-purposed satellite dishes or other pieces of equipment can help improve the coverage of cellular mobile service. Possibly some types of very small aperture terminals (VSATs) could be used for internet connectivity. Local residents could use them for receiving educational material and improving sales channels for small businesses. Depending on the area, it would need to be determined when a VSAT solution would be beneficial over an increase in cell phone coverage.

Remote Sensing

Remote sensing (RS) technology has found hundreds of applications as discussed in the online article by GISGeography [18]. The question then becomes how the technology could be leveraged for the developing world to help them improve access to information and data or improve small operations such as crop production [19]. As telecomm infrastructure increases and access to data becomes more feasible for many areas, then application of RS technologies will become more feasible. Different sensors use different wavelengths (infrared, radar, etc.) and data can be collected and utilized for different purposes.

In the agricultural area, infrared systems, synthetic aperture radar (SAR) systems and other RS systems can be used to detect the health of crops, amount of moisture in the soil, and amount of fertilizer required. As this data becomes more available, appropriate smart phone apps could be developed for farmers. Applications could help compare the trade-off between increases in yield versus the cost. Using remote sensing in agriculture is a component of precision farming:

> "Precision farming is like a hidden goldmine in agricultural production. Savings estimate 10% in fertilizer. On top of that, crop yields are also improved. Precision farming uses different wavelengths of light to see how healthy crops are. Variable amounts of fertilizer are worked out keeping money in farmer's pockets." [18]

The Normalized Difference Vegetation Index (NDVI) is one way to use RS in crop production. In addition, near-infrared radiation can be used to detect healthy vegetation since healthy crops reflect green light and absorb red and blue light and this can be detected in the light and near infrared regions. Therefore, near infrared radiation in combination with NDVI is a primary remote sensing application in agriculture. Developing simple smart phone apps and developing procedures to request the correct data be available in other countries could help with crop production and yield.

One very beneficial use of RS data is to assist local fisherman with the current location of fish. GISGeography states, "There are plenty of fish in the sea *from a satellites viewpoint*. Satellites monitor sea surface temperature and ocean colors because they are indicative of specific fish species. The top-down view of remotely sensed data can be communicated with local fisherman. Fishermen use this information to save time and fuel in real-time." [18] Computer scientists and

engineers can work together with local fisherman and agencies to provide the data and image viewing tools that will benefit the fisherman.

Radio

A foundational Scripture for this paper is Romans 10:14 in which technologies are used to spread God's Word. In some areas such as in South America, short-wave radio is still used to transmit educational material. Inexpensive AM/FM and slightly out-of-band short-wave radios are available and solutions need to be investigated to include attachments or modifications to the radios to allow the small inexpensive radios to receive the appropriate short-wave frequencies. SIM has requested that options be investigated to convert AM/FM radios or modify inexpensive out-of-band short-wave radios [20]. Critical questions for this would be to determine which AM/FM radios are currently available, which ones would allow an add-on to convert the frequency, and the cost of the materials. For an inexpensive solution, the local people would likely be willing to pay for them, which would help more people receive His Word. The local residents could also be trained to make the modifications. A collaboration opportunity could be to work with a South American university that offers an electronics degree to see if their students could help design and build these add-ons or modifications to the radios.

Agriculture

Agriculture is one area that AT could prove to be very beneficial. Several applications of RS and information logging have already been mentioned in the area of agriculture. Efforts such as aquaculture and aquaponics could benefit greatly from a data logging and telecommunications capability. Facilities such as greenhouses to raise vegetables or aquaponics systems in which fish could be raised in addition to vegetables could be monitored with simple instrumentation or data logging systems. If cellular mobile service is available, then data can be transferred to engineers or other people in other locations to help monitor the system. This data could be used to help improve the systems and train the local residents on the critical information to be monitored.

In some areas such as in the Vacas region of Bolivia, the diet of many people are short in protein. Adding meat such as fish would greatly improve their diet. The BOL-CAN Foundation, in Bolivia, is currently collaborating with other organizations to investigate the types of fish that could be raised in Bolivia to help improve the diets of the residents. Fish could potentially be grown in an aquaponics system. A data logger could be used along with a small electrical power system to help monitor the system.

The duration of the life of fruits and vegetables can be improved if they are dehydrated. If the products can be shipped further, then additional markets would be available to the sellers. A number of technologies are available to dehydrate or measure the water content of fruits and vegetables. These technologies may be too expensive for some areas and research projects to analyze which dehydration technologies would be appropriate for different crops or areas could benefit many people.

