Mississippi State University's makerspace: Founding of The Factory

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This paper discusses the creation of a makerspace on Mississippi State's campus. A makerspace is a location that provides prototyping and design tools, and is made available to students, faculty, and staff. The process of starting, staffing, and funding the space are discussed, as well as, the liability of operating the space. The paper outlines the operation of the space as a student organization partnered with the university, and the unique approach of networking existing campus resources into a shared organizational structure.

DEDICATION

Meager though it is, I dedicate this work to those who have supported me every step of the way. I never would have completed this if it wasn't for the constant support of my friends and family. I would like to dedicate the makerspace project to all those who come after me. I hope that The Factory (or whatever it may be called in the future) grows to be a place of constant innovation, and a future source of great thinkers, doers, and makers. I encourage those leading MSU's makerspace in the future to strive to build a program second to none. A makerspace that is the envy of makers the world over, but also accessible to all those who care to learn.

ACKNOWLEDGEMENTS

I would like to thank the Mississippi State Center for Entrepreneurship and Innovation for funding my graduate degree, and giving me the opportunity to work on this project. I appreciate the unprecedented cooperation of the MSU Mechanical Engineering program in supporting this project, and my pursuit of a degree built around it. I want to thank Dr. Schneider for encouraging me to attend graduate school, and pursue my ambitions. I never would have even considered attending graduates school if it was not for you. I want to thank Taylor for supporting me while we build both our family and engineering careers together. Finally, I want to thank my mother for always being a source of constant encouragement and love.

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CHAPTER I

INTRODUCTION

1.1 Motivation

Makerspaces are becoming more common on university campuses around the United States. In simple terms, Makerspaces provide tools and resources to users to facilitate the process of creating things. These tools go beyond the simple hand tools found in a standard tool box. Ideally, these would be advanced tools that would enable the creation of anything and everything. As a result, Makerspace locations are popping up in many different environments. They are available as either commercial prototyping facilities, public resources within libraries or museums, as well as in universities to enhance the learning experience of the students.

The background of the movement, and its history, provided the ground work for selecting the unique approach implemented in the Makerspace located at Mississippi State University (MSU). Creation of the Makerspace on the MSU campus relied on networking the resources already available. This unique approach resulted in the rapid implementation of the MSU Makerspace. This thesis documents the process from conception to implementation, discusses the strengths and weaknesses, and provides suggestions to assist the future growth and development of the MSU Makerspace.

1.2 Objective

This thesis documents the implementation of a university based Makerspace, called The Factory, on the MSU campus. The approach is based on university Makerspaces which have been established at many institutions across the country. Using these other Makerspaces as a model, MSU customized its approach to facilitate rapid implementation. MSU has the advantage of already possessing many of the tools typically found in a Makerspace. However, without an existing mechanism for providing student access to these tools, their usage was limited to classes or research. This thesis will explore the various aspects of establishing a Makerspace within the MSU academic environment including: staffing, access, and financial management. By networking resources from across the campus, the Makerspace has been rapidly implemented, as compared to the extended time scale experienced at other institutions that relied solely on equipment purchased exclusively for the Makerspace.

1.3 Approach

To develop and launch the MSU Makerspace, approaches used at other universities were evaluated. The approach of providing students access to a network of laboratories located across campus is unique to MSU. This plan offers the advantage of avoiding the wait for a need to arise and be recognized, followed by the wait to acquire the equipment before students can access the resources.

CHAPTER II

BACKGROUND

2.1 The Maker Movement

There is a renewed interest in the creation of things. Providing easier access to knowledge, capital, and the marketplace, has resulted in a surge of creativity that has become known as the Maker Movement. [1] The Maker Movement is a reclamation of the Do-It-Yourself (DIY) approach in a high technology age. Advances in technology have lowered the price of computers, design software, and manufacturing hardware which previously presented a barrier to their utilization. Thus, tools once only available at large industries are now available to the general public. Homebrew computer numerically controlled (CNC) machines, 3-dimensional (3D) printers, low cost computer assisted design software (CAD), and inexpensive digital prototyping boards, are a few of the tools which have lowered barriers for the average person to tinker and invent new things. [1] Although these tools are now within the price range of the average person, the knowledge to effectively use them may still present a barrier to their utilization.

Makers have always existed. Many people are driven to make things or inventions in their daily lives without analyzing what drives them. In the past, these individuals were known as “DIYs”, or “handymen”, but in recent decades their numbers have dwindled. The rapid growth of high technology consumerism relegated invention to the realm of a more specialized and higher skilled section of the community. As technology became more complex, interested individuals were less likely to experiment on their own. It seemed that the age of DIY was becoming something of the past. [2]

Since 2010, Making has shifted in a direction that Chris Anderson refers to as a "new industrial revolution." [3] This new revolution is driven access to a combination of resources that allow nearly anyone to rapidly learn the skills needed to use advanced tools to make things. With the internet, CNC's and 3D printers, accessible digital design tools, and sharing communities available; rapid integration and development have become easier. The continually growing community of people taking advantage of these new developments make up todays Maker Movement.[4] Dale Dougherty encourages American institutions to "look to the Maker Movement for tips on how to create an ecosystem of talent, connections, and learning that will lead to a truly innovative economy and society." [5] The Maker Movement is about creating an environment that encourages hands on problem solving, using a culture of creativity to inspire each other to design and build.

2.2 Maker Space

A Makerspace is any location where the tools and training are available for building things. Individual Makerspaces are available to many that have garages or workshops. However, student lifestyles, as well as a trend toward urban lifestyles, do not necessarily support access to these individual workshop venues. Thus, the Makerspace is a location where tools are made available without the personal investment. Much like paying for a membership at a gym to get access to free weights and stationary bicycles, an individual can gain access to shared tools in a Makerspace through a similar membership fee structure. [3] Additionally, the new technology available often requires training to understand the capabilities the tools provide. The Makerspace provides an arena for “experimental play”. [6] Students can exploit the knowledge they are learning in the classroom and have the opportunity and ability to utilize that knowledge on projects they are personally motivated to complete. The community that espouses this play based learning is housed in places like a Makerspace.

2.3 Methods Observed Elsewhere

To better understand the academic approach to building makerspaces, similar institutions, summarized in Table 1.2, were researched. All three organizations were visited and researched in literature. This provided insight into various methods used to encourage and support both makers and entrepreneurship at these institution. Of those investigated, three institutions were found to be most relevant to this study and included: Rice University (Rice), Georgia Institute of Technology (GT), and Arizona State University (ASU). All these institutions have Makerspaces that have been integrated into their programs in one fashion or another. The primary differences between these three example schools are their management structure. Each took a different approach. Rice created a fully staffed university center. Georgia Tech created a student run organization housed in the Mechanical Engineering (ME) Department. Arizona State University partnered with a commercial organization, Tech Shop, to provide the facilities and staff off campus, and paid for their students to have access. Many universities offer makerspaces in some form, but these three were identified due to uniqueness of management, and apparent program success.

