UNIVERSITY OF AGDER

THE LEAP-FROGGING POTENTIAL OF INFORMATION TECHNOLOGY FOR DEVELOPMENT:

THE CASE OF 3D PRINTING IN POHNPEI (FEDERATED STATES OF MICRONESIA)

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This master's thesis is carried out as a part of the education at the University of Agder and is therefore approved as a part of this education. However, this does not imply that the University answers for the methods that are used or the conclusions that are drawn.

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DEFINITION OF TERMS AND ACRONYMS

3DP4D:

Three-dimensional printing for development purposes

3D Printing:

A process for making a physical object from a three-dimensional digital model, typically by laying down many successive, thin layers of a material (Oxford, 2014).

Action Research (AR):

A research method which involves multiple, engaged stakeholders who are dedicated to determining and taking a decisive action, which should change not only the environment, but also have an effect on the researchers themselves, who work without a pretext of impartiality (Diessner, 2000).

DTC&I:

The Federated States of Micronesia Department of Transportation, Communications & Infrastructure.

FSM:

The Federated States of Micronesia

Goldilocks Island States:

Territories that have a lower level of development, an extreme amount of isolation, and a population which is both large enough (>15,000 c.a.) to posses development ambitions and organize their society, yet too small (<200,000 c.a.) to justify the economies of scale which typically allow import items to be sold at a competitive cost arrangement. There are many such states in the Pacific, each with its own unique cultural, historical and economic context. The name is a reference to the story of The Three Bears, by Robert Southey.

ICT4D:

Information & Communications Technology for Development.

Import substitution:

Government strategy that emphasizes replacement of some agricultural or industrial imports to encourage local production for local consumption, rather than producing for export markets. Import substitutes are meant to generate employment, reduce foreign exchange demand, stimulate innovation, and make the country self-reliant in critical areas such as food, defense, and advanced technology (Bruton, 1998)

Leapfrogging:

A conceived way for nations to avoid environmentally harmful stages of development by skipping inferior, less efficient, more expensive or more polluting technologies and industries and move directly to more advanced ones (Goldemberg, 1998).

M-gov:

The extension of government services and delivery of information to citizens via mobile apparatus (Olanrewaju, 2013).

MDG:

Millennium Development Goals.

PAR:

Participatory Action Research is research that involves significant stakeholder contributions, as they stand to benefit directly from its conclusions (Kindon, Pain and Kesby, 2008).

SBOC:

The Federated States of Micronesia's national department of Statistics, Budget and Economic Management, Overseas Development Assistance and Compact Management.

ABSTRACT

This modified, participatory action research study investigates the potential for 3D printing for development (3DP4D) on the remote Pacific island of Pohnpei (The Federated States of Micronesia), specifically in an attempt to visualize opportunities for the technology to affect the state and national trade imbalance. The study examines import statistics and coordinates with government leaders and business managers as stakeholders to eventually generate and recommend a business model to restructure supply chains to the advantage of islanders. Through the study, the research classifies Pohnpei as a "Goldilocks Island State", where demand exists, but in quantities too small to effectively service through traditional resource strategies. The research suggests the recommended 3D printing business model may have applications in other locations where long-distance replacement part sourcing can cause significant economic strains/drains for micro-economies.

The study reviews available 3D printing technologies, identifies the role of *density* in import substitution, and makes suggestions for the technology's promise in Pohnpei for such industries as industrial components, automotive/marine and dental replacements.

The study asserts that certain revolutionary new factors such as bioplastics and recycled materials are sustainable game-changers for remote locations, and recognizes great potential to positively affect the trade imbalance that lies in domestic agricultural policy.

Finally, with 3D printing comes the opportunity to bring limited manufacturing capabilities, which along with utilizing locally available resources, can permit a type

of *insurance buffer* as a hedge against international traders, especially for outer-islands where it has historically been impossible for government to provide a full range of services.

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For Joshua

CHAPTER I: INTRODUCTION

This thesis addresses the leapfrogging potential of Information and Communication Technology for Development (ICT4D). Specifically, it examines how modern 3D printing technology can be utilized through a coordinated model to impact development in one of the most remote parts of the world, the island of Pohnpei in the Federated States of Micronesia (FSM).

The thesis originated from my lifelong interest in Micronesia, combined with my academic study of development, fascination with cutting edge technology and professional background in entrepreneurship.

The form of presentation for this thesis will be first a brief introduction, followed by an exploration of information and communication technology used to advance development goals (ICT4D). After a discussion about the context of my fieldwork site of Pohnpei, I will present a description of the methodology used to conduct the research, before revealing my findings and discussing their implications. Finally, the paper will present its conclusions and make recommendations based upon its research findings. I'll begin with some background to introduce myself and my role in this research.

A. Researcher background

Prior to becoming engaged as a masters student in the development management program at the University of Agder, I led a varied life and had a career in journalism. After completing my degree in journalism from California State University, Chico in 2004, I immediately founded a newspaper on the Hawaiian Island of Molokai; the island is the only Hawaiian island with an ethnic Hawaiian majority composition. I used the weekly newspaper to report local news and events, and became personally

engaged in development discussions and local politics. In late 2007, I moved back to the mainland United States and worked as the assistant to the director of national media for the Dennis Kucinich for President Campaign. By late 2009, I was compelled to understand processes of development in my ancestral homeland of Europe, and was able to use DNA markers to trace my family to nearly every country on the continent. I spent six months touring (Nov, 2009 – May, 2010), visiting 15 countries, and blogging about my observations and meeting long-lost relatives in my ancestral villages. Understanding people from very different cultures contributed to my interest in visions of development and inspired my ambition to work in the field of international development. After another summer directing a national congressional campaign in San Diego, Calif., followed by two more years as a small-town newspaper publisher near Seattle, Wash., I finally moved to Norway to pursue a career in international development. As an American without a visa, in order to stay in Norway and learn the language, I was required to move to arctic Svalbard, where I worked as a taxi driver while awaiting acceptance to the University of Agder Development Management program. The program contributed greatly to my knowledge of relevant global issues in development and social systems. Through fieldwork, the program has also taken me to Turkey, Palestine, Jordan, Dubai, Sri Lanka, Kenya, Tanzania, Zambia, Namibia, Botswana, South Africa and other places to observe development projects and non-profit work. Next I will introduce the relevant setting for this research.

B. New technology, age-old problems

Since the moment when Spanish explorer Alvaro de Saavedra first encountered the tropical, north Pacific islands of Micronesia in the middle of the 16th century, there

has been an attempt to incorporate them into the context of the western world (as I will describe later); the tiny islands are among the most isolated places on the planet (Micronesia.com, 2014). The Federated States of Micronesia's (FSM) four island states make up a country with a combined population of about 115,000 people (slightly larger than Andorra), over a combined land area (including 607 islands) of 702km^2 (just smaller than Singapore), spread over a sea area of 2.6 million km^2 (just smaller than Argentina). As a result of these vast distances between small, sparsely populated islands, infrastructure development has always been limited and a challenging endeavor.

Attempts at economic development have long been hampered by a small work force, a scarcity of resources, and the distance between Micronesians and their relevant commercial markets (Hanlon, 1998). Nearly everything has to be shipped tens of thousands of kilometers (at great temporal, spatial and environmental expense), while the tiny parcels of land and seas have offered few products of any global trade value (coconuts and fishing being the primary exceptions).

However, in the 21st century, as in centuries past, purveyors of modernity are attempting once again to engage new technology and apply it to age-old problems all across the planet, including Micronesia. Among these progressive technologies being applied in the developing world is 3D Printing, which could be effective in this environment if useful applications can be identified and it can be put to use.

The challenge in this nation today is to utilize Information & Communication Technology (ICT), such as 3D printing, which is now reaching cost-efficient maturity (Bilton, 2013), to address these and other development issues in ways that have not been possible in the past. This thesis explores developmental theory surrounding ICT for development (ICT4D), through literature by Heeks, Aker & Mbiti, Miscuraca,

Unwin and Beuermann. In the next chapter, their discussion centers on how ICT can be a contributor to development goals.

In regard to development issues, we include reducing the national trade deficit, while empowering the local economy and simultaneously cleaning up the environment.

Next we shall explore the purpose of the study itself.

1.1: PURPOSE

The purpose of this participatory study was to explore the needs and demands of the FSM context and select and begin the implementation of appropriate 3D printing technology solutions to longstanding logistical development problems. The study used a variety of data sets from official government documents to the personal accounts of government agency directors and business owners. The resulting document is an accounting of the processes, which have led to the formation of a solid business plan that is being pursued by Pohnpeian partners intent on taking impactful action to improve the national situation for succeeding generations.

Throughout the methodological process, it should be observed that the study was begun as an example of a modified *action research* thesis, by which I mean the process of 'investigate, reflect and re-approach' has been attempted in earnest. The study began with the ambition of engaging government agents to take action directly on behalf of their citizens to meet national goals as well as for altruistic reasons based on universal human development rights. However, the approach to achieving these results shifted to a private-sector initiative whereby the citizen benefit would be indirectly achieved as a natural byproduct instead.

The reasons for the shift will be explored in further detail in succeeding chapters.

Finally, another purpose of this document is to provide a detailed accounting of the process through which these conclusions were reached, to aid future studies, in other regions, when determining the appropriateness of applying 3D printing or other ICT4D technologies to address distinct national or local goals in other similar or dissimilar environments.

A. Research questions

The specific research questions I asked to frame the project:

1) REPLACEMENT: What is FSM currently importing that they could use 3D printed manufacturing for instead? What are the benefits of doing so?
2) DEVELOPMENT: What useful *new* services could be provided which weren't possible previously?
3) PROCESS: What is the best way to bring about this action?

These questions were derived from a series of more specific topics of study from the beginning of associated research, investigating the role and interaction of organizations, agencies and industries in this setting. General topics also included public resources and obligations, stakeholder interests and national visions and identities.

Next I will explain the relevance of this study in a wider context.

1.2 IMPORTANCE OF THE STUDY

This study is of vital importance because it seeks to use cutting-edge technology, implementable within the decade, to leapfrog development challenges that have plagued this region of the world since first contact. The study investigates what possibilities are achievable, examines their impact, and asks the question: “If the opportunity does exist, how can it be seized?”

The situation facing The Federated States of Micronesia is wholly unique because the country is dealing not only with a serious logistical problem, but with the impending expiration of US-supported compact funds in the year 2023, after which the country will be faced with an initial budget deficit of USD $40.4 million. It is acknowledged that only increased self-reliance and a reduction in the total value of imported goods can impactfully and permanently reduce the troublesome trade deficit. The use of 3D printing technology may hold this very capacity, in a way never before conceivable. This study was able to determine the potential of this technology to be applied in meaningful ways to impact development specifically for FSM’s capital island of Pohnpei.

Next, I will briefly demonstrate this potential.

A. Demonstration

The information from this study has led directly to a development plan (*Appendix A*) that can provide a more consistent and regular supply of specialty components needed for Pohnpei businesses to serve their clients and customers. It does so by providing more efficient service to all parties involved, at comparable or reduced rates to their customers. Through utilization of the technology, it becomes possible to reduce

overhead while offering more services to citizens of Pohnpei. The findings may also be relevant for those considering providing similar services in other regions, which could also be designated as “Goldilocks island states”.

Next I describe how data was evaluated and which theoretical lens I used in making my assessments.

1.3 EVALUATION OF DATA

The data from literature and statistical research of government and independent sources have been analyzed based on the multiple aspects of possibilities and likelihoods, using the frameworks described by Sein & Harindranath, and Malone.

The study applied the research questions for the purpose of reaching a clear understanding of:

- What is technically possible?
- Who are the stakeholders and what are their interests? (*Appendix D*)
- In what ways can 3D printing impact development goals?

These factors were all weighed in the analysis of the data. Much of this research had never been performed in this context, and will hopefully provide a valuable tool for future development work in FSM and other isolated world regions.

CHAPTER II: INFORMATION & COMMUNICATION TECHNOLOGY FOR DEVELOPMENT (ICT4D)

This participative research study draws upon the literature of ICT4D. It was further informed by an extensive review of literature relevant to 3D printing technology/research, along with FSM's development and economic history with perspectives on the future, within the context of the country's stated national goals. The relatively new field of 3DP4D was reviewed as well. These are divided into relevant sub-headings to aid presentation in a concise and orderly fashion.

We will begin with literature on ICT4D.

2.1 LITERATURE ON APPLICATION OF ICT IN DEVELOPING COUNTRIES (ICT4D)

There is an extensive existing literature on the application of ICT in the context of developing countries. For example, governments are inspired by the m-gov benefits of improved management of supply chains, and facilitating the delivery of financial, agricultural, health and educational services (Aker and Mbiti, 2010, p.8). M-gov is likely to produce new business and organizational models, including partnerships, and faster online application forms to revise how government processes information (Misuraca, p.419). Improved database management, reductions in travel and resource costs, and cutting through administrative barriers will allow government departments to keep up with citizen pressure to do more, faster, while government messaging reaches a wider audience at reduced communication costs (Beuermann et al., 2012).

Regulatory and human resource capacity issues have been traditional blockages to achieving some desired efficiency outcomes (Aker and Mbiti, 2010, p.29).

Expanding educational options via technology could alleviate some of these

blockages.

Heeks names the act of "diversifying into new activities" as a new "livelihood strategy", which includes employment in the mobile sector, or using mobiles to complete "micro-work" tasks (Heeks, March 2012). Such livelihood strategies are further enhanced by the capabilities of 3D printing, which have been expanded upon through this research.

Heeks has entered a moral argument that developed countries should put a major priority on ICT expansion to the developing world because it is the "right thing to do," and because the problems of the poor today become the problems of the rich tomorrow (Heeks, 2008). Heeks said that not addressing the inequality gap could result in widening and further exclusion of those currently suffering (Heeks, 2009). He defined the dimensions of exclusion as social, political and psychological, while making a social justice argument for intervention (Heeks, 2009).

Unwin defined post-developmentalism as the exploring of "alternate models of development," saying that ICTs are concerned with the *ways* in which individuals and societies experience space and time (Unwin, 2009). These perceptions commonly change with the growth of communication technology.