Topics related to the intersection of engineering, agriculture, and missions have unlimited potential. Any project to help reduce the costs of fertilizer, decrease time planting and harvesting, decrease labor, decrease shipping and storage costs, and improve processes is worth investigating. Greenhouses are becoming more useful and methods to monitor the health of plants and vegetables would be beneficial. Any advances in the data logging and system monitoring capabilities would also contribute to the agricultural area.

Medical Equipment

Developing low-cost technical solutions for medical applications for remote areas is an enormous area of opportunity. A couple of ideas proposed here include developing medical data monitoring capabilities, producing medical supplies, and designing location monitors for disabled people or small children.

Some previously mentioned projects involve collecting, processing and logging signals, and then sending the data through a cell phone to another location to be analyzed. In the medical area, a similar project has resulted in a small tablet to monitor heart information and passing it to cardiologists at a central location as described below:

> Himore Medical in Cameroon has designed CardioPad, a wireless solution that enables the efficient monitoring of cardiovascular diseases (CVDs). While the majority of cardiovascular specialists practice in the capital city of Cameroon, Yaoundé, 80% of the country's population lives in rural areas. The CardioPad, therefore, provides improved access to cardiovascular healthcare for patients living in remote areas. It is a touchscreen tablet smaller than most conventional tablets, making it easier to operate. The device includes a set of four wireless electrodes and a sensor that is attached to the patient's chest; this generates a signal, which is then transmitted via Bluetooth to the tablet. A digitised electrocardiogram (ECG) of the patient's heart function is then taken and transmitted through a mobile network to a second CardioPad device – situated in a city hospital – where a registered cardiologist can make a diagnosis. [21]

The solution developed is designed to monitor cardiological data (see Fig. 3) but other types of medical data could be monitored depending on common medical problems in the area of interest. Medical professionals at centralized locations can analyze the data that is sent from remote locations. Some of the experience gained with other data monitoring and logging solutions could be leveraged to begin looking at these types of medical applications.

Figure 3: Monitoring Cardiological Data with a CardioPad *[22]*

Inexpensive solutions for items used in surgeries or medical procedures would be useful. Technology such as 3-D printing could be used to produce small medical items and supplies. Educating and training local people to produce the medical items appears to be a huge

growth opportunity. Other topics which result in inexpensive replacements would be advantageous such as cheaper LED lights used in place of blue lights that can provide a huge cost savings [22].

Other universities such as Letournea are designing wheelchairs as previously mentioned. One possible idea is to put GPS or other tracking device on the wheelchair or person where safety is a concern so staff members, family, or friends can monitor the location of the person. The location of disabled people or small children at schools or orphanages could be monitored.

Developing effective, inexpensive medical equipment and supplies is a great area of opportunity. Many countries have orphanages with children with various medical conditions that could be helped tremendously with appropriate technologies. God commands us to help the orphans and this is one area that Christian engineers can carry out this command. However, there are challenges using the technologies in new areas such as the availability of appropriate power, spare parts, and consumables [3]. These challenges need to be considered as the technologies are designed, developed, and implemented.

Security

One topic that continued to be mentioned by missionaries interviewed for this project is the security of small technology solutions. Theft can be a common problem even for small electrical devices. Solutions that provide security or alarm signals to the user or owner of the technology would be an important topic.

Summary of Topics

A list of the proposed engineering projects is provided below in Table 1 that could be researched by students and faculty in Christian engineering programs. Other topics in other engineering disciplines such as mechanical, biomedical, and civil could also be investigated.

Table 1: Summary of Proposed Engineering Projects for Developing Countries

Area/Topic	Description
Power	
Solar-powered Cell Phone Charger	Small solar-powered cell phone chargers are needed for people in remote areas in Africa and other areas to listen to educational material, especially Biblical programs. The experience gained designing and assembling solar-powered lights or radios can be leveraged.
Natural Gas Generator	Natural gas and other petroleum-based resources in a nation that has been blessed with these resources can be used for small power generators.
Distributed Power or Energy Storage for Data Loggers	Inexpensive batteries, solar power, or other types of distributed power generation or energy storage are required for data loggers or monitors. A data logging capability could improve the monitoring of equipment such as water pumps, agricultural devices, or medical equipment.
Micro Hydropower	Small hydro-electric power units for distributed power in remote areas could be very beneficial. This topic includes hydro-aero power that combines windmills with hydro-electric power generation.
Instrumentation/Data Logging	
Data Logger for Water Pumps	Instrumentation and a data logger are needed for hand-operated water pumps. A system is needed that can be used to collect data such as the long-term cycles of a pump.