2.3.1 Rice – Oshman Engineering Design Kitchen (OEDK)

The OEDK at Rice University (Figure 1.1) includes a complete complement of facilities including 3D printing, laser cutting, a machine shop, wood shop, electrical shop, as well as meeting space, and project specific work tables. [7] Founded through a 2.5 million dollar gift from Mr. and Mrs. Kenneth Oshman and a corporate donation from National Instruments, the OEDK is intended primarily to support the yearlong capstone design projects of Rice's engineering courses.[8] The OEDK is supervised by ten full time staff. [9]

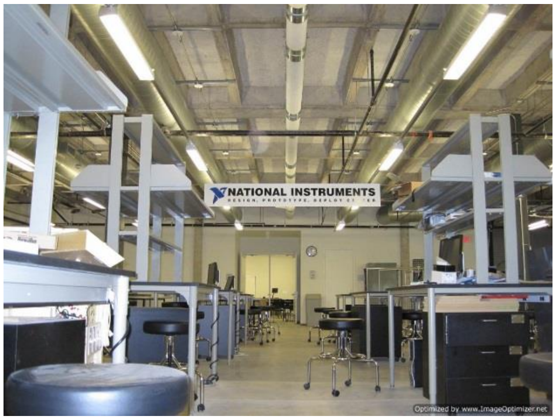

Figure 1.1 OEDK Student Work Area
[10]

The OEDK aims to support undergraduate engineering design projects with the following principles [11]:

1. Provide space to work on design projects for all eight engineering departments.
2. Provide interdisciplinary, real world design challenges
3. Provide opportunities for younger undergraduates
4. Use special topics training in areas such as entrepreneurship to enrich design

The OEDK provides a wide range of equipment to its students as reflected summarized in Table 1.2. Student gain access through coursework, student organizations, and even for personal projects with prior approval. Students are restricted from working on for-profit personal projects in the space [11]. A unique feature available in this space that was not seen in others was the wet laboratory: a space where students with the proper training could conduct research using chemicals. This wet laboratory would be difficult to replicate anywhere else without professional supervisory staff.

2.3.2 Georgia Technical Institute – Invention Studio

The Invention Studio (Figure 1.2) is housed in the ME Department at Georgia Tech and is a student operated and university funded Makerspace. The space is open to all students, faculty, and staff on the GT campus [12]. The motivation for creating the space was to improve retention of engineering students while enhancing their capstone design experience [12].

Figure 1.2 GT Invention Studio

[13]

The resources provided to students are reflected in Table 1.2. Their description includes their operating principles [12]:

1. Student run
2. Open 24/7 to members
3. No restrictions on projects
4. Free use
5. Well - equipped facility
6. Linked to the engineering design curriculum
7. Centrally located on campus

According to the organizations student vice president [Alexis Noel, 13 November, 2015], the space is almost entirely managed by students. Students are responsible for training users, maintaining equipment, and supervising the space. To accomplish this goal, they use a rigorous training process for all student supervisors. The space is housed within the ME Department and is supervised by the members of the student Maker Club. Financial expenditures are made on a per semester basis in accordance with a proposal submitted by the Maker Club to the university. An interesting feature of the space's operation was free use of the 3D printers. The space uses funds that are charged to all students' tuition to cover the recurring expenses of the space.

2.3.3 Arizona State University – Tech Shop

Arizona State University partnered with a commercial Maker Studio, called the Tech Shop (Figure 1.3) based out of the San Francisco Bay Area. The Tech Shop manages and operates a Makerspace that is available free of charge for ASU students taking classes in the College of Technology and Innovation, and at a reduced rate for all other students while also being available to community members. The resources provided are summarized in Table 1.2. The Tech Shop provides the tools and knowledge base to Arizona State without the difficulty of managing the space using university resources [14]. An unusual ally in the creation of ASU's Tech Shop was the support of the City of Chandler, AZ through investment in the facility. The city saw the benefit of bringing this type of facility to the community and partnered with ASU and Tech Shop to make it possible [15].

Figure 1.3 Tech Shop Chandler Arizona

[15]

Table 1.2, referenced above and seen below, summarizes the resources available at these three different institutions. Even though very different approaches were taken to making these tools available, there are similarities at each institution. The MSU Factory's current resources are included for easy comparison. Those items that are immediately available to students are marked with an X. Those resources that are possible to obtain, but require special permissions, or will soon become available are listed with an O. Finally, those that are not available (and currently do not have a plan to become available) are marked with a Z.

Table 1.2 Makerspace Capabilities as of Fall 2015

Equipment	3D Printers	Laser Cutter	Wood Cutter	Water Jet Cutter	Metal Shop	Electronics	Textile Lab	Computers	White Boards	Wood Shop	CNC Mill/Lathe	Wet Laboratory
Rice	X	X	X	Z	X	X	Z	X	X	X	X	X
GT	X	X	X	X	X	X	O	X	X	X	X	Z
ASU	X	X	X	X	X	X	X	X	X	X	X	Z
MSU	O	O	X	Z	O	X	O	X	X	O	Z	Z

Active:	X	Some:	O	Absent:	Z

[16]

CHAPTER III

MSU'S INVOLVEMENT IN THE MAKER MOVEMENT

3.1 Entrepreneurship and Prototyping

In 2014, the MSU Center for Entrepreneurship and Innovation, or E-Center, began investigating the creation of a facility on campus to support students interested in hardware prototyping and showcasing of product mock ups. The initial focus was on 3D printing for rapid production of prototypes for student entrepreneurs [17]. To make this resource available to students they were sponsoring, the E-Center investigated the cost of creating a prototyping space within the E-Center to assist technological startups. During the fall of 2013, and summer of 2014, trips were made to some of the leading entrepreneurship programs in the United States (Table 1.3). While touring these facilities, it was observed that all of these programs offered access to prototyping facilities of some capacity for their students. This observation spurred the E-Center's interest in providing this resource in support of Mississippi State's own entrepreneurial students.

Table 1.3 Universities Visited Fall 2013 and Summer 2014

University:	**Location:**	**Program:**
Massachusetts Institute of Technology	Cambridge, Massachusetts	Martin Trust Center for Entrepreneurship
Rice University	Houston, Texas	Rice Alliance for Technology and Entrepreneurship
University of Houston	Houston, Texas	Wolff Center for Entrepreneurship
Texas A&M University	College Station, Texas	Center for New Ventures and Entrepreneurship

The E-Center's initial study evaluated not only the up-front cost of the equipment, but the training, operation, and maintenance required to support this type of resource. In the process of the study, the E-Center became aware of the ME Department's new Rapid Prototyping Laboratory. This laboratory, established with donations by an alumnus (Charles B. Holder, BSME 1961), consisted of two quality 3D printers from Stratasys [18]. By teaming, the E-Center and the ME Department established a collaboration to allow access to both students and community members requiring basic prototyping in support of their business interests. Since the ME Department had purchased the equipment with an alumni donation, they staffed the laboratory with one person to represent the educational interests of the department. Using funds from the E-Center, a second person was added to support the E-Center's entrepreneurial interests. A cost structure was established to charge users not using the lab in support of courses offered within the ME Department.

3.2 Answering the White House Call to Action

Simultaneous to the E-Center's efforts to offer prototyping facilities to student startups, universities in the USA were receiving an invitation to participate in the USA national Maker Faire. The Maker Faire was initiated by President Obama in 2014 to highlight creativity and innovation within the USA. [19] The Maker Movement was perceived to be strategically critical to the economic growth of the USA especially for the manufacturing sector. The President believes that a Maker movement could stimulate the interest of students within the USA in the science-technology-engineering-math (STEM) fields. He, therefore, issued a national call to the educational system to draw more students into the science, technology, and engineering fields. The Factory at MSU was proposed to the MSU Bagley College of Engineering to reinforce the letter and demonstrate Mississippi State's commitment to the goals of the movement. [Appendix B.1]

3.3 The Factory

The approach of networking existing resources on a university campus offers the advantage of allowing the student access to tools faster. Waiting for a central location to be established on campus would result in a longer lead time for startup and heavy upfront costs. Thus, the Factory was initially envisioned as a network of existing laboratories across the university campus that could become more centralized as the organization matured. As of Fall 2015, the current and soon to be partner laboratories at MSU are illustrated in Appendix C.1.

3.3.1 Mechanical Engineering Patterson Laboratories

3.3.1.1 Hand and Power Tool Room

The Factory, the central hub of the Makerspace, was initially installed within the ME Department's space in the Patterson Engineer Building shown in Appendix C.2. This location was selected based on its proximity to other ME Department Laboratories willing to grant access outside of class times.