Meanwhile, Sein and Harindranath noted that scholars are calling for more theorizing about ICT implementation (Sein and Harindranath, 2004, p.16). They describe an ensemble view of ICT implementation where success depends on whether the chosen technology "fits" the context in which they are implemented (Sein and Harindranath, 2004, p.19). Along with Ahmad & Harindranath, Sein describes four necessary conditions for sustainability of such initiatives: the positioning of the project for finance flow, the application of appropriate content,

the need for a local catalyst, and the view of ICT within the project (Sein et al., 2008). In this same article, they define five types of relevant sustainability: economic, social, technological, institutional and environmental (Sein et al., 2008, p.4). Sein and Harindranath (2004) also describe three central types of developmental impacts that derive from the way ICT is used and the way it is viewed during an application.

- The *first* or *primary* impact is that the new technology is used to *replace* the older technology.
- In the *secondary* impact, the technology is used more frequently and there is a quantitative increase.
- In the *tertiary* impact, the ICT is used to bring new innovations that did not previously exist in the research setting.

Malone (2012) gives a more comprehensive description of the key success factors for a particular ICT4D intervention. He says successful interventions must: be available at low cost, users must be aware of them, they must be accessible, user friendly, and have a clear and incentivized strategy, among other recommendations (Malone, 2012, p.18). Malone also suggests researching other forms of revenue to support ICT4D projects (Malone, 2012, p.21).

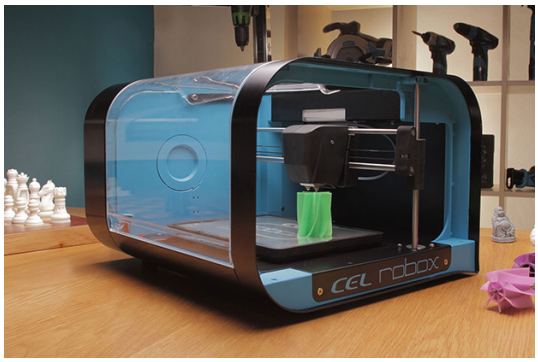
Next I will discuss the specific innovations associated with 3D printing technology.

2.2 LITERATURE REGARDING THE KNOWN CAPABILITIES OF ICT AND 3D PRINTING

Holding perhaps more potential than extending Internet & m-gov to main and outer islands are the possibilities generated through use of 3D printing, which can create functional three-dimensional objects from digital models, to create special-purpose products.

Oxford dictionary defines 3D printing (also known as additive manufacturing) as "A process for making a physical object from a three-dimensional digital model, typically by laying down many successive, thin layers of a material" (Oxford, 2014).

Image 1: Typical Desktop 3D printer



The possibility of 3D printing to eliminate the need for mechanical components or other proprietary machinery to be shipped on special order from across the planet (Goodler, 2014) could remove some of the most severe disadvantages associated with market isolation.

According to the literature, 3D printing is being utilized by a growing list of developing countries, including China, India, Brazil, Sudan, South Africa and even Haiti (Cheng, 2014; Akl, 2013) for a variety of practical and specific purposes. Uses discovered thus far include manufacturing medical equipment (such as umbilical clamps for hospitals), replacing amputated limbs (Chivers,

2014), water pumps, piping and microscopes (The Guardian, 2014). Brazil has considered sourcing water test measures via 3D printing, which could save that large country an estimated $19 million annually (The Guardian, 2014). Other "game changing" applications on the horizon include eyeglasses (Gwamuri, et al., 2014) and agriculture tools (3d4AgDev.org, 2015).

Hobbyists in the United States have used 3D printing to build boats from recycled materials, while functioning toilets and other, currently inconceivable developments in applications, speed and quality are coming in the near future (The Economist, 2012). With refinement and further experimentation, such examples could be duplicated and put to practical use in other world regions.

The governments of developing countries could accelerate the arrival of benefits through the creation of committees to study the possibilities of communal 3D printing centers (Birtchnell & Hoyle, 2014), possibly funded through The World Bank. Environmentally, the process has been described as a "two'fer" as, in many cases, moldable plastic base material is already available locally through both biologically-based products (Bliss, 2013) and the recycling of existing supplies of spent plastic (The Economist, 2012), including derelict ocean plastic washing ashore everyday in FSM. It is thus possible to preserve natural resources and eliminate garbage simultaneously, whilst sparing the energy loss associated with long-distance shipping. Amplifying the impact, Pacific Island Nations are often suffering from lack of landfill space (Pariatamby& Tanaka, 2014), and recycling old junk to fill contemporaneous needs also helps in this way.

The literature regarding 3D printing development came mostly from journal articles, recently published magazines, attending conferences and direct contact with experts in the field as new applications for this cutting edge technology are being reported

every month. A routine and ongoing search continued throughout the study life, attempting to keep up with the most current research available, and determining its relative merits.

Other literature sources pertaining to action research and ICT4D theory were examined in preparation for this research.

Next I will specifically discuss the potential of 3DP4D.

2.3 POTENTIAL FOR 3D PRINTING TECHNOLOGY FOR DEVELOPMENT

A. Economic & Environmental Savings

In a comparison study to determine the global sustainability aspect of 3D printing published in the journal *Energy Policy* in November of 2014 (Gebler, et.al), it was described that, through anticipated levels of technology adoption globally and the reduction of required materials trafficking, a range of 130.5-525.5 megatons of Co^2 should be saved internationally via 3D printing by 2025. This was determined through a quantitative process that derived a formula to calculate the changes in costs/energy and how that translated into emissions. Through this same calculus, their model demonstrated how 3D Printing could reduce global expenditures by USD $170-593 million. The explanation for such a broad variance came from the weight of projections in adoption contained in the study.

Of the four industries used to calculate these averages: aerospace, medical components, automotive and tooling, the latter three of these are relevant and proved to mirror my independent research findings identified on Pohnpei. The study concludes that 3D Printing “offers development opportunities for remote areas with low economic profiles as it bridges the gap to the next market and it supplies these

areas with objects needed to improve the quality of life." The Gebler study also concludes that "spare parts" are another relevant industry for the developing world, where poor access to replacement components can generate significant problems. Another effect on developing markets cited in the *Energy Policy* piece and the thesis from which it was adapted is that 3D Printing technology is expected to shift much global manufacturing back to consumer markets, reducing manufacturing employment in underdeveloped regions as the supply chains are shortened. This will free up the labor market in those countries, which currently provides most of the related manufacturing. This will force a reorganization of the labor markets, with this low wage employment going away.

B. Emancipatory

Another set of studies was carried out by Birtchnell & Hoyle (2014) on the potential emancipatory and empowering effects of 3D Printing for development (3DP4D). Examining projects spanning the developing world tackling hunger, creating solar lamps from soda bottles, building waste recyclers, prostheses, renewable energy systems, custom footwear and farming tools (Birtchnell & Hoyle, 2014, p.16), they demonstrate the potential of the technology to upend established systems of distribution, including power distribution (Birtchnell & Hoyle, 2014, p.13), and carry their impact all the way to the MDGs (Birtchnell & Hoyle, 2014, p.16). Calling it a "Swiss Army knife" for development problems (Birtchnell & Hoyle, 2014, p.15), they determine that 3D Printing has the potential to "irrevocably alter the roles of producers and consumers" (2014, p.49). Though they admit there are remaining questions involving international politics, intellectual property, supply chains and infrastructure (Birtchnell & Hoyle, 2014, p.13), they anticipate more than 1 million

total 3D Printing units sold annually by 2017, based on current growth projections (Birtchnell & Hoyle, 2014, p.14), which include models such as the accessible, community-based 3D Printer model (Birtchnell & Hoyle, 2014, p.81).

In summary, the topic of applying 3D printing in Micronesia is, in itself, new ground in the dimension of development. Though no direct comparison exists, we can summarize the following points from an analysis of Micronesian development history, application of ICT in developing countries, and the state of modern 3D printing technology.

- 3D printing can shorten the time and expense required for delivery of end products
- 3D printing can permit local people the possibility to create their own products and manufacture them to a limited scale
- 3D printed manufacturing can reduce the amount of energy and the environmental impact required to deliver finished products to consumers, with the potential to reorganize the financial situation through economic restructuring

Next I will discuss the knowledge we need before we can address the research questions.

2.4 KNOWLEDGE WE NEED

To answer the research questions, this study has generated appropriate and useful new knowledge about the best approaches for the future, and ways that technology can be applied for dramatic problem-solving purposes:

- What are the unique elements to consider from the Pohnpei setting?
- What products are 3D printers capable of producing that are currently being imported into Pohnpei?
- What types of 3D printing applications are most useful and contain the highest development “return” on remote Pacific islands?
- What is the best “model” for delivering these services?

In the following chapter, I will begin to explore this knowledge.

CHAPTER III: CASE STUDY: POHNPEI (FSM)

To bring understanding to the Pohnpei situation, I will present an overview of the Pohnpei environment. Following this, I explore the historical background of Micronesia and discuss its economic development context, before describing the modern technology action plan the country of FSM is now putting into practice.

3.1 AN OVERVIEW OF THE POHNPEI SITUATION

Pohnpei is the mountainous capital island of FSM, which contains almost exactly 50% of the country's dry land area (FSMGov, 2015).

The trouble in Pohnpei today relates directly to the modern "way of doing things," which have come about as a result of both historical trends and a unique heritage of specific development decisions made over the past 100 years by local and foreign power agents. Chief among these operational issues is an over-reliance on international imports for both food and non-food purposes. These issues will be explored in this thesis.

In 2014, the government of FSM operated an annual trade deficit of approximately $197 million, a figure which alone equaled 59% of the total GDP, including annual imports of $271 million, equal to 81.9% of the country's nominal GDP (Kushnirs, 2014). To compensate for some of this gap, the United States has been providing assistance in the form of annual grants to FSM since it achieved independence in 1986, providing approximately $69 million in annual aid (2014), which will continue to decrease until the current pact expires in 2023 (CFA, 2006).

Because of geographic isolation, addressing the development concerns has been a constant challenge for those seeking to bring part of the modern world to these most distant shores of the planet Earth. This includes meeting the Millennium Development

Goals (MDGs), which commit FSM to achieving the same benchmarks as every other nation in the world, despite the unique challenges presented by the island context. By 2010, the country was 75% off track toward achievement of the eight international goals, with one measure (maternal mortality) actually appearing to worsen over the preceding decade (PIFS, 2010). However, through the course of this research, some light was shed on the reasons behind the maternal mortality issue, which is characterized unfairly in this tiny sample.

Next I will explain where the literature on FSM was sourced.

A. Locating relevant literature

Because few have reported research on technology in FSM and Pacific Island Nations, the most relevant literature was found as primary statistics, or through direct contact with institutions in that region, including various government agencies, colleges and development organizations, including the authors of the 2012 ICT plan. This literature was augmented with first-person interviews involving government leaders and business owners.

To establish a context for this developmental data, I will first discuss the historical background of the country.

3.2 HISTORICAL BACKGROUND FOR FSM

The development history of Micronesia includes an era of possession by, successively, the Spanish (1500s-1899), German (1899-1922), Japanese (1922-1947) and American empires (1947-1979) (USDOS, 2015). Each empire left their mark on the culture and economy of Micronesia with attempts to utilize native resources for their own purposes. The Spanish left a strong Catholic heritage on many islands, and

built some early infrastructure (Hezel, 2003). Germany used the island state of Yap's strategic far eastern location as a telegraphy base for its powerful navy (Bruton, 2014). The Japanese occupied the islands and industriously used their fertile soil and other resources to create a prosperous export economy, while simultaneously developing air defense systems and taking advantage of the safe harbor of Chuuk's lagoon (Oliver, 1989).

Following the Second World War, the United States took over the role of administering a trusteeship in the Pacific, including both the states of FSM (then called the Caroline Islands) and the Marshall Islands to their southeast.

Throughout the years of trusteeship, the United States pursued a variety of policies aimed at raising the standard of living in the island territories by setting education, health and economic goals with various degrees of success. The primary support, however, has come in the form of USD $3.6 billion in "compact funds" dispersed to the FSM government through two agreements spanning from 1986-2023 (USDOI, 2005).

This dependence on international funding for government operations has created a unique environment in FSM, where government actors simultaneously speculate about solutions to the impending budget gap, while trying to escape this fate entirely through a renewed agreement (SNLC, 2015). The funding gap is currently projected at USD $40.4 million (Chuuk, 2014) after the year 2023 between the amount of money received in the final year from the compact agreement and the amount of interest earned through the trust fund, from which FSM will begin to receive interest in that year. The funding compact has been reduced each year annually, which has caused departments to annually reduce their budgets across the board (Santos, personal communication, March 15, 2015) – including health and education – to

compensate. One knock-on effect is higher prices for goods and services, while simultaneously stagnating wages to employees; minimum hourly wage on Pohnpei is $1.75 (NOK 13.8kr, at May 2015 exchange rates).

This historical background provides perspective as we next discuss specific examples of development in FSM.

3.3 LITERATURE ON HISTORY OF DEVELOPMENT IN THE FEDERATED STATES OF MICRONESIA

A thorough review of Micronesia's development history is required to assure that the mistakes of the past have been considered, as well as the context of their failure.

The recorded history of attempted development in FSM dwells mostly on the American possession of the islands as a "trust territory" in the post WWII world, spanning approximately 40 years, from 1947 to 1986 (Worldstatesmen, 2014). The lessons from this period are spelled out in several articles, most notably Hanlon's work in "Remaking Micronesia" (1998). Reflective descriptions of recent development attempts and associated obstacles were described by economist Francis Hezel of the Micronesian Seminar (MicSem); Hezel frequently wrote on history and economics. These writings provide the relevant context and historical backdrop for the type of ICT4D that is being considered as part of this study.

The ICT market in FSM today is extremely limited, despite a current attempt to diversify, as specified by the national ICT plan. The country's population of about 115,000 people share 702km^2 of land area (607 islands), distributed over 2.6 million km^2 of the western Pacific Ocean (CIA, 2014). As a result, infrastructure development has been limited and has remained a considerable obstacle. The most recent figures available point to just more than 8,700 telephone landlines

(ICDE.org, 2008) reaching 7.8 percent of citizens, and 35,000 mobile devices, reaching 31 percent of the population (FSM ICT & TP, 2012, p.7), with an internet use rate of approximately 15 percent (ICDE.org, 2008).