Data Logger for Radio Transmitter	A data logger for radio transmitters is needed to monitor the status and critical parameters of the amplifiers and other components. The initial design and experience of a previous solution for SonSet Solutions could be leveraged.
Data Logger for Agricultural Equipment	A system monitor and data logger are needed for various pieces of agricultural equipment such as greenhouses and aquaponics systems. For aquaponics systems, parameters such as water temperature and pump status could be monitored.
Telecommunications	
Satellite Dishes to Amplify Cell Phone Signals	Since mobile cellular service is highly desired in remote areas, a project to increase cellular phone service by amplifying cell phone signals is worth investigating. Passive components could be used to minimize the power requirements.
VSATs for Internet Connectivity	Very Small Aperture Terminals (VSATs) solutions and system designs could be researched for internet connectivity and data access. For some locations and groups, VSATs may be affordable and can provide the desired services as compared to cellular phone coverage.
Remote Sensing (RS)	
RS Data for Agricultural Applications	RS information such as imagery, infrared, and radar data could be used to determine and improve crop health and yield. The significant research currently being conducted in RS could be leveraged to develop simple apps that use satellite RS data.
Fish Location Data	Develop processing or data tools for RS data on the location of fish to assist fisherman.
Radio	
Convert Inexpensive Radios to Short-Wave	Common inexpensive AF/FM radios or slightly out-of-band short-wave radios need to be converted or modified to receive short-wave frequencies in locations such as South America to receive Biblical educational material. Reportedly, this is possible with some radios but detailed engineering work is required to determine which radios, antennas, and receiver configurations will permit modification.
Agriculture	
Data Logger for Greenhouses and Aquaponics Systems	Parameters such as temperature, humidity, pump status and other parameters in the systems need to be monitored to maximize the yield. As components for greenhouses and aquaponics systems become more available, instrumentation and data logging systems will be useful.
Dehydration Technologies	Low-cost technologies are needed such as infrared and solar devices for dehydrating fruits and vegetables. Fruits and vegetables that have been well dehydrated could be shipped further so more markets are available to the producers.
Medical Equipment	
Data Monitoring, Viewing, and Transmission	Technologies are needed to monitor and view medical data on a phone or tablet and send the data to medical professionals. The intent is to monitor data for patients who are in remote areas so doctors or other medical professionals who are in a central location can analyze the information.
Manufacturing of Medical Supplies	Inexpensive medical supplies are needed in numerous areas and could be manufactured by local residents. Capabilities such as 3-D printing could be used to make inexpensive medical supplies.
Location Monitoring System	A low-cost GPS or other device could be used to help monitor the location of disabled persons or small children. This capability would be beneficial for family members or staff members to monitor the location of small children or orphans who are under their care.
Security Systems	
Security or Alarm System for Equipment	A low-cost security or alarm system is required for many of the electronic devices described above to prevent theft. Developing a security or alarm system was mentioned as a high priority by missionaries who were interviewed.

Conclusions and Recommendations

Based on a Biblical foundation and a brief introduction to appropriate technology, various technologies have been considered after discussions with missionaries and conducting literature searches. Future activities could include interdisciplinary teams and collaboration with other Christian engineering programs. Interdisciplinary teams could be formed to investigate different

technologies involving multiple fields such as engineering, biology (agriculture), chemistry (energy storage), and business (local businesses). Possible collaboration with the nursing school to design and prototype medical supplies or devices is a possibility. Even an interdisciplinary research center could be established if the organization would benefit the researchers and potential receivers of the technologies. The business school or international studies areas could potentially analyze the potential for the technologies to be the foundation of small businesses for local peoples. Investigating the manufacturing capability in an area to get more local people involved could be advantageous to the acceptance of the technology. Additional relationships with missionaries in other countries who are onsite would provide beneficial feedback and suggestions. Connections and networking with people in remote areas, either on the mission field or in the states, could also drive excellent ideas for needs. In addition, possible collaboration opportunities with other Christian universities would be highly encouraged based on overlapping interests as discussed in this paper.

The paper focused on specific technologies, but education and training is very important. For example, SIM in Bolivia educates the people on the fabrication and assembly of the wells and water pumps. This helps the people build confidence. With any of the engineering topics discussed, education and training of the local people should be a high priority.

This survey on missions-related engineering projects with emphasis on appropriate technology will help faculty and students gain insight into possible future undertakings. It is critical for faculty and students to understand the time and effort that they should dedicate toward these types of projects in the future. The engineering teams will be able to make wise decisions about the use of future resources. The most promising efforts will be incorporated into senior design projects or technical electives and will help students understand other cultures as they learn how to apply their skills to help others. The education and experiences gained by the faculty and students will be grounded in Biblical truth such as Matthew 25:35-36 and Romans 10:14.

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