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An analysis of the current strength of the academic relationship with the aerospace industry

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AN ANALYSIS OF THE CURRENT STRENGTH OF THE ACADEMIC RELATIONSHIP WITH THE AEROSPACE INDUSTRY

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For my parents – Thank you for your love, support, and encouragement of my academic career.

You instilled in me a love for discovery that no one can ever take away.

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TABLE OF CONTENTS

Page

Page

Page

Page

Page

LIST OF TABLES

Table Page

LIST OF FIGURES

ABSTRACT

Stratton, James A. Ph.D., Purdue University, August 2016. An Analysis of the Current Strength of the Academic Relationship with the Aerospace Industry. Major Professor: Richard Mark French

The objective of this research was to discover which methods of technology transfer were most commonly accessed within the Indiana manufacturing sector in an effort to best serve companies in the Hoosier State. Previous work has explored the perceived importance of various academic sources, but there has not been an investigation to identify the specific preferences of industry professionals. If these preferences can be identified, university assistance programs and other academic engagement programs will be able to predict, and hopefully influence how to grow and develop the domestic manufacturing sector, ultimately strengthening the channels of knowledge transfer between academia and industry. In order to properly assess the current preferred methods of technology transfer and the industrial interaction with academia, a survey was conducted with a highly technical company to establish the magnitude of the dependence industry has on academia, as well as the magnitude of any partnerships that may exist. A five (5) question survey was disseminated to R&D and engineering personnel at the Rolls-Royce facility in Indianapolis, Indiana. Rolls-Royce was chosen as the focal point for this study due to their large employment population, R&D capabilities, and the breadth of their manufacturing abilities. The data obtained from the survey found that online encyclopedias are the most preferred source of technical information among the participants. The results of this study were then used to infer possible solutions to the shortcomings of the status quo, and to suggest what changes could be made to strengthen the academic partnerships that most positively impact industry.

CHAPTER 1: INTRODUCTION

This chapter establishes the scope and direction of the research conducted for this dissertation. It also provides the basis for the research questions and the significance of the research contained within. A list of assumptions, limitations, and delimitations is also provided.

1.1 Background

The Technical Assistance Program (TAP) at Purdue University is a state funded program that provides technical assistance to any company with a physical facility located within the state of Indiana. The goal of TAP is to stimulate and foster industrial growth by engaging university faculty and students with the private sector through consulting activities. As a graduate student, I was employed through TAP as a graduate research assistant for seven years during the course of my studies. In my experience, the companies with which I consulted rarely interacted with academia for technology transfer and knowledge adoption purposes. Activities, ranging from simply accessing academic journal articles to engaging in fully developed research partnerships were rarely observed during my travels. This observed lack of industrial participation in academic resources led me to believe that this limited level of knowledge transfer could perhaps be more pervasive among a wider range of industries.

It is my hypothesis that companies, of any size or level of technical complexity, do not fully utilize the resources produced by academia. This hypothesized lack of information transfer between the two entities is troublesome, primarily due to the fact that industrial research being performed in academia is intended to supplement, and bolster the U.S. manufacturing sector through the dissemination of technological breakthroughs. If the information *is* trickling towards industry, then by which methods is the transfer occurring? What channels of technology and knowledge acquisition are professionals using to innovate and develop new technology? It is important to seek the answers to these questions to improve the effectiveness of technology and knowledge transfer between academia and industry.

From a narrower perspective, it is important to gauge not only how companies are growing, but also how companies are accessing the innovative technologies developed within academia. It was determined that the most effective way to approach this problem was to examine the academic relationship of a highly technical manufacturing firm. As per the criteria established in Chapter 2, it was deemed important to investigate a company that was highly technical, had the capital to perform extensive in-house research and development (R&D), and had a large employment population of engineers. After being selected as a viable candidate, Rolls-Royce ultimately agreed to participate in this study. Their Indianapolis location designs, builds, and tests jet engines for both commercial and defense applications. With roughly 4,000 employees, Rolls-Royce provided an excellent synergistic opportunity to serve as a focal point for this investigative study. The contents of this dissertation will establish the framework by which this hypothesis was examined, as well as develop a basis to further study the strength of the active engagement between industry and academia.

1.2 Research Questions

The specific questions to be answered by this research are as follows:

1. What are the most influential academic channels for the dissemination of knowledge within the aerospace manufacturing sector of industry?
2. What academic channels are professionals in the aerospace industry most likely to employ while researching an unknown topic?
3. What, if any, barriers exist to accessing academic resources in a non-academic setting?

Academic channels being evaluated are as follows (in no particular order):

- Recent Graduates
- Current/Retired Faculty
- University Partnership
- Assistance Programs
- Trade Shows/Conferences
- Industrial Journals/Periodicals
- Peer-Reviewed Academic Journals/Periodicals
- Review articles
- Online encyclopedias

1.3 Significance

By determining the most effective method for a company to be exposed to new technological resources, we will be able to influence and exploit academic opportunities that were once lost. Not only will this research be of substantial interest to industry due to the bolstering nature of a symbiotic relationship with academia, but it can also guide academia to serve a more fulfilling civic mission. Being that the proposed mission of academia is to foster societal growth through innovation, it is important to uncover and gauge the primary modes of dissemination. Until now, previous studies have only examined the importance of academic resources in industry, rather than the actual usage of academic resources. Moreover, much of this previous work was completed before the internet was considered a prominent and relevant source of academic information. This work will provide much needed modern insight into the current usage rates of academic sources that could potentially alter the methods by which academicians disseminate information; methods of which have remained largely unchanged in an increasingly dynamic academic environment.

1.4 Statement of Purpose

The purpose of this research was to investigate and strengthen the connection between industry and academia by evaluating industry professionals to determine the methods by which they access academic resources in a highly technical manufacturing environment. Through this research, I hoped to not only determine which conduits for knowledge exist, but also what conduits for knowledge were broken. By asking participants in this study to evaluate the extent of their current usage of academic resources, I was able to gauge how well the current system of dissemination is operating.

A hypothetical scenario was also presented, in which participants are asked to determine their likelihood of choosing various academic resources for their employment duties. The combination of these two questions should offer a glimpse at the strength of the current relationship between academia and the aerospace industry, as well as offer insight on where improvements can be made.

1.5 Assumptions

A list of assumptions is as follows:

1. There was a need to strengthen the relationship between academia and industry.
2. Peer-reviewed academic journals are the most common form of technology transfer between industry and academia (Bekkers & Freitas, 2008)
3. Participants in this study were honest and truthful about their usage of academic and non-academic resources
4. Participants were not influenced by predisposed notions of proper research methods.
5. Participants were actively involved in research and development (R&D) or engineering roles for Rolls-Royce.

6. Participants were able to complete the survey in a complete, thoughtful fashion.
7. The sample size of the participants involved was large enough to draw meaningful conclusions from the data.

1.6 Limitations

A list of limitations is as follows:

1. The study was restricted to Rolls-Royce and the divisions contained within.
2. The study was limited by the number of voluntary participants in the survey.
3. The study was limited by the number of R&D and engineering employees at Rolls-Royce.

1.7 Delimitations

A list of delimitations is as follows:

1. Participants of this study were employees of Rolls-Royce.
2. Participants were employed in engineering and R&D departments at Rolls-Royce.
3. Personal contact for follow-up questions with participants will be prohibited for anonymity concerns.
4. The list of academic resources presented to participants was not exhaustive.
5. A time period of one semester for data collection.

1.8 Definition of Key Terms

Current/retired faculty – Professors or staff members that are of personal acquaintance.

Firm – “the name or title under which a company transacts business” (Merriam-Webster, 2001)

Industrial journal – Non-peer reviewed periodical journals for a certain industry or genre (Stankus, 2001).

Online encyclopedia/resource – Online collections of common knowledge and resources (Konig, 2013).

Peer-reviewed academic journal – Periodicals of which the content is refereed by experts in the same field (Guerrieri, 2012).

R&D – abbreviation for Research and Development

Recent graduates – Co-workers or friends who have attended a university in the past five (5) years.

Review article – Often published in academic journals, review articles summarize the base of knowledge for a particular subject or topic (University of Texas - Austin).

STEM – acronym for Science, Technology, Engineering and Mathematics.

TAP – acronym for Technical Assistance Program

Technology – "a manner of accomplishing a task esp. using technical processes, methods, or knowledge" (Merriam-Webster, 2001)

Trade Show – Exhibition organized so that companies in a specific industry can showcase and demonstrate their latest products (Aspers & Darr, 2011).

TTO – acronym for Technology Transfer Office (Andreopoulos, 2000)

University partnership program – Co-funded partnerships between a specific private sector company and a publicly funded university (Lee, 2000).

1.9 Summary

This chapter provides an overview of the study contained in this dissertation, an argument for the scope of the study, the defining parameters, and intended purpose of evaluating the research questions. The limitations and delimitations are important to note, as they define the boundaries of the areas to be explored in the coming chapters, as well as set the stage for the following chapter, in which I will discuss the background research and precursory events that led me to pursue this topic of research.

CHAPTER 2: LITERATURE REVIEW

This section will provide a review of the literature as it pertains to the dissemination of technical knowledge to industry. Topics included will establish the historical aspects related to academia, technology diffusion and significant legislative hurdles, as well as literature pertaining to the current state of the field and potential gaps in the knowledge base of which this study intends to fill.

2.1 Brief History of Academia

The primary objective of higher education, historically speaking, has been to promote the widespread dissemination of knowledge. The word “university” was derived from the Latin phrase, universitas magistrorum et scholarium, meaning simply: a collection of teachers and scholars (Encyclopedia Brittanica, 1911). This fact has remained largely unchanged since the inception of the university. The purpose of the university, however, has changed drastically. What once was a communal philosophical think-tank has evolved into a corporate research machine (Berbegal-Mirabent, Garcia, & Ribeiro-Soriano, 2015; Klofsten & Jones-Evans, 2000). The evolution began in the late 1700s as universities turned to government sources for funding just prior to the industrial revolution. This transition occurred largely over battles of the ego, by which one university would claim prestige over another by claiming that their research warranted government attention (David, 2004). As government sponsored research became mainstream, the new policies now meant that the public needed return on their investment, mainly through the form of economic improvement (Salter & Martin, 2001; Geuna, 2001). The fruits of this evolution became what we now know as the university-industry partnership. Both the academic community and industry alike rely on the research and breakthroughs produced in the academic environment to push the world forward and provide that ever-needed economic boost (Van Dierdonck, Debackere, & Engelen, 1990). While this was not necessarily a devolution of the university mission, it was important that this connection to industry was nourished and exploited; otherwise, the industrial economic implications can far outweigh the benefits gained from academic research. According to the National Science Foundation, Purdue University, alone, spent a combined 600 million dollars in 2014 on R&D (Academic Institution Profiles: Purdue University, 2015). How do we ensure that this money is being invested wisely? We need to ensure that the information developed with these funds is both accessible and beneficial to the U.S. manufacturing sector. As of 2013, the total spent on R&D by U.S. educational institutions topped 67 billion dollars, with roughly 13 percent of that coming from private industry (Britt, 2015). How does this investment trickle towards industry? What are the most influential channels of dissemination for the academic-industrial relationship? The following sections of this chapter will aim to uncover answers to these questions.

2.2 Diffusion of Innovations

To understand the dissemination of knowledge from academia to industry, it will be imperative to uncover the underlying hurdles that exist with technology adoption in general. The most logical place to begin this exploration is with Everett Rogers, an American scholar and sociologist, who studied how technological innovations pertain to the social aspects of society. His work, *Diffusion of Innovations,* is arguably the most important piece of literature when discussing methods of technology adoption and the social barriers associated with adopting new technologies. The reason his work was so monumental to the field was due to the fact that no one had associated technology, diffusion, and the social aspects that tie it all together as a single concise theory. This section will break down the three main components of the "diffusion of innovation" theory: diffusion, change agents, and innovation. Also discussed will be Roger's theory of adopters.

2.2.1 Diffusion

The formal study of diffusion originated in the late 19th century, by a French sociologist named Gabriel Tarde. During the course of his studies of social behavior, namely crowd psychology, Tarde noticed that individuals within the crowd, or group, had a tendency to form independent ideas which ultimately diffused to the rest of the group. This was contrary to the current beliefs that change within crowds or groups happened simultaneously. His new theory stated that many of these diffusions of knowledge were largely centered around technological advances, or inventions, and appeared to be the underlying foundation of social change (Kinnunen, 1996). Moreover, this theory stated that social interaction, on a macro scale, was the driving force behind innovation, and that the interaction between members of a society bred technological novelty. Tarde referred to this as the "law of imitation", after which he named his most notable work, published in 1890. Tarde stated that innovations likely spread through imitation, or repetition, by members of a society observing the technological advantages of a certain innovation. In the most primitive of examples, Tarde analyzes the domestication of livestock for purposes other than food, namely horses. The realization that horses could be used as a tool, or method of transportation, came long after their initial purpose as a source of sustenance, and the diffusion of this technological breakthrough likely came from observation, or imitation, of the horse being used as a utility (Tarde, 1903). Tarde argues than many other forms of livestock domestication, as well as cultivars, can be attributed to imitation sparked by "accidental" innovations.

However, this is where Tarde garnered criticism from both sociologists and anthologists alike. How could two seemingly isolated societies come to the same logical conclusions despite having never met? The opponents argued that these were merely coincidences, and that the geographical distances between isolated civilizations could easily debunk his theory. Tarde countered this with the notion that his opponents were assuming that time was irrelevant, when in reality there existed a real possibility that the diffusion of these "coincidences" was the result of a "gradual prolonged" imitation and that the "immense duration of prehistoric times" must be considered (Tarde, 1903). For example, Tarde's theory of imitation could be used to explain the relationship between two civilizations that used flint to start fire, much the same way Darwin's theory of evolution could be used to explain the relationship between two remote species of flightless birds. While both are separated by inconceivable distances, and time, their relationship can be explained through a single common ancestral factor. In other words, diffusion, while dependent on imitation, may not be as direct and instantaneous as previously thought, but was nonetheless diffusion.

Everett Rogers expanded on Tarde's work in the mid-20th century by studying the rate of diffusion with respect to how quickly individuals adopt an innovation; and by empirically confirming Tarde's theories. Like Tarde, Rogers was a sociologist by trade who studied technology adoption in rural communities. Born and raised in Iowa, Rogers was deeply rooted in the agricultural community and noticed that innovations of any magnitude had a profound effect on the day-to-day lives of people within the farming community. However, contrary to the supposed benefits of these innovations, the diffusion of new and emerging technologies moved rather slowly. One particular case study, performed by Bryce Ryan and Neal Gross (1943), focused on the diffusion of hybrid seed corn between two rural communities in Iowa. Ryan and Gross studied the adoption rates and diffusion methods of this new technology using data spanning roughly 15 years. Their results, in accordance with Tarde's theory, found that the main mode of diffusion was realized through direct communication, and observation, between farmers (Ryan & Gross, 1943). In the beginning, many farmers were skeptical of implementing hybrid seed corn, fearing that such a drastic change in practices would be detrimental to their yield, possibly harming their livelihood. However, a select few decided that the proposed benefits might be worth the risk. Year after year, as word spread between farmers, new farmers gradually began to adopt the hybrid seed varieties until the vast majority of farmers in the area had fully adopted hybrid seed corn over the traditional strains. While not expressly stated by Ryan and Gross, this theory of adoption was expanded upon, and ultimately became the basis for Rogers work. Rogers studied the rate of adoption in relation to individuals' willingness to assume the risk, and assigned adopters into five categories: Innovators, early adopters, early majority, late majority, and laggards (Rogers, 1983). He found that, contrary to his opponents' beliefs, the rate of adoption was independent of profitability, and rather based on a social construct of perceived economic benefit (Havens & Rogers, 1961). In other words, the innovation required more than just the upfront profitability in order to diffuse through a group. The perception of profitability was just another cog in the social constructs of the theory of diffusion. Regardless of profitability, farmers still adopted the innovation in a systematic fashion, adhering to the categories of adopters. Definitions of these categories, as described by Gallaher and Wentling (2004), can be found in Table 2.1.

Table 2.1
Descriptions of adopter categories proposed by Rogers (Gallaher & Wentling, 2004).

Adopter Category	**Description**
Innovators	Innovators are very eager to try new ideas. There are three primary prerequisites for being an innovator: (a) control of substantial financial resources to off-set the cost of unprofitable innovations, (b) the ability to understand and use complex technical knowledge, and (c) the ability to handle the high level of uncertainty about an innovation when the innovator adopts. The innovator plays a significant role in the diffusion process by introducing the idea or technology to the social system.
Early Adopters	Early adopters are a more integrated faction of the local social system than innovators. Early adopters are exceedingly ahead of the average individual in innovativeness. Because of this, the early adopter is respected by peers and viewed as a role model in the social system. Prospective adopters seek out early adopters for information and advice about an innovation.
Early Majority	The early majority adopt a new idea right before the typical member of a social system. A lengthy period of deliberation may occur before the early majority adopts an innovation. Consequently, the innovation-decision period is relatively longer than that of the innovator and the early adopter. The early majority make up approximately one-third of the members of a social system.
Late Majority	The late majority adopts an innovation shortly after the average member of a social system. Like the early majority, the late majority make up one-third of the members of a social system. Individuals that fit this category often adopt because of economic necessity and mounting network pressure from peers. The innovation must become part of the system norms before this group will consider adoption.
Laggards	Laggards are the last few in a social system to adopt an innovation. The only point of reference for the laggard is the past. Decisions are based on the history of what has been done previously, they rarely have any opinion leadership and many are near isolates in social networks. When laggards finally adopt an innovation it has often been displaced by a new idea that is already being used by innovators.

In addition to these basic definitions of adopter categories, Rogers also proposed that the rate of adoption resembled a bell-curve. According to this framework, the innovators are represented as the first 2.5% of the population to indulge in an innovation. This is determined by subtracting 2 standard deviations from the mean. The early adopters are calculated as being 13.5% of the target population and can be calculated as being between 1 and 2 standard deviations off of the mean. The early and late majorities, which individually represent 34% of the population, are calculated as the mean plus or minus 1 standard deviation. The laggards, which make up the remaining 16% of the population, can be calculated as 1 standard deviation above the mean or greater. Although the categories are not symmetrical, Rogers felt the distinction between innovators and the early adopters was crucial, and therefore cumulatively represent the same portion of the population as laggards. An illustration of this framework can be seen in Figure 2.1.

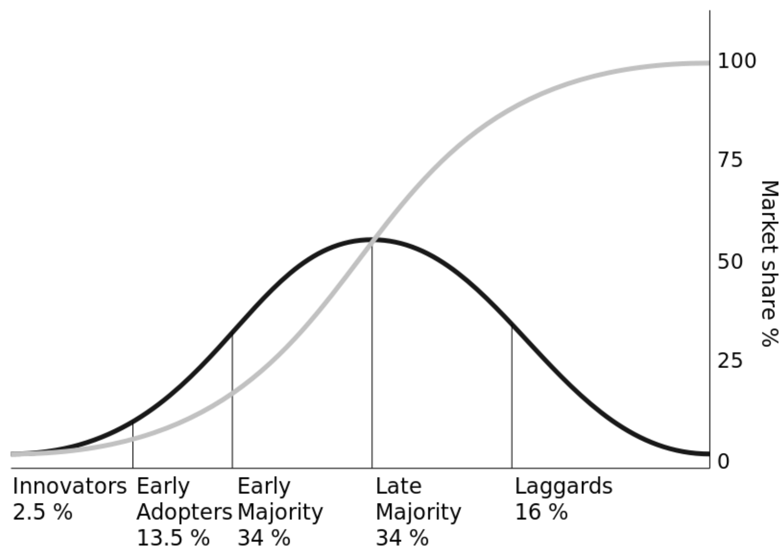

Figure 2.1: Illustration of the adopter categories as a proportion of market share, as proposed by Everett Rogers (Diffusion of Ideas, 2012).

2.2.2 Change Agents

For any new technology to be adopted, there needs to exist the change agent. The change agent is the entity that presents an innovation and can be a person, company, or in the case of this research, an academic institution. According to Rogers, there would not be a need for such a change agent if not for the barrier between the social and technological constructs of society (Rogers, 1983). The social norm, or status quo, handles slow evolutional changes much better than rapid revolutionary changes. Change agents challenge the status quo with innovations, discussed in the next section, which are typically deployed at a much faster rate than they system can handle, and therefore, are often faced with initial rejection and hesitation (Johnson, Gatz, & Hicks, 1997). This requires the change agent to distance itself from its own social construct, and either reinforce or recruit others to take initiative to adopt the innovation (Battilana & Casciaro, 2012). In the case of an individual acting as the change agent, this can mean abandoning one's personal social circle, which in itself can be a daunting task. When an institution acts as the change agent, the issue lies more with creating the social constructs that allow for the acceptance of an innovation. Using academia as an example, this could include the publication of research in an attempt to gain traction for a given innovation (Gogan, Belanger, Patriarca, & O'Neill, 2010). While there may still exist some interpersonal and political hurdles within an institution, the academic environment was created by, and fostered with, the innovative mindset (Rusaw, 1998; Comin & Mestieri, 2014). Therefore, with academia as the change agent, the task of technology adoption requires macroscale social changes, whether they are economic, political, religious, or scientific in nature (Godin, 2015; Johnson, Gatz, & Hicks, 1997).

2.2.3 Innovation

Innovation, as defined by Rogers (pg. 11) is "an idea, practice, or object that is perceived as new by an individual or other unit of adoption". Innovation is generally perceived as a positive influence. However, this has not always been the case. Prior to the 18th century, innovation carried a much more ominous meaning. While the definition was not entirely different than it is today, the connotations meant significant disruptions to the powers that be, which at the time were primarily the church and the government; arguably one and the same entity (Godin, 2015).

As with today, innovation typically arrived in the form of scientific, technological, and social advances, all of which were the primary nemesis of the church, and in turn, the social hierarchy of the government. Many associated the term innovation with revolution, which was perceived result of change, or at least rapid change. These innovations violated the core teachings of the church; fundamentals that had been created over centuries. As a result, society was much more comfortable with slow changes, as these typically allowed for the church to adapt. This obstinate social mindset was evident with the persecution of scientists, namely Galileo Galilei, who were the outspoken change agents of the era (Robinson, 2010). Although accepted over time, many of Galileo's postulations were in direct conflict with the current knowledge base and teachings of the church. In fact, the sentiment was so pervasive that this vilification of innovation would continue for centuries.

It was not until the industrial revolution in the late 18th and early 19th centuries that innovation was finally viewed in a positive light. This was the result of two factors. The first being that society had begun to notice the prosperity, and utility, that emerged from scientific, technological, and societal innovations. Although unknown at the time, this social change reinforced the theories of imitation and diffusion proposed by Tarde and Rogers. Secondly, the church, which was accustomed to slow evolutionary changes, had begun to adapt to the ever-changing environment. Change had become so pervasive in everyday life that even the church had begun to notice, as well as accept, the benefits and applications of innovation (Godin, 2015). As society evolved, so did innovation. Technological advances in both academia and industry fueled the industrial revolution, dropping the stigma once associated with innovation; yet, there arose new barriers between academia and industry became in the form of intellectual property and funding. These hurdles will be discussed in Section 2.3.

2.3 Notable Changes in Legislation

Globally speaking, prior to the 1980s the academic setting had primarily been a place for training and educating the general populous. With the exception of the United States, largely due to the scale of our educational system, global academic environments shied away from collaborative research with industry due to concerns over the ownership of intellectual property (Mowery & Sampat, 2004; Welsh, Glenna, Lacy, & Biscotti, 2008). Over the years, industry slowly pushed their R&D duties towards academia for both access to resources and to save costs associated with performing R&D in-house (Markman, Siegel, & Wright, 2008). Academia is the breeding ground for basic research, and for all intents and purposes, the source of many technological innovations (McMillan, Narin, & Deeds, 2000; Lin & Bozeman, 2006). It would only make sense that industry would eventually capitalize on this resource. However, determining ownership of these innovations needed to be addressed.

Due to the already established relationship between academia and industry, the United States pioneered the movement for implementing national policies regarding the ownership of intellectual property created by academic institutions for the private sector. By the mid-20th century, the U.S. private sector had begun to transfer in-house research duties to academia (Markman, Siegel, & Wright, 2008). While this switch in was great for the industrial bottom-line, it did not fully account for the ownership of intellectual property. Before 1980, partnering a university with a private company was difficult to accomplish. Patent laws ensured that the rights to intellectual property created during the course of academic research was owned and maintained by the financier of the research, which, in most cases was the United States Government (Levenson, 2005). Additionally, these IP rights maintained by the U.S. Government were rarely utilized, with roughly 5% actually being commercialized (Schacht, 2012).

Moreover, federal laboratories were also struggling to disseminate their research among the private sector due to legalities concerning confidentiality, licensing, and commercialization (Dorf & Worthington, 1987). Even though the research efforts at national laboratories had peaked after World War II, during the height of the Cold War, the technologies that were being created in these laboratories were not being commercialized (Lee, 1996). While the technologies being created were most certainly groundbreaking, they rarely survived to fruition, let alone commercialization. This was largely due to the fact that the national laboratories were not intended to function as commercial entities, but rather as applied research institutions to develop the technological foundations for classified government applications, often militaristic in nature. Contrarily, industry specialized in commercialization, but not applied research, therefore lacked the resources to conduct the necessary R&D to simultaneously develop similar innovations. The barrier was that industry needed various aspects of these confidential technologies, which often had non-military applications, but no mechanism existed to properly transfer ownership.

The first step towards bridging this gap came in October of 1980, in the form of the Stevenson-Wydler Technology Innovation Act. Named after Senator Adlai Stevenson III (Illinois) and Congressman John Wydler (New York), the Stevenson-Wydler act required that national laboratories must incorporate, into their budget, a way to transfer knowledge to the private sector (Stevenson-Wydler Technology Innovation Act of 1980, 1980). It was observed that certain processes and products created for mission critical military applications might have some relevance in the civilian market, but there did not exist a method to commercialize these technologies. The Stevenson-Wydler Act ensured that these laboratories had an option, and the funds, to properly transfer technology. The act also created the Office of Research and Technology Applications, designed to serve as a fully staffed office dedicated to technology transfer initiatives on a national scale.