The nation's new ICT and telecommunications policy was written in 2012, when there were only about 100 broadband subscribers in the entire country, all of them on the island of Pohnpei (FSM ICT & TP, 2012, p.7). Broadband access is planned for 3 of the 4 states via a submarine cable, connecting to FSM via Guam, before it continues on to the Marshall Islands. The fourth state, Yap, is negotiating a connection to Guam, where the cable would then pass on to the Republic of Palau (SubmarineNetworks, 2014). The high-speed connection to the most populous state of Chuuk is expected within 18 months of the writing of this thesis (Johnnyboy, personal communication, March 26, 2015).

In attempts to modernize their governing systems, FSM created a national ICT and telecommunications policy in 2012, and the top objective under the goal of "utilizing ICT for good governance" was to "Develop an e-government system" (FSM ICT & TP, 2012, p.19). The process has now begun to conduct feasibility studies, outline strategies for implementation, and procure the necessary technologies to leapfrog directly from web 1.0 to mobile government (m-gov), and modernize telecom legislation at the same time. 3D printing offers one more element in the quest to leapfrog technology.

The legislation contained in this collaborative plan includes both site-specific and "cookie-cutter" reforms authored in part by The World Bank, which mimic those found around the globe. For instance, commitments are given to information transparency policies (FSM ICT & TP, 2012, p.4), which do not fully represent historical actualities on the ground in FSM (Hezel, 2006). Reforms include steps

to modernize land tenure laws to increase foreign investment, end the public monopoly of the telecommunications sector, as well as deregulating the market through the creation of the new independent office of a regulation authority supported by service fees (FSM ICT & TP, 2012, p.22).

FSM also plans to support the creation of a central portal for information and public service applications for all government ministries and agencies (FSM ICT & TP, 2012, p.21). The plan specifically advocates the development of disaster readiness, telemedicine programs, the creation of an m-money system, and mandates the release of public information through ICT channels.

One cultural challenge that some believe (Hezel, 2006) has held back development in Micronesia would be the existing traditions of land tenure and related cultural/property traditions. Today property rights are exceedingly hard to separate from private citizens (Hezel, 2006). The ICT & Telecom plan commits to settling some of these issues in the name of progress. While future reforms may address intellectual property rights (IP), FSM's lack of agreement to such legislation permits citizens to download and appropriate 3D printing designs, as well as other electronic goods, without a requirement to provide compensation; this free content can be an advantage if utilized by citizens or businesses.

ICT can also help address endangered elements of Micronesian culture, and the ICT & Telecom Plan stipulates that the technology will be used to create a cultural record to preserve Micronesian languages and oral histories, songs and crafts for future generations, including online translation capabilities for traditional languages (FSM ICT & TP, 2012, p.19).

Currently, the physical barriers of great sea distances present the largest challenges for m-gov development. In 2010, a high-speed submarine fiber-optic

cable connected Pohnpei to Guam, permitting broadband Internet for the first time in FSM. However, bringing last-mile service to the people is another matter altogether to be resolved. Securing a reliable energy supply to power these information networks is a related issue that must also be addressed.

Finally, in the final section of this chapter I will make a surface assessment about the relationship between the ICT4D literature and the Micronesian context.

3.4 PURPOSE: COOPERATION CREATES PLAN, ACTION & REALITY

In light of the context of budgetary hardships of Micronesia and the development of this technology, I began to consider ways in which the country could potentially benefit from the application of 3D printing. The thinking went from hypothesis to a detailed study around all relevant topics before engaging local actors and beginning to devise an approach to generate consequential action.

FSM have crafted a national plan to expand broadband connectivity (FSM ICT & TP, 2012, p.7), and subsequently the possibilities created by high-speed Internet access have expanded through global development of 3D printing technology.

In the past decade, new applications of 3D printing have given birth to creative modernization approaches that utilize technology, which might strongly diminish The FSM's previously unyielding competitive obstacle of remoteness. 3D printing machines, which also have the ability to replicate themselves, are *already* making accessible to the developing world technologies as diverse as remotely "printed out" medical/scientific tools, such as microscopes, water test measures and even prosthetic appendages (Chivers, 2014). In a significant industry development, in late October of 2014, billon-dollar technology/printing giant Hewlett-Packard (HP) announced a breakthrough, with the most sophisticated, fast and versatile, high-volume 3D printing

device yet (Heller, 2014), adding further legitimacy to the viability of 3D printing with an investment from one of the world's leading technology companies.

Through utilization, the FSM's government's transport costs can be reduced. Goodler points out that 3D printing "reduces the need for delivery" to isolated geographic areas, as only raw materials need to be supplied to feed the printer (Goodler, 2014) – some of which can be sourced through locally recycled and biologically-sourced materials, including sand as a source for glass products, and agriculture products which can be used to develop plastics. The price of some commercially-available 3D printing devices has already dropped to less than $400 USD, with further price reductions expected periodically (Bilton, 2013).

CHAPTER IV: METHODOLOGY

I begin this chapter by explaining the theoretical approach that grounded this research from the initial stages. Following this, I explain how this approach was applied through each distinct stage of the study. After this chronological description, I explain in greater detail the types of materials that were selected for the research, the stakeholder participation, before concluding with an analysis portion.

4.1 ACTION RESEARCH

Participatory research models have existed since before Lewin defined action research (AR) as a spiral of steps of planning, action and fact-finding (Lewin, 1946). The research method involves multiple engaged stakeholders who are dedicated to determining and taking decisive action. Ultimately this action should change not only the environment, but also have an effect on the researchers themselves, who work without a pretext of impartiality. Torbert describes "moment-to-moment theorizing" as common, with data collecting and inquiry occurring "in the midst of emergent structure" (Torbert, 2002). This agrees with Lyotard's description of the artist and writer "working *without* rules to formulate the rules of what will have been done" (Lyotard, 1979). Baskerville et al. (2004) described as John Dewey's five-element pattern of all forms of human inquiry: indeterminate situation, problem formulation, determination of a solution, reasoning, and operationalization of relevant facts (Baskerville et al., 2004).

Following the recommended procedures, this project first designed, then developed and enhanced with education and training, before obtaining political and identifying financial support structures to implement its decisions (Braa et al., 2004, p.347).

Provisions for sustainability are a chiefly-touted staple of successful action research work (Reason, 2006).

Like trying to describe a box dimensionally, without trying to lift it, Brydon-Miller describes as the fundamental idea that the social world "can only be understood by trying to change it," calling action researchers, "doers" (2006, p.13).

Faure (2010) describes AR methodology as that balance between the will to change and the pursuit of research objectives. While aiming to resolve a problem and generate knowledge, in PAR the goal is a collaborative work between researchers and stakeholders with an ethical framework shared by those stakeholders (Faure, 2010).

Bradbury and Reason emphasize that a broad range of researcher choices and how they are explained defines action research as a method (in Maiter et al., 2008). McNiff & Whitehead agree, explaining that every piece along the way should be saved as "data-evidence" to tell the story of how the research took place (McNiff & Whitehead, 2010, p.231).

Pedler & Burgoyne refer to Revans' 3-step approach to conducting action research, with the alpha (surveying existing), beta (planning action) and gamma (surveying results and *learning*) all specified (Pedler & Burgoyne, 2008).

Finally, Khan makes a solid argument for action research in the developing world. "In countries like Pakistan…would it not be a luxury to do research that is *not* action research? Is it a luxury a researcher or a research institution can afford? And if so, then at what social cost?" (Khan, 2013, p.157). Indeed, with FSM's approaching national funding gap after 2023, there is little time to spare for the country to begin addressing their trade imbalance – only just enough time to take action.

These descriptions found in AR literature describe the process attempted through the conduct of this study, as I demonstrate in section 4.2.

4.2 PROCEDURES

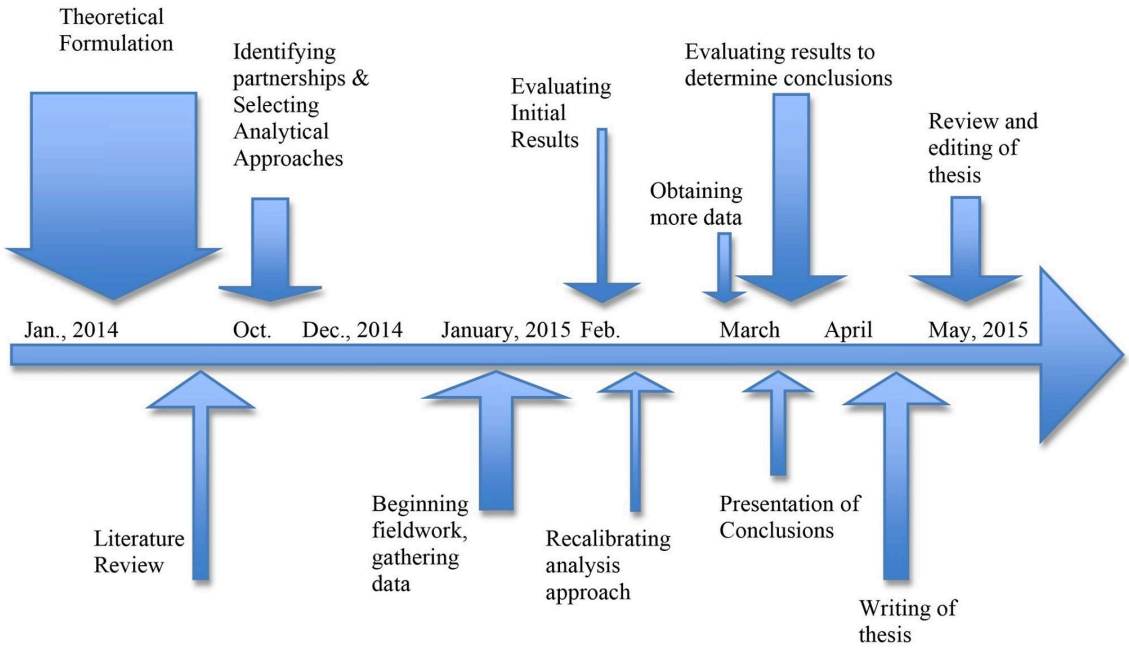
This study began as a concept in January of 2014, during the coursework portion of the University of Agder's Masters in Development Management program. Through the process of reading related literature, I read an article that mentioned the transformative power of 3D printing to produce prosthetic limbs in Africa (many such articles exist now). As I read this, I also became informed of plans underway to bring 3D printing technology to the International Space Station – because the cost and energy of transporting extraterrestrial items constitute a significant burden.

The consideration of a method for building customized items for people far away from traditional manufacturing machinery inspired me to consider alternative degrees of remoteness, which brought my thinking to the isolated and underdeveloped islands of Micronesia, which lies among the most isolated inhabited regions of the world.

I had always had an interest in the islands, dating back to my high school obsession with South Pacific maps on my bedroom walls, featuring destinations that few of my peers had even heard of.

This phase of the research could be called the "theoretical formulation," which marked the beginning of this process; the general phases, as I've identified them, are described next.

Image 2: Research timeline



A. Theoretical formulation (January 2014 – June 2014)

I became aware of the idea of a technology that can produce complex items thousands of miles away from where the ideas may originate. I saw the theoretical potential to at least partially combat the obstacle of "remoteness" which had left the people of Micronesia behind the rest of the developing world; this was what I sought to investigate and address.

Through relevant coursework relating to ICT4D, I developed my theories regarding methods outsiders could use in appropriating technology to help bring development in economically depressed countries throughout the world. Some specific examples are referred to in the literature portion of this study.

B. Literature review (August 2014 – October 2014)

The literature review was conducted to provide as much background knowledge as possible on existing conditions and the heritage of those conditions. Because no studies had been conducted on 3D printing technology in Micronesia, instead the

literature analysis hoped to bridge the knowledge gap by learning about Micronesian development as well as 3D printing technology and the application of 3DP4D in other places where it had been attempted. Once informed by the literature, I began to seek out research partnerships.

C. Identifying partnership opportunities (October 2014 – December 2014)

1. FSM Development bank

While I was performing research in advance of the fieldwork, I contacted executives at the FSM Development Bank (FSMDB). The development bank's mission as stated is to promote "the growth of micro, small and medium enterprises in The Federates States of Micronesia and support programs designed to help business(es) achieve greater efficiency in their operations."

When I couldn't find the appropriate address to email, I called their office during business hours on April 10, 2014 and was transferred to the extension of VP Ignacio Stephen. Ignacio had heard of 3D printing and was fascinated at the concept of it being employed on the island. His email to me from the same day said he would be "interested in joining as a partner" to my research. At that point, it seemed the best way they could assist with my research was to sponsor a grant application for funding through the US Department of the Interior's Office of Insular Affairs (USDOI), which offers a popular funding option for many purposes in Micronesia. The FSMDB happily sponsored my application, although no response ever came of either acceptance or denial via the US DOI. However, the development bank remained an active, vital and reliably involved partner throughout the life of the study.

2. Department of Transportation, Communication and Infrastructure (DTC&I)

Perhaps the most relevant, revealing and inspiring document of source material in the writing of the research proposal was FSM's National ICT & Telecommunications Policy, written in 2012 by the FSM Department of Transportation, Communications & Infrastructure (DTC&I). This document indicated that the country had become forward thinking, and was taking action to lay the groundwork for a more technically proficient national future; the document was the most frequently referenced piece in my research proposal. Accordingly, I reached out to the authors within the department, and found enthusiastic support from Joldan J. Johnnyboy, the consultant who had actually led the authorship of the document. Joldan immediately saw the benefits of 3D printing technology, but was skeptical about the functionality of the current government to provide the necessary support to see such a plan through. His skepticism was based not on the functionality of the technology, but strictly related to the political will of government to follow through. In any case, he pledged to provide as much necessary assistance as he was capable of, through his official capacity.

