Semiconductor Industry Merger and Acquisition Activity from an Intellectual Property and Technology Maturity Perspective

by

James T. Pennington

B.S. Mechanical Engineering (2011)
University of Pittsburgh

Submitted to the System Design and Management Program
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Signature of Author _____
System Design and Management Program
August 7, 2020

Certified by _____
Bruce G. Cameron
Thesis Supervisor
System Architecture Group Director in System Design and Management

Accepted by _____
Joan Rubin
Executive Director, System Design & Management Program

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ABSTRACT

A major method of acquiring the rights to technology is through the procurement of intellectual property (IP), which allow companies to both extend their technological advantage while denying it to others. Public databases such as the United States Patent and Trademark Office (USPTO) track this exchange of technology rights. Thus, IP can be used as a public measure of value accumulation in the form of technology rights. As perceived value increases in the child company, M&A occurs .

Extensive bodies of research exist concerning merger and acquisition (M&A) activity. This is likely due to the increasing trend of M&A in the market overall and the trillions of dollars involved. Between 1985 and 2018, US M&A value increased by 5.32% with 2017 US deals alone amounting to $1.7 trillion. These figures demonstrate the increasing importance of M&A. This is especially true in technology-centric industries where prior surveys identify a specific product or technology as the prime motivator for mergers. Understanding the transfer of technology and its value will become important in the future if high-tech industries also follow this increasing trend.

This study explores M&A activity within the context of the semiconductor industry by focusing on two parent companies, Intel and AMD, and their child company acquisitions from 1997 to 2017. These acquisitions total more than $53 billion and extend into 35 separate high-tech industries outside the parents' core semiconductor business. In terms of IP as assets, all 91 acquired companies represent 5K in pipeline patent applications and 37K patents. The research suggests that there is a buildup of technological value as measured by the increase of applications and patents by the child company prior to the merger event with the parent (e.g. Intel or AMD).

Additional relationships such as child company M&A acquisition value to IP quantities, IP lifespan to child company lifespan, and technology maturity are explored.

This study also proposes and implements a TRL (Technology Readiness Level) scale specific to the semiconductor industry and maps it to IP cycle times (USPTO processing times). The application of TRLs to IP data creates an approximate idea as to which maturity of technology is most valuable: new concepts or mature ideas. Results suggest that the child companies seek technology IP with higher TRLs, and these child companies are in turn acquired by the parent company (e.g. Intel or AMD).

Technology as value plays a role in semiconductor M&A activity, and it can be measured through IP. Parent companies such as Intel or AMD purchase the target company through an M&A event as perceived IP value builds up. Additionally, mature IP technology is more highly sought after applying the proposed TRL scale. Thus, mature technology appears to carry the most perceived value.

Thesis Supervisor: Dr. Bruce G. Cameron
Title: Director System Architecture Group

Acknowledgements

I wish to express my gratitude to all the individuals and institutions who have supported my MIT System Design and Management (SDM) learning experience. I consider the past two years to be some of the most transformative and thought-provoking periods of my life, both professionally and personally. The COVID-19 pandemic imparted many shocks on our global society. One of which was virtual coordination and distancing; however, I never sensed any drop in dedication from either of these sources of support.

Specifically, I wish to thank my thesis advisor, Dr. Bruce Cameron, for his unwavering guidance and patience. Even during the pandemic, Dr. Cameron continued to guide me (virtually) through my thesis journey to a more finely-honed topic. Attempting to connect M&A activity with TRLs has been a unique yet rewarding challenge full of twists and turns. Dr. Cameron worked through the topic with me during all these stages. As Seneca aptly states, "When a man does not know what harbor he is making for, no wind is the right wind" (2011). Helping me to determine my harbor is exactly what Dr. Cameron did.

I want to thank Allison Kuzeja, Lisa Norris, and Nina Cassie who coordinate the Raytheon Technologies Work Study program. This program provided the support necessary to maintain a healthy work-school balance. I would also like to thank the following work colleagues for their continued encouragement and flexibility: Erik Nordhausen, Peter Patalano, John Bettencourt, and Tom Fuhrmann.

Through the SDM program, I met a wonderful, supportive group of talented individuals with a drive to change the world for the better. Their efforts, ideals, and talents inspired me to grow as an individual. I am grateful for the opportunity to know fellow SDM'ers, from the Outward Bound teambuilding events on Thompson Island, to the DC challenges, and to the social events such as BBQ's. In addition to the members of my SDM cohort, I want to thank Executive Director Joan Rubin, Academic Director Bryan Moser, and Academic Coordinator Bill Foley for fostering my interest in the program that changed the way I look at the world around me. SDM helped me develop the skills I need to problem solve while learning how to learn better, which is a reward in and of itself.

Finally, I want to thank my family and friends for their sacrifices and strength throughout my time at MIT. They freed up the time necessary for me to concentrate on learning by taking on extra duties and were extremely considerate regarding tight project deadlines. I simply could not have undertaken such an epic journey without them. Thank you to my good friend Dr. Matthew Klepacz for his sound advice and guidance throughout my academic journey!

Thank you!

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Sources Inspiration

The complexity of the elements involved and the sheer size of the system known as M&A activity provided many challenges and rewards during my journey. I would be remiss if I did not mention the two following literary inspirations that helped me as well:

Melinda Mae

"Have you heard of tiny Melinda Mae,
Who at a monstrous whale?
She thought she could,
She said she would,
So she started right at the tail.

And everyone said, 'You're much too small,'
But that didn't bother Melinda at all.
She took little bites and she chewed very slow,
Just like a good girl should…

…And in eighty-nine years she ate that whale
Because she said she would!" (Silverstein 1974)

"Because a thing is difficult for you, do not therefore supposed it to be beyond mortal power. On the contrary, if anything is possible and proper for man to do, assume that it must fall within your own capacity." ~Marcus Aurelius (Aurelius 2005)

"Begin – to begin is half the work, let half still remain; again begin this, and thou wilt have finished." ~Decimus Magnus Ausonius (McGuire and Abitz 2001)

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1 - Introduction

The importance of mergers and acquisitions (commonly referred to as M&A) as a subject is hard to ignore due to its substantial business and organizational implications. It is often considered a tool of rapid growth leading to either success or failure as an organization (Ibrahimi 2018). 2017 US M&A deals alone are worth $1.7 trillion with US M&A valuing increasing overall by 5.32% between 1985 and 2018 (Brealey et al. 2019; "https://Imaa-Institute.Org/"). Not only is the monetary value high, but M&A is a trend that is on the rise which means companies will be more likely to encounter these events in the future (Brealey et al. 2019). For these reasons, there are large bodies of work dedicated to the studying M&A phenomena and their causes.

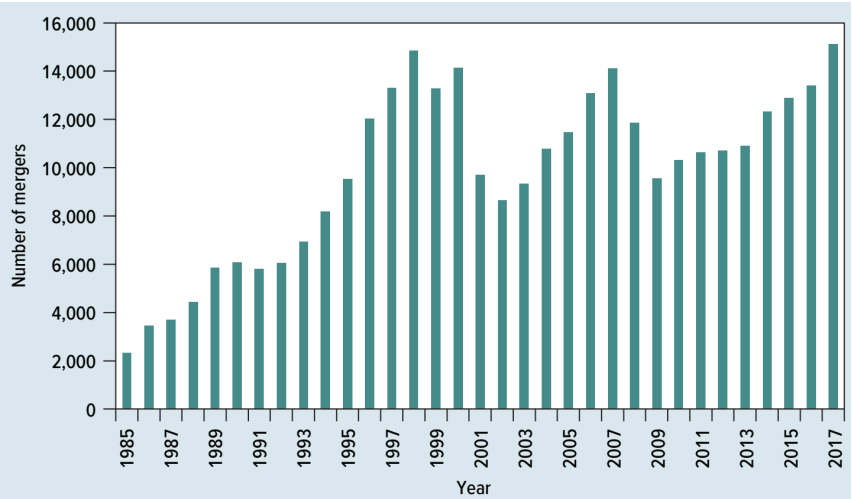

Figure 1-1: Number of US Company Mergers on the Rise (1985-2017) (Brealey et al.; "Https://Imaa-Institute.Org/")

The exact conditions that trigger M&A events are numerous in the overall market; however, one method to explore these concepts to learn more about possible motivations within a specified industry using a subset of companies with similar concepts of value. Companies create value when they succeed in meeting their objectives. They may seek this value though examples such as attaining resources, vertical integration, following clients, or synergy (Ibrahimi 2018). Regardless of the method, companies seek value.

This study focuses on exploring the accumulation of value in the form of technologies and ideas as measured by the transfer of intellectual property (IP) leading up to an M&A event. Technologies and the rights to use them are a form of resources that add value to a company, thus allowing the company to meet its objectives in turn causing more value creation. A prior survey of professionals from industries classified as high-technology (high-tech) supports this concept of a technology/product as a catalyst for mergers. This survey will be discussed more in detail later; however, it implies that people and companies

perceive technology as a form of value. It is important to note that this only applies to industries that find worth in technology. For example, a merger between financial institutions will be more likely driven by other forms of valuable resources such as people, clients, and markets rather than new technology.

The high-tech industry explored in this study is semiconductor manufacturing with a focus on the two main contenders in the CPU market: Intel and AMD. These two companies became parent companies in 91 mergers between 1997 and 2017 ("Intel Acquisitions"; “AMD Acquisitions”). Access to technological ideas and the rights to use them or deny them from a competitor clearly plays some part in a technology-centric industry such as semiconductor; however, does technology play an important role and can it be tracked with some type of external metric such as IP? If so, are new concepts or mature, established technologies perceived to be most valuable?

Examining this last question necessitates using an objective scale to determine the maturity of a technology. Technology Readiness Levels (TRLs) have been traditionally used in the defense industry but are experiencing growth outside this domain. TRLs and their use will have to be refined for the semiconductor industry based on its definition of technology maturity. Due to fast turnover times, this study proposes that a time-based scale applied to intellectual property cycle times will be an effective measure for broadly estimating the value of new versus mature technology at the time of an M&A event. This scale will be discussed more in detail.

These potential relationships between M&A, IP, and technology maturity will be based on information maintained and provided by the United States Patent and Trademark Office (USPTO), which is publicly available through its database .csv file downloads. MATLAB® source code was developed for this research and used to extract the information from large USPTO datasets using Intel/AMD merger lists maintained by AcquiredBy.co. The basic function of this source code will be described in the Methodology section with results found in the Results section. Specific details concerning the code are outside the scope of this study; however, the exact source code use for information extraction is documented in Appendix II. It is important to note that code listed in Appendix II covers major milestone data processing events. Basic knowledge of MATLAB® may be required for interim exploration of data and tables prior to running the programs.

It is important to note some key vocabulary used throughout the remainder of this study. IP will be considered both patent applications and patents, unless otherwise specified. “Application” is shorthand for “patent application” and refers to information submitted to the USPTO but has not yet become a “grant.” The term “grant” is used in the USPTO database and means “patent.” Intel and AMD will typically be referred to as “parents” or the “parent company,” and the 91 companies acquired by them will be referred to as “children” or “the child company.” These terms are used to help clarify which company is being acquired and by whom.

The extracted data primarily comes from the USPTO Patent Database where it will be analyzed in terms of overall IP counts (both applications and patents), buildup of perceived IP value prior to mergers

using a constructed time-distance variable (discussed more in detail later), approximate child company acquisition value versus IP counts, IP age at procurement versus the child company age at time of procurement, and the application of a TRL scale to determine whether new or mature technology is perceived as more valuable by both the child and the parent.

To understand the inspiration for this study along with concepts such as merger waves, it is important to discuss prior work and research. These ideas are covered in the Literature Review section, and will be applied to the data analysis found in the Methodology and Results sections.

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2 - Literature Review and Core Concepts

There are many factors that contribute to the complexities of M&A. M&A has been analyzed through overarching concepts such as System Dynamics, econometrics, statistical time series, and singular studies such as interviews/surveys. We will review these example studies to provide the reader with a sense of past tools, how they contribute to building a mental framework for analyzing M&A activity, IP, and technology maturity. We will also review major motivations for M&A in addition to technology as a valuable resource while providing background on TRLs and why they are useful. We will also discuss IP and explore the intersections of M&A, IP, and technology maturity.

2.1 - M&A Prior Research

System Dynamics excels at exploring exogenous and endogenous variables contributing to M&A complexity because it allows for an understanding of the overall system through causal feedback loops. This means that the causal loop structure itself can be the center of focus rather than determining singular statistical validity (Miczka and Größler 2010). A System Dynamics model was created by Miczka and Größler to bridge the gaps between traditional studies of M&A. They concluded that a comprehensive model can be built using System Dynamics, though they also state that there is plenty of room for future study. As seen in **Figure 2-1** below, their system of systems shows four sub-models: 1) capability transfer, 2) integration management, 3) employee morale, and 4) cultural change. These sub-models, and their underlying variables, represent one great unifying attempt to explain complexities that govern M&A.

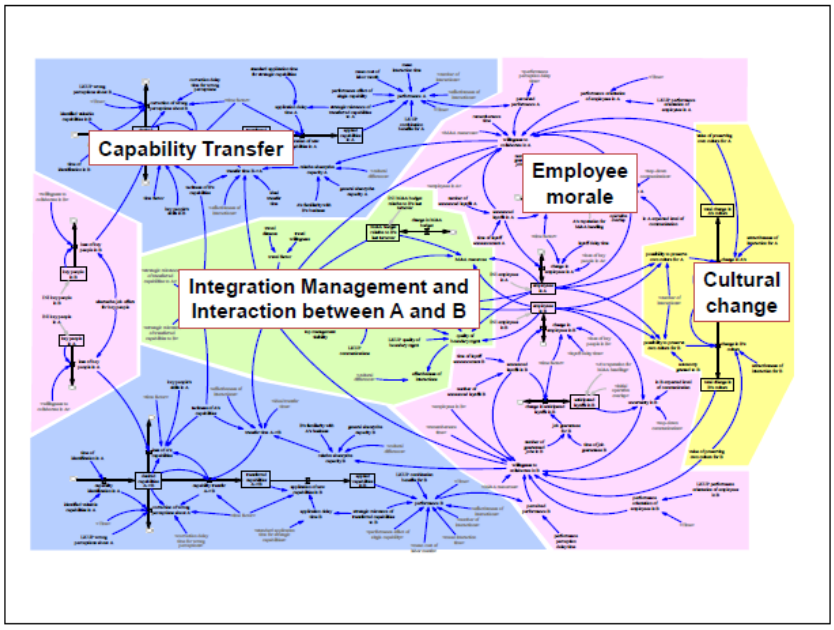

Figure 2-1: System Dynamics Model of Mergers using Sub-Models

The Miczka and Größler study suggests a thought-provoking concept that traditional inconsistencies and a lack of a unified model prior to their System Dynamics representation is likely due to the fact that M&A may not be one-dimensional, but rather several variables producing an aggregate result (Miczka and Größler 2010).

This is important to the study of M&A, IP, and technology maturity for two reasons: 1) technology and its perceived value is only one part of a larger system. Even though this paper only examines the value of technology, one needs to remember that there are many other possible conditions that could trigger an M&A event. Focusing on high-tech companies within a specific industry such as Intel and AMD attempts to limit the influence other of elements in the system to isolate and clearly analyze the role technology plays within the semiconductor domain. 2) This attempt to isolate the role of technology shifts the focus to the "Capability Transfer" section of the Miczka and Größler System Dynamics model seen in **Figure 2-1**. This part of the model is regarded by Miczka and Größler as the basis of value creation because the competitive value of the firm is improved though better deployment of resources in combination with organizational processes. In the case of this study, the resource is technology.

Another tool in addition to the System Dynamics view can be found in a time-series study performed by Town in which he explores general M&A wave structures. It is well understood that M&A is rising trend and that it occurs in waves as seen in Figure 1-1. Increases in merger activity manifest

themselves as a wave pattern and each wave is thought to be prompted by deregulation, changes in technology, or changes in demand (Brealey et al. 2019). Town takes a more econometrics-view of historical M&A (not necessarily technology-specific) to tie merger wave phenomena to external events in history to determine which factors are statistically significant. His goal echoes a similar desire to that of the Miczka and Größler System Dynamics model: create an overarching framework to answer general question such as "how do we best explain M&A activity" He wants to learn if these waves coincide with events.

Town discovered that M&A behavior overall is characterized better statistically by a nonlinear, two-part Markov switching regime using a Hamilton two-lagged smoother rather than a linear model (Town 1992). He splices together five different datasets due to the lack of one singular source. These sources include studies done by Randolf Nelson (spanning 1895 to 1920), Willard Thorp (spanning 1919 to 1954), the Federal Trade Commission or FTC (spanning 1948-1979), the Mergers and Acquisitions magazine or *MA* (spanning 1967 to present as of this article's publication), and the United Kingdom's government publication called *Acquisitions and Mergers of Industrial and Commercial Companies* (spanning 1969 to the present as of this article's publication). Why is this important? He analysis discovered 9 statistically important M&A wave events, 4 major and 5 minor. He learns that these waves can be explained by historical events as shown below in **Figure 2-2**, **Table 2-1**, and **Table 2-2**.

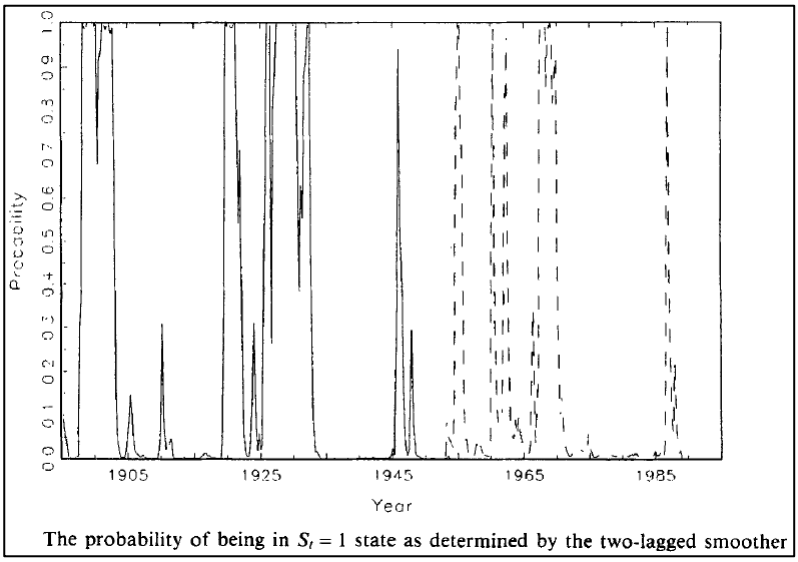

Figure 2-2: Excerpt from "Merger Waves" Displaying Time Series Data

Table VII. Dates where the probability of being in State I is greater than 0·5 from the two-lag smoother

1. 1898:I–1902:IV
2. 1919:II–1921:IV
3. 1925:III–1932:II*
4. 1945:IV–1946:I
5. 1954:III–1955:III
6. 1960:I–1960:II
7. 1962:I–1962:II
8. 1967:II–1969:IV
9. 1986:IV

* Two periods had a Prob($S_t = 1$) < 0·5 during this episode: 1926:III and 1930:III.

Table 2-1: Except from "Merger Waves" Displaying Significant M&A Events from Figure 2-2

	Year Range	Exogenous Event	Statistical Impact	Factor
1	1898 to 1902	Changes in the antitrust environment around the time of the Appeal Court ruling of *Addyston Pipe and Steel*. Price fixing ruled illegal per se.	Major	Regulatory
2	1919 to 1921	End of a World War. Possibly economic shift of resources from military to civilian manufacturing. Transfer of productive assets.	Minor	Financial
3	1925 to 1932	No specific initiating event identified; however, merger waves appear coincide with booms in economies and stock markets. Drive for limited competition (oligopoly) and vertical integration.	Major	Financial Competition
4	1945 to 1946	End of a World War. Possibly economic shift of resources from military to civilian manufacturing. Transfer of productive assets.	Minor	Financial
5	1954 to 1955	Not Directly Discussed	Minor	Not Directly Discussed
6	1960	Not Directly Discussed	Minor	Not Directly Discussed
7	1962	Not Directly Discussed	Minor	Not Directly Discussed
8	1967 to 1969	No specific initiating event identified; conglomerate M&A common during this era	Major	Corporate Structure
9	1986	Tax Reform Act of 1986, repealing many tax benefits of M&A. Elimination of deferred capital gains	Major	Tax

Table 2-2: M&A Waves and Events in Time

The importance of the Town study in regard to the semiconductor industry is not as critical the methods he used. After all, his model is not technology-centric. His work is important because it provides the inspiration and mental framework for analyzing M&A as waves tied to events. Instead of stating that M&A happens in periods of increased activity, he points to more specific, statistically significant reasons. This was the inspiration for the time-distance variable x_{ijk} described later in Methodology and Results. If M&A happens in waves, this paper suggests wave formations may also occur through the buildup of technology value measured through IP in the form of patent applications and patents.

2.2 - Value Creation

The value of technology in M&A is a core concept of this study. It is helpful to look further into ways to perceive technology as valuable and causes for M&A success or failure. Dynamic high-tech industries must respond to changes in the market to stay competitive. This is especially true when the product is predicated on selling the latest and the greatest. However, companies may undergo M&A simply because the parent company can bring a new product or technology to market quickly while simultaneously acquiring the organizational skills required to develop future iterations (Graebner 2004).

This value can be broken down into two major categories named “expected” and “serendipitous” as found in a study performed by Graebner (2004). Expected value includes the benefits the company hopes to acquire through M&A activities while serendipitous value is unanticipated benefits acquired though new synergy. Serendipitous value examples include new strategic ideas, improved production development techniques, and unanticipated new technologies (Graebner 2004). The primary focus of this study is expected value because it is the child company’s perceived value that

is expected to trigger an M&A event. Serendipitous value is outside the scope of this study because the USPTO database will likely provide little post-merger synergy information. For example, determining whether that new post-merger idea or product was the result of contact between technologies and organizations would be much harder to determine using IP as a metric. The USPTO database is more likely to simply record the transaction between parties and the status of an idea (e.g. application status as active, abandoned, or grant).

Post-merger success or failure is outside the scope of this study but is useful to discuss. Empirical results are generally difficult to obtain, but many reasons have been observed (Ibrahimi 2018). Ibrahimi states that these reasons can be related to management, strategy, culture, or politics and can occur during the three major phases of M&A: pre-combination, combination and integration, and solidification of the new entity. We can gather some idea of success or failure rates based on Graebner's 2004 study in which she discusses reasons why acquisitions either exceeded or failed to meet the parent company's expectations. Her study involved eight acquisitions in total, representing four industry sectors. Key individuals from these M&A events were selected as a sample population in addition to follow-up emails and archival data. Based on the survey data, performance with respect to expected value was split with 50% claiming "high" and 50% claiming "low." The determining factor she discovered was leadership. The most effective leaders were able to promote change. This change included completing the acquisition of the new technology and realizing synergies, both planned and unanticipated (Graebner 2004).

2.3 - Reasons for M&A

There are many accepted reasons for M&As to occur from "the right conditions," to egos, or to value creation. As mentioned in earlier by the Miczka and Größler model, there are many complexities involved.