Figure 1.4 The Factory Hand and Power Tool Room

The Factory, the central hub of the Makerspace, was initially installed within the ME Department's space in the Patterson Engineer Building shown in Appendix C.2. This

location was selected based on its proximity to other ME Department Laboratories willing to grant access outside of class times.

3.3.1.2 Rapid Prototyping Laboratory

The main space for The Factory was co-located with the ME Department's Rapid Prototyping Laboratory (Figure 1.5) or 3D printing laboratory. Figure 1.6 shows this laboratory which houses two Stratasys uPrint SE plus and one uPrint [18] printer which are available to students who wish to print their own design projects. Based on the previously established fee structure, students print their designs for a fixed cost, if the project is not associated with a class project. SolidWorks [20], Sketchup [21], Blender [22], and FreeCAD [23] 3D design software are available in The Factory for students to use in design projects and instruction is provided on how to export models to the 3D printers. Students design their devices utilizing various solid modeling software packages. Due to the complexity of the 3D printers, The Makerspace staff uploads the design to the 3D printers and oversees their operation.

Figure 1.5 uPrint Plus 3D Printer

[17]

Figure 1.6 ME Rapid Prototyping Laboratory

3.3.1.3 Fusion Welding Laboratory

As noted in the overall floor plan in Appendix C.2, this laboratory is co-located near The Factory. The fusion laboratory houses four Lincoln metal inert gas (MIG) fusion welding machines, one of which is shown being used in Figure 1.7. The equipment is used for the ME Department's Casting and Joining (ME 4413/6413) class. These machines are easy to use with minimum training, to allow the member a hands-on experience.

Figure 1.7 Mechanical Engineering Fusion Welding Laboratory

Student leaders interested in conducting the fusion welding training are identified and trained by a qualified ME staff member. Once these members have been trained to the requisite skill level, they are classified as Tool Masters and can, in turn, train new members on the operation of the equipment. These leaders then supervise the use of the equipment, and aid in the subsequent training of the next new leaders.

3.3.2 MSU Library Instructional Media Center

The MSU Library instructional media center has joined The Factory's network of facilities on campus. They offer a variety of new resources as well as the many resources already in place and available to the MSU community. Both members and non-members can check out hand tools, use CAD programs such as AutoCAD Inventor [24], SketchUp [21], and use a Makerbot 3D printer [25]. The MSU library is evaluating expansion plans which include the possibility of converting the former 2D printing laboratory into a 2D/3D printing laboratory. The library has staff resources to offer training in various CAD programs as well as oversee the operation of the equipment. The library plans to purchase additional 3D printing equipment in the future, as well as provide a dedicated space for 3D printing in a future expansion. Other university libraries have successfully implemented Makerspaces that are available to the student body by repurposing existing space. Tufts University utilized a conference room to provide a wide variety of tools to students. The centralized location of the space helped to promote the university's Maker efforts. [26]

3.3.3 Clothing Laboratory

The Clothing Laboratory, part of the Human Sciences Department which is located in Moore Hall (Appendix C.1), is a hands-on space where students engage in different methods of apparel construction, fitting, and visual analysis. The laboratory, shown in Figure 1.8, is designed to provide students with adequate space and equipment similar to that available within a major apparel manufacturing company [27]. Access to the clothing laboratory is restricted to Fashion Design and Merchandising majors and Factory members with a Clothing Laboratory certification.

Figure 1.8 MSU Clothing Laboratory

CHAPTER IV

THE FACTORY OPERATION

4.1 Staffing

As a student organization, the staff must be self-motivated to not only take advantage of the space themselves, but to also take on the extra responsibility of operating the space.

The primary aspects of operation include:

- Makerspace Financials
- Membership Management
- Training of members and leaders
- Maintaining Equipment
- Expanding the Scope and Capability of the Space
- Creating Documentation
- Managing the University and Community Relationships

The Factory at MSU was established as a student organization. All of the tasks required to establish the space and oversee its operation are time consuming, and generally not directly related to the process of making. These are not different from the responsibilities of any student organization, although The Factory is complicated by the introduction of capital equipment and the potential for serious bodily harm.

Finding methods to motivate students to shoulder these burdens in addition to the numerous time constrains already experienced by the undergraduate or graduate student is difficult. The balancing act of school work, personal obligations, and potentially part/full time work can make it difficult for a full time student to make running this type of space a priority.

During The Factory's first semester, a multi-level approach, outlined in Figure 1.9, was used to manage the space. The E-Center's investment in a graduate student to focus on the entrepreneurial interests that would be met by the Makerspace provided the funding for the initial Team Leader. The E-Center's interest meant that the graduate student was incentivized to both facilitate establishment, and provide management, of the space. Getting the operation off the ground relied heavily on that first graduate student's ability to facilitate interactions between departments, interactions with the community, and to manage the student leadership. The E-Center contribution, in the form of a graduate stipend, provided the opportunity to research what was needed to establish and operate the space.