3. Johnny Hadley, Jr. & Family

In mid November, 2014, Saori Imaizumi, a technology writer from The World Bank blog, connected with me on LinkedIn and suggested that I consider following a model of workshop construction known as a "Fab Lab" (Fabrication Laboratory), which had seen success in many developing countries. In these cases, the labs had been initiated by local residents of their respective countries and used by the community on special creative projects. The labs are commonly equipped with 3D printing devices as well as cutting tools and other useful shop features.

I considered this a possibility, since they seemed to have a proven formula. However, I eventually decided that, because I was an outsider, and because the Fab Lab model required an extensive financing process, and because a small fabrications laboratory would not make the more profound footprint this intervention was aiming at on a national trade level, it would not meet the mission of the specific intended research. Still, while researching the Fab Lab model, I made contact with the lab located closest to FSM geographically, in New Zealand. When I contacted Wendy Neale, the lab's director, about setting up a lab in Pohnpei, one of the first questions she asked me was whether I was working with "the other gentleman who had contacted her about setting up a lab for Pohnpei" This was a revelation to me, as I had not been aware of any other interest in a 3D printing operation on Pohnpei. I excitedly requested that Wendy provide the contact information of the person whom she had spoken with, and she shared that.

A Pohnpeian man in his 30s named Johnny "June" Hadley, Jr. had contacted her, and he quickly agreed to partner with me because of our common mission. June and I discussed the idea of bringing 3D printing to Pohnpei via email and telephone before meeting in Honolulu in mid January. At our meeting, I learned more about June's background in government, and his connections to current and former government ministers, which I hoped to leverage to forward our cause.

After arriving on Pohnpei, June's main contribution to the research was providing a place for me to stay with his family while I conducted my study throughout the duration of the fieldwork.

As my partnerships and fieldwork were arranged, I selected my analytical approach.

D. Selecting Analytical Approaches (October – December, 2014)

For this research study, which had been originally conceived of as AR, a mixed-methods approach was called for out of the necessity of accumulating many different data sets and comparing them with reality in the field. It wasn't enough to simply interview respondents without gathering import data to compare the accounts of the experts with the facts. Though I could not predict the turns that the research would take, from the beginning I expected there would be a study of official documents, surveys and interviews along with some level of direct observation.

Once the approaches were selected and I took to the field, I was able to begin gathering data.

E. Beginning fieldwork, gathering data (January, 2015)

My initial approach to engaging the islanders with the concept of 3D printing was, after meeting with the initial partners at FSMDB and DTC&I, to speak to government ministers interested in promoting economic development. My operating assumption was that the development capabilities and benefits of 3D printing should speak for themselves. I believed that government leaders, once informed about the potential, would support the idea of bringing 3D printing to Pohnpei.

When I arrived at the offices of DTC&I, there was a significant annual conference going on, which I was encouraged to attend. The conference, called the State & National Leadership Conference (SNLC), immediately changed my perspective on the best way to effectively bring 3D printing technology to FSM. The conference was held at the College of Micronesia's main auditorium and was open to the public. Leaders from both state and national government as well as most national agencies publicly debated national challenges, especially with regard to the approaching 2023

deadline after which compact monies coming from the United States would cease. Pessimistic projections leading to an estimated gap in general funding of USD $40.4 million following the final year of the compact were shown (SLNC, 2015). To counter the funding gap, the leading proposal offered by SBOC was to increase tourism revenue by USD $100 million annually (over 2003 figures). This led me to a careful evaluation of the data in front of me.

F. Evaluating initial results (February, 2015)

The proposal SBOC presented on tourism expansion was nearly identical to the proposal endorsed back in 2003, at the beginning of the second US-FSM compact agreement. In the 12 years since that time, actual tourism had fallen by nearly 6% (SNLC, 2015), a situation punctuated by the closing of the Village Inn, which had been considered the most renowned hotel on the island. It did not appear anyone at the conference took the outlook for tourism expansion as a serious suggestion for replacing compact funding, especially when a discount, round-trip plane ticket from Hawaii cost USD $1,746 (NOK 13.800kr).

The rest of the conference was essentially spent bickering about petty state vs. state and state vs. national government issues, contributing to my assessment that government does not function effectively in FSM, and that seemingly minor issues had become impassible due to bitter power struggles (a point which was made even clearer as a state ballot measure for succession was added to the national election during the course of my field work).

It was after observing this scene that I decided, for the 3D printing proposal to move forward in a reasonable time frame, in spite of potential need for the services it may

provide, the action must be led from the private sector and must sustain itself through a profit model. With this in mind, I began recalibrating my approach.

G. Recalibrating analysis approach (February, 2015)

Leaning on my professional experience as a businessman and entrepreneur, I have historically demonstrated success at finding profit angles. While the successes of 3D printing with plastic materials are notable, studies from the literature often demonstrate theoretical models of usefulness over actual value (Gilpin, 2014). That is to say there are often considerations about the quality and usefulness of many 3D printed items made out of plastic.

To *profitably* apply 3D printing in Micronesia as a private sector concept, it was necessary to consider it for the priority task of *import substitution*, which is primarily concerned with transferring value of imported products back into the domestic economy. To achieve this, I needed to obtain more data on imports.

Table 1: Pohnpei Sourced Data

Pohnpei Import Data 2014	Appendix C
Import Surveys	Table 5
Local Resource Investigations	Appendix F
List of Importers	Aux data
Other FSM State Import Data	Aux data
Evaluation of Oceanic Nation Imports	Appendix H
Eco-Miracle Micronesia Business Plan	Appendix A

H. Obtaining more data (March, 2015)

To do this, it was necessary to acquire and evaluate the quantity and variety of imported products coming into Pohnpei. After inquiring from knowledgeable sources, I discovered the best way to get import data was through the customs and tax authority (CTA) of FSM. The CTA was agreeable to provide itemized customs data

(*Appendix C*), as well as lists of registered importers for the island state. The import data provided included more than 1600 listed categories of imported item types. Digesting the information took several days before patterns and conclusions began to emerge (*Appendix E*), which I eventually labeled as "Best chance interventions", "Probable", and "Later down the line", and "Needs more information."

I followed these patterns, identifying categories of products and sought to uncover higher-resolution data about the results. When I returned to ask the department leaders who had provided the data, they told me that no higher-resolution data existed beyond that which had been submitted by importers themselves. It became clear that the only way to obtain more information on the listed imports was to contact the registered importers and survey them directly.

I created a simple import survey, and distributed it to 27 of the most significant commercial/industrial importers of apparent relevancy (*Table 5*). Each case led to important conversations and interviews with business owners, revealing their demands in volume and type, and learning which items created the most significant problems in the cases of an interruption of production or supply.

I also conducted an extensive survey of locally available agricultural products and forestry, botanical, livestock and soil resources (*Appendix F)*.

During the fieldwork phase, data were collected initially through distance communication about technology and then through office visits with local development experts and national/state agencies in FSM. Citizen groups, government and private sector experts were consulted about the implications and applications for the new technology, during fieldwork carried out on the main island of Pohnpei, where national offices are located.

Much of the data was sourced from government offices, as the public sector makes up 40 percent of the national economy (Hezel, 2006). The most relevant partnering agency for co-research efforts has been the Department of Transportation, Communications and Infrastructure (DTC&I), although valuable data came from the department of statistics (SBOC), as well as the department of resource and development (R&D).

The country is currently in the process of collecting and devising action plans related to their 2012 national ICT plan.

In-person meetings were carried out during the fieldwork portion, over the months of January-April, 2015, on the capital island of Pohnpei.

Once the data were collected, I began to analyze it to determine the emerging patterns.

I. Evaluating results to determine conclusions (March - April, 2015)

This qualitative survey data led to a refining of the imports list, helping to identify which items constituted the most relevant focus of 3D printed manufacturing on Pohnpei.

After using these discussions to identify the imports that were most in demand, with my group of trusted 3D printing advisors, I was able to determine which of them could be replicated, with mature 3D printing technology, to bring about the desired import substitution.

Finally, after identifying the required technologies to meet the market needs, an innovative business model was devised to cater to the needs of islanders while operating at a profit and financed through established capital avenues. After we were confident in our results, I set a time to present my findings in public.

J. Presentation of conclusions (March, 2015)

This new business model is thoroughly explained through the Eco-Miracle Micronesia business plan document, which is presented as *Appendix A*, included with this thesis. This document was distributed, along with the display of a 46-slide PowerPoint presentation (*Appendix B*) at two public community meetings, which were held at the Pohnpei State Hospital's Administrative Conference Room in Kolonia on Sunday, March 22 (4p.m.) & Monday, March 23 (6p.m.). The meetings were advertised in the local newspaper, *The Kaselehlie Press*, prior to the event, although there was a delay in distribution of the paper until the day of the second meeting. In this edition, there was a feature story about the 3D printing project in general and myself, noting the upcoming event. The meetings were attended by a total of six persons, including some whom I had not met previously. The meetings were also advertised on public bulletin boards throughout the town. They featured PowerPoint presentations that introduced and explained 3D printing and the potential it is thought to have to address development concerns, followed by a discussion. The attendees expressed enthusiasm about the idea of using 3D printing on Pohnpei, however some were unsure if it would be possible to bring the technology reliably to such a remote part of the world.

Following these meetings, an additional forum was scheduled for Thursday, March 26 (11a.m.) in the capital region of Palikir at a building housing FSM's national archives. This meeting received only emailed promotion and two days' notice, but was still attended by 3 leaders of the national DTC&I agency and a public legal advocate. Following this presentation and the following discussions, I began formalizing the study and its findings into a thesis paper.

K. Writing of thesis (April – May, 2015)

Thesis writing took place following the fieldwork, which concluded April 10, with my return to the United States. The formal writing began initially in Carlsbad, California, and was completed in a single-family home in Bend, Oregon during the month of May, 2015. Once a draft was completed, it was sent out for peer review.

L. Peer & supervisor review of thesis (May, 2015)

Peer review took place electronically, as the document was emailed to trusted cohorts and action research professionals, as well as Pohnpeians with knowledge of the project and technology academics, and friends inside the academic community. Feedback was received and addressed over the month of May, strengthening the critical analysis and validity segments. Specific points of revision included a shift away from the action research elements, moving more closely toward ICT4D theory, as well as the addition of new chapters and the re-organization of short sections.
For the sake of painting a digestible outline of research events, section 4.2 has been generalized for the purposes of story flow. I will now explore a number of facets in greater detail.

4.3 MATERIALS

I used data materials obtained from both official government sources, such as customs and tax registries, as well as reference books published by the University of Hawaii Press, and the verbal accounts of informed parties in the technological communities and local development and business experts. My own import surveys also contributed as critical research materials.

In general, these materials – even electronic documents – were received via personal office visits while on the islands, during which the elements were transferred into my possession via a electronic memory stick device. Although some follow-up documentations were emailed, email is not the primary method of official communication in Pohnpei, and even among many business owners, it is seen more as an augmentation or luxury than a "primary method of conducting business".

Electronic materials were transferred onto my Apple MacBook Air, where they were sorted and examined. After my MacBook Air was unnaturally removed from my possession, the data, most of which had been backed up, was transferred onto other devices until I came into possession of another personal Apple computer. Subsequently, nearly all materials that had been present on my original MacBook Air were transported onto the replacement MacBook for the remainder of the study.

Another asset that allowed me to gather all of this information and meet with the individuals who provided it was a small, 125cc Honda motorcycle, which I purchased after arriving on the island. This was an invaluable tool for transportation on an island that had no scheduled bus service, and taxicabs were exceedingly unreliable for meeting scheduled appointments.

A survey of imports was utilized to determine the types of products that were being imported by Pohnpei-based businesses. This survey asked businesses that were importing greater than USD $10,000 annually in materials to itemize those things they paid the most to import.

An additional "material" which was used to create understanding of the concept of 3D printing and generate feedback on its application on Pohnpei was the demonstration of 3D printing viewable on a You Tube clip called "Amazing 3D printer", published Sept. 9, 2011 by Syed Abrar featuring a segment from the National Geographic

channel; I used this clip to educate more than 20 individuals about the process I was seeking to bring to the island. Of these individuals, some of them became involved as stakeholder partners.

4.4 STAKEHOLDER PARTNERSHIPS & PARTICIPATION

A) Phases

Each phase of the study has required relationships with relevant research partners (*Appendix D*). The first stage required relationships with the scientific and technological communities – locating and consulting with journal authors who were informed about and reported on the newest capabilities and latest applications for 3D printing around the world. Communication with online technology communities and constant research and information marketplace surveillance kept the study informed about innovations through daily web alerts and academic journal subscriptions.

The second and third stages required more localized partnerships. The second phase consisted of an evaluation of how these technologies could be effectively brought to FSM and deployed in this context. This required partnerships with development, government, and private sector organizations in FSM.

A leadership group of active participant stakeholders was identified and exchanged regular communication during the fieldwork portion of this research, which has continued post research.

Engaged stakeholders have included local citizen groups, government agencies, economists, entrepreneurs, politicians, retailers and members of the environmental, university, non-profit, and health sectors. International involvement has included 3D

printing technologists and plastics experts, as well as development experts and international financiers.

As for agency stakeholders, prior to the fieldwork portion of the study, FSM Development Bank sponsored the research, and submitted a grant funding application with the US Department of the Interior's Office of Insular Affairs. Communication was established with the FSM Department of Transportation, Communication and Infrastructure (DTC&I), FSM office of Statistics (SBOC), the US Department of the Interior's technical assistance program, the Pacific Islands Private Sector Organization (PIPSO), College of Micronesia, the Micronesian Chambers of Commerce, and economic specialists who have written extensively about Micronesia. All of these contributed to preparation prior to fieldwork (*Appendix D*). While everyone on the island could be said to hold some small stake in the project outcomes, a wide list of participants ensuring a diversity of opinions was taken into account.

B) Participation

Ultimately, the 71 stakeholders involved represented all conceivable directly interested parties to the research. These include government branches concerned with economic development and resources (Department of Resource & Development), as well as international trade (Foreign Affairs), infrastructure & technology (DTC&I), statistics (Statistics, Budget and Economic Management, Overseas Development Assistance and Compact Management) and administration (FSM President & Pohnpei Governor's Office). Essential cooperation was also received by smaller state and national government branches such as the FSM Office of Emergency Management, the Pohnpei Transportation Authority, the Customs and Tax Administration (CTA) and the Public Utilities Commission (PUC).