Shortly after the enactment of the Stevenson-Wydler Act, congress passed the Bayh-Dole act on December 12th, 1980; a bill sponsored by Senators Birch Bayh (Indiana) and Bob Dole (Kansas). The bill essentially opened the ownership of intellectual property created using federal funds to the university or company participating in its development. Not only did this protect the intellectual property created during the research, but it also provided protection for confidential projects, allowing companies to more freely engage with academia (Bayh-Dole Act, 1980). Now industry could collaborate with academia without the fear of losing their intellectual property. With these two monumental bills, there now existed two *new* pathways for the dissemination of knowledge to industry: National Laboratories → Industry and Academia → Industry.

By the early 1980's, it had begun to appear that the Bayh-Dole act had opened a relationship between two seemingly incompatible entities. However, there was still much skepticism, especially within academia, regarding the intentions of the research being performed for industry. As mentioned earlier, the primary objective of academia is the pursuit of knowledge: This is undeniable. But, industry relies heavily on the "bottom line" and might not be motivated by the same pure intentions as academicians (Abelson, 1982). To further exemplify this disparity, researchers in academia might be solely focused on the scientific method, with no regard for a meaningful timeline, whereas their industrial partners are focused primarily on the profits and expeditiousness of the products being developed by academic R&D (Hall & Scott, 2001). Neither views are fundamentally wrong; they just originate from a differing set of values (Van Dierdonck, Debackere, & Engelen, 1990). As a result, there began to emerge a commercial sector within academia, with the onset of faculty titles such as "associate dean for industry relations" and technology transfer offices (TTO) (Andreopoulos, 2000; Van Dierdonck, Debackere, & Engelen, 1990). These academic liaisons, and specialized offices, are employed to interact with the private sector and develop industrial relationships for collaborative research. While the original intentions were to foster widespread collaboration, they often resulted in focused projects, where particular faculty members were performing specific research for their industrial counterparts (Blumenthal, Campbell, Causino, & Louis, 1996). Although this framework was not indicative of a widespread institutional symbiotic relationship, it has become something transformative for both parties. Even though the projects are more specific, there has been an increase in faculty participation with industry partners (Blumenthal, Campbell, Causino, & Louis, 1996). In fact, a study conducted by researchers at the University of Colorado – Boulder, found that of the 50 U.S. Universities that receive the most U.S. National Institute of Health (NIH) funding, over 50 percent indicated substantial relationships with industry (Watson-Capps & Cech, 2014). Additionally, they found that many universities have moved away from off-campus research parks, and have begun bringing industrial partners directly to dedicated spaces on campus. In 2012, roughly 5,000 patents were granted to U.S. academic institutions by the United States and Trademarks Office, a substantial increase over the mere 1,500 awarded in 1992 (National Science Foundation, 2015). This relationship with industry can be a great benefit to the students through increased opportunities for internships, experience with research practices and ultimately employment prospects (Lee, 2000). Additionally, it forms a bond of trust and co-inhabitance for the university and the industry involved (Watson-Capps & Cech, 2014).

In Europe, similar shifts in academic R&D had been occurring (Geuna, 2001). The wake of World War II had created a surge in academic enrollment, as well as an increase in the number of firms seeking academic assistance for R&D activities. However, the laws pertaining to intellectual property, especially if created in an academic setting, varied greatly between nations. "Professor's privilege", as it is known in many countries, allows the professor associated with innovative *publicly funded* research to maintain the rights to that research (Smith, Dahlstrand, & Baines, 2013; Geuna & Rossi, 2011). In fact, in many cases, even the university forfeits their rights to intellectual property in favor of the professor. Historically speaking, German-speaking and Scandinavian countries had adopted the professor's privilege approach (Geuna & Rossi, 2011). Many opponents have criticized the professor's privilege as a biased policy, since private sector IP laws differ in that ownership is maintained by the parent company, not the individual who created the IP. Meanwhile, other countries have adopted policies similar to the United States, where the ownership lies with the institution or organization that participates in the creation of intellectual property. Additionally, in the United Kingdom, the policies on intellectual property differ from institution to institution. While this does allow for greater competition between universities, the ambiguity of IP ownership legislation may be damaging the industrial-academic relationship (D'Este & Patel, 2007). In some restrictive scenarios, studies have shown that faculty would rather work independently of their institution than forfeit IP ownership, ultimately neglecting their employment duties (Breschi, Lissoni, & Montobbio, 2007; Murray & Stern, 2007). The validity of these concerns, as they pertain to this research, will be discussed in Section 2.6.1.1. Regardless of legislative framework, Europe as a whole is slowly moving away from archaic policies that protect the "professor's privilege" in favor of policies that more closely reflect the Bayh-Dole act.

According to researchers in Taiwan, the rapid pace of research in technological fields had also forced Taiwanese universities to act as the change agent. Again, this shift from industrial to academic R&D was largely due to the rising costs of private research (Lai, 2011). Lai's research findings show that nearly 70 percent of Ph.D. researchers in Taiwan work in Universities, mainly due to the fact that government grants and funding for advanced research are often funneled towards academia, as opposed to industry, with the hopes that the technology transfer will eventually disseminate the findings to all players in a given industry, rather than just a single entity. Likewise, researchers in Korea also found that private corporations were exceedingly focused on using the universities as R&D centers for technological innovations (Kim & Normile, 1997). While beneficial for industry, Kim and Normile (1997) found that this shift in funding sources was actually a source of friction among the academic community. A 1992 Korean law gave funding priority to research projects that entailed collaboration with industry (Kim & Normile, 1997). As a result, the funding for basic research began to stagnate. This became a major source of contention for academics that felt that the purpose of the university was to fund basic research, not applied research in collaboration with industry. However, the Korean private sector saw the value of applied research and the benefits it could have on their growth and long-term success. The flow of new knowledge was much more direct; therefore the dissemination of technology was expedited on a national scale.

These international trends show that during the last few decades of the 20th century, there was a massive shift in not only the type of research being performed in academia, but also how this research was being funded and credited. Various forms of legislation have bolstered the industry-academia connection by creating smoother transitions for knowledge transfer between the two entities. Now that these pathways exist, it will be important to study impacts of each specific channel to determine the most efficient medium by which information transfers.

2.4 Technology Transfer vs. Technology Diffusion

In order to gauge the flow of knowledge from academia to industry, there needs to be some insight into the interpretation and definitions of the terms technology transfer, and technology diffusion. Many use the terms interchangeably, and apply them to a myriad of concepts (Stewart, 1987). Liu, et. al. (2010), state that technology transfer refers to the macro-sense of the adoption process, and are deliberate in nature, while technology diffusion refers to the unintended side-effects of technology adoption (Liu, Fang, Shi, & Guo, 2010; Stewart, 1987). For example, technology diffusion would be applicable to a product hitting the market, and selling to the general public, whereas technology transfer would be the widespread dissemination of the knowledge required to reproduce that product. This is further reinforced in Everett Roger's work, where he states that diffusion, unlike transfer, requires the cultural and social aspects of society, in the form of adopters, conform to a new technology in order for the widespread adoption of said technology to exist (Rogers, 1983). Rose and Joskow (1990) state that diffusion is dependent on economic factors. For example, larger companies, or individuals who are wealthy, will often be the first to adopt new technology for the simple fact that there is a greater chance for expendable capital. Once a smaller competitor observes the benefits of the adoption, their conformity with the new technology is inevitable, implying that the diffusion, or local effects, are also greatly influenced by economic factors (Rose & Joskow, 1990). While this relationship is not surprising, it should be duly noted since this research aimed to study R&D professionals at a major aerospace firm: Rolls-Royce. Furthermore, the purpose of this study was to gauge the strength of technology transfer by gauging the industrial-academic relationship. To accomplish this, I will be examining which academic resources are most commonly used within such a highly technical firm.

2.5 Types of Academic Resources

Being that the ultimate goal of this research was to gauge the relationship between academia and industry, it was imperative that this literature review dissect, and investigate the academic resources that are available to industry, which have been summarized into three broad categories: people, programs and events, and literature.

2.5.1 People

Interpersonal relationships can be a tremendous source of information. One suspected influential connection between academia and industry exists between former professors or recent graduates and members of the work force (Cohen, Nelson, & Walsh, 2002). This relationship is typically referred to as “academic engagement.” This channel has the potential to provide a more direct source of information, where the person in industry would contact a member of the faculty or recent graduate for information regarding a new technology or technique. According to

Rogers (2003), social learning can be a driving factor in technology diffusion. Social learning theory states that humans learn and transfer knowledge quite effectively through interpersonal relationships (Bandura, 1971). With respect to this research, this would include any direct contact between employees of Rolls-Royce and people associated with an academic institution. These personal relationships come in two forms: informal and formal (Bonaccorsi & Piccaluga, 1994). Informal relationships are those which occur outside of any formal written agreement. This could include the direct communication (email, phone call, social media, etc.) or face-to-face meetings between employees of Rolls-Royce and current/former faculty, students, or colleagues (Bekkers & Freitas, 2008; Cohen, Nelson, & Walsh, 2002; Smith, Gopalakrishna, & Smith, 2004). Research shows that informal contacts often have the highest degree of potential knowledge transfer between academia and industry (Meyer-Krahmer & Schmoch, 1998; Ponomariov & Boardman, 2008). Formal relationships, in a similar fashion to informal relationships, typically consist of direct communication or face-to-face meetings, but with a formal written agreement between the two parties. This could include cooperative research, consultancy, and the exchange of personnel (Bekkers & Freitas, 2008; Bonaccorsi & Piccaluga, 1994; D'Este & Patel, 2007). Often, due to the value of informal contacts, formal agreements are often made between the private sector and academicians in an effort to secure the flow of knowledge (Bozeman & Gaughan, 2007; Amara, Landry, & Halilem, 2013). Due to the importance of these personal relationships, it is imperative that they are included in this study.

2.5.2 Programs and Events

This category is rather broad, but in the context of this research, programs refer to any academic partnerships or assistance programs offered by, or employed in cooperation with an industry counterpart, whereas events refer to an industry-specific trade show or exhibition.

Partnership and assistance programs are a great resource for the private sector. The most common reasons for partnership were compiled by Lee (2000). This list concisely summarizes the industrial benefits of partnering with a university.

- To solve specific technical or design problems
- To develop new products and processes
- To conduct research leading to new patents
- To improve product quality
- To reorient R&D agenda
- To have access to new research (via seminars and workshops)
- To maintain an ongoing relationship and network with the university
- To conduct "blue sky" research with no specific application in mind
- To recruit university graduates

Utilizing either a partnership or assistance program is highly dependent on the scale and duration of the needs at hand. Generally speaking, partnership programs are oriented towards long-term, complex projects which require large amounts of capital and are focused primarily towards R&D activities (Berbegal-Mirabent, Garcia, & Ribeiro-Soriano, 2015). Assistance programs are reserved for short-term, small-scale issues that can be handled by a small team of researchers. Research has shown that roughly 26% of faculty members participate in some capacity with partnership programs, while 22% manage their projects through assistance programs with consulting arrangements (Lee, 2000). Examples of these, as pertaining to Purdue University, would be the Rolls-Royce/Purdue Research Aerospace District and the Purdue Technical Assistance Program, respectively.

The Purdue Research Aerospace District was a joint venture between Rolls-Royce and Purdue University established as an on-campus, long-term, aerospace R&D center (Purdue

University, 2015). Co-funded operations, such as this, are collaborative efforts designed to incubate the latest aerospace technologies and companies in an active research environment. Not only does it provide an active learning center for students and faculty, but it gives the industry access to the latest equipment and resources, not to mention the added benefit of potential future employees.

The Purdue Technical Assistance Program (TAP) specializes in managing compact, goal-specific projects on a short-term basis. As with many assistance programs, the client, or firm working with the university makes little or no investment in the research being conducted. Instead, as is the case of the Purdue Technical Assistance Program, funding is subsidized through both the state and federal government in an effort to bolster local manufacturing operations. The trade-off is increased economic benefit for the state. However, in addition to providing manufacturing assistance, many assistance programs also offer training, education, and certification courses at little or no cost to the client. Perhaps the greatest benefit of assistance programs is the tendency for future work and engagement from the connections gained from pro bono collaboration with industry.

Lastly, there are many events in which both industry professionals and academics can engage and share ideas and information. Specifically, trade shows and exhibitions offer an all-inclusive venue for industry professionals to view and engage with relevant industrial and academic players to learn about emerging products and technologies in a given field. These shows and exhibitions are often frequented by industry experts and academicians alike, creating opportunity for technology diffusion, as well as technology transfer, due to the public nature of the exhibition. Researchers from Sweden studied this diffusion, and ultimate transfer, using the surge in digital signal processing (DSP) techniques in the 1990's (Aspers & Darr, 2011). Being that DSP was still an emerging technology, Aspers and Darr (2011) were able to study how trade-shows facilitated the exposure of this innovation. They found, in accordance with their theory, that the trade show environment provided the social interactions necessary to facilitate proper diffusion (Aspers & Darr, 2011). Recall that, according to Rogers, social interaction is the driving force behind the diffusion of innovation (Rogers, 1983). Trade shows and exhibitions provide this on a much larger scale (Smith, Gopalakrishna, & Smith, 2004). While it should be noted that these events do not offer the same frequent access as other academic resources, the impact on the overall academic-industrial connection may be far greater but in a shorter amount of time than other resources. For this reason, trade shows and exhibitions will be included in this study.

2.5.3 Literature

Literature, in terms of published academic resources, is arguably the most abundant resource produced by academia. According to the National Science Foundation (NSF), the United States' academic sector produced nearly three quarters of all publications related to science and engineering in 2011, with the remaining quarter belonging to the federal government, industry, private nonprofit organizations and local governments (National Science Foundation, 2015). Additionally, of the more than 800,000 STEM articles produced globally in 2011, roughly one quarter were produced in the United States. Ten year trends show that the number of articles produced increases approximately 1 percent each year. So where do we begin to determine what literature to include in this study?

Published literature comes in many forms. In order to limit the scope of this research, it was determined that the most likely used resources in industry would be industrial journals, peer-reviewed academic journals, and review articles, which are often published in both industrial and academic journals.

2.5.3.1 Peer-Reviewed Journals

Probably the most logical place to start is with the peer-reviewed academic journal. After all, publishing in the right peer-reviewed academic journal can make, or break, an academician's career. The peer-review process adds a certain level of validity to a journal, or specific article, by ensuring that professionals in the author's field have reviewed and accepted the content of the research as true and correct (Guerrieri, 2012). Most often, this process is conducted in double-blind manner, meaning the author is anonymous to the reviewers, and vice-versa. However, some single-blind reviews do exist. Another important aspect of peer-reviewed journals is their impact factor. The impact factor is a simple calculation: divide all citations for a specific journal by the total number of citable items in that specific journal over the course of a two year timespan. For example, if the current year is 2016, the most recent impact factors would examine the ratio between physical citations and possible citations for a specific journal for the years 2013 and 2014, but cited during the year 2015 (Holden, Rosenberg, Barker, & Onghena, 2006; Garfield, 1999). Since the ratio is calculated over the course of 2015, final results would not be available until 2016, hence the delay. Developed by Eugene Garfield in the 1960's, impact factors were designed to rate scientific journals on their relevance to their field. Journals with higher impact factors indicate that they are cited more often by experts in a given field, therefore that journal must be highly relevant to that field. Some opponents argue that since impact factors only account for the frequency of citations, not the quality of the content, that it is an unreliable metric for judging the relevance of peer-reviewed academic journals (Holden, Rosenberg, Barker, & Onghena, 2006; Lutz & Hans-Dieter, 2008). Furthermore, as the preferred media shifts away from print, traditional calculations for impact factors are beginning to show some weakness. Garfield suggests a variant of the original impact factor be applied to individual articles, as opposed to the journal as a whole (Garfield, 2001). Regardless of individual opinion on impact factor, the debate on their legitimacy does not pertain to this research; therefore this discussion will be reserved for another study.

2.5.3.2 Industrial Journals

Industrial journals, occasionally referred to as trade journals or trade magazines, are similar to academic journals in that they are a collection of articles that pertain to a specific area of study. However, they differ in that they are typically geared towards a specific industry, rather than a specific field of study. Like academic journals, there are many that employ a peer-review process in an effort to guarantee the subjects being published, but this is not always the case. These journals are often geared towards industry professionals, therefore they are usually written using industrial jargon as opposed to highly scientific verbiage (Stankus, 2001). Furthermore, authors can range from industry professionals to academicians. Perhaps the biggest benefit offered by industrial journals is their ease of access. Many publishers offer their publications at no cost, since most of the revenue comes from advertisements. Others, which are part of societies or trade associations, offer their publications for free with a societal membership. Another substantial benefit is that these resources offer industry specific information in a single concise location. Industrial firms can keep tabs on their sector through a very small number of publications (Stankus, 2001).

2.5.3.3 Review Articles

The last form of literature to be discussed is the review article. Review articles are often published in both academic and industrial journals, so their inclusion compounds the literature category. Review articles are simply literature reviews on a specific topic. Often composed by a number of authors, the review article is a complete summation of the current body of knowledge pertaining to the topic at hand (University of Texas - Austin). According to the University of Texas Libraries, a proper review article will cover the following items:

- The main people working in a field
- Recent major advances and discoveries
- Significant gaps in the research
- Current debates
- Ideas of where research might go next

Review articles are important because they serve as milestones for a specific area of research, and serve as an unbiased entry point to new participants in the field; emphasis on unbiased (Oxman & Guyatt, 1991). Since they are intended to act as the "current state of knowledge", it is imperative that bias has been removed from the authors' stance, addressing only the necessary information for an in-depth review (Oxman, 1994; Tranfield, Denyer, & Smart, 2003). Moreover, review articles can be useful in updating the old guard on new methods and techniques, serving as a form of continuing education (Palermo, 2013).

Online encyclopedias, like Wikipedia, are essentially collections of unverified, crowd-sourced, review articles (Konig, 2013; Guldbrandsson, 2014). Some other notable examples might include Scholarpedia, Citizendium, and MSN Encarta. While similar in nature to websites like Wikipedia, these examples have varying levels of content accuracy, as well as access fees, but the overall premise is the same. Nevertheless, regardless of reputation, Wikipedia is by-far the most popular of the options listed due to the amount of content and free access (Guldbrandsson, 2014). Even though most of the content on Wikipedia has origins in academia, and references are provided with each article, the content is not verified by any official peer-review panel; therefore it often is considered unreliable. The biggest success of Wikipedia has been the number of content contributors. Since anybody can edit their articles, the amount of unique contributors is part of the reason why Wikipedia has been so successful; content is always refreshed (Konig, 2013). This is also a major reason why it has the reputation as an incredible source. Unlike a peer-reviewed journal, anybody can alter the content; therefore each entry cannot be screened for bias. This means that access to Wikipedia's content requires in-depth scrutiny of the information at hand.

2.6 Current State of the Field

As has been stated numerous times, the purpose of this research was to measure the strength of the university-industry relationship; in particular, which academic resources have the greatest influences on industrial professionals. In order to properly set the stage for this argument, it is necessary to uncover current literature outlining this relationship, as well as the predicating factors involved in fostering healthy collaboration. There appears to be a significant gap in the literature. Much of the research thus far had been studying how direct contact with industry enabled the flow of knowledge. This provided an important first-step to gauging how academic resources are being used, as it established a framework by which to determine an institution's overall propensity for knowledge transfer. Using this baseline, we should expect technical, engineering based industry to have a relatively strong connection with academia through personal connections, partnership programs, and literature based resources (Bekkers & Freitas, 2008; Shartinger, Rammer, Fischer, & Frohlich, 2002). The specifics of these key studies are discussed in the following sections.

2.6.1 Commercialization vs. Academic Engagement

One of the most prevalent topics returned during literature searches in the field of university-industry relationships is the debate between commercialization and academic engagement. While both are technically forms of university-industry collaboration, they each have unique characteristics that define their place in the academic relationship with industry.

2.6.1.1 Commercialization

In the context of this research, commercialization can be defined as an academic's incentive, or drive, to research and develop technology for the sole purpose of introducing a new product to the market (Etzkowitz, Webster, Gebhardt, & Terra, 2000; Klofsten & Jones-Evans, 2000). This form of engagement with industry would be most synonymous with technology diffusion, since the products being developed are being distributed directly to the consumer base.

Commercialization, as it pertains to the university-industry relationship, is fostered entirely under an academic roof and then applied in industry, thus completing the connection between the two entities. Typically, this process is achieved through the patenting of discovered technologies in an academic setting. As discussed earlier, the practice of product commercialization was largely introduced to academia through, and facilitated by, the Bayh-Dole act of 1980. Commercialization in academia is actualized through two main channels: the results of funded research or the collaboration with industrial partners. When evaluating both scenarios, it can be seen that a plausible outcome of research, be it federally or privately funded, would be the actualization of new or novel technologies worthy of patent recognition. While not a primary goal, it is often the case that advanced academic research yields many breakthroughs that can be exploited and commercialized, essentially making the academic setting a maturation chamber for start-ups and academic entrepreneurs (Bercovitz & Feldman, 2008). Alternatively, collaboration with industry can also lead to the commercialization of products, resulting in a shared patent between the university, researcher, and private institution (Etzkowitz, Webster, Gebhardt, & Terra, 2000). In essence, the university is acting as the R&D department for their industrial counterpart, with the ultimate goal being shared commercialization (Berbegal-Mirabent, Garcia, & Ribeiro-Soriano, 2015). In many cases, this type of symbiotic research is funded through non-conventional means, e.g., access to equipment or resources, which can be very beneficial for the private firm. When collaborating with private industry, academics gain experience, connections, and ultimately, albeit rarely, the opportunity for commercialization (Fabrizio & Di Minin, 2008; Mansfield, 1995). This provides a significant advantage to the principal investigators, since the risk of commercialization or starting a business based off of an awarded patent is divided amongst all participating members. However, although the occurrence of a university-based startup is rare, the survival rates are typically much higher. When compared to non-academic start-ups, the survival rate of university-based startups is roughly 70 percent (based on data since the passage of the Bayh-Dole Act of 1980), whereas non-academic startups survive only 10 percent of the time (Di Gregorio & Shane, 2003).

Some studies show that commercialization through the production of patents in an academic setting has an inconsequential impact on technology transfer to industry and the overall academic mission. (Agrawal & Henderson, 2002). In many cases, the options are simple: patent or publish. Some argue that with a focus on monetary gain, the fundamental research in the basic sciences become overlooked (D'Este & Patel, 2007; Breschi, Lissoni, & Montobbio, 2007). Additionally, data has shown that faculty members who are focused on commercialization tend to neglect their traditional academic duties (Crespi, D'Este, Fontana, & Geuna, 2011). One fear is that if faculties merge their ideals towards commercialization, then the dissemination of publicized research falls to the wayside (Louis, Jones, Blumenthal, & Campbell, 2001). This is corroborated by a study conducted with 62 universities. Researchers found that 71% of academically based inventions require long term participation on behalf of the faculty in order to survive to commercial fruition (Toole & Czarnitzki, 2010). This prolonged attention to outside entrepreneurship could mean less attention is devoted to basic research and teaching responsibilities (Gulbrandsen & Smeby, 2005). Moreover, faculties might hesitate on publishing new and relevant information for fear that the novelty of their research will be made publicly available, thus diminishing their ability to secure a patent (Campbell, Clarridge, Gokhale, &

Birenbaum, 2002; Gulbrandsen & Smeby, 2005). This thought process creates a significant delay in the dissemination of knowledge to industry and the general public since patent applications can take years to process (Breschi, Lissoni, & Montobbio, 2007; Huang & Murray, 2009). Multiple studies have found that entrepreneurial faculty, especially in technical scientific fields, publish less and engage with industry on fewer occasions when pursuing patentable research; this ratio also drops when private funds exceed two-thirds of the a universities research budget (Crespi, D'Este, Fontana, & Geuna, 2011; Perkmann, King, & Pavelin, 2011). The connotations of this interaction are debatable since both activities can be considered a form of engagement. Nevertheless, the possible effects should be noted as a possible barrier to a successful university-industry relationship through a decreased amount of publications.

2.6.1.2 Academic Engagement

Academic engagement, on the other hand, refers to the propensity of the faculty to participate with industry from a number of fronts, one of which could be commercialization (Perkmann, et al., 2013). With relation to technology transfer and technology diffusion, academic engagement would be akin to technology transfer. That is, the university-industry relationship is fostered simultaneously between two or more parties, rather than a single-sided entrepreneurial endeavor. This would be exemplified by the dissemination of knowledge in a manner that allows for the re-creation, or widespread understanding of an innovation as it pertains to the definition established in Section 2.4.

Recalling the types of relationships discussed in Section 2.5.1, personal academic engagement can be both informal and formal. According to Perkmann et al. (2013), the primary formal engagement activities would include “collaborative research, contract research, and consulting,” whereas the informal engagement activities would include “ad hoc advice” and networking with industry (Bonaccorsi & Piccaluga, 1994). Specific example of formal activities may include research parks, technical consulting services, and on-campus corporate sponsored laboratories. Examples of informal activities may be as simple as contact with previous colleagues, former students, and network connections with common research interests (D'Este & Patel, 2007; Cohen, Nelson, & Walsh, 2002). Many universities, across the United States and Canada allow for faculty participation with outside consulting activities, whether it be in the form of formal or informal engagement; the theory being that these connections produce long-term relationships with industry partners (Amara, Landry, & Halilem, 2013). These personal relationships are the foundation of academic engagement.

Personal academic engagement activities are facilitated through specialized university offices, briefly discussed in Section 2.4. Although the nomenclature varies, common examples would include TTOs, offices for outreach and engagement, and the like (Van Dierdonck, Debackere, & Engelen, 1990; Bercovitz & Feldman, 2008). At Purdue University, a specific example would include the Office of Engagement and the Office of Technology Commercialization. In many institutions, these offices are responsible for managing existing university-industry partnerships, as well as developing and fostering the pathways to transfer the knowledge created within the institution to various industrial and social partners (Perkmann, et al., 2013). Academic engagement is considered to be the one of the most influential forms of knowledge transfer between industry and academia (Cohen, Nelson, & Walsh, 2002). Therefore, it is imperative that these personal relationships, and outreach entities are included in this study. The specific association between commercialization and academic engagement will be discussed in the following section.