A study performed by Ford et al. zooms into technology acquisition from the level of the individual. From this perspective M&A is only one of the three general categorizes of tech acquisition: Integrative, Collaborative, and Options-Based (Ford et al. 2012). For the purposes of this study the focus is on the first category of Integrative Technology Acquisitions, specifically M&A. Collaborative and Options-Based are outside the scope of this study since they do not encompass M&A activity. However, these three categories proposed by Ford et al. are relevant to the context of this paper by providing the reader with knowledge that M&A is not the only form of technology acquisition, though it plays a large part. Refer to **Table 2-3**.

Integrative Technology Acquisitions	Collaborative Technology Acquisitions	Options-Based Technology Acquisitions
• ***Mergers & Acquisitions*** • In-Licensing • Purchasing • Intellectual Property Markets (e.g. IP Auctions, Patent Brokers)	• Joint Ventures • Non-Equity Alliance or Consortium • R&D Subcontracting • Idea Competitions and Crowdsourcing	• Corporate venture capital investments • Minority Holding Investments

Table 2-3: Types of External Technology Acquisitions (Ford et al. 2012)

The Ford et al. study examined a list of 16 useful questions for consideration, which they compiled using a semi-structured questionnaire and interviews of senior technology managers. These questions can be seen on **Table 2-4**. Not all the questions are relevant to this study. For example, the Partner Issues are less relevant to evaluating technological value. However, these questions provide insight into reasons considered for technology acquisitions through careful examination of value to the firm. For example, Internal Issues may concern current IP, organizational acceptance of new technology, and current knowledge (strengths and gaps). Technology Issues considers the value to the parent's strategic objectives, IP protection, cost, and if the technology requires supporting individuals.

Internal Issues	Complementarity	*What existing knowledge do we have that will allow us to benefit from the acquired technology?*
		What know-how and skills do our employees possess that will allow us to benefit from the acquired technology?
		What IP do we possess related to the technology acquisition?
	Organizational Readiness	*What internal resistance might there be to the technology acquisition?*
		Where will the acquired technology fit within our organizational structure?
		Who within the organization will support the integration of the acquired technology?
Technology Issues	Match with Acquisition Motivation	*How well does the technology achieve our desired objectives?*
	Valuation	*What is our valuation of the technology?*
	IP Protection	*How well protected is the technology?*
	Development Requirements	*What technical challenges still need to be overcome?*
	Importance of Tacit Knowledge	*How important is it to acquire the people who developed the technology?*
	Total Cost of Acquisition	*What is the total cost of acquiring the technology?*
Partner Issues	Existing Relationships	*How well do we know the potential partner?*
	Cultural Alignment	*How well will we be able to work with the potential partner?*
	Strategic Alignment	*How well do the partner's strategic interests align with ours on this technology acquisition?*
	Transaction Experience	*How much experience does the partner have with this type of technology transaction?*

Table 2-4: Issues Firms Must Consider in a Potential Technology Acquisition (Ford et al. 2012)

In addition to the Ford et al. 16 useful questions, Ranft and Lord (2000) conducted a survey of high-tech industry professionals to determine more direct answers. The sample group of professionals had the following information:

- **Average Acquisition Transaction:** $69 million
- **Acquisition Range**: $11 to $249 million
- **Average Experience at Current Position**: 6 years
- **Average Experience at Firm**: 10 years:
- **Parent and Acquired Company Split (Respectively)**: 52% and 48%

35% responded that a specific, product-related technology was the primary motivator. See **Figure 2-3** below:

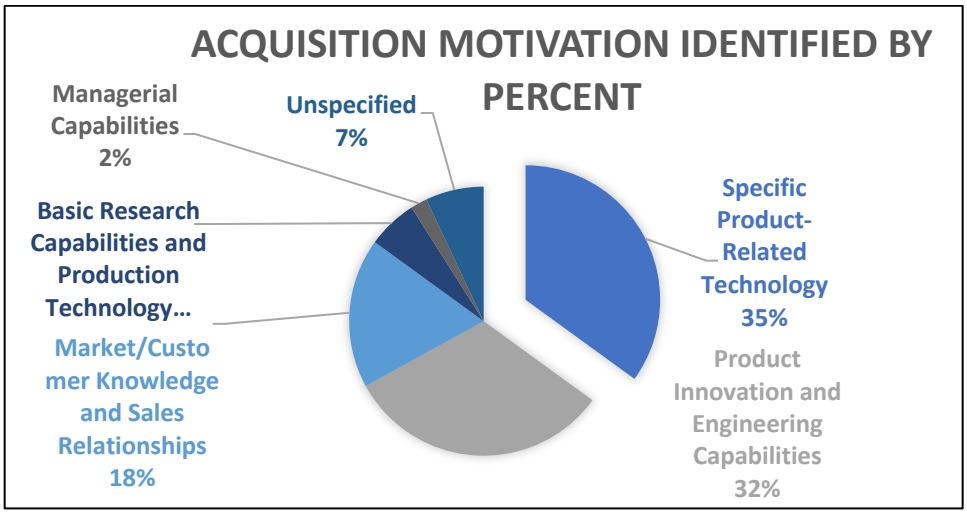

Figure 2-3: Acquisition Motivation Survey Results by Percent (Ranft and Lord 2000)

These survey results appear to support the idea that there is a link between technology value and M&A, at least from the perspective of individuals involved in an M&A event. This concept is important to the study of IP accumulation in the Results section since technology IP transactions are a proxy for perceived value.

There are other reasons for M&A and it is useful to discuss them as contextual information. **Appendix Table I** presents a comprehensive list of ten M&A studies published between 1986 and 2000 with many themes and results (Ibrahimi 2018). The exact list is outside the scope of the report but provides the reader with a sense of motivation variation between different M&A events, which may or may not involve technology. As with the System Dynamics model discussed earlier, it is useful to know that technology is just one part of the equation. Even in technology-centric fields, the possibility exists that the M&A events are not caused by technology. This study assumes semiconductor IP transactions

are inherently focused on the need to acquire technology and the right to use it. Fortunately, Ibrahimi admits that one should allow for emotional and irrational M&A decisions in addition to the firm's strategic, financial, resources-based, and opportunistic objectives (see **Figure 2-4**). This paper mainly focuses on technology maturity and IP in relation to M&A. Thus, this study focuses on the motivations related to the Resource-based Objective of "rapid acquisition of new technology" as see in **Figure 2-4** below.

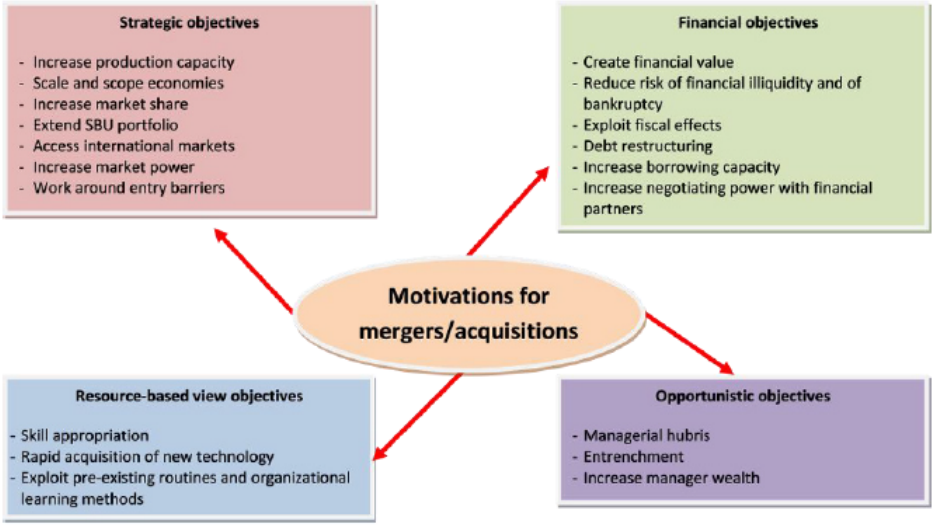

Figure 2-4: Framework for M&A Motivation (Ibrahimi 2018)

Another way Ibrahimi characterizes M&A motivation is by company size over time and the wave formation created through increased acquisitions. This concept of waves ties back to Town's study and trends noticed in the overall market. Ibrahimi suggests that motivation may change over time and parent company size. As alluded to earlier, this study specializes on the semiconductor business, specifically semiconductor technology. Intel Corp. and AMD are ostensibly the only competitors in this space (Hayes 2020). While Intel is much larger than AMD, their size difference could have an impact on their motivation as Ibrahimi suggests in **Figure 2-5** below:

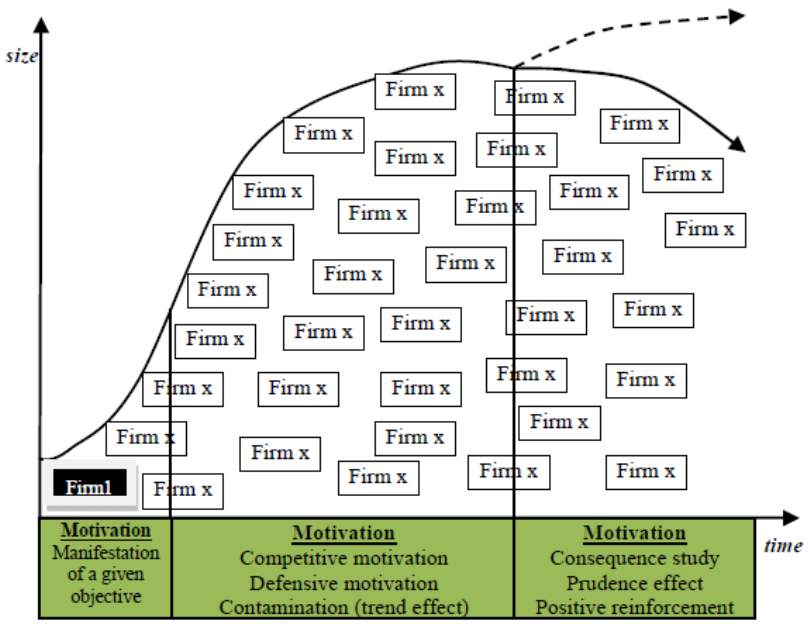

Figure 2-5: Company M&A Motivations Zones Relative to Company Size and Time (Ibrahimi 2018)

In summary, there is likely no singular reason behind merger motivations. We must be prepared to see some variation in motivation, even in a technology-centric industry such as semiconductor where tech value is likely the primary trigger of M&A. Sometimes the behavior is not even rational. Value is created when companies attain their objectives and could include: 1) the pursuit of resources, 2) vertical integration, 3) entry into a market, 4) following clients, 5) scale economies, 6) increasing market share, and 7) fiscal incentives and differentiation (Ibrahimi 2018; Hubbard and Palia 1999). The source of value examined later in the results section is the pursuit technology as tracked by IP and technology maturity. This study also believes its reasonable that mergers only add value if they are worth more together than apart in terms of complementary resources such as technology (Brealey et al. 2019). Thus, mergers happen because people and institutions rationally believe technology and teams create value.

2.4 - Measuring Technology Maturity

Why measure technology maturity? The short answer is that measuring the progress of technology development is critical to understanding concepts such as Time-to-Market (hereafter shortened to TTM) and product readiness. New technology development always carries risk, and improperly managing this risk can lead to overruns, delays, performance gaps, or cancellations in the worst of cases (Olechowski et al. 2015). Measuring maturity will help this study know if new concepts or mature technologies are more valuable based on the development risks they carry. As ACNielsen succinctly states, "'the price of light is much less than the cost of darkness'" (Ross 2018).

The consequences of poor innovation performance, especially at technology-centric companies, can be extreme. As an example, Intel Corp recently ousted their Chief Engineering Officer after the company started to fall behind competitors. Financial analysists lost faith and Intel's market value dropped by more than $40 billion. Intel is currently attempting to, '"accelerate product leadership and improve focus and accountability in process technology execution'" (King 2020).

One such measurement tool exists, and it is called Technology Readiness Levels (hereafter shortened to TRLs). TRLs have been traditionally used at NASA and in the defense industry to prevent the so-called "readiness chasm." This event typically occurs when marginally funded programs fail to develop technology to acceptable levels of demonstration in high risk, high cost programs (Sadin et al. 1989).

So how does this apply to lower risk, high cost programs (e.g. semiconductor chip makers)? Like their defense counterparts, allocating funding and resources is important. As seen in a Product Lifecycle chart example below (**Figure 2-6**), Intel was able to respond successfully to the business needs of their Supercomputing Systems Division (SSD) in the mid 1990's due to TTM issues like missed commitments, de-featured launches, customer quality expectations, and cost of development by understanding resource allocation (Galluzzo 2007). If technology maturity can be measured, uncertainties can be managed through resource allocation, and the results can be impactful.

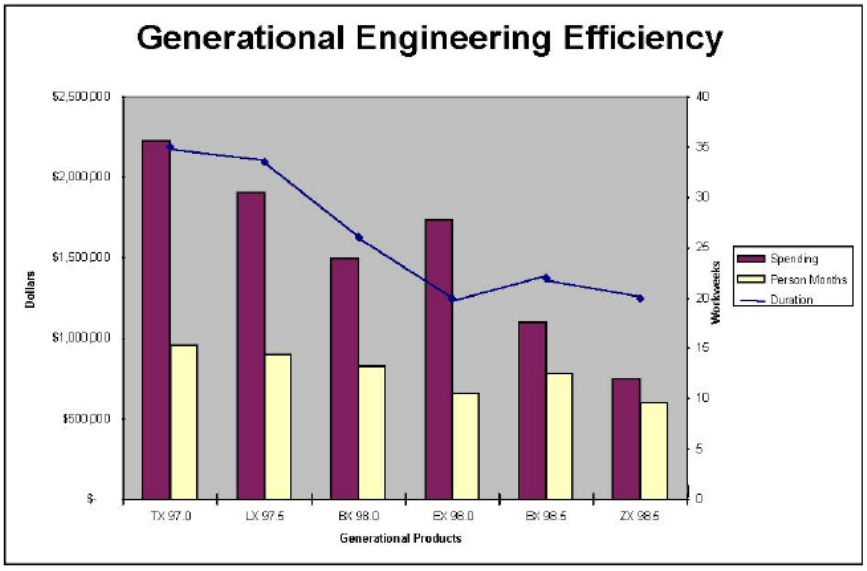

Figure 3. Decrease in Time-to-Money

Figure 2-6: Example PLC Implementation Development Efficiency Improvements (Galluzzo 2007)

More important to this study is determining if new versus mature technology is a tradeoff companies consider during the technology procurement as measured by IP. Companies may choose to purchase IP that is low in maturity because it is new, novel, and full of promise; however, they may also choose to purchase IP that is high in maturity to avoid the uncertainties of development. These choices may affect the merger with the parent (e.g. Intel or AMD).

TRLs are essentially maturity through performance history of system elements, which can help define program cost, scope and schedule (Shea 2017). The rating is a 1-9 scale and can be mapped to phases as follows in **Figure 2-7** and **Figure 2-8**.

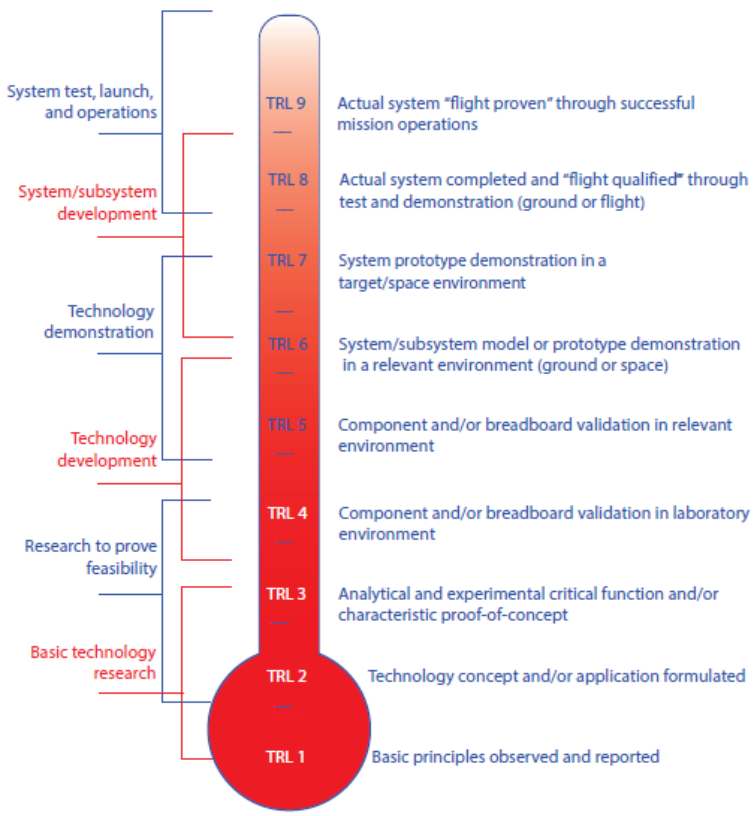

Figure 2-7: TRL Ratings and their Respective Descriptions (Shea 2017)

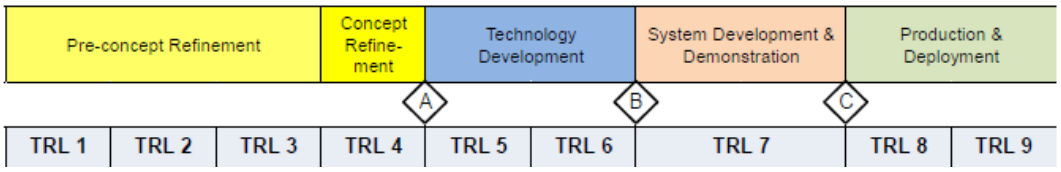

Figure 2-8: TRLs Mapped to Program Phases (Olechowski et al. 2015)

This study is not an extensive discussion on TRLs, but it proposes that TRLs are useful in the commercial world. Companies such as Google, John Deer, and Bombardier are examples of TRL expansion

into the commercial world (Olechowski et al. 2015). Measuring technology development helps offset the same product innovation difficulties found in the defense industry. TRLs establish a more objective, numeric scale that can be used in this study to explore the effects of maturity as measured by IP. Mapping this scale to IP will be discussed more in detail later.

2.5 - Intellectual Property (IP) as both a Tech Weapon, Defense, and Indicator

Patents are general property right grants that are generally good for a 20 year term to protect and promote technological progress (*General Information Concerning Patents | USPTO* 2015). The role of Intellectual Property (IP) also plays a central role in company strategy, especially in industries that can maximize its benefits for its sources of values. Patents analyzed in this report originate from the United States Patent and Trademark Office (USPTO), which is an agency of the US Department of Commerce. Thus, the patent discussed here are only applicable to the United States, its territories, and US possessions.

As a brief overview, there are three types of patents as listed below in **Table 2-5** by the USPTO (*General Information Concerning Patents | USPTO* 2015):

Utility Patents	Design Patents	Plant Patents
Invention or discovery of a new and useful…	***Invention of a new, original, and ornamental design for an…***	***Invention or discovery (and asexually reproduces) any distinct and new variety of…***
• **Process** • **Machine** • **Article of Manufacture** • **Composition of Matter** • **Or and any new and useful improvement thereof**	• **Article of Manufacture**	• **Plant**

Table 2-5: US Patent Categories and Their Contents

Type 1 Utility Patents is the focus of this study since computer hardware such as CPUs clearly inhabits this region; however, it is useful to see the entire list to gain a better understanding of both how broad and specific patents can be. Patents are filed with two possible routes: a provisional patent or full patent application as summarized below in **Figure 2-9** ("Part 1: A Primer on Patents"). Knowing the differences between a full patent, patent application, and provisional patent application becomes important when examining the data because it shows the researcher which database to use and some vague idea of the firms' intentions.

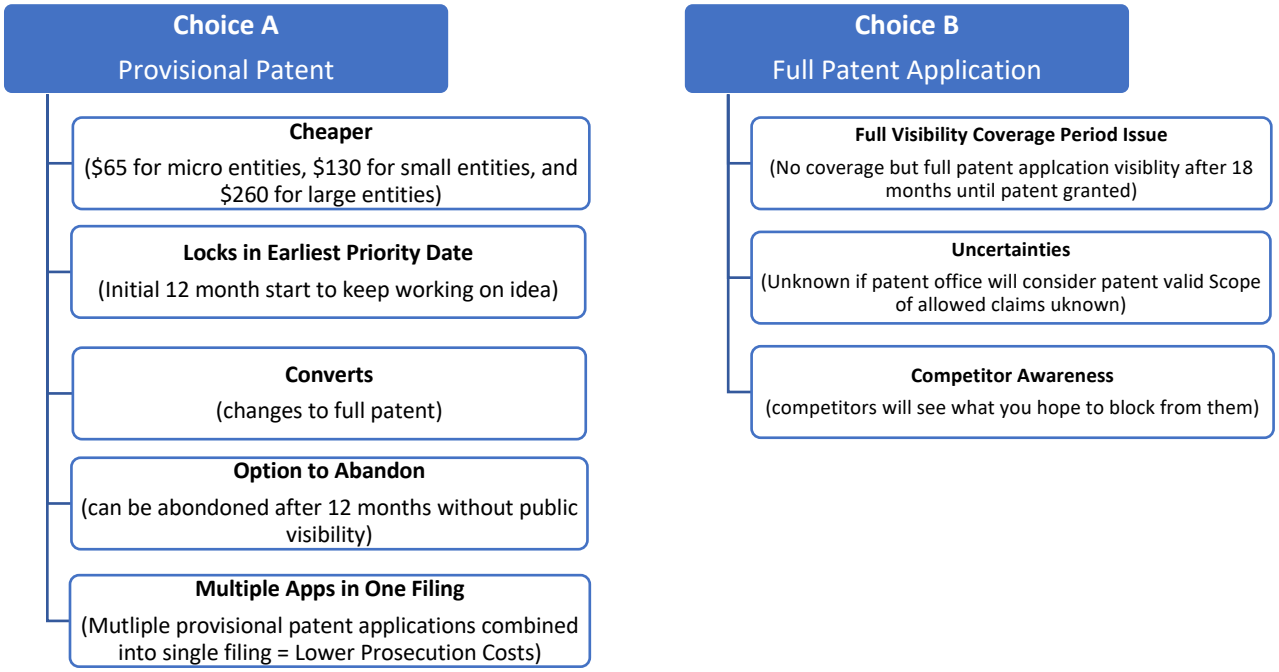

Figure 2-9: Summary of Patent Application Paths ("Part 1: A Primer on Patents")

The average time to receive a patent 32 months as quoted by the Erickson Law Group ("How Long Does It Take to Get a Patent?"). This approximate number is echoed by various other sources and calculated to be roughly correct based on the average wait time from 2013-2019 posted by the USPTO, which is 34 months (refer to **Figure 2-10**). For the purposes of this study, 34 months is used because it is the most conservative choice and supported by USPTO data ("USPTO Patents Dashboard").