Equally important in the accumulation of data was the feedback from local business owners, large and small. The business owners ranged from every conceivable industry having a dependency on a supply of imported products. On Pohnpei, this includes most businesses.

Nearly all government sources, and most business owners interviewed were native Pohnpeians. Key exceptions include administrator David Hawkins of the Program Management Unit of the FSM government, as well as business owners Larry, Rich and Denise Adams who own three significant import/retail businesses in the primary city of Kolonia. All of these persons held US Citizenship, but had lived on Pohnpei for more than a decade.

Each contributing stakeholder was interviewed at their own office or place of business.

Appendix G contains an accounting of all institutions met with either in person or coordinated with electronically throughout the research. After the data was accumulated, a thorough analysis was organized, utilizing the theoretical lenses distilled from the literature analysis.

4.6 ANALYSIS

The data were organized chronologically through the dedicated employment of a research journal, which cataloged every step along the AR journey.

Using Revans' circular approach to conducting action research, the methodology has been arranged to exhibit the alpha (examining the current imports), beta (identifying the capabilities of 3D printing), and gamma (to create a sustainable plan to use mature technology to meet the needs of government and business in Pohnpei), as specified by Pedler & Burgoyne (2008).

The data obtained from the research were, as described in Revans' approach, immediately analyzed inductively and fed back into the research loop for the purposes of constant re-assessment of the approach, which naturally changed as qualitative or quantitative data suggested new directions.

Quantitative data also resulted in new directions, as the substance of the imports led to conclusions about whether or not there was enough existing product demand to justify investments of a particular machinery type. A general formula (Table 2) was created to determine the worthiness of equipment investments based upon the value of the product being imported and its total demand against the cost of producing that type of item via 3D printing. This statistical analysis, in addition to interviews, contributed significantly to the conclusions the study was able to reach.

Table 2: General quantitative formula to evaluate the value of 3D printing interventions

Intervention worthwhile **if**	***X<Y*** **[The savings (F) and Import quantity (G) must be factored in to determine the total annual savings (H), along with the cost of the required hardware (G)]**
X=	Cost of producing an item via 3D printing
Y=	Cost of supplying item via import
X=	A (Cost of delivered, raw materials) + B (Cost of operational expenses, including labor, electricity, maintenance, shop rent and various overhead)
Y=	C (Cost of item) + D (Cost of transport) + E (Cost of **delay**, sometimes difficult to assess)

Below (Table 3) demonstrates how the previously described research events align with Revans' stages of action research.

Table 3: Action Research Stages (As defined by Revans)

Step 1: Alpha	A. Theoretical formulation (January – June, 2014) B. Literature Review (August – October, 2014)
Step 2: Beta	C. Identifying partnership opportunities (October – December, 2014) D. Selecting analytical approaches (October – December, 2014) E. Beginning fieldwork, gathering data (January, 2015)
Step 3: Gamma	F. Evaluating Initial Results (February, 2015) G. Recalibrating Analysis Approach (February, 2015)
Step 4: Alpha (2)	H. Obtaining More Data (March, 2015)
Step 5: Beta (2)	I. Evaluating Results to determine conclusions (March – April, 2015)

Step 6: Gamma (2)	J. Presentation of conclusions (March, 2015) K. Writing of thesis (April – May, 2015) L. Peer review of thesis & edits (May, 2015)

CHAPTER V: FINDINGS

I begin this chapter by revisiting the research questions and applying them to explain the research findings. Each question is analyzed individually, covering replacement potential, new service application, and the best approaches to achieve these. The chapter ends with a summary of the greater findings.

5.1 ADDRESSING THE RESEARCH QUESTIONS

Throughout the research phase, the questions, as presented in chapter I, remained:

1) REPLACEMENT: What is FSM currently importing that they could use 3D printed manufacturing for instead? – What are the benefits of replacing them?
2) DEVELOPMENT: What useful *new* services could be provided which weren't possible previously?
3) PROCESS: What is the best way to bring about this action?

5.2 REPLACEMENT POTENTIAL

There are multiple aspects to answering this question of "What imports could be replaced by 3D printing?" Advanced 3D printing technologies exist and have been utilized across the planet. As with many development projects, the difficulty is finding a way to impactfully appropriate technologies in distinct environments where there may be additional benefits possible. This replacement potential can be seen as Sein and Harindranath's *first-order* impact (Sein & Harindranath, 2004), as locally

3D printed objects may be used to replace the direct importing that has become the standard method of acquisition on Pohnpei.

Through this research I was able to identify 3D printing technologies that could bring limited manufacturing capabilities to Micronesia. This manufacturing would utilize plastics, metals, and other substances, to meet customized product quantity demands.

A. Industrial Parts

Through the import data for Pohnpei, we discovered a series of product categories which 3D printing has been proven to be capable of producing (*Appendix F)*, including various metal components, which on Pohnpei held a fiscal value of more than USD $2,547,000 in the 2014 calendar year (*Appendix C*).

Parts and machinery of this type can frequently be produced through a metal 3D printing process (Naiju, et. al, 2011) known as *direct metal laser sintering* (DMLS). The process utilizes a laser, which fuses powdered metal into solid objects (Shellabear, 2004), which require no additional tooling; DMLS is used in a broad range of applications, including replacement parts and aerospace components. Furthermore, the technology exists to replicate 3D models from existing parts, even modifying the digital mesh to correct imperfections, before producing functional cloned replacement parts.

The DMLS process can take several hours to complete a print, however, many items can be printed at the same time. Still, the time comparison is notable, because when comparing sourcing via DMLS/3DP (proposed) versus traditional manufacturing (developed countries), there is something of a false dichotomy.

While traditional manufacturing might produce one unit in 30 seconds (compared to a 3-hour 3D print), the traditionally manufactured item is then shipped to Pohnpei, a

process that can take 4 weeks or longer (vs. same day delivery). It is the low quantity demand of Pohnpei that makes it possible to fill small product orders efficiently via 3D printing.

1) Demonstration

The most emblematic example I came across in my research involved the island's largest construction company, known as VCS Construction & Pohnpei White Sand. In conversations with CEO Jose San Nicholas, he expressed frustration about the constant need to source replacement equipment. At the time of my visit, his main excavator, which was positioned on the coral reefs to break up coral heads to be ground into white sand, was out of commission. A broken steel bearing had made the machine unusable, and it was sitting and waiting for the replacement to arrive. The steel bearing which broke was approximately USD $100 in value. The required shipping time for this part would be about 4 weeks, while it arrived from Korea. Though the part itself cost only USD $100, Jose said that being unable to use his excavator for the month was costing him approximately USD $2,000 in lost business. Parts such as Jose's steel bearing are easy to replicate with DMLS printers.

Jose explained that he spent between USD $10,000 and USD $15,000 per month on replacement parts, and the idea of having access to a 3D printing machine that allowed him to keep his equipment running would be a major business enhancement. Expanding on this line of thought, it isn't hard to imagine that on any given month there are at least 25 (conservative estimate) industrial/business interests on Pohnpei that are experiencing some kind of breakdown resulting in an inability to utilize their assets. In Jose's case, he estimated a USD $2,000 loss in revenue, but a more conservative average estimate might be USD $200 lost per affected business per

month. If, on any given month, 20 businesses are losing an average of USD $200 each, there is an average of USD $5,000/month in lost economic activity on Pohnpei, equaling USD $60,000 annually.

B. Dental

Another example of an important industry that can be bolstered through the use of 3D printing technology is orthodontics and dentistry. On Pohnpei, the relatively small dental community is surprisingly active. Likely due to the cultural habit of chewing the addictive betel nut and avid drinking of the kava beverage known as "Sakau", through my inquiry I was able to determine an approximate 150 combined crowns, bridges and dentures are required each month on Pohnpei. The high demand of these customized specialty pieces has translated into a combined USD $291,509 for dental appliances and cements (Pohnpei import data, 2014). Machines now exist which are capable of utilizing digital scans to produce more accurate tooth models and create appliances that perfectly match a patients' mouth (Rogers, 2012). These machines, sold by companies such as industry leader Stratasys, can reduce the amount of time a patient must wait to receive new teeth by as much as one month – which can be a long time to go without teeth in any case. Switching to digital/3D printed dental products allows small dental practices to eliminate the need to furnish a laboratory, maintain old mouth models or stock dental cements. The simplification may even allow practices to reduce the staffing required for laboratory work.

Currently, some dentists on Pohnpei are sending their models to the Philippines, while others are using the West Coast of the United States, and, in at least one case (Dr. Wynn), even making the trip themselves to personally carry the cargo. All of this might be unnecessary, given the availability of dental 3D printing technology.

C. Automotive

A significant situation in need of address in FSM relates to the automotive industry. Road infrastructure is severely underfunded (annual vehicle registration fees are less than USD $10, as observed during my research), and road maintenance is extremely inadequate. Add to this the fact that the vast majority of vehicles are imported used and sometimes in disrepair from Asian markets with replacement parts often hard to acquire, and one can understand the prevalence of "dead" cars along the belt highway that encircles the island. As many as 300 non-functional vehicles (observation) may be found on Pohnpei, an island with an approximate population of 34,000 (SBOC, 2010). According to import statistics, in 2014, more than USD $250,000 was spent on imported automotive parts, included in an unspecified share of the USD $3+ million in industrial metal printable parts and components. Despite this high value of imported auto parts, it doesn't scratch the surface of the total appetite for replacement auto parts on Pohnpei – which helps explain why so many of them are no longer operable. The problem is deeper than that, because auto parts stores on Pohnpei are forced to choose between three unfavorable options to serve their customers.

Auto parts stores on Pohnpei must choose one of the following:

1) Carry overstocked inventory in anticipation that one of their customers will be needing a random part (e.g., the alternator for a 1998 Toyota)
2) Ask their customers to pay an outrageous price to have the part shipped to them via air freight
3) Ask their customers to wait for a month or more while the part is shipped via cargo boat from a major port.

In the third situation, it can be especially difficult for customers who must maintain a regular job to get to work while their car is non-functional. This complex situation has contributed to retard development in Pohnpei and other isolated micro-markets of the world.

Three-dimensional printing can contribute to address and solve this issue with a new and enterprising approach (Stratasys, 2015). A high-resolution scan of a compromised automotive part can create a computer model. A powerful software program such as Cloud Compare can edit the digital image (.stl file) to repair the flaws in the existing component. Finally, a DMLS 3D printer can fuse metal (aluminum, stainless steel, inconel or others) to create a new, flawless replacement part to repair the vehicle. All of these tasks can be completed in less than a day, costing only the price of the actual metal consumed and the costs of supplying the required electricity.

Addressing auto parts via 3D printing allows auto parts stores to stock only inventory they know they can sell, thereby reducing their large stockrooms full of unsold parts (Sharma, 2014).

Use of this technology can be expected to also reduce the number of missed workdays due to employees being unable to commute to their jobs from other parts of the island. Not only does the 3D printing of auto parts improve the financial health of the auto parts stores, but it reduces the dependency on international shipping patterns to satisfy product demands; this speeds up product delivery for customers while often reducing the overall cost of repair significantly and simplifies product sourcing.

D. Plastic specialty items

More than $1.3 million in combined plastic items was imported into Pohnpei in the past year (Pohnpei import statistics, 2014), including plastic bottles, tubes, pipes, tableware, office supplies etc. Using traditional milling and lathing, molds can duplicate the desired items and plastic can be injection molded via plastic 3D printers to manufacture many of these items on island (Noble, Walczak & Dornfeld, 2014). Though not always as dramatic as repairing failing automobiles, the ability to manufacture and produce items on demand is something that has not been previously available on Pohnpei and clearly has uses beyond those imagined thus far.

1) Demonstration

One specific example relates to the application of 3D printing in the production of furniture. Plastic furniture is becoming a more popular item to design or replicate using 3D printers (Dehue, 2012). And though USD $430,000 was imported in Pohnpei furniture categories in 2014, that doesn't tell the full story. With relatively low employment and low wages, the prohibitive cost of importing furniture has created a situation where many households simply opt to keep with their historic and Japanese imperial traditions, forgoing furniture in their homes altogether. My host family kept this tradition and commonly sat, ate, and slept on the floor. When I needed to purchase furniture to complete my research, I did so, and they were excited to have the furniture when I left – yet never would they have bought it on their own. I took this as observed evidence that, if furniture was available at a more accessible price, more households would choose to have it. Three-dimensional printed plastic furniture could make this possible.

2) Density

One reason furniture is particularly expensive is because it is typically not very dense. One of the findings of the research was that density is a main factor when considering what import products make good candidates for 3D printing. Because everything has to be shipped, those items which take up large amounts of space (volume) on container ships, yet don't contain much actual material (mass) are often the ones which receive the most mark-up at the retail end. Because of this, I was frequently petitioned by survey respondents to 3D print waste bins and large diameter PVC pipes.

Other suggested plastic 3D-printed items to replace imports include parts used routinely by FSM Telecom when outfitting a home for telecommunications services. Several thousands of the small, plastic devices are used in a year, and could be replicated easily with a CNC milling to create an injection mold.

Finally, in many parts of the world, 3D printers have been used to build prostheses. In most cases the limbs are required because the people are living in war zones or near mine fields. However, in Pohnpei, people are suffering from a high rate of diabetes, which frequently requires limb amputations; data were not available on the annual number of amputees. While 3D printing shows adequate potential for replacement as described here, in the next section I will discuss applications to bring new services to the island.

5.3 NEW SERVICES

As Sein & Harindranath described their *tertiary* or *third-order* impacts of ICT for development (Sein & Harindranath, 2004), 3D printing can be used to produce new items that have not been regular imports to Pohnpei for one reason or another. A variety of contextual explanations such as price, logistical complication or the state of

existing ICT have managed to restrain the Pohnpei environment from having full access to many goods and services. Some of the following are conceivable innovations, suggested by stakeholders, made possible through the application of 3D printing ICT. We shall begin with the role of recycling.

