AN INVESTIGATION OF THE IDEA GENERATION AND PROTECTION PROCESS IN ACADEMIA

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The Bayh-Dole Act of 1980 enabled U.S. universities to patent inventions developed through federally funded research programs. This provided an opportunity for academia to develop technologies from the research conducted by faculty. Over 25 years have passed and 39,671 patents have been granted to academic inventors. Unfortunately, this accounts for less than two percent of the total patents awarded in the U.S. during this time. To address this concern, the research presented here investigates the academic technology development process to determine factors that are critical to shaping ideas towards creating patentable technologies. While past research has been corporate-focused and conducted from the managerial perspective; this research examined the process from the inventor perspective and from the technology transfer office through two investigations that utilized a common framework.

Study One, focused in the area of Radio Frequency Identification, explored the process from idea generation to protection of 11 successful patent inventors. The inventors created concept maps describing their development process. Five investigations were conducted on the maps: three quantitative and two qualitative. The participating corporate inventors *focused* more on financial issues and in regards to "challenges" found strategic issues to be more problematic and societal aspects to be more time-consuming and problematic than did the academic inventors. Part II of Study One involved an inventor questionnaire based on the information

gathered in Part I. Unfortunately, the response rate was ineffectively poor resulting in inconclusive data. Study Two identified the critical duties being performed by technology transfer offices (TTOs). One qualitative and two quantitative analyses were conducted on the data collected from a TTO licensing manager survey. Analyses from this study provided insight on elements that influence TTO success factors.

From these two studies, a model for academic technology development was created. If new and existing TTOs can facilitate academic inventors with respect to the elements identified in this model, the possibility exists to further stimulate the quality and quantity of the number of patents arising from academia.

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PREFACE

This dissertation is the outcome of a personal aspiration to gain a greater understanding for how inventor's develop technologies from a completely abstract idea to a tangible product that can be held in ones hand. In addition, the desire to be of assistance in converting university research into technologies and products that can be used for the betterment of society made me strive to the end. It was only possible through the continued guidance and support of my advisor, Dr. Mary Besterfield-Sacre. She kept me focused and constantly moving forward and without her I would have never reached my goal.

Without the participation of the inventors in the concept mapping approach, the inventor survey and the technology licensing managers, I would never have been able to gather the data that was needed to perform the studies that were conducted. Thank you to all of you. Unfortunately, I am unable to mention you individually (due to my promise to keep the discussions and your input confidential), but you know who you are. I am indebted to Frank Kremm and Jim Segneff, Department of Industrial Engineering - Computer and Networking Services, for their help in the development and implementation of the online surveys that were used to gather the data for my research.

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1.0 INTRODUCTION

The Bayh-Dole Act of 1980 enabled U.S. universities to own and patent ideas and inventions developed through federally funded research programs. This has provided an opportunity for academia to develop patentable technologies from the research conducted by faculty and students. Over a quarter of a century after the establishment of the Act, a total of 39,671 (through 2003) technologies[1] have been patented by inventors from academia. Unfortunately, the proportion this number represents remains less than two percent of the total patents awarded in the United States. Further, only 37% of the U.S. academic institutions[2] have established technology transfer offices[1] (TTOs). This may be because the academic technology transfer process remains a gray area in terms of how to best expedite the conversion of research results into patents or licensing agreements that then can be transferred into commercial products. Wright, Birley, and Mosey[3] in a study of entrepreneurship, recognized the need to investigate academic entrepreneurs further and examine how they shape their ideas towards meeting a market. They noted that while "some universities have adopted approaches whereby TTOs work very closely with departments and academics to proactively identify opportunities that may have significant market applications, we need to know more about these processes of opportunity realization." Herein lies the motivation for this research.

[1] This is based on the top three levels of the Carnegie Classification (Doctoral Extensive, Doctoral Intensive and Master's I).

In investigating the academic inventor and the TTO processes, one might look first at the corporate equivalent. The corporate analogy to academic research and technology transfer is corporate technology development. According to Meredith[4], emerging technologies now are being developed quicker, more efficiently, and at less cost overseas than in the U.S. One consequence is that many U.S. companies are outsourcing both manufacturing and research and development jobs[5]. While this has allowed a number of companies to reduce labor costs, it has resulted in domestic corporate cutbacks and high unemployment levels in certain technology and engineering related fields[6]. Coupled to this shift is the fact that although the U.S. still leads in the number of patentable technologies granted by the United States Patent and Trademark Office, many countries (e.g., Japan, China, South Korea, and India) have made substantial gains with recent yearly percent increases much larger than the U.S.[7]

It is this researcher's contention that the academic process cannot be treated in the same manner as the corporate equivalent as the drivers[8] and barriers[9&10] of academic research and development are likely to be different than for the corporate environment. However, understanding and capitalizing on what one can learn from the corporate process can potentially inform the academic technology development process, which in turn, may increase overall success for academic institutions. Further it is important to understand those activities that TTOs actually perform in comparison to those conducted by academic inventors and conversely in comparison to corporate inventors. *The overarching goal of this research is to determine the areas where university technology transfer offices can potentially aid the academic inventor in furthering his / her invention disclosure to the point where it is a licensable, patentable technology.* Specifically, this research will attempt to address the following questions:

- **Research Question 1 –** Academic versus Corporate Inventors - How do the technology development processes differ between academic and corporate inventors in terms of the particular process elements that the two groups utilize and their focus on particular categories (technological, strategic, financial, etc.)? Further, are the challenges encountered in the processes similar for both groups?
- **Research Question 2 –** Technology Transfer Office Critical Duties - What critical elements do university technology transfer offices engage in to aid academic inventors in furthering their invention disclosures?; and how do these elements coincide (or do not coincide) with the inventors' processes. Further, in terms of these elements, is there a relationship between the elements and institution's Carnegie Classification and the tenure of a particular TTO; and are successful patenting and licensing institutions focusing their efforts differently than the less successful institutions?

The identification of elements that corporate inventors are performing (and perhaps designating as critical to a technology's development) coupled with the elements that successful TTOs are identifying as critical to getting a technology ready for patenting and licensing may provide guidance and enable academic institutions to disclose and possibly license and patent a greater number of technologies. Certainly there exist a multitude of underlying reasons for the differences in the two processes including: the inventor's motivation for developing the particular technology, the organization's entrepreneurial climate and philosophy on innovation, and the organization's invention "reward" policies. This research will partially investigate these issues secondary to the two primary research questions. In addition, issues on an inventor's decision on whether or not to disclose an idea (academic) and the time to disclosure and patent filing will also be addressed.

Past research has primarily focused on corporate technology development and has been primarily conducted from the managerial perspective[11]. This research examines both the academic and corporate processes from the *inventor* perspective, areas that are under-researched. In addition to comparing academic and corporate processes, an expansion of the academic process to include the duties being performed by their university's TTO provides an accompanying comparison. To date, little research is available on the specific duties that TTOs perform and those considered critical to furthering an invention disclosure towards a patentable and licensable technology. It is speculated that areas where the academic inventors are "minimal" in their development process correspond to targeted activities of the TTO (i.e. filling the critical "gaps"). To address the overarching research goal, a specific framework will be used to address each research question. This framework or conceptual model is based on literature (and further enhanced during the pilot testing stage). Hence, the elements that were used in addressing research question one (i.e. academic & corporate inventors) were also used in addressing research question two (i.e. TTO managers).

Why is this research important? Again, Meredith[12] says that emerging technologies are now being developed quicker, more efficiently, and at less cost overseas than in the United States. At least one major U.S. company – Motorola - plans to move all of its research to China[13]. If research and development follows manufacturing to off-shore locations, what will be left in the U.S.? That is, while off-shoring has allowed a number of companies to reduce labor costs,[14] such outsourcing potentially impedes the innovative strength of the U.S.

If differences exist between academic and corporate processes (as Scott[15] indicates) and there are particular activities that corporate inventors use that are void of both academic and TTO activities, then these particular activities may require investigation to determine if such activities could capitalize on opportunities to increase the number of invention disclosures, and potentially the number of patents and licensing agreements from academia. This result would be consistent with Jensen's and Thursby's[16] claim that the most important goal for TTOs is maximizing revenue with "close seconds" being the number of licenses executed and inventions commercialized.

In this research, a general framework was established to address the questions posed for analyzing the technology development process. Models describing the new product development process have been well documented in text books[17, 18, 19, 20, & 21]. These models were used to develop the conceptual model for technology development available later in Table 1. The conceptual model was expanded through four pilot tests of the methodology with non-related academic inventors and the concept mapping approach by Study One participants (to be discussed). The expanded model is available in Table 2 later in this dissertation.

Other approaches to studying the technology development process have been utilized. Ravasi and Turati[22] recently used a case study approach looking at two cases (one successful and one unsuccessful) by the same corporate entrepreneur to investigate the constraints that affect the learning process of entrepreneurs engaged in developmental efforts. Cooper and Kleinschmidt[23] analyzed a successful and an unsuccessful new product case in terms of 13 activities. While these methods took a higher level approach at distinguishing between successful and unsuccessful cases, the research presented here is interested in identifying the specific process that successful inventors employ. To accomplish this, it is necessary to identify the number and types of elements utilized in their technology development, and how this use is likely to differ between academia and the corporate world since barriers (or challenges) and drivers to creating innovative technologies may be different in their respective setting. Calantone and di Benedetto[24] devised an integrative model highlighting the relationships between the determinants of new product success. They say that "among the key variables directly affecting the success rate are the *specific* marketing, technical and launch activities." This research will begin to identify these specific activities.

To gather data about the academic and corporate technology development processes, a series of structured interviews with academic and corporate inventors was conducted. For these interviews, the inventors reflected upon and explained their "idea generation to patent (and beyond)" experiences by developing a concept map[25] describing the particular process used to develop the patentable technology. The concept maps were developed using the comprehensive set of elements obtained from the literature review and pilot tests. The use of concept maps (or process maps) allowed each inventor to show both the relationships among and the relative importance of the various elements in the process followed.

From the initial interviews in Part I of Study One, an online questionnaire (one for academic inventors and one for corporate inventors) was developed and administered to patent-obtaining inventors from both industry and academia. The online questionnaire consisted of three sections: Inventor characteristics, Corporation/University characteristics, and Process characteristics. The inventor section gathered information including: the individual's motivation behind the technology's development, a self rating of innovative abilities, whether they were an inventor on any other patents and their primary funding sources for their research. The corporate/university section gathered information regarding the internal environment (rewards, ownership, etc.) for innovation. The process characteristics section asked inventors to provide similar information on the elements used to create the technology. Unfortunately, the response rate for this follow up study was extremely poor; and hence, findings from this portion of Study One are inconclusive.