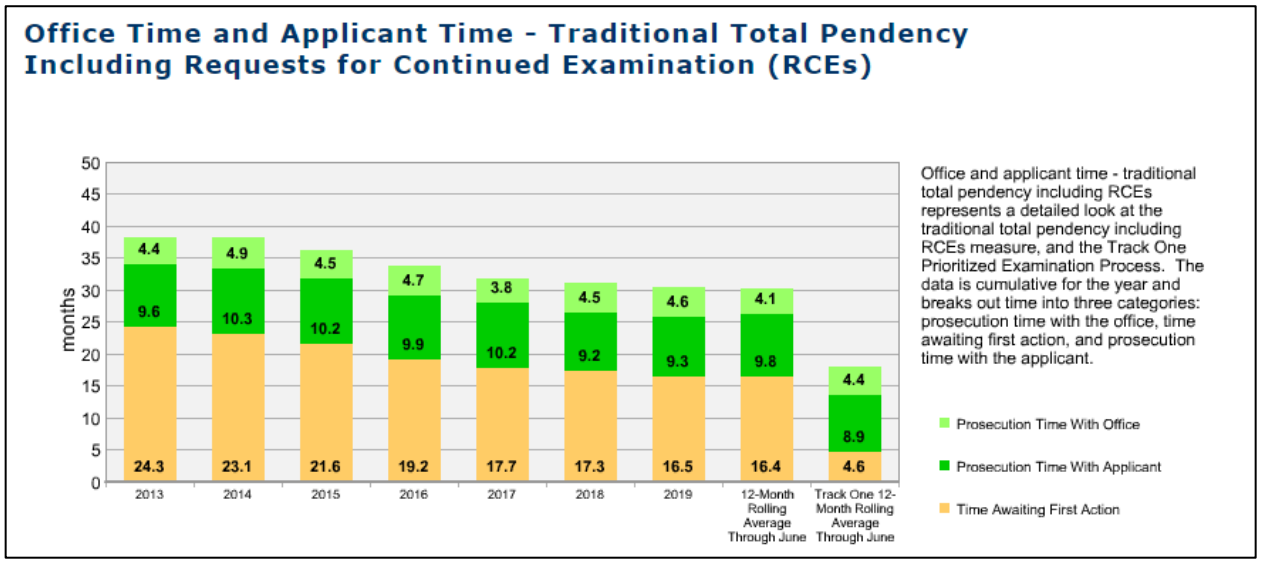

Figure 2-10: USPTO Data Visualization Center's Traditional Total Pendency 2013 to Present

Trade secrets are economically valuable information outside the patentable domain. A great example is the Coca-Cola recipe, customer lists, supplier lists, and process steps. The value of trade secrets is destroyed when revealed. For this reason most companies keep trade secrets hidden ("Part 1: A Primer on Patents"). Thus, this paper does not examine them since they are likely not published. Additionally, just because a technology can be patented does not mean that the protection is equally effective. Some industries like pharmaceuticals will be more effectively protected by patents than software or process technologies (Ford et al. 2012). Effective protection is something to keep in mind while studying IP.

The concept of using IP as an indicator of technology is not new. An example of a prior study using IP as an indictor of technology was conducted by Benson and Magee. They found that patent information strongly correlates with technology progress within its respective field. They did this by establishing 11 hypotheses and 10 independent variables to discover that the following patent factors driving improvement rates: 1) average importance, 2) recency, and 3) immediacy (Benson and Magee 2015). A list of their variables, concepts , and each description can be seen below on **Table 2-6**.

Patent characteristics	Concept	Description
(1) Simple Patent Count	A: Effort	number of issued US patents in a domain from 1976–2013
(2) Average number of forward citations	B: Importance of Patents	average number of times each patent in a domain is cited
(3) Ratio of important patents	B: Importance of Patents	ratio of patents with cited by over 20 to total patents in a domain
(4) NPL Ratio	C: Impact of Science	ratio of scientific citations to total citations from the domain patents
(5) Average publication year	D: Recency	the average date of publication for all patents in a domain
(6) Average Age of backward citation	E: Immediacy	average age of backward citations for each patent (averaged over the domain) at the time of the citing patents publication
(7) Price Index (3 years)	E: Immediacy	average proportion of citations that a domain patent receives within 3 years of publication
(8) Ratio of Backward Citations to Other Domains	F: Breadth of Knowledge	ratio of citations from patents in the domain to patents in other domains
(9) Mean publication date of backward citations	D & E: Recency and Immediacy	average date of publication for backward citations from patents in a domain
(10) Average City by within 3 years	B & E: Immediate Importance	average number of citations that a domain patent receives within 3 years of publication

Table 2-6: Independent Variable Summary Table Compiled by Benson and Magee (2015)

These exact variables on **Table 2-6** will not be used in this study because our focus is on IP accumulation as a proxy for technology value as a precursor to an M&A event. However, this study demonstrates two major principles that inspired methodologies used later: 1) IP can be used as a metric for measuring technology, 2) creation of a new variable will likely be needed to accomplish this task. In addition to Town's research mentioned earlier, Benson and Magee's work greatly influenced this study's creation of the time-distance variable x_{ijk} (discussed more in detail later).

2.6 - The Potential Intersection of M&A, TRLs, and IP

Based on the research above, this paper hypothesizes the following:

Hypothesis 1 – TRLs are reasonable method of measuring technology maturity with the semiconductor industry. TRLs are used in other defense and commercial spaces and are becoming more widely adopted to manage technology and uncertainties. They should be able to adapt to the semiconductor industry.

Hypothesis 2 – IP activity is a reasonable method of tracking technology innovation in the semiconductor industry since the idea must be made visible to the world. Since the USPTO publicly tracks applications and patents in their database they should be a good, accessible method to track technology in the form of "assignor" to "assignee" transactions and execution dates. These variables of "assignor," "assignee," and "execution dates" will be described more in detail under the Methodology section.

Hypothesis 3 – Technology and the need to procure it is a significant driver of M&A activity the CPU semiconductor industry because it adds value. While adding value may not be the only reason, the scope of this research focuses on the value technology can bring and if it has a significant influence.

Hypothesis 4 - IP helps date the maturity of technology. Patenting should happen before selling to avoid trapping oneself with his or her own prior art. One major tenant of patents is that an idea must be novel, and published announcements could jeopardize the grant. This paper proposes approximate links between TRL and IP based on a high level research of each as seen on **Table 2-7**. Refer to **Figure 2-8** for program phases and TRLs:

IP Mapping	Approximate IP Mapping	TRL Range	CPU Architecture Phase	Rationale
0-18 Months	Provisional Patent Or Full Application	1-2	Pre-Concept Refinement	Avoiding "prior art" trap but concept may not be fully realized. First to file is important.
18-34 Months	Patent Applications Published. Pending Review, Reexaminations, and Final Grant (If Successful)	3-7	Concept Refinement, Technology Development, System Development and Demonstration	Patent application visible. Period of Tech Development and Demonstration
>34 Months	Application/Patent Granted and Fully Covered	8	Production and Deployment	Ready for production/sale ("flight ready")
>46 Months	Grant Awarded and Long-Established Technology on the Market	9	Long-Established Technology	Proven, Long-Established ("Flight Proven")

Table 2-7: Proposed Approximate TRL Range and IP Life Cycle Timing

This paper posits that technology is a resource of value in high-tech industries such as semiconductor manufacturing. Access to the technology or the idea helps the parent company achieve its business goals. Tracking the accumulation of tech value can be accomplished through IP transactions in

the USPTO database in the form of patent applications and patents (e.g. “assignor” to “assignee” relationships and “execution dates”). The value of the technology may also depend on its age or maturity and can be more objectively viewed through the application of TRLs. As the child company accumulates valuable technology (as tracked by IP in this study) and the parent requires access to it, this triggers an M&A event. Refer to **Figure 2-11** below for a basic representation of these proposed relationships explored in this study.

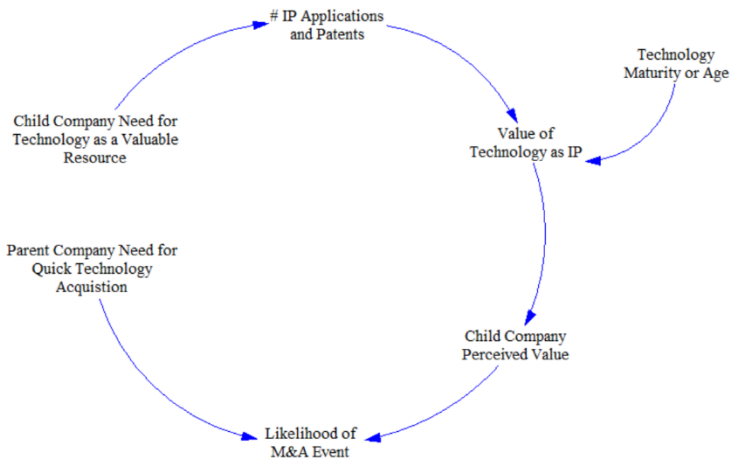

Figure 2-11: Basic Representation of the Proposed Interaction between Tech Maturity, IP, and M&A

The tools, prior studies, and concepts discussed in this section provide greater background information for the Methodology and Results sections. As mentioned earlier, this prior research provided much of the inspiration to explore the relationships between M&A, IP, and technology maturity in the context of the high technology domains such as semiconductor manufacturing. The next section will provide greater detail concerning the two parent companies (e.g. Intel and AMD) and their 91 acquisitions from 1997 to 2017. It will discuss basic financial measures, their relative size, and the industries each parent branched out into based on the acquisition of their respective child companies.

3 - M&A Activity in the CPU Industry: Intel vs AMD

The intent of this paper is to focus on the interplay of M&A, technology maturity, and IP in the semiconductor industry, specifically the CPU manufacturing sector. As alluded to earlier, this segment of the industry has two dominate players: Intel and AMD (Hayes 2020). It is general knowledge that Intel historically dominates this field with AMD playing the underdog; however, this is more objectively measured by the following general financial metrics (Healy 2020):

Metric	Intel (INTC)	AMD (AMD
Market Cap	$258.2B	$57.7B
Previous Year Revenue	$72B	$6.7B
Forward P/E Ratio	11.3	41
5-Year Avg Profit Growth per year	9.1%	35.7%
Year-Over-Year Revenue Growth	1.7%	4%

Table 3-1: Basic Financial Summary CPU Manufacturers Intel and AMD (Healy 2020)

Based on the overview above, Intel's Market Cap is over four times larger with a previous year's revenue eleven times larger. These size differences and the fact that both companies dominate the CPU market provide an interesting glimpse into possible behavior. For example, how will their oligopoly affect both companies in terms of M&A? Will they conform to the M&A Motivation chart proposed by Ibrahimi in which size of the company changes over time along with their motivation (refer to **Figure 2-5**)?

The chart of current basic financial metrics suggests that if these two companies do follow the M&A Motivation chart. They should be in different phases due to their substantial differences is size and expected performance. Intel's profit and revenue growth are lower relative to it size, its stock less valued (hinted by the Forward P/E), but its overall revenue is ten times larger. This means Intel should be currently closer to the top of the curve and clearly in the Phase 2 "competitive/defensive" motivation region as suggested by Ibrahimi, an area in which most large firms inhabit. Phase 2 is also where more child firms are acquired by the parent (i.e. Intel). AMD should be currently closer to the Phase 1 "manifestation of a given objective" motivation region. This expectation stems from the observation that AMD's larger revenue growth potential relative to its size and valuable stock (as indicated by the Forward P/E ratio) mean it will reach large-company status like Intel in the future. Ibrahimi's curve provides additional insight as to the expected motivation behind each company's search for value: as of current financial metrics, Intel should be acquiring more firms for both competition and defense while AMD is expected to acquire far fewer companies; however, AMD child companies will help them achieve a more singular core objective. Presumably, this core objective is AMD's traditional semiconductor business.

Learning more about the histories of these two companies can provide greater M&A context within the CPU domain. Acquisitions histories for each company can be found on AcquiredBy.co.

Combining Intel and AMD lists yielded a total of 91 total acquisitions (86 by Intel and 5 by AMD) between 1997 and 2017 ("Intel Acquisitions"; “AMD Acquisitions”). These lists form a critical set of inputs for the model discussed later in this study. For now, it is interesting to observe the difference in M&A behavior. While this study focuses on semiconductor, it is also useful to see how each company branches out into other segments of the technology industry, presumably to remain competitive. **Figure 3-1** below shows a by-industry percent breakdown of Intel and AMD acquisitions graphed by this study using the AcquiredBy.co data. The pie chart is unweighted by acquisition price.

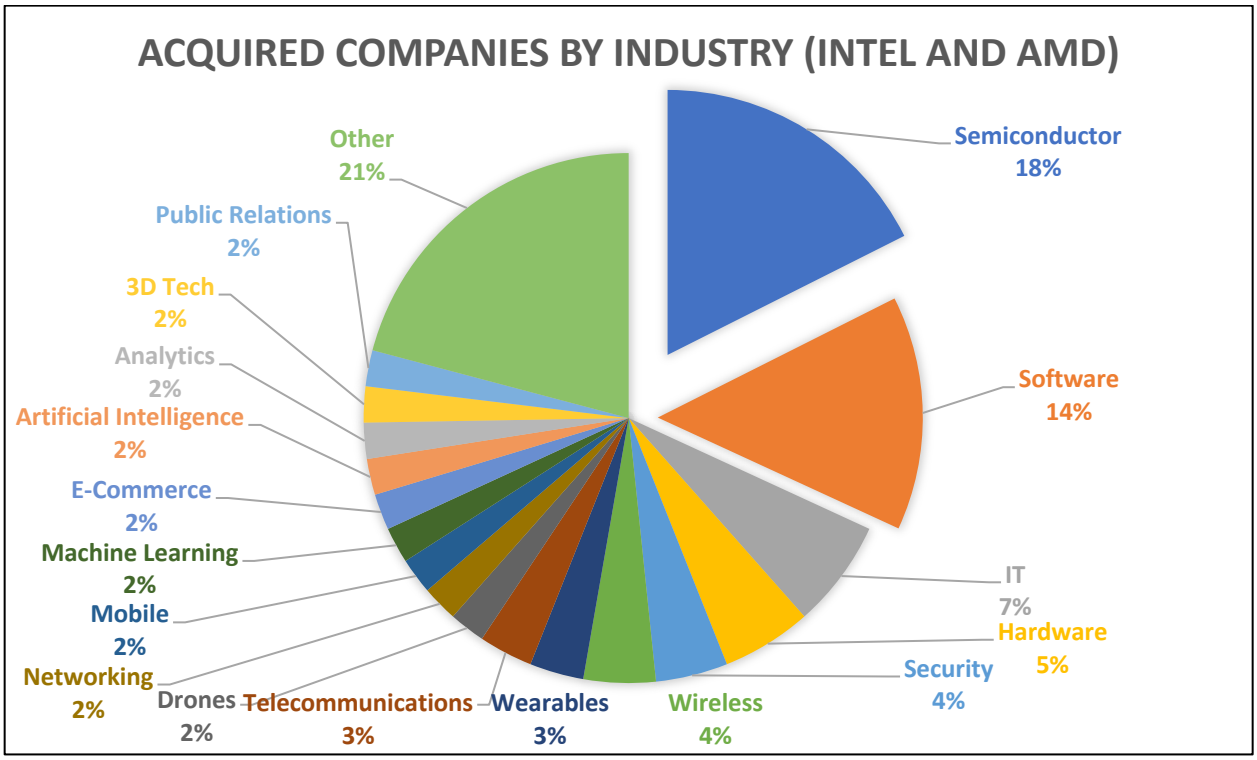

Figure 3-1: Breakdown of Intel/AMD Acquisitions by Industry graphed using Aquiredby.co Data

As predicted, most companies acquired by Intel and AMD remain within the semiconductor industry at an 18% majority. The second largest is software at 15%. While apparently larger, the category labelled “Other” represents the combined list of industries contributing 1% or less that have condensed for ease of viewing. These “Others” include:

- IoT
- Electronics
- Simulation
- Advertising
- Data
- PC Games
- Insurance
- Education
- Internet Security
- Automotive
- Facial Recognition
- Communications
- Network Security
- Broadcasting
- Virtual Reality
- Cloud Computing
- Open Source
- Web Hosting
- Data Center

Both Intel and AMD appear to be diversifying heavily; however, is this diversification driven by one company or both? This data can be broken down further by company to see which is likely more active in the acquisition process. Refer to **Figure 3-2** below.

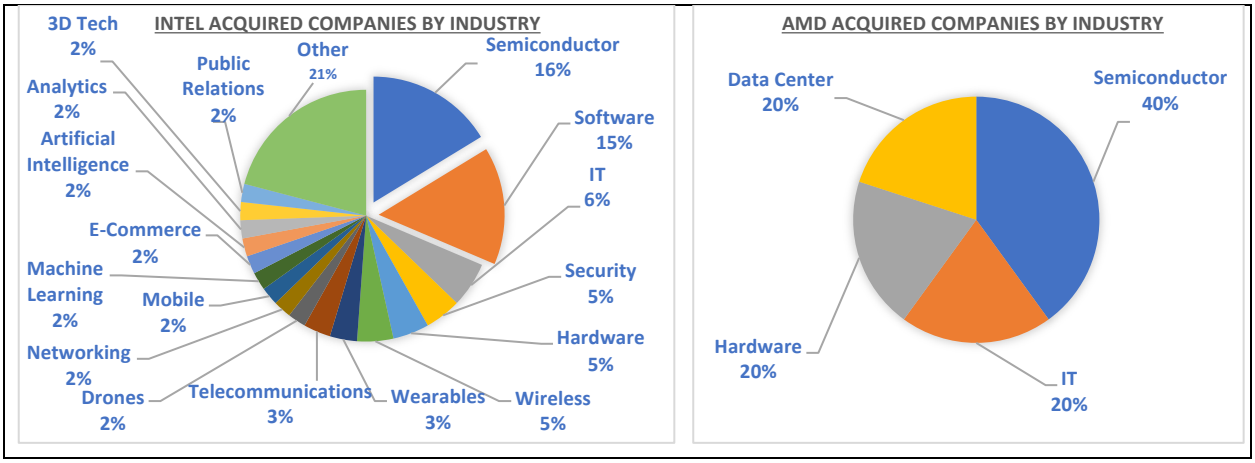

Figure 3-2: Side-by-Side Comparison of Acquired Companies and Industries by Parent Company

As stated earlier, these percentages are with respect to the 86 companies acquired by Intel and the 5 acquired by AMD between 1997 and 2017. Not all child company acquisition prices are disclosed; however, the approximate value of the Intel acquisitions is greater than $48 billion. The approximate value of AMD's acquisitions is greater than $5 billion ("Intel Acquisitions"; "AMD Acquisitions"). Intel's M&A activity by number of acquisitions and by approximate value is driving the trends observed. Despite this, both remain within the semiconductor industry as a core business strategy. This is an indicator that semiconductor and its technology are perceived to have value to Intel and AMD. As with the combined chart, the "Other" category (21%) represents the following industries which contribute %1 or less to the overall Intel acquisition profile.

- IoT
- Electronics
- Simulation
- Advertising
- Data
- PC Games
- Insurance
- Education
- Internet Security
- Automotive
- Facial Recognition
- Communications
- Network Security
- Broadcasting
- Virtual Reality
- Virtual Reality
- Cloud Computing
- Open Source
- Web Hosting

Interestingly, both Intel and AMD appear to be following the M&A curve proposed by Ibrahimi (**Figure 2-5)** when plotted over time. Intel more strongly follows the wave structure, but both generally perform as predicted by the M&A motivation with Intel acquiring more firms that AMD. This curve suggests that the motivation for M&A goes in waves with different periods of motivation as companies increase their size through external growth opportunities. The period 1 motivation (earliest in time and smallest) is called "Manifestation of a Given Objective." Period 2, the largest and center of the bell curve,

is called “Competitive Motivation, Defensive Motivation, Contamination (trend effect).” Period 3 is called “Consequence study, Prudence Effect, positive Reinforcement” (Ibrahimi 2018). This means that as Intel and AMD go through time, motivations to go through M&A and the resulting acquisitions should occur in waves. To explore this idea with Intel and AMD, the AcquiredBy.co data can be plotted with a trend line added. Refer to **Figure 3-3** below.

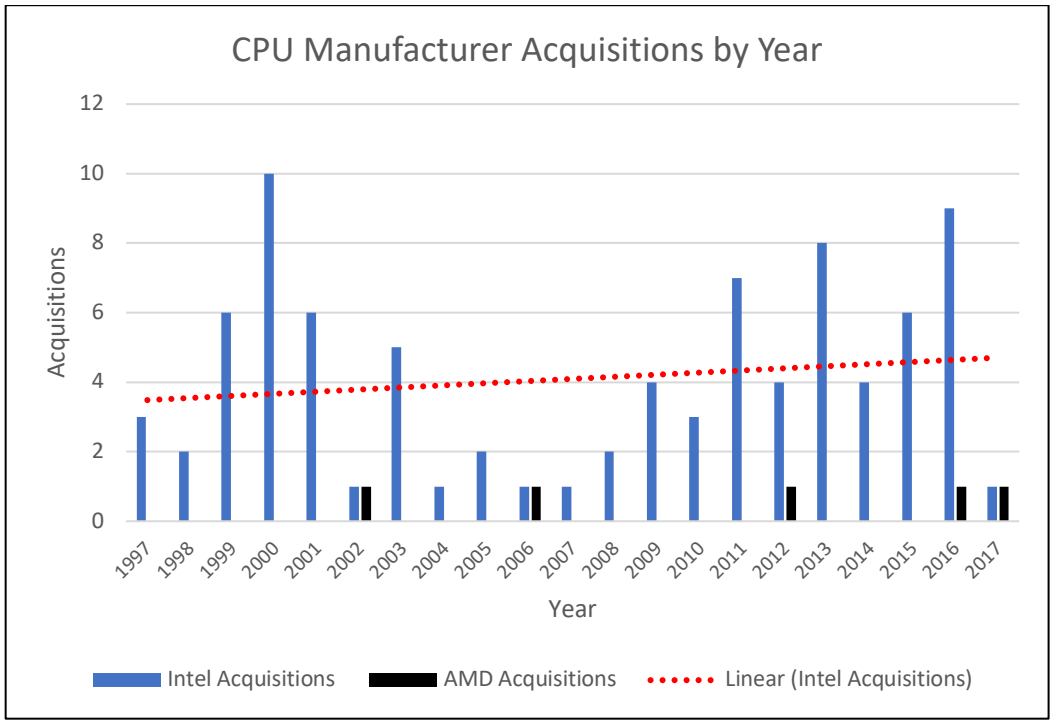

Figure 3-3: Intel/AMD Acquisitions with Linear Trend derived from AcquiredBy.co Data

Applying a linear trend reveals a slow acquisition increase with general wave patterns that are less extreme but reflective of the overall US market. Applying a three-period moving average also highlights the wave pattern behavior. Refer to **Figure 3-4** below. This wave structure is likely driven by the market overall since Intel’s acquisitions are outside semiconductor alone, and Intel has greater participation in it. Also, it reasonable to believe that the more acquisitions made by a Phase 2 company on the Ibrahimi M&A motivation curve, the more wave structures will become apparent.

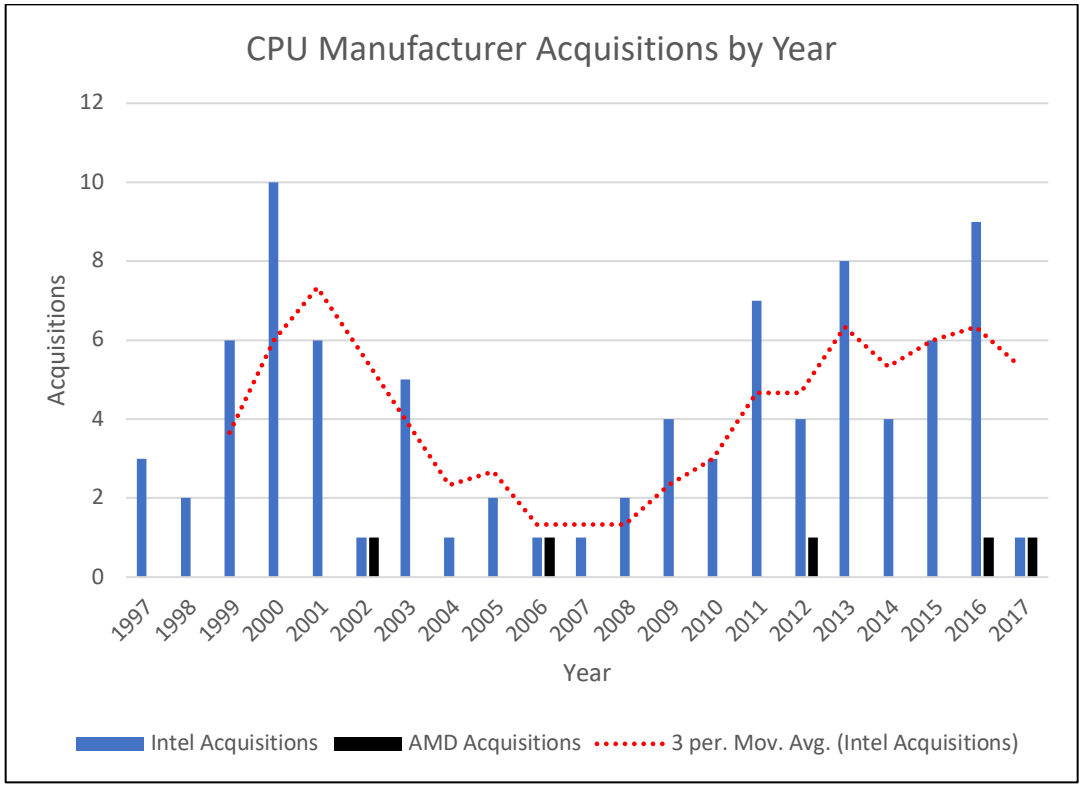

Figure 3-4: Intel/AMD Acquisitions with Moving Average Trend derived from AcquiredBy.co Data

The plotted data appears to support the Ibrahimi model overall by suggesting a wave pattern; however, it is important to see that AMD acquisitions appear to be dispersed over time, uniform in size, and limited to one acquisition per year with gaps in between. As shown earlier, Intel's activity appears to be driving M&A activity between the two CPU manufacturers. This means that Intel conforms well to the Ibrahimi model since it appears to go through the M&A motivation periods and merger waves. AMD does not seem to correspond well to this same model concept. What happens if this data is corrected for semiconductor industry only? Refer to **Figure 3-5** below.

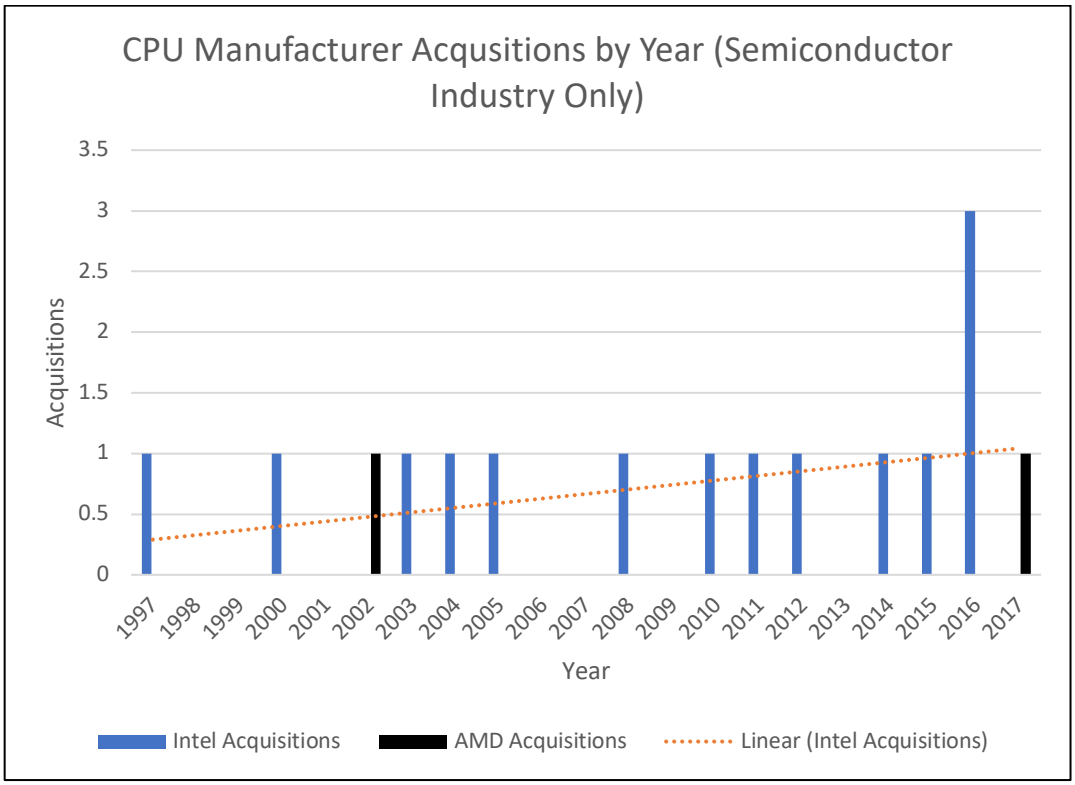

Figure 3-5: Semiconductor Acquisitions per Year derived from AcquiredBy.co Data

Restricting the search to semiconductor-industry-only presents a different and less expected result. It appears that acquisitions for Intel and AMD remain relatively flat. This indicates that Intel and AMD activity within the semiconductor industry alone appear to be similar despite the brief Intel acquisition spike in 2016. Greater detail into each industry is outside the scope of this research; however, it may be prudent to consider that the Ibrahimi wave concept may apply to the market overall rather than one company in a specific industry. It is reasonable to assume companies will branch out into other business areas as needed to remain competitive, especially in industries where an established oligopoly dominates (e.g. Intel and AMD). It is also possible that major semiconductor merger waves occurred prior to 1997. After all, the histories of each company extend back to the mid and late 1960's (Hayes 2020). This research focuses on the relatively recent research based on the AcquiredBy.co data and the USPTO database, meaning earlier wave phenomena would be missed (*United States Patent and Trademark Office's Main Web Site*).

Initial financial metrics and merger records suggest a couple key takeaways that will be useful later in this paper. Intel and AMD dominate the CPU industry with Intel being the much larger company. Intel's M&A drives the overall Intel/AMD trends when the data is plotted; however, AMD is more focused on the semiconductor in terms of percentage. Filtering the data for the semiconductor industry exclusively

reveals that Intel and AMD have similar activity with a steady, flat trend. AMD's focus on semiconductor in terms of percentage at least partially explains its behavior in the combined plot including mergers in all industry domains. Also, both Intel and AMD conform to expectations expressed through Ibrahimi's M&A motivation model. Since wave structures are common elsewhere in the data, it is reasonable to assume that exploring the underlying IP transaction data will reveal waves. These waves should manifest themselves as transaction data points surrounding the merger dates with a ramp up rather than a uniform distribution. A completely uniform structure is unlikely because it is expected that new patents would be the owner of the parent and no longer listed in the database under the child.

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4 - Methodology

To explore the relationships between M&A, IP, and technology maturity this study primary uses two majors sources of information: the USPTO Patent Database and the AcquiredBy.co lists (United States Patent and Trademark Office 2020; *Intel Acquisitions*; "AMD Acquisitions"). United States Patent and Trademark Office maintains the Patent Application and Patent databases. The AcquiredBy.co lists are a compilation of press release information. The USPTO Application Database is a secondary source of information for preliminary research. Refer to **Table 4-1** below.

Patents	**Patent assignment economics data for academia and researchers: created/maintained by the USPTO Chief Economist (JAN 1970 - DEC 2017)**

- https://developer.uspto.gov/product/patent-assignment-economics-data-stata-dta-and-ms-excel-csv

Patent Applications	**Patent Examination Research Dataset (Public PAIR)**

- https://www.uspto.gov/learning-and-resources/electronic-data-products/patent-examination-research-dataset-public-pair

Table 4-1: USPTO Database Information Used

4.1 - Preliminary Patent Application Exploration

If a link exists between M&A and IP it would likely be visible within the first five years leading up to the eventual acquisition. This wave of critical build should in theory precede M&A activity of the market overall or the specific industry. To accomplish this the Patent Application Database is a good first place to start. It was initially the assumption that applications would provide an indicator more reflective of industry behavior. This assumption was proved incorrect later.

After downloading the Patent Application datasets (**Table 4-1**, second tab), a datastore can be created using MATLAB®. This allows the user to extract data using tall arrays since the datasets are far too large to pull into MATLAB® working memory. The datastore simply points MATLAB® to the correct data files for it to examine in parts as needed. A complete listing of the MATLAB® source code created for this research is provided in Appendix II.

The application dataset comes with a complete database schema, allowing the user to navigate the various tables. It is important to thoroughly examine the schema to gain a better idea of the data

intended for extraction. As mentioned earlier, the data is much larger than what can be pulled into memory so having a plan based on the schema is extremely important. The schema structure as provided is as follows ("Patent Examination Research Dataset (Public PAIR)"):

- Appendix A: Description of the Application Data Tab Release
- Appendix B: Description of the Transaction History Tab Release
- Appendix C: Description of the Continuity Data Tab Release
- Appendix D: Description of the Foreign Priority Tab Release
- Appendix E: Description of the Patent Term Adjustment Tab Release
- Appendix F: Description of the Address and Attorney/Agent Tab Release

Appendix F shows that application number can be tied to correspondence information such as name, street, city, and country. This is found in the dataset labelled "correspondence_address." Since this study focuses on specific parent and child companies, the Intel and AMD AcquiredBy.co lists provide the initial search criteria. A comprehensive review of each company shows that the AcquiredBy.co lists will need to be updated to capture different past company names or variations. For example, NetEffect was Banderacom, Ziilabs was 3DLabs, LSI includes Axxia, and ATI owned Radeon (EETimes 2004; *ZiiLABS About Us*; "LSI - Axxia Networking Business"; Talevski 2010). Refer to the updated AcquiredBy.co list (**Table 4-2**) below which now includes useful name variations based on company research.

Intel Acquisitions		
• Acirro	• IDesia	• Picazo Communications
• Aepona	• Indisys	• RapidMind
• Altera	• Infineon Technologies	• Recon Instruments
• Ambient Technologies	• Iospan Wireless	• Replay Technologies
• Appmobi	• iPivot	• Saffron Technology
• Ascending Technologies	• Itseez	• Sarvega
• Basis Communications	• Kno	• Scale Eight
• Basis Science	• Kuck & Associates	• Sensory Networks
• CAD-UL	• Lantiq	• Shiva Corporation
• Chips and Technologies	• Level One Communications	• Silicon Hive
• Cilk Arts	• LightLogic	• SiPort
• CoFluent Design	• LSI – Axxia	• Soft Machines
• Cognet	• Mashery	• Softcom Microsystems
• CognoVision	• MAVinci GmbH	• Sparkolor Corporation
• Composyt Light Labs	• McAfee	• Swiftfoot Graphics AB
• Conformative Systems	• Mobileye	• SySDSoft
• Corollary	• Mobilian Corp	• Telmap
• DataKinetics	• Movidius	• Thinkit Technologies
• Dayna Communications	• Nervana	• Voice Technologies
• Docea Power	• NetBoost	• VOKE
• Envara	• NetEffect / Banderacom	• VxTel
• Ford Microelectronics	• Nordic Edge	• West Bay Semiconductor

• Fulcrum Microsystems • GIGA • Hacker League • Havok • iCat • ICP vortex Computersysteme	• Olaworks • Omek Interactive • Opened Hand • Oplus Technologies • Parity Software Development • PasswordBox	• Whamcloud • Wind River • Xircom • XLNT • Xtreme Insights • YOGITECH • Ziatech • ZiiLabs / 3DLabs Inc.
AMD Acquisitions		
• Alchemy Semiconductor • ATI Technologies / Radeon Technologies Group	• HiAlgo • Nitero	• SeaMicro

Table 4-2: Child Company Search Criteria based on Updated AcquiredBy.co Lists

The search for company patent application hits requires two main steps: 1) fuzzy search, 2) human filtering, and 3) company verification with possible loops back to numbers one and two as required based on new information learned.

The fuzzy search uses the names provided on **Table 4-2** plus possible alternate spellings to perform searches of the tall array correspondence file using the MATLAB® datastore. After child company names are extracted, they must be reviewed manually to ensure no false positive hits are included. This review includes a combination of filtering the data and verifying each company name (including misspellings). This part is critical because the correspondence field is the only major entity-identifying indicator and is usually not entered into the database uniformly. Once this step is complete, a complete count of patent applications can be determined. As reviewed in the Discussion section, this research switched over the Patent Database (**Table 4-1**, first tab) for clearer results. The Patent Database remained the primary resource for the rest of the study.

4.2 - Patent Database Extraction

The same table of search values (**Table 4-2**) can be used for searching the Patent Database; however, new methods of searching must be used to prevent creating unwanted cartesian products during table joining process. Cartesian products are generally unwanted because they can create many duplicate entries and can use up much needed RAM. This happens because there is no apparent relationship defined between the tables (Burleson 2020), which easily occurs with this dataset if not careful. The tables are joined by "rf_id," which is the table key. Paying attention to the one-to-many relationships is critical (e.g. 1:m or m:1). For this reason, creating one large file with results is impractical from a computer memory and resource standpoint. Refer to the USPTO Patent Database schema provided in Appendix I for a detailed breakdown of the table structure (United States Patent and Trademark Office's Main Web Site). The updated MATLAB® code used in this study can be found in Appendix II.

Updating MATLAB® code can help to gather results from each tall array and datastore. For this study, the "assignee" table is used to find the companies with a fuzzy search. This list is again filtered and verified to ensure no false hits were included, allowing the user to compile a list of unique rf_id keys belonging to each company researched. This study used a short SQL script (e.g. using Oracle SQL Developer or equivalent) to compile one long list of unique rf_id's by company and found this can be done more easily outside the MATLAB® environment; however, MATLAB® can be used if needed.

These unique rf_id's can be re-imported into MATLAB® to complete the remaining search activities using the code provided in Appendix II. This study retrieves the following information from each table using the unique company rf_id information compiled in SQL:

assignor	documentid
• or_name • exec_dt • ack_dt	• title • appno_doc_num • appno_date • grant_doc_num • grant_date

Table 4-3: Variables by Table Used to Search Patent Database in this Study

While not the focus of this study, it is useful to summarize the function of the code provided in Appendix II. The variable terms are "gathered" by MATLAB® using the tall arrays and datastores of each USPTO database table file. Only the variable columns listed in **Table 4-3** are retrieved from each table. They are placed in the following order: "grant_doc_num" (the patent number), "grant_date" (the date the patent was awarded), "appno_doc_num" (the patent application number that preceded the patent), "appno_date" (the patent application date), "title" (title of the application or patent), "or_name" (the name of the last owner), and "exec_dt" (the date the application or patent was transferred to the assignee, which in this study, is the child company of Intel or AMD). The code flattens the table by removing the names of the former patent and application owners prior to the latest, which is just before the IP is transferred to the Intel/AMD child company. The program then simply adds a column of the number of prior owners including the latest. For example, "John Doe" is the latest owner and is preceded by 3 others who transferred the patent to him. "John Doe" transfers the patent to an assignee of this study (e.g. Intel). The program will write this as: "or_name=John Doe, num_prevous_grant_owners=4." This 4 includes "John Doe" AND the 3 previous owners of the patent or application.

In addition to the specific patent information gathered above, the code also provides summary statistics such as patent/application total page count, average page per rf_id, keywork hits on the word "merger" from the convey text, and the average "merger" keyword hits per rf_id.

4.3 - Patent Data Variables & Exploration

After extracting the information from the USPTO Patent Database files, new variables are required to examine the connections between M&A, IP, and tech maturity. This study proposes the construction of the following variable:

$$x_{ijk}$$

where i=parent company, j=child company, and k=patent

This variable represents the time distance from the time of purchase by the child company until the merger event with the parent company (e.g. Intel or AMD). The purpose of this variable is to see if there is a time element involved between initial purchase of IP and when the child is acquired by the parent. There should be a buildup of IP with a wave structure prior to the merger if there is a connection since accumulating IP is collecting technological value.

Other areas examined are the following:

- Acquisition Value vs. Number of Applications and Patents
- Number of Applications vs. Patents per Child Company
- IP Lifespan vs. Child Company Lifespan
- Proposed TRL Estimates (refer to **Table 2-7**)

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5 - Results

The results can be split into five sections as follows:

1. Overall Application/Patent Counts for All Acquired Companies and the Semiconductor Industry
2. Build Up of Perceived IP Value Prior to Merger Event (Time-Distance Variable X_{ijk})
3. Value as Measured by Acquisition Amount
4. Age of Child Company and Its Acquired IP
5. Application of TRLs

5.1 - Overall Application & Patent Counts

This study initially used the Patent Application Database but switched over to the Patent Database. There were too few companies from the search to do a comprehensive test being that only 16.5% of the original company list resulted in positive hits; however, this did not prevent this research from including application information found in the Patent Database. The Patent Database also contains some information concerning applications.

The company list from **Table 4-2** was used as inputs for another round of fuzzy searches, filtering, and manual company verification to remove false hits. The database table used for the search was labelled "assignee." The table variable called "ee_name" provided three functions during the search: it facilitated an easy cross-reference by company name, helped find unique rf_id keys for the other tables, and provided a definitive point when the patent or application transferred from the previous owner.

To provide some context, the assignor is the party relinquishing rights to the IP and transferring them to the assignee, which in this case is the child company of Intel or AMD (DeRuyter 2019). The previous owner of the IP can be found on database table labelled "assignor" along with the execution date between the two entities. This information from the "assignee" table is useful in this study because we have two critical pieces of information: the unique company rf_id's that permit searching application/patent information and a link to the company search list. The rf_id's were then used to look up other values on the various tables such as the execution date from the "assignor" table.

The preliminary findings can be found on **Figure 5-1** and **Figure 5-2**, which is the total count of both applications and patents. This study hypothesizes that IP is an indicator of technological value. Since companies may perceive the value of applications and patents differently, this study decided to treat them as two separate categories: "Pipeline Applications" and "Patents." Applications are referred to as pipeline because they not yet granted patent status, thus are possible future IP.

The first important item to note from **Figure 5-1** and **Figure 5-2** is that the companies with large pipeline application and patent counts are generally the same as the ones found in the original Patent Application Database; however, 59 more companies represented in the Patent Database search results. For example, Altera, Infineon, LSI-Axxia, and McAfee still are more represented than the others. Presumably, this difference between the Application and Patent databases is due to the assigning of entities as the formal application is submitted or transferred from the assignor to the assignee (e.g. the child company of Intel or AMD).

Figure 5-1 and Figure 5-2 on Next 2 Pages

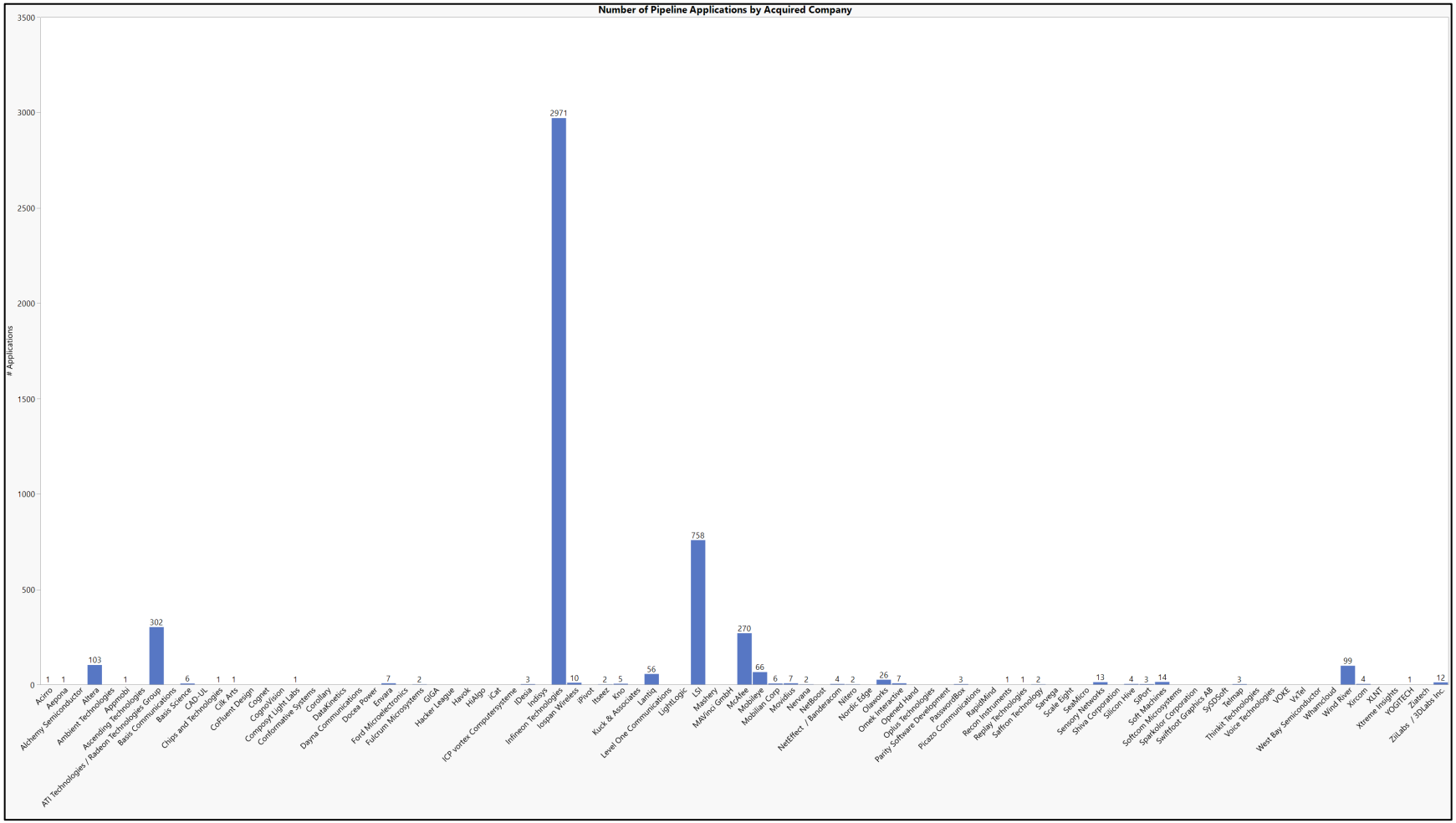


Figure 5-1: Patent Database Number of Pipeline Applications Search Results

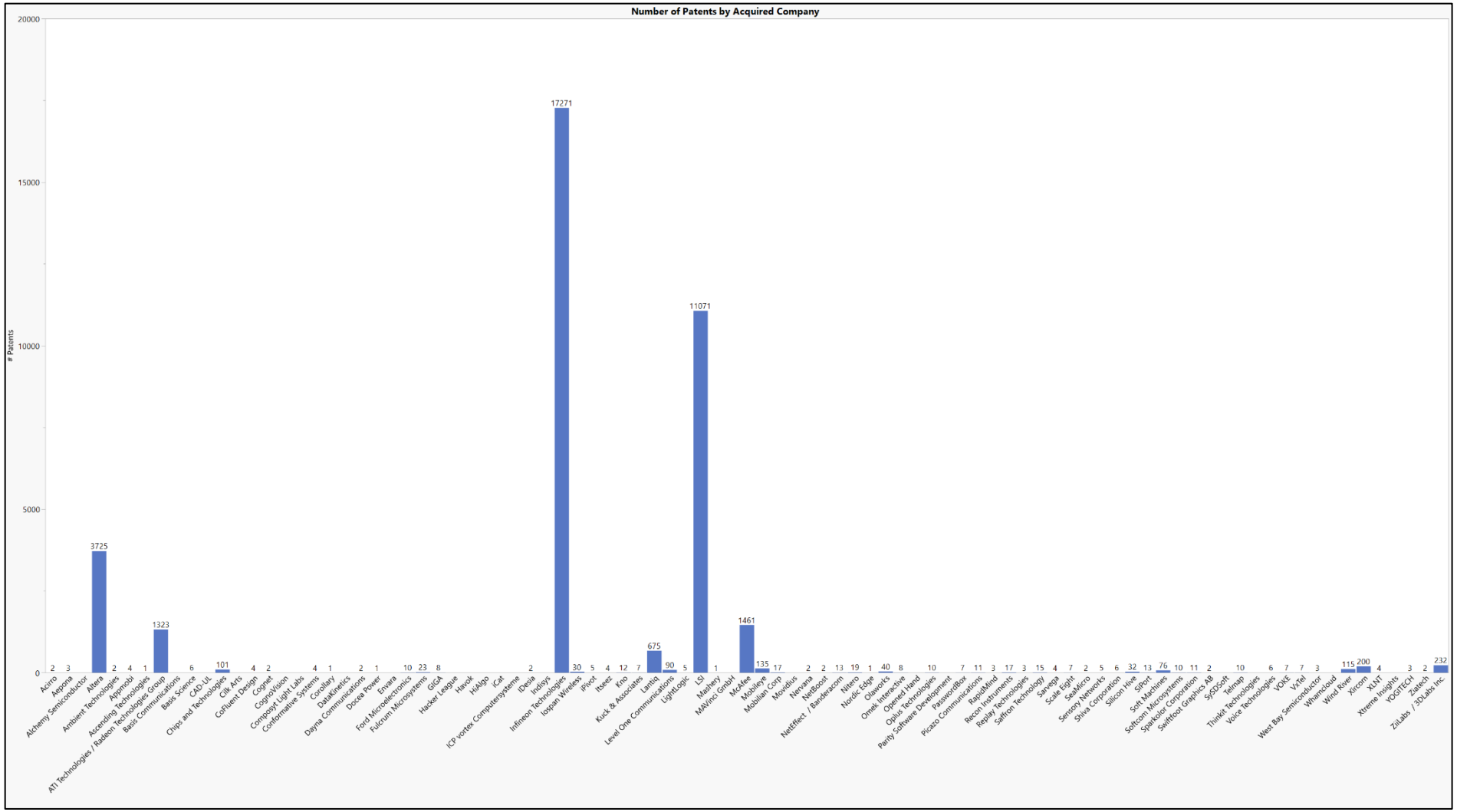


Figure 5-2: Patent Database Number of Patents Search Results

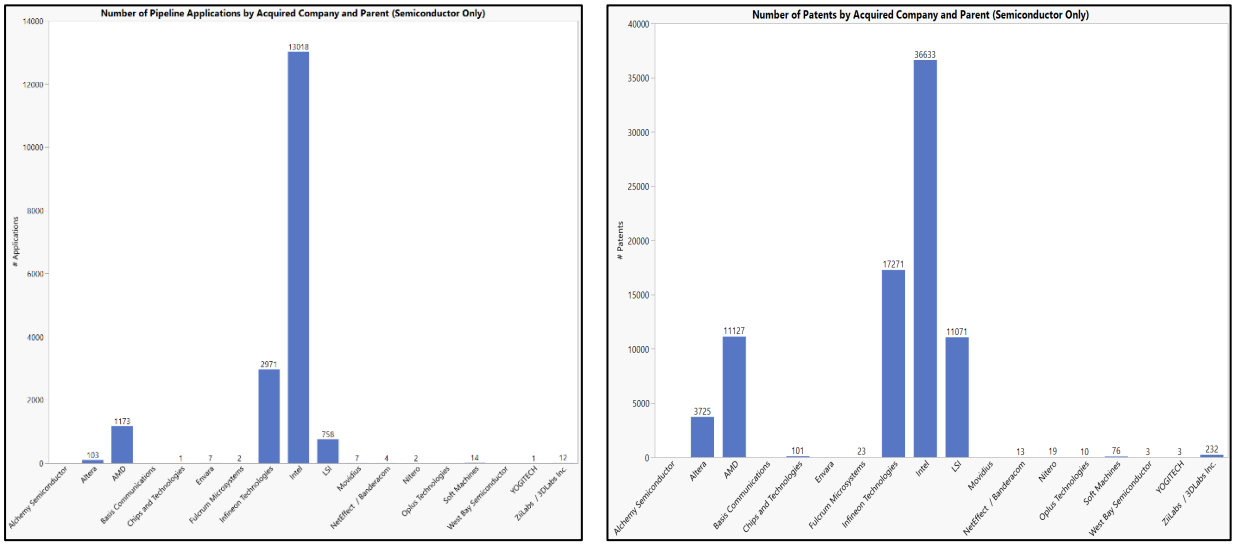


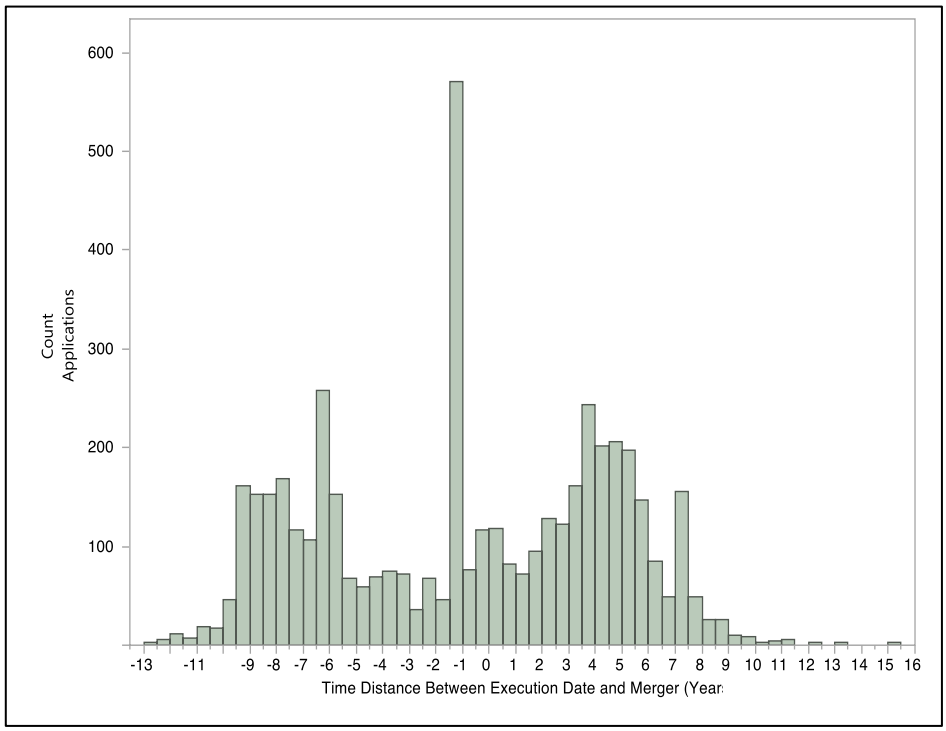
Figure 5-3: Side-by-Side Comparison of Applications and Patents (Semiconductor Industry-Only)

Seeing both the bar chart with all Intel/AMD acquisitions, all industries, and semiconductor-only helps to highlight the activity of IP within the semiconductor industry itself. Semiconductor companies such as Infineon, Altera, and LSI have both many more applications and patents than do other Intel/AMD acquisitions in other industries. Semiconductor child companies have an average of 277.3 applications with a standard deviation of 800.8 compared to the average of 14.98 and a standard deviation of 53.09 of their fellow non-semiconductor peers. In terms of patents, semiconductor companies have an average of 2325 with a standard deviation of 5256, while their non-semiconductor peers have an average of 72.82 and a standard deviation of 263.9. This seems to suggest technology IP carries more value in the semiconductor industry. Intel/AMD applications and patents of the same time period are also included in **Figure 5-3** as a reference and were not included in these averages.

5.2 - Build Up of Perceived IP Value Prior to Merger Events

The results of constructed variable x_{ijk} were plotted using histograms to determine if value in the form of technology IP builds up in the child prior to merger with the parent. As mentioned in the Methodology section, the variable is meant to study the duration between each patent's execution date (the date it was transferred to the Intel/AMD child) and the merger event with the parent company. A negative value represents latent transactions after the merger date at year zero. As this time-distance decreases (approaching the merger event), there should be a buildup applications or patents. This would indicate the buildup of perceived value by the parent company (e.g. Intel or AMD), thus triggering M&A. This variable only considers the execution date of the individual application/patent with respect to its owner's

merger event with Intel/AMD. This helps to eliminate temporal differences and compare same-to-same. **Figure 5-4** below provides the application results, and **Figure 5-5** provides the patent results. It is important to note that year zero is the merger event between the child and the parent company (e.g. Intel or AMD).



Quantiles

100.0%	maximum	15.3
99.5%		9.09
97.5%		7.57
90.0%		5.72
75.0%	quartile	3.94
50.0%	median	-1.170
25.0%	quartile	-6.07
10.0%		-8.27
2.5%		-9.37
0.5%		-10.9
0.0%	minimum	-12.7

Summary Statistics

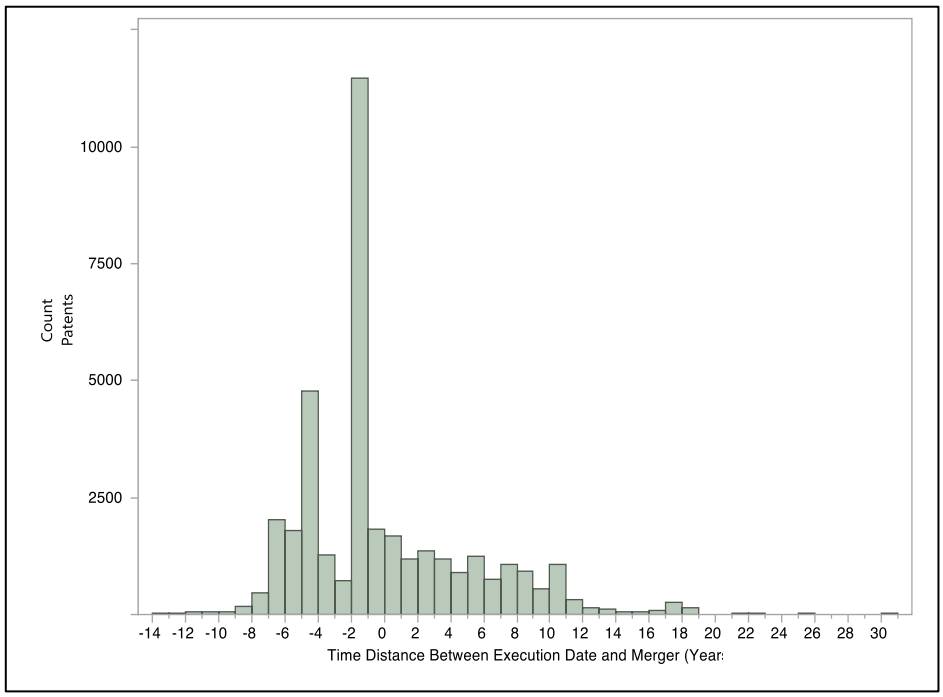
Mean	-0.826
Std Dev	5.340
Std Err Mean	0.0773
Upper 95% Mean	-0.675
Lower 95% Mean	-0.978
N	4769

Test Mean

Hypothesized Value	0
Actual Estimate	-0.826
DF	4768
Std Dev	5.338
Sigma given	5.07

	z Test
Test Statistic	-11.254
Prob > |z|	<.0001*
Prob > z	1.0000
Prob < z	<.0001*

Figure 5-4: Variable X_{ijk} No. Applications by Child Companies prior to Merger



Quantiles

100.0%	maximum	30.18
99.5%		17.96
97.5%		11.21
90.0%		7.785
75.0%	quartile	2.401
50.0%	median	-1.471
25.0%	quartile	-3.955
10.0%		-5.666
2.5%		-6.622
0.5%		-8.232
0.0%	minimum	-13.13

Summary Statistics

Mean	-0.07199
Std Dev	5.067
Std Err Mean	0.02638
Upper 95% Mean	-0.02028
Lower 95% Mean	-0.1236
N	36893

Test Mean

Hypothesized Value	0
Actual Estimate	-0.072
DF	36892
Std Dev	5.067
Sigma given	5.07

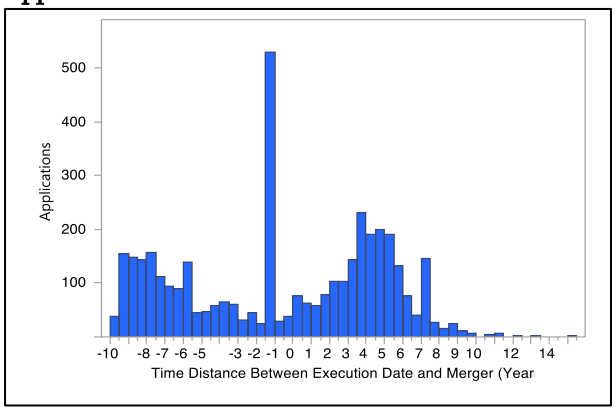
	z Test
Test Statistic	-2.7271
Prob > |z|	0.0064*
Prob > z	0.9968
Prob < z	0.0032*

Figure 5-5: Variable X_{ijk} No. of Patents by Child Companies prior to Merger

Using a hypothesis test mean of 0, both applications and patents were either far below or near the p-value of 0.05, which is a strong indicator for significance. This means that perceived value accumulation in the form of increased IP procurement can be noticed for semiconductor companies child companies of Intel/AMD across various industries. It is important to note, however that this is just a buildup of transactions from previous companies to the child, which is in turn merged with the parent at year zero upon being perceived as valuable. The large spike in IP procurement activity between years -1 and -2 appears to show the completion latent transfers initiated prior to year zero (e.g. positive number years). What does this look like for the semiconductor industry only?

Re-running the results for both applications and patent yielded similar results as seen in the side-by-size comparison below in **Figure 5-6**.

Applications



Quantiles

100.0%	maximum	15.26
99.5%		9.090
97.5%		7.419
90.0%		5.748
75.0%	quartile	4.192
50.0%	median	-0.9232
25.0%	quartile	-5.660
10.0%		-8.293
2.5%		-9.211
0.5%		-9.599
0.0%	minimum	-9.868

Summary Statistics

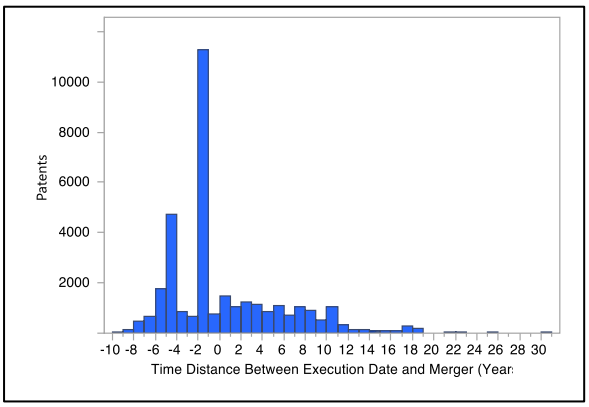
Mean	-0.5517
Std Dev	5.367
Std Err Mean	0.08613
Upper 95% Mean	-0.3829
Lower 95% Mean	-0.7206
N	3882

Test Mean

Hypothesized Value	0
Actual Estimate	-0.5517
DF	3881
Std Dev	5.367
Sigma given	5.101

	z Test
Test Statistic	-6.7396
Prob > |z|	<.0001*
Prob > z	1.0000
Prob < z	<.0001*

Patents



Quantiles

100.0%	maximum	30.18
99.5%		17.96
97.5%		11.37
90.0%		8.074
75.0%	quartile	2.840
50.0%	median	-1.471
25.0%	quartile	-3.362
10.0%		-4.688
2.5%		-6.564
0.5%		-7.893
0.0%	minimum	-9.732

Summary Statistics

Mean	0.1986
Std Dev	5.101
Std Err Mean	0.02827
Upper 95% Mean	0.2541
Lower 95% Mean	0.1432
N	32546

Test Mean

Hypothesized Value	0
Actual Estimate	0.1986
DF	32545
Std Dev	5.101
Sigma given	5.101

	z Test
Test Statistic	7.0258
Prob > |z|	<.0001*
Prob > z	<.0001*
Prob < z	1.0000

Figure 5-6: Variable X_{ijk} No. Applications/Patents by Child Companies prior to Merger (Semiconductor)

It is interesting to note that application and patent behavior appear to be different in terms of structure. Applications appear to exhibit a more bi-model structure when compared to patents, which have a slow buildup in activity with a decrease following year zero. In both cases, activity after year zero could mean each child company was still acting under its original child name for application/patent creation and IP procurement. This would make sense since it might be in the parent's best interest to maintain the child company's semi-autonomy depending on the brand recognition or other business considerations. Additionally, even if the child company eventually changes its name to adopt the parent's along with a transfer of IP, there would likely be lag as the assignor to assignee transactions complete.

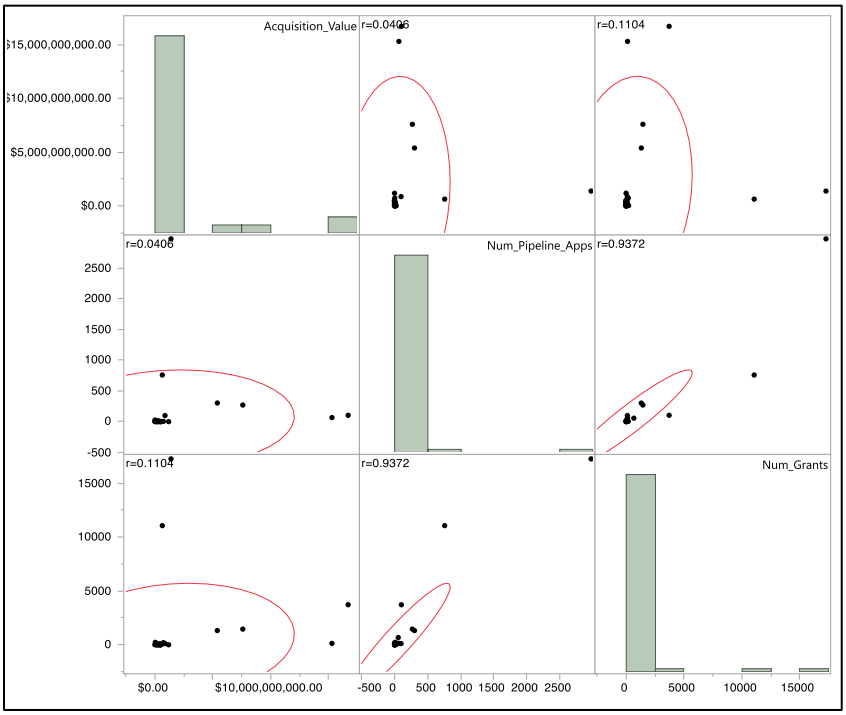
5.3 - Value as Measured by Child Company Acquisition Cost

In addition to the construction of the time-distance variable, the resulting dataset was examined by acquisition value (based on the AcquiredBy.co lists), the number of applications, and the number of patents. The attempt of this study was to attach an acquisition dollar value to the number of applications/patents to see if there were any apparent relationships. For example, perhaps a company's IP/technology is considered worth more in terms of dollar value as part of the acquisition process.

As seen in the scatterplot, correlation, and covariance matrix (refer to **Figure 5-7**), no clear relationship could be found between acquisition value (money paid by Intel or AMD for the acquisition of a child company) and the number of applications or patents prior to the date of acquisition.

All relationships show a strongly positive covariance (far above zero), which indicates a direct or increasing linear relationship; however, the correlation is near-zero for relationships between acquisition value and application or patent number. This means that while there is an increasing linear relationship, the strength of that linear relationship is not very strong.

The number applications to patents appears to have a much stronger relationship (e.g. strongly positive covariance and a near-one correlation of 0.9372). This strong correlation between the number of applications and patents is obvious because companies with many applications should have many patents as well due to active IP acquisition, generation, or simply an attentive IP legal department. It is reasonable to expect that these active companies have many applications in the pipeline becoming patents. However, this result does not establish any hints towards IP/technology and its perceived value in terms of acquisition value. This will be discussed more in detail in the Discussion section.



NOTE: Axes for All Plots Located on Bottom and Left

Multivariate Correlations

	Acquisition_Value	Num_Pipeline_Apps	Num_Grants
Acquisition_Value	1.0000	0.0406	0.1104
Num_Pipeline_Apps	0.0406	1.0000	0.9372
Num_Grants	0.1104	0.9372	1.0000

Covariance Matrix

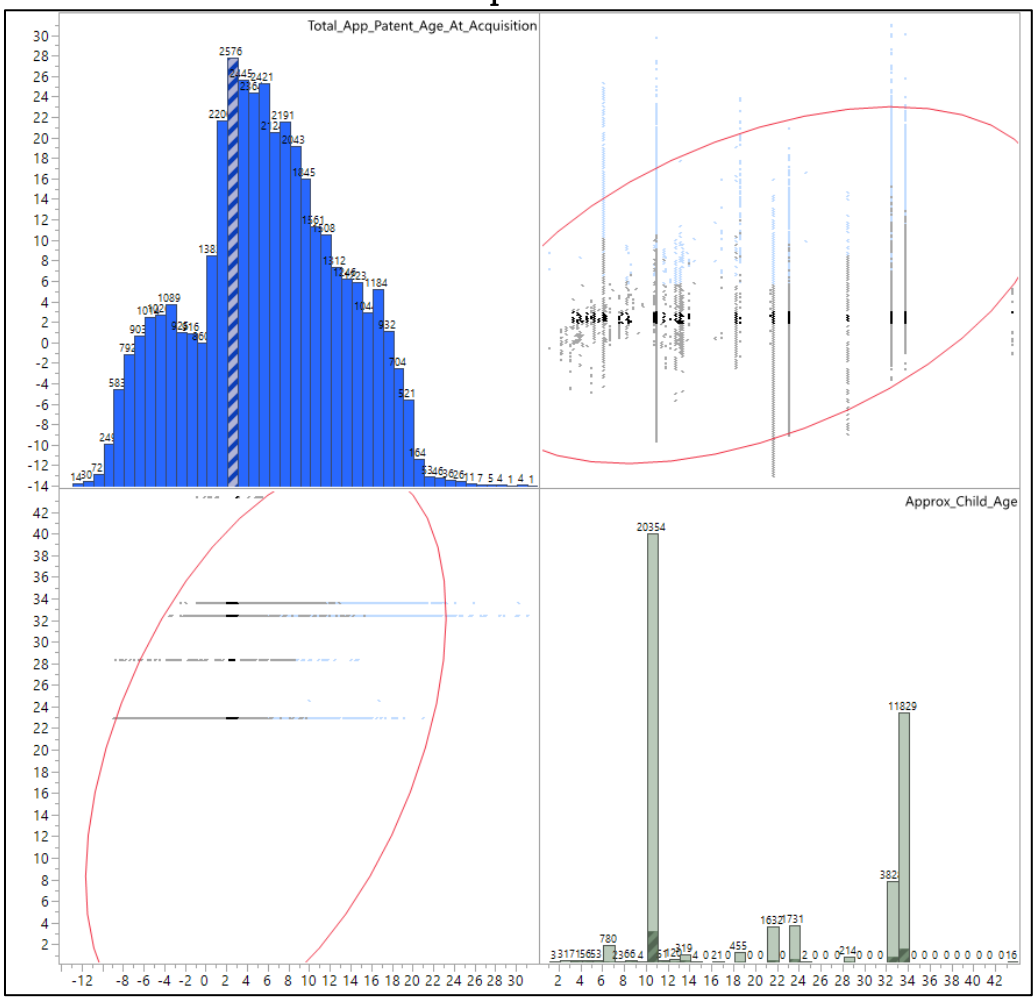
	Acquisition_Value	Num_Pipeline_Apps	Num_Grants
Acquisition_Value	1.754e+19	5.48e+10	1.004e+12
Num_Pipeline_Apps	5.48e+10	103820.74	655634.19
Num_Grants	1.004e+12	655634.19	4713903.2

Figure 5-7: Relationships between Acquisition Value, Number of Applications, and Number of Patents

5.4 - Age of Child Company and Its Acquired IP

Another result was the study of child company age versus IP age at the time of its acquisition by the parent. This can be thought of as a ratio of IP age (either an application or patent) to child company age (e.g. the time difference between child company founding and its merger with the parent). For example, it would be interesting to see if relatively older companies procure newer or established IP. Which IP ages do younger companies acquire? The results of this analysis can be seen in the scatterplot, correlation, and covariance matrix shown below in **Figure 5-8**.

Scatterplot Matrix



NOTE: Axes for All Plots Located on Bottom and Left

Multivariate Correlations

	Total_App_Patent_Age_At_Acquisition	Approx_Child_Age
Total_App_Patent_Age_At_Acquisition	1.0000	0.4648
Approx_Child_Age	0.4648	1.0000

Covariance Matrix

	Total_App_Patent_Age_At_Acquisition	Approx_Child_Age
Total_App_Patent_Age_At_Acquisition	50.68222	35.44642
Approx_Child_Age	35.44642	114.77280

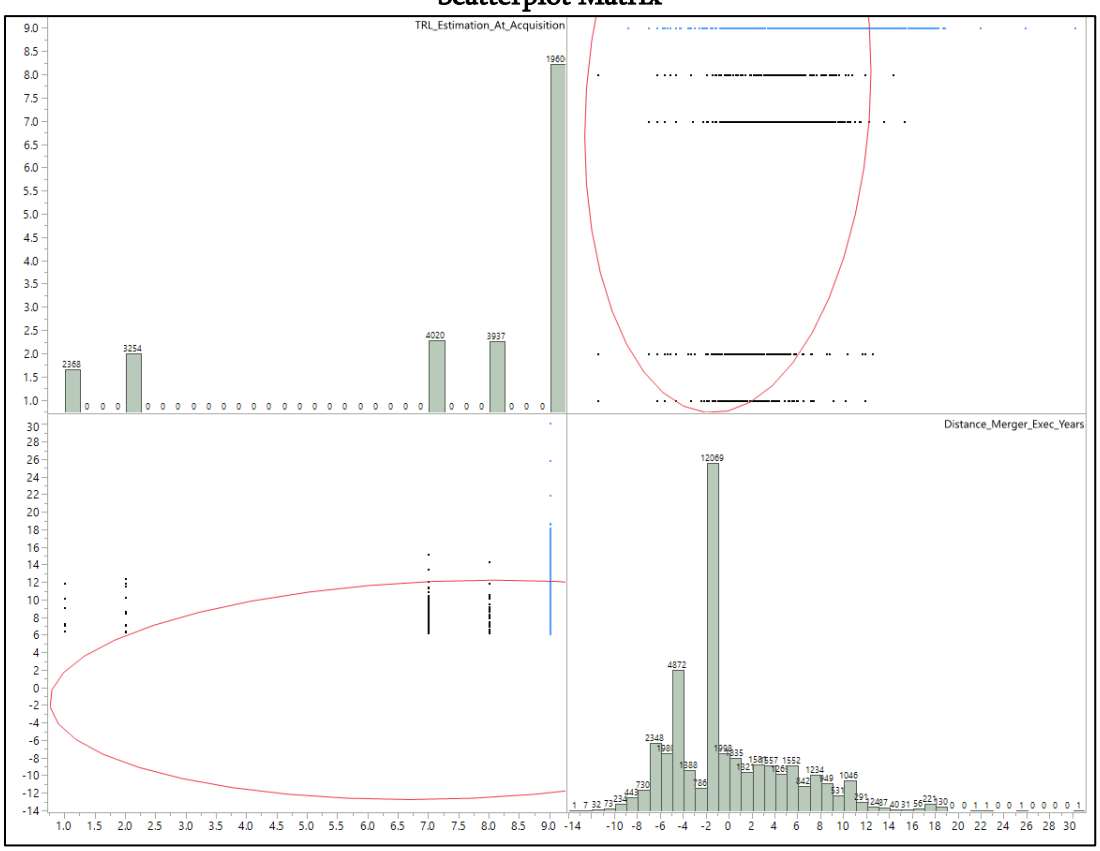
Figure 5-8: Relationships between IP Age and Child Company Age at Acquisition

The structure of the scatter plots does not suggest a linear relationship nor do the correlation and covariance analyses. However, the histograms from the scatterplot matrix suggest some items of interest: the largest grouping of IP (based on age) fall within two to three years old at a count of 2576 followed by years 3 through 4 old and 5 through 6 at counts of 2445 and 2421, respectively (as highlighted in the top left of Figure 5-8 above). The most applications/patents were acquired by companies between 10.7-10.8 years old (as highlighted in the bottom right of Figure 5-8 above). The second highest grouping of IP procurement is by child companies around 33.6 years old. Despite these interesting histogram findings, the relation between IP age and child company age appears to be weak with no discernable structure.

5.5 - Application of TRLs

Using a study of TRLs, program phases, and general IP cycle time (USPTO application processing time), this study hypothesizes that IP and technology maturity are linked. This study proposed mapping TRLs to IP per **Table 2-7**. These proposed TRLs (constructed variables) were compared to the IP transaction buildup examined earlier to see if there is a relationship. This attempts to answer which IP maturity is procured most often prior to the merger. However, the structure has a low correlation and a low variance, suggesting that there is no relationship between perceived value buildup prior to acquisition and TRLs (as proposed by this study). Refer to **Figure 5-9** to see the results. One item of interest is that most of the applications/patents chosen would be considered TRL9 by the scale on **Table 2-7**. This would make sense as companies would likely attempt to choose proven technology rather than deal with the uncertainties of research and development.

Scatterplot Matrix



NOTE: Axes for All Plots Located on Bottom and Left

Multivariate Correlations

	TRL_Estimation_At_Acquisition	Distance_Merger_Exec_Years
TRL_Estimation_At_Acquisition	1.0000	0.1060
Distance_Merger_Exec_Years	0.1060	1.0000

Covariance Matrix

	TRL_Estimation_At_Acquisition	Distance_Merger_Exec_Years
TRL_Estimation_At_Acquisition	7.35658	1.46745
Distance_Merger_Exec_Years	1.46745	26.05479

Figure 5-9: Relationship between Proposed TRLs (Technology Maturity) and Perceived Value

This study also decided to break the TRL Estimation at Acquisition down into applications versus patents to get better granularity. Such granularity could help see which form of IP (pre-grant or post grants) are driving the results. As seen in the side-by-side comparison in **Figure 5-10** below, companies are attempting to acquire technology with the highest maturity regardless if it is in the form of applications or patents. Again, this would make sense since companies would try and limit development uncertainties. It is important to note that applications per the proposed scale could never go above an TRL8. This is because TRL9 technology would be long-established. TRL8 may be ready to produce but it is unlikely that a company in the semiconductor industry (or similar) would fail to release a technology without IP protection. Failing to protect oneself with a patent could trigger the prior art clause, disrupting the patent grant process altogether.

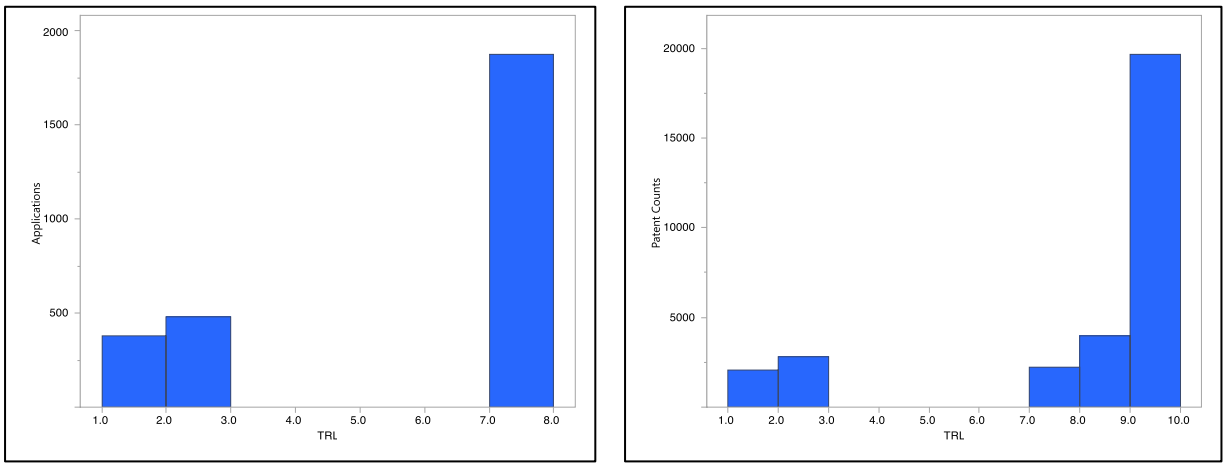
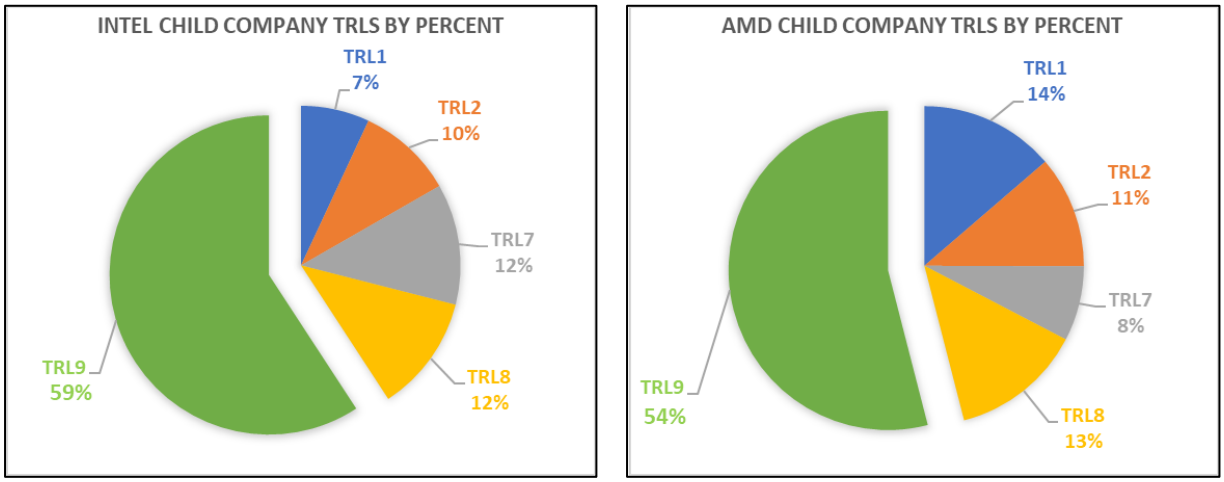


Figure 5-10: Comparison of Applications and Patents using the TRL Estimation Scale on Table 2-7

Examining these technology maturity results by parent company demonstrates that IP at TRL9 acquired by child companies represents greater than 50% of the total IP. These results are presented in **Figure 5-11** as a percent to offset the effect caused by IP counts and company size. It becomes clear that the Intel and AMD are in pursuit of child companies of high perceived value, and TRL9 (high maturity technology) is most prized.



Total Intel Child IP = 32290 **Total AMD Child IP = 898**

Figure 5-11: Child IP TRLs Acquired by Parents Intel/AMD through Merger Event by Percent

6 - Discussion

This research endeavors to explore the interactions between Merger and Acquisition (M&A) activity, Intellectual Property (IP), and technology maturity using TRLs. The scope of this paper is limited two major companies within the semiconductor industry: Intel and AMD. As Intel and AMD attempt to remain competitive, they have purchased many children companies. In total, both companies have acquired 91 major companies. A complete list of these companies can be seen on **Table 4-2.**

A detailed literature review of perceived technology value, TRLs, and patent grant cycle times helped to develop and refine the following hypotheses:

- **Hypothesis 1** – TRLs are reasonable method of measuring technology maturity within the semiconductor industry.
- **Hypothesis 2** – IP activity is a reasonable method of tracking technology innovation in the semiconductor industry since the idea must be made visible to the world.
- **Hypothesis 3** – Technology and the need to procure it is a significant driver of M&A activity the CPU semiconductor industry because it adds value.
- **Hypothesis 4** - IP helps date the maturity of technology.

6.1 - Overall Application & Patent Counts

Overall Application/Patent counts and averages began to demonstrate the value of technology within the semiconductor industry compared to non-semiconductor companies acquired by Intel/AMD. It also demonstrated that tracking IP in the semiconductor industry seems reasonable. Nowhere was this more visible than when the full list of Intel/AMD-acquired child companies and their applications/patents were filtered by industry (**Figures Figure** 5-1, **Figure** 5-2, and **Figure** 5-3). Since this research focuses on M&A, IP, and technology maturity in the semiconductor industry, the semiconductor counts are most relevant. Companies representing some of the largest application and patent quantities are in the semiconductor industry. These include Altera, Infineon, and LSI. McAfee was the only non-semiconductor company with comparable quantities of IP. This likely suggests that technology and its IP are imporant to semiconductor companies. McAfee may also perceive value in technology, but since they are in security, it is also likely that they have a very active legal department. This could explain this outlier.

These results mostly support Hypothesis 2: “IP activity is a reasonable method of tracking technology innovation in the semiconductor industry because the idea must be made visible to the world.” Semiconductor continues to represent most of the IP even when filtered. Many companies with few to no patents appear to reside within industries where IP provides limited protection; however, semiconductor

also contain companies with no applications or patents such as Basis Communications, Oplus Technologies, Envara, and Movidius. There could be many reasons for this. For example, Movidius is a younger company, appears to have applications in the pipeline, but has no awarded patents yet. Companies like Envara and Oplus Technologies are based outside the United States. They may apply for US patents, but their IP traceability may be limited outside the core countries in which they operate and sell. They are more likely to use resources applying for patents for their important technologies or for products sold on the US market. Basis Communications qualifies as semiconductor, but they are likely better categorized as telecommunications, which would place them in an industry where IP protection may not be as strong.

6.2 - Build Up of Perceived IP Value Prior to Merger Event

The combined industry results using the time-distance variable x_{ijk} suggestions that technology has value to companies, and that value can be expressed in terms of IP buildup as transaction activity prior to merger at year zero. There is likely an element of both correlation and causation driving this behavior. Correlation is associated with the child companies building up IP for their own autonomous goals without the intent of being acquired by Intel or AMD. Causation is associated with the child companies building up IP with the intent of looking more valuable by the future parent company (e.g. Intel or AMD). The exact intentions of the child companies are not easily discernable from the USPTO database; however, the buildup appears to align better with correlation. Thus, the companies are likely acquiring IP for their own purposes without regard of future merger intentions. The basis for this assumption and observation is that the results do not support the presence of sharp spikes prior to the event, just a gradual ramp up suggesting organic growth. Large spikes would be expected if the behavior was likely more causation, since the child company would procure as much IP as possible in shorter time spans.

These transactions demonstrated low p-values suggesting significance. Both application and patent procurement counts rise prior to each child company's respective merger date **Figure 5-7,** thus supporting Hypothesis 3. Filtering the data by semiconductor revealed that this counts still maintained a reasonably low p-value as seen on **Figures Figure** 5-4 and **Figure** 5-5. Wave structures of IP build up prior to the merger event at year zero. This increase in IP prior to mergers could be the proxy for the value of perceived technology and the desire to acquire it, especially in the semiconductor industry. This supports Hypothesis 3 – "Technology and the need to procure it is a significant driver of M&A activity the CPU semiconductor industry because it adds value."

6.3 - Value as Measured by Child Company Acquisition Cost

The results of the scatterplot matrix, correlation, and covariance examining merger acquisition value to number of applications and number of patents revealed no strong relationship. The attempt to explore the relationship between merger acquisition value and the number of applications and patents was to assign a more concrete dollar value to the value of technology. It answers the question, "how much is IP worth during an acquisition." The results do not support any meaningful relationship between the number IP and the price of a child company. There could be many reasons for this. One major possibility is that the value of IP may be only one of many factors influencing the final price. For example, how many physical assets is the parent purchasing? Does this include factories and machines?

A second possibility is a lack of data for a meaningful analysis. The AcquiredBy.co lists contained much useful information; however, many acquisition values were declared as "Undisclosed" and had to be removed from the analysis. This is because the acquisition data was collected from press releases as they became available. A way to improve this would be investigate IRS records or other similar public databases to get a better estimation of the final acquisition price. This could strengthen the acquisition value to IP relationship in future studies.

6.4 - Age of Child Company and Its Acquired IP

The purpose of examining the IP age versus the child company age is to determine how value in the form of technology IP may manifest itself as a function of age. It is essentially a ratio used to normalize the information for comparison with other companies procuring IP. The results did not suggest any strong relationship, which means this study could not determine if older IP is still worth the same value as newer IP. One suggestion is to examine this theory more in the future would be to build on the acquisition value of company IP relationships mentioned under "Value as Measured by Child Company Acquisition Cost."

This part of the research did reveal some useful information concerning IP age and company. It suggests that a majority of applications/patents were acquired by companies between 10.7-10.8 years old. The second highest grouping of IP acquisition is by child companies around 33.6 years old. Determining approximate ages of companies could eventually help to learn the approximate ages of companies that reach this critical buildup of IP prior to merger events in the high technology industries researched. It is useful from a business perspective to anticipate potential company ages when technology could lead to a buy-out.

6.5 - Application of TRLs

The intent of applying TRLs to technology in the semiconductor industry serves two objectives: to study links between technology maturity, IP, and M&A and to suggest a TRL scale that could work for semiconductor. Research on TRLs applied to semiconductor technology suggests that companies chose IP with the highest maturity for both applications and patents using the scale found on **Table 2-7**. As mentioned earlier, this is in alignment with intuition because IP procurement could be a way to avoid the risk of technology development. This result supports Hypotheses 1 and 4, which state that TRLs are a reasonable method of measuring technology maturity in the semiconductor industry, and IP can be used to help assign technology maturity. Data on failed mergers (e.g. cancelled in the early pre-merger phase) was not found, only lists of companies that successfully completed the pre-merger and integration phases; however, it would be an interesting study to see if these results still hold true in pre-merger cancellations between Intel/AMD and a potential child company. Additionally, it would be interesting to see if this holds up at other high-tech computer hardware companies that still value technology IP highly but are not in semiconductor.

There are some limitations to applying IP cycle time as shown on **Table 2-7**. While IP processing cycle times and general program phases are well-established, time is not the only factor in technology maturity. An idea for complex technology may not be fully realized for decades and could have a slower development cycle when compared to the USPTO processing IP cycle times. For example, the idea for fusion technology has existed for decades but it is far from working and established as mature. Patent application ideas for fusion could be submitted; however, their timeline of development will likely far outpace USPTO grant processing times. This means that using USPTO IP processing times as estimates of maturity are likely only useful in domains such as semiconductor where new TTM (time to market) is quick with patent award times being a gate. Additionally, technology could be abandoned only to be picked up later by companies seeking a competitive edge. Thus, time alone does not bring technology to maturity just because the initial concept is old. It requires development. To refine this age estimate in slower TTM industries, extra parameters using title and conveyance text could help future research determine a truer estimate of maturity. This would require building substantial code onto the MATLAB® search provided in Appendix II; however, the conveyance text states changes or updates to the record and the title could provide enough detail via keyword searches of a technology to link it to a well-known product sold by the company who owns the patent. For example, certain patented pipeline chip microarchitectures could be searched and their maturity revised based off cross references such as Stanford's CPU DB (known as the CPU Database). Additionally, there is a separate USPTO research dataset containing full-text patent files

extending back to the database's initial founding in 1976. Creating a new search method using programming could permit better data mining based on keyword hits with in this full-text dataset. An alternate suggested method to refine TRLs will be discussed below in "Potential Future Research Ideas for TRLs."

6.6 - Potential Future Research Ideas for TRLs

Metrics are useful for seeing aggregate CPU technology maturity over time based on cataloged information. For example, the Stanford's CPU DB's information such as number of transistors or die size provide highlight technology progress through a physical characteristic. This would be ideal if a TRL could be applied to the industry; however, TRL's are typically applied on the system, subsystem, and component level with the lowest TRL gating the overall system. Additionally, architecture or environmental changes could constantly drop initially-mature concepts back down to a TRL of 5 (Shea 2017).

The rapid progress made in semiconductor technology, components or systems would mean all systems could easily be low TRLs due to uniformly low component TRLs. As mentioned earlier, even slight alternations to the architecture would drop the TRL each time. This could diminish effectiveness of TRLs since they are intended to provide a more precise means of determining which areas of a system need more research and attention. Additionally, acceptable readiness is not necessarily fixed and there is certainly is a judgement call involved in determining similarities between elements of a system (Sadin et al. 1989; Shea 2017). If all or most elements are equally low due to quick CPU advances, TRLs in CPU technology may not fit the industry need to highlight areas requiring the most need to demonstrate maturity.

A proposed method of addressing this issue and refining the IP cycle time scale used in this study is to determine TRLs based on CPU instruction set extensions. For example, perhaps similarities between elements and previous mature architectures should be compared by how the Instruction Set Architecture (ISA) is expressed by the microarchitecture (e.g. physical hardware organization). Many microarchitectures may be designed to support the ISA ("Microarchitecture (uarch)"). The ISA concerns computer design from the aspect of which basic operations are available and is supported by the microarchitecture, which may vary between manufacturers. However, despite the manufacture microarchitecture differences, they support a similar basic operations ("Microarchitecture and Instruction Set Architecture" 2018). To explore this application, this future research would focus future research to the following: M&A activity, within the CPU industry (semiconductor), with a focus on x86-64 architecture. X86 is a type of CPU architecture that is dominate in most computers and maintains backward compatibility (Bryant and O'Hallaron 2005). This backward compatibility could be exploited to assign TRLs

since the x86 CPUs to retain instruction sets while adding new ones for new feature releases. This means that x86 CPUs could have a basic evolutionary measure since the TRL is assigned to the instruction set capabilities. Older instruction sets that have been well tested would constitute a TRL9 where newer releases that could start lower. The further the instruction set gets from its initial release date, the more mature it is considered. To reach TRL 9, the instruction set could be considered one CPU release behind and part of CPU's backward capability. The following basic timeline with x86 instruction set extensions could be used to assign a basic TRL. Refer to **Figure 6-1** below for a timeline of x86 extension sets ("Timeline of X86 Instruction Set Extensions - 10stripe").

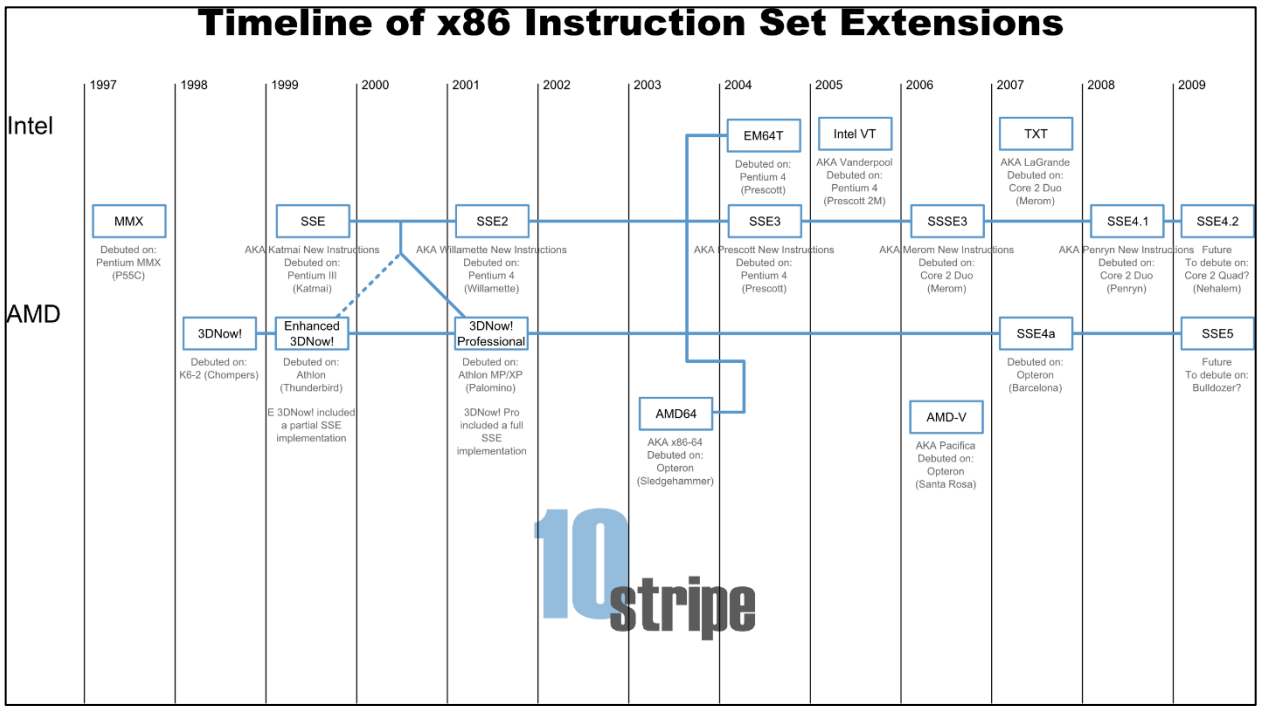


Figure 6-1: x86 Instruction Set Extension Timeline

6.7 - Application Database Results and Possible Reasons

This study initially started searching the USPTO's Patent Application Database, which is distinct from the Patent Database. The reasons for switching to the Patent Database likely stem from technical, functional, and behavioral complications.

From a technical perspective the Application Database information such as correspondence name is not as uniform as the Patent Database "ee_name" variable. The correspondence fields could be filled out multiple ways. This really caused complications during the Application Database search process, which means that data could not be found easily. Many misspellings also caused major issues. Combined, these two factors lowered confidence of retrieved data. For example, the final Application Database search

resulted in only 15 of the total 91 companies researched. That is only a 17% success rate searching for company names alone compared to the 88% success rate of the Patent Database.

To understand the functional database complication, it is important to understand some of the major differences between the two databases. The Application Database deals more with the intricacies of the application process itself while the Patent Database appears to document more finalized results in the form of transactions. For example, the Application Database focuses on all aspects of an application such as recording signed documents, updates, abandonment status while the Patent Database documents basic transactions like conveyance information (e.g. some basic words as to the nature of the transaction), title, assignee, assignor, execution date, rf_id, reel number, page count, application number, etc. Refer to the Appendix I Table II for a complete listing of the Patent Database structure and information recorded. As the grant is awarded, the Patent Database includes the grant number, which is the patent number. While a one-page schema is all that is needed for the user understand the Patent Database, the Application Database contains extremely detailed application information which is covered in a the USPTO appendices A through F supplied with the dataset. Some information from both databases may overlap, but their intended function appears to be very different. Patent Application Database appears to contain information that is more "in-work," thus the information may not yet paint the complete picture whereas the Patent Database is the finalized picture in the form of a transaction.

The reason for the reduced search results from the Application Database could also be behavioral and prompts many questions. Why are there so few companies represented and why is there such a disparity between companies such as Infineon, Altera, LSI-Axxia, and McAfee, and the others?

A cursory review of the Application Database reveals many law firms acting on behalf of people or entities. This could mean that a company name is obscured by the law firm name representing it, either intentionally or unintentionally. This is a good topic for future research.

For companies found in the Application Database such as Infineon, Altera, LSI-Axxia, and McAfee, they far out-represented other Intel/AMD-acquired firms by a large margin in terms of application counts. Almost no companies existed between these two groups. This divide could be due to activity of legal departments and the resources available to processes IP. As mentioned earlier, IP is a form of layered protection, and some companies are bound to be more proactive in defending their technology.

It is also possible that most initial technology applications are submitted prior to the formation of a company, thus the patent application is filed under a list of individuals rather than an entity's name. This is anecdotally supported by the number database entries filed under various personal names and addresses.

For these reasons, the remainder of the study was performed using the Patent Database. More information was able to be collected from a more coherent, transactional database that tied entities such as companies to IP. As mentioned earlier, this simple switch led to a large increase in company name hits (e.g. 17% to 88%).

7 - Conclusion

Support for the four hypotheses exploring the relationship between M&A, IP, and technology maturity is imporant due to the financial consequences of mergers. Reviewing the AcquiredBy.co lists in this study supports what has been seen in the market overall: mergers happen in waves and they are an increasing trend. Using TRLs can help the semiconductor industry apply time-tested methods from the defense industry to manage resources and development risk. IP can be used to guard that technology which was so carefully developed. Also, IP could be used to determine when merger events are more likely to occur based on the accumulation of IP, which could be a proxy for technology value. The results found in this study support the idea that technology does have a perceived value and that mergers likely do occur to acquire technology. This was demonstrated using a constructed time-distance variable x_{ijk}. This aligns with previous studies such as Ranft and Lord (2000) survey in which 35% of people responded that acquisition occurred due to product-specific technology. Since US mergers in 2017 accounted for $1.7 trillion and the trend is increasing, M&A has both become more important and more prevalent than ever before.

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Appendix I: Additional Figures

Year	Authors	Themes	Results
1986	Roll	Over-confident management	Over-confidence is the reason for several combinations
1989	Hayn	Fiscal motivations	Validated hypothesis of fiscal motivations
1990	Seyhun	Managers' personal motivations	No conflict of interest was observed
1991	Martin and McConnell	Synergy, disciplinary motivations	Validated hypothesis of disciplinary motivations
1991	Saint-Pierre	Motivations in opposing takeover bids	Opposition is linked to target performance and manager compensation
1993	Berkovitch and Narayanan	Potential to gain synergy, managers' personal motivations, overbidding due to overvaluation	Results highlight the search for synergy and managers' personal motivations
1994	Shih	Fiscal motivations in conglomerate operations	Validated hypothesis of fiscal motivations in conglomerate operations
1996	Franks and Mayer	Disciplinary motivations in hostile takeover bids	Hypothesis of disciplinary motivation in hostile situations was not validated
2000	Walker	Concentration and diversification objectives	58% of firms in the study aimed to concentrate their activities, 42% wished to diversify
2000	Ghosh and Lee	Synergy, disciplinary motivations	Validated hypothesis of disciplinary motivations

Appendix Table I: Comprehensive List of M&A Motivation Studies Over Time (Ibrahimi 2018)

USPTO Patent Assignment Dataset Schema

assignor

Variable	Type	Label
rf_id	long	Reel Frame ID Number
or_name	str244	Patent Assignor Name = Entity Assigned From
or_name_len	int	Length of Patent Assignor Name = Entity Assigned From
exec_dt	float	Execution Date between Entities
ack_dt	float	Acknowledgement Date

1:m
key: rf_id

assignee

Variable	Type	Label
rf_id	long	Reel Frame ID Number
ee_name	str244	Patent Assignee Name = Entity Assigned TO
ee_name_len	int	Length of Patent Assignee Name = Entity Assigned TO
ee_address_1	str244	Patent Assignee Address Line 1
ee_address_1_len	int	Length of Patent Assignee Address Line 1
ee_address_2	str244	Patent Assignee Address Line 2
ee_address_2_len	int	Length of Patent Assignee Address Line 2
ee_city	str40	Patent Assignee City
ee_state	str59	Patent Assignee State
ee_postcode	str15	Patent Assignee Postal Code
ee_country	str44	Patent Assignee Country

1:m
key: rf_id

assignment

Variable	Type	Label
rf_id	long	Reel Frame ID Number
file_id	int	US Patent Assignment ID
cname	str50	Correspondent Name
caddress_1	str50	Correspondent Address Line 1
caddress_2	str50	Correspondent Address Line 2
caddress_3	str50	Correspondent Address Line 3
caddress_4	str44	Correspondent Address Line 4
reel_no	int	Reel Number of Microfiche Record
frame_no	int	Frame Number of Microfiche Record
convey_text	str244	Conveyance Text - Describes Type of Assignment
convey_text_len	int	Length of Conveyance Text
record_dt	float	Recorded Date with USPTO
last_update_dt	float	Last Update Date
page_count	int	Page Count of Assignment Record
purge_in	byte	Purge Indicator = 1-yes assignment deleted

1:m
key: rf_id

documentid

Variable	Type	Label
rf_id	long	Reel Frame ID Number
title	str244	Invention Title
title_len	int	Length of Invention Title
lang	str8	Language of Invention Title
appno_doc_num	str8	Application Document USPTO Number
appno_date	float	Application Date
appno_country	str2	Application Country
pgpub_doc_num	str8	Pre-Grant Publication Document USPTO Number
pgpub_date	float	Pre-Grant Publication Date
pgpub_country	str2	Pre-Grant Publication Country
grant_doc_num	str8	Granted Patent Document USPTO Number
grant_date	float	Granted Patent Date
grant_country	str2	Granted Patent Country

1:1
key: rf_id

1:m
key: rf_id

assignment_conveyance (constructed)

Variable	Type	Label
rf_id	long	Reel Frame ID Number
convey_ty	str10	Conveyance Type
employer_assign	float	Employer Assignment Indicator

documented_admin (constructed)

Variable	Type	Label
rf_id	long	Reel Frame ID Number
appno_doc_num	str14	Application Document USPTO Number
grant_doc_num	str8	Granted Patent Document USPTO Number
admin_appl_id_for_grant	str14	Application number for grant_doc_num from administrative data
admin_pat_no_for_appno	str7	Patent number for appno_doc_num from administrative data
error	str61	Identifier Error

Appendix Table II: USPTO Data Table Schema for the Patent Assignment Database (*United States Patent and Trademark Office's Main Web Site*)

Appendix II: MATLAB® Source Code Used Process, Save, Load, and Extract USPTO Database .CSV Files

Creates Datastores Using USPTO Database Files

```
%Created by: Tim Pennington
%Creatd on: 7/5/2020
%Created for: Imports CSV files for TabularData Stores and Large Arrays


clc


%*********Opens File Browse Prompt***************
[file,path] = uigetfile('*.csv');
if isequal(file,0)
   disp('User selected Cancel');
else
   disp(['User selected ', fullfile(path,file)]);
end

%*********Inserts Selected File into Datastore***************

ds =
tabularTextDatastore(strcat(path,file),'NumHeaderLines',0,'MissingValue',0,'TreatAsMis
sing','NA','ReadVariableNames',1);

ds.SelectedFormats(:,:) = {'%q'};

viewdata1 = preview(ds);
disp(viewdata1)

disp('Your Default Selected Formats are initially string values')


%*********Determines Size and Updates Fields in Prompt Gui***************
%Allows user to re-enter or edit choices

[rows,cols] = size(ds.SelectedFormats);

retry = 'y';

while retry == 'y'|retry == 'Y'

for i=1:cols
    prompt1(i) = "Column " + i + " - " + ds.VariableNames(1,i);
end
prompt2 = convertStringsToChars(prompt1);

prompt = prompt2;
dlgtitle = 'Datastore Selected Formats';
dims = [1 50];
definput = ds.SelectedFormats;
answer = inputdlg(prompt,dlgtitle,dims,definput);

ds.SelectedFormats = transpose(answer);

disp('Your Datastore Selected Formats are ')
```

```
disp(ds.SelectedFormats)

viewdata2 = preview(ds);
disp(viewdata2)


retry = input('Would you like to change your Selected Formats? (Y/N): ','s');

end

clear answer cols definput dims dlgtitle i path prompt prompt1 prompt2 retry rows
viewdata1 viewdata2

%*******Creates a Tall Array of Data***********

TA = tall(ds);

%********Preview Request****************************************

response = input('Would you like to preview the data? (Y/N): ','s');

while response == 'Y'|response == 'y'


    %******Second Prompt GUI to Determine Heads/Tails Preview**********


    retry1 = 'N';

    while retry1 == 'N'

    prompt = {'How many lines of the file would you like to see? ' 'Head or Tail
Preview (H/T)? '};
    dlgtitle = 'Number of Preview Lines';
    dims = [1 35];
    definput = {'10000', 'H'};
    answer = inputdlg(prompt,dlgtitle,dims,definput);

    retry2 = string(answer(2,1));

        if retry2 == 'H'
            TA_Subset = gather(head(TA,str2num(string(answer(1,1)))));
            retry1='Y';
            response='N';

        elseif retry2 == 'h'
            TA_Subset = gather(head(TA,str2num(string(answer(1,1)))));
            retry1='Y';
            response='N';

        elseif retry2 == 'T'
                TA_Subset = gather(tail(TA,str2num(string(answer(1,1)))));
                retry1='Y';
                response='N';

        elseif retry2=='t'
            TA_Subset = gather(tail(TA,str2num(string(answer(1,1)))));
            retry1='Y';
            response='N';

        else
            retry1='N';
```

```
        end

    end

    disp(TA_Subset)

    clear answer definput dims dlgtitle prompt retry1 retry2


end

clear response answer definput dims dlgtitle prompt retry1 retry2



[rows,cols]=size(TA.Properties.VariableNames);
     for j = 1:cols
         column_no(j,1) = "Column " + j;
     end
 header_names = transpose(TA.Properties.VariableNames);
 variable_prototable = [cellstr(column_no),header_names];
 variable_table =
cell2table(variable_prototable,'VariableNames',{'Column_No','Header_names'});


clear rows cols column_no header_names variable_prototable j


assignin('base',erase(file,".csv"),TA);
assignin('base',erase(file,".csv")+"_ds",ds);
%assignin('base',erase(file,".csv")+"_ref_table",variable_table);

clear file TA ds variable_table TA_Subset
```

Saves Tall Data Variables in Workspace as MAT Files

```
%Created by: Tim Pennington
%Creatd on: 7/8/2020
%Created for: Saving Work as MAT files for later


clc

WIP=who;
[rows,~]=size(WIP);
%path='C:\Users\JimTi\Dropbox (MIT)\09 - Models\Matlab\Patent_Mat_Files\';
path='D:\MATLAB_MAT_File_Backups\';

answer=input('Do you have any variables you want to clear from the workspace? (Y/N): ','s');

if answer=='Y'
    disp('abort, clear, then re-excecute program')
    pause
    clear WIP rows cols answer path
    return

elseif answer=='y'
    disp('abort, clear, then re-excecute program')
    pause
    clear WIP rows cols answer path
    return

elseif answer=='N'

    answer3=input('Do you want to save files all at once or individually? (A/I): ','s');
```

```
    if answer3 == 'A'
        for i=1:rows
            filename=string(path)+string(WIP(i,1));
            save(filename,string(WIP(i,1)),'-v7.3')
        end

        disp('Bulk Save Complete')

    elseif answer3 == 'a'
         for i=1:rows
            filename=string(path)+string(WIP(i,1));
            save(filename,string(WIP(i,1)),'-v7.3')
         end

        disp('Bulk Save Complete')


    elseif answer3 == 'I'
        answer2=input('Which files do you want to save? ','s');
        filename=string(path)+string(answer2);
        save(filename,answer2,'-v7.3')

        disp('Individual Save Complete')

    elseif answer3 == 'i'
        answer2=input('Which files do you want to save? ','s');
        filename=string(path)+string(answer2);
        save(filename,answer2,'-v7.3')

        disp('Individual Save Complete')

    else
        disp('error Will Robinson')

    end

elseif answer=='n'

    answer3=input('Do you want to save files all at once or individually? (A/I): ','s');

    if answer3 == 'A'
        for i=1:rows
            filename=string(path)+string(WIP(i,1));
            save(filename,string(WIP(i,1)),'-v7.3')
        end

        disp('Bulk Save Complete')

    elseif answer3 == 'a'
         for i=1:rows

            filename=string(path)+string(WIP(i,1));
            save(filename,string(WIP(i,1)),'-v7.3')
         end

        disp('Bulk Save Complete')


    elseif answer3 == 'I'
        answer2=input('Which files do you want to save? ','s');
        filename=string(path)+string(answer2);
        save(filename,answer2,'-v7.3')

        disp('Individual Save Complete')

    elseif answer3 == 'i'
        answer2=input('Which files do you want to save? ','s');
        filename=string(path)+string(answer2);

        save(filename,answer2,'-v7.3')
```

```
        disp('Individual Save Complete')

    else
        disp('error Will Robinson')

    end

end


clear answer answer2 answer3 WIP rows cols i path filename
```

Loads in Tall Data Saved as MAT Files

```
%Created by: Tim Pennington
%Creatd on: 7/8/2020
%Created for: Loading MAT Files Saved at Previous Sessions

clc

path='C:\Users\JimTi\Dropbox (MIT)\09 - Models\Matlab\Saved MAT Files\*.mat';

answer=input('Do you want to load One or Many variables into workspace? (O/M): ','s');

if answer=='O'
    files = dir(path);
    new_cell=struct2cell(files);
    subfolder_list=transpose(string(new_cell(1,:)));

    [rows,cols]=size(subfolder_list);

    for i=1:rows
        Column(i,1)='File Number '+string(i);
    end

    large_subfolder_list=[Column,subfolder_list];
    disp(large_subfolder_list)
    column_select=input('Enter File Number to load. ');

    filename=string(erase(path,'*.mat'))+string(large_subfolder_list(column_select,2));

    load(filename)


elseif answer=='o'
    files = dir(path);
    new_cell=struct2cell(files);
    subfolder_list=transpose(string(new_cell(1,:)));

    [rows,cols]=size(subfolder_list);

    for i=1:rows
        Column(i,1)='File Number '+string(i);
    end

    large_subfolder_list=[Column,subfolder_list];
    disp(large_subfolder_list)
    column_select=input('Enter File Number to load. ');

    filename=string(erase(path,'*.mat'))+string(large_subfolder_list(column_select,2));

    load(filename)

elseif answer=='M'

    files = dir(path);
    new_cell=struct2cell(files);
    subfolder_list=transpose(string(new_cell(1,:)));
```

```
    [rows,cols]=size(subfolder_list);

    for i=1:rows
        filename=string(erase(path,'*.mat'))+string(subfolder_list(i,1));
        load(filename)
    end

elseif answer=='m'
    files = dir(path);
    new_cell=struct2cell(files);
    subfolder_list=transpose(string(new_cell(1,:)));

    [rows,cols]=size(subfolder_list);

    for i=1:rows
        filename=string(erase(path,'*.mat'))+string(subfolder_list(i,1));
        load(filename)
    end

else

    disp('Danger Will Robinson')

end

clear i new_cell rows cols subfolder_list files Column column_select filename
large_subfolder_list path answer
```

Searches Patent Application Database

```
%this script allows the user to search

answer=input('name the target source variable: ');

interim=answer;

answer2=input('how many search parameters do you need? ');
answer3=(answer2);


for i=1:answer3

    answer4=input('word '+string(i)+' contains?: ','s');

    c1=contains(string(interim.correspondence_name_line_1),answer4,'IgnoreCase',true);
    c2=contains(string(interim.correspondence_name_line_2),answer4,'IgnoreCase',true);
    c3=contains(string(interim.correspondence_street_line_1),answer4,'IgnoreCase',true);
    c4=contains(string(interim.correspondence_street_line_2),answer4,'IgnoreCase',true);

    keywordhit=0.*c1;


    keywordhit(:,i)=c1+c2+c3+c4;



    clear c1 c2 c3 c4 answer4
end

keywordhit2=sum(keywordhit,2);


interim.keywordhits=keywordhit2;

interim2=interim(interim.keywordhits>0,:);

answer5=input('What would you like to name this variable?: ','s');

interim3=gather(interim2);

small=head(interim3)
```

```
assignin('base',answer5,interim3)


clear small interim interim2 interim3 answer answer2 answer3 answer4 answer5 s i keywordhit
keywordhit2
```

Creates List of Patent Database RFIDs by Company for Use in Final Application/Patent Table Creator

```
% This is the Main File for Extracting, Appending, and Combining Merger
% Data
%Created by: Tim Pennington
%Created on: 7/22/20
%Requires Parallel Computing Package

clear
clc

delete(gcp('nocreate'))

poolobj=parpool; %Starts Parpool - Make sure Parpool is shutdown before starting

retry='y';
path=string(pwd)+"\Pre_Processed_Patent_Mat_Files\*.mat";

while retry=='y'|retry=='Y'

    %*******Brings in Datastores and MAT File Variables******************


    files = dir(path);
    new_cell=struct2cell(files);
    subfolder_list=transpose(string(new_cell(1,:)));

    [rows,cols]=size(subfolder_list);

    for i=1:rows
        filename=string(erase(path,'*.mat'))+string(subfolder_list(i,1));
        load(filename)
    end

    clear rows cols filename files i new_cell subfolder_list

    %******Re-assigns File Names to Prevent Over-Saves********************

    auto_search3=auto_search2;
    assignee=Patent1_Assignee;
    assignee_ds=Patent1_Assignee_ds;
    assignment=Patent2_Assignment;
    assignment_ds=Patent2_Assignment_ds;
    assignment_conveyance=Patent3_Assignment_Conveyance;
    assignment_conveyance_ds=Patent3_Assignment_Conveyance_ds;
    assignor=Patent4_Assignor;
    assignor_ds=Patent4_Assignor_ds;
    document_id=Patent5_DocumentID;
    document_id_ds=Patent5_DocumentID_ds;
    document_id_admin=Patent6_DocumentID_Admin;
    document_id_admin_ds=Patent6_DocumentID_Admin_ds;
    file_=Patent7_File_;
    file__ds=Patent7_File__ds;

    clear auto_search Patent1_Assignee Patent1_Assignee_ds Patent2_Assignment
Patent2_Assignment_ds Patent3_Assignment_Conveyance Patent3_Assignment_Conveyance_ds
Patent4_Assignor Patent4_Assignor_ds Patent5_DocumentID Patent5_DocumentID_ds
Patent6_DocumentID_Admin Patent6_DocumentID_Admin_ds Patent7_File_ Patent7_File__ds

    %*************Ask User for Search Term******************************
```

```
    answer=input('Auto Search or Manual Search?(a/m): ','s');
    answer2=input('What would you like to name this search?: ','s');

    %****Searches and Compiles Companies Patent Ref IDs based on Pre-Sets

    if answer=='a'

        [rows,cols]=size(auto_search3);

       No_Hits="";
       Positive_Hits="";

        for i=1:rows

        c=contains(string(assignee.ee_name),auto_search3(i,1),'IgnoreCase',true);
        result1=gather(c);

        if sum(result1)==0

            No_Hits=vertcat(No_Hits,string(auto_search3(i,1)));

        elseif sum(result1)>0

            Positive_Hits=vertcat(Positive_Hits,string(auto_search3(i,1)));

        end


        result2=assignee(result1,:);

        result3=gather(result2);

            if i==1

                result4=result3;

            elseif i>1

                result4=vertcat(result4,result3);

            end

        end

        clear rows cols i c

        previewdata=head(result4);
        disp(previewdata)

        [rows1,cols1]=size(No_Hits);
        [rows2,cols2]=size(Positive_Hits);

        T_No_Hits=table(No_Hits([2:rows1],1),'VariableNames',{'No_Hits'});
        T_Positive_Hits=table(Positive_Hits([2:rows2],1),'VariableNames',{'Positive_Hits'});


        disp(T_No_Hits)
        disp(T_Positive_Hits)

        clear result1 result2 result3 rows1 rows2 cols1 cols2 No_Hits Positive_Hits T_No_Hits
T_Positive_Hits previewdata

        %***Manaul Single Company Search*****************************


    elseif answer=='m'

        retry2='y';
        i=0;

        while retry2=='y'|retry2=='Y'
```

```
            i=i+1;

        answer3=input('Enter Single Company Name to Search: ','s');

        if i==1

         No_Hits="";
       Positive_Hits="";

        elseif i>1

        end

        c=contains(string(assignee.ee_name),answer3,'IgnoreCase',true);
        result1=gather(c);

        if sum(result1)==0

            No_Hits=vertcat(No_Hits,answer3);

        elseif sum(result1)>0

            Positive_Hits=vertcat(Positive_Hits,answer3);

        end


        result2=assignee(result1,:);

        result3=gather(result2);

            if i==1

                result4=result3;

            elseif i>1

                result4=vertcat(result4,result3);

            end

        clear rows cols c answer3

        previewdata=head(result4);
        disp(previewdata)

        retry2=input('Would you like to add another company to the search?(Y/N): ','s');

        end

        [rows1,cols1]=size(No_Hits);
        [rows2,cols2]=size(Positive_Hits);

        T_No_Hits=table(No_Hits([2:rows1],1),'VariableNames',{'No_Hits'});
        T_Positive_Hits=table(Positive_Hits([2:rows2],1),'VariableNames',{'Positive_Hits'});


        disp(T_No_Hits)
        disp(T_Positive_Hits)

        clear i retry2 result1 result2 result3 rows1 rows2 cols1 cols2 No_Hits Positive_Hits
T_No_Hits T_Positive_Hits previewdata


    else

        disp('Danger Will Robinson')

    end

    clear answer
```

```
    %************Start of Table Flattening from Other Files and Append*************

%     clc
%
%
%     location1=ismember(assignment.rf_id,result4.rf_id);
%     location2=ismember(assignment_conveyance.rf_id,result4.rf_id);
%     location3=ismember(assignor.rf_id,result4.rf_id);
%     location4=ismember(document_id.rf_id,result4.rf_id);
%     location5=ismember(document_id_admin.rf_id,result4.rf_id);
%
%     [a1,a2,a3,a4,a5]=gather(location1,location2,location3,location4,location5);
%
%     A1=assignment(a1,:);
%     A2=assignment_conveyance(a2,:);
%     A3=assignor(a3,:);
%     A4=document_id(a4,:);
%     A5=document_id_admin(a5,:);
%
%     [R1,R2,R3,R4,R5]=gather(A1,A2,A3,A4,A5);
%
%     append1=outerjoin(result4,R1,'Keys',1,'MergeKeys',true);
%     append2=outerjoin(append1,R2,'Keys',1,'MergeKeys',true);
%     append3=outerjoin(append2,R3,'Keys',1,'MergeKeys',true);
%     append4=outerjoin(append3,R4,'Keys',1,'MergeKeys',true);
%     append5=outerjoin(append4,R5,'Keys',1,'MergeKeys',true);
%
%
%     assignin('base',answer2,append5)

%     search_results=head(append4,1000);
%     disp(search_results)
%
%      filename2=answer2+".xlsx";

    %writetable(append5,filename2,'Sheet',1,'Range','A1')

    RF_ID_by_Company=result4;
    head(RF_ID_by_Company)

    clear filename2 location1 location2 location3 location4 location5 a1 a2 a3 a4 a5 A1 A2 A3 A4
A5 R1 R2 R3 R4 R5 append1 append2 append3 append4 append5 result4 answer2 search_results


    retry=input('Would you like to retry the program?(Y/N): ','s');

end

delete(poolobj);

clear retry poolobj path
```

Creates Final Application/Patent Table and Company Overview Data

```
%This scrip is used to search, analyze and graph patent data

clc
clear


retry='y';
```

```
while retry=='y'|retry=='Y'

    delete(gcp('nocreate'))

    filename_registry{1}="C:\Users\JimTi\Dropbox (MIT)\09 - Models\Matlab\Patents\005
Data Analysis\UniqueCompanyRFID.xlsx";
    filename_registry{2}="C:\Users\JimTi\Dropbox (MIT)\09 - Models\Matlab\Patents\005
Data Analysis\MnA_Activty_Intel_AMD.xlsx";

    %Loads in M&A Activity File and Unique Patent RFIDs

    opts1=detectImportOptions(filename_registry{1});
    RFIDs=readtable(filename_registry{1},opts1);
    clear opts1

    %Reads in MnA Activity Table from Compiled Merger Excel File

    opts2=detectImportOptions(filename_registry{2});
    opts2=setvartype(opts2,{'Acquisition_Value'},'double');
    MnA_Activity=readtable(filename_registry{2},opts2);
    clear opts2

    %Sorts MnA Activity by date in ascending order

    interim2=sortrows(MnA_Activity,'Date_Acquired');


    %Determines Min and Max Year to create X-axis of plot by quarter year
    yearmax=year(max(interim2.Date_Acquired));
    yearmin=year(min(interim2.Date_Acquired));
    timeline=transpose(yearmin:.25:yearmax);

    %Creates sorted lists by company

    Intel_mna=interim2(interim2.Parent_Company=="Intel",:);
    AMD_mna=interim2(interim2.Parent_Company=="AMD",:);

    %Company Acquistions by year

    Intel_mna.year=year(Intel_mna.Date_Acquired);
    AMD_mna.year=year(AMD_mna.Date_Acquired);

    %Creates list of unique merger years by company for buckets

    [~,ia1,~]=unique(Intel_mna.year);
    [~,ia2,~]=unique(AMD_mna.year);
    Intel_Unique_Years=Intel_mna.year(ia1,1);
    AMD_Unique_Years=AMD_mna.year(ia2,1);
    clear ia1 ia2

    %Counts number of occurances of acquisition per year per company and
    %adds them to each company unique list as a new column

    [rows_intel1,~]=size(Intel_Unique_Years);
    [rows_amd1,~]=size(AMD_Unique_Years);

    [rows_intel2,~]=size(Intel_mna.year);
    [rows_amd2,~]=size(AMD_mna.year);

    Intel_Unique_Years(:,2)=zeros(rows_intel1,1);
    AMD_Unique_Years(:,2)=zeros(rows_amd1,1);


    for i=1:rows_intel1

        for k=1:rows_intel2

            if Intel_Unique_Years(i,1)==Intel_mna.year(k,1)
```

```
            Intel_Unique_Years(i,2)=Intel_Unique_Years(i,2)+1;
        else
        end
    end
end
for j=1:rows_amd1
    for l=1:rows_amd2
         if AMD_Unique_Years(j,1)==AMD_mna.year(l,1)
            AMD_Unique_Years(j,2)=AMD_Unique_Years(j,2)+1;
        else
        end
    end
end
clear i j k l
%Totals # of Mergers by Company for Plot
[rows,~]=size(timeline);
Intel_Mergers=[timeline(:,1),zeros(rows,1)];
AMD_Mergers=[timeline(:,1),zeros(rows,1)];
for i=1:rows
    for j=1:rows_intel1

        if timeline(i,1)==Intel_Unique_Years(j,1)

            Intel_Mergers(i,2)=Intel_Mergers(i,2)+Intel_Unique_Years(j,2);
        else
        end

    end
end
clear i j
for i=1:rows
    for j=1:rows_amd1
        if timeline(i,1)==AMD_Unique_Years(j,1)

            AMD_Mergers(i,2)=AMD_Mergers(i,2)+AMD_Unique_Years(j,2);
        else
        end

    end
```

```
end
clear i j
%Totals Mergers Per Year Overall
timeline(:,2)=zeros(rows,1);
for i=1:rows
    for j=1:rows_intel1
        if timeline(i,1)==Intel_Unique_Years(j,1)
            timeline(i,2)=timeline(i,2)+Intel_Unique_Years(j,2);
        else

        end
    end
end
clear i j
    for i=1:rows
        for j=1:rows_amd1
            if timeline(i,1)==AMD_Unique_Years(j,1)
                timeline(i,2)=timeline(i,2)+AMD_Unique_Years(j,2);
            else

            end
        end
    end
    clear i j
%Bar Graph of Results
fig1=figure;
values_bar=[timeline(:,2),Intel_Mergers(:,2),AMD_Mergers(:,2)];
bar(timeline(:,1),values_bar,2)
title('CPU Manufacturer Acquisitions by Year')
xlabel('Year')
ylabel('# of Acqusitions')
legend('Combined Acquisitions','Intel Acquisitions','AMD Acquisitions')
hold off
%Plot of Results
fig2=figure;
plot(timeline(:,1),timeline(:,2))
hold on
plot(Intel_Mergers(:,1),Intel_Mergers(:,2))
hold on
plot(AMD_Mergers(:,1),AMD_Mergers(:,2))
title('CPU Manufacturer Acquisitions by Year')
xlabel('Year')
ylabel('# of Acqusitions')
```

```
    legend('Combined Acquisitions','Intel Acquisitions','AMD Acquisitions')

    clear rows rows_amd1 rows_amd2 rows_intel1 rows_intel2 yearmax yearmin interim2
fig1 fig2 values_bar


    %******************Start of Patent Analysis************************

    %Starts Parpool Session for Pooled Search to increase speed




    poolobj=parpool;

    %Loads in specific tables needed from saved .mat files pre-processed into a
datastore by
    %BigDateLoader.m file. Also loads in datastore in case of issues.

     filename_registry{3}="C:\Users\JimTi\Dropbox (MIT)\09 - Models\Matlab\Saved MAT
Files\Patent1_Assignee.mat";
     filename_registry{4}="C:\Users\JimTi\Dropbox (MIT)\09 - Models\Matlab\Saved MAT
Files\Patent1_Assignee_ds.mat";
     filename_registry{5}="C:\Users\JimTi\Dropbox (MIT)\09 - Models\Matlab\Saved MAT
Files\Patent2_Assignment.mat";
     filename_registry{6}="C:\Users\JimTi\Dropbox (MIT)\09 - Models\Matlab\Saved MAT
Files\Patent2_Assignment_ds.mat";
     filename_registry{7}="C:\Users\JimTi\Dropbox (MIT)\09 - Models\Matlab\Saved MAT
Files\Patent3_Assignment_Conveyance.mat";
     filename_registry{8}="C:\Users\JimTi\Dropbox (MIT)\09 - Models\Matlab\Saved MAT
Files\Patent3_Assignment_Conveyance_ds.mat";
     filename_registry{9}="C:\Users\JimTi\Dropbox (MIT)\09 - Models\Matlab\Saved MAT
Files\Patent4_Assignor.mat";
     filename_registry{10}="C:\Users\JimTi\Dropbox (MIT)\09 - Models\Matlab\Saved MAT
Files\Patent4_Assignor_ds.mat";
     filename_registry{11}="C:\Users\JimTi\Dropbox (MIT)\09 - Models\Matlab\Saved MAT
Files\Patent5_DocumentID.mat";
     filename_registry{12}="C:\Users\JimTi\Dropbox (MIT)\09 - Models\Matlab\Saved MAT
Files\Patent5_DocumentID_ds.mat";
     filename_registry{13}="C:\Users\JimTi\Dropbox (MIT)\09 - Models\Matlab\Saved MAT
Files\Patent6_DocumentID_Admin.mat";
     filename_registry{14}="C:\Users\JimTi\Dropbox (MIT)\09 - Models\Matlab\Saved MAT
Files\Patent6_DocumentID_Admin_ds.mat";

     [~,file_cols]=size(filename_registry);

     for i=3:14

        load(filename_registry{i})

     end
     clear i file_cols

     %Converts to internal variables to prevent over-save of master files

     assignee=Patent1_Assignee;
     assignee_ds=Patent1_Assignee_ds;
     assignment=Patent2_Assignment;
     assignment_ds=Patent2_Assignment_ds;
     assignment_convey=Patent3_Assignment_Conveyance;
     assignment_convey_ds=Patent3_Assignment_Conveyance_ds;
     assignor=Patent4_Assignor;
     assignor_ds=Patent4_Assignor_ds;
     doc_id=Patent5_DocumentID;
     doc_id_ds=Patent5_DocumentID_ds;
     doc_id_admin=Patent6_DocumentID_Admin;
```

```
     doc_id_admin_ds=Patent6_DocumentID_Admin_ds;

     clear Patent1_Assignee Patent1_Assignee_ds Patent2_Assignment
Patent2_Assignment_ds
     clear Patent3_Assignment_Conveyance Patent3_Assignment_Conveyance_ds
     clear Patent4_Assignor Patent4_Assignor_ds Patent5_DocumentID
Patent5_DocumentID_ds
     clear Patent6_DocumentID_Admin Patent6_DocumentID_Admin_ds


%=====Builds Overall Stats Table Summary and Extracts Key Dates per Patent
%for each Company==========================================================


filename_registry{15}="C:\Users\JimTi\Dropbox (MIT)\09 - Models\Matlab\Patents\006
Date Tables\Matlab Variables\Patent_Info_Extracted.mat";

if isfile(filename_registry{15})==0

          disp('No Extracted Variable Mat File Available - Will Create a New One')
          savequestion=input('Would you like to save this information as a Mat file
and CSV? (Y/N): ','s');

          tablepath="C:\Users\JimTi\Dropbox (MIT)\09 - Models\Matlab\Patents\006 Date
Tables\zz_";


          num_refs=string(unique(RFIDs.COMPANYNAME)); %Company-specific RFID keys to
search other tables for each company
          [rows,~]=size(num_refs);

          Patent_Company_Overview=zeros(rows,8);

          Patent_Company_Overview=num_refs(:,1);

          Patent_Activity_Log=cell(rows,3); %Intializes matrix with zeros


          for i=1:rows %i respresents the company name on List of Companies studied.
Change number "rows" to grap specific companies

              %filter=RFIDs(RFIDs.COMPANYNAME==Patent_Company_Overview(i,1),1);


              c=contains(RFIDs.COMPANYNAME,string(Patent_Company_Overview(i,1)));

              filter=RFIDs(c,1);
              clear c

              [rows2,~]=size(filter);

    %++++++++++++++++++++++++++Start of Patents, Titles, and Dates+++++++++


            %Populates Patent Activity matrix which is used for later time series
analysis

            Patent_Activity_Log{i,1}=Patent_Company_Overview(i,1); %Adds company name

            %Searches for total rfid record pages and average pages per RFID for each
company.
            %Assignment table is already unique RFIDs (1:1, not 1:M), no need to run
extra unique search.


assign_L=gather(assignment(ismember(assignment.rf_id,filter.rf_id),[1,10,13]));

            [num_rfids,~]=size(assign_L);
```

```
            total_pages=sum(assign_L.page_count,'omitnan');
            avg_pg_per_rfid_record=total_pages/num_rfids;

            Patent_Company_Overview(i,2)=total_pages; %Total pages per company
            clear total_pages;

            Patent_Company_Overview(i,3)=avg_pg_per_rfid_record; %Average Page per
RFID record
            clear avg_pg_per_rfid_record

            %Retrieves number of hits for the word merger from Assignment table.


total_merger_hits=sum(contains(assign_L.convey_text,'merger','IgnoreCase',true));
            avg_merge_hits_per_rfid_record=total_merger_hits/num_rfids;

            Patent_Company_Overview(i,4)=total_merger_hits; %Key word "Merger" hits
per company
            clear total_merger_hits;

            Patent_Company_Overview(i,5)=avg_merge_hits_per_rfid_record; %Average
"Merger" keyword hits per RFID record
            clear avg_merge_hits_per_rfid_record;

            clear assign_L




            %Populates application data per company

            L=doc_id(ismember(doc_id.rf_id,filter.rf_id),[1:2,4:5,10:11]);

            L2=assignor(ismember(assignor.rf_id,filter.rf_id),:);

            [list,list2]=gather(L,L2);
            clear L L2

            list3=outerjoin(list,list2);
            clear list list2
            appended_list=list3(:,[5:6,3:4,2,8:9]);
            clear list3


                temptable=sortrows(appended_list,'grant_doc_num');


                %Processes Applications into a table and flattens

                temptable_apps=temptable(temptable.grant_doc_num=="",:);

                temptable_apps=sortrows(temptable_apps,'appno_doc_num');

                temptable_apps_filtered=unique(temptable_apps.appno_doc_num);

                [num_apps_filtered,~]=size(temptable_apps_filtered);

                for g=1:num_apps_filtered


c=contains(temptable_apps.appno_doc_num,string(table2array(temptable_apps_filtered(g,1
))),'IgnoreCase',true);
                    temptable_apps_filtered2=temptable_apps(c,:);
                    clear c


temptable_apps_filtered2=sortrows(temptable_apps_filtered2,'exec_dt');
                    [num_total,~]=size(temptable_apps_filtered2);
```

```
                    [num_unique,~]=size(unique(temptable_apps_filtered2.or_name));

                    num_prev_app_owners=num_unique;

                    temptable_apps_selected=temptable_apps_filtered2(num_total,:);

                    temptable_apps_selected.num_prev_app_owners=num_prev_app_owners;

                     Patent_Activity_Log{i,2}(g,:)=temptable_apps_selected;


                end

                clear num_total num_unique



                 %Processes Patents into a table and flattens

                loc=cellfun('isempty',temptable.grant_doc_num);
                todelete=loc;
                temptable_patents_filtered=temptable;
                temptable_patents_filtered(todelete,:)=[];


temptable_patents_unique=unique(temptable_patents_filtered.grant_doc_num);

                [num_patents_filtered,~]=size(temptable_patents_unique);


                for h=1:num_patents_filtered


c=contains(temptable_patents_filtered.grant_doc_num,string(table2array(temptable_paten
ts_unique(h,1))),'IgnoreCase',true);

                    temptable_patents_filtered2=temptable_patents_filtered(c,:);
                    clear c


temptable_patents_filtered2=sortrows(temptable_patents_filtered2,'exec_dt');

                    [num_total,~]=size(temptable_patents_filtered2);
                    [num_unique,~]=size(unique( temptable_patents_filtered2.or_name));

                    num_prev_grant_owners=num_unique;


temptable_patents_selected=temptable_patents_filtered2(num_total,:);


temptable_patents_selected.num_prev_grant_owners=num_prev_grant_owners;


                    Patent_Activity_Log{i,3}(h,:)=temptable_patents_selected;


                end

                            if savequestion=='n'


                             elseif savequestion=='N'
```

```
                                elseif savequestion=='y'
                                        [temptable_app_size,~]=size(temptable_apps);
                                        if temptable_app_size==0
                                            message=string(Patent_Activity_Log{i,1})+"
has no applications";
                                            disp(message)
                                            clear message
                                        else

tablename_app=string(tablepath)+"app_"+string(Patent_Activity_Log{i,1})+".csv";

writetable(Patent_Activity_Log{i,2},tablename_app,'Delimiter',',','QuoteStrings',true)
                                            %Patent_Activity_Log{i,2}=[];
                                        end


[temptable_pat_size,~]=size(temptable_patents_filtered);
                                        if temptable_pat_size==0
                                            message=string(Patent_Activity_Log{i,1})+"
has no patents";
                                            disp(message)
                                            clear message
                                        else

tablename_pat=string(tablepath)+"pat_"+string(Patent_Activity_Log{i,1})+".csv";

writetable(Patent_Activity_Log{i,3},tablename_pat,'Delimiter',',','QuoteStrings',true)
                                            %Patent_Activity_Log{i,3}=[];
                                        end


                                elseif savequestion=='Y'

                                        [temptable_app_size,~]=size(temptable_apps);
                                                if temptable_app_size==0

message=string(Patent_Activity_Log{i,1})+" has no applications";
                                                    disp(message)
                                                    clear message
                                                else

tablename_app=string(tablepath)+"app_"+string(Patent_Activity_Log{i,1})+".csv";

writetable(Patent_Activity_Log{i,2},tablename_app,'Delimiter',',','QuoteStrings',true)
                                                    %Patent_Activity_Log{i,2}=[];
```

```
                                                end

[temptable_pat_size,~]=size(temptable_patents_filtered);
                                                if temptable_pat_size==0

message=string(Patent_Activity_Log{i,1})+" has no patents";
                                                    disp(message)
                                                    clear message
                                                else

tablename_pat=string(tablepath)+"pat_"+string(Patent_Activity_Log{i,1})+".csv";

writetable(Patent_Activity_Log{i,3},tablename_pat,'Delimiter',',','QuoteStrings',true)
                                                    %Patent_Activity_Log{i,3}=[];
                                                end

                                else
                                    disp('')
                                    disp('CSV Save Error')
                                    disp('')
                                end

                    message="Analysis of "+string(Patent_Activity_Log{i,1})+" is
complete";
                    disp("")
                    disp(message)
                    disp("")
                    clear message

          end
                clear num_total num_unique


            clear temptable list list2 filter j appended_list
            clear g num_unique temptable_apps_filtered2 num_prev_app_owners
temptable_apps_selected temptable_apps temptable_apps_filtered
temptable_patents_unique
            clear h temptable_patents_filtered2 num_prev_grant_owners
temptable_patents_selected todelete loc num_patents_filtered temptable_patents_unique




          if savequestion=='y'
              save(filename_registry{15},'-v7.3')
          elseif savequestion=='Y'
              save(filename_registry{15},'-v7.3')
```

```
        elseif savequestion=='n'

        elseif saveqeustion=='N'

        else

            disp('')
            disp('Mat file save error')
            disp('')

        end

        clear savequestion

else

    disp('')
    disp('Extraction Variable File available and will be used')
    disp('')

end


f_name="C:\Users\JimTi\Dropbox (MIT)\09 - Models\Matlab\Patents\006 Date Tables\Matlab
Variables\Patent_Info_Extracted.mat";

load(f_name)





    retry=input('Would you like to repeat data analysis? (Y/N): ','s');

end

clear retry tablename_app tablename_pat tablepath savequestion
```