A. Recycling

A reshuffling of resources and their origins could result in a more sustainable arrangement. A full exploration of recyclable materials and implementation of a recycling program would reduce the pressure on landfill space, and utilize plastic bottle materials currently being discarded. An organization known as *The Plastics Bank* is engaged with assisting locales throughout the world in addressing similar resource issues, and has expressed interest in piloting a project on Pohnpei. A survey of waste material (Jaware, 2013) on Pohnpei gave a picture of the resources available for recycling (*Table 4*).

Table 4: Pohnpei Waste/Recycling

Average Waste Per Day (kg/day) (Jaware, 2013)	3,457.4
Waste Per Capita (g/day)	399
Waste Per Day (liters/day)	62,233
Estimated recyclable mass (kg/day) (Indiana.edu, 2015)	2,593

B. Bioplastics

The land in Pohnpei in particular is incredibly fertile, largely due to its organic composition (Deenik, 2011). These soils are capable of growing a great variety of agricultural products, including many, such as sugar beets, that are currently being explored for their potential as plastic filament (Bliss, 2013). If manufacturing can be

done utilizing a locally renewable resource such as sugar beets or an endemic alternative, the potential for 3D printing's impact in Pohnpei expands even further. Bioplastics could result in a reduction of import volume and value through continued development of printing materials derived from organic matter. There are native agricultural products on Pohnpei, such as cassava and yam, which might potentially be utilized in a similar way if studies prove their potential, and possibilities are being investigated by the University of Hawaii's agricultural programs (Trifonovitch, 2014). Utilization of something like breadfruit trees as a renewable source of latex (NTBG, 2015) could greatly enhance the ability of 3D printing as a manufacturing option to reduce the country's dependency on imports.

C. Medical equipment

Another conceivable application for this technology can be the repair of medical equipment. Edgar Santos, the director of administration at Pohnpei state hospital shared his frustration with the fact that he has had to throw out medical equipment that becomes non-functional, with no practical avenue to repair it. With an ever-shrinking budget due to the ending of the US compact agreement, he is unable to order new parts (if he can even identify the cause of the malfunction). By scanning, digitalizing, repairing and replicating the old parts, it may be possible to bring useful medical equipment back to life. This could contribute to reduce or reverse the trend of declining medical capabilities on the island.

D. Economic development

Outcomes from the private sector model, determined by the availability of assets, could include the addition of many benefits that Pohnpei is currently lacking. There is a need for several services, based upon observation, and the process of bringing a successful 3D printing business via the private sector improves/strengthens the overall economic situation on Pohnpei.

3D printing can contribute to infrastructure enhancements through being a substitute for actual delivery of traditionally-manufactured goods to isolated areas (including outer islands). While Pohnpei Governor Ehsa informed me that FSM's constitution declares states to have the same obligations for service provision on outer islands as they do on main islands, the hither-to inescapable fact has remained that this has been impossible to execute on the smaller and more remote islands of Pingelap (pop. 250), Kapingamarangi (pop. 500), and Sapwuahfik (pop. 430), and Nukuoro (pop. 370). However, 3D printers can operate to build simple and complex items on demand and on location. Without a requirement for extensive technical proficiency training, people living on remote islands can "order up" one of literally thousands of computer designs and print them as needed. Though the best method is to pre-load computers with designs, satellite internet can permit the downloading of designs for unanticipated purposes of all kinds, and eventually islanders will be creating their own. With pre-stocked plastics inventories, the machine would be prepared to serve a broad variety of build purposes. The machines could be housed in a general store and all-in-one units take up little more space than a desktop paper printer when not in use. The machines require a total investment of less than USD $7,000 (such as the Makerbot Z18) to provide a utility of services that address a variety of uses. Objects required for purposes from education and household to personal items like

replacement eyeglasses (Gwamuri, et al., 2014) and even eye-disease checkup tools (Biggs, 2015) and life-saving medical equipment can be produced with relatively simple 3D printers. These same qualities can be utilized on main islands too, though they are seen as especially useful on islands that currently receive such irregular supply service (as few as three shipments or less per year).

Finally, if citizens of FSM develop a proficiency in 3D printing and distribute their own creations via an online marketplace, they may stand to collect royalties from product downloads all over the world. This may constitute an alternative form of revenue from a modern livelihood strategy in the country.

E. Marine services

3D printing opens the door for the local ocean services company to offer near immediate services to fishing boats and other vessels that come into dock in need of repairs. Currently many ships have to remain in dock for several weeks while replacement parts are being ordered and carried by trans-oceanic vessels. The ability to repair marine engines, pumps and other components can bring an invaluable service to Pohnpei, which has not been possible before.

F. Agriculture

One of the outstanding findings from the import study was that USD $26 million was spent in the past year on food-related imports. With such a fertile island and a population of only 34,000 persons, this is an alarming figure. However, 3D printing is being increasingly used for the production of farming tools (3d4AgDev.org, 2015), such as the 3D for Agriculture Development program kick-started by the Bill & Melinda Gates Foundation in 2013. Other examples include the movement to spread

3D printed hydroponic systems to expand agricultural efficiency into homes (Milkert, 2015). The potential exists that 3D printed agricultural tools could assist with a future shift to more domestic agriculture, aimed at reducing food imports. Now that we've discussed both the targets for replacement and innovation, let's discuss the avenues for achieving them.

5.4 OUTCOMES: GETTING THERE FROM HERE

The third research question addresses the necessary processes for creating a bridge between the present and the future. Given the context of FSM today, using existing institutions and creating those necessary for the purposes of successfully bringing about this development, the following findings were made regarding bringing about the development described in the first research question.

A. Business model

To see the type of economic advancement stakeholders are striving for, the new 3D printing business primarily needs to succeed and profit. The potential for ICT4D to contribute to economic development has been demonstrated, in cases such as the Nepali Wireless Networking Project, where the technology has contributed to an increase in export products (via market access) and efficiency upgrades (Sein, Thapa & Sæbø, 2012).

The enterprising business model that came out of the stakeholder meetings on Pohnpei is designed to reduce the total value of imports, returning that value back to the island. Though consumer prices may go down in some cases, the identified model is to simply find ways to replace the supply of imported items with ones produced on

island, of the same quality, with a steadier supply chain and reduced inventory expense (i.e. zero inventory theory) for similar cost. All 27 surveyed businesses stated that they would be interested in purchasing products of the described quality, availability and cost. The economic benefit to Pohnpeians would be realized by having the business succeed and profit its shareholders, who are, by a majority, citizens of FSM. This profit would enrich the local economy both through expanded employment and the effect of a large portion of the preserved economic expenditure circulating in the local economy. It is considered an advantage that most Pohnpei importers are regular business operations, which import their own merchandise – rather than import-centered businesses, counting on that specific revenue for their profit. For most Pohnpei businesses, importing is the default way of acquiring merchandise. Therefore, part of the business plan is to sell at wholesale rates to businesses, and allow them to retain the majority of the retailing. It is not the ambition of this business to replace established businesses on the island. For similar reasons, it was important to secure local financing for the business. Although it may be possible to finance it with American-based investment funds, there is no economic development benefit to the island economy if imports are reduced and the money saved is exported back to the United States.

B. Physical/Technological

To fulfill the vision of using 3D printing technology, a system needed to be devised which performs the specified printing tasks that stakeholders had identified (*Table 5*) as most heavily imported/in demand. The most useful service they had determined, by far, was for DMLS metal parts for specialty industrial purposes. However, existing large print-area DMLS machines currently cost upwards of $1.5 million, require a

regular supply of metallurgical gasses, a hefty deposit and have waiting lists of 12 months or longer according to industry leader EOS solutions. Therefore, the only practical way to create a DMLS machine for Pohnpei meant finding a startup engineering project that was developing alternate solutions. Through a deep Internet search, I was able to locate a young engineer named Ivaylo Guenkov, who had posted about his successes on the Facebook page of a non-profit organization called "Metalbot" on 25 January, 2014. I looked up his contact information and the two of us connected. Guenkov, a 20-year-old engineering student had been part of a team that created the first working DMLS printer for less than $100,000 in 2014. Immediately the two of us began extensive online conversations about the special needs of the Pohnpei environment, and addressing how we could make a machine that would work efficiently in this climate. Apart from the construction accommodations for the machine in Illinois and having to be shipped halfway across the planet, two of the largest issues are with electrical power stability and access to metallurgical gasses. Because of frequent power outages and the high drainage of the powerful laser, a strong uninterruptable power supply (UPS) system had to be selected to accommodate. Such systems are not uncommon (especially on Pohnpei), but in the case of the DMLS machine, a power interruption can mean the total loss of an extended metal printing session. As for metallurgical gasses, the most common gas utilized is argon, however, the supplies available locally cost as much as 10x the standard costs for gas available in the US mainland. Therefore the system had to be custom designed to function in a vacuum space that eliminated the need for a supply of metallurgical gasses; this is uncommon in practice. A finished product can be delivered for approximately USD $260,000.

Acquisition of the dental and plastics printers is much less complicated. Standard devices can be purchased and employed without special accommodations. The supply of filament can be arranged constantly to meet the observable local consumption patterns.

Table 5: Survey Responses

Company	Contact	Imported items	Quantity	Total Value
True Value	Garry Garsain	PVC Pipes, Lumber, Electrical, Furniture	None given	None given
NAPA	Yvonne Hawkins	**Auto Parts**	None given	None given
APSCO	Takuro	**Specialty machinery parts**		
Pohnpei Hardware	Tim McVey	**Doors, Toilets, Sinks**, **Countertops**, **PVC Pipes, Plastic wares**		
High Speed Auto Parts		Plastic components, Radiator frames		
ACE Hardware	Rich	**Tools**		
ACE Office Supplies	Denise	**Furniture**		
ABCOR	Larry	**Machinery parts**		
Pohnpei Water	Sengero	Plastic bottles		
Island Smile	Annette Vera Cruz/Dr Darwin	Dentures, Bridgework	1.5/mo, .5/mo	None given
Vital	Olivier	Machinery components		
PUC	Marcelino	Machinery components		
FSMicro Telecom	Alex W.	Generator parts, AC Parts, Vehicle Parts, Computer Supplies, Office Supplies and Hardware supplies		$100k+
VCS Construction/Pohnpei White Sand		Replacement industrial components		$10-15k/month
Pohnpei Mascot	Scooby's Chien Hsing Hsu	Auto Parts, Gasket, Oil Seals, Belts		
Island Water Company		Water bottles		
Ocean Care Company	Jun	Marine equipment for clients		
MicroByte MicroPC Pohnpei Electronics Outlet (P.O.E.)				
PTA (transportation authority)	Sadorino Martin	Construction machinery, **OIL SEALS and Hydraulic hose nozzles**		

Department of Ed	
	Replacement components for medical equipment
Dept of Health	
College of Micronesia	
Computer Networks Int'l	

C. Economic

Currently, Pohnpei imports USD $85 million or more annually (Pohnpei Imports, 2014). Pohnpei's share is consistent with the national value, where imports equal more than 81% of FSM's GDP. Of this $85 million, $26 million is comprised of food imports. Of the remaining $59 million in non-food imports, as much as $7.182 (12.2%) falls into import categories which have a high confidence rating ("best chance" or "probable") for 3D printing to make an impact in the future (*Appendix E*). Through 3D printing there exists the potential to transfer a portion of the funds that have been exported to opportunistic foreign nations into value-added Pohnpei manufacturing services, the majority of which could remain on-island as a boost to the economy.

D. Logistical

The logistical outcomes will be achieved through the challenge to source a changing set of imported products. When the industrial demand shifts from finished products (made available through proprietary sources) to suppliers of bulk quantity raw materials (such as powdered steel), the market power shifts to the buyer, who can choose from many suppliers to find a pricing that seems more appropriate. When new suppliers are selected in response to the realignment in product type, quantity and demand, logistical decisions are made that bring about a new purchasing scenario in the Pohnpei import market.

A logistical realignment is possible with the use of 3D printing to satisfy some important economic needs on Pohnpei. While 3D printing may reduce the end value of imported products into FSM/Pohnpei, there is still the need for a supply of raw materials, especially metals. Raw metal powders will likely come from Asia, and many plastics will also originate in distant markets. The anticipated result will be a reduction in the overall value of imported products, with different products replacing a percentage of those currently being imported, now coming from alternate sources. This realignment will require a logistical reshuffling, which should have an overall limited impact on trade volume in the end, at least until bioplastic material development is mature and can replace raw plastics as an import.

Private businesses and government agencies will also see their supply chains shrink and simplify once it is possible to source their materials locally from a 3D printing business.

1) Goldilocks

Pohnpei is a prime example of what I've been able to identify as "Goldilocks island states", where there is a strong enough market and population to create a demand for business services, but not a large enough market to justify bulk inventory purchases and receive the associated price breaks when establishing a supply chain. As a result, Pohnpeians end up paying a higher cost for each product they import (more than most developed marketplaces), and those supplying them still have a difficult time seeing much of a profit from their sales, in spite of the higher prices paid by end consumers. (For an appraisal of other Pacific Island Markets, please refer to *Appendix J*.)

An emphasis to utilize recycled plastics to the fullest extent will result in some reduction of end-use import product demand, though the expansion in availability of

services may eventually lead to a cyclical increase in consumption too; this may constitute something of a countervailing force to the import substitution efforts. Evidence suggests that having a functioning 3D printing industry as a source of specialized products will impact other businesses and industrial sourcing patterns. The end effect of 3D printing for other businesses means a faster and cheaper supply chain than has been possible previously. Access to a faster and cheaper supply chain traditionally results in a quantifiable degree of business success and improved options for consumers. It will be possible for residents of Pohnpei to essentially examine a digital "catalog" of thousands of items they may desire, and "order up" products they could have never found in island stores previously.

This new pattern of availability can be seen as an "insurance buffer" or leverage against the inconsistency of the outside world. Never before have customized manufacturing services been available at the fingertips of residents, and 3D printing could change the way the people of Micronesia experience the world.