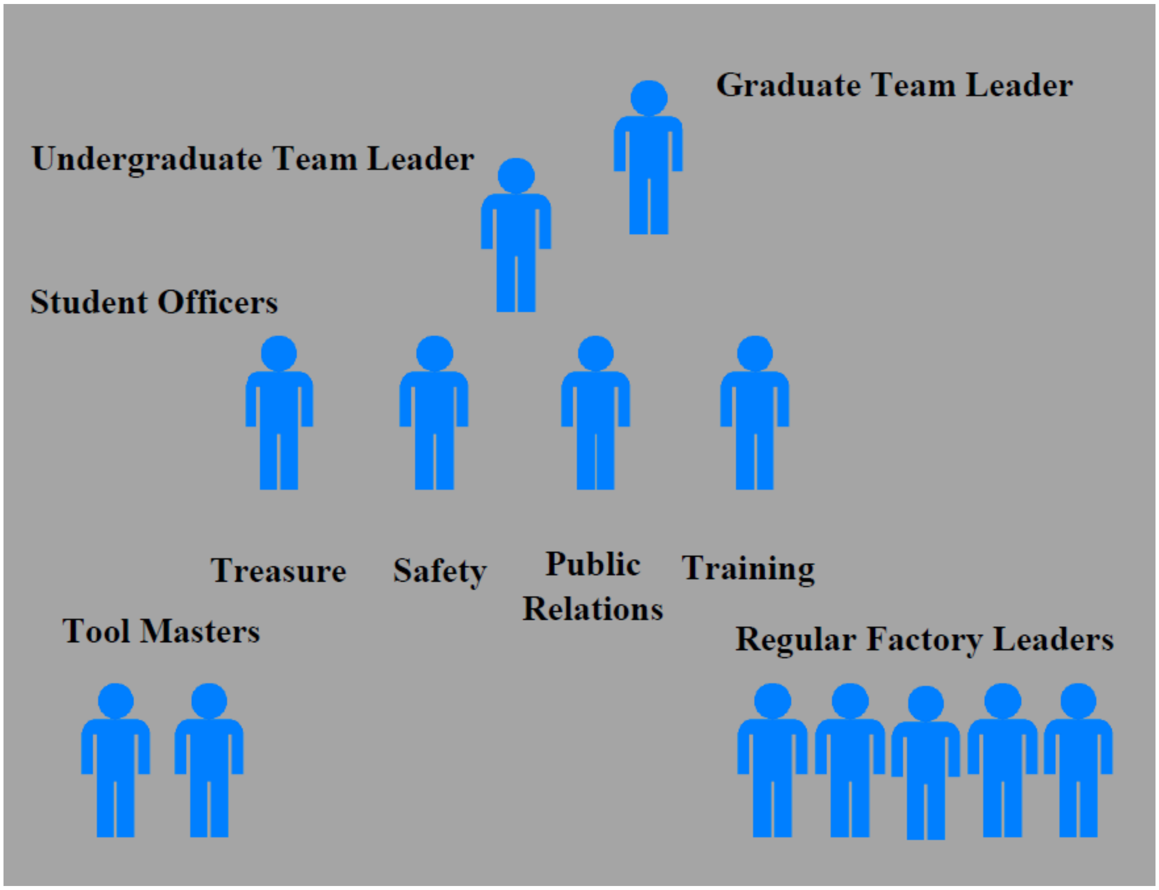

Figure 1.9 Student Leadership Hierarchy

Student leaders, nominated by faculty or self - selected, were chosen to handle the initial training of members and provide supervision in the operation of the space. In return for this responsibility, the Leaders were given special access to the space which included a key and after - hour access to the Patterson building. Ten student leaders were initially identified and were expected to be in the space one day every two weeks during the operating hours. Leaders were instructed to identify a replacement leader to cover their shift if needed. A private social network was established for the purposes of handling this communication. For the most part, this mitigated the number of days that the space was closed due to a lack of leadership. If new members accessed the space, the leaders would train them on use of the equipment and safety procedures, and collect dues.

Student leaders can take on responsibilities beyond supervising The Factory space if they so choose. Tool Masters are tasked with learning how to use equipment that has an especially steep learning curve so they can then instruct new members and leaders. Tool masters are also responsible for the regular maintenance and repair of that equipment. Officer roles created so far include: treasurer, responsible for managing space finances; safety officer, supervises the creation of safety plans and materials; public relations, manages website and campus events; and training officer, schedules training sessions. Finally, the undergraduate boss works with the graduate boss to ensure the space is operating smoothly, and pursues the goal of continuing to expand in capabilities and membership.

For long term operation of The Factory, a succession plan is necessary. Newly identified student leaders should provide the pool to replace the previous team leader. This relies on the natural progression of student leaders from the undergraduate community to continue onto graduate school to take on Team Leader roles. The need for a succession plan from the student population could be eliminated or complemented with a paid staff member to oversee operation of The Factory and coordinate volunteers.

Other universities, like Georgia Tech, have been able to utilize a volunteer model similar to the initial efforts at MSU [12]. There are also universities which have a purely commercial interaction with their technology providers, where operation is effectively out sourced such as Arizona State's partnership with Tech Shop [14].

The particular challenge in The Factory's specific circumstance is most other universities have a centralized location for most of their resources. This allows a smaller staff, student or professional, to supervise a wide variety of equipment. The distributed nature of The Factory poses a challenge for long term operation. The Factory student leadership is currently mitigating this challenge by either moving portable items to the central location in Patterson labs, or making arrangements for the partnering lab to provide supervision arranged by that lab's supervisors. For instance, the clothing laboratory is supervised by the Teaching Assistant (TA) responsible for supervising the equipment in support of Fashion Design and Merchandising students.

4.2 Financials

Student members pay a per semester fee of $40 to access resources in The Factory. Short courses are offered to train students regarding the equipment capabilities, in addition to training regarding proper and safe usage. Once students obtain the proper training, they are awarded access to the networked resources on the MSU campus under The Factory umbrella.

The financials of The Factory can be placed into two categories:

Internal: Funds raised through fundraising and dues.

External: Funds made available through the university's colleges, departments, or grants.

Internal funds offer the benefit of being under the complete control of the students and faculty managing the space. The funds are managed by the student leadership, and kept in a local bank account. Funds collected through dues are intended to maintain the equipment in the space and replace consumables. These funds collected from dues are currently managed at the discretion of the student management organization. Funds acquired through fundraising or grant writing are to be used to upgrade the space, either by improving on equipment and tools available, or by acquiring new tools. Items purchased using internal funds belong to The Factory organization, and are not property of MSU.

External funds are those provided by the university in support of the space. The Factory was initiated by funding provided by the College of Business' Center for Entrepreneurship and Innovation. Additional funding was provided by the Jack Hatcher Grant and Bagley College of Engineering, and is managed by MSU Entrepreneurship Center. In order to use these funds, the purchases are initiated through the applicable department. Items purchased above $500 must be included on the MSU department inventory. As these funds generally expire at the end of the fiscal year, they must be expended prior to the July deadline for spending.

Georgia Tech's Invention studio's expenses are approximately $100k for equipment maintenance, and $100k for operations. Half of this expense is covered by the engineering capstone design courses which partner with industry to secure both funding and projects. 30% of the funds come from a Technology Fee Fund included with tuition, 15% from university research projects, and the remaining 5% is collected from industry and alumni donations. [12] While the Georgia Tech program is several years ahead of MSU's, the source of funding is indicative of the importance of their Invention Studio to their academic program. They use funds made available for capstone design projects to make the space available to senior engineering undergraduates. They leverage tuition dollars to make the space available to all their students. They also allow university researchers to use the resources in support of their projects, all the while making the space available for personal projects. [12]

4.3 Safety and Legality

4.3.1 Safety and Legality Overview

Makerspaces are growing all over the country. University Makerspaces are uniquely capable of providing a variety of tools and necessary training to teach people how to use them. Managing the risk of providing access to these tools is essential to the successful operation of a Makerspace. This risk can ideally be managed through compliance with applicable regulations, training on the use of the equipment, and the signing of a liability waiver by all users.

4.3.2 Introduction to Liability

Tort is a non-criminal wrong that results in injury to a person or property [28]. An organization that provides access to and training with tools opens itself to liability due to the risk of providing inexperienced users a means of causing injury. The Factory is a Makerspace recently started on the MSU campus. This student organization provides training and access to tools in a network of labs across the MSU Campus. To better understand the motivations for providing this kind of access, a brief background should be given.

4.3.3 Liability

Potential liability for an organization such as The Factory will be divided into three groups: the facility users, the student leadership, and the university. All three groups hold a certain amount of responsibility for maintaining the safety of the participants and property. Because torts can be divided into both intentional and unintentional, the assumption will be made that an organization such as this will primarily be concerned with unintentional or negligent torts. These two categories are differentiated by the intent of the defendant to cause harm. [28]

Four elements must be present in order for the user, student leadership, or university to be liable. A **duty** to the victim, a **breach of that duty**, the breach must have been the **cause** of the injury, and there must be an **injury** [29]. Once all four of these conditions are met, a tort may be brought. The two elements, relevant to Makerspaces, include duty and the breach of that duty. A better understanding of the relationship of these two elements will provide the most help in mitigating risk in a Makerspace.

According to Ronald Standler's essay on the topic, the common issues resulting in torts in university laboratories are as follows [29]:

- Unclear warning of non-obvious hazards
- Instructor not present
- Otherwise occupied instructor or assistant
- Unnecessarily dangerous assignment
- Incompetent Supervisor
- Lack of proper emergency equipment
- Lack of appropriate safety equipment

Addressing these specific issues would certainly reduce the risk for those involved in the organization. The organization should publish standards which govern the safe use of the space. According to Occupational Safety and Health Administration (OSHA) standards [30], a university is obligated to follow OSHA regulations in the same manner as a business. This provides a reference set of rules that can be used to manage risk in a university laboratory environment. This would imply that the university has a duty to its students when they are using a facility in conjunction with a class in pursuit of a degree. The argument would then depend on whether or not there was a breach of this duty. A breach would result from an injury resulting from either inadequate instruction or inadequate supervision by the responsible individual.

In the case of a student-run Makerspace, users are not required to use the equipment in order to obtain a degree. This brings into question the duty of the student leadership to the user who is taking on the risk of using the equipment. The supervisors of a program like this needs to ask "is it the university who is allowing a student organization to use the equipment, or is it the user who is potentially contributing to their own injury, or the injury of others, through their voluntary use of that equipment?" The answer to this question could determine the liability of those involved in managing a program like this one.