Following Study One, a second study was conducted to identify the duties being performed by technology transfer offices and their licensing managers. This study utilized the same framework of elements as in Study One. Analyses from this second study provide insight on variables that potentially influence TTO success. The findings of these studies were then compiled together to provide recommendations and suggestions for particular activities that can be facilitated and encouraged by TTOs that may eventually lead to an increased number and quality of invention disclosures. An academic technology development model was created that can be used by both academic inventors and TTOs. The elements presented can become the main focus of either new TTOs or those in their infancy. In addition, existing TTOs whom are not performing the elements identified would benefit by refocusing their efforts to the areas presented in this model. The increased quality of the invention disclosures should, in turn, increase the number of patentable technologies and licensing agreements originating from academic institutions. It is from these two studies that a model for the academic technology development was created.

1.1 PROBLEM FRAMEWORK AND EXPECTATIONS

The technology development process can be broken down into two main phases: idea generation[26] and idea protection[27] as schematically depicted in Figure 1 for both academic and corporate processes. Generally, idea generation begins with an initial motivation and idea. The greater part of the idea generation incorporates the development of an initial concept to a physical technology. Idea generation typically "ends" with the disclosure of the invention to the appropriate new technology committee (Office of Technology Management (OTM) / TTO). Idea generation may continue as the TTO performs additional activities on the technology prior to when a licensing / patenting decision is made. Idea protection involves the portion of the process where decisions about invention disclosure are made (i.e. should a patent application be filed or should other alternatives be pursued?). For this research, the "path" idea generation aspect of pursued successful patents was investigated (both academic and corporate inventors), as delineated below. Further, the critical elements involved in the TTO's general responsibilities and idea protection were tracked.

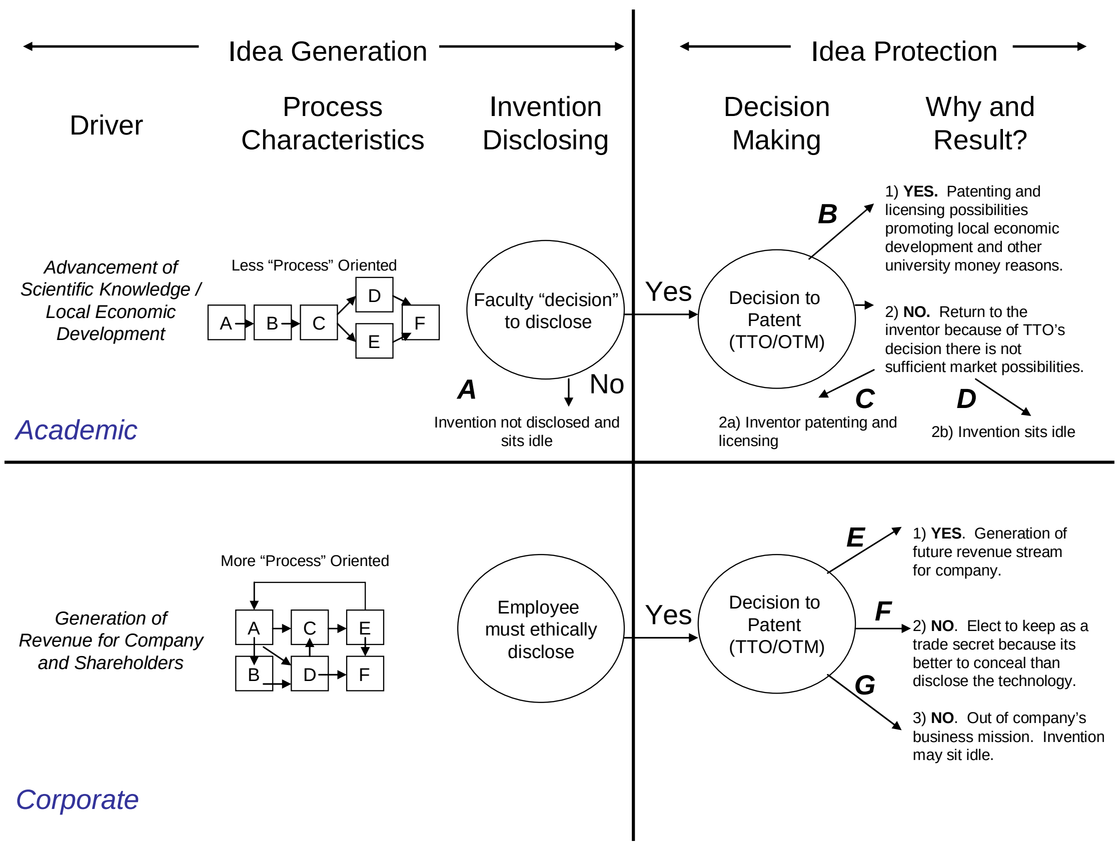

Figure 1. General Idea Generation and Protection Process Structure

1.1.1 Academic Idea Generation and Protection

It is the faculty member's decision to submit an invention disclosure. Upon disclosure, the TTO locates a potential "… partner for commercialization. Typically, if the TTO is unable to find an established firm willing to acquire a license for this new technology, then it shelves the invention. That is, the TTO returns it to the inventor, who may then seek venture capitalists or angel investors to help fund a start-up firm in order to attempt to commercialize the invention. The TTO may return it to the inventor immediately, without even trying to find an established firm to license it. In this event the TTO may assist the inventor in searching for an investor to fund a start-up, but typically TTOs focus their efforts on licensing inventions to established firms[28]". This decision is normally based on a desired level of market possibilities, potential regional economical development and other monetary reasons[29].

1.1.2 Corporate Idea Generation and Protection

In a corporate setting, it is the inventor's responsibility to his / her company to disclose inventions discovered during work hours and while using company resources. Upon disclosure of an invention to the company's OTM / TTO, the staff investigates market potential, determines if the technology would be valuable as a trade secret, and if the proposed technology complements the company's vision, mission, and objectives[30]. The resulting technology is patented, held as a trade secret, or discontinued.

1.2 SCOPE AND EXPECTATIONS OF THIS RESEARCH STUDY

To remove unintended variance in the research, this investigation has focused on technology development in the area of Radio Frequency Identification (RFID). RFID is an evolving technology with the underlying premise of unique identification via the transfer of information through electromagnetic waves in the radio frequency spectrum[31]. It is envisioned that RFID technology will eventually replace bar codes[32]; such that if the cost of manufacturing individual tags can be sufficiently reduced, all consumer items may be marked with a unique identification tag, thus improving supply chain management issues.

In selecting successful and innovative inventors, patented technologies were investigated. A patent[33] is "any new and useful process, machine, article of manufacture, or composition of matter, or any new and useful improvement thereof." It is well noted that using patents as a measure for innovation is controversial[34, 35, 36 & 37]. However, granted patents readily provide a means to identify corporations, academic institutions, and specific people who have been active in the process of invention and technology transfer in the area of RFID through the United States Patent and Trademark Office (www.uspto.gov).

For this research, it was anticipated that the academic inventors would utilize fewer overall elements (or activities). Further, it was expected that academic inventors would focus on technological issues and possibly societal aspects while the corporate inventors would center on strategic, financial and competitor aspects. These hypotheses stem from potential perceived differences in the motivation that the inventors had towards technology development. Further, it was hypothesized that the corporate inventors would exhibit a more structured, complete technology development process than the academic maps. This theory stems from a belief that the corporate inventors' are likely following a more formalized development process[38].

1.3 DOCUMENT ORGANIZATION

This dissertation is organized in the following way. First a literature review is provided in Section 2.0. The literature review spans two areas including: research related to university technology transfer and studies related to corporate product / technology development. This background literature has been used to develop a conceptual model for product / technology development process that is presented and explained in Section 3.0. The methodology section (Section 4.0) presents the inventor subject pool and the methodology for Studies One and Two. Section 5.0 presents and analyzes the results of the inventor concept mapping and the online questionnaire. An analysis of the critical duties performed by the staff at TTOs is presented in Section 6.0. A discussion of the findings from Studies One and Two along with the resulting model and contributions of the research is available in Section 7.0. Finally, Section 8.0 presents the future work uncovered during the current research.

2.0 LITERATURE REVIEW

The literature review for this research is focused in two areas: research on the various factors of the university technology transfer process, and research about the corporate product / technology development process (i.e. how it is managed, how development time is reduced, and how the process is modeled).

2.1 TECHNOLOGY LICENSING / TRANSFER

Since the Bayh-Dole Act, there has been a growing interest in the transfer of technology from research-based academia to the commercial sector. At the present, there are over 200 universities in the U.S. that have technology transfer offices[39]. The primary goal of these offices is focused on "... increasing the transfer of university technologies to the commercial sector, and increasing technology-licensing revenue for the university[40]." For example, the Office of Technology Management (OTM) at the University of Pittsburgh receives nearly 140 invention disclosures per year which have resulted in the patenting of over 50 technologies[41], the creation of several companies and licensing agreements, and has yielded significant revenue to the university.

A primary area of research is the impact of university policy and cultural barriers on academic technology development, transfer, and licensing. Lee and Gaertner[42] investigated the conversion of academic research to new technologies and whether a research university can actually break through its own cultural barriers and efficiently produce commercially viable, cutting-edge technology. They developed a model for technological innovation available below in Figure 2.