E. Resource

To make better use of Pohnpeian materials, used plastics will come to be seen as resources, and a cash-value recycling program will encourage residents to collect and sort plastic waste. Such waste, as used water bottles will now be a key manufacturing resource, leading to reductions in imported raw and finished materials. Eventually, agriculture products will be utilized to create filament for a variety of purposes. For example, sugar beets or coconuts may be used to produce plastic products.

F. Capacity

Capacity building can be contagious, and sometimes it needs to be. The personnel capacity expansion required to staff a 3D printing business on Pohnpei needs to contribute to the dispersion of technical skill sets across the island so as to develop a pool of qualified employees in the future, as 3D printing becomes a more common way of sourcing parts and materials. Computer-aided design (CAD) skills are currently in short supply, and outreach through public schools and the College of Micronesia are required to generate interest in the technology and sow the seeds of future success. Not all these practitioners will work directly with the 3D printing company, though it is hoped they may utilize the technology to create their own business endeavors, prototype new products, or for personal inspiration. Representatives of the 3D printing company can contribute to the public knowledge by hosting workshops to encourage use of CAD editing software, such as Solidworks or Cloud Compare, and offer introductory CAD engineering training to the public. To reach the required personnel capacity, initially, hired engineers will train a local staff on the procedures for safe operation of machinery and basic CAD skills to create and edit digital products. The hired engineers will also conduct the first public skills workshop and help initiate the training relationship with the College of Micronesia and the Pohnpei Department of Education. A continuing relationship will stimulate interest with younger students, as they develop a sustained interest in 3D printing and CAD. This relationship with the education community is crucial, as business expansion will require additional hiring.

G. Maternal Mortality discussion

From the beginning of my time on Pohnpei, I was concerned about the perceived high maternal mortality rate, as it had been reported at 317 incidents per 100,000 births (PIFS, 2010).

However, I found health officials were clueless about the issue and didn't know it was being reported as a problem. After a time, some simple math cleared up the issue.

The birth rate in FSM is about 21 per 1,000 people. With a population of 100,000 in the country, that means there are about 2,100 births in the country every year.

The maternal mortality rate (MMR) in the country is determined by number of deaths per 100,000 live births. Given that there were 2 MMR deaths last year, it equaled 2 out of 2,100, translating to a rate of 95.23. This rate of 95 out of 100,000 is pretty close to the rate of 83, which was registered in 1990. Therefore, it appears that there were also just 2 MMRs in 1990, judging by the historic population count.

It is rather unfair to judge a small country, when the base numbers are so low. To achieve a rate of 317/100,000 (as reported in 2010), there would need to be only 6.65 MMRs in the whole country, meaning an actual difference of approximately 4.5 mothers.

While this finding has absolutely no conceivable connection to the 3D printing research, it was also uncovered through the conduction of this study on Pohnpei.

5.5 SUMMARY OF FINDINGS

To summarize, there is a viable opportunity for 3D printing to provide a valuable development function in what I've identified as "Goldilocks islands states", such as Pohnpei. Here the impact of alleviating both project specific and ongoing work

stoppages can have an exponential multiplier effect, which could significantly affect overall development timelines across the island. Additionally, there is a possibility to reduce not only actual imports, but also the historic dependency on imports through the use of 3D printing and especially the use of both recycled plastic materials and plastics made from agricultural products such as sugar beets.

With 3D printing comes the opportunity to bring limited manufacturing capabilities, which, along with utilizing locally available resources, can permit a type of "insurance buffer" as a "hedge" against international traders. One advantage for FSM in this arena is the country's lack of constricting intellectual property (IP) legislation, which means they are not required to pay for the use of international product designs. The financial benefits of reducing imports would have impact throughout the economy. Meanwhile, services, including industrial work, automotive and marine parts sourcing and dental services stand to profit the most through the execution of a private-sector business providing these specialty services.

Opportunity also exists to vastly improve services provided to outer island residents, as a result of this technology, possibly through a government initiative at some future point.

3D printing has the potential to allow government and business service provision on outer islands that lack sophisticated infrastructure. On the most remote islands, which only receive supply shipments irregularly, 3D printing has the unique potential to create products that can solve local problems in a timely manner.

While the study revealed the role of density as a factor in the potential impact of import substitution, it became clear that action on agriculture policy holds still greater potential for short and intermediate term impacts on trade. In the next chapter, we will discuss the implications of these findings.

CHAPTER VI: DISCUSSION

I begin this chapter by presenting an overview of the purpose of the study. Following this, I will relate the findings to the literature analysis, before discussing some of the limitations that have affected the study, and its implications for future research.

6.1 OVERVIEW

A. General Purpose

The general purpose of this study was to work with local stakeholders to determine in which ways 3D printing could contribute to development in FSM, specifically on the island of Pohnpei. The idea was to identify the specific needs of government, business and citizens of Pohnpei. If their goals could be fulfilled through the application of 3D printing, how could this be brought about and performed in this critical social and economic climate? Finally, once these conclusions were reached, the goal was to lean on the knowledge gained through research to propose a plan of action that would lead to a sustained and productive impact.

B. Obtaining results

Results were obtained through a participatory process where, as a researcher, I received most of my direction from the advice of Pohnpei residents. I postulated that 3D printing might hold potential because of the import/economic statistics and certain circumstantial factors, primarily the cumbersome supply chain. The study was given direction as a result of the apparent political powerlessness of the federal government to take action on the measure, and the willingness of business owners to get behind the project when they identified their own potential to make use of the technology.

I was able to get actionable information about imports from business owners who imported the majority of their inventory. I was able to make a quantification of that data as a result of actual import statistics provided by the national government's CTA. With the gathering of this information it is possible to relate the business plan to the theoretical methods that contributed to its formation.

6.2 RELATING FINDINGS TO THE LITERATURE

A) Sein et al.

Because the business plan is based on a private sector model, it endeavors to creatively fulfill the imperative framework of Sein et al. by satisfying the four conditions of sustainability. The conditions set forth are the positioning the project for finance flow (with a for-profit model championed by local investors), the application of appropriate content (selected as a result of a market study), the need for a local catalyst (through local direction and stakeholder involvement) and the view of ICT within the project (understood as a development means and endorsed by the DTC&I) (Sein et al., 2008). Fulfilling these requirements should position the proposed business plan well for success.

B) Malone

The project also fulfills the related framework described by Malone (2012), who gives a more comprehensive description of the key success factors for a particular ICT4D intervention. He says successful interventions must be: available at low cost (which the business plan assures by providing technical items at the cost of raw ingredients + markup), users must be aware (all importing businesses have been consulted),

accessible, user friendly, and with a clear strategy offering incentives (Malone, 2012, p.18). The business plan, as written, supports all of these imperatives. Malone also suggests researching other forms of revenue to support ICT4D projects, which the private sector plan also satisfies (Malone, 2012, p.21). In fact, the plan also leaves open the possibility for public financing to fund service delivery expansion to outer islands, as the company develops the capacity to do so.

Still, there were limitations that affected the research, as we will discuss in the next section.

6.3 LIMITATIONS OF THE STUDY

A. Critical Analysis

A critique of this study's approach would be that it attempts to address multiple, succeeding angles of analysis in the same study and apply them simultaneously. This has been a challenge, however all sides are applicable to the same question, and all three (ICT4D, 3DP and FSM) are relevant to produce a useful, effective and informed action plan. There are also concerns about the social effect of employing such powerful technology on a new culture (Warner, 1998).

Stakeholders have taken an active role in observing the work to ensure legitimacy, including hosting numerous personal meetings, playing direct advisory roles, attending public presentations, giving updates and actively engaging with their input. A website (www.3DPrintMicronesia.net) has been kept current and used to keep parties informed throughout the process. Semi-structured interview questions were also distributed regarding anticipated impacts of application of the proposed technologies.

A further point is that although 3D printing may successfully reduce the import of finished products, there should be an expected parallel increase in raw forms of metal and plastic, at least until a native bioplastic can be developed that reduces the need for importation of that source material.

Though I've hoped that the results of this study have produced a generalizable model, specific factors at each location will reveal just how transferable the findings are in each unique environment.

The researcher must bear in mind still that "deep-rooted social problems cannot be solved with technical fixes," as Sein & Harindranath stated (2004, p.21). Though often underdeveloped countries are quick to adopt new ICT, often they "do not diffuse or use them in any meaningful manner" (Sein et al., 2008, p.14). Malone et al. offer a list of challenges for ICT4D, citing the securing of government resources or commitments, the private sector finding sustainable business models, the appropriate integration of information sources, and appropriate content all as primary concerns for successful implementation (Malone et al., 2012, p.18).

B. Validity

The validity of research data is assured by the resources used to compile them, including official documents with quantitative data and qualitative interviews involving all relevant importers on Pohnpei. The accountings from both source types support the assessment that 3D printing can be effective for sourcing products on Pohnpei. The documents in reference are included in this thesis as appendices, proving the accuracy of assessments made throughout the study. The methodology of the research has been cataloged devoutly though a research journal, which was shared weekly throughout the fieldwork portion of the study with my advisor, Professor

Maung K Sein of the University of Agder. However, it is possible to question the validity of the import data itself, as I discuss in the following section.

C. Things that may have hindered or affected my findings

During a discussion with a chief officer at FSM's CTA, he revealed that there might be some degree of question as to the confidence of the import statistics that I used to identify categories of need. He explained that, due to budget shortfalls, his teams are understaffed, and therefore concentrate primarily on searching for unregistered shipments of alcohol and tobacco products when they inspect cargo. Most non-alcohol/tobacco products are taxed at a similar, lower level and, as a result, most importers will do their best to identify them. However, it is possible that importers choose the wrong category when listing their products, as I encountered in one significant case.

Pohnpei CTA item 84859000 is described as "Machinery; parts, not containing electrical connectors, insulators, coils, contacts or other electrical features, n.e.s. in chapter 84".

The 2014 numbers for this category were listed at more than $2.9 million. When I cross-referenced this number against previous years, it was found to be more than 800% of the previous year's figure. When I inquired as to the reason, the result was an internal investigation that revealed the number had likely come from a Japanese fishing vessel that had forgotten to convert the actual figure from yen, and an adjustment in the national import statistics resulted.

Also it is possible that importers may try occasionally to attempt to misrepresent shipments of alcohol/tobacco in product categories relevant to this study, thereby skewing the results of this research.

The study was also difficult to complete because of a severe lack of financial resources. International staff at my university failed to complete paperwork, which would have allowed United States to fund my research. As a result, I could not afford to rent a home, and was only able to sustain myself through the charity of an extremely generous local family affiliated with my initial research partner, Johnny Hadley, Jr. The housing provided was functional, but the leaky roofs, cockroach infestation, and kerosene stoves would have discouraged some researchers. It was during my stay at this home that the house was burglarized, and my Apple computer was stolen. Luckily, my backup materials weren't too out of date, and I was able to find a nearly-functional computer which helped me continue to re-gather and present my data during the final weeks of my fieldwork.

Another frustrating (though anticipated) challenge was the often-sluggish response of many officials and business owners to questionnaires and information requests. However, this usually resulted in personal follow-up visits, during which I was able to extract the desired data. Sometimes the data was provided with greater clarity than would have been allowed if the respondent had simply replied to the original paper request. An expected challenge from the beginning included a general tradition of bureaucratic non-cooperation; despite the proclamations of full accountability and openness described in the new national ICT plan (2012). Such responsiveness and cooperation still remains to be demonstrated by some relevant public assets, such as SBOC leadership. However, my personal background in investigative journalism, entrepreneurship and media sales led me to not be easily dismissed or dissuaded. The need to find solutions to unexpected blockages was anticipated and planned for, effectively defining the action research process I undertook.

D. Ethical evaluation

Ethical evaluation is a relevant reflectional framework for the research I've conducted. Because significant opportunities have been deemed to exist as a result of the assessment of existing technology and localized opportunities on Pohnpei, it is conceivable that this development could eventually present relevant changes in lifestyle. For example, previous "modern" dietary innovations have lead to an increase in non-communicable health conditions (WHO, 2010). It will be dependent upon a robust and vigilant oversight effort to ensure that the social benefits are maximized, and the lifestyle changes that occur are optimized. Therefore, there is an ethical context to this study. This is why an aspect of the second phase of research sought input and included a discussion with Pohnpei medical professionals regarding health outcomes.

Because the primary sources of data for the research have been official entities and businesses, rather than individuals, there are no privacy considerations beyond what businesses choose to keep to themselves as proprietary business secrets. Institutions have decided via policy what information could be shared and revealed.

6.4 FUTURE RESEARCH DIRECTIONS

A. Implications for practice

From this study, we discovered important implications for practice in the form of a development plan directed from stakeholder input. The plan, which is being promoted on Pohnpei, is a direct byproduct of the research. Additionally, the research conclusions relating to imports puts additional pressure on state government to take

action on agriculture policy to reduce food imports and also promote the cultivation of plants which have the potential to serve as plastic filament, among others.

B. Implications for theory

The frameworks I used, Sein & Harindranath and Malone, were useful in building grounded theory to conduct the study. When evaluating my results, it was extremely useful to show that the findings of the eventual business plan met the theoretical requirements outlined by the team of Sein et al. (2008) and Malone (2012). By positioning it for capital investment, applying appropriate content selected by business owners, finding local catalysts, making accessible products available at low cost, user friendly, and operating with a clear strategy, the business plan fulfills the given conditions of each framework.

In the unique environment of a "Goldilocks island state," where there is a firm cap on the demand potential facilitated by the island environment, my predictions are that through application of 3D printing technology in Pohnpei, the impacts may fall out of order from those proposed by Sein and Harindranath (2004). Instead of first order impacts, followed by second order and third, my research suspects first order, followed by the third, and then, potentially the second. This is because it is only after new innovations in material supplies (an aspect of the 3rd order impact) will resource costs be reduced to a level affordable by many on Pohnpei. This would be a prime example of leapfrogging technology, as a totally new biological "ink" may need to be invented before many on the island can afford to purchase items as basic as a simple living room couch.

C. Future research implications

More research on future developments for Pohnpei (as a result of this study) should be enlightening, and the case study should be continued.