4.3.4 Mitigation

The standard defenses in a negligent tort include proving either a combination of contributory negligence, comparative negligence, or an assumption of risk [28]. In the case of a university Makerspace, the assumption of risk is the ideal defense. By ensuring that the user is fully aware of all risks involved in the use of equipment and providing all the instruction necessary for the proper use of that equipment, the user then knowingly assumes the risk of injury when using that equipment.

The current method for mitigating liability in the MSU Makerspace is to comply with Occupational Safety and Health Administration (OSHA) requirements. These requirements are implemented under the direction of the university's laboratory supervisor and the equipment staff who provide basic instruction on the use of the equipment. Each Maker Space user signs a waiver of liability which releases the student leadership and the university from liability.

Operating the space in compliance with the appropriate agency regulations will ensure the highest degree of safety in the workspace given the available resources. To ensure that those standards are being met, the workspaces are ensured to meet or exceed the standards set by those tasked by the university with managing them. This kind of cooperation helps to reduce the chances of an accident as a result of hazardous working conditions.

Providing instruction on the use of equipment is essential to avoiding a breach of duty regarding the risks of injury in the Makerspace. A training program should include:

- Basic understanding of how the machine/tool operates
- A working knowledge of how to use the machine/tool safely
- Any relevant emergency procedures
- An understanding of the limitations of their training
- A test of that knowledge to ensure that they are retaining the information
- Ensure that members are not alone when using dangerous tools

The training in a Makerspace is inherently limited in scope. The user who is learning to use these tools must understand that they are learning to use the tools in the most basic sense. It would be prohibitively expensive and unnecessarily complex to instruct these users to the level at which they would be considered an expert. The goal is to give them the ability to use the machine without injuring themselves, hurting another user, or damaging the equipment. Becoming proficient in the use of the machine will be the responsibility of the user. The risks must be understood by the user and accepted by the user before they can be allowed to use the tool.

Other spaces tackle the issue of safety by using clear documentation and a baseline set of rules. Georgia Tech has standing rules such as “clean up, do not hurt yourself or the machines, respect the people and culture, wear safety glasses, keep hair short and pulled back, wear closed toe shoes.” They include penalties for breaking these or other rules, which can include barring access to the space [12]. The Makerspace Playbook recommends writing rules in your own words and repeating them often. Identifying the dangers (flying objects, burns, metalwork, etc.) involved with tools is important in adequately preparing the area and users. The playbook also recommends writing out a safety plan for the space [31]. The Factory is following this advice by developing its own written safety guidelines, and instructing all users on safe practices in the space.

A waiver is a contract that releases the owner and facilitator of a facility from liability in instances where dangers may exist that could potentially harm the user. In order for the liability waiver to hold, the language of the waiver must be clear, there cannot be a “vast” difference in the parties bargaining power, and the waiver cannot violate the law or public health [32]. A potential problem with the waiver would be university students who are directed to use the Makerspace for a project. In this instance the bargaining power would be uneven because the user would be unable to satisfy the class requirements without assuming the risk. Additionally, the space must be in compliance with all regulations required of it, or the waiver would fail to protect the space in the event of an injury. The Factory requires all users to complete a waiver [Appendix B.5] before they are permitted to use the facilities.

4.3.5 Liability Conclusion

The goal of a Makerspace is to provide people with the tools they need to create. The pursuit of this goal should not put the users of the Makerspace in harm's way, nor should the risks of providing the tools be a roadblock for the facility. A structured process of managing the risk is essential to ensure that the facilitator is performing their duty. Additionally, the user must be made aware of the risks associated with use of the tools. These two approaches combined with training will ensure that a breach of duty will not occur, and the possibility lawsuit is minimized.

CHAPTER V

FUTURE WORK

The potential for future expansion of The Factory is very high. However, many questions still need to be answered. A Makerspace on campus offers students, faculty, and staff more resources than they have had before, but the benefits should be quantified and studied. After starting the program, several research topics were made apparent. These are summarized in this section.

5.1 Benefit of Program to MSU Curriculum

MSU students utilizing the Makerspace for capstone projects and competitions could be compared to those working without the same resources. If there is a measurable improvement in the quality of their work, or more successes in the competitive arena, more could be invested in the development of the Makerspace to maximize on the unlocked potential of the students. In the fall of 2015, the Agricultural and Biological Engineering (ABE) Department sponsored the memberships of 11 senior design students to investigate whether or not these tools improve their capstone projects. It is recommended to follow up with the ABE Department to capture this information.

5.2 Appeal of Makerspace to Prospective Students

Showcasing the Makerspace to new prospective students with an interest in design and making could assist with university recruitment. The Maker Movement is not isolated to big cities, and universities. Many high schools are incorporating making into their curriculum, and these students will likely expect to have the same capabilities or more at their chosen university.

5.3 Impact on Entrepreneurial Student Success

One of the initial motivations for starting the Makerspace was the ability to offer prototyping facilities to students interested in starting their own businesses. Data is being collected by the E-center with regards to the development of companies utilizing the Makerspace to develop consumer products. Students interested in starting hardware dependent businesses face the challenge of acquiring the capital they need to develop a product. Having prototyping resources readily available significantly reduces the amount of funds required to perfect their product, and allows the students to develop some of the skills that could be required to actually create their invention. Finding an engineer to build your product can pose a more difficult challenge than learning to do the task yourself. Having a mechanism in place to solve this problem could give these students an edge over other fledgling companies that must rely on the skills of others to advance.

5.4 Further Investigate Liability Issues

Future work on this topic must include the investigation of liability insurance for the Makerspace. In the scenario of a case going to court, liability insurance would ensure that the potential risk mitigation techniques outlined before would not put the Makerspace at risk in the event of a lawsuit. Even a lawsuit decided in favor of the Makerspace could be detrimental to the program just because of the cost of a legal defense absent liability insurance that would provide coverage for attorney representation. The university should further explore the available options for covering the liability of the university and ensuring the safety of students.

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APPENDIX A

CONTACT LIST

The contact list in Table 1.4, summarizes the network of university staff, faculty, and administrators that were involved in the launching of The Factory at the time of writing (Fall 2015). This list can serve as a reference, and as an indication of the scope of the program.

Table 1.4 Contact List

College:	Office:	Name:	Title:	Email:
College of Business	Office of the Dean	Dr. Sharon Oswald	Dean	SOswald@business.msstate.edu
College of Business	Center for Entrepreneurship & Innovation	Mr. Eric Hill	Manager	EHill@ecenter.msstate.edu
Bagley College of Engineering	Office of the Dean	Dr. Jason Keith	Interim Dean	Keith@che.msstate.edu
Bagley College of Engineering	Mechanical Engineering	Dr. Pedro Mago	Department Head; Faculty Advisor	Mago@me.msstate.edu
University of Alabama in Huntsville College of Engineering	Mechanical and Aerospace Engineering	Dr. Judy Schneider	Professor	Judith.schneider@uah.edu
Bagley College of Engineering	Mechanical Engineering	Mr. Victor Latham	Staff	Latham@me.msstate.edu
Bagley College of Engineering	Electrical Engineering	Dr. Mike Mazzola	Professor; Hatcher Chair	Mazzola@ece.msstate.edu
Bagley College of Engineering	Electrical Engineering	Dr. Jean Mohammadi-Aragh	Assistant Professor	Jean@dasi.msstate.edu
Bagley College of Engineering	Electrical Engineering	Dr. Jane Moorehead	Instructor	JaneM@ece.msstate.edu
College of Architecture, Art & Design	Office of the Dean	Dr. Greg G. Hall	Associate Dean	GHall@caad.msstate.edu
College of Architecture, Art & Design	Interior Design	Dr. William Reihm	Assistant Professor	WRiehm@caad.msstate.edu
College of Architecture, Art & Design	Interior Design	Dr. Lyndsey Miller	Assistant Professor	LMiller@caad.msstate.edu
College of Architecture, Art & Design	Art	Dr. Critz Campbell	Associate Professor; Sculpture Concentration Coordinator	CCampbell@caad.msstate.edu
College of Architecture, Art & Design	Art	Dr. Adrienne Callander	Lecturer; Exhibition Coordinator	ACallander@caad.msstate.edu
College of Agriculture and Life Sciences	Fashion, Design & Merchandising	Dr. Charles Freeman	Assistant Professor	CFreeman@humansci.msstate.edu
MSU University Libraries	Mitchell Memorial Library	Dr. Thomas La Foe	Instructional Technology Specialist	TLaFoe@library.msstate.edu
University Administration	Office of the President	Dr. Mark Keenum	University President	Executive Assistant: KMcElroy@pres.msstate.edu
University Administration	Office of the Provost	Dr. Jerry Gilbert	University Provost	Administrative Assistant: Martha@provost.msstate.edu

APPENDIX B

DOCUMENTS

B.1 Initial Factory Proposal

The Factory

Mississippi State University's Maker Space

Bryan Patton, Factory Team Lead
Eric Hill, Entrepreneurial Advisor
Pedro Mago, Faculty Advisor
Mike Mazzola, Faculty Advisor

Summary:

"The Factory" at MSU is a Maker Space organized and led by students that will teach its members how to make tangible, physical things by building upon resources already available. The Factory is interested in utilizing Patterson Labs as its initial home to provide central access to key resources and people in the heart of the college. The success of the Factory will help promote a positive outward image for the ME department, Bagley College of Engineering, and prospective students.

Overview:

Creating a maker space at MSU is the natural next step after the BCoE's decision to officially partner with the National Maker Movement. Following examples set at Georgia Tech and Case Western Universities, a student-led organization will be created whose goal will be to pool accumulated knowledge among the students and faculty about making anything and everything. The goal of The Factory is to add a dimension outside traditional education with a physical hub where ideas can freely flow and come to life in a physical sense and give engineering students opportunities to build real objects beyond the rigors of the classroom & curriculum.

Operation:

To facilitate The Factory, policies will be established to ensure funding and safety. Figure 1 shows the proposed layout of the space to be utilized within Patterson. To not interfere with regular classes, the main activities of the Factory will be from 5 to 10 pm. Similar to other technical societies at MSU, trained students from the membership will be present during operational hours.

Safety:

As with any traditional lab, safety is a core concern and The Factory team, along with its advisors, are developing a detailed training program that ensures that everyone is not only capable of using the tools, but also knowing how to use them safely. The groundwork is already being laid to write training material for all the hardware that will be available to students. This training material will be approved by faculty and staff involved, and will also involve a hands on training course and a safety quiz.

Space:

As shown in Figure 1, the initial location for the proposed space is the vacant laboratory adjacent to the current Rapid Prototyping Lab. This location provides a space for securing hardware and is located next to a large workspace across the hall. It is intended that this space showcases the work of the students, thus providing positive attention to the Bagley College of Engineering and the Mechanical Engineering department.

1

Figure 1 Patterson Mechanical Engineering Laboratories

Funding:

To launch the Factory, the Entrepreneurship Center has pledged a $1000 dollars toward the start-up costs. This is expected to be spent on hand tools common to a factory as listed in Table I.

Table 1 Initial Budget

Item:	Qty:	Cost	S. Total
Storage:			
47 Bin Floor Mount Parts Rack	1	$79.99	$79.99
40 Bin Organizer with Full Length Drawer	1	$14.99	$14.99
Multipurpose Workbench with Cabinet Light	1	$100.00	$100.00
Workspace Utility:			
Rubbermaid Commercial Products 32-Gallon Gray Outdoor Garbage Can	2	$30.00	$60.00
Shop-Vac 14-Gallon 4.5-Peak HP Shop Vacuum	1	$90.00	$90.00
PPE:			
Crews 2230R Chemical Splash Goggle w/ Indirect Ventilation and Adjustable Strap, Clear	10	$3.00	$30.00
First Aid Kit With Hard Case- 326 pcs- First Aid Complete Care Kit - Exceeds OSHA & ANSI Guidelines - Ideal for the Workplace - Disaster Preparedness (Color Red)	1	$24.00	$24.00
MSA Safety Works 10028560 Dust and Pollen Masks, 50-Pack	1	$13.50	$13.50
Moldex Goin' Green Cordless Ear Plugs (Set of 200)	1	$52.00	$52.00
First Alert 5 lb Premium Rechargeable Fire Extinguisher	1	$40.00	$40.00
Custom Leathercraft 2046B Work Gloves with Safety Cuff and Wing Thumb, 12-Pair	1	$28.00	$28.00
Liberty T2010W Nitrile Industrial Glove, Powder Free, Disposable, 4 mil Thickness, Large, Blue (Box of 100)	1	$10.00	$10.00
Liberty T2010W Nitrile Industrial Glove, Powder Free, Disposable, 4 mil Thickness, Medium, Blue (Box of 100)	1	$9.00	$9.00
Hand Tools:			
22 Pc Fully Polished SAE & Metric Combination Wrench Set	1	$18.00	$18.00
Screwdriver Set 22 Pc	1	$12.00	$12.00
IRWIN 14-Piece Plastic Spring Clamp Set	1	$13.00	$13.00
16 oz. Claw Hammer with Fiberglass Handle	1	$4.00	$4.00
Utility Knife	2	$2.00	$4.00
Measuring Tools:			
6 in. Digital Caliper with Metric and SAE Fractional Readings	1	$21.00	$21.00
25 ft. x 1" Tape Measure	1	$5.00	$5.00
Power Tools:			
PORTER-CABLE 20-Volt Max Lithium Ion (Li-Ion) Cordless Combo Kit	1	$178.00	$178.00
K Tool International K Tool International 10330 326-Piece Drill Bit Master Set	1	$77.83	$77.83
		Total:	**$946.21**

Funding for the Factory's consumables will be provided through a combination of membership dues and individual project fund raising. Dues for staff, community members, and non-workshop leading mentors will be 20 dollars a month. Dues for student members will be 20 dollars a semester. With 50 student members and 20 non-students, the budget per semester for consumables will be approximately $2200 dollars. This budget will provide initial starting materials for projects and replace items used throughout the semester.

Non-consumables will be acquired through fund raising and sponsorships. These funds will also be used to sponsor the bi-annual Maker Faire where the project teams will showcase their work to the community and student body. The most impressive projects will be showcased at Maker Faires nationally, and could eventually receive national recognition.

Timeline:

The current semester will be a building semester for the space. Key mentors and senior students will be identified who are willing to take a leading role in the organization. Projects will begin this semester, but he first club hosted Maker Faire will be held in the spring of 2015.

4

B.2 Bagley Letter to the White House 2014

MISSISSIPPI STATE
UNIVERSITY™
Bagley College of Engineering

June 2, 2014

Dear Maker Movement:

On behalf of the Bagley College of Engineering (BCoE) at Mississippi State University (MSU), we would like to participate in the Maker Faire event being organized by the White House this summer. We are embracing the basic concepts of Maker Ed's mission to create more opportunities for students to develop confidence, creativity, and interest in STEM learning by making or creating to realize ideas.