2.6.1.3 The Relationship

While commercialization and academic engagement are interrelated, it is important to evaluate the relationship that each has on the transfer of knowledge. Commercialization has been coined by some as the “third-mission” of academia (Etzkowitz, Webster, Gebhardt, & Terra, 2000; Florida & Cohen, 1999; Martinelli, Meyer, & Tunzelmann, 2008). Therefore, in addition to research and teaching, economic development would encompass the proverbial third pillar of academia. While this academic entrepreneurial trend is being witnessed in many developed nations, the primary focus of this literature review will focus on the impacts it has had on U.S. universities (Rothaermel, Agung, & Jiang, 2007; D'Este & Perkmann, 2011). By incentivizing faculty to produce intellectual property, the universities have been able to supplement research costs through the commercialization of products discovered during these research activities, even though the payoff is typically sporadic and unpredictable. Nonetheless, over the years there has been an ever increasing push for economic development in academia. As discussed in the previous section, this can be witnessed through the addition of specific academic offices related to technology transfer, commercialization, entrepreneurship, and research development (Bercovitz & Feldman, 2008). Without these administrative services, the opportunity for engagement would land solely on the faculty, likely inhibiting any further engagement; the exception being consulting services, which have been shown to be significantly self-supporting (O'Shea, Allen, Chevalier, & Roche, 2005; Owen-Smith & Powell, 2001; Amara, Landry, & Halilem, 2013). As a result, in accordance with the increase in commercialization-specific offices, there has also been a sharp increase in the number of individual faculty listed on U.S. patents over the past few decades (Azoulay, Ding, & Stuart, 2007; Markman, Gianiodis, Phan, & Balkin, 2005). Not only do these awarded patents provide industrial outreach and engagement for the faculty, but they provide a certain level of prestige to the university (Sine, Shane, & Di Gregorio, 2003). Though, even given these advantages, not all faculties, across all demographics, are participating in commercialization practices equally. In fact, some data show that the majority of engagement is performed by a minority of academicians (D'Este & Patel, 2007). Predictors for participation include: the individuals reputation, seniority, age, field of study, as well as the institution's reputation, resources for commercialization, and active participation in research (Azoulay, Ding, & Stuart, 2007; Boardman, 2008; Boardman, 2009). Historically speaking, institutions with specialized colleges in the STEM fields have the highest propensity for producing intellectual property in the form of U.S. patents (Di Gregorio & Shane, 2003; Martinelli, Meyer, & Tunzelmann, 2008). Land-grant institutions in particular are champions of this endeavor due to a long relationship with the agricultural community (Welsh, Glenna, Lacy, & Biscotti, 2008; Liu, Fang, Shi, & Guo, 2010). Furthermore, universities that emphasize polytechnic and engineering research tend to show higher levels of knowledge transfer through partnership programs, cooperative R&D and consulting activities than their liberal art counterparts (Berbegal-Mirabent, Garcia, & Ribeiro-Soriano, 2015; Klofsten & Jones-Evans, 2000). While this does not come with much surprise, as a majority of patents are technically based, it does offer some insight into the types of universities which show the greatest likelihood of interacting with industry.

From a demographical standpoint, it was found that younger faculty members tend to participate in commercialization, whereas the older faculty tend to engage with industry (Amara, Landry, & Halilem, 2013; Klofsten & Jones-Evans, 2000). Though the specific reasons for this are unclear, there have been some correlations that show that older faculty members are better connected through professional networks and have more secure positions as a result of tenure, therefore find it easier to connect with a wide range of industries and risk the time necessary to foster those relationships (Haeussler & Colyvas, 2011). Although, some older faculty struggle if they were hired as faculty before engagement was an institutional focus (Louis, Blumenthal, Gluck, & Stoto, 1989). Contrarily, younger faculty who were trained with this entrepreneurial mindset focus more on commercialization due to their relatively weak professional network (Bercovitz & Feldman, 2008; D'Este & Patel, 2007). With respect to gender, it was found that women generally contribute less to engagement with industry, although this is most likely due to the fact that women represent a smaller proportion of faculty in STEM fields (Ponomariov, 2008). Again, these trends are noted purely as a form of discourse, but should be noted nonetheless as they help define the relationship between widespread academic engagement and the propensity for faculty involvement.

2.6.2 Academic Resources in Industry

The most comprehensive study on this topic was performed by Bekkers and Freitas (2008). In this study, the authors investigated various academic outputs, and their perceived importance within R&D disciplines across four Dutch industrial sectors: pharmaceuticals and biotechnology, chemical (excluding pharmaceuticals), electrical and telecommunications, and machinery, both basic and fabricated (Bekkers & Freitas, 2008). These results were compared to an identical survey disseminated to academicians in similar fields. Bekkers and Freitas (2008) were trying to determine if industry professionals valued the same resources as academics. If academicians value certain academic outputs that differ from the values of industry professionals, then an important disconnect is directly apparent.

To establish a set of outputs, Bekkers and Freitas consulted the literature to determine the most popular modes of knowledge transfer. Many sources agreed that the most important academic outputs are academic publications and patents (Bekkers & Freitas, 2008; Narin, Hamilton, & Olivastro, 1997; Nilsson, Rickne, & Bengtsson, 2010). Other sources deemed important were collaborative and contract research (Meyer-Krahmer & Schmoch, 1998), and informal contacts, such as current/former students, faculty or colleagues (Cohen, Nelson, & Walsh, 2002; Nilsson, Rickne, & Bengtsson, 2010). It was observed, while examining the various studies, that different industries appeared to value different sources of knowledge. Bekkers and Freitas (2008) state that among the aerospace industry, the literature shows that collaborative research is most valued, whereas publications, conferences and informal contacts were found to be important across many specializations (Cohen, Nelson, & Walsh, 2002). Most importantly, patents were only found be important in the pharmaceutical industry (Bekkers & Freitas, 2008). Using this literature as a template, we were able to narrow down a short list of resources to investigate. This list will be discussed further in Section 3.3.

The survey created by Bekkers and Freitas (2008) to gauge the importance of the various academic resources asked two questions: (Q1) have you used this resource and (Q2) how well do you feel it transfers knowledge? The responses were tallied to create a summary of which academic sources were perceived to be most important. In descending order, industrial R&D performers found the most important sources to be (1) scientific publications, (2) professional publications, (3) patent texts, (4) personal contacts and (5) university graduates (B.S. and M.S.) as employees. Likewise, academics found (1) scientific publications, (2) personal contacts, (3) university graduates (Ph.D.) as employees, (4) conferences and (5) financing of Ph.D. projects to be the most important, also in descending order. A summary of these results can be seen in Table 2.2.

Table 2.2
Results from Bekkers and Freitas (2008) summarized. This table shows which academic resources had the HIGHEST perceived value.

	Perceived Importance of Resources to:	
Rank	**Industry**	**Academia**
1	Scientific publications	Scientific publications
2	Professional publications	Personal contacts (informal)
3	Patent text	University graduates (Ph.D.)
4	Personal contacts (informal)	Conferences
5	University graduates (B.S. & M.S.)	Financing of Ph.D. projects

It is interesting to note that the hierarchal order of the results from both academia and industry do not match beyond the resource perceived most important. Additionally, according to the raw data, the individual scores for each category were higher for all academic categories, meaning that academicians perceive all academic resources more favorably than their industrial equivalents. It should also be noted that the researchers did not account for any online academic sources of information, which today may have scored much higher on the list of resources perceived important by R&D professionals. When looking at the differences of perceived importance, there are a few sources that drastically varied in importance between industry and academia. The items which were ranked as having the lowest importance are summarized in Table 2.3.

Table 2.3
Results from Bekkers and Freitas (2008) summarized. This table shows which academic resources had the LOWEST perceived value.

	Perceived Importance of Resources to:	
Rank	**Industry**	**Academia**
23	Personal contacts via alumni organizations	Personal contacts via alumni organizations
22	Contract-based training delivered by universities	Knowledge transfer organized by university's TTO
21	Knowledge transfer organized by university's TTO	Licenses of University-held patents
20	Consultancy by university staff	Contract-based training delivered by universities
19	University spin-offs	Patent text

Probably the most obvious difference is the discrepancy between the perceived importance of patents between groups. Industry professionals ranked "patent text" as the 3rd most important resource, while academia ranked "patent text" as the 19th most important resource. For reference, there were 23 total resources evaluated. Bekkers and Freitas (2008) attribute this difference to the fact that patent databases are often more accessible to industry R&D performers. The difference in institutional goals might also explain this difference (Abelson, 1982). The private sector is much more interested in commercialization, and competition, therefore might seek competitors patents for ideas and inspiration.

Bekkers and Freitas (2008) concluded their study by stating that, in a general sense, the sectoral categories studied did not have any significance on explaining which academic resources were favored by each industry, therefore could not be used to explain the preferred flow of knowledge. While there were differences between the perceived importance between industry and academia, these differences were statistically insignificant. According to Bekkers and Freitas (2008), for a company that relies on cutting edge research, or wished to act as an early adopter, they should focus their efforts on obtaining information from academic publications and creating informal contacts through university students and faculty.

2.7 Summary

Does this engagement, or collaboration with industry through commercialization, have a significant impact on the transfer of knowledge between the two entities? How much of the information created in academia supports industrial growth? One thing that none of the literature has seemed to address is whether or not the information being transferred is being transferred through an effective channel. For instance, a litany of academic resources were studied for their perceived importance within R&D fields, both academic and industrial based, but the study did not account for what resources are most frequently used or preferred by industry professionals (Bekkers & Freitas, 2008; Mowery, 2004). The researchers found that both industrial professionals and academics found peer-reviewed journals to be important, but to different degrees. In fact, when comparing items solely based upon “high importance”, the researchers found that industrial professionals found professional and industrial publications to be of highest importance, while academics perceived peer-reviewed journals as the most important resource (Bekkers & Freitas, 2008). While perceived importance does play an important role in determining the most effective pathways for technology transfer, one cannot negate the fact that, regardless of perceived importance, practical application will always persevere. For example, the internet has been, and will continue to be, a great source for largely free information. In a world of open access information, the peer-reviewed academic journal is slowly outdating itself (Martin & Quiros, 2014). While academic journals may have a high perceived importance, the often restrictive access may be a prohibitive barrier to actualization. Another example, as studied by Cohen et al. (2002), shows that in many industries, a majority of the breakthroughs come from within the industry or their direct supply chain, rather than originate in academia (Mowery & Sampat, 2004). Additionally, the overall direct transfer of publicly funded research to the private sector (with the exception of the pharmaceutical industry) was insignificant at best, and the primary diffusion happens through third-party channels (Cohen, Nelson, & Walsh, 2002). By conducting a study to determine actual usage rates, as well as preferred methods of gathering information, this study aims to fill in an important gap in the technology transfer field by determining which academic sources are most used, and most favored by industry professionals.

2.8 What Gap Needs to be Filled?

What is the most influential academic channel for the dissemination of knowledge within the manufacturing sector of industry? What academic channels are professionals in the aerospace industry most likely to employ while researching an unknown topic? What, if any, barriers exist to accessing academic resources in a non-academic environment?

In accordance with the research questions, restated above, there needs to exist a gap in the knowledge base for which these questions can answer. It is evident from the literature on this topic that the gap exists in the context of which academic sources are most commonly accessed by industry professionals. Over the years, legislation has changed to open the pathways of knowledge transfer between the universities and industry. Everett Rogers defined diffusion in a way that opened an entire field of study; the mechanisms of which are very well understood. And, previous work has shown which academic resources are most valued.

The research proposed in this dissertation aims to take this one step further: regardless of perceived value, what resources are most commonly accessed by industry professionals? Not only does this study examine the current influence of academic sources, but it intends to study which sources are preferred by industry professionals. This process might also uncover barriers that prevent professionals from using preferred sources of information.

CHAPTER 3: METHODOLOGY

Using the literature review as a foundation, Chapter 3 discusses the nuances of the methodological approach used to survey industry professionals. The purpose of this research was to strengthen the connection between industry and academia by evaluating industry professionals to determine the methods by which they access academic resources in a highly technical manufacturing environment. In order to properly accomplish this, a quantitative approach was deemed to be the most appropriate method for analyzing the data obtained from this study. Supplemental qualitative methods were employed for the anecdotal evidence provided by respondents of the survey.

This chapter outlines the methods used for this study, including the selection of an industry partner, subject determination, survey method, data collection methods and topics pertaining to the statistical analysis. Conclusions about the aforementioned topics will end this chapter.

3.1 Industry Selection

Rolls-Royce was chosen as the basis for this study particularly for the complexity of the components produced at their manufacturing facility in Indianapolis, Indiana. The literature indicates that firms of larger size, with complex products, have the highest propensity to partner with academia (Bekkers & Freitas, 2008; Rose & Joskow, 1990; Cohen, Nelson, & Walsh, 2002; Pavitt, 1984). These larger firms are also more likely to act as technological innovators (Rose & Joskow, 1990). The Rolls-Royce manufacturing facility in Indianapolis employs roughly 4,000 people, and their aerospace divisions alone generated approximately 13 billion dollars in revenue in 2015 (Rolls-Royce, 2015). Their Indianapolis facility designs, assembles and tests engines for both defense and civil applications. Additionally, Rolls-Royce has a substantial international presence with access to a multitude of technological academic resources. These qualities, as well as being located within the geographical boundaries of Indiana, were the primary reasons for their selection as the focus of this study.

3.1.1 Internal Permissions

The internal permissions for access to Rolls-Royce employees were facilitated through the ProSTAR program at Purdue University. ProSTAR is a non-traditional degree program that partners with industry with a mission to educate full-time members of the workforce. The program was piloted through a partnership with Rolls-Royce and has grown to encompass a number of private sector participants. Once it was determined that Rolls-Royce would be the focus of this study, existing partnerships between Rolls-Royce and Purdue helped to facilitate the deployment of this study. It was determined, through internal channels, that the Rolls-Royce Library & Resource Knowledge Center would provide the best opportunity for the successful implementation of this study. The contacts at Rolls-Royce largely participated in, and facilitated, the successful internal transmission of the survey instrument to qualified Rolls-Royce personnel.

3.1.2 Institutional Review Board (IRB) Approval

In order to survey employees at Rolls-Royce, the research methodology needed to be cleared by the institutional review board (IRB) to ensure that no physical and psychological harm would come to the participants. The IRB determines whether or not researchers will be granted access to work with human subjects by reviewing the survey instrument itself, method of instrument dissemination, methods for the collection of personal data, and the amount of contact time with participants. For this project, IRB approval was sought due to the nature of indirect contact with Rolls-Royce employees. After such review, it was determined that this study was exempt (Category 2) from IRB oversight due to the noninvasive design of the survey instrument. Please refer to Appendix A for the full IRB application and approval notice. Documents included within are the application for Category 2 exemption and permissions from Rolls-Royce to perform research on their employees.

3.2 Participant Selection

The participants for this study were selected by their employment in engineering related positions at Rolls-Royce. Adhering to the scope of the research questions, and results of the literature review, it was determined that the instrument would be applied to professionals working in either engineering or R&D positions (Bekkers & Freitas, 2008). It was our theory that these individuals would be most likely to utilize academic resources in their day-to-day duties while being employed for an aerospace firm. Prospective participants were contacted via email through our Rolls-Royce contact in the Rolls-Royce Library & Resource Knowledge Center. Participation in the study was voluntary. However, Rolls-Royce sponsored an internal incentive in the form of a company gift card in an effort to boost the response rate of the survey. The winner of the gift card was selected randomly from the pool of respondents.

3.3 Resource Selection

As per the literature review, the following academic resources were selected for further investigation. The list was modified to allow for resources deemed most important for the context of this study. While this list is not exhaustive, it encompasses the essence of the university-academic relationship in a summarized form. The following academic resources were selected for investigation:

- Trade show
- Technical assistance program

- University partnership program
- Recent graduates
- Current/retired faculty
- Industrial journal
- Peer-reviewed academic journal
- Review article
- Online encyclopedia/resource

These selections, as adopted from previous studies, were selected for their relevance with industry (Bekkers & Freitas, 2008; Shartinger, Rammer, Fischer, & Frohlich, 2002). Due to the design of this survey instrument, it was not feasible to include all 23 items evaluated by Bekkers and Freitas (2008), so an abridged list was created. Most notably omitted from other studies were patents. Patents were not included in this study due to the complex nature of determining which patents were of academic origin. It was important that the resources chosen were mainly academic in nature. Furthermore, the sporadic nature of patent production in academia establishes an impossible metric for using patent production as a reliable academic output. The specifics of the design considerations for the survey will be discussed in the next section.

3.4 Survey

This section will discuss items pertaining to the survey instrument. These items include the survey style, length, and contents.

It was determined that the most effective way to obtain a meaningful sample size was to employ an internet-based survey using Qualtrics, a software package available through Purdue University. The purpose for using an automated survey tool was for both ease of dissemination, as well as ease of data collection. It was imperative that the survey was easy to access and easy to submit as to ensure the highest possible response rate. In addition to the ease of completing the survey, it was also important to ensure that the survey was short enough as to not inhibit the professional duties of the individuals participating in the study. According to a study conducted by Jepson, et al., it was observed that the response rates of questionnaires distributed to physicians saw a significant drop once the length of the questionnaire surpassed 1,000 words (Jepson, Asch, Hershey, & Ubel, 2005). On the other hand, surveys too short are perceived by respondents to be "unimportant", and can have a detrimental effect on the response rate (Wilson, 2013). Due to the fact that the survey was being distributed to professionals in an engineering field, it was determined that three (3) mandatory questions would provide a sufficient sampling of data without being overbearing to the participants, and the risk of a low response rate was worth meaningful introspection on behalf of the respondents. For additional information, two (2) optional questions were provided on the questionnaire. These questions are discussed in Section 3.4.3.

3.4.1 Survey Style

A survey, as opposed to an interview, was chosen as the primary method of engagement with industry professionals. The respondents' time is important both to Rolls-Royce and to the researchers, so it was imperative that the involvement with Rolls-Royce employees was as minimally invasive as possible to ensure no significant loss of time to Rolls-Royce. Interviews have the potential to be expensive and time consuming, and are best suited for situations where the sample population might be difficult to reach, whereas questionnaires can be crafted to a specific length with an estimated time of completion (Molitor, Kravitz, To, & Fink, 2001; Couper, Traugott, & Lamias, 2001). Specific guidelines for the determination of survey length will be discussed in Section 3.4.2.

It was determined that a web-based survey, limited to three (3) substantive questions, would be the best delivery method. The researcher chose to employ a web-based survey, using Qualtrics, because it was low-cost, easy to disseminate, and aided in clean and concise data collection (Dillman, Smyth, & Christian, 2014). While web-based surveys lack human interaction, it was determined that the target population was too large and time constraints were too prohibitive to make a hard-copy questionnaire feasible. Some researchers argue that the lack of the interviewer presence has the benefit of removing interviewer bias from the study (Schwarz, 1995; Sheehan & Hoy, 1999). There could occur a situation where, in the face-to-face delivery of a questionnaire, the respondent may become confused about the wording of a question. In this case, it would be expected that the participant would ask the interviewer for clarification. Schwarz (1995) warns that the wording, or repetition of the question by the interviewer, should be identical to the wording on the questionnaire to avoid influencing the participant. As a result, the mere nature of web-based instruments eliminates this particular introduction of interviewer bias, thus the reason for employing an online instrument in this study (Couper, Traugott, & Lamias, 2001).

Survey cost was another deciding factor in the choice to employ an online instrument. Depending on the size and spread of the target audience, the dissemination of a hard-copy survey can quickly become cost-prohibitive, especially if face-to-face interaction is required (Dillman, Smyth, & Christian, 2014). While using online web-based survey software typically involves subscription, this service was provided to the researcher at no-cost though Purdue University. Coupled with email distribution, the net cost of survey dissemination was zero. Moreover, data collection was simplified without the need for return mail, or manual collection of surveys. By utilizing online survey tools, like Qualtrics, data collection was instant with real-time analysis tools. This greatly reduced the cost, and time constraints associated with traditional survey techniques (Sheehan & Hoy, 1999). According to McCullough (1998) the two most expensive components of survey-based research are "data collection and analysis", both of which are eliminated by the use of online survey methods. Another added benefit is the fact that collection errors are almost entirely eradicated by removing human error from the equation (McCullough, 1998).

The last and arguably most important factor in choosing a web-based survey was for the fact that an online instrument would be the least invasive method of data collection on behalf of the respondents (Hoerger, 2010). While a certain level of participant attention would be required for the survey, it was critical that the time consumed by survey would be insignificant in regards to the professional workload of the respondents. A web-based survey provided the means for a sub-ten minute survey, facilitated by an easy to use, clear interface for which the participants could interact. Additionally, in an attempt to minimize invasiveness, the web-based platform allowed for an increased threshold for anonymity on behalf of the participants, which research has shown increases participants willingness to respond fully and truthfully to the questionnaire (Sheehan & Hoy, 1999).

3.4.2 Survey Length

The length of the survey proved more difficult to determine. Some critics argue that shorter surveys lack depth, and can negatively influence the results of the survey. The theory is that the question set, so long as the questions are interrelated, reflects the true conditions of the population (Cortina, 1993). This relationship is known as Cronbach's alpha, which is a method of quantifying the reliability of a survey, or test, by comparing the question set as a whole to the results of the test (Tett, Guterman, Bleier, & Murphy, 2000). The shorter the survey, the less likely the results of the questionnaire will reflect the true state of the population (Lord & Novick, 1968). It should be noted that Cronbach's alpha was not computed for this study, as it is most commonly used when comparing multiple questions within a survey, or test, to determine if the questions are reliably producing similar results. In the case of this study, the two substantive questions are measuring two different "rates"; therefore their interrelatedness is not a concern. Another proposed weakness of short surveys states that respondents value longer surveys as more meaningful. Dillman, Smyth, and Christian (2014) warn that short surveys can cause participants to view the information they are providing as unimportant, and might rush through their responses. On the other hand, lengthy surveys have the potential to be too broad, thus diluting the results, statistically hiding trends that may otherwise be significant (Maloney, Grawitch, & Barber, 2011).

However, it has been proven that shorter surveys often have higher response rates (Wilson, 2013). One of the primary goals of this study was to maximize the feedback received from a relatively small population. The focus of the study was on a single manufacturing company, so from the start the population was greatly limited. Therefore, further limiting the possibility of high response rate with a long survey was not acceptable. One related study found that roughly 6% of participants withdrew from the study after giving consent, and a total of approximately 10% withdrew after the first twelve questions (Hoerger, 2010). To combat this phenomenon, many sources agree that informing respondents about the length of the survey in advance is essential to maintaining their attention (Couper, Traugott, & Lamias, 2001; Wilson, 2013). For the survey used in this research, participants were informed of the survey length in the introductory correspondence that contained the link the questionnaire. While a progress bar was not employed, participants were presented with a single webpage of questions in an attempt to remove any ambiguity in regards to the length and expectations of the survey instrument (Dillman, Smyth, & Christian, 2014).

3.4.3 Survey Contents

In an effort to maintain a meaningful, yet comprehensive set of survey questions, one (1) demographical question, and two (2) practical questions were presented to the participants. The objective of the study was to measure both the current usage of academic resources, as well as preferred methods for accessing academic resources. Two (2) optional follow-up questions were provided to the participants to gain any extra input they might have regarding their use of academic resources. This section will outline the five (5) total individual components of the survey instrument administered to participants.

3.4.3.1 Education Level (Question 1)

First and foremost, a baseline of participant education needed to be established; specifically, the highest complete level of education. This was used to evaluate the presence of correlation between education level and the participants preferred academic resource. In other words, does the education level of the participants predict their usage of academic resources? The following six (6) levels of education were presented as options to the participants:

1.1 – High School/GED

1.2 – Technical Certificate

1.3 – Associate's Degree

1.4 – Bachelor's Degree

1.5 – Master's Degree

1.6 – Ph.D.

3.4.3.2 Current Usage (Question 2)

One of the objectives of the survey instrument was to gauge the current state of the problem. In other words, how much influence do academic resources currently have in the workplace?

This was accomplished using a Likert-based question where participants were given options from "Less Than Once a Year" to "Daily". The question posed to the participants:

2 – In a given year, how often do you utilize the following resources while doing background research for a project? This includes information obtained from a company librarian.

Likert-based responses were chosen primarily due to the ease of response by the participant, but also since the data is not expected to be continuous, but rather discrete in nature. The Likert-type scoring system for Question 2 is shown in Figure 3.1 below.

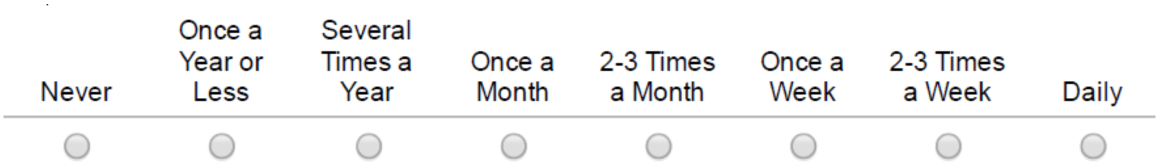

Figure 3.1. Likert-type scoring system used for Question 2 of the survey.

3.4.3.3 <u>Hypothetical Usage (Question 3)</u>

Another objective of the survey instrument was to measure the likelihood that a participant would choose particular academic sources, given an unknown subject. In contrast to collecting data on current usage statistics, this would provide some context as to whether or not certain academic sources are preferential to industry professionals. To gauge this, the following hypothetical question was presented to participants:

3 – If you were tasked with implementing a new technology, how likely would you be to consult the following resources:

Respondents were given a Likert-type scale, similar to Question 2, although with adjusted categories. The scoring system for Question 3 is shown in Figure 3.2 below.

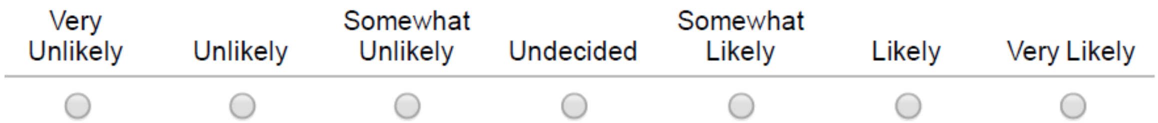

Figure 3.2. Likert-type scoring system used for Question 3 of the survey.

3.4.3.4 Follow-up (Questions 4 and 5)

The list of resources provided to the respondents of the survey was obviously not exhaustive, as shown by Bekkers and Freitas (2008). However, the need for additional feedback prompted the addition of two (2) optional follow up questions. The first of which prompted the respondent to provide their personal preference in academic information:

4 – What is your favorite resource for technical information?

This question was posed for a few reasons. First of all, it was important to allow the participants the opportunity to provide a resource other than those provided in the mandatory questions, as this information may reinforce the hypothesis of this research. Secondly, the preferred resources may significantly differ from those provided for the mandatory questions. This could provide insight into an alternative unconventional resource for interacting with academic information. Again, the ultimate purpose of this research was to uncover the most influential channels of knowledge transfer between academia and industry. If it were discovered that an alternative resource is preferred, it could be valuable knowledge for the academic community.

The last field posed to the participants allowed for an open dialog regarding the research topic. This was provided to retrieve feedback, beyond radio-buttons, that could offer insight into the preferences and concerns that might be present in industry. The verbiage for this question is as follows:

5 – If you have any additional comments regarding your access to academic resources, please feel free to use the text box below to convey your thoughts.

The open-endedness of this question was supplied as an outlet for respondents to expand upon their previous answers. This was done in an effort to gauge any shortcomings in the status quo by allowing the respondents to vent any frustrations or commend any strengths of their current method for gathering academic information. The responses from these optional questions will be used as qualitative evidence, thus no statistical analysis will be performed in regards to Questions 4 and 5.

3.5 Data Collection

Data collection was performed using Qualtrics. As discussed in Section 3.4.1, automated systems are inexpensive and greatly aid in the collection of data. Human error is almost entirely removed from the equation by using an automated data collection system. These platforms also allow for the exportation of the raw data in multiple formats, thus reducing the chance for data corruption when transferring the raw data between processing platforms.

3.6 Statistical Analysis

The analysis of the data obtained from this study was evaluated using a combination of the following methods: analysis of variance (ANOVA), comparison of means, and regression models. Only the responses of the three (3) mandatory survey questions will be used for statistical inference. The fourth and fifth questions, pertaining to preferred resources, were used primarily for discussion purposes, and will not be evaluated statistically; although the responses may be used to corroborate the statistical results. This section will outline the various methods and the applicability to this particular research project.

For this study, the data will be treated as continuous due to the high response rate although it was recorded in an ordinal discrete format via a Likert-style response. There is some contention among the field of statistics regarding the use of analytical means for Likert-scale data. Many argue that the nature of discrete data does not allow for the use of parametric methods since the data is not continuous (Allen & Seaman, 2007). However, evidence shows that with enough data, the data can be treated as if it was continuous, thus enabling the employment of parametric methods such as ANOVA and means comparisons (Norman, 2010). Norman (2010) computed statistical analyses on a multitude of studies and found that, regardless of parametric or non-parametric methods, the results did not vary significantly. These results, in conjunction with advice from the Purdue Statistical Consulting Service, have established enough reason to treat the data obtained in this study as continuous, thus allowing for the use of parametric methods (Song, 2016).

3.6.1 Analysis of Variance (ANOVA)

In conjunction with the Statistical Consulting Service at Purdue University, it was determined that the most logical approach to analyzing the data was to utilize an ANOVA for comparing the usage rates of the various academic resources; specifically a two-way mixed ANOVA.

The two-way mixed ANOVA was chosen primarily due to the fact that the interpretation of the data was dependent on two factors: education level and academic resource. This allowed for the investigation of the two main effects, as well as the interactions between the two. The model was a mixed model since it contains both a random effect (the participants) and fixed effects (education level and academic resource). The mixed design also accounts for the fact that each participant answered each question multiple times. For example, the participants were presented with nine (9) resources for the second question: “In a given year, how often do you utilize the following resources while doing background research for a project?" Since each respondent answered that particular question nine (9) times, once for each resource, there was a need to control for within-subjects variability; variability between each of the respondent's answers. Additionally, there was a need to control for the between-subjects variability; variability between all of the respondents. The mixed methods ANOVA design accounts for both of these scenarios. The results of the two-way mixed ANOVA for Questions 2 and 3 are presented in Sections 4.3.3 and 4.3.4 respectively

The purpose of employing an ANOVA was to discover whether or not a difference exists between group means. In this case, when investigating the current usage of academic resources, the ANOVA output will indicate whether or not a difference exists in the usage rates among the nine (9) resources, but not necessarily which resource is used more frequently than another. For this situation, post hoc means comparison is required. A common compliment to the ANOVA, a means comparison procedure investigates which group means are different from one another, and to what degree a difference exists. For this type of analysis, a Tukey means comparison measures the differences between group means, evaluates the standard deviations, and determines the significance of pairwise comparisons. The Tukey means comparison is generally considered the most powerful of the means comparison procedures as it is the most conservative of the many means comparison methods, meaning it is most likely to reject the alternative hypothesis in favor of the null. In other words, it tightly controls the Type I (false positive) error. The details of interpreting Tukey means comparisons are discussed in Section 4.3.2.2.

3.6.2 Correlations

One outcome of the research was to predict the likelihood of a firm's workforce to participate and engage with academic resources. To do this, the respondents were asked to provide their highest completed level of education, as education level should act as the greatest predictor for an employee’s engagement with academic resources. For statistical reinforcement, a regression model was chosen as this will provide a correlation matrix for the factors involved. Knowing not only the strength of the correlations, but knowing whether or not the correlations are positive or negative can greatly influence the conclusions of this study. The results of the correlation analysis are discussed in Section 4.3.5.

3.7 Summary

This chapter has provided an overview of the methodology employed for this study. Included was the methodology for selecting a willing industry partner, the participant identification process, as well as a description of the survey instrument. Also covered was a description of the statistical methods that were employed for the data analysis. The next chapter will present the data obtained through this methodology. Chapter 4 will contain an overview of the sample demographic, as well as discussion regarding data collection techniques and data manipulation.

CHAPTER 4: PRESENTATION OF DATA

This chapter provides a presentation of the data obtained in pursuance of the research questions established in Chapter 1. The questions being investigated were presented to participants in an order to discover (1) the level of current industrial participation in academic resources and (2) the likelihood of choosing various academic resources given the task to implement a new technology. The results from these two questions were evaluated in a quantitative manner, the results of which will be presented in this Chapter. In addition to the research questions, additional feedback from the participants was obtained through two open-ended response questions in an effort to bolster the quantitative analysis. This qualitative dialog will be presented as it pertains to the research questions. The raw data is presented in Appendix B. Discussion and conclusions drawn from the data will follow in Chapter 5.

4.1 Participant Demographics

As established in the previous chapters, the survey instrument was disseminated to engineering professionals at the Rolls-Royce manufacturing facility in Indianapolis, Indiana. According to the Rolls-Royce representative facilitating the dissemination of this instrument, the final copy of the survey was distributed to a population of approximately 1,000 Rolls-Royce employees. An exact number was not available since the survey was distributed through internal channels. A total of 227 participants completed and returned the survey, resulting in an approximate 22 percent response rate.

It was important to obtain a snapshot of the demographics of the sample population, so the first question, Question 1, on the survey inquired as to the highest completed level of education for the participants. It was hypothesized that education level would have the greatest impact upon the propensity of the participants to access academic information, thus the need for a question establishing the educational credentials of the participants. A summary of the participant demographics can be found in Table 4.1 below.

Table 4.1
Demographics of respondents

	Response	**%**
High School/GED	1	0%
Technical Certificate	7	3%
Associate's Degree	1	0%
Bachelor's Degree	106	47%
Master's Degree	91	40%
Ph.D.	21	9%
TOTAL (n)	227	100%

It was noted that the percentage of respondents possessing below a Bachelor’s degree was not proportional to the percentage of those possessing higher than a Bachelor’s Degree. In fact, both High School/GED and Associate’s Degree education levels had only one respondent. This disproportionality will be discussed further in Section 4.3.1. However, the remainder of the educational distribution appeared to coincide with the preconceived expectations pertaining to the formal education of employees at an aerospace firm.

4.2 Data Collection

The data were collected over a nearly two-week period during the spring semester, 2016. The survey was initially disseminated on February 15, 2016 and was officially closed on February 26, 2016, allowing for 12 full days of data collection. Recalling the demographics mentioned in Section 4.1, the overall response rate was 22 percent, with a total of 227 respondents. As such, the first three questions of the survey were mandatory, thus ensuring 227 data points. The remaining two optional questions, Questions 4 and 5, resulted in 186 and 33 respondents, respectively. A summary of these response rates can be found in Table 4.2.

Table 4.2
Response rates for individual survey questions, out of n=227 respondents

	Response	**%**
Question 1	227	100.00%
Question 2	227	100.00%
Question 3	227	100.00%
Question 4	186	81.94%
Question 5	33	14.54%

While the response rates for the two optional questions were not ideal, the responses gathered were still useful for the qualitative study of the responses. The next section will discuss the statistical analysis, as it pertains to the presentation of the data. Refer to Section 3.6 for the in-depth methodology of the statistical analysis employed.

4.3 Quantitative Analysis

This section outlines the statistical analysis as it pertains to the quantitative analysis of Questions 2 and 3 from the survey instrument. Included are subsections covering data conditioning, the coding and method selection within the software package, as well as the statistical results from Questions 2 and 3. This section will end with a discussion of correlations between Questions 1 and 2, and Questions 1 and 3.

4.3.1 Data Conditioning

The data, in raw form, were imported from Qualtrics into Microsoft Excel, where it was coded for use in a dedicated statistical package. The data were sorted into column form, with replicating respondent ID's to account for the nine (9) responses, corresponding to the nine (9) academic resources, for both of the quantitative questions. No data points were removed or altered for any of the respondents or questions.

Recalling Table 4.1, it was observed that there was a lack of respondents with a claimed highest-completed level of education below a Bachelor's Degree. The lack of data for these education levels could cause skewness of the results due to the fact that low group sample sizes have a tendency to act as outliers. In an effort to mitigate these effects, the three lowest levels of completed education were combined into a single group. This combination of education levels averages out the responses over a concise group, rather than influencing the entire data set with a single outlier. Since all three education levels were below the requirements of a Bachelor's Degree, it can be assumed that these education levels can be reclassified as a single group, comprising of individuals having completed "less than a 4-year college degree". It was determined that this outcome would more appropriately represent the sample population, in contrast to the deletion of these data points, as these participants still provide meaningful input to the research at hand. As such, Table 4.3 shows the combined grouping for education level.

Table 4.3
Demographics of respondents, adjusted with the combined education levels

	Response	**%**
< 4-year College	9	4%
Bachelor's Degree	106	47%
Master's Degree	91	40%
Ph.D.	21	9%
TOTAL	227	100%

4.3.2 Statistical Analysis Software (SAS)

SAS (Ver. 9.4) was chosen as the software package for the quantitative analysis of the data primarily for its prominence in the statistical software arena. Additionally, the SAS interface allows for greater user flexibility with regards to model selection, data input, and analytical output. The code shown in the following sections were used for Question 2. Identical code was used for Question 3, but with altered file names corresponding to the appropriate data sets. For the sake of redundancy, the code for Question 3 was omitted from these sections.

4.3.2.1 Proc Mixed

The SAS code used to execute the two-way mixed ANOVA for Questions 2 and 3:

```
/* IMPORT DATA */

PROC IMPORT OUT= WORK.Q2combined
            DATAFILE= "\\Client\J$\Purdue
Classes\PhD\Dissertation\Statistics\Data\Q2combined.txt"
            DBMS=TAB REPLACE;
     GETNAMES=YES;
     DATAROW=2;
RUN;

/* COMBINED Education Levels 1, 2 and 3 */

PROC MIXED DATA=Q2combined;
   CLASS ID Education Treatment;
   MODEL Score = Education Treatment
Education*Treatment/RESIDUAL;
   LSMEANS Treatment / ADJUST=tukey;
   REPEATED / TYPE=un SUBJECT=ID r;
RUN;

/* CREATES INTERACTION PLOT */

/* (i) Sort the data set using the two categorical variables
under consideration. CREATES INTERACTION PLOT */

PROC SORT DATA=Q2combined OUT=Q2combined_sort;
BY Treatment Education;
RUN;

/* (ii) Calculate the mean of the response for all the
combinations of Treatment and Education. */
```

```
PROC MEANS DATA=Q2combined_sort NOPRINT;
BY Treatment Education;
VAR score;
OUTPUT OUT=Q2combined_score_mean MEAN=score_mean;
RUN;

/* (iii) Produce a line plot by PROC SGPLOT. */

PROC SGPLOT DATA=Q2combined_score_mean;
VLINE Treatment / RESPONSE=score_mean GROUP=Education MARKERS;
LABEL score_mean = "Mean of Score";
RUN;
```

For the results of this code, refer to Sections 4.3.3 and 4.3.4.

4.3.2.2 Tukey Means Comparison

One optional output from the "Proc Mixed" procedure, shown in Section 4.3.2.1, was a Tukey means comparison. An ANOVA can only indicate whether a difference in group means exists, but will not decipher which groups are different or to what extent they differ. A means comparison procedure will conduct pair-wise comparisons of all of the groups involved, returning significance tests for each pair-wise comparison. These significance tests are then grouped in a table, and alphabetic letters are associated to factor levels that share similar group means. Significance is determined by comparing each factor level's mean, and standard deviation to the t-distribution to establish a test statistic. The magnitude of the test statistic determines whether or not the comparison conveys a statistically significant difference in group means.

Table 4.4
Example of Tukey means comparison grouping

	Grouping		
Factor Level 1	A		
Factor Level 2	A		
Factor Level 3		B	
Factor Level 4			C

Using Table 4.4 as an arbitrary example, it is evident from the grouping letters that Factor Levels 1 and 2 are not significantly different from one another since they share a common grouping letter. In other words, due to possible error, it would be inconclusive to state that either factor level was better or worse than the other. However, Factor Levels 1 and 2 are significantly different from Factor Levels 3 and 4 due to the mismatched letter pairs. Furthermore, it can be noted that Factor Levels 3 and 4 are also uniquely different from all other factor levels since they each possess a single unique grouping letter. Tukey means comparisons for Questions 2 and 3 are supplied in Sections 4.3.3 and 4.3.4.

4.3.2.3 Proc Reg and Proc Corr

The SAS code used to execute the regression model, as well as the correlations, for Questions 2 and 3:

```
/* IMPORT Question 2 DATA */

PROC IMPORT OUT= WORK.Q2regression
            DATAFILE= "\\Client\J$\Purdue
Classes\PhD\Dissertation\Statistics\Data\Q2regression.txt"
            DBMS=TAB REPLACE;
     GETNAMES=YES;
     DATAROW=2;
RUN;

/* REGRESSION Question 2 */

PROC REG DATA = WORK.Q2regression;
MODEL Education = TradeShow UAP UPP Grads Faculty IndJournal
PRJournal RA Encyclo;
RUN;

/* CORRELATION MATRIX Question 2 */

PROC CORR DATA = WORK.Q2regression RANK;
VAR Education TradeShow UAP UPP Grads Faculty IndJournal
PRJournal RA Encyclo;
RUN;
```

For the results of this code, please refer to Section 4.3.5.

4.3.3 Question 2

The second question on the survey, recalling Section 3.4.3.2, was presented to the participants in an effort to retrieve the current usage statistics for the provided list of academic resources. Question 2 stated: "In a given year, how often do you utilize the following resources while doing background research for a project? This includes information obtained from a company librarian."

Due to the nature of a two-way ANOVA, there are multiple hypotheses to account for the increased number of model factors. The factors include the education level, academic resources, and the interaction between the two main effects. For this question, we will be evaluating the following statistical hypotheses at alpha (α) = 0.05:

Factor = Education:

H_0: There is no difference between the means of the various levels of education level with respect to Question 2 (All μ's equal)

H_A: A significant difference exists between group means of education level with respect to Question 2 (One or more μ's not equal)

Factor = Academic Resources:

H_0: There is no difference between the means of the current usages of academic resources with respect to Question 2 (All μ's equal)

H_A: A significant difference exists between group means of the current usages of academic resources with respect to Question 2 (One or more μ's not equal)

Factor = Education*Academic Resources:

H_0: There is no interaction between education level and the usage of academic resources with respect to Question 2

H_A: An interaction does exist between education level and the usage of academic resources with respect to Question 2

With these hypotheses in mind, a two-way mixed ANOVA, as outlined in Section 3.6.1, was performed on the data. The results of this analysis are presented in Table 4.5.

Table 4.5
Two-way mixed ANOVA results for Question 2

Effect	**Num DF**	**Den DF**	**F Value**	**p Value**
Education	3	223	3.84	0.0104
Resource	8	223	19.79	<0.0001
Education*Resource	24	223	2.84	<0.0001

Looking at this output, it was evident that there was sufficient evidence to reject the null hypotheses, on all accounts, in favor of the alternatives that there exists a significant difference between group means for education level and academic resource, as well as a significant interaction between these two variables. Since the interaction was significant, it will be imperative that an analysis be conducted to explain this interaction. This analysis will be discussed in Section 4.3.5.

Since the primary focus of this question was to investigate the industry preference of various academic resources, it was also important to explore the inequalities between these academic resources signified by acceptance of the alternative hypothesis. Although our primary focus was on the interaction term, it was still deemed important to look at the main effect individually. To do this, a Tukey means comparison on the nine (9) academic resources was employed. The Tukey grouping method allows for a researcher to group the levels of a factor in a descriptive manner to allow for quick comprehension of the statistics. For Question 2, the results of the Tukey means comparison can be found in Table 4.6.

Table 4.6
Tukey comparison of the group means for Question 2 regarding daily usage of academic resources. Items with similar grouping letters are not significantly different from one another. Ranked from least to most frequent by mean usage, with "1" being "Never" and "8" being "Daily".

Resource		**Mean**	**Grouping**				
2	Assistance Programs	1.3767	A				
1	Trade Show	1.5035	A	B			
3	University Partnership Program	1.7267		B			
4	Recent Graduates	2.1712			C		
5	Current/Retired Faculty	2.1818			C		
8	Review Article	2.7031				D	
6	Industrial Journal	2.7291				D	
7	Peer-Reviewed Journal	2.7446				D	
9	Online Encyclopedia	3.9655					E

Using the analytical methods for Tukey means comparisons, as discussed in Section 4.3.2.2, it was evident that the most frequently accessed academic resource was “Online Encyclopedia”. In fact, the results show that online encyclopedias were favored significantly over all of the other academic resources, as indicated by the fact that it is grouped alone with a unique letter. The results also show that peer-reviewed journals, industrial journals, and review articles are favored behind online encyclopedias, but do not differ significantly from one another in the current rate of usage. “Current/Retired Faculty” and “Recent Graduates” share a common group, indicating an insignificant difference between two. The remaining resources, “University Partnership Programs”, Trade Show” and “Assistance Programs” showed signs of varying levels of significance between the three resources. Direct conclusions regarding this analysis can be found in Chapter 5.

4.3.4 Question 3

The third question on the survey, recalling Section 3.4.3.3, was presented to the participants in an effort to gauge the likelihood that an aerospace engineering professional would choose certain academic resources over others when posed with an unknown subject. Question 3 stated: "If you were tasked with implementing a new technology, how likely would you be to consult the following resources:"

Due to the nature of a two-way ANOVA, there are multiple hypotheses to account for the increased number of model factors. The factors include the education level, academic resources, and the interaction between the two main effects. For this question, we will be evaluating the following statistical hypotheses at alpha (α) = 0.05:

Factor = Education:

H_0: There is no difference between the means of the various levels of education level with respect to Question 3 (All μ's equal)

H_A: A significant difference exists between group means of education level with respect to Question 3 (One or more μ's not equal)

Factor = Academic Resources:

H_0: There is no difference between the means of likely usage of academic resources with respect to Question 3 (All μ's equal)

H_A: A significant difference exists between the means of likely usage of academic resources with respect to Question 3 (One or more μ's not equal)

Factor = Education*Academic Resources:

H_0: There is no interaction between education level and the likely usage of academic resources with respect to Question 3

H_A: An interaction does exist between education level and the likely usage of academic resources with respect to Question 3

With these hypotheses in mind, a two-way mixed ANOVA, as outlined in Section 3.6.1, was performed on the data. The results of this analysis are presented in Table 4.7.

Table 4.7
Two-way mixed ANOVA results for Question 3

Effect	**Num DF**	**Den DF**	**F Value**	**p Value**
Education	3	223	4.38	0.0051
Resource	8	223	15.32	<0.0001
Education*Resource	24	223	1.97	0.0059

Again, it was evident from the output in Table 4.7 that there was sufficient evidence to reject the null hypotheses, on all accounts, in favor of the alternatives that there exists a significant difference between group means for education level and academic resource, as well as a significant interaction between these two variables. Since the interaction was significant, it will be imperative that an analysis be conducted to explain this interaction. This analysis will be discussed in Section 4.3.5.

The primary focus of Question 3 was to measure the likeliness that an engineering professional at a highly technical company would choose certain academic resources when presented with the task of implementing new technology. Since the ANOVA results do not specify which academic resources are favored, a Tukey means comparison was again employed to quantify the group differences. For Question 3, the results of the Tukey means comparison can be found in Table 4.8.

Table 4.8
Tukey comparison of the group means for Question 3. Items with similar grouping letters are not significantly different from one another. Likelihood of usage ranked from lowest to highest by group mean, with "1" being "Very Unlikely" and "7" being "Very Likely"

Resource		**Mean**	**Grouping**				
1	Trade Show	2.9995	A				
2	Assistance Programs	3.2860	A				
4	Recent Graduates	3.4763	A	B			
3	University Partnership Program	3.7730		B	C		
5	Current/Retired Faculty	3.9162			C		
6	Industrial Journal	4.5061				D	
8	Review Article	4.9976					E
9	Online Encyclopedia	5.0288					E
7	Peer-Reviewed Journal	5.0679					E

Using the analytical methods for Tukey means comparisons, as discussed in Section 4.3.2.2, it was evident that the Tukey comparison for Question 3 differs greatly from that of Question 2. “Peer-Reviewed Journal”, “Online Encyclopedia”, and “Review Article” were scored as the most likely academic sources to employ when conducting research on a new technology. It should also be noted that since these three (3) resources share the same letter grouping, the favorability between the three (3) are not significantly different. As with Question 2, the remaining resources differed greatly. Direct conclusions regarding this analysis can be found in Chapter 5.

4.3.5 Interactions and Correlations

Recalling the presentation of data for both Questions 2 and 3, in Sections 4.3.3 and 4.3.4, respectively, there was a significant interaction between education level and the academic resources. Interactions are important to interpret because they allow inference on how one factor of the model may be influencing another. The visualization of this is done by producing interaction plots, where one factor is plotted on the x-axis and the score of the other on the y-axis.

For Question 2, the interaction plot is shown in Figure 4.1.

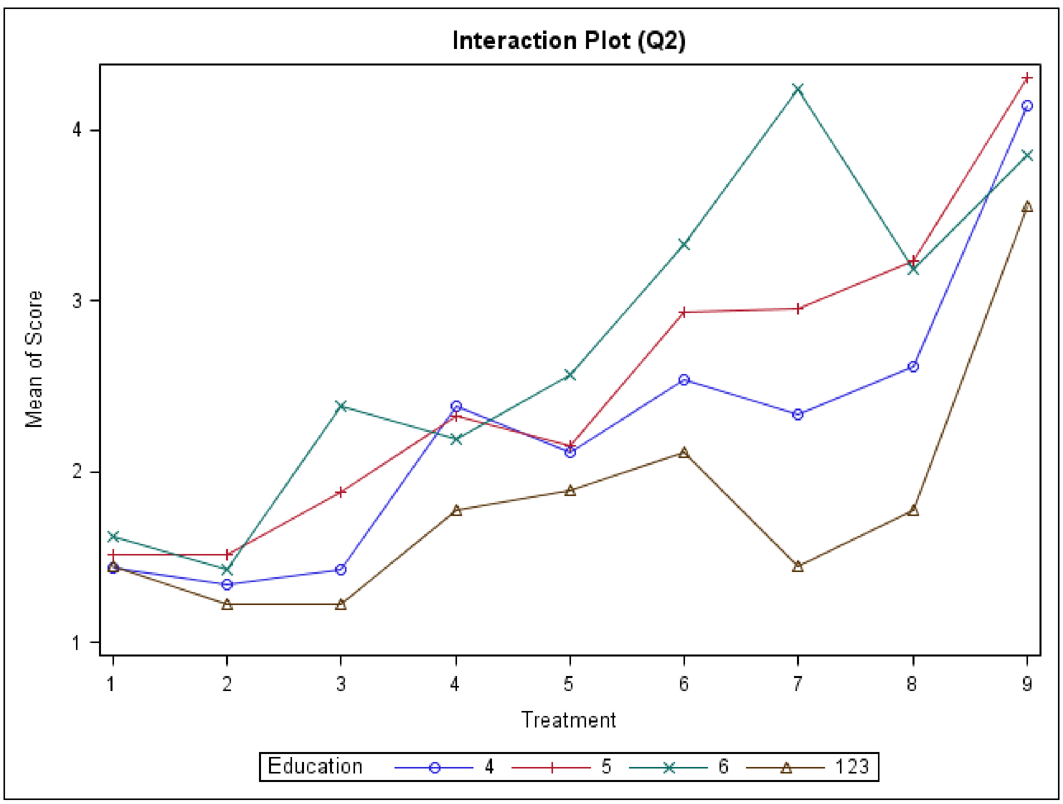

Figure 4.1. This graphical output is the interaction plot for education level and academic resource for Question 2. The x-axis in this case represents the nine (9) different treatments, or academic resources: (1) Trade Show, (2) Assistance Programs, (3) University Partnership Programs, (4) Recent Graduates, (5) Current/Retired Faculty, (6) Industrial Journal, (7) Peer-Reviewed Journal, (8) Review Article, and (9) Online Encyclopedia. The y-axis represents the mean score for each resource, by each level of education. The levels of education: (123) <4-year College, (4) Bachelor's Degree, (5) Master's Degree, and (6) Doctor of Philosophy.

Probably the most notable of the interactions for Question 2 were with (7) “Peer-Reviewed Journals”, which had the widest spread in the average score between all education levels. According to this interaction plot, employees holding a doctoral degree exhibit the highest current usage of peer-reviewed academic journals in the workplace, followed by master’s degree recipients, bachelor’s degree recipients, and then those who have not completed a 4-year degree. To determine whether or not this interaction was significant, a procedure called a slice was performed on the interaction. A slice determines the extent to which an interaction is significant by measuring the difference between means for one factor, while sorting for another. In this case, the slice will determine the difference between education levels for each of the individual academic resources. The results of the slice for Question 2 are shown in Table 4.9. From Table 4.9, the significant interactions, at alpha (α) = 0.05 are between education level and (3) “University Partnerships”, (7) “Peer-Reviewed Journal”, and (8) “Review Article”. This significance indicates that education level has a significant effect on the current usage of the aforementioned academic resources. The interaction plot shown in Figure 4.1 reinforces these findings, as the spread between these group means is much wider than for the other resources.

Table 4.9

Significance tests for interaction effects, sliced by education, for Question 2.

	Resource	**Num DF**	**Den DF**	**F Value**	**p Value**
1	Trade Show	3	223	0.50	0.6802
2	Assistance Programs	3	223	1.11	0.3439
3	University Partnership Programs	3	223	6.21	0.0005
4	Recent Graduates	3	223	0.45	0.7194
5	Current/Retired Faculty	3	223	0.53	0.6624
6	Industrial Journal	3	223	2.49	0.0611
7	Peer-Reviewed Journal	3	223	11.89	<0.0001
8	Review Article	3	223	3.93	0.0093
9	Online Encyclopedia	3	223	0.52	0.6713

In order to determine the magnitude of these interaction effects, an analysis of the correlations between education level and the nine (9) academic resources was performed for Question 2. There were four (4) significant correlations at alpha (α) = 0.05. The results of this analysis are shown in Table 4.10. It should be noted that although (6) “Industrial Journal” (6) was not found to have a significant interaction with education level, there was a significant correlation between the two. Additionally, these results show that a positive correlation exists, meaning that as education level increases, so does the usage of (7) “Peer-Reviewed Journal”, (3) “University Partnership Program”, (8) “Review Article”, and (6) “Industrial Journal”.

Table 4.10
Table of significant correlations between education level and academic resources for Question 2. Ranked from strongest correlation to weakest correlation.

Resource		**Pearson's r**	**p Value**
7	Peer-Reviewed Journal	0.34112	<0.0001
3	University Partnership Program	0.25737	<0.0001
8	Review Article	0.19406	0.0033
6	Industrial Journal	0.16534	0.0126

As with any correlation, it should be noted that correlation does not imply causation. In other words, this research does not reveal whether or not the education level of a workforce causes a rise in the participation in academic resources. The active participation in academic resources could be an artifact of the work environment, previous training, or other outside influences. These results merely indicate that there was a positive linear relationship between education level and the current usage rates of certain academic resources, listed in Table 4.10, at Rolls-Royce.

The next step was to evaluate the interaction terms for Question 3, shown in the interaction plot in Figure 4.2.

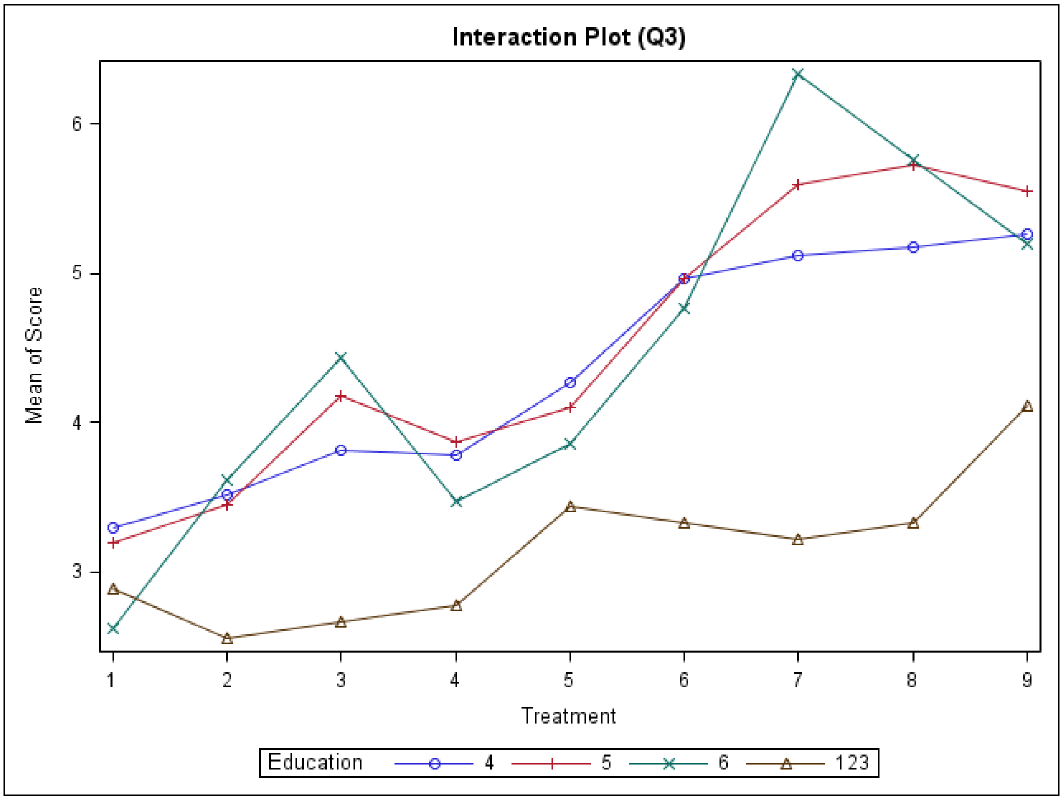

Figure 4.2. This graphical output is the interaction plot for education level and academic resource for Question 3. The x-axis in this case represents the nine (9) different treatments, or academic resources: (1) Trade Show, (2) Assistance Programs, (3) University Partnership Programs, (4) Recent Graduates, (5) Current/Retired Faculty, (6) Industrial Journal, (7) Peer-Reviewed Journal, (8) Review Article, and (9) Online Encyclopedia. The y-axis represents the mean score for each resource, by each level of education. The levels of education: (123) <4-year College, (4) Bachelor's Degree, (5) Master's Degree, and (6) Doctor of Philosophy.

Again, we see that education has a profound effect on the likelihood of accessing various academic resources. However, it appears from the interaction plot in Figure 4.2 that employees who have completed a 4-year college degree, or beyond, are equally likely to participate with academic resources. While there does appear to be slight variations between the higher education levels, the evidence indicates that employees who have not completed a 4-year degree are much less likely to participate in academic resources, according to this plot. To further investigate these speculative claims, significance tests on the sliced interaction needed to occur. The results of this slice are shown in Table 4.11, where at alpha (α) = 0.05. From these results, it appears that only (7) “Peer-Reviewed Journal” and (8) “Review Article” have significant interaction effects with education level. This indicates that education level has a significant effect on the likelihood of employing the aforementioned academic resources.

Table 4.11

Significance tests for interaction effects, sliced by education, for Question 3.

	Resource	**Num DF**	**Den DF**	**F Value**	**p Value**
1	Trade Show	3	223	0.77	0.5102
2	Assistance Programs	3	223	0.89	0.4455
3	University Partnership Programs	3	223	2.38	0.0706
4	Recent Graduates	3	223	1.19	0.3150
5	Current/Retired Faculty	3	223	0.73	0.5375
6	Industrial Journal	3	223	2.60	0.0531
7	Peer-Reviewed Journal	3	223	9.69	<0.0001
8	Review Article	3	223	7.79	<0.0001
9	Online Encyclopedia	3	223	1.92	0.1274

In order to determine the magnitude of these interaction effects, an analysis of the correlations between education level and academic resources was performed for Question 3. There were three (3) significant correlations at alpha (α) = 0.05. The results of this analysis are shown in Table 4.12. Again, it should be noted that although (3) University Partnership was not found to have a significant interaction with education level, there was a significant correlation between the two. Additionally, these results show that a positive correlation exists, meaning that as education level increases, so does the likelihood of accessing, or engaging with, (7) “Peer-Reviewed Journal”, (8) “Review Article”, and (3) “University Partnership Program”.

Table 4.12
Table of significant correlations between education level and academic resources for Question 3. Ranked from strongest correlation to weakest correlation.

Resource		Pearson's r	p Value
7	Peer-Reviewed Journal	0.30899	<0.0001
3	University Partnership Program	0.25737	<0.0001
8	Review Article	0.19406	0.0033

As with any correlation, it should be reiterated that correlation does not imply causation. In the context of Question 3, there was no evidence that the education level of a workforce causes an increase in the likelihood of participation in academic resources. The likelihood of participation in academic resources could be an artifact of the work environment, previous training, or other outside influences. These results merely indicate that there was a positive linear relationship between education level and the current usage rates of certain academic resources, listed in Table 4.12, at Rolls-Royce.

4.4 Qualitative Analysis

This section outlines the qualitative analysis as it pertains to Questions 4 and 5 from the survey instrument. Included are subsections covering data conditioning and the grouped responses for Questions 4 and 5. The primary purpose for including the qualitative analysis was to provide anecdotal evidence which reinforced the hypotheses tested for the quantitative analysis. Participant feedback was key to fully investigating the usage of academic resources in the work environment. Conclusions drawn from these anecdotal responses are discussed in Chapter 5.

4.4.1 Data Conditioning

Conditioning the open-ended responses for interpretation proved to be a difficult matter. First and foremost, there was an uneven number of respondents between Questions 4 and 5, recalling Table 4.2, which meant that it would be difficult to track trends between participants. Secondly, being open-ended in nature, the questions produced a number of unique responses on a multitude of ranging topics. As a result, the initial task was to group these responses into a handful of categories based upon the question set as a whole. The cataloguing of the responses would provide a summarized overview of the question set, and present it in manner that would most meaningfully describe the sentiments of the respondents. Beyond grouping, no other manipulation was performed on the data for Questions 4 and 5. The specific grouping guidelines, as they pertain to the individual questions, are discussed in their respective sections. All participant responses in the following sections are presented in an un-edited, verbatim state.

4.4.2 Question 4

The fourth question on the survey, recalling Section 3.4.3.4, was presented to the participants in an effort to gather the personal preferences of the participants with respect to their favorite sources of technical information. It was assumed that the respondents of the survey were professionals in an engineering or R&D role, so understanding their preferential source for technical information was an important piece of this puzzle. Question 4 simply asked: “What is your favorite resource for technical information? “

Of the 227 respondents, 186 people responded to Question 4. This equates to 82 percent of the total number of respondents who participated in the survey. The 186 responses were then evaluated for common themes, and grouped into categories corresponding to these themes. Subcategories of these main themes were then formed in an effort to more closely detail the responses as a whole. In cases where the primary category did not warrant multiple subcategories, a singular subcategory was created in an effort to provide specific detail to the responses given by the participants. The primary categories and subcategories are shown in Table 4.13. The percentages and cumulative percentages for the number of respondents who prefer the listed resources are provided as well.

Table 4.13

Summarization of the preferred source of technical information, categorized by primary groups, including the subcategories, for Question 4. Percentages are calculated based upon the 186 respondents for this question.

	Responses	%	Cum. %
Internet			
Online Encyclopedia	20	10.75%	40.32%
Google Search	18	9.68%	
Database	17	9.14%	
Not Specified	20	10.75%	
Publications			
Industrial Journal	45	24.19%	37.63%
Peer-Reviewed Journal	16	8.60%	
Textbooks	6	3.23%	
Review Article	1	0.54%	
Not Specified	2	1.08%	
Personal Contacts			
Colleagues	17	9.14%	13.44%
Academics	4	2.15%	
Suppliers	3	1.61%	
Not Specified	1	0.54%	
Internal Sources			
Rolls-Royce Historical Reports	10	5.38%	5.38%
External Sources			
NASA	3	1.61%	1.61%
Events			
Conference/Trade Show	3	1.61%	1.61%
Total	186	100%	100%

The most prominent response for the favorite source of technical information was the internet. The internet is a very broad category, so the responses were broken into four main subcategories based upon the responses received: “Online Encyclopedia”, “Google Search”, “Database”, and “Not Specified”. Roughly 25 percent of those who answered this question within the “Internet” category did not specify a particular website or resource preference. It was not inferred as to whether or not these responses implied a “Google Search” since specific details were not provided. Contrarily, the most common response among participants who did specify an online preference was online encyclopedias. Nearly all of these respondents referenced Wikipedia as their encyclopedia of choice, but often times also referenced a form of Google search in conjunction. As a result, there could be some confounding within this subcategory in the event of listing multiple answers. However, in cases where both resources were listed, the responses were separated into the group “Encyclopedia” for the pure fact that a specific online encyclopedia was mentioned in the response. For this reason, responses only containing references to a Google search were categorized differently. There was also no inference made on the results of using a Google search to uncover technical information. With this is mind, a nearly equal number of respondents specified databases where they prefer to gather technical information. These were grouped in yet another category for the purpose of differentiating between a generic Google search and a specific database for technical information. The most prevalent of the databases listed was Knovel, with 6 respondents referencing the database, followed closely by Scopus and Science Direct.

The next most frequent responses related various types of publications. For this category, it was important to differentiate the type of publication, due to the fact that many of the resources provided in the survey were forms of published literature. Publications were divided into five (5) subcategories: “Industrial Journal”, “Peer-Reviewed Journal”, “Textbooks”, “Review Article”, and “Not Specified”. According to the responses from Question 4, 45 respondents indicated that

“Industrial Journal” was their preferred source of information. Responses in this category were primarily aerospace centric, which was expected due to the fact that the sample population was employed for a leading aerospace manufacturing firm, Rolls-Royce. Other popular specific sources from industrial literature were the American Society of Mechanical Engineers (ASME) and the American Institute of Aeronautics and Astronautics. Surprisingly, the number of participants who recorded a “Peer-Reviewed Journal” as a preferred source was less than 25 percent of those who responded within the “Publications” category as their preferred source of technical information; a definite contrast to the relatively even spread among the subcategories of the “Internet” category. One resource not considered in the original survey, but indicated as a frequented academic resource according to resource preference was “Textbooks”. Six participants indicated that textbooks from their academic careers were their favorite source of technical information. While not a traditional publication, textbooks can often act as a review article, or encyclopedia, wherein they contain summarized reviews of the state of a current field or topic.

Personal contacts made up only 13 percent of the total responses for Question 4. This category was split into four (4) subcategories: “Colleagues”, “Academics”, “Suppliers”, and “Not Specified”. In an overwhelming majority, “Colleagues” were the most favored within the personal contact category, consuming 68 percent of the 25 participant responses. It should be noted that nearly all of the responses appeared to be in reference to informal, rather than formal, personal contacts. “Academics” and “Suppliers” had minimal response, with no particularly notable anomalies.

The last three (3) categories had significantly fewer respondents than the former categories. These last three categories include: “Internal Sources”, “External Sources” and “Events”. Internal sources, namely “Rolls-Royce Historical Reports” were referenced by 10 participants. According to the comments, these documents are very useful for identifying proven processes and materials for current applications. Another common "External Source" was the National Aeronautics and Space Administration (NASA). The Rolls-Royce facility in Indianapolis designs, manufactures, and tests turbine engines for both civil and military applications, so the technological overlap between Rolls-Royce and NASA creates a substantial need for common information. While not common overall, the fact that multiple respondents reference NASA as a preferential source warranted its inclusion as a subcategory. The least common yet still relevant preferred resource was "Events", subcategorized as "Conference/Trade Show", had no notable comments, but still deserved inclusion.

In order to get a detailed overview of the preferred resources, as indicated by the 186 respondents, the subcategory totals were calculated and ranked from most respondents to least respondents. This ranking of preferred resources provided a greater overview of the data by giving a more detailed perspective into the trends present at Rolls-Royce. The ranked list of categorized responses is shown in Table 4.14, on the next page.

Table 4.14
Subcategories for Question 4 ranked from most preferred to least preferred.

Rank	Source	Count
1	*Industrial Journal*	45
2	*Online Encyclopedia*	20
3	*Internet (Not Specified)*	20
4	*Google Search*	18
5	*Database*	17
6	*Colleagues*	17
7	*Peer-Reviewed Journal*	16
8	*Rolls-Royce Historical Reports*	10
9	*Textbooks*	6
10	*Academics*	4
11	*Suppliers*	3
12	*NASA*	3
13	*Conference/Trade Show*	3
14	*Publications (Not Specified)*	2
15	*Review Article*	1
16	*Personal Contacts (Not Specified)*	1
	Total	186

4.4.3 Question 5

The final question on the survey, Question 5, was intended to serve as an open ended question to allow the participants to provide feedback on the details surrounding accessing and using academic resources. The question stated: "If you have any additional comments regarding your access to academic resources, please feel free to use the text box below to convey your thoughts." Examples of participant responses are presented in this section to provide qualitative context as to the general consensus among participants.

The analysis and collection of this question was much different than that of the previous questions. First of all, there were considerably fewer respondents for Question 5 than the previous questions, totaling only 33 people. This equates to roughly 14 percent of the 227 total respondents for the survey instrument itself. Furthermore, the types of responses varied to a greater degree as a result of the open-endedness of the question, resulting in greater challenges for categorizing the participant responses.

The first step towards meaningful categorization was to read through and understand all 33 responses. It was immediately noticeable that the underlying theme for most of the 33 responses was negative, meaning that the comments left by participants were complaints about the status quo for gathering academic information. It was determined that there were five (5) sentiments regarding the use of academic resources present among nearly all of the responses: “Difficult to Access”, “Expensive to Access”, “Irrelevant to My Job”, “Not Advertised” and “Inefficient”. With these five (5) sentiments established, each comment was dissected to see which of the five (5) sentiments were present within each comment. It was not unlikely that a single comment had multiple common sentiments, so many were scored among multiple categories.

The most common response entailed the difficulty of accessing academic resources. Of the 33 responses, 17 mentioned the difficulty of accessing academic information. These included people who felt that information was difficult to search, difficult obtain, or generally tough to access even if the location of the resource is known. For example, Participant 79 stated: “I can find articles through Google, but the publishers' websites are usually hard to navigate.” This is further corroborated by Participant 88 who commented “University resources are generally too difficult to search on-line. Almost always requires a telephone call.” In lieu of navigating difficult databases, Participant 196 responded:

> “It appears that I gravitate towards sources that are easily accessible and searchable. Usually obtaining large quantities of data from various low-quality sources will answer technical information questions faster than looking for singular high-quality data sources. Whether it's the "pay to access" firewalls, the difficulty of knowing which peer-reviewed source is likely to contain the topic of interest, or ignorance of the information sources

> available I am probably not using academic resources as much as those producing the content would like."

Some participants complain that, even with the assistance of a company librarian, accessing academic information can take an exorbitantly long time to receive the searched information. Participant 62 wrote:

> "Academic journals are difficult to obtain and makes it hard make that my go-to source for information. I can get almost any article that I find though our librarian, but it can take a few weeks, which is often too long for my research which moves quickly."

In the case that the company librarian does not have access to a particular resource, the next possible route is a third-party, as stated by Participant 84:

> "I have also used our company library extensively for technical information and if they don't have it, we find what I need through their channels, which are either Amazon or NASA library. I will also use the internet to dig up papers."

The problem does not seem isolated to the purely academic realm. Recalling Question 4, where participants indicated that industrial journals were the most popular form of published resources, Participant 227 stated: "It is almost impossible to get articles from AIAA, ASME etc." The difficulty of accessing information from these societies does not appear to be an isolated event, as Participant 80 responded: "Access to electronic proceedings from technical conferences is often dependent on personal attendance, or knowing someone that attended a conference. We need to make sure our company library has access to such proceedings as much as possible."

These comments indicate that not only are there problems with accessing academic databases, but that even once the information is found, there are additional obstacles in the form of pay-walls and site-registrations. While only 4 responses indicated such barriers, Participant 48 replied: "I would probaly [sic] use academic resources if they were free, meaning no on-line subscriptions required, and I knew how to access them internally." Moreover, Participant 63 writes: "Make your research articles freely available to the taxpayers who fund your research."

Regardless of accessibility or cost, a significant proportion of the respondents felt that many academic resources were irrelevant to their current job. Out of the 33 responses, 10 suggested that academic resources played an insignificant role in their day-to-day duties or job description. The reasons for this appear to vary, but the most common responses dealt with the fact that the roles of the respondents do not require the use of innovative methods or processes.

For instance, Participant 124 commented:

> "I develop the electronics for control systems. My needs may be different than what you expect. Few things are really new but rather existing products applied using a novel method. I look for experts for the type of problem I need to solve. That is usually the field applications engineer from a supplier. Academic resources usually lack an understanding of production whereas the applications engineer has a track record of applying his product in a production environment. / Seems that an applications engineer should be included in the choices above.

Another respondent, Participant 47 stated:

> "A majority of my work is to review engine components that we are manufacturing and assembling. Because of this, when I am doing research on a problem, rather than going to outside sources, I comb through old documents and reports we have internally on the given component to find a similar problem set and see what was previously troubleshot. / / As I learned in college, the easiest way to find a good generic source it to go to Wikipedia and from there, go to the cited source for a piece of information you need.

It seems that many of these participants reference internal documents when conducting research. Participant 128 stated: "Texts available through my company's library or public library are often valuable for technologies that are not extremely new. These can be located through library resources, Amazon, and more specialized services like Knovel." This is further corroborated by Participant 209, who wrote:

> “I marked "never" quite often above. Mostly because my role does not usually require a large degree of research to be done on a given project. A lot of the process/methods are already in place - research need not apply in many cases.

Participant 22 also stated: “In my opinion, engineers at my company under-utilize the library resources and rely to [sic] heavily on inside knowledge within the company.”

A smaller, yet equally important few discussed concerns regarding the availability of academic resources, particularly with regard to assistance programs and partnership programs. Participant 112 wrote: “Need to make University Partnership Programs more visible.” This sentiment was shared by Participant 205 who commented:

> “The how-tos [sic] of accessing the knowledge of a University-Based Technical Assistance Program or University Partnership Program are not communicated efficiently, therefore they resulteed [sic] in low scoring. Frankly, I was vaguely aware of their existance [sic] but had no knowledge or training on how to utilize them effectively.

The issue of intellectual property was addressed by two of the respondents, especially concerning the partnership or collaboration between industry and academia. While these concerns have mainly been address by legislation, namely the Bayh-Dole Act, and other international policies, their concerns are legitimate and should be noted. Participant 213 wrote:

> “Academia and advanced development projects are nearly incompatible due to the IP issues. A company wishing to get a jump on the competition with the incorporation of advanced technologies into a product does so at risk and with the intention of reaping a profit through control of the intelectual [sic] property. A university is bound to diseminate [sic] any information developed for all to see and use (i.e. articles, journals, thesis, etc.).”

In addition to intellectual property, these relationships can be complicated for reasons of differing values. Participant 50 touched on these issues with their response:

> “I appreciate your attempt at a survey, but a lot of the survey's response will depend upon the project(s). For example, I'm working on a project to introduce a new material to RRC. We're working quite closely with the vendor who developed the new material and

> have never considered working with a college because the vendor has never worked with a college and the nature of the project has no need of a university partnership. On another project, RR has a partnership with a university in the UK, but the project's needs are so far outside of what the partnership covers that, at least for my project, the partnership has no value. Then there are intellectual property issues with many new technologies, so there may be generalities of a new technology published in journals and on the internet, but the specifics are going to be withheld and released to RR only when non-disclosure agreements are signed. / I would much rather talk about how the college curriculum can be better matched to the needs of industry. / Thanks for your survey and good luck."

As stated earlier, the lack of participant response, and open-endedness of Question 5 prohibited the use of quantitative analytical methods. Qualitative interpretation was deemed more valuable to the research as a whole, and as such, will bolster the quantitative results from Questions 2 and 3. The feedback gained from the participants in this study will be invaluable to both the research at hand, as well as the directive of future work.

4.5 Conclusions

This chapter presented the data and covered the quantitative analysis of Questions 2 and 3, as well as the qualitative aspects of Questions 4 and 5. It was found that for the current usage of academic resources, online encyclopedias are the preferred source of technical information. However, when presented with the hypothetical scenario of implementing an unknown new technology, participants were most likely to employ peer-reviewed journals, review articles, and online encyclopedias with equal likelihood. A significant interaction effect indicated that education level does have an effect on the usage rates of traditional academic resources, but the participants indicated that their access to academic resources was often discouraged by cumbersome databases and pay-walls. The data was presented in an unbiased manner; conclusions based upon this presentation of data will be discussed in the following chapter. The full data, in raw form, is provided in Appendix B of this document.

CHAPTER 5: CONCLUSIONS, DISCUSSION AND RECOMMENDATIONS

This chapter provides a summary of the methodology, general conclusions pertaining to the research questions and the current status of the academic relationship with industry, discussion regarding the implications of the results of this study, and recommendations for addressing the impacts of the discoveries uncovered by this research. Recommendations for future work conclude this chapter.

5.1 Summary of the Study

The data collection process was conducted over a two-week time-span during the spring semester of 2016 at Purdue University in West Lafayette, Indiana. The data were collected through an online survey instrument administered to engineering and R&D professionals employed by Rolls-Royce in Indianapolis, Indiana. Rolls-Royce was chosen as the focal point of the study for their ability to meet the selection criteria, discussed in Section 3.1. The five (5) question survey, disseminated to Rolls-Royce employees, yielded 227 responses from a population of approximately 1000 individuals, resulting in an approximate 22 percent response rate. Question 1 on the survey instrument identified the highest completed level of education for the respondents and was used to establish a basis for correlations between education level and the remaining questions on the survey. Mandatory Questions 2 and 3 were evaluated in a quantitative manner in unison with Question 1. These questions established the current usage rates of academic resources, as well as the likelihood of using academic resources when presented with the task of implementing a new technology. Questions 4 and 5 were optional questions intended to receive qualitative feedback with regards to the personal preference of academic sources of information, as well as provide feedback pertaining to the process of accessing academic resources. The remainder of this section will recap the methodology used for the analysis of the data and draw direct conclusions on how the research questions were addressed by the statistical analysis.

5.1.1 Review of the Method

Both quantitative and qualitative methods were used for the analysis of the data. The responses for Questions 1, 2, and 3 were used for the quantitative analysis. As stated in the previous section, the purpose of Question 1 was to establish a profile for the respondents' educational background. This information was used primarily to investigate correlations between Questions 2 and 3. Questions 2 and 3 were analyzed using a two-way mixed ANOVA, with an ad hoc Tukey means comparison on the various academic resources. Due to the presence of significant interactions of the main effects for both questions, slices were performed to investigate the significance of the interactions themselves. Lastly, correlations between Questions 1 and 2, and Questions 1 and 3 were performed in an effort to evaluate the predictive qualities of "Education" on both the current usage of academic resources, as well as the likelihood of accessing academic resources for future projects.

Questions 4 and 5 were used for qualitative purposes. This was largely due to the fact that the questions were not mandatory for the participants; therefore the number of responses for these two questions was considerably lower than that of the three mandatory items. The open-endedness of the design for these questions was another factor considered for choosing a qualitative analysis. While it was possible to group the question responses into explanatory categories, the variation between responses did not lend itself well to appropriate quantitative analytical methods. As a result, the responses for Questions 4 and 5 were used only as anecdotal reinforcement to the quantitative analysis of Questions 1, 2, and 3.