Most pressing is the need for a preliminary study into ways to apply 3D printing to bring services to outer islands. An analysis of basic needs should be conducted and the results should be compared to the more urban islands. As the 21st century presses on, research should shine light upon the ways humans are living in every corner of the planet, allowing for mutual knowledge exchange – and life on remote Pacific islands should be no exception.

CHAPTER VII: CONCLUSIONS

7.1 CONCLUSIONS & RECOMMENDATIONS

The study produced conclusions which were both expected and unexpected. While it was anticipated that 3D printing might have some useful purpose on Pohnpei, the actual applications for which it would find use were almost completely unknown. The specific directions given by business owners ultimately led to the conclusion that 3D printing could provide an advantage to those looking to level the global commerce "playing field" for residents of Pohnpei. The data show legitimate opportunities to do this and, through the development of the recommended business plan, a minor economic realignment could improve the circumstances for a variety of stakeholders. Of particular surprise was the significant need for 3D printed dental services on Pohnpei. It is supposed that this seemingly oversized need stems from the chewing of betel nut, although this conclusion could be investigated further. One wonders what a comparative result for dental services would be on an island similar to Pohnpei in statistical measures, yet without a betel nut chewing habit.

Another relevant finding from the application of the action research process was the anticipated "ghost" need for furniture among citizens, who have traditionally gone without it because of the currently unbearable cost of imported furniture. This hidden demand could be satisfied if denser plastic materials imports or a bioplastic substance could be applied to build furniture locally and at an affordable cost to Pohnpeians.

One of the largest points derived from data analysis (which has little to do with 3D printing directly) is that, when assessing economic impact of interventions, it seems a much more significant (at least in the near to intermediate terms) to initiate a major

change in state agricultural policy. On Pohnpei, I observed an extremely fertile environment (soil analysis verified by Natural Resource Conservation Service). Yet, instead of relying on the fertile land and one of the most bountiful fishing zones in the world for sustenance, Pohnpei alone imports more than USD $26 million in food products. That $26 million made up 30% of Pohnpei's imports, all of which was superfluous given that a better arrangement of local agricultural resources could have successfully fed the population. Pohnpei's $26 million in food imports could alone account for 65% of the national 2023 funding gap. Therefore, I conclude, regardless of 3D printing's maximum potential to affect development on Pohnpei, a still greater, simpler, and measurable impact could be made (and may indeed be made as a response to the ending of the US compact agreement) in short order via agriculture policy. As described in the Chapter V, 3D printing could also potentially make valuable contributions to a shift in agricultural production.

Research often leads to unexpected findings, and one of those findings for this development study related to the maternal death rate (MMR).
In conducting this research with an attention to the millennium development goals, I was able to uncover an explanation through my process of research. After connecting with a local women's group, I began asking about the alarmingly high maternal mortality numbers. They were unaware of the problem of a high maternal death rate, which had been leaving a black mark on the national image due to a poor sample distribution. The source of the poor numbers has now been identified and authorities have been informed to comment on the misrepresentative record.

I was able to conceive development solutions as a result of the current state of 3D printing technology, which is just now becoming capable of producing affordable

metal printers. Key aspects have been integrated in the final business plan that demonstrate an enterprising new business model, designed specifically for what I have called "Goldilocks island markets." In these locales, there is geographic/market isolation and enough people to create product demand, with a dependency on international products, yet not enough buying activity to generate economies of scale and receive price reductions from international suppliers by meeting their minimum orders. These markets have always constituted a frustration in trade. Because they are expensive to supply, yet don't purchase enough quantity for their suppliers to profit much, they make strong candidates for custom-supplied 3D printing services. Following development on Pohnpei with this business model, I strongly recommend further study for other identified "Goldilocks" markets dealing with similar supply complications (*Appendix H*). I suggest this for the purpose of confirming which common trade and development issues could be addressed in these specialized markets via the application of 3D printing for development (3DP4D), and for the overall benefit of these groups of people.

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APPENDICES

APPENDIX A – PRIVATE BUSINESS PLAN

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APPENDIX I – PROPOSED BUSINESS ACCOUNTING/INVESTMENT

Eco-Miracle Micronesia

Business plan

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Business plan summary

The business

- Joint stock holder, with majority under Pohnpeian ownership
- Registration number: ____
- Primary Business location: Pohnpei, FSM
- Business was established: 2015
- Business is owned 49% by Brennan Purtzer (minority), and the remaining 51% (majority) is divided among citizens of The Federated States of Micronesia
- Founder's Relevant experience: 10 years of business management and successful marketing experience as an entrepreneur with professional business and development education.
- Products/Services: Producing, via limited 3D printing manufacturing processes, various items which are costly to import – with a macro-economic goal to reduce the national import/export trade imbalance.

The future

- Provide an alternative to importing, providing products at a cheaper cost than was previously available, at a dramatically faster turn-around rate.
- Expand to provide services in other FSM states.

The market

- Targets consumers: FSM businesses are currently paying the highest shipping rates in the world due to their isolation and small population.
- 3D Printing technology allows for the production of numerous product types, including metals, extrusion, powders, ceramics and even textiles.

The finances

- Startup investments are being provided by both private investor funding (10%) and government-affiliated lending programs (90%).
- Future operational funding will come from investors and business profits as needed.

Business Details

Business Information

- Business Purpose:
  To provide limited, professional grade manufacturing services to retailers and suppliers on-island, while simultaneously reducing the amount of imported goods, thereby strengthening the local economy.

- Business Size:
  With a group of joint stakeholders, 2 full time and 2 part time employees may begin the operation, with employment growth to come as soon as the island produces adequate capacity through educational ventures.

- Operational history:
  Conceived in January 2014 as part of Brennan Purtzer's masters thesis in Development Management, the concept grew into a business when it was accepted that this business plan was the most feasible way bring it to fruition.

Business Premises

- Location:
  Operations conducted on the island of Pohnpei, with planned expansion to other islands, growth permitting.

Organization chart

- Mr. Brennan K Purtzer (primary minority shareholder) is initially the chief/principal agent of the company. Mr. Purtzer's objective is to direct and organize all foundational elements of the operation, overseeing training and setting the pieces in motion successfully. Once a local general manager/director is selected and hired, s/he will take over this role. An engineering contractor will be utilized to set up operations and train local personnel.
  Both full and part-time local workers will be hired to specialize in metal replication, plastics and rubber services and dental services, with further expansion in the foreseeable future as new technology is acquired and market preparations undertaken. Future hiring should result as an outgrowth of related educational training and partnership utilizing the college and high schools to prepare students for jobs in this growing industry.

- Names of owners:
  Brennan K Purtzer (46.6%), Ivaylo Guenkov (3.3%), Walberg Hadley (3.1%), Johnny Hadley, Jr. (2%).

Products and Services

- Details of products and services:
  Eco-Miracle Micronesia (EMM) plans to offer three distinct premium services:
  1) EMM uses a cutting edge Direct Metal Sintering System (DMLS) custom designed for the purposes of Pohnpei businesses owners to create certifiable-grade replacement machinery and auto parts for less than the previous cost to supply them, and delivered within a 30-hour time window.
  2) EMM uses a MakerBot Z28 plastic and rubber-like filament printer to replicate specialty replacement parts for household, automotive and marine purposes.
  3) EMM scans and manufactures dental/orthodontic bridgework and dentures available to all clinics on the island, simplifying the process and reducing both cost and turnaround time for clients.

- Market Position:
  Our products are successful because the initial products were chosen after a personal survey with business owners and government agencies regarding the specific needs of each. In each case, the company is focused on the items with high demand, capable of being produced using our technology for a lower price than they were currently being imported for.

- Unique selling position:
  We are able to supply products for a comparable price than was previously possible, at an accelerated delivery window, with the added benefit that buying from us means more money is circulating the local economy and improving the import/export position of the country. In other words, buying from us is good for the client because they spend less on supplies, but also puts more money their customers' pockets too.

- Anticipated Demand:
  The business was actually designed around customer demand at every stage of the process. We have identified more than $7.182 million in imports coming into Pohnpei annually which could conceivably by replaced by 3D printed products, according to current national import data. Fifteen percent (15%) of after-tax profits will be invested in research and design (R&D) to expand the line of offered services and replace more imports for more businesses. Half a dozen product lines have already been identified, with existing markets already ready for these products.

- Growth potential:
  As the investment pool for R&D grows, we will expand both horizontally and

vertically, adding new lines of products, especially as new technology becomes available, and expanding to other islands and states within FSM as appropriate. More than $1.75 million in annual imports has been identified in serviceable industries in both Chuuk and Yap states combined.

Insurance and risk management

- Liability Insurance:
  Insurance policies will be carried on the valuable equipment purchased by EMM and its shareholders. EMM will also offer a limited guarantee the parts replicated using its equipment, if any should prove faulty. Insurance will also be carried to cover equipment breakdowns and subsequent business losses.
- Risk:
  Risks include mechanical breakdown and need for repair.
- Likelihood:
  There is a low, but manageable probability of risk occurrence, which will become progressively smaller as engineering instruction is augmented via college and high school technical capacity building programs.
- Impact:
  Equipment breakdowns, depending on their scope, could set our clients back while they wait for the equipment to be repaired – however, they will still not be required to wait as long as they currently have to wait for parts shipments.
- Strategy:
  EMM's three-pronged company strategy is to maintain its equipment tenaciously, insure the equipment and company profits, while proactively developing technician skills throughout the island so that the company machinery can be repaired in the case of a breakdown. One strategy for protecting equipment lies in the utilization of an uninterruptable power supply (UPS), which prevents equipment from being damaged by occasional power outages. Another lies in the machine's ability to replicate many of its replacement parts. Parts likely to require replacement will be identified and replications made in advance, prior to anticipated servicing.

Legal considerations

- Taxes:
  The company is subject to domestic FSM tax laws (21%) and regulations.

Finances

- Finance Required:
  Funds required, approximately $450,000 at startup. These funds are being solicited through investment financing and a loan from the FSM Development Bank. To raise the initial 10% ($45,000), out of 1,000 total shares, 450 will be

sold at an initial price of $100/share. There are also grants available, which could lessen the startup costs.

- Cash flow statement:
  Opening balance: $50,000

  Cash Outgoing (monthly):
  $12,910
  4,600 Metal Alloys
  4,460 Wages
  2,000 Dental filament
  0,500 Plastic filament
  0,500 Business Lease
  0,350 Electricity
  0,300 Business Insurance
  0,200 Internet

  Cash Incoming (monthly):
  Contingent on *Market Penetration/Capitalization*
  2.1% = $13,000 – Break even operational expenses
  3.2% = $38,410
  4.2% = $50,820
  5.3% = $63,230
  6.3% = $75,640
  7.3% = $88,050
  10% = $119,700

  - Break-even analysis:
    The business is breaking even at 2.1% primary market penetration, meaning that if the company is securing just 2.1% of the existing primary market import revenue, the business is self-sufficient.

  - Wild Card:
    These figures do not take into account the percentage of secondary-market industries we may also move into within the 24 initial months. Expanding the focus of business opens up more than double the amount of available imports to target.

Pricing model

Pricing of general print services (excluding dental) determined by a formula of:

- Cm^3 of material (aluminum, steel, inconel, ABS, PLA, Rubber)

- Print time (with an extra cost associated with *"rush"* print jobs, as well as slower prints to achieve additional precision, or huge jobs which occupy resources for extended periods of time)
- *Dental pricing will feature set prices for a standard menu of regular services, to be developed and agreed upon through a board-approved process.*

Proposed Investment Timeline

- July 2015: Secure investment commitments, establish corporation and place orders for required equipment

- Aug-December 2015: Assemble, test equipment, interview Pohnpei-based employee candidates and lead engineers who will train employees and establish business operations. Gain hands on experience with all three technologies while in the United States: DMLS & Plastics training @ Forecast 3D in Carlsbad, California as well as dental experience at Center Point Dental Group in San Diego.

- January 2016: Ship equipment to Pohnpei, hire Pohnpei-based employees to begin in October

- February 2016: US based contractors will assemble Equipment in Pohnpei, begin training new employees required skills

- March-April 2016: Begin serving clients on Pohnpei

- 3rd Quarter, 2016: First investment dividends, hire additional workers, expansion to new industries, expansion to Chuuk, Yap and other islands, Development of educational training partnerships

Summary

- Eco-Miracle Micronesia succeeds by:
  1) Providing superior products at market prices, faster, and eliminating the need for our clients to stock additional inventory.
  2) Utilizing cutting edge technology to level the playing field for Pohnpeians
  3) Innovating using business and technology experts
  4) Leveraging unique market conditions that exist in Pohnpei
  5) Reducing the total amount of international shipping required, thereby reducing the ecological footprint

Revenue/ROI Scenarios

Revenue and ROI will be *determined by the company's performance at converting existing imports into products manufactured locally.*

Below are 5 different performance scenarios, each demonstrating the equivalent investor's return *over the first 24-month period*.
Loan payments must also be subtracted from earnings, once the arrangements are calculated.

- Scenario A

10% Market Penetration
$1.436M Gross Revenue
$1.124k Gross Profit (after expenses)
$955,740 Profit - R&D (15%)
$755,034 Net Profit after Tax
$755 Dividend per share
755% ROI over initial 24 months

- Scenario B

7.3% Market Penetration
$1.056M Gross Revenue
$744,600 Gross Profit
$632,900 Profit Minus R&D (-15%)
$500,000 Net Profit after Taxes (-21%)
$500 Return/Share
500% ROI (initial 24 months)

- Scenario C

6.3% Primary Market Penetration
$907,681 Gross Revenue
$595,681 Gross Profit
$506,329 Profit Minus R&D (-15%)
$400,000 Net Profit after Taxes (-21%)
400% ROI (Initial 24 months)

- Scenario D

5.3% Primary Market Penetration
$758,760 Gross Revenue
$446,760 Gross Profit
$379,746 Profit Minus R&D (-15%)
$300,000 Net Profit After Taxes (-21%)
300% ROI (Initial 24 Months)

- Scenario E

2.1% Primary Market Penetration

$312,000 Gross Revenue
$0 Gross Profit
$0 Profit Minus R&D (-15%)
$0 Net Profit After Taxes (-21%)
0% ROI (initial 24 months)