Our students are exposed to design-build-test concepts in a number of our undergraduate engineering courses and through participation in annual national competitions such as the U.S. DOE EcoCAR, Formula SAE Series, AUVSI Student Unmanned Aircraft Systems (UAS), ASME Human Powered Vehicle Challenge, and ASCE Concrete Canoe, to just name a few. The notion of project-based learning has been adopted in many engineering disciplines within the BCoE. Although the terminology used may vary, the basic principles in concept realization through prototype development and evaluation are well established at MSU. In this letter, I would like to highlight some of the ways we are accomplishing the goals of "Maker Ed" at MSU.

Our students have been very successful in Advanced Vehicle Technology Competitions (AVTC) sponsored by the U.S. Department of Energy by finishing first place overall in 2007, 2008, 2010, and 2012 competitions. The MSU team was also selected to compete in the next round of AVTC in EcoCAR 3. In this project, students are tasked to modify a stock vehicle by redesigning its drivetrain, computer user interface, or other subsystems to improve its fuel efficiency, ride quality and other performance characteristics. Some of the parts used are actually built by the students. The multidisciplinary team of students participates in design, development and testing of numerous subsystems that extend their knowledge beyond classroom instruction, with actual road tests validating their concepts.

Another way we are accomplishing the goals of "Maker Ed" at MSU is through fabrication of composite structures by various student design teams. Our AUVSI UAS, ASME Human Powered Vehicle, and Formula SAE teams have relied on design and construction of composite structures to bring their concepts to realization while achieving significant performance gains. Fiber-reinforced composite components are typically fabricated by combining unidirectional fibers with polymeric resin to create very light but strong structures. Students use hand-layup techniques to build structural

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June 2, 2014
Page 2

components in construction of their vehicles. The use of composite materials has offered our students an opportunity to understand the role of laminate design in the performance of composite structural systems. In 2008, our UAS team, made up of a multidisciplinary group of undergraduate and graduate students, won the national championship at the 6th annual AUVSI competition.

We also have a long tradition in research and education in additive manufacturing. The experience of taking a design from a computer rendering to an actual hardware has provided our students considerable experiential learning opportunities. Within the BCoE, 3D printers are providing the opportunity for students in various core classes to visualize concepts from theories. Outside of conventional classes, this technology has also inspired several students to propose experiments utilizing the 3D printers that have been highlighted in the BCoE sponsored research poster competitions.

The availability of these resources on campus is also extended to interdisciplinary student teams. For the Formula SAE 2014 competition, the team tried out 3D printing for 2 parts on their car realizing a reduction in fabrication time from several weeks to less than a day with 60% reduction in weight.

As part of our outreach activities, the BCoE sponsors student projects at the nearby Mississippi School for Math and Science (MSMS) High School. These students are very bright and eager to interact with MSU and the 3D printing lab has turned out to be a tremendous recruitment tool! One of the MSMS student teams from the spring advanced to competition at the Intel International Science and Engineering Fair from May 11-16, 2014, in Los Angeles, California.

The BCoE has also teamed with the MSU Office of Entrepreneurship and Technology Transfer (OETT) to promote the University's entrepreneurial efforts. These efforts are centered on two objectives:

1) Provide basic prototyping needs of MSU student start-ups
2) Create a sustainable growth financial model through services rendered for external university customers to expand available prototyping capabilities within the BCoE.

It should be noted that students supported by the OETT office for initiating business concepts won several awards this past semester. One student was able to print a prototype of his concept which took a 3rd place award in a recent competition. Another student group was able to print a new patent-pending nebulizer enhancement. Without this prototype their efforts to begin commercializing their concept would have stopped at the conclusion of their capstone project. This team is now exploring their product as a viable business opportunity.

June 2, 2014
Page 3

I hope in reading this letter you will agree that MSU is embracing the Maker Ed Movement by incorporating new technologies on campus. Providing the ability for students in formal classes or competition teams brings together design and theory in the visualization of engineering concepts. We believe this concept will continue to grow at MSU BCoE and also into our various summer camps promoting the STEM fields.

By having the opportunity to participate in the Maker Faire, we would be able to showcase some of the student led projects to inspire greater participation in the Maker Ed Movement.

Regards,

Jason M. Keith
Interim Dean and Professor
Earnest W. and Mary Ann Deavenport, Jr. Chair

B.3 Mechanical Engineering Commitment January – March 2015

MISSISSIPPI STATE UNIVERSITY

Mechanical Engineering

November 26, 2014

Dr. Judy Schneider
Coleman and Whiteside Professor
Mechanical Engineering Department
Mississippi State University

Subject: The Factory – Bagley College of Engineering Maker Space

Dear Dr. Schneider,

In support of the Bagley College of Engineering's commitment to the Maker Movement, The Mechanical Engineering department is willing to dedicate Room 100H in Patterson Laboratory as an incubator to grow a Maker Space. The laboratory space will be made available from December 1, 2014 to July 30, 2015. Following this incubation time, the Mechanical Engineering Department and Bagley College of Engineering will evaluate future further growth of the Maker Space. In addition, we would like to see the name of the mechanical engineering department as sponsor of this space.

Please let me know if you have any questions,

Regards,

Pedro J. Mago
Department Head and PACCAR Chair
Mechanical Engineering Department

cc: Dr. Jason Keith
Bryan Patton

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B.4 Mechanical Engineering Commitment August – December 2015

MISSISSIPPI STATE UNIVERSITY

Mechanical Engineering

August 26, 2015

Brayn Patton
Mechanical Engineering Department
Mississippi State University

Subject: The Factory – Bagley College of Engineering Maker Space

Dear Bryan,

In support of the Bagley College of Engineering's commitment to the Maker Movement, The Mechanical Engineering Department is willing to extent our initial agreement to use Room 100H in Patterson until December 15, 2015. In addition, we will let you use Room 100D in Patterson until the same date to put your new additional equipment. Following this time, the Mechanical Engineering Department and the Bagley College of Engineering will evaluate future further growth of the Maker Space. In addition, we would like to see the name of the Mechanical Engineering Department as sponsor of this space.

Please let me know if you have any questions,

Regards,

Pedro J. Mago
Department Head and Professor
PACCAR Chair
Mechanical Engineering Department

cc: Dr. Jason Keith

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B.5 The Factory Member Waiver

The Factory
Mississippi State's Maker Space

Liability Waiver

This agreement is between ______________________________
(print your first and last name)

and the Factory

______ *Initial* By signing this agreement, I acknowledge that The Factory, Mississippi State's Maker Space, is a dangerous place and I agree to HOLD HARMLESS the Factory, its members, its officers, its directors, its sponsors, and Mississippi State University.

______ *Initial* I also understand that I am personally responsible for my safety and actions, and that I will follow all safety instructions and signage while at the Factory.

______ *Initial* I WAIVE ANY AND ALL RIGHTS OF RECOVERY, CLAIM, ACTION OR CAUSE OF ACTION AGAINST The Factory and Mississippi State University FOR ANY INJURY OR DAMAGE THAT MAY OCCUR, REGARDLESS OF CAUSE OR ORIGIN, INCLUDING NEGLIGENCE AND GROSS NEGLIGENCE.

______ *Initial* I will not attempt to use any equipment with which I have not received instruction. I will use all appropriate personal protection equipment for any equipment I use myself, or that is being used by others in my work area.

______ *Initial* I affirm that I am at least 18 years of age and mentally competent to sign this liability waiver.

SIGN HERE

______________________________ SIGNATURE

______________________________ PRINTED NAME

______________________________ DATE

This form is copied using the Dallas Makerspace form as a template as of 20 Jan, 2015

APPENDIX C

LOCATION MAPS

C.1 Affiliated Labs on Mississippi State's Campus

Figure 1.10 gives an overview of the MSU campus showing the location of the laboratories discussed in this thesis which make up the Factory.

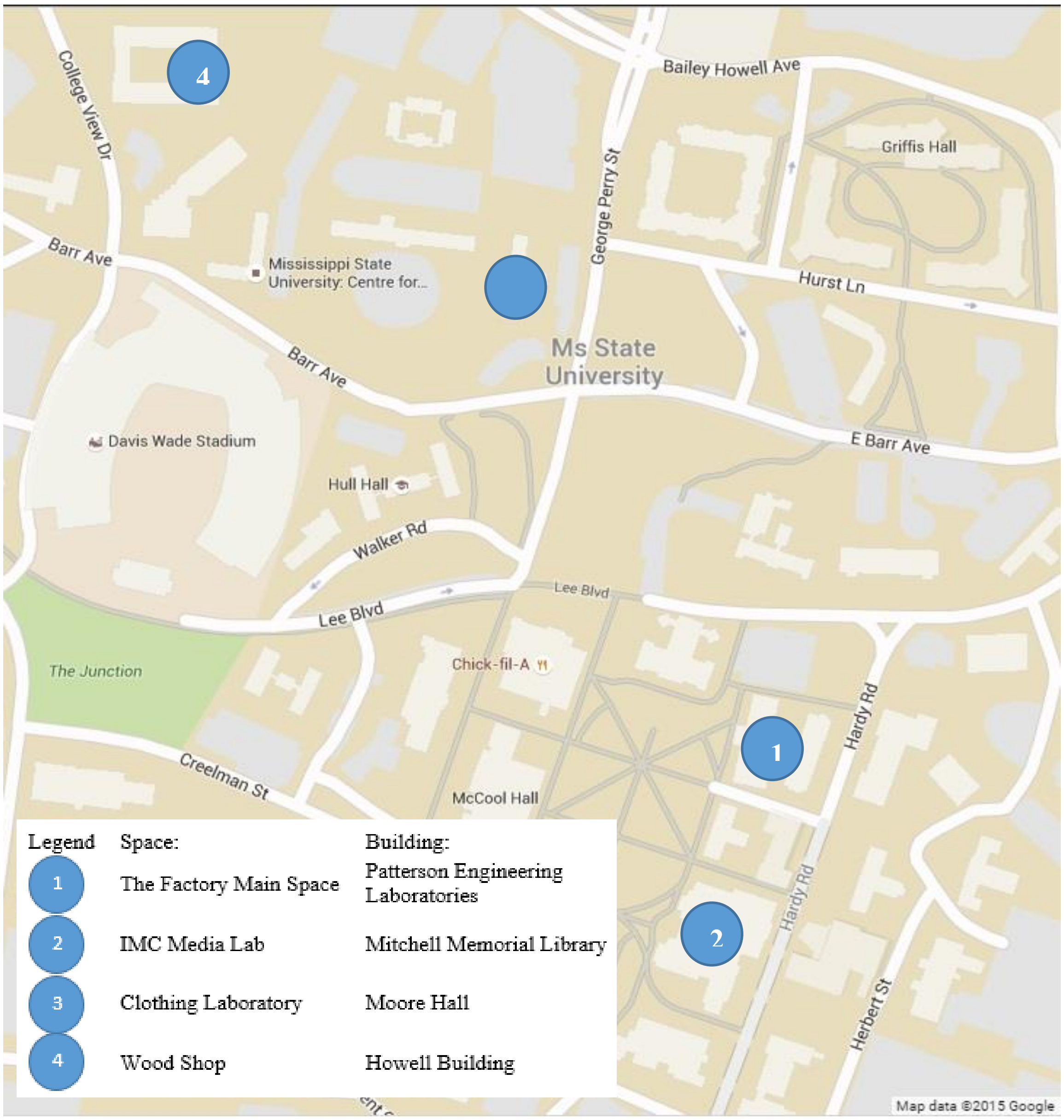

Figure 1.10 The Distribution of Participating Labs as of Fall 2015

C.2 The Factory Main Space

Figure 1.11 shows the layout of the laboratories located in Patterson Engineering which is home to the Central Hub of the Factory.

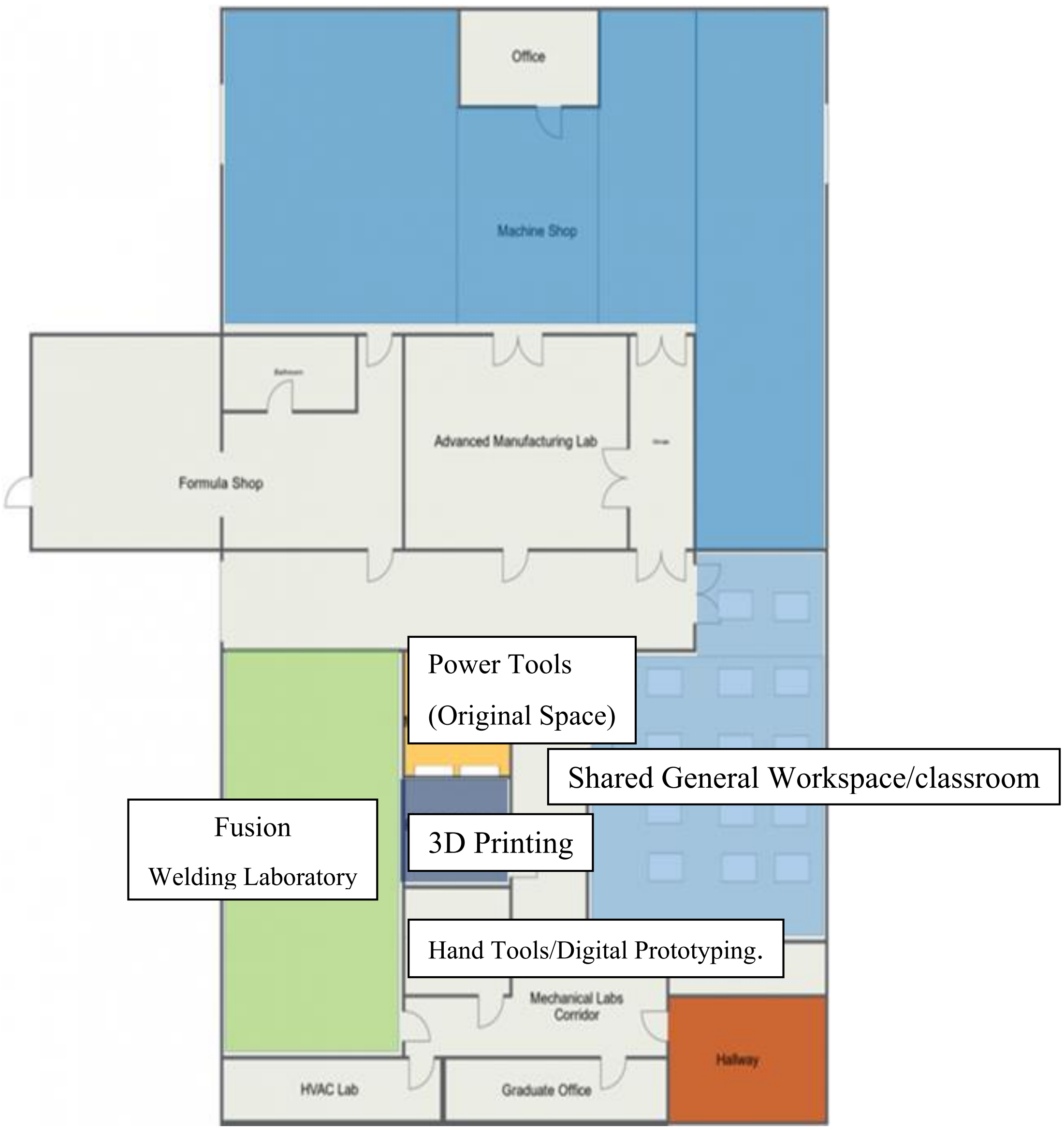

Figure 1.11 Patterson Engineering Laboratories