5.1.2 Research Questions

When discussing the conclusions of this study, it is important to consider the context of the research questions. This section recalls the research questions and provides direct conclusions to these questions based upon the empirical results presented in Chapter 4. Further discussion regarding the implications of these conclusions is presented in Section 5.2.

5.1.2.1 Research Question 1

1. What are the most influential academic channels for the dissemination of knowledge within the aerospace manufacturing sector of industry?

Based upon the statistical analysis of the survey questions, it was concluded that the most influential academic channel for academic information was the internet, specifically: online encyclopedias. This was further confirmed by the corroborating evidence from respondent feedback, where online resources were the most prevalent favored source of academic information. According to the participants, the primary reasons for utilizing online encyclopedias and other general internet sources are cost and ease of access. Many participants cited that pay-walls and complicated database interfaces prevent common access to many of the formal academic resources. Online encyclopedias, like Wikipedia, are free to access and have much of the general knowledge required for further exploration. Search engines, specifically Google, have vastly increased access to scholarly resources through Google Scholar, although these databases are still severely lacking in overall content when compared to the vast databases available to academicians.

5.1.2.2 Research Question 2

2. What academic channels are professionals in the aerospace industry most likely to employ while researching an unknown topic?

When faced with an unknown research topic, respondents of the survey were split between three (3) possible outlets for obtaining new information: “Peer-Reviewed Journal”, “Online Encyclopedia”, and “Review Article”. According to the statistical analysis, these three resources do not differ significantly amongst themselves, meaning ranking them from most-likely to least-likely would require extrapolation of the data. Therefore, it should be considered that these three resources would experience an equal likelihood of being chosen when conducting research on an unknown topic. When taking into account the comments provided by respondents, many made it clear that academic resources like peer-reviewed journals and industrial journals would be a preferred source if it were not for the limited access. Contrarily, others felt that the information contained within many academic resources was irrelevant to their jobs. This contrast between groups is likely the reason why all three resources were found not significantly different from one another. In summary, internet resources are the favored source for professionals at Rolls-Royce; yet, if given the opportunity for something different, they would choose something more purely academic in nature.

5.1.2.3 Research Question 3

3. What, if any, barriers exist to accessing academic resources in a non-academic setting?

When just looking at the barriers to accessing academic resources, by far the most popular sentiment was the fact that many academic resources are difficult to access from a number of fronts. First and foremost, the databases that contain many of the purely academic resources are very difficult to search. Respondents cited the complexity of the websites, as well as the ambiguity of the database user interfaces as common barriers. Additionally, nearly all of the databases that store academic resources are subscription services, meaning some form of monetary exchange is required to access the information contained within. Another important barrier to note is the irrelevancy noted by a number of participants. Comments from the participants indicate that many of the pure academic resources are far too theoretical, and do not have much relevance in a manufacturing environment. Furthermore, participants indicated that many of the processes or materials involved in their current roles are not necessarily new or novel, therefore the utilization of academic resources does not add much value to their daily duties. So to draw a specific conclusion, the most common barriers for accessing academic resources for industry professionals are "pay-walls", difficulty navigating academic databases, and a lack of practical publications.

5.2 Discussion

This section covers the implications of the conclusions drawn in the previous sections, and the ramifications this research could have on the status quo for the production of academic information. Many of the discussion points provided in this section indicate solutions that would require systematic change. As a result, it would be of great value to both industry and academia that further investigation be completed to determine the magnitude of the deficiencies noted in this study.

After employing the selection criteria, Rolls-Royce was chosen as the focal point of this study to measure the current usage of academic resources at a highly technical, cutting edge manufacturing facility with the capital, resources, and manpower for extensive R&D operations. As established in the literature review, Chapter 2, companies of this nature have the highest propensity to interact with academia, therefore provide the greatest opportunity for measuring the strength of industrial participation with academic resources. By this logic, a company like Rolls-

Royce should be in the upper percentiles of companies who participate actively with academia. Furthermore, engineering and R&D professionals should have even more of a necessity to engage with academia given the nature of their roles within the company. However, the results of this study show that not only was the use of academic resources low, but it was also discouraged by cumbersome and expensive barriers to entry. This was evident through the direct comparison between the results of Questions 2 and 3 on the survey instrument. The Tukey means comparison for Question 2 determined that "Online Encyclopedia" was the most commonly used academic resource among the participants of this study. However, when looking at the likelihood of choosing a certain academic resource for the task implementing a new technology, the pure academic resources are grouped similarly with "Online Encyclopedia", meaning that no significant difference exists in the likelihood that any of those resources will be chosen over another. Yet, even with the perceived preference, pure academic resources such as peer-reviewed journals, review articles, and industrial journals are not being used extensively in this non-academic setting. Even with the anecdotal evidence provided by the respondents in Questions 4 and 5, there appears to be a shared sentiment that a number of barriers prevent the pure academic resources from being used in their day-to-day duties. So what are the implications of these findings?

To answer this question, there needs to be some insight into the production of academic resources and the culture surrounding their production. In academia, there is substantial motivation, in the form of job retention, to produce publications. As the saying goes, "publish or perish". But the question must be asked: For whom are these publications being produced? Published peer-reviewed research comes in two forms: Basic and applied. Basic research tests and investigates the cutting edge of knowledge, whereas applied research focuses more on the practical aspects, or application, of a technology. For example, basic research might include the formulation of a new polymer chain. Applied research would then investigate the mechanical properties of said polymer for end-use applications. With the exception of the pharmaceutical industry, most manufacturing operations rely on the applied research domain for new or novel information (Bekkers & Freitas, 2008; Cohen, Nelson, & Walsh, 2002). But, the results of this research showed that this is not necessarily the case. This study indicates that peer-reviewed publications, and other pure academic resources, are being produced by, and for academics – not industry. It could also indicate that much of the research being published is theoretical in nature, and therefore not applicable to industries' needs.

Funding is yet another concern when considering the fact that peer-reviewed sources appear to be incestual in nature. As mentioned in Chapter 2, Purdue University alone spent $600 million dollars on research oriented projects in 2014. Also established in Chapter 2 was the fact that the primary deliverables of such academic research projects are publications and/or patent production (Agrawal & Henderson, 2002). As such, in the same year, 2014, Purdue University produced 93 patents, all of which were utility patents, resulting in a record breaking year for patent production (Sequin, 2015). According to the literature, only a small fraction of patents survive to commercial fruition, meaning that of the 600 million spent on research, only a fraction will trickle back towards the economy (Toole & Czarnitzki, 2010). Is this deficit necessarily a negative outcome to the investment in research? No. But one could deduce that publicly funded research should have a greater impact on the domestic economy by disseminating academic information to the industry; rather than producing publications and patents that are of largely no value outside of the academic setting.

However, these conclusions are not to say that academic resources are not being utilized at all. Recalling Section 4.3.5, it was found that a significant correlation existed between education level and both the current usage and likelihood of using academic resources. According to this correlation, education level has a positive effect on these metrics, meaning that as education level increases, so does the use of the traditional academic resources. As stated earlier, this correlation does not imply causation, but rather that as the education level of the workforce increases, so does the propensity for the workforce to interact with academic resources. This is further corroborated by the significance of the interaction between main effects for both Questions 2 and 3 where education level was shown to significantly interact with “Peer-Reviewed Journal”, “Review Article”, and for Question 2, also “University Partnership Program”. This indicates that education level has a significant effect on the current and hypothetical usage rates of academic resources.

Another correlation worth noting is that the participation with university partnership programs and university assistance programs strongly correlated with the use of all of the other academic resources listed on the survey, with the exception of online encyclopedias. This implies that employees who engage with these university programs are more likely to employ academic resources in their day-to-day duties, as well as when faced with researching or implementing new technologies. In fact, the only academic resource not found to exhibit a significant correlation with both “University Partnership Program” and “University Assistance Program” was “Online Encyclopedia.” This finding suggests that individuals or companies who participate with partnership programs or assistance programs tend to interact with a wider range of academic resources. Now, it could be plausible that these programs are the sole facilitators of this interaction between industry professionals and academic resources, but it is still engagement nonetheless. These correlations for “University Partnership Program” and “University Assistance Program”, with respect to the context of the Question 2 current usage statistics and hypothetical usage statistics can be found in Tables 5.1 and 5.2 below, respectively

Table 5.1
Table of significant correlations between "University Partnership Program" and the remaining academic resources for Question 2. Ranked from strongest correlation to weakest correlation.

Resource		Pearson's r	p Value
2	University Assistance Program	0.46191	<0.0001
1	Trade Show	0.36433	<0.0001
7	Peer-Reviewed Journal	0.35661	<0.0001
5	Current/Retired Faculty	0.33110	<0.0001
6	Industrial Journal	0.27293	<0.0001
4	Recent Graduates	0.24836	0.0002
8	Review Article	0.16349	0.0137
9	Online Encyclopedia	0.01846	0.7821

Table 5.2
Table of significant correlations between "University Assistance Program" and the remaining academic resources for Question 2. Ranked from strongest correlation to weakest correlation.

Resource		Pearson's r	p Value
3	University Partnership Program	0.46191	<0.0001
1	Trade Show	0.35472	<0.0001
4	Recent Graduates	0.29345	<0.0001
6	Industrial Journals	0.29266	<0.0001
7	Peer-Reviewed Journals	0.27651	<0.0001
8	Review Article	0.24416	0.0002
5	Current/Retired Faculty	0.20048	0.0024
9	Online Encyclopedia	0.01395	0.8344

Note again, that in both Tables 5.1 and 5.2, the only resource not to have a significant correlation with either “University Assistance Program” or “University Partnership Program” was “Online Encyclopedia.”

The same trends hold true when looking at the correlations for “University Partnership Program” and “University Assistance Program” in the context of the likelihood of using academic resources when faced with implementing a new technology. In some cases, the correlations were considerably stronger. These correlations can be found in the following Tables 5.3 and 5.4.

Table 5.3
Table of significant correlations between "University Partnership Program" and the remaining academic resources for Question 3. Ranked from strongest correlation to weakest correlation.

Resource		Pearson's r	p Value
2	University Assistance Program	0.75859	<0.0001
4	Recent Graduates	0.51189	<0.0001
5	Current/Retired Faculty	0.44583	<0.0001
1	Trade Show	0.44168	<0.0001
6	Industrial Journal	0.31032	<0.0001
7	Peer-Reviewed Journal	0.30903	<0.0001
8	Review Article	0.25599	<0.0001
9	Online Encyclopedia	0.01775	0.7903

Table 5.4
Table of significant correlations between "University Assistance Program" and the remaining academic resources for Question 3. Ranked from strongest correlation to weakest correlation.

Resource		Pearson's r	p Value
3	University Partnership Program	0.75859	<0.0001
1	Trade Show	0.49615	<0.0001
4	Recent Graduates	0.40760	<0.0001
5	Current/Retired Faculty	0.38402	<0.0001
6	Industrial Journal	0.29980	<0.0001
8	Review Article	0.21888	0.0009
7	Peer-Reviewed Journal	0.19798	0.0027
9	Online Encyclopedia	0.00665	0.9207

From Tables 5.3 and 5.4, it is suggested that respondents who felt likely to use either university partnership programs or assistance programs when implementing a new technology displayed less of a likelihood for using the traditional academic resources in favor of personal contacts and events. This is contrary to Tables 5.1 and 5.2 that show the opposite with regards to the current usage statistics. One possible theory for the discrepancy is that individuals who are likely to employ university partnerships or assistance programs are relying on supplemental assistance for accessing traditional resources; whereas participants who currently utilize the services provided by partnerships and assistance programs already possess the tools required to perform the searches on their own. My personal experience with clients through the Technical Assistance Program at Purdue University corroborates this theory. A large number of companies seeking assistance through TAP were doing so in an effort to gain access to the Purdue Library database. In essence, they knew what they wanted; they just did not possess the tools to access it. Again, it should be noted that these correlations do no imply causation.

5.3 Recommendations

So how do we encourage more widespread participation in academic resources? There are a few possible suggestions that can be made, both on an immediate scale and also in a more gradual manner to address the deficiencies of the academic-industrial relationship.

5.3.1 Outreach

It was discovered that university partnership programs and assistance programs had a significant correlation with the participation with nearly all of the other academic resources. One recommendation I would make on this front would be to encourage and more openly advertise the benefits of utilizing university based technical assistance programs and higher level university partnerships. As is the case with the Technical Assistance Program (TAP) at Purdue University, basic technical consulting services are provided free of charge to the client, allowing the creation of a risk-free connection to academia for any company with a physical location within the geographical boundaries of Indiana. In my personal experience with TAP, many of these companies maintain their relationship with Purdue long after the project has ended. Some clients return for additional projects, while others have established partnerships with faculty for more advanced research. For those companies wishing to maintain deeper, longer lasting relationships, Purdue University should encourage some of the numerous partnership opportunities available by creating a smoother segue between short term assistance program activities and the longer term partnership activities. Although more specific than assistance program services, partnership programs can create a lasting channel for transferring, sharing, and engaging industrial partners with new and novel technology.

5.3.2 <u>Open-Source Publication</u>

A recommendation broader systematic change might take shape with the way research is published and disseminated. There is much debate in the current academic environment over the validity of open-source outlets for publishing research. The ultimate goal of open-source publications is to broadcast published research to the masses at no cost. In 2013, the Office of Science and Technology Policy (OSTP), a division of the Executive Office of the President, initiated a memorandum which would require that the results of publicly funded research be published in a manner that would allow for unrestricted access to the general public (Van Epps, 2016). The OSTP mandate established a handful of basic requirements. First, any U.S. agency with over $100 million in “annual conduct of research and development expenditures” should use available funds to develop a plan to facilitate open access publications (Holdren, 2013). Each agency’s directive should cover access to existing private databases, means to improve public ease of access, long term accessibility issues related to database structure, a method to educate recipients of federally funded projects on dissemination stipulations, and also internal mandates on metrics for policy success (Holdren, 2013). As of April 29th, 2016, sixteen departments had completed and submitted their plans for open access publications (Holdren, 2016). This initiative has been a significant step forward for the academic community with regards to disseminating knowledge to the masses, from both an ethical and professional viewpoint.

Many private publishers in the medical realm, as well as many STEM fields, have been slowly moving toward open-access publications as a result of claims that closed-access medical publications violate the ethical boundaries of humanity. So how do private, for-profit publishers turn a profit when their publications are offered for free? This gray area of the open-access arena gave way to a business model where fully edited versions are retained for paying subscribers. In this scenario, pre-edited versions are published online, for free, but in order to view the versions in an edited, “official” state, one must subscribe to the publication. These “free” versions, however, are often incomplete or missing important data. Another popular alternative is the “author-pays” model. In this situation, the author of the article pays the publisher a one-time fee, ranging anywhere from $500 to $2,500 depending on the length of the publication, contents of the research, and credibility of the journal (Clarke, 2004). From that point forward, the published article is supplied at no cost to the public and is therefore considered “open-source” (Clarke, 2004; Van Epps, 2016). But is this still truly open-source? Both of the aforementioned models require some sort of monetary compensation in order to access the information contained within, whether it be from the author or the general public. While there are repositories where true open-source publication is encouraged, many critics argue the legitimacy of such outlets over claims that the review processes are not nearly as rigorous as their closed-source counterparts. One such outlet is the arXiv database. The arXiv database was originally founded as a place for professionals in the field of physics to share and temporarily publish innovative physics research, but has since grown to include many of the science fields (Cornell University Library). In most cases, arXiv acts as an outlet for researchers to publish scientific breakthroughs in a manner that establishes a traceable research timeline. However, arXiv does not peer-review publications, and as a result suffers in terms of credibility. As a result, publishing in this domain does not strengthen ones promotion and tenure document. While arXiv may be a unique example, the “open-access” nomenclature, in a general sense, does not necessarily imply “not peer-reviewed; it simply states that the information contained within the publication is available freely to the general public (Van Epps, 2016). An example of a peer-reviewed open-source archive is the

PubMed Central repository, established by the National Library of Medicine (NLM). As of 2009, the Omnibus Appropriates Act created a law requiring that any published National Institutes of Health (NIH) funded research be submitted to the NLM PubMed Central database (United States National Library of Medicine; National Institutes of Health, 2016). PubMed Central is not a publisher per se, but rather a database or archive containing peer-reviewed publications from a number of known academic publishers. Nevertheless, the information contained within is provided at no cost to the general public. In this particular case, legislature was the driving factor in creating an open-source repository for the general public.

The open-source framework of PubMed Central is primarily limited to the medical field, with branches slowly expanding to include other biological sciences and chemistry related fields. As it stands, the remainder of the STEM community is largely closed-source, with a few exceptions subscribing to the “author-pays” model (Van Epps, 2016). The OSTP mandate aims to fill this gap by incorporating a directive that ALL federally funded research be available for free, as it arguably should be. It is recommended that Purdue University, or academia in general, incentivize the publication of research in the open-source arena. Undoubtedly, there is a much deeper relationship between academia and the private publishing industry that would most certainly hinder any significant movement in this general direction, but the recommendation needs be made. Recalling the data, the driving theme of the participants’ responses was that too many barriers exist with regards to their access to academic information; namely cost and difficulty of database navigation. As a result, the participants resort to less reliable sources of information, even when pure academic resources were favored. If academicians are required and incentivized to publish in open-source venues, then active industry participation in academic resources will eventually rise, in turn strengthening the academic-industrial relationship and ultimately the economy.

5.3.3 Industry Portal

During my undergraduate studies at Eastern Illinois University (EIU), I was employed as a student-worker in the EIU library system's periodical department. My duties were menial, but included organizing the periodical section and directing library patrons to their destinations within the vast array of stacks. Towards the end of my studies, the library system decided to move away from print periodicals in favor of their electronic counterparts. Before the transition, any person could visit this particular public university library and flip through any number of our print periodicals in search of a specific peer-reviewed publication. After the transition, the only portal to this collection of resources was a PC workstation that required university credentials to access. No longer were the days of unfettered public access.

The same trends hold true at Purdue University. In fact, in the Potter Engineering Library, only two PC workstations provide guest-access to the Purdue Library network. If we take a step back, and evaluate the overall system, it is evident that publicly funded research is slowly taking steps towards open-access dissemination through the OSTP mandate. But what about the services paid for by Purdue University? Although public funding accounted for approximately 15 percent of the total endowment, Purdue University is still considered a state funded public university (Purdue University, 2014). By this logic, the taxpayers of Indiana should have at least a little access to the extensive resources of which Purdue University has subscribed. Before the digital revolution, this might have been easier to accomplish since public access to print materials was relatively easy to facilitate. However, in the wake of the shift to digital media, access to these once accessible resources has become, ironically, more cumbersome. One recommendation to remediate this hurdle would be to provide short-term industry access through an industrial portal. As mentioned in Section 5.2, an alarming number of Indiana companies contacted the Technical Assistance Program because of restricted access to academic publications. This indicates that not only is there a need for such a service, but also that the benefits of an industrial library portal could incubate long-term industrial research partnerships with Purdue University. The University could even host industry-centric workshops for searching and accessing academic resources. In other words, make Purdue University the proverbial one-stop-shop for technical assistance.

This framework can be taken one step further through the implementation of a program that would allow Purdue graduates the opportunity to re-activate career accounts for access to the Purdue Library system. Not only would this facilitate active industrial participation in academic resources, but it would give potential employers of Purdue graduates an incentive to employ Purdue alumni. Again, there are certainly hurdles for such systematic change. Purdue University subscribes to a number of databases that ultimately comprise the Purdue Library as it is currently known. The subscription fee for this service is based upon the total full-time equivalent (FTE) of the university (Van Epps, 2016). As such, drastically increasing the number of users through the retroactive addition of alumni could cause a substantial increase in the cost for this service. However, the potential benefits of a fully equipped alumni population could offer a significant increase in the demand for Purdue graduates, as well as serve as a framework for other universities who wish to implement similar programs.

Regardless of the implementation method, an industry portal to the Purdue Library could greatly increase the frequency of industrial collaboration, creating abundant opportunity for further partnership and research initiatives. It would provide a lifeline for smaller companies who simply need a leg up on the competition. For large companies, it has to potential to serve as a foundation for a deeper collaborative research agreement. At the very least, Purdue could pilot this program through companies with which it already has an existing partnership. In either scenario, both the State of Indiana and Purdue University would come out ahead.

5.4 Future Work

The final section of this dissertation outlines the future work that can be used to continue the focus of this study. This particular study offered a glimpse as to the current strength of the academic relationship with the aerospace industry. Going forward, there are a few studies that could be completed in an effort to fully define this relationship. While the breadth of these proposed studies may vary, the underlying objective aims to explore the ever-dynamic relationship between industry and academia.

5.4.1 Scalability

This study investigated the magnitude of the relationship between a highly technical manufacturing firm and academia. One of the assumptions established by the literature review was that a company like Rolls-Royce would have the greatest likelihood of participating with academic resources. The next logical step in this research would entail a comparison between the results from Rolls-Royce and the manner by which smaller, less technical operations access academic information. This would determine if firm size, complexity of the product, or the expendable capital of the firm have any bearing on the propensity of a firm’s employees to access academic resources. A sample survey, identical to the one completed by Rolls-Royce employees was sent to a small, technologically advanced machine shop as an investigative study to gauge the necessity of such follow-up work. This machine shop was chosen for their extensive repertoire of highly technical manufacturing equipment, and the fact that they approached the Technical Assistance Program at Purdue University for assistance gathering peer-reviewed journal articles. The initial results found that their staff highly depends on trade shows for learning about, and procuring the latest in manufacturing equipment. As a result, a follow-up study of this nature should include both the technology readiness level (TRL) and the manufacturing readiness level (MRL) as factors. These readiness level metrics establish a quantifiable value to both the sophistications of a firms technologies and their ability to meet manufacturing needs (Engel, Dalton, Anderson, Sivaramakrishnan, & Lansing, 2012; Peters, 2015). These metrics, combined with the survey instrument created for this research would provide important feedback on how various operational aspects of the evaluated companies contribute to their use of academic resources. Linking either TRL or MRL to academic engagement would be a monumental step forward for measuring the industrial-academic relationship.

5.4.2 Trustworthiness

Another important follow-up study would gauge the epistemic qualities of academic resources. A common sentiment regarding the use of online encyclopedias, namely Wikipedia, is that they are untrustworthy sources of information (Konig, 2013). However, there has been some recent speculation as to the trustworthiness, or rather lack thereof, with regards to the pure academic publications. In fact, a recent study published in Science found that nearly two thirds of the psychological studies they sampled could not be reliably reproduced (Nosek, 2015). If the same holds true for fields outside of psychology, then what does this say about the credibility and trustworthiness of the most holy of academic publications? At that rate, they are no more trustworthy or reliable than Wikipedia. One study found that the articles contained within Wikipedia were found to be more incomplete than inaccurate, making it a surprisingly reliable source for basic information (Fallis, 2008). With this in mind, it would be an interesting follow-up study to survey industry professionals to determine their level of trust with academic resources, namely published peer-reviewed work. It is already known that the pure academic resources are not being widely used in industry, so add to that the level of distrust and larger themes may begin to appear.

5.5 Summary

This chapter provided summary of the study and a review of the methodology employed for the analysis of the data. The conclusions drawn from the analysis were provided as they relate to the research questions established in Chapter 1, and discussion pertaining to the implications of these conclusions was also included. Although broad in scope, the implications were addressed in a compartmentalized fashion in order to properly recommend extensive, yet feasible solutions to the shortcomings established by this study. By no means will the remediation of these shortcomings be simple, but the future work established in this section should provide a systematic approach to fully characterizing the true strength of the academic relationship with industry.

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LIST OF REFERENCES

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APPENDICES

Appendix A. IRB Exemption Request Documents

RESEARCH EXEMPTION REQUEST – CATEGORY 2 or 3
Purdue University – Institutional Review Board

INSTRUCTIONS

Failure to follow these instructions may result in the submission being returned to the principal investigator.

1. Use this form to request an exemption under Title 45 CFR §46.101(b)(2) or (3).
2. Use lay language and spell out acronyms. Do not cut and paste from or refer to grant or abstract.
3. Study activities may not be implemented until the investigator receives final written IRB notification the exemption has been granted.
4. In order to qualify for either of these exemptions, the study must fall into one of the following categories. Additionally you may wish to consult the decision chart for these categories.
5. Research involving **PRISONERS*** or other incarcerated individuals (or their existing data and/or specimens) do not qualify for exemption.

Category 2 involves **ONLY** the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures or observation of public behavior, unless:

- information obtained is recorded in such a manner that human subjects can be identified, directly or through identifiers linked to the subjects; and
- any disclosure of the human subjects' responses outside the research could reasonably place the subjects at risk of criminal or civil liability or be damaging to the subjects' financial standing, employability, or reputation.

Category 3 involves the use of **ONLY** the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures or observation of public behavior that is not exempt under category 2 if:

- the human subjects are elected or appointed public officials or candidates for public office; or
- federal statue(s) require(s) without exception that the confidentiality of the personally identifiable information will be maintained throughout the research and thereafter.

* **PRISONER** – means any individual involuntarily confined or detained in a penal institution. The term is intended to encompass individuals sentenced to such an institution under a criminal or civil statute, individuals detained in other facilities by virtue of statutes or commitment procedures which provide alternatives to criminal prosecution or incarceration in a penal institution, and individuals detained pending arraignment, trial, or sentencing [45 CFR 46.303(c)].

INVESTIGATOR INFORMATION

HAVE QUESTIONS about this section?
Principal Investigator Eligibility policy
Your Role and Education Requirements guidance

1. Principal Investigator contact information:

Name and Title	Department	Campus Address	Phone	Email	CITI Training Complete? Y/N
Dr. Richard Mark French	SOET	KNOY 138	[redacted]		Yes

2. Co-Investigators and/or Key Personnel contact information:

Name and Title	Department/ Institution	Phone	Email	Directly Interacting with Subjects? Y/N	CITI Training Complete? Y/N
James Stratton	SOET	[redacted]		Yes	Yes

3. Consultant(s) contact information:

Name and Title	University/ Institution	Phone	Email	Directly Interacting with Subjects or Accessing Identifiable Information? Y/N

CONFLICT OF INTEREST

4. Do the investigators or personnel have a significant financial interest in this study?
☒ NO - If no, skip to question 6.
☐ YES - If yes, proceed to question 5.

5. Has a Significant Financial Interest Disclosure Form been filed?
☐ NO - If no, refer to Financial Conflict of Interest: Policy and Procedures.
☐ YES - If yes, proceed to question 6 below.

6. Do the investigators or personnel have any other known conflict of interest in this study?
☒ NO
☐ YES - If yes, please explain the conflict: _____

STUDY INFORMATION

7. Study Title:

A REVIEW OF TECHNOLOGY ADOPTION OPPORTUNITIES FOR HIGHLY TECHNICAL COMPANIES IN INDIANA

8. Funding Source: Select all that apply:

☐ Sponsor-External Funds (Includes PRF, Kinley Trust and McCoy awards)
Identify the Sponsor and grant/award number: _____
☐ Departmental Funding: _____
☒ Other Self-Funded: _____

9. Anticipated Duration of Study: Please indicate when this project will end 8/31/2016

10. Identify the expected age range(s) of participants to be included or targeted for this research and for which there is a reasonable expectation of enrollment into this research study.
Check all that apply:
☐ under 18 years of age
☒ 18-64
☐ 65 and older

11. Identify where the research data collection will occur.
Check all that apply:
☐ Purdue University, please identify campus: _____
☐ Elementary/Secondary School(s), please identify school(s): _____
☐ Community Center, please identify: _____
☐ Other University/College, please identify: _____
☐ International Population(s) studied in their home country or within the US. Please identify the population(s) and the location of the data collection below. A**LSO** Section L, International Research, of the non-exempt research application must be completed and submitted with this exemption request in addition to the required supplemental materials: _____
☐ Internet
☐ Subject's Home
☒ Other location(s), please identify: Rolls-Royce Manufacturing Facilities

12. Will the study collect data from focus group(s)?
☒ NO
☐ YES

13. Will elected or appointed public officials, or candidates for public office, participate in the research?

☒ NO
☐ YES – Identify which public office(s) participants either hold or are candidates for: _____

14. Will prisoners and/or individuals involved in court-ordered programs or community corrections (or their data and/or specimens) be participants in the research?
☒ NO
☐ YES - If yes, the research does not qualify for exemption. Please complete and submit a Non-Exempt Research Application for review by the convened board (aka full review).

15. Will the research involve surveys or interview procedures with participants under age 18?
☒ NO
☐ YES - If yes, the research does not qualify for exemption. Please complete and submit a Non-Exempt Research Application for review.

16. Will the research involve observations of participant behavior and the investigators will interact with those participants?
☒ NO
☐ YES - If yes and the participants will be **under age 18**, the research does not qualify for exemption. Please complete and submit a Non-Exempt Research Application for review.

STUDY PROCEDURES

17. Briefly state your research question using non-technical *lay language* that can be readily understood by someone outside the discipline.

How often do industry professionals access and utilize various academic resources?

18. Will survey procedures be used? Survey procedures CANNOT be used with children under 18 years of age.

☒ YES - Identify all surveys to be used **AND** submit them with this exemption request. See Attached
☐ NO

19. Will interview procedures be used? Interview procedures CANNOT be used with children under 18 years of age.

☐ YES – Describe the interviews **AND** submit all interview questions/scripts with this exemption request. _____

☒ NO

20. Will educational tests be conducted?

☐ YES - Check the test categories to be used below and identify each test in the text box below. If the study tests do not fit into the categories below, the study does **NOT** qualify for this exemption.
☒ NO - Skip to question 21.

☐ Cognitive – Identify test(s) below and submit with exemption request.
☐ Diagnostic – Identify test(s) below and submit with exemption request.
☐ Aptitude – Identify test(s) below and submit with exemption request.
☐ Achievement – Identify test(s) below and submit with exemption request.

Identify the tests to be used: _____

21. Will observations of public behavior be made? Observational research involving sensitive aspects of a participants' behavior, or in settings where subjects have a reasonable expectation of privacy, does **NOT** qualify for exemption.

☐ YES – Describe the observations **AND** identify the venue(s) where data will be collected. _____
☒ NO

22. Will audio, visual or image (e.g., photograph) recordings be made?

☐ YES - Indicate below the type of recordings to be used. Check all that apply.
☒ NO - Skip to question 23.

☐ Audio recordings
☐ Video recordings
☐ Image recordings/photographs

Use of audio, visual or image (e.g., photographs) recordings are only permissible under these Exemptions if:

a. they are used for memory purposes ONLY to assist investigators in ensuring the accuracy of their collected data; AND
b. they will be destroyed once transcribed.

Explain in the text box below why the above-checked recording procedure(s) is necessary and how it meets both criteria **a** and **b** above.

23. Will any other procedures be used to collect data in the study? Please note, in most cases procedures that do not fall under those identified in questions **18-22** above do not qualify for exemption under these categories 2 and 3.

☐ YES - Identify all other procedures to be used in the study. _____
☒ NO

PRIVACY & CONFIDENTIALITY

24. Does this research involve the collection of any data that falls under any federal statute(s) requiring, without exception, that the confidentiality of the personally identifiable information will be maintained throughout the research and thereafter?

☐ YES - Identify the regulation(s): _____
☒ NO

25. Describe the provisions to protect the privacy interests of the participants. Consider the circumstances and nature of information to be obtained, taking into account factors (e.g., age, gender, ethnicity, education level, etc.) that may influence participants' expectations of privacy.

Education level will be collected, however, no other identifying information will accompany this data. This data will not be shared with anybody other than the researchers, and will be used for correlative purposes only.

26. Indicate below how the investigator will receive/record the research data.

☒ No identifiable data received – **Skip to question 30.**
☐ Coded data received; investigators have NO access to code key – **Skip to question 30.**
☐ Coded data will be received; investigators have access to code key
☐ Identifiable data received/recorded by investigators

27. Describe what provisions, if any, will be taken to maintain confidentiality of identifiable data (e.g., surveys, audio, video, etc.). Please state where the data will be stored, how long it will be kept and who will access it.

28. Will identifiable data and/or coded (linked) data be made available to anyone other than the research team?

☒ NO
☐ YES - If yes, please identify to whom data will be made available and the reason for the disclosure. _____

29. Indicate below what will happen to the identifiable data at the end of the study.

☐ Identifiers permanently removed from the data and destroyed
☐ Recordings transcribed without identifiers and destroyed
☐ Identifiable or coded (that can be linked) data are retained

RECRUITMENT

30. Identify below all recruitment procedures and materials used in the study. Submit a copy of all materials or text summaries for phone calls and media advertisements.

☐ Face-to-face contact
☐ Flyer(s)
☐ Letter (s)
☐ Phone
☒ Email(s)
☐ Media Advertisement(s) – Indicate below the media outlet used
  ☐ newspaper
  ☐ radio
  ☐ television
  ☐ social media site(s) – identify media site(s) below: _____

31. Briefly describe how potential participants will be contacted and identify **who** will contact them.

Participants will be contacted via email for their voluntary participation in our study. Either the PI or the Co-PI will be the only two people making contact through our company contact.

32. Is participant contact information publicly available?

☒ NO
☐ YES - skip to question 35.

33. Will you obtain participant contact information from records?

☒ NO
☐ YES – Indicate record type below.

- ☐ Education records
- ☐ Employment records
- ☐ Medical Records
- ☐ Other – Explain: _____

34. Explain how you will have permissible access to the records identified above.

We will only have access to employees via our industry contact, whose permission letter is attached to this document. We will not have any access to personal contact information beyond what is provided to us by our industry contact.

COMPENSATION

35. Will you give the participants gifts, payments, compensation, reimbursement, or services in return for their participation in the research study? See guidance **Compensation for Research Participation.**

☒ NO - Skip to Principal Investigator's Assurance section.
☐ YES - Describe the compensation type (e.g. monetary, extra credit, etc.) and amount: _____

> **Extra credit** – When extra credit is used as compensation for research participation, it cannot exceed 3% of the participant's grade. The investigator is obligated to make the class instructor aware of this limit and the requirement that students be offered an alternative non-research activity, comparable in time and effort, to earn a comparable amount of extra credit.

PRINCIPAL INVESTIGATOR'S ASSURANCE

As principal investigator of this study, I assure that the information supplied in this form and attachments are complete and correct. I have read the ***Researcher Responsibilities*** and will conduct this research in accordance with these requirements.

Principal Investigators Signature: ___________________________________ Date: _____________

Submit this signed form and attachments to the Human Research Protection Program office either via hardcopy or electronically. **Forms received without signatures will be returned.** A signed form and attachments can be submitted electronically as an email attachment to irb@purdue.edu. If a signed form is submitted electronically, a paper copy need not be submitted.

Campus Address:
Human Research Protection Program
YONG 10th Floor, Rm. 1032
765-494-5942
irb@purdue.edu
Office Hours: M-F 8-11 am 1-5 pm

U.S Mail Address:
Human Research Protection Program
Purdue University
YONG, Rm. 1032
155 Grant Street
West Lafayette, IN 47906-2114

QUESTIONS? Call our office at 765-494-5942 or attend walk-in hours.

WALK-IN HOURS – Come speak to a Protocol Analyst
Monday 9:30 am - 11:30 am
Tuesday 2:00 pm - 4:00 pm
Thursday 9:30 am - 11:30 am

Jim,
You have been given permission to proceed with the survey.

Gabriele (Gabi) Hysong, MLS
[redacted]

[redacted]

Hey Gabriele!

Hope you had a great holiday! Looks like the cold weather is finally upon us.

I just wanted to touch base and see how things were going with our collaboration. Last we spoke, you mentioned that you needed to check with HR to see if there were any issues with the questions. We discussed the possibility of doing away with the last few questions out of concerns for anonymity. I would like to submit my project to the Purdue IRB, but I want to make sure I have the questions in an acceptable form be for I do.

Also, once you get the green light, would it be possible for you to provide a quick permission letter for my study? IRB needs a form of approval from you to show that I do indeed have permission to disseminate my survey.

Please let me know if there is anything you need from me. Like I said, I am free to travel most days and could easily make the trip to Indy if need be.

Hope the New Year is off to a great start,

Sincerely,

-Jim

PURDUE UNIVERSITY

HUMAN RESEARCH PROTECTION PROGRAM
INSTITUTIONAL REVIEW BOARDS

To:	RICHARD FRENCH KNOY 138
From:	JEANNIE DICLEMENTI, Chair Social Science IRB
Date:	02/04/2016
Committee Action:	**Exemption Granted**
IRB Action Date:	02/04/2016
IRB Protocol #:	1601017080
Study Title:	A Review of Technology Adoption Opportunities for Highly Technical Companies in Indiana

The Institutional Review Board (IRB) has reviewed the above-referenced study application and has determined that it meets the criteria for exemption under 45 CFR 46.101(b)(2) .

If you wish to make changes to this study, please refer to our guidance "**Minor Changes Not Requiring Review**" located on our website at https://www.irb.purdue.edu/policies.php. For changes requiring IRB review, please Create a New Amendment through the CoeusLite Online Submission System. Please contact our office if you have any questions.

Below is a list of best practices that we request you use when conducting your research. The list contains both general items as well as those specific to the different exemption categories.

General

- To recruit from Purdue University classrooms, the instructor and all others associated with conduct of the course (e.g., teaching assistants) must not be present during announcement of the research opportunity or any recruitment activity. This may be accomplished by announcing, in advance, that class will either start later than usual or end earlier than usual so this activity may occur. It should be emphasized that attendance at the announcement and recruitment are voluntary and the student's attendance and enrollment decision will not be shared with those administering the course.
- If students earn extra credit towards their course grade through participation in a research project conducted by someone other than the course instructor(s), such as in the example above, the students participation should only be shared with the course instructor(s) at the end of the semester. Additionally, instructors who allow extra credit to be earned through participation in research must also provide an opportunity for students to earn comparable extra credit through a non-research activity requiring an amount of time and effort comparable to the research option.
- When conducting human subjects research at a non-Purdue college/university, investigators are urged to contact that institution's IRB to determine requirements for conducting research at that institution.
- When human subjects research will be conducted in schools or places of business, investigators must obtain written permission from an appropriate authority within the organization. If the written permission was not submitted with the study application at the time of IRB review (e.g., the school would not issue the letter without proof of IRB approval, etc.), the investigator must submit the written permission to the IRB prior to engaging in the research activities (e.g., recruitment, study procedures, etc.). This is an institutional requirement.

Categories 2 and 3

- Surveys and questionnaires should indicate
  - only participants 18 years of age and over are eligible to participate in the research; and
  - that participation is voluntary; and
  - that any questions may be skipped; and
  - include the investigator's name and contact information.
- Investigators should explain to participants the amount of time required to participate. Additionally, they should explain to participants how confidentiality will be maintained or if it will not be maintained.
- When conducting focus group research, investigators cannot guarantee that all participants in the focus group will maintain the confidentiality of other group participants. The investigator should make participants aware of this potential for breach of confidentiality.

Category 6

- Surveys and data collection instruments should note that participation is voluntary.
- Surveys and data collection instruments should note that participants may skip any questions.
- When taste testing foods which are highly allergenic (e.g., peanuts, milk, etc.) investigators should disclose the possibility of a reaction to potential subjects.

You are required to retain a copy of this letter for your records. We appreciate your commitment towards ensuring the ethical conduct of human subjects research and wish you luck with your study.

Ernest C. Young Hall, 10th Floor - 155 S. Grant St. - West Lafayette, IN 47907-2114 - (765) 494-5942 - Fax: (765) 494-9911

Appendix B. Raw Data

Verbatim responses to Question 1 through Question 5 from the survey are provided in this appendix. Question 1, regarding education level, is built into the tables for Questions 2 and 3. All respondents are shown for Questions 4 and 5, even if no response was left. Column descriptors: ID = Participant, Edu. = Education, TrdS = Trade Show, AP = Assistance Program, UPP = University Partnership Program, RG = Recent Graduates, C/RF = Current/Retired Faculty, IJ = Industrial Journal, PRJ = Peer-Reviewed Journal, RA = Review Article, OE = Online Encyclopedia. Values correspond to the Likert-style responses. For Education Level, please refer to Table 4.1. For Questions 2 and 3, please refer to Figures 3.1 and 3.2, respectively.

Q2 - How often do you use the following resources?

ID	Edu.	TrdS	AP	UPP	RG	C/RF	IJ	PRJ	RA	OE
1	5	1	1	2	1	1	3	1	1	4
2	5	2	1	8	4	5	2	3	4	7
3	5	2	3	3	2	2	2	2	2	2
4	4	1	1	1	1	1	1	1	1	4
5	5	1	1	1	2	2	1	1	1	2
6	5	1	1	1	2	1	2	2	1	3
7	4	1	1	1	3	3	2	1	2	4
8	4	1	2	2	4	5	3	2	3	7
9	4	1	1	1	1	1	1	1	1	1
10	5	6	7	7	7	5	6	6	6	3
11	5	2	1	1	1	1	4	3	3	7
12	4	1	1	1	1	1	2	2	2	3
13	4	1	1	1	3	1	3	2	3	4
14	6	1	1	2	1	2	1	3	3	3
15	5	2	3	2	4	4	6	6	6	3
16	4	2	1	1	1	1	1	5	1	5
17	4	1	1	1	1	3	1	1	1	3
18	4	1	1	5	4	4	2	2	1	6
19	4	1	1	1	2	1	1	1	1	1
20	5	2	1	3	4	2	3	3	6	7
21	5	1	1	1	3	2	5	3	4	5
22	5	2	1	3	3	2	1	4	5	5
23	6	2	1	1	2	1	5	6	8	7
24	4	1	1	1	1	1	1	1	1	3
25	5	1	1	1	2	2	3	5	6	7
26	5	2	2	2	3	3	4	4	5	7
27	2	1	1	1	1	1	2	1	2	7
28	5	2	1	2	4	2	3	4	4	4
29	6	1	1	2	1	4	1	5	3	4
30	4	1	1	1	1	1	1	1	1	1
31	5	1	1	1	2	3	1	2	3	4
32	1	1	1	1	6	8	4	4	5	6
33	5	1	1	1	1	1	1	1	1	8
34	4	1	1	1	1	1	1	1	1	1
35	5	1	1	2	1	1	2	1	1	2
36	4	2	1	1	2	2	3	2	3	3
37	6	1	1	2	2	6	4	7	3	1
38	5	1	2	2	3	3	3	1	3	3
39	4	1	1	2	3	1	3	3	1	6

ID	Edu.	TrdS	AP	UPP	RG	C/RF	IJ	PRJ	RA	OE
40	4	2	1	1	1	2	3	2	2	8
41	5	1	2	1	3	1	1	1	2	4
42	6	1	1	1	3	2	1	2	2	5
43	5	1	2	2	2	2	3	3	3	3
44	5	2	1	1	2	1	2	4	4	5
45	4	2	1	1	1	1	2	3	1	3
46	5	1	1	1	1	2	2	3	5	7
47	4	2	1	1	1	1	3	3	3	6
48	5	4	1	1	2	1	5	1	4	3
49	5	1	2	1	2	1	3	3	3	4
50	4	2	1	2	1	1	2	2	2	5
51	4	2	2	2	2	3	7	4	7	4
52	4	1	1	1	1	1	2	3	3	2
53	4	1	1	2	2	1	5	1	5	1
54	5	1	1	3	3	3	1	3	2	3
55	4	1	1	1	1	1	2	4	4	6
56	5	2	2	1	3	1	3	1	1	6
57	4	2	1	1	8	1	5	5	7	8
58	4	1	1	1	1	1	3	3	3	3
59	5	1	2	2	1	1	1	3	4	5
60	5	2	2	2	2	2	3	3	3	5
61	6	1	3	2	3	3	1	6	6	7
62	5	2	4	4	4	4	7	6	3	8
63	4	1	1	1	2	2	2	3	3	6
64	4	1	2	2	1	1	1	1	3	6
65	6	2	1	8	2	6	6	6	3	2
66	5	1	1	1	4	6	4	4	4	3
67	6	5	2	3	3	1	3	2	2	3
68	4	2	1	1	3	1	4	1	4	6
69	5	2	2	2	4	1	3	4	4	2
70	5	2	1	1	1	1	1	1	2	1
71	4	1	1	1	1	4	3	2	3	6
72	4	1	1	2	6	3	3	3	1	7
73	5	2	1	1	2	1	7	1	1	1
74	5	1	1	2	3	2	2	4	2	5
75	5	1	1	1	1	1	1	1	1	6
76	4	1	1	1	1	1	3	3	3	4
77	5	2	2	2	1	2	3	3	3	3
78	5	2	2	2	2	2	2	2	7	7
79	6	2	2	2	3	3	4	6	4	8

ID	Edu.	TrdS	AP	UPP	RG	C/RF	IJ	PRJ	RA	OE
80	4	3	1	3	7	3	5	3	3	8
81	4	1	1	1	1	1	1	2	2	4
82	5	2	1	1	1	1	2	1	3	2
83	6	1	1	3	1	1	5	5	1	3
84	4	2	2	2	2	3	3	3	3	4
85	4	3	1	1	8	6	5	5	5	7
86	4	1	2	2	3	7	4	4	2	2
87	4	1	3	3	1	3	1	1	1	1
88	4	2	2	1	2	1	2	2	3	5
89	4	1	1	1	1	1	1	2	2	3
90	4	2	1	1	8	8	3	3	3	3
91	5	1	2	1	1	2	1	1	2	4
92	5	1	3	1	1	1	1	1	4	1
93	5	1	1	1	1	1	3	3	1	1
94	4	1	1	1	2	1	2	1	1	3
95	5	1	1	1	2	3	2	2	3	3
96	5	1	1	1	1	1	2	4	2	4
97	4	1	1	1	1	1	1	4	4	4
98	4	1	4	1	8	1	4	4	5	7
99	5	2	1	1	3	2	3	2	5	5
100	4	2	1	3	1	1	4	3	2	1
101	4	1	1	1	1	3	1	3	2	5
102	4	1	1	1	1	1	1	1	4	8
103	4	1	1	1	4	1	2	4	2	6
104	5	1	1	1	3	1	4	2	1	4
105	5	2	1	4	2	1	3	4	6	6
106	6	1	1	1	1	2	3	3	4	6
107	4	1	2	2	2	1	2	2	2	2
108	4	1	1	1	1	1	1	1	1	2
109	4	2	2	2	3	3	2	2	2	3
110	4	1	2	2	2	2	3	1	1	1
111	4	2	1	1	1	1	2	1	1	2
112	4	2	2	1	3	3	4	2	4	5
113	4	1	2	1	3	3	1	1	1	2
114	5	1	1	1	1	1	1	1	1	1
115	6	2	1	2	3	3	2	3	3	1
116	3	1	1	1	1	1	1	1	1	7
117	4	1	1	1	7	7	2	1	1	8
118	4	1	1	1	2	3	1	1	1	3
119	5	1	1	3	1	2	4	3	3	3

ID	Edu.	TrdS	AP	UPP	RG	C/RF	IJ	PRJ	RA	OE
120	4	2	1	1	2	1	1	1	1	3
121	4	1	1	1	1	1	2	1	2	1
122	4	1	1	1	3	1	1	2	1	3
123	5	1	1	2	3	1	2	6	5	7
124	4	2	1	1	1	1	4	1	1	1
125	5	1	1	2	2	1	2	2	1	2
126	4	2	2	2	3	2	2	1	4	1
127	5	1	1	1	1	2	3	3	3	4
128	5	1	1	2	2	2	1	2	2	3
129	4	1	1	1	3	4	4	2	1	4
130	5	1	1	1	1	1	1	1	3	5
131	4	1	2	2	2	3	4	4	4	5
132	4	2	2	1	3	3	5	5	5	7
133	5	2	2	3	3	3	4	3	3	5
134	4	2	1	1	2	1	2	2	2	3
135	4	1	1	2	6	2	5	3	4	6
136	4	1	1	1	1	1	5	3	3	5
137	5	1	2	3	2	1	1	4	2	3
138	4	2	1	1	5	4	4	4	4	6
139	5	2	1	2	3	1	3	2	4	6
140	5	1	1	2	3	1	4	2	4	5
141	4	1	1	2	3	3	1	1	3	6
142	5	1	1	1	2	2	2	2	3	7
143	4	3	2	2	3	2	3	4	3	6
144	5	2	2	2	1	1	3	2	2	2
145	5	2	2	4	4	2	5	6	6	8
146	4	1	1	1	2	3	1	1	1	4
147	4	1	1	1	3	1	2	3	3	4
148	5	1	1	1	3	4	3	3	3	5
149	5	1	1	1	2	1	2	3	3	4
150	5	1	1	1	1	1	2	2	1	3
151	5	1	2	2	3	3	3	4	4	5
152	4	1	2	1	1	1	3	3	3	4
153	4	1	3	1	1	1	7	4	2	2
154	5	1	1	1	3	1	2	2	2	4
155	5	2	2	1	8	8	5	5	7	7
156	4	2	1	1	1	1	2	2	2	3
157	5	2	1	1	3	3	3	3	3	5
158	4	1	2	2	6	2	2	2	3	4
159	5	1	2	2	1	3	2	3	2	3

ID	Edu.	TrdS	AP	UPP	RG	C/RF	IJ	PRJ	RA	OE
160	5	2	1	1	1	1	3	2	2	5
161	6	1	1	1	1	1	5	5	5	4
162	4	2	2	1	3	2	3	2	5	5
163	4	1	1	1	2	1	2	2	1	3
164	5	3	2	2	2	3	5	5	3	5
165	6	3	2	5	3	6	6	4	3	2
166	4	1	1	1	6	1	2	3	3	7
167	5	2	2	2	3	1	2	2	2	5
168	4	1	1	1	2	1	1	1	1	1
169	4	1	1	1	1	2	1	1	2	2
170	2	2	1	1	1	1	1	1	1	2
171	5	1	1	1	1	5	5	5	4	8
172	4	1	1	1	1	1	4	2	4	4
173	4	2	1	1	1	1	1	1	1	1
174	5	1	1	1	1	8	7	7	7	7
175	5	1	1	1	1	2	4	2	5	2
176	5	1	1	2	3	2	3	6	3	8
177	4	2	2	2	1	3	3	3	1	5
178	5	1	1	1	2	1	2	2	2	6
179	5	2	1	1	1	4	8	7	7	7
180	4	2	1	1	1	1	2	1	5	8
181	2	2	1	1	2	1	1	1	1	2
182	4	1	1	1	1	1	2	2	2	1
183	6	2	1	2	1	2	3	3	2	1
184	4	2	1	1	1	1	3	3	6	5
185	6	1	1	1	1	1	3	2	2	5
186	5	1	2	2	3	4	1	1	1	1
187	4	1	2	2	5	1	3	3	2	7
188	6	2	3	3	1	1	4	2	1	3
189	5	2	2	2	1	1	6	6	6	1
190	4	1	1	1	1	1	2	1	2	2
191	6	1	2	2	2	2	2	3	3	3
192	4	2	2	2	3	3	3	2	3	7
193	4	2	2	2	3	8	4	6	6	8
194	6	2	2	2	6	3	6	8	6	8
195	4	2	1	1	1	3	1	1	2	3
196	5	2	1	2	5	3	3	3	2	5
197	5	1	5	6	6	7	8	8	8	8
198	4	3	1	1	1	8	2	3	4	6
199	4	1	3	3	1	1	3	3	3	3

ID	Edu.	TrdS	AP	UPP	RG	C/RF	IJ	PRJ	RA	OE
200	2	3	2	2	1	1	3	2	2	1
201	5	1	1	1	3	2	7	4	7	7
202	6	1	1	2	3	2	3	1	1	2
203	5	1	1	1	1	1	1	3	3	3
204	4	1	1	1	1	1	1	1	1	1
205	4	2	1	2	5	7	4	6	7	8
206	4	1	1	2	3	1	2	1	2	3
207	2	1	2	2	2	2	2	1	2	2
208	4	3	3	3	4	2	2	2	3	2
209	4	1	1	1	4	1	1	1	1	8
210	5	2	2	5	2	3	6	6	4	2
211	2	1	1	1	1	1	4	1	1	4
212	4	1	1	1	2	1	4	1	2	3
213	5	2	2	3	4	3	2	2	2	2
214	4	2	1	1	1	2	4	4	5	3
215	4	1	2	2	2	2	1	3	3	8
216	5	1	1	1	1	1	1	2	2	6
217	4	1	1	1	1	1	3	3	3	4
218	5	2	2	2	3	2	3	2	3	1
219	2	1	1	1	1	1	1	1	1	1
220	5	2	2	2	3	1	2	1	1	1
221	4	2	2	4	2	3	4	3	3	3
222	4	2	2	1	3	2	4	5	4	5
223	5	1	1	1	1	1	1	1	3	4
224	4	2	1	4	1	5	3	3	3	3
225	5	3	2	5	3	4	1	4	2	6
226	5	1	1	1	1	1	1	1	1	1
227	6	1	1	3	3	2	2	7	2	3

Q3 - How likely would you be to use the following sources?

ID	Edu.	TrdS	AP	UPP	RG	C/RF	IJ	PRJ	RA	OE
1	5	2	2	2	2	2	6	5	7	7
2	5	3	3	7	7	7	7	7	7	7
3	5	5	5	5	5	5	5	5	5	5
4	4	5	5	6	4	4	5	6	5	5
5	5	1	1	1	5	6	6	6	6	6
6	5	2	3	4	5	3	6	6	5	6
7	4	1	5	5	5	5	1	3	5	5
8	4	3	5	6	5	6	5	5	6	7
9	4	5	4	4	4	4	5	4	5	5
10	5	6	6	6	6	6	7	6	7	6
11	5	7	1	1	1	1	7	7	7	7
12	4	1	1	1	1	1	5	5	5	5
13	4	2	2	3	3	5	7	6	6	6
14	6	1	1	1	1	1	5	6	6	6
15	5	5	2	6	3	6	6	6	6	4
16	4	3	3	3	1	3	2	6	1	1
17	4	3	3	3	3	5	4	5	6	3
18	4	1	5	6	6	6	4	3	3	7
19	4	4	4	5	5	5	4	4	4	1
20	5	3	2	3	5	3	5	5	7	7
21	5	1	1	3	6	4	5	6	6	6
22	5	2	2	6	5	5	5	7	7	7
23	6	6	4	4	4	4	6	7	7	6
24	4	1	1	1	1	1	5	5	6	6
25	5	6	6	6	7	7	7	7	6	6
26	5	4	4	4	4	7	7	7	7	6
27	2	2	2	2	2	6	2	2	6	6
28	5	6	2	5	6	5	7	7	7	7
29	6	1	1	2	2	4	2	7	4	4
30	4	6	1	1	1	1	5	6	6	1
31	5	1	3	3	2	5	1	6	6	6
32	1	5	5	6	7	7	7	7	7	6
33	5	1	6	1	1	6	1	1	6	6
34	4	4	5	5	5	6	6	6	6	6
35	5	5	5	5	4	4	5	6	5	3
36	4	2	2	2	2	2	5	5	5	5
37	6	7	2	5	4	6	4	7	5	3
38	5	4	5	5	5	5	5	5	5	5
39	4	4	3	5	5	5	6	6	6	7

ID	Edu.	TrdS	AP	UPP	RG	C/RF	IJ	PRJ	RA	OE
40	4	5	5	5	4	3	6	7	6	7
41	5	3	2	5	6	4	4	4	6	7
42	6	1	1	6	5	4	5	6	4	5
43	5	1	1	1	1	7	7	7	7	7
44	5	2	1	1	1	1	3	7	7	7
45	4	6	7	6	2	5	6	6	4	6
46	5	5	3	3	2	2	7	7	7	7
47	4	6	6	6	5	5	5	2	2	6
48	5	5	3	3	4	5	6	3	6	7
49	5	3	5	5	3	2	6	6	6	6
50	4	2	4	4	2	1	4	4	4	7
51	4	6	5	5	4	4	7	7	7	3
52	4	2	2	2	2	2	4	4	5	5
53	4	1	5	5	3	3	6	5	6	6
54	5	5	3	6	2	5	5	5	5	6
55	4	1	1	1	1	4	5	6	6	6
56	5	6	3	4	5	1	7	1	1	7
57	4	3	4	4	5	5	7	7	7	7
58	4	1	3	5	3	2	7	7	7	6
59	5	2	4	5	3	4	5	7	6	6
60	5	2	2	2	2	3	6	6	6	6
61	6	1	6	6	6	6	1	7	7	7
62	5	5	5	5	3	3	5	6	7	7
63	4	1	1	1	2	5	2	5	5	7
64	4	2	6	6	4	5	5	4	7	7
65	6	3	6	7	4	6	6	6	6	1
66	5	1	3	3	4	6	6	6	6	3
67	6	2	5	6	5	4	5	4	5	4
68	4	5	4	2	6	3	7	6	7	7
69	5	5	5	5	6	5	6	7	7	4
70	5	3	2	2	1	2	6	6	7	5
71	4	3	5	4	4	5	5	6	6	7
72	4	1	1	2	6	6	6	5	4	7
73	5	2	2	2	5	2	2	7	2	1
74	5	3	3	4	4	5	5	6	5	6
75	5	2	2	2	2	2	2	1	5	6
76	4	2	5	5	3	5	5	5	5	2
77	5	1	3	3	1	5	6	6	7	7
78	5	5	5	5	5	4	5	5	5	5
79	6	4	5	5	1	4	6	7	7	7

ID	Edu.	TrdS	AP	UPP	RG	C/RF	IJ	PRJ	RA	OE
80	4	1	4	1	1	5	6	6	6	7
81	4	5	4	4	6	5	5	6	6	6
82	5	5	6	6	6	6	5	5	7	7
83	6	2	4	5	5	6	7	7	5	7
84	4	5	2	3	2	6	6	6	6	6
85	4	7	6	5	6	6	7	6	6	7
86	4	1	1	1	3	6	6	6	2	2
87	4	1	5	5	4	5	4	5	5	5
88	4	1	1	1	2	1	1	1	3	7
89	4	1	1	1	1	1	1	1	1	1
90	4	5	3	3	7	7	6	7	5	4
91	5	4	5	5	5	5	6	6	6	7
92	5	5	6	5	2	2	6	6	6	4
93	5	1	1	1	1	1	4	4	4	4
94	4	1	1	1	3	2	5	5	5	6
95	5	4	4	3	5	6	4	5	5	5
96	5	1	2	3	2	3	2	7	4	7
97	4	2	2	6	2	5	5	3	6	6
98	4	4	5	5	5	4	6	6	6	7
99	5	3	4	4	5	4	6	6	7	7
100	4	2	4	7	1	6	6	5	4	1
101	4	1	1	1	6	4	1	1	7	7
102	4	1	5	5	4	5	5	7	7	7
103	4	3	2	2	5	4	3	6	6	6
104	5	5	3	3	5	4	5	6	5	7
105	5	5	4	7	3	2	4	7	7	6
106	6	1	1	1	2	3	5	6	6	6
107	4	5	5	6	5	4	5	5	5	5
108	4	6	6	6	5	6	7	7	6	7
109	4	2	3	3	4	5	4	4	4	3
110	4	5	4	4	5	6	6	6	4	4
111	4	6	6	6	4	2	4	4	5	5
112	4	5	5	5	6	6	6	6	6	6
113	4	6	7	7	7	7	5	5	6	5
114	5	1	7	7	7	7	7	7	7	7
115	6	2	2	4	4	5	5	6	4	3
116	3	1	1	1	1	1	1	1	1	7
117	4	1	1	1	2	1	1	1	1	7
118	4	5	5	5	5	5	5	5	5	5
119	5	1	5	6	6	6	7	6	6	5

ID	Edu.	TrdS	AP	UPP	RG	C/RF	IJ	PRJ	RA	OE
120	4	3	2	4	5	5	4	5	5	5
121	4	4	4	4	6	6	6	6	6	6
122	4	1	4	4	5	3	5	6	5	6
123	5	1	4	5	5	2	5	7	7	7
124	4	4	1	1	1	1	6	1	3	1
125	5	5	2	7	5	5	6	6	6	6
126	4	5	5	6	5	5	6	4	6	2
127	5	1	4	4	3	5	6	6	6	6
128	5	1	4	6	5	6	2	6	6	6
129	4	5	4	7	6	7	3	5	3	3
130	5	1	1	1	1	1	3	5	5	6
131	4	2	5	6	5	6	6	6	6	5
132	4	5	5	5	4	7	7	7	6	7
133	5	5	6	7	7	7	7	7	7	7
134	4	3	5	5	5	5	5	5	5	5
135	4	1	1	6	6	4	6	6	6	6
136	4	1	3	3	2	4	6	6	6	6
137	5	2	4	7	3	4	3	7	6	4
138	4	2	2	2	5	5	6	6	6	7
139	5	5	4	4	5	1	6	6	7	7
140	5	1	3	3	2	3	5	5	5	5
141	4	1	1	3	5	6	3	6	7	7
142	5	3	5	7	5	6	5	6	5	6
143	4	6	5	4	4	3	5	5	6	4
144	5	3	4	5	2	4	5	4	5	4
145	5	3	2	5	5	3	6	7	7	5
146	4	1	1	1	1	7	4	1	1	4
147	4	2	5	5	2	4	5	5	3	2
148	5	1	1	5	6	7	7	7	7	7
149	5	1	4	4	4	4	4	6	6	1
150	5	4	6	6	4	4	6	5	5	6
151	5	3	5	7	6	7	5	7	7	5
152	4	2	3	3	4	4	6	6	6	7
153	4	4	6	6	5	6	6	6	6	6
154	5	1	1	1	1	1	1	1	1	6
155	5	3	2	2	5	7	7	7	7	7
156	4	2	1	1	1	1	7	6	7	7
157	5	2	2	2	5	5	6	6	6	6
158	4	5	5	5	7	6	6	6	7	7
159	5	1	4	4	2	5	3	5	4	3

ID	Edu.	TrdS	AP	UPP	RG	C/RF	IJ	PRJ	RA	OE
160	5	5	5	6	3	3	5	5	5	5
161	6	1	1	1	1	2	6	7	7	6
162	4	6	5	4	6	5	6	6	7	7
163	4	1	1	1	5	1	5	5	1	5
164	5	6	5	4	4	4	6	6	6	4
165	6	5	6	7	5	3	5	4	5	5
166	4	1	2	5	5	2	6	6	6	7
167	5	5	4	5	4	2	5	6	6	6
168	4	4	4	4	6	6	6	7	7	6
169	4	3	5	5	4	4	5	5	5	5
170	2	1	1	1	1	1	2	2	2	3
171	5	1	5	5	1	7	6	6	6	7
172	4	1	1	1	1	1	5	5	5	5
173	4	6	1	1	1	1	1	1	1	1
174	5	5	5	5	2	7	6	7	6	5
175	5	2	3	3	2	2	6	2	7	6
176	5	1	1	4	3	5	1	7	7	7
177	4	4	5	5	4	5	5	6	4	6
178	5	2	5	5	4	2	3	5	4	5
179	5	4	4	4	4	4	4	4	4	6
180	4	2	3	3	2	5	3	1	6	6
181	2	5	2	2	2	2	2	2	2	2
182	4	1	1	1	1	1	5	5	5	1
183	6	5	5	5	2	3	3	5	3	2
184	4	4	2	3	5	4	6	6	7	5
185	6	1	1	1	1	1	1	6	6	7
186	5	1	5	6	7	6	3	3	2	4
187	4	2	3	3	5	2	5	5	2	7
188	6	5	6	7	2	2	7	7	6	7
189	5	6	5	7	1	1	7	7	7	1
190	4	1	1	1	1	1	1	1	2	2
191	6	1	3	3	3	3	7	7	7	4
192	4	6	5	7	5	3	3	7	7	7
193	4	4	5	6	5	7	5	6	6	7
194	6	4	5	5	5	6	6	7	7	7
195	4	6	5	3	2	5	3	5	3	5
196	5	1	1	2	3	1	2	6	5	6
197	5	7	5	6	7	4	6	6	6	7
198	4	6	2	5	2	7	6	5	6	7
199	4	6	6	6	6	3	7	7	7	7

ID	Edu.	TrdS	AP	UPP	RG	C/RF	IJ	PRJ	RA	OE
200	2	6	5	4	2	2	5	6	6	1
201	5	1	1	1	5	5	7	6	7	7
202	6	1	5	5	5	5	7	7	7	5
203	5	5	2	1	1	1	1	7	7	4
204	4	6	6	4	4	5	6	4	5	6
205	4	5	2	2	6	7	3	6	6	7
206	4	5	5	5	4	4	6	4	5	4
207	2	1	2	3	2	2	2	4	1	2
208	4	6	6	6	4	4	5	5	6	2
209	4	7	6	6	4	6	7	7	7	7
210	5	7	5	7	3	5	7	5	6	3
211	2	1	1	1	4	6	5	1	1	6
212	4	3	3	4	3	4	5	4	5	5
213	5	2	2	3	2	1	1	1	1	1
214	4	1	2	2	2	6	6	7	5	3
215	4	1	1	1	1	1	1	7	7	7
216	5	1	2	2	4	5	2	6	6	7
217	4	5	2	2	2	2	5	5	5	6
218	5	5	5	5	5	5	5	5	5	1
219	2	4	4	4	4	4	4	4	4	4
220	5	5	4	4	4	2	5	2	2	2
221	4	6	5	7	2	7	7	7	6	2
222	4	2	3	3	7	7	7	7	7	7
223	5	1	1	1	5	1	5	5	5	5
224	4	5	5	5	4	5	5	6	5	5
225	5	5	2	7	5	6	2	7	6	7
226	5	6	6	6	6	6	6	6	6	6
227	6	1	6	7	6	3	1	7	7	7

Q4 - What is your favorite source for technical information?

ID	Response
1	Industry journals / magazines
2	I start with Google or Wikipedia and extend into technical organizations and papers
3	Internet sources
4	Knovel
5	Google
6	Online encyclopedia and journals
7	Fellow engineers
8	engineering toolbox
9	web
10	Journals
11	
12	MMM's
13	
14	
15	
16	ASME & AIAA Journals, Text Books, Online Text through Knovel
17	Google. Kidding aside, I would be most likely to do a general search for a topic on Google then I would gravitate towards the peer-reviewed/review article genre.
18	Online Encyclopedia
19	Suppliers
20	Google - it is so easy to search. It isn't complete especially for indepth technical material but it is a good place to start.
21	internal legacy data
22	Peer-Reviewed Academic Journals and Articles
23	Professional Conferences and Societies
24	Internal company resources and experts.
25	Technical Journals and Peer-Reviewed papers
26	Professional Journals
27	Existing Rolls-Royce data bases for current specs and Online resources
28	Internet, then academia
29	Peer-Reviewed Journals
30	Engineering textbooks and online databases of journal abstracts.
31	aiaa journals
32	People who have been in the field for years.
33	Internet
34	Scopus
35	Technoical experts in the field

36
37 Science Direct
38 Industrial journals
39 Knovel
40 Machinery's Handbook
41 Work colleagues and wikipedia/google
42 Peer-Reviewed Academic Journal
43 Industrial Journal
44 Scopus
45 Industrial journals and conferences. SAE and INCOSE are the most common.
46 Internet, Scopus, Science Direct
47 Internal historical reports
48 Wikipedia for general information to get started.
49
50
51 Industrial Journals
52 Google
53
54 Peer Reviewed journals
55
56 A Subject Matter Expert (SME) I can talk to who can point me in the right direction. These are usually employees of a technical company.
57 Google Scholar
58 Trade journals
59 Technical journals and RR specialists
60
61 Textbooks, Journals (ASME, AIAA)
62 Online Encyclopedia and Industrial sources
63 The most convenient and most fruitful resources is an internet search.
64 Peers, Text Books, and Online Engineering Resources
65 google scholar search
66 colleagues, academic journals
67 Nasa
68 Company Library and it's resources
69 journals
70 Wikipedia
71 Collegues in the field or company published documents.
72
73 ASME resources
74 Google, which often leads me to academic journals or online encylopedias.
75 Google or Wikipedia

76 Wikipedia, followed by general internet search. Knovel is also a good resource.

77 ASM Handbooks and industry material data sheets.

78 Knovel

79 google

80 Mix: info sources I personally explore; networking with technical specialists inside and outside of my company; interaction with my company's Intellectual Property Staff.

81 Online Reviewed Journals

82 Rolls-Royce Intranet

83 peer-revieweed academic journals and conferences

84 AIAA Books on specific topics or books written in the past (e.g. a/c design Raymer or Nicolai, helo aero by Johnson or Prowty

85 ASME

86

87 Internet/Online Encyclopedia or Library

88 Wiki or Google

89 IHS; Online content

90 RR library

91 Simple online Google search.

92 Nasa Tech Briefs

93 engineering library

94

95 Company history documents

96 Academic Journals

97 RR Library-Knovel / IHS

98 wikipedia

99 Google. I find aan on-line search engine a very convenient way to obtrain general information quickly.

100 Industrial Journals

101 Online Encyclopedias

102 google

103 NTIS Database, DTIC Database, independent tech document database searches.

104

105 IGTI

106

107 discussions with industry experts

108 internal (corporate) documents/reports then whatever I can find through Google

109 internet

110 IHS

111

112 online resources

113 The internet

114 Online sources

115 Peer-reviewed journal or expert, often university professor.

116

117 internet

118

119 Industial Journals and University knowledge besides government agencies like NASA.

120 Jane's

121

122 Online, Academic Journals

123 Journal Articles and Books

124 Supplier field application engineer.

125 In-house resources, wikipedia, ASME TurboExpo papers

126 Technical Experts

127 Online (Web Based) Publications

128 Current/Retired Faculty

129 Professional / Industrial Journals (ASM, ISASI, etc)

130 Online Encyclopedia; Online search for articles relating to technology.

131 CRC handbook of fuel properties-publication

132

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134

135 Co-workers including recent graduates.

136 Google Scholar

137 Peer reviewed journals, specifically Journal of Heat Transfer

138

139

140 Wikipedia

141 Textbooks

142 online summary information for a broad array of topics (as a project engr, my requirement is a high-level working knowledge)

143 Network of contacts I'v emade over the years, Academic, Sales, colleagues etc...

144 Industrial Journal

145 White Papers and Peer Reviewed

146

147 Peer-reviewed academic journals or online encyclopedia resources depending on the depth of information needed

148 Company specialist is related topics, Company design standard, internet searches for related topics

149 Internet research for tecnical papers such as theses, publications, etc.

150 published textbooks...whether available online or in library

151

152 internet

153

154 Internet

155 Face-to-Face Communication with employees/experts

156 The internet.

157 Aviation Week

158 knowledgeable people

159 Online Encyclopedia/Resource

160 industrial journals

161

162 Monthly Science journals and or trade magazines.

163

164 Scopus & Science Direct

165 Subject matter experts both inside and external to the company

166 None specific; mostly on-line resources, published articles, local experts

167 Online Encyclopedia and Subject Matter Experts in the Company

168

169 Knovel.com

170 Google

171 Online Lectures / resources and college notes / books

172 Aerospace handbook, Knovel, MMPDS, IHS, AMS publicaitons

173 conferences and trade shows

174 knovel, library

175 Trade Journals

176 ASME Journal of Turbomachinery

177 Peer-Reviewed Academic Journal

178 Internet

179

180

181 internet

182 internet

183 On-line journals, both trade and research

184 Aerospace & Defense Technology

185 Online, open share sources (no cost)

186 Current Staff

187 Google -> NASA reports or similar

188 Industrial and acadamic Journals

189	Published technical papers from credible sources
190	Technical Books after searching the Internet.
191	peer reviewed academic journal
192	Online Encyclopedia
193	Science Direct/Scopus/wiki
194	Google search
195	Co-Workers
196	Wikipedia
197	scholar.google.com
198	Current/Retired Faculty
199	The internet and buisness/academic journals/articles
200	ASM International
201	Data aggregation services such as Aviation Week, Jane's
202	
203	Academic Journals
204	-
205	Review Article
206	internet
207	internet
208	Trade conferences
209	Coworkers, Wikipedia, and College Text Books.
210	Trade publications or academic journals
211	
212	Professional organizations
213	AIAA
214	People, whether it's fellow employees or resources outside the company that really know what they are talking about.
215	Google
216	Wikipedia
217	Industry Trade Publications
218	Industrial Journals
219	
220	
221	
222	wikipedia, internet provided info
223	
224	Technical journals and conferences
225	NASA Technical Reports Server, DTIC online
226	
227	www.sciencedirect.com

Q5 - Additional comments regarding academic resources.

ID	Response
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9	n/a
10	RR on-line library resource is limited, should partner with University to get better access.
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22	In my opinion, engineers at my company under-utilize the library resources and rely to heavily on inside knowledge within the company.
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33	none
34	My role doesnt involve anything novel that would require research. As such, I don't ever use the resources for this.
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47 A majority of my work is to review engine components that we are manufacturing and assembling. Because of this, when I am doing research on a problem, rather than going to outside sources, I comb through old documents and reports we have internally on the given component to find a similar problem set and see what was previously troubleshot. / / As I learned in college, the easiest way to find a good generic source it to go to Wikipedia and from there, go to the cited source for a piece of information you need.

48 I would probaly use academic resources if they were free, meaning no on-line subscriptions required, and I knew how to access them internally.

49

50 I appreciate your attempt at a survey, but a lot of the survey's response will depend upon the project(s). For example, I'm working on a project to introduce a new material to RRC. We're working quite closely with the vendor who developed the new material and have never considered working with a college because the vendor has never worked with a college and the nature of the project has no need of a university partnership. On another project, RR has a partnership with a university in the UK, but the project's needs are so far outside of what the partnership covers that, at least for my project, the partnership has no value. Then there are intellectual property issues with many new technologies, so there may be generalities of a new technology published in journals and on the internet, but the specifics are going to be withheld and released to RR only when non-disclosure agreements are signed. / I would much rather talk about how the college curriculum can be better matched to the needs of industry. / Thanks for your survey and good luck.

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62 Academic journals are difficult to obtain and makes it hard make that my go-to source for information. I can get almost any article that I find though our librarian, but it can take a few weeks, which is often too long for my research which moves quickly.

63 Make your research articles freely available to the taxpayers who fund your research.

64

65 I think this is very unique to each person. Many of our choices are choices out of habit or familiarity. I use whatever I feel is appropriate and rarely follow the same formula each time.

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74 If there was a system in place to give people easy access to University Faculty

75 None.

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79 I can find articles through Google, but the publishers' websites are usually hard to navigate.

80 Access to electronic proceedings from technical conferences is often dependent on personal attendance, or knowing someone that attended a conference. We need to make sure our company library has access to such proceedings as much as possible. /

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84 I have also used our company library extensively for technical information and if they don't have it, we find what I need through their channels, which are either Amazon or NASA library. I will also use the internet to dig up papers.

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88 University resources are generally too difficult to search on-line. Almost always requires a telephone call.

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103 Limited contacts in the SE department from recent graduates/alumni from my school, most tech documents are found online or through coworkers from field experience.

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107 I don't do much of this in my current role

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112 Need to make University Partnership Programs more visible.

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114 I generally don't have access to academic resources.

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119 Another source of information we use in research is the US patent database both issued and published.

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124 I develop the electronics for control systems. My needs may be different than what you expect. Few things are really new but rather existing products applied using a novel method. I look for experts for the type of problem I need to solve. That is usually the field applications engineer from a supplier. Academic resources usually lack an understanding of production whereas the applications engineer has a track record of applying his product in a production environment. / Seems that an applications engineer should be included in the choices above.

125 Rolls-Royce uses UTC support for answering techincal questions. Better visibility to these UTCs for general employees would be useful. Opportunity to submit ideas for projects...

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128 Texts available through my company's library or public library are often valuable for technologies that are not extremely new. These can be located through library resources, Amazon, and more specialized services like Knovel.

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140 None

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144 N/A

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167 Subject Matter Experts (SMEs) and the technical fellowship were omitted from this survey, yet they play the largest role in new technology. These individuals are active in the research community and are the individuals who branch out and acquire the knowledge from the areas mentioned above. Going to them is a one stop shop.

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182 the concept of libraries is dated and obsolete
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189 My observation is that very few in idustry perform a proper "literature search" before launching a technology project.

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196 It appears that I gravitate towards sources that are easily accessible and searchable. Usually obtaining large quantities of data from various low-quality sources will answer technical information questions faster than looking for singular high-quality data sources. Whether it's the "pay to access" firewalls, the difficulty of knowing which peer-reviewed source is likely to contain the topic of interest, or ignorance of the information sources available I am probably not using academic resources as much as those producing the content would like.

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200 The journal of thermal spray technology is an excellent resource but not available due to the fee not being covered by RR

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205 The how-tos of accessing the knowledge of a University-Based Technical Assistance Program or University Partnership Program are not communicated efficiently, therefore they resulteed in low scoring. Frankly, I was vaguely aware of their existance but had no knowledge or training on how to utilize them effectively.

206

207 no comment

208

209 I marked "never" quite often above. Mostly because my role does not usually require a large degree of research to be done on a given project. A lot of the process/methods are already in place - research need not apply in many cases.

210

211

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213 Academia and advanced development projects are nearly incompatible due to the IP issues. A company wishing to get a jump on the competition with the incorporation of advanced technologies into a product does so at risk and with the intention of reaping a profit through control of the intelectual property. A university is bound to diseminate any information developed for all to see and use (i.e. articles, journals, thesis, etc.).

214

215 Google provides access to many useful documents, reports, and presentations from universities, companies, books, etc

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224

225 Technical conferences such as ASME and AIAA often have trade shows attached, but they are not trade shows in and of themselves. I find technical conferences useful because they bring many experts together in one place. The trade shows that are attached have much less value to me.

226

227 It is almost impossible to get articles from AIAA, ASME etc.

VITA

VITA

James A. Stratton

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Education:

Purdue University, West Lafayette, Indiana **August 2016**

Doctor of Philosophy, Mechanical Engineering Technology GPA:3.84/4.00

Research Title: An analysis of the current strength of the academic relationship with the aerospace industry

Master of Science, Mechanical Engineering Technology **August 2011**

Research Title: Automating the fret slotting process using a PLC controlled 1.5 axis CNC mill

Eastern Illinois University, Charleston, Illinois **May 2009**

Bachelor of Science, Engineering Technology GPA:3.44/4.00

Area of Study: Specific focus in industrial automation and manufacturing systems

Experience:

Technical Assistance Program Graduate Consultant, Purdue University, West Lafayette, Indiana **2010-2016**

Consulted with 80+ companies across Indiana, in all fields of engineering and manufacturing

Graduate Teaching Assistant, Purdue University, West Lafayette, Indiana **2009-2016**

MET 143 – Materials and Processes I

MET 451 – Manufacturing Quality Control

MET 349 – Stringed Instrument Design and Manufacture