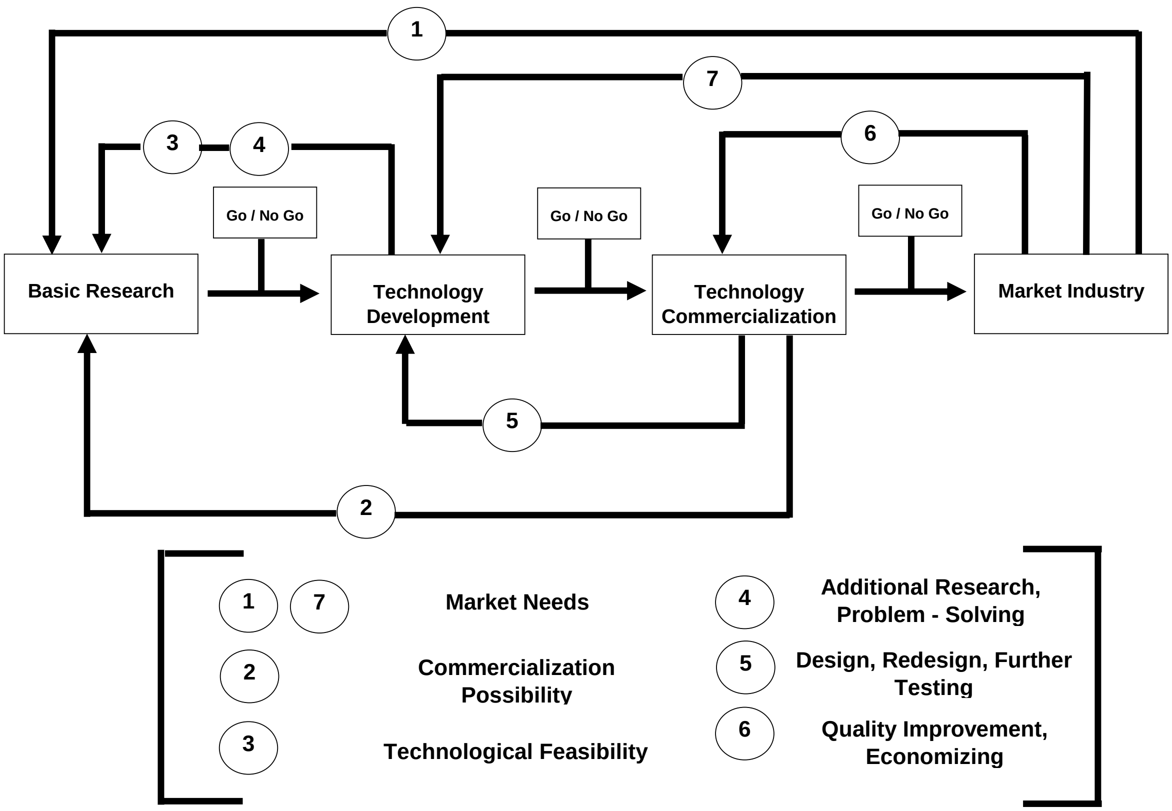

Figure 2. Technological Innovation Model from Lee and Gaertner

They presented the experience of Iowa State University and found that there were positive signs of reducing cultural barriers and there was also a sign of a shift in the academic culture, where a growing number of administrators and faculty are becoming increasingly concerned with economic development. Matkin[43] used a case study approach on the University of California (UC) to investigate colliding public policy agendas for the university: "1) that it maintains its traditional independence, carrying out its roles of teaching and research untainted by the lures and demands of the marketplace, and 2) that it become more active in economic development activities, including the development and sale of its intellectual property and the establishment of companies to exploit university research." He found that UC, along with many other universities had difficulty establishing a nonprofit foundation to manage its portfolio of intellectual property. He identified lessons learned including: avoidance of real or apparent conflicts of interest between inventors and commercial relationships, articulation of a clear and timely public policy agenda, to provide a forum and process for internal debate, avoidance of the appearance of unfair advantage, choosing appropriate partners, seeking external support, establishing appropriate oversight and integrating technology transfer activities on a broad scale. Lowe[44] developed a model to investigate the role and impact of inventor tacit knowledge (knowledge that requires repeated or prolonged interaction between two people to exchange[45]) and university TTO cooperation on the later-stage development and post-licensing involvement of university technology to start-ups. He found that inventions associated with high levels of tacit knowledge will be developed via inventor-founded start-up firms; and inventors who perceive their effort as very costly will license their invention initially rather than pursue a start-up.

A second area of research involves the faculties' decision on invention disclosure and the universities' decision on patenting and licensing. Jensen, Thursby, and Thursby[46] examine the relationship between the three major university actors in technology transfer: the faculty, the TTO, and the central administration. They produced a theory for predicting faculty disclosure of inventions, and if so, at what stage. Interestingly, they found that the proportion of inventions disclosed at different stages varies with faculty quality and that quality is inversely related to the share of license income allotted to faculty. Owen-Smith and Powell[47] dispute that faculty decisions to disclose are shaped by their perceptions of the benefits of patent protection and their perceived costs of interacting with TTOs and licensing professionals. They find that decisions are mostly influenced by whether the institutional environment is supportive or oppositional to the simultaneous pursuit of academic and commercial endeavors.

Another focus of research has been to determine the effect of incentives for professors who develop patentable ideas. Thursby[48] et al. surveyed 62 research universities considering various factors (i.e. ownership, income splits, licensing policies, personal goals, the role of the inventor in licensing, etc.). They then analyzed the relationship between licensing outcomes, the objectives of the TTOs, and the characteristics of the technologies. Markman[49] et al. looked at similar factors, but from the eyes of the TTO. Surprisingly they found that incentives to scientists and to their departments are negatively related to entrepreneurial activity. Friedman and Silberman[50] found that an entrepreneurial climate, high quality faculty, a focused mission, and continued involvement of the inventor had significantly positive relationships on licensing agreements. Lach and Schankerman[51] investigated factors from a public versus private university basis. Intuitively, the incentive effect is much larger at private universities than for public universities.

A fourth area of research about university technology transfer involves the relationship between academic R&D dollars and number of patents developed and licensing agreements secured. Specifically, Coupe[52] investigated the relationship between university R&D expenditures and total patent output. He found a positive correlation between the money spent on academic research and university patents. Powers[53] studied the funding sources in higher education and found that (1) institutions with high amounts of federally funded research outperformed those with lower amounts, (2) institutional funding sources led to licensing with small companies, (3) state funding led to involvement with large companies, and (4) corporate funding was found to be insignificant in terms of licensing partner.

Following the passing of the Bayh-Dole Act, patenting activities from universities has increased. Prior to 1980, only 3,048 total utility patents were assigned to U.S. colleges and universities. Since that time there has been a remarkable 39,671 obtained (through 2003)[54]. The effect of the Bayh-Dole Act on academic patenting[55 & 56] has concluded that patent figures are up significantly since the passing of the Act, but it remains unclear if this increase is attributed to factors such as increased university incentives to professors who disclose potentially commercial ideas or an overall increased exposure of TTOs and the academic patenting process. Verspagen[57] investigated the effects of the Act on universities and the knowledge they develop. He points out the potential negative effects of university patenting including: the impact on the "culture of open science," the potential blockade that patents may form on further research, and the potential for universities to be researching only in those areas where patents are easily obtained. Sampat, Mowery, and Ziedonis[58] re-analyze a previous study in which the quality of academic patents declined dramatically after the passing of the Bay-Dole Act. In a larger study, they found that inter-temporal distributions of citations changed, not necessarily the total number of citations the patents ending up receiving.

Finally, little research has been performed on the technology transfer *process* itself, which is a focus of this research. Ndonzuau[59] et al. looked at a conceptual model for creating academic spin offs; however this model was not tested. In reviewing TTO websites, this researcher has observed that the process differs greatly between institutions; and the methods by which invention disclosures are obtained also differs. Offices use either a reactive approach (i.e. wait for invention disclosures to be submitted by faculty), a proactive approach (i.e. hold information sessions; promote the technology transfer office and its benefits to faculty, etc.) or some hybrid thereof.

2.2 NEW PRODUCT DEVELOPMENT (NPD) AND TECHNOLOGY DEVELOPMENT (TD)

The corporate equivalent of academic research and technology transfer is new product / technology development. For the purposes of this research, the new product / technology development literature available is categorized into three primary areas: managing the process of new product development, evaluating the factors of the organization that influence development time, and modeling of the process. Each area is briefly described.

Several researchers have investigated how best to manage the process of NPD / TD by identifying success and failure factors in a company's approach. Lewis'[60] case study of two companies, one with a successful product and one with a failure, found that depending on whether a time or financial outcome measure is used, a product could be labeled successful when it actually may be a failure. Correspondingly, Balachandra and Friar[61] studied why companies successful in one market often fail when they attempt to penetrate a new market or technology. Wakasugi and Koyata[62] investigated the effects of R&D investment and firm size on the number of patent applications and product developments. They found that although large firms concentrated on innovation more aggressively than smaller firms, higher R&D expenditures did not reveal economies of scale for patent applications, and product developments did not increase with firm size; however, patent applications did. Radnor and Robinson[63] identified internal blocks and external factors impinging upon the innovation process. They found that the greatest level of innovation was obtained via the use of cross-functional teams. They also found that top management support and involvement, rewards for innovative behaviors and ideas, and a positive attitude for cultivating ideas were keys to innovation. Oltra and Flor[64] found that a systematic approach to research and development leads to greater levels of innovation. Knight[65] investigated management's role in innovation and found that the first step in creating innovation within a firm is to create an environment where everyone is an "intrapreneur." Knight also identified a list of management obstacles to innovation to include inadequate support, unrealistic expectations, and poor planning. Bonner, Ruekert, and Walker[66] investigated the negative relationship between control mechanisms available to upper-management and NPD project performance; though, they did find that early upper-management involvement in the setting of goals and procedures for monitoring and evaluating the project were positively associated with project performance. Wind and Mahajan[67] reexamined the product development process and suggest 13 strategic guidelines that could improve a firm's chances of developing and introducing successful new products.

The second area of focus in NPD / TD has been on how to best reduce cycle time. Droge[68] et al. states that "the ability to reduce cycle time in new product development and commercialization is increasingly viewed as a key to innovation success and profitability." In this study they found that synergistic integration and supplier closeness were both significantly related to the ability to minimize development and introduction time. Mabert[69] et al. performed a case study across six sectors of NPD projects that aided in the determination of four structural elements in examining development times: motivation, workings of teams, external vendor's cooperation with the teams and project control. They found that knowledgeable leadership coupled with organizational commitment led to reduced times. They also concluded that focusing on the initial phases of development can reduce the overall time by thirty percent. Finally, using regression analysis, Kessler and Chakrabarti[70] looked at the effect of variables involving corporate strategic orientation and organizational capability on development time of 75 new products. They found that clear time-goals, longer tenure among team members, and parallel development significantly reduced development time; however design for manufacturability, frequent product testing, and computer-aided design systems increased development time. Further, factors that increased the radical innovation process actually slowed the incremental innovation process.

The third target research area of NPD / TD has investigated how to best model the system. McGuiness[71] has modeled the first phase of the process or idea generation as a four step search phase. The four steps within search are: problem definition, detection, credibility seeking, and intensive search. He found that in larger organizations that search occurred in a top down manner that focused on problems or opportunities that were visible to upper management. Other research that has been done is primarily from an organizational level and examines the factors involved in development. Cooper and Kleinschmidt[72] analyze a successful and an unsuccessful new product case in terms of 13 activities. They found that the surveyed companies used a variety of practices and were particularly weak in areas such as market studies, initial idea screening, and preliminary market assessments. Zirger and Maidique[73] empirically tested a model of NPD that incorporated organizational sub-units, development activities and communication channels as well as external factors such as characteristics of the product and the competitive environment. They found the following to affect product outcome: 1) the quality of the R&D organization, 2) the technical performance of the product, 3) the product's value to the customer, 4) the synergy of the new product with the firm's existing competences, and 5) management support during the product development and introduction processes. Cunha and Gomes[74] modeled the NPD process five different ways: sequential, compression, flexible, integrative, and improvisational. The authors indicated that NPD practices are evolving from a structured to a structured chaos approach. McCarthy[75] et al. extended the view of NPD from being very linear to that of being a complex adaptive system with three levels of decision making – in-stage, review, and strategic. Similarly, March-Chorda[76] et al. produced a conceptual model with three main areas: top management support, analysis of market requirements/demands, and product development planning and process. They visited and interviewed managers from 65 firms across 11 sectors. Based on their questioning, they developed a 12 variable model. From the model, they found two obstacles to innovation: (1) excessive cost of maintaining the project; and (2) the uncertainty of market acceptance. A different perspective was taken by Spivey[77] et al. who indicated that independent of the focus (organization, division, team or individual) the NPD process can be viewed as a set of two factors: management factors and resource factors. Each of these factors incorporates several interrelated sets of concerns. Management factors lead to concerns about leadership and the management system and resource factors lead to concerns about information, infrastructure, time and money. Smith and Morrow[78] performed an extensive evaluation of the models of product development. The models were then grouped into five categories depending on the intended goal: sequencing and scheduling, decomposition, stochastic lead time, design review timing and parallelism models. Veryzer[79] studied eight discontinuous product development projects and developed a descriptive model for the process. He found the developments to be more exploratory and less customer-driven than the typical incremental process and found these processes to focus on formulating a product application for the emerging technologies.

Although NPD / TD has been researched and modeled, it has been primarily at the organizational level. This researcher contends that there is a gap in the literature relative to the processes that specific inventors use to develop new technologies/products. Studies to date have modeled and evaluated aspects of NPD / TD through the perspective of Chief Executive and Chief Technological Officers via questionnaires. Few have focused on evaluating the process from the inventors' (or team of inventors') perspective and the relevant connections to the organizational processes that take the product to full fruition. Knight[80] conducted a comparison of corporate and independent entrepreneurs. The independent entrepreneurs rated marketing problems high on their priority list. Iwamura and Jog[81] identified factors distinguishing innovators from non-innovators in the securities industry. The most significant difference they found was the management of the idea generation process, including concept generation and the support of management. The inventors' perspective is critical if NPD / TD models are to be effective in the academic setting where faculty researchers have perhaps more autonomy than inventors/employees in corporations. As an example, in a study using the Delphi method, Scott[82] studied 24 technology management issues. He found that academic and industry participants differed significantly in their perspectives of technology management.

The research being presented here is looking explicitly at the differences between academic and corporate inventors in terms of the actual elements that each group of inventors is utilizing in developing patentable technologies (as opposed to the process from a managerial perspective). In addition, there is a gap in the literature with respect to the particular activities that TTOs effectively use to aid academic inventors. Both studies were conducted using a common framework of elements found in large part, from the literature surrounding product development and added to by the participating academic and corporate inventors. The research clearly identifies a model for academic technology development. This model can be used by both new and existing TTOs as well as academic inventors. The completion of the elements present in the model was found to have significant implications towards licensing and patenting success factors.

3.0 CONCEPTUAL MODEL OF THE TECHNOLOGY DEVELOPMENT PROCESS

A company's financial well-being typically depends on the success of its product line. The majority of revenue for most technology-based companies comes from products that are less than five years old[83]. As a result, there has been substantial research concerning the development and commercialization of technologies and services (e.g., Rouse[84], Rouse[85], and Sage[86]) resulting in a number of technology development models, specifically (Urban[87], Kahn[88], Kmetovicz[89], Armstrong[90] and Molina, Sanchez and Kusiak[91]). For this particular research, these various resources have been combined into a single five stage general model of the technology development process: opportunity identification, design and development, testing and preproduction, introduction and production and life cycle management. Because the references used to create the model primarily stem from the study of a corporate perspective, it is expected that the corporate technology development proceeds, to some extent, through all five stages. The process of the academic based technology development, however, has not been examined in the same manner. Each stage of the model is briefly explained.

Stage 1 begins with the conception of the idea. At this stage a target market is selected along with similar products to benchmark. A scope is defined, resources are allocated, and personnel selected to carry out the development. Technical feasibility, risk assessment and financial evaluations are conducted. If one or more of these studies proves to be unviable, then the process is terminated until a solution is found.

Stage 2 involves the design and physical development of the product. A critical activity is an assessment of customers' needs and specifications. Engineering and ergonomic evaluations are performed along with functional analyses. A marketing plan is drafted and sales are forecasted to determine production levels and supply chain logistics. The design is also inspected for regulatory compliance. Finally, the detailed design is confirmed and a prototype(s) is developed.

Functional capability and design for manufacturability is ensured during the third stage. Product testing is completed to guarantee reliability and operability under the intended environment and anticipated users. Certifications and compliances are obtained; and alpha and beta tests can be conducted. Once user-compliant issues are completed, advertising and test marketing begin. Finally, customer support is established along with the initiation of quality and process reviews.

The fourth stage in the process involves launching the product with full production whereby the production is taken from pilot plant level to full-scale. At this point, effective collection and management of data for production and sales is critical for customer feedback to possibly begin redesign or product line expansion.

The final stage involves managing the life cycle of the product. Market response to the product and competitor reaction to the new product is monitored. During this time, product warranty issues are established. Determination of how costs can be reduced; and the use of statistical quality control and total quality management methods are introduced to minimize bad product. The final step in the entire process is the decision of divestment of the product line.

An additional ongoing stage was added to the conceptual model as there are several elements that should not be limited to a single stage, but rather could occur throughout the development process.

From the literature sources an exhaustive list of 99 process elements was identified that span each of the five main stages (plus the ongoing stage) of technology development. They are presented in Table 1 below.

Table 1. Conceptual Technology Development Model from Literature

Stage 1 - Opportunity Identification	Stage 2 - Design and Development	Stage 3 - Testing and Preproduction	Stage 4 - Introduction and Production
Create Product Description	Produce 2 and 3-Drawings	Develop a Product Manufacturing Plan	One, Three and Five Year Product Plans
Choose Product Design From Multiple Alternatives	Finalization of Technical and Physical Requirements	Operator/Training/Assembly/Maint. Documentation	Creation of Operational Data Management System
Conjoint Analysis of Customer Needs	Quality Function Deployment	Testing Data Analysis, Evaluation and Reporting	Actual Versus Planned Cost Evaluation
Competitor Benchmarking	Customer Needs Analysis	Pilot/Prototype Review	Production Line Design and Setup
Define the Market and Its Growth Potential	Design For Assembly	Reliability Testing, Test to Failure, Limit Testing	Full Scale Operational Testing and Evaluation
Target Customer Determination	Design For Automation	Final Design Approval	Final Financial Reviews (Ratio, Overhead, etc.)
Construct a House of Quality	Design For Manufacturability	Alpha/In-house Testing	Pilot Scale Operational Testing and Evaluation
Multifunctional Team Development	Determination of Product Positioning / Segmentation	Product Packaging and Protection	Documentation of Lessons Learned in Development
Create a Schedule for the Product	Product Functional Analysis	Pretest/Pre-Launch Forecasting	
Define the Product Scope / Statement of Work	Ergonomic Evaluation	Gamma Testing / Actual User Testing	
Create a Product Financial Plan	Product Advertising Plan	Product Bill of Materials	**Stage 5 - Life Cycle Management**
Develop a Work Breakdown Structure	Product Marketing, 3 C's, 4 P's	Proposed Design within Target Costs	Life Cycle Cost Analysis
Develop a Human Resources Plan	Situational Analysis	Product Use / Knowledge Dissemination	Reaction to Customer Response
Define Product's Performance Requirements	Optimization of Conceptual Design	Prototype Testing	Product Warranty
Evaluate Potential Time to Market Requirements	Product Component Tradeoffs and Optimization	Limited Rollout, Test Marketing	Evaluation of Competitor Reactions
Cost Estimate Projections	Regulatory Certification / Compliance	Product Meets Actual User Needs	Part/Product Cost Reduction
Determination of Product Cost	Modeling and Simulation to Study Design	Design Manuals Written	Product Quality Reviews, TQM, SQC
Determination of Product Retail Price	Optimization of Detailed Design	Customer Service and Logistical Support	Determination of Product Phase-out / Divestment
Product Feature Determination	Prototype Development	Production Pilot Review	Concurrent Engineering Principles
Technical Risk Assessment	Create a Part Sourcing / Partnership Plan	Quality and Process Reviews	
Determination of Investment Req. / Potential Returns	Design For Environment (Is Product Recyclable, Reusable, Reducible, Disposable?)	Beta Testing – Product Works in Customer Operations	**Ongoing Stage**
Product Risk Assessment	Sales Forecasting		Design Modifications
Financial Risk Assessment	Supply Chain Management		Design Reviews
Evaluate Product's Mesh With Corporate Vision, Mission, and Objectives	Sought Guidance From Outside Sources (Experts)		Technical Problems Arising During Development
			Corporate Infrastructure Changes
Incorporate Available Technologies to Improve Functionality, Safety, Etc.			Schedule / Cost / Technical Performance Summaries
Product Need Determination Based on Development Lead Time			Forces of Nature Effect
			Customer Feedback Evaluation
Strength, Weakness, Opportunity, Threat (SWOT) Analysis			Determination of Changing Customer Needs / Market Requirements
Resource Requirements			Continuous Competitor Monitoring
Staffing Levels and Turnover Considerations			

This generic model is normative in nature and does not describe what actually occurs in companies. For example, startup companies may not have the opportunity to invest sizably in research and development; hence may not fully address all aspects of new technology development. With economic changes and globalization of manufacturing and design, large companies also may not follow the model explicitly having placed specific importance on certain catalysts in the model or adding additional considerations. In the case of academic inventions, it may be possible that only certain stages are carried out in the technology transfer process. Further and critical to this research, because the model was developed from a corporate perspective it may not be reflective of the academic setting in terms of which elements serve as drivers or barriers that potentially enable or impede the development of ideas to patents.

Because this research is interested in how both inventors in academic institutions and corporate environments traverse the technology development process, the 99 elements were divided into six categories: technological, strategic and financial issues; and societal, human and competitor aspects. These six sub-categories are similar to ones proposed by Mohanty[92] for the classification of the issues involved in implementing a new manufacturing technology. In classifying these elements, a corporate engineer with design expertise assisted the process. Through four pilot tests of the methodology with non-related academic inventors, seven elements were added to the literature based list. Further, during the first inventor interview 12 additional elements were added, more specific to intellectual property. Interviews with the other ten inventors resulted in identifying an additional 15 elements. These additions (highlighted in Table 2 with asterisks) brought the total technology development model to 133 elements. The exhaustive listing of all 133 elements in their respective stage and category is available in Table 2 below. Definitions for each of the 133 elements are available in Appendix A.

Table 2. Exhaustive Technology Development Model by Stage

Stage 1 - Opportunity Identification	Stage 2 - Design and Development	Stage 3 - Testing and Preproduction	Stage 4 - Introduction and Production
Technological Issues (8)	***Technological Issues (14)***	***Technological Issues (18)***	***Technological Issues (4)***
Create Product Description	Produce 2 and 3-Drawings	Develop a Product Manufacturing Plan	* - Consideration of Product Service Opportunities
* - Preliminary Research	Design For Manufacturability	* - Product Test Method Definition	Pilot Scale Operational Testing and Evaluation
* - Generate Multiple Product Alternatives	Design For Assembly	Prototype Testing	Production Line Design and Setup
Choose Product Design From Multiple Alternatives	Design For Automation	Testing Data Analysis, Evaluation and Reporting	Full Scale Operational Testing and Evaluation
Incorporate Available Technologies to Improve Functionality, Safety, Etc.	Finalization of Technical and Physical Requirements for Design	Beta Testing – Product Works in Customer Operations	***Strategic Issues (2)***
Define Product's Performance Requirements	* - Evaluate / Select CAD Tools	Pilot/Prototype Review	One, Three and Five Year Product Plans
Evaluate Potential Time to Market Requirements	Product Functional Analysis	Reliability Testing, Test to Failure, Limit Testing	Documentation of Lessons Learned in Development
Technical Risk Assessment	Optimization of Conceptual Design	Final Design Approval	***Financial Issues (2)***
Strategic Issues (8)	Product Component Tradeoffs and Optimization	Alpha/In-house Testing	Actual Versus Planned Cost Evaluation
Define the Market and Its Growth Potential	* - Reverse Engineering Protection	Product Packaging and Protection	Final Financial Reviews (Ratio, Overhead, etc.)
Construct a House of Quality	Modeling and Simulation to Study Design	* - Refine Tests and Models	***Human Aspects (1)***
Create a Schedule for the Product	Optimization of Detailed Design	Gamma Testing / Actual User Testing	Creation of Operational Data Management System
Define the Product Scope / Statement of Work	Prototype Development	Product Bill of Materials	
* - Intellectual Property Awareness	* - Software Development	Operator/Training/Assembly/Maint. Documentation	
Cost Estimate Projections	***Strategic Issues (9)***	Design Manuals Written	**Stage 5 - Life Cycle Management**
Product Risk Assessment	Product Advertising Plan	* - Patent Prosecution	***Technological Issues (3)***
Product's Mesh With Vision, Mission, and Objectives	Product Marketing, 3 C's, 4 P's	* - Site Surveys / Installation Considerations	Part/Product Cost Reduction
Financial Issues (6)	* - Licensing In Considerations	Production Pilot Review	Product Quality Reviews, TQM, SQC
Create a Product Financial Plan	* - Licensing Out Considerations	***Strategic Issues (5)***	Concurrent Engineering Principles
Determination of Product Cost	Situational Analysis	* - Identify Potential Future Innovations	***Strategic Issues (1)***
Determination of Product Retail Price	* - Identify Primary Innovation	* - Develop Peripheral Innovation(s)	Determination of Product Phase-out / Divestment
Determination of Investment Req. / Potential Returns	* - Patent Filing Initiated	Pretest/Pre-Launch Forecasting	***Financial Issues (1)***
* - Funding Considerations	Create a Part Sourcing / Partnership Plan	Limited Rollout, Test Marketing	Life Cycle Cost Analysis
Financial Risk Assessment	Supply Chain Management	Quality and Process Reviews	***Societal Aspects (2)***
Societal Aspects (6)	***Financial Issues (1)***	***Financial Issues (2)***	Reaction to Customer Response
Conjoint Analysis of Customer Needs	Sales Forecasting	* - Estimate / Predict Customer ROI	Product Warranty
Target Customer Determination	***Societal Aspects (10)***	Proposed Design within Target Costs	***Competitor Aspects (1)***
Product Need Based on Development Lead Time	Customer Needs Analysis	***Societal Aspects (5)***	Evaluation of Competitor Reactions
Product Feature Determination	Quality Function Deployment	* - Evaluation of Insurance Risks due to Product Errors	
Strength, Weakness, Opportunity, Threat Analysis	Determination of Product Positioning / Segmentation	Product Use / Knowledge Dissemination	**Ongoing Stage**
* - Stakeholder Analysis	Ergonomic Evaluation	Product Meets Actual User Needs	***Technological Issues (4)***
Human Aspects (9)	* - Evaluate Prior Art (Similar Patents)	* - Train / Transfer Technology, Actual User Training	Design Modifications
* - Create Communication Plan Among Team Members	* - Identify Litigation Issues and How to Avoid Them	Customer Service and Logistical Support Development	Design Reviews
Develop a Human Resources Plan	Sought Guidance From Outside Sources (Experts)	***Competitor Aspects (1)***	Technical Problems Arising During Development
* - Create Communication Plan For Briefing Management	Design For Environment (Is Product Recyclable, Reusable, Reducible, Disposable?)	* - Anticipate Competitor Responses	* - Documentation of Design Work in Technical Memorandums
* - Team Brainstorming	* - Product Design to Meet Government Mandate		***Strategic Issues (2)***
Multifunctional Team Development	Regulatory Certification / Compliance		* - Corporate Strategy Change
Resource Requirements			Schedule / Cost / Technical Performance Summaries
Staffing Levels and Turnover Considerations			***Societal Aspects (4)***
Develop a Work Breakdown Structure			Customer Feedback Evaluation
* - Individual Brainstorming			Forces of Nature Effect
Competitor Aspects (1)			* - Interaction With Support Groups
Competitor Benchmarking			
			Determination of Changing Customer Needs / Market Requirements
			Human Aspects (2)
			Corporate Infrastructure Changes
	* - Indicates items added to conceptual model		* - Re-scope Development Team
			Competitor Aspects (1)
			Continuous Competitor Monitoring

4.0 DESCRIPTION OF METHODOLOGY

As mentioned, the research initiated with a study of the processes by which inventors (academic and corporate) move from idea generation to patentable technologies (Study One). Upon investigating their similarities and differences, TTOs were surveyed to determine what activities are critical (Study Two). This was followed by a comparison of the TTO activities to those of the academic and corporate activities. Specifically, to approach this research, an interview protocol was employed that combined process mapping with knowledge representation to enhance and specify a conceptual model for technology development obtained from the literature (as illustrated in the previous section) in Part I of Study One. In Part II of Study One, further comparisons of the two groups were conducted based on the feedback of an online questionnaire pertaining to the inventor's characteristics, the inventor's organizations' characteristics and characteristics of the process used by the inventors. Based on the outcomes of Study One, a second study was conducted. This study investigated the specific duties that TTOs are performing and which elements they feel are the most critical to furthering an invention disclosure towards a licensable or patentable technology. An online survey was developed and distributed to the office managers of technology licensing / transfer offices within academic institutions in the United States and Canada. Following a description of the inventor subject pool, the methodology of each study is described.

4.1 INVENTOR SUBJECT POOL

For Study One of this research, two databases of inventors were reduced from the larger publicly available United States Patent and Trademark Office database (www.uspto.gov). The first database consisted of inventors working as individuals or in corporate settings. Abstracts of all U.S. granted patents were searched for the keyword "Radio Frequency Identification." The abstracts were then reviewed to ensure that the product is/was using RFID as a major component of the product and not merely appearing in the abstract as an aside. 477 patents met this criterion. Of these patents, there were 418 unique inventors[2] that stemmed from 101 companies and 18 individuals. Table 3 provides a demographic overview of corporate based RFID technology patents. This information was used to ensure that a representative sample was obtained during the data gathering process.

Table 3. Demographic Breakdown of Corporate-based Patents

Geographic Region	**Northeast** 19	**West Coast** 28	**Central U.S.** 23	**Southern U.S** 15.	**Foreign** 16
Number of Employees	**< 500 employees** 7	**500-1000 employees** 7	**1000-5000 employees** 3	**> 5000 employees** 28	**Unknown** 56
Total Sales	**Less than $100 Million** 3	**$100M - $1B** 12	**$1B - $10B** 20	**Greater than $10 Billion** 11	**Unknown** 55

The second database consists of inventors from the academic setting. Unfortunately due to the relative newness of many RFID technologies and the lag between the time a patent is filed for and granted (and then available on the USPTO's website), there was only one academic-based patent involving an RFID technology. This may be attributed to the large difference in the

[2] Note: After further development, some patents were re-filed; hence the same individual could have appeared on multiple patents. In addition, one patent may have multiple inventors.

number of total patents in the corporate sector versus the academic environment. The 477 corporate-based RFID patents consisted of only 0.03% of the total patents granted in the respective time frame. Therefore, of the 29,862 patents awarded during this time period to academic inventors, one would only expect to see a total of eight patents awarded to universities. Given this constraint, 50 patents were selected from eight similar classifications to the corporate RFID patents. These classifications include Electrical Communications, Coded Data Generation or Conversion, Radio Wave Communications, Static and Dynamic Magnetic Information Storage or Retrieval, Multiplex Communications, and Data Processing Artificial Intelligence. A total of 400 patents were found with this expanded search. Of the 400 patents, there are 806 unique individuals (i.e. professors, graduate students) from 112 universities. Table 4 provides a demographic overview of academic based RFID-related technology patents.

Table 4. Demographic Breakdown of University-based Patents

Geographic Region	**Northeast** 19	**West Coast** 11	**Central U.S.** 22	**Southern U.S** 18.	**Foreign** 42
Number of Employees	**< 500 faculty** 7	**500-1000 faculty** 11	**1000-1500 faculty** 15	**> 1500 faculty** 32	**Unknown** 47
Carnegie Classification	**Doctoral - Extensive** 51	**Doctoral – Intensive** 11	**Master's I** 6	**Unknown** 44	

4.2 STUDY ONE – COMPARING ACADEMIC AND CORPORATE TECHNOLOGY DEVELOPMENT PROCESSES

During Part I of Study One, inventors created concept maps of the technology development process from their perspective, as well as commented on their process during their interview. Part II of Study One comprised of the development and administration of a closed-form questionnaire (one academic and one corporate) based on the information gathered in Part I. This questionnaire was tailored to ask specific, but similar questions about many of the elements present in the expanded conceptual models. The questionnaires were then administered to the appropriate inventor databases previously described.

For the one-on-one interviews with successful academic and corporate inventors a hands-on interview approach was utilized. This approach combined both knowledge representation[93] and process or concept mapping[94] which permitted interviewees to discuss their particular process of idea generation to patent in a more structured manner. The use of a questionnaire for this portion of the study was eliminated because of the propensity of the questions to be biased according to the researcher's beliefs. Behavioral observation was also considered, but eliminated because the development process typically lasts anywhere from six months to five years and observing for a short time would allow only a portion of the process to be studied[95]. Plus, the research utilized inventors who have already developed a particular idea to patent.

4.2.1 Concept/Process Maps of the Innovation Process

To accomplish this phase of the research, 11 concept/process maps were collected from inventors; six being academic and five corporate in origin. The concept mapping/interview protocol included a reflection period whereby the inventor could think about the patent of interest. Prior to conducting the mapping exercise the participants were provided with a short tutorial about concept mapping. Participants were then provided with "tiles" labeled with the elements from the conceptual model of the technology development process (and those added from the multiple pilot tests that were conducted). The inventor then had the opportunity to organize the "tiles" according to the process they actually employed from the time of their initial

"A-ha"[3] to the time the patent application was filed (and beyond, when applicable). Additional blank tiles were provided so that elements not available in the conceptual model could be added. The interviewee was not required to use all of the tiles, only the ones they performed as part of their technology's development. The interviewees were also encouraged to create new tiles. This was important as the elements were initially generated from literature that was primarily business focused in terms of the vocabulary used (i.e., academic inventors may use different terminology). From the pilot interviews and the 11 inventors it was confirmed that the terminology provided on the tiles was appropriate and useful for developing process maps. Upon completion of their maps, the interviewees were then asked to describe their map and any relationships between the elements present on their maps. Once the inventors had described their maps, they were asked to identify seven[4] elements for each of the following designations[5]:

- Most critical elements of the process,
- Most time-consuming elements of the process, and
- Most problematic elements of the process.

The researcher then aimed to establish the following through questioning: how the idea came about (i.e. expansion of existing work or new concept); how and when the inventor realized that they had something patentable; when was it decided to file for a patent and why; and the ultimate result (i.e. commercially viable product). The average interview lasted approximately two hours with the longest and most in depth lasting just over four hours.

A representative corporate map is shown in Figure 3 with one section highlighted. Although the actual issues and aspects are not included, this map schematically provides the

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[3] The time when the inventor first realized he/she had an innovative idea.
[4] The number seven was arbitrarily chosen, but felt to be sufficiently large to identify the key elements.
[5] These three designations are not necessarily mutually exclusive as something that is critical could also be time consuming, etc.

overall structure of what a typical inventor process map looked like. All inventor maps are available in Appendix B.

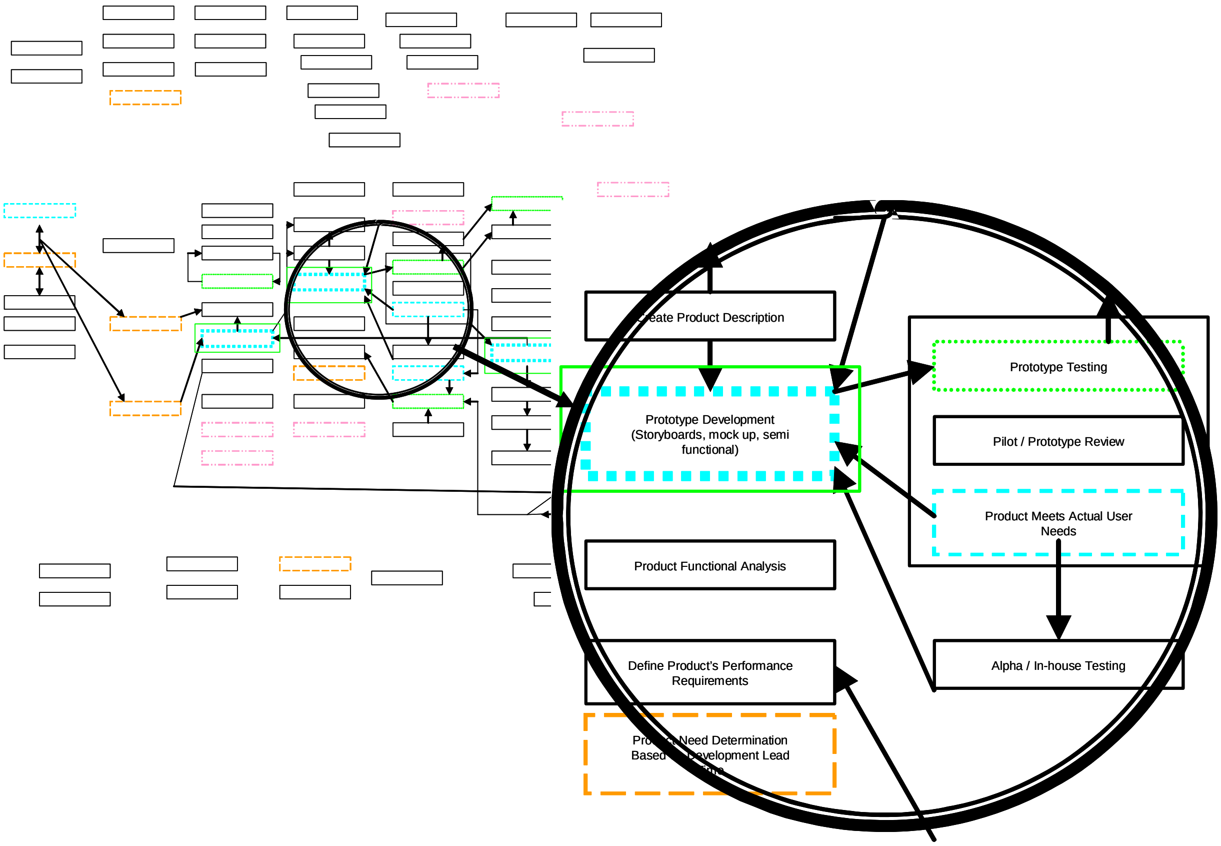

Figure 3. Representative Corporate Inventor Map

Literature on how best to analyze these types of process maps is limited to scoring methods [96 & 97] that quantify the number of nodes, links, and hierarchies in the maps. This research adopted a similar scoring method, but with additional emphasis on the category of the node (i.e., technological, strategic, and financial issues, and societal, human, and competitor aspects). This provided perspective on whether academic inventors focus on different elements of the process than do corporate inventors. The quantitative analysis of the process maps coupled with the answers to the questions asked of the inventors and development/technology transfer managers supported the development of the model(s) and subsequently aided in the construction of the closed-form surveys.

4.2.2 Closed-form Inventor Survey Construction

Upon completion of Part I, two closed-form survey instruments were created – one for academic inventors and one for corporate inventors. Using the two derived databases, these surveys were sent to inventors who had been granted patents that use RFID or similar technologies as a major component to their invention.

The instrument had three primary sections: Inventor characteristics, Corporation/University characteristics, and Process characteristics. The questions and available responses are accessible in Appendix C. The inventor section gathered information about the individual's motivation behind the technology's development and the origination of the idea. The corporate/university section gathered information about the environment for innovation (i.e., how innovation is encouraged and rewarded, ownership of ideas developed, etc.). Finally, the process section gathered information specifically pertaining to particular elements of the development process and to milestones such as first prototype being developed, invention disclosure and patent filing. Similar studies[98] were investigated and additional relevant questions included. The element-based questions included whether or not they used a particular element, how much time was spent on the elements that were utilized and the stage of the process in which the elements were performed. Once inventors had gone through the 77 element-based questions, they were also asked to identify seven[6] elements for each of the following designations[7]:

- Most critical elements of the process, and
- Most problematic elements of the process.

It was initially thought to administer the questionnaire through the internet using the University of Pittsburgh's On-Line Student Survey System (OS^3)[99]. Unfortunately due to limited editing and customizing capabilities, the OS^3 system was found to be inadequate for the researcher's needs. An open source software package was found called phpESP or php Easy Survey Package. This package allowed for multiple questions on a page, advanced logic features, and easier, more reliable web-based administration. The survey was developed with the help of the Department of Industrial Engineering's Computer and Network staff. It was hosted on the department's server and accessible at www.invent.ie.pitt.edu. A screen shot of the home page is available below in Figure 4.

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[6] The number seven was arbitrarily chosen, but at ~10% of the elements provided, was felt to be sufficiently large to identify the key elements.

[7] Since the inventors were indicating how much time they spent on each element, there was no need to ask them about the seven most time-consuming elements as those could be found through analysis of the survey questions.

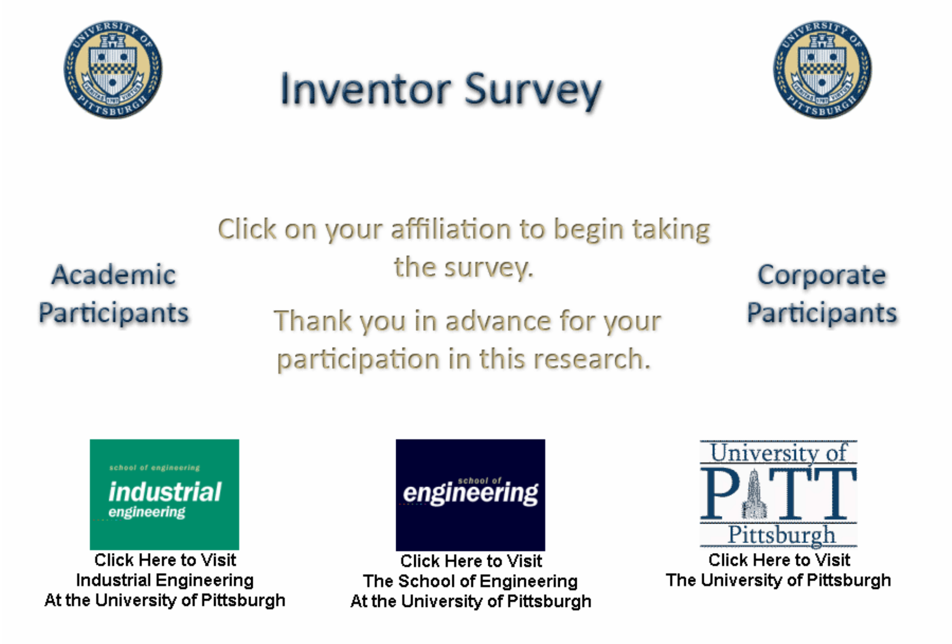

Figure 4. Internet Home page for the Inventor Survey

The home page contained hyperlinks for the corresponding academic and corporate inventor surveys in addition to hyperlinks for the University of Pittsburgh, the School of Engineering, and the Department of Industrial Engineering.

4.2.2.1 Survey Population

The initial academic database of 806 individuals was reduced to 222 inventors. This reduction was due to the inability to obtain accurate contact information. Plausible explanations include faculty members moving to new institutions, and students who graduated with unavailable contact information. Available contact information for the academic inventors typically included email addresses and office phone numbers. The initial corporate database of 418 individuals was reduced to 291 inventors (similar reasons were noted for this reduction). Many of the corporate websites encountered did not allow non-employees to search for people within the company;

therefore the contact information that was found for the corporate inventors included home phone numbers and home mailing addresses. Each of the questionnaires was administered two times (i.e. either an email for academic inventors or a letter for corporate inventors) along with a follow up phone call to each potential interviewee.

4.3 STUDY TWO – TECHNOLOGY TRANSFER INVESTIGATION

Based on the findings of Study One, a second study was identified. This study involved the support provided to academic inventors by their respective TTO. The steps taken by the TTO after disclosure can be critical to whether the technology eventually gets licensed or patented.

A closed-form survey instrument was created for office managers of technology licensing / transfer offices within the United States and Canada. A database of technology licensing managers was gathered from The Association of University Technology Managers' (AUTM)[100] website. Email addresses were collected from each of the university's websites for a total of 199 technology licensing managers. This survey was developed in the same software package as the Inventor Survey, phpESP, with the help of the Department of Industrial Engineering's Computer and Network staff. It was hosted on the department's server. It consisted of two questions:

1. For your Technology Licensing / Transfer Office, please select the seven[8] most critical elements that your office does to aid the academic inventor in furthering their invention disclosures towards becoming a patentable, licensable technology.
2. How many persons are employed by your technology licensing / transfer office?

[8] Seven was selected as it equated to 10% of the total number of elements (70) that were provided to the office managers.

In the TTO survey, 70 elements from the original 133 element model were available to the licensing managers. The 12 human aspects elements were eliminated as they dealt with the internal relationships of the technology development team; and hence not likely performed by a TTO. Other elements eliminated pertained to those strictly performed by the inventor or those that would typically be performed by a licensing company in the production or post-production phases. The 70 survey elements are available in Table 5 below.

Table 5. Process Elements for Technology Licensing Manager Survey

Opportunity Identification	**Design and Development**	**Testing and Preproduction**	**Introduction and Production**
Technological Issues (5)	***Technological Issues (8)***	***Technological Issues (7)***	***Technological Issues (1)***
Create Product Description	Design For Mfg, Assembly, Auto	Prototype Testing	Pilot Scale Operational Testing and Evaluation
Generate Multiple Product Alternatives	Prototype Development	Testing Data Analysis, Evaluation and Reporting	***Strategic Issues (1)***
Define Product's Performance Requirements	Product Functional Analysis	Reliability Testing, Test to Failure, Limit Testing	One, Three and Five Year Product Plans
Evaluate Potential Time to Market Requirements	Optimization of Conceptual Design	Gamma Testing / Actual User Testing	***Financial Issues (2)***
Technical Risk Assessment	Product Component Tradeoffs and Optimization	Design Manuals Written	Actual Versus Planned Cost Evaluation
Strategic Issues (5)	Reverse Engineering Protection	Site Surveys / Installation Considerations	Final Financial Reviews
Define the Market and Its Growth Potential	Optimization of Detailed Design	Beta Testing – Product Works in Cust. Operations	
Create a Schedule for the Product	Finalization of Requirements for Design	***Strategic Issues (3)***	**Life Cycle Management**
Intellectual Property Awareness	***Strategic Issues (4)***	Identify Potential Future Innovations	***Financial Issues (1)***
Cost Estimate Projections	Product Advertising Plan	Develop Peripheral Innovation(s)	Life Cycle Cost Analysis
Product Risk Assessment	Product Marketing, 3 C's, 4 P's	Limited Rollout, Test Marketing	***Societal Aspects (1)***
Financial Issues (5)	Licensing In / Out Considerations	***Financial Issues (2)***	Reaction to Customer Response
Create a Product Financial Plan	Identify Primary Innovation	Estimate / Predict Customer ROI	***Competitor Aspects (1)***
Determination of Product Cost	***Financial Issues (1)***	Proposed Design within Target Costs	Evaluation of Competitor Reactions
Determination of Investment Req. / Potential Profit	Sales Forecasting	***Societal Aspects (4)***	
Funding Considerations	***Societal Aspects (7)***	Evaluation of Insurance Risks due to Errors	**Ongoing**
Financial Risk Assessment	Customer Needs Analysis	Train / Transfer Technology, Actual User Training	***Technological Issues (1)***
Societal Aspects (5)	Determination of Product Positioning	Product Meets Actual User Needs	Design Modifications / Reviews
Target Customer Determination	Evaluate Prior Art (Similar Patents)	Product Use / Knowledge Dissemination	***Strategic Issues (1)***
Product Need Based on Development Time	Identify Litigation Issues and Ways to Avoid	***Competitor Aspects (1)***	Schedule / Cost / Technical Summaries
Product Feature Determination	Sought Guidance From Outside Sources	Anticipate Competitor Responses	***Societal Aspects (2)***
Strength, Weakness, Opportunity, Threat Analysis	Regulatory Certification / Compliance		Customer Feedback Evaluation
Stakeholder Analysis	Design For Environment (Is Product Recyclable, Reusable, Reducible, Disposable?)		Determination of Changing Customer Needs / Market Requirements
Competitor Aspects (1)			***Competitor Aspects (1)***
Competitor Benchmarking			Continuous Competitor Monitoring

The analyses conducted on each of two studies are explained in Sections 5 and 6.

5.0 STUDY ONE – COMPARING ACADEMIC AND CORPORATE INVENTORS

As part of the larger study investigating the idea generation and idea protection processes of academic and corporate inventors, a series of structured interviews with academic and corporate innovators was conducted on their technology development processes. Each inventor developed a concept map describing their particular process followed. In this section, the results of five different investigations of the maps will be presented.

The results of structured interviews were used to develop and implement a closed-form questionnaire. This questionnaire was intended to obtain responses from the population of inventors (both academic and corporate) who had obtained a patent in a related RFID area. From the responses, empirical models of the idea generation and protection process were to be evaluated. Unfortunately, even through proper and determined administration of the questionnaire a very poor response rate was obtained; hence, no empirical models could be established.

In this section, the results of the two investigations in Study One are presented and described. In Part I (Section 5.1), the analyses and results of the inventor in-depth interviews and resulting concept maps are described. In Part II (Section 5.2), a description of the data obtained from the inventor closed-form surveys is presented.

5.1 COMPARISONS USING A CONCEPT MAPPING APPROACH

For this study, a set of 11 structured interviews and their maps were analyzed. Six maps were created by academic inventors at Carnegie Research I institutions and five maps were developed by inventors employed by various sized companies. Both qualitative and quantitative methods were used to analyze the maps. Both quantitative and qualitative results investigating the differences between academic and corporate technology development processes are then presented. Finally, a discussion of the results and possible implications of this part of the research is presented.

5.1.1 Methodology and Response

From the two (previously described) databases, patent holders were invited to participate in the structured interview process. The first 11 acceptances were interviewed. Process maps were obtained from each inventor, five of whom were classified as academic and five as corporate inventors. The remaining one was considered a "hybrid" inventor, since the inventor moved from academia to the corporate world during the technology development process in order to commercialize the technology. Because of that crossover, this individual was left out of some of the inter-group statistical comparisons that follow, but was included in the qualitative analyses. A brief description of each of the inventors and their technologies is available in Table 6 below.

Table 6. Descriptions of the Participating Inventors and Their Inventions

Inventor	Description of Inventor and Their Inventions
Hybrid	H began working on the idea as a faculty member at a Research I institution. The technology was then released by the institution back to the inventor. The inventor and a partner then founded a small company, performed additional work on the technology and it is now a principle technology in the multibillion dollar global positioning industry.
Academic 1	A1 worked on the idea as a faculty member at a Research I institution in partnership with a regional company. When the technology had reached proof of concept stage the inventor was taken off the project and the company then developed it into a principle technology in the multibillion dollar cellular telephone industry.
Academic 2	A2 worked on the idea as the faculty advisor to a student project group at a Research I institution. The technology was integrated as a component for use in the virtual reality industry.
Academic 3	A3 was a graduate student at a Research I institution working under the direction of another successful inventor. The work was part of a Master's degree research project in electrical engineering.
Academic 4	A4 worked on the idea as a faculty member at a Research I institution. The technology that was developed became the building block for a multibillion dollar industry.
Academic 5	A5 worked on the idea as a faculty member at a Research I institution. With the help of a graduate student and a corporate partner, the group evolved a technology in the computer industry.
Corporate 1	C1 worked on the idea as the Chief Technology Officer at a small company. The technology became incorporated into the postal service industry.
Corporate 2	C2 worked on the idea as the Design Engineer at a small company. The technology became incorporated into the postal service industry.
Corporate 3	C3 worked on the idea as a Human Factors Specialist as part of an idea generation group within a large corporation. The technology became a key component in the library filing industry.
Corporate 4	C4 worked on the idea as a Technology Specialist as part of an idea generation group within a large corporation. The technology was integrated in a manufacturing process at the company's facilities.
Corporate 5	C5 worked on the idea as the Vice President of Advanced Research at a large corporation in the fire and security industry. The technology became an integral part in many of their products.

5.1.2 Analyses and Results

To address the various hypotheses expressed, five separate investigations were conducted on the maps. The first three were primarily quantitative in nature, while the last two were more qualitative. Gartner and Birley[101] observe that qualitative analyses have rarely been used in the entrepreneurship field and that many of the important questions can only be answered through qualitative methods and approaches. A description of each investigation follows.

First, a series of categorical comparisons between inventor groups of the entire development process was conducted. Academic and corporate inventors were compared relative to their utilization of the aspects and issues throughout the entire process. Second, the two inventor groups were compared relative to how they designated elements as critical, time-consuming or problematic. Following this comparison, a qualitative analysis of the particular elements that were designated as most critical, time-consuming and problematic provided further insight. Next, categorical comparisons between inventor groups for each process stage as well as ongoing elements were performed. The fourth inquiry involved a qualitative sorting exercise performed by design experts. Here, two design experts conducted a blind qualitative sorting of the 11 inventor maps into a continuum of technology development processes. The final investigation involved investigating those specific elements used by all of the inventors or none of the inventors.

Each of these investigations is explained in depth. The hybrid inventor was not included for those statistical analyses that compared academic and corporate inventors directly, but was included in the qualitative analyses.

5.1.2.1 Categorical Comparisons of the Entire Development Process

To analyze the maps, the number of elements in each category was summed for both academic and corporate innovators and the percentages used from each category were highlighted, as shown in Table 7 below. This is similar to the method used by Mohr[102] in which he focused on element and process analyses. Overall, the academic inventors used between 23% and 60% of the elements with an average percent utilization of 41.2% or 55 elements. The corporate inventors used between 61% and 90% of the elements with an average percent utilization of 73.7% or 98 elements.

Table 7. Inventor Process Map Percent Utilization

	Inventor	Technological Issues (51 total)	Strategic Issues (27)	Financial Issues (12)	Societal Aspects (27)	Human Aspects (12)	Competitor Aspects (4)	Totals (133)
Academic	1	56.9	25.9	0	37	50	50	40.6
	2	80.4	40.7	33.3	51.8	75	25	60.2
	3	52.9	48.1	33.3	29.6	58.3	50	45.9
	4	47.1	44.4	16.7	22.2	33.3	25	36.8
	5	19.6	33.3	16.7	29.6	0	25	22.6
	Average	51.4	38.5	20.0	34.0	43.3	35.0	41.2
	Std. Dev.	21.8	8.9	13.9	11.2	28.5	13.7	13.7
Hybrid		86.3	70.4	91.7	77.8	66.7	100	80.5
Corporate	1	86.3	81.5	83.3	81.5	50	50	79.7
	2	72.5	48.1	66.7	51.9	66.7	25	60.9
	3	64.7	70.4	75	92.6	83.3	75	74.4
	4	64.7	66.7	58.3	55.6	66.7	100	63.9
	5	88.2	85.2	91.7	92.6	91.7	100	89.5
	Average	75.3	70.4	75.0	74.8	71.7	70.0	73.7
	Std. Dev.	11.4	14.6	13.2	19.8	16.2	32.6	11.7

Based on raw counts, an Analysis of Variance (ANOVA) revealed that corporate inventors used significantly more elements ($\alpha = 0.10$) for each category. This is not surprising since overall, the corporate inventors used 43 (on average) more elements than the academic inventors. Next a determination if the *focus*[103] of the elements present on each of the groups' maps differed was determined. (It was initially proposed that the academic maps would focus more on technological and societal elements while the corporate maps would center on strategic, financial and competitor elements.) This was accomplished by using ANOVA to identify differences in the proportion of elements used from each category relative to the total number of elements on the map. The results are shown in Table 8 below.

Table 8. ANOVA Results on Inventor Proportions

	Academic Mean	Academic Variance	Corporate Mean	Corporate Variance	P-value	Significant
Technological Issues	0.46	0.006	0.39	0.002	0.135	
Strategic Issues	0.21	0.005	0.19	0.000	0.729	
Financial Issues	0.04	0.001	0.09	0.000	0.005	*
Societal Aspects	0.18	0.003	0.20	0.001	0.372	
Human Aspects	0.08	0.002	0.09	0.000	0.849	
Competitor Aspects	0.03	0.000	0.03	0.000	0.876	

In analyzing these proportions, the only significant difference found was for financial issues. That is, corporate inventors utilized such financial issues as C*reating a Financial Plan, Determination of the Product Cost and Retail Price* and *Funding Considerations* significantly more than the academic inventors. There existed no significant differences in the proportion of elements used for the other five categories. An initial hypothesis that the academic inventors would focus more on technological issues and possibly societal aspects while the corporate maps would center on strategic, financial and competitive aspects was only weakly supported. (The corporate inventors' focus on financial (strong) and the p-value of 0.135 for technological issues (weak) indicates two supported initial expectations.)

5.1.2.2 Comparisons in Critical, Time-Consuming and Problematic Elements

Upon completion of the maps, inventors were asked to identify the seven *most* critical, time-consuming and problematic elements which they encountered for their particular technology. To determine whether the two groups selected statistically different proportions of the elements as most critical, time-consuming and problematic, a third ANOVA was conducted on the statistical intersection of the probability (or proportion) of elements of each category used in their map and the probability (or proportion) of those elements selected as being either most critical, time-consuming, and / or problematic. The ANOVA results in Table 9 indicate that overall the corporate inventors selected proportionally more societal issues as being time-consuming and problematic and proportionally more strategic issues as being problematic than did the academic inventors.

Table 9. ANOVA Results on the Proportional Intersections of Critical, Time-Consuming and Problematic with the Issues and Aspects

	Issue/Aspect	Academic Mean	Academic Variance	Corporate Mean	Corporate Variance	P-value	Significant $\alpha = 0.10$
Critical and	Technological	0.27	0.024	0.35	0.012	0.335	
	Strategic	0.07	0.005	0.13	0.017	0.330	
	Financial	0.01	0.000	0.05	0.014	0.392	
	Societal	0.06	0.009	0.16	0.008	0.134	
	Human	0.06	0.002	0.04	0.004	0.570	
	Competitor	0.00	0.000	0.00	0.000	1.000	
Time-Consuming and	Technological	0.37	0.042	0.53	0.011	0.160	
	Strategic	0.07	0.006	0.02	0.003	0.314	
	Financial	0.00	0.000	0.03	0.003	0.347	
	Societal	0.02	0.001	0.19	0.020	0.034	*
	Human	0.02	0.002	0.00	0.000	0.347	
	Competitor	0.01	0.000	0.00	0.000	0.347	
Problematic and	Technological	0.36	0.039	0.29	0.029	0.551	
	Strategic	0.02	0.002	0.17	0.025	0.081	*
	Financial	0.01	0.000	0.05	0.004	0.189	
	Societal	0.06	0.003	0.21	0.003	0.002	*
	Human	0.03	0.002	0.00	0.000	0.182	
	Competitor	0.01	0.000	0.06	0.016	0.411	

A further elemental-level investigation into these results revealed that two societal elements - *Customer Needs Analysis* and *Product Meets Actual User Needs* - were the main contributors to significance. Pavia[104] found customer input and needs as critical sources for new products. *Customer Needs Analysis* was identified as a critical element in 60%, time-consuming in 40%, and problematic in 20% of the corporate maps. This matches well with Slater and Mohr[105] who note that a firm's ability to successfully develop and commercialize technological innovations is related to how it comes to understand customer needs. *Product Meets Actual User Needs* was identified as a critical element in 20%, time-consuming in 20% and problematic in

40% of the corporate maps. This finding is also consistent with Slater and Mohr. (Lists of other qualitative findings are discussed in Table 10 later in the paper).

A second significant intersection found was associated with problematic and strategic issues. A deeper investigation into this revealed that two strategic issues - *Defining the Market and Its Growth Potential* and *Creating a Schedule for the Product* - were found to be more problematic for corporate inventors than for academic inventors.

There was little similarity within or across the two groups in terms of the particular elements that the inventors classified as being critical, time-consuming and problematic, as noted in Table 10 below. On the academic maps, there was no consistency in their designation of the critical elements of the process. Three of the academic inventors did agree that the *Documentation of Design Work in Technical Memos* was time-consuming, *Technical Problems Arising During Development* was problematic and *Testing, Data Analysis, Evaluation and Reporting* was both time-consuming and problematic. Three of the corporate inventors agreed that *Customer Needs Analysis* was critical, *Beta-Testing* was time-consuming and *Defining the Market and Its Growth Potential* was problematic. Upon collapsing the two groups, no common critical, time-consuming or problematic elements were found in the maps. In general, this analysis led the researcher to believe that the often troublesome technology development process is unique to each inventor.

Table 10. Elements Classified as Most Critical, Time-Consuming and Problematic

Inventor Group	Finding(s)
Academic *Noted on three of five maps*	• *Critical:* None • *Time consuming*: Documentation of Design Work in Technical Memos, and Testing, Data Analysis, Evaluation and Reporting • *Problematic*: Technical Problems Arising During Development, and Testing, Data Analysis, Evaluation and Reporting
Corporate *Noted on three of five maps*	• *Critical*: Customer Needs Analysis • *Time Consuming*: Beta Testing – Product Works in Customer Operations • *Problematic*: Defining the Market and Its Growth Potential

5.1.2.3 Categorical Comparisons by Development Stage

For the third investigation, a determination if there were differences between the two inventor groups when the process was broken down into the five stages of technology development and the ongoing elements was made. Table 11 provides an overview of the average element count per technology development stage. From Table 11, the raw counts equate to the average percent utilization dropping from 42% to 20% from Stages 1 to 5 for the academic inventors and from 83% to 66% for the corporate inventors.

Table 11. Concept Mapping Approach - Percent Utilization per Technology Development Stage

	Stage 1 (37)	Stage 2 (34)	Stage 3 (31)	Stage 4 (9)	Stage 5 (7)	Ongoing (14)
Academic Inventors	42.1	43.5	41.9	22.2	20	51.4
Corporate Inventors	82.7	66.5	72.9	66.6	65.7	74.3

Similarly to what was done in the first analysis, an ANOVA was utilized to identify differences in the proportion of elements used from each category relative to the total number of elements on the map, but this time it was done by stage. The results are shown in Table 12 below.

Table 12. ANOVA Results on Inventor Proportions by Stage

		Academic Mean	Academic Variance	Corporate Mean	Corporate Variance	P-value	Significant
Stage 1	Technological Issues (8)	0.236	0.003	0.242	0	0.816	
	Strategic Issues (8)	0.222	0.006	0.216	0.001	0.884	
	Financial Issues (6)	0.108	0.006	0.171	0	0.111	
	Societal Aspects (6)	0.165	0.008	0.142	0.001	0.61	
	Human Aspects (9)	0.269	0.028	0.223	0.001	0.61	
Stage 2	Technological Issues (14)	0.53	0.023	0.459	0.008	0.399	
	Strategic Issues (9)	0.238	0.021	0.22	0.002	0.798	
	Financial Issues (1)	0	0	0.025	0.001	0.049	*
	Societal Aspects (10)	0.233	0.002	0.3	0.008	0.194	
Stage 3	Technological Issues (18)	0.687	0.008	0.577	0.003	0.048	*
	Strategic Issues (5)	0.167	0.006	0.175	0.002	0.849	
	Financial Issues (2)	0.052	0.006	0.054	0.001	0.969	
	Societal Aspects (5)	0.076	0.005	0.178	0.001	0.019	*
	Competitor Aspects (1)	0.017	0.001	0.016	0.001	0.982	
Stage 4	Technological Issues (4)	0.333	0.074	0.476	0.014	0.321	
	Strategic Issues (2)	0.5	0.185	0.235	0.005	0.211	
	Financial Issues (2)	0	0	0.23	0.002	0.001	*
	Human Aspects (1)	0.167	0.037	0.058	0.007	0.287	
Stage 5	Technological Issues (2)	0.625	0.063	0.263	0.024	0.023	*
	Strategic Issues (1)	0	0	0.073	0.01	0.196	
	Financial Issues (1)	0	0	0.113	0.011	0.069	*
	Societal Aspects (2)	0.375	0.063	0.36	0.015	0.909	
	Competitor Aspects (1)	0	0	0.19	0.015	0.019	*
Ongoing	Technological Issues (5)	0.47	0.022	0.379	0.007	0.266	
	Strategic Issues (2)	0.194	0.005	0.136	0.001	0.149	
	Societal Aspects (4)	0.227	0.002	0.331	0.003	0.193	
	Human Aspects (2)	0.025	0.003	0.083	0.007	0.228	
	Competitor Aspects (1)	0.083	0.006	0.071	0.002	0.756	

In analyzing these proportions by stage, it should have been expected that financial issues would come out significant in most of the stages; since based on overall focus; it was found to be the only significantly differing category. This held true for Stages 2, 4, and 5. In investigating the stages were it was not significant; Stage 1's alpha value was 0.111 which is close to being significant, there were only two financial issues in Stage 3 so little variation could be expected and there are no financial issues in the ongoing stage. In Stages 3 and 5, the academic inventors used a significantly larger proportion of technological issues than did the corporate inventors. This focus would likely stem from the academics' desire to test, analyze and document the technology in a manner much more proficiently than a corporate inventor. In addition, the academics used a larger, but insignificant proportion in Stages 2 and ongoing than did the corporate inventors. This partially supports the initial speculation; that the academics would focus more on technological issues than the corporate inventors. In Stage 3, the corporate inventors used a significantly greater proportion of societal aspects. This focus would likely arise from the corporate inventors wanting to meet the customer needs and educate and train them about the new technology. The final significant difference was in Stage 5, competitor aspects. There is only one element present in this category, *Evaluation of Competitor Reactions*, and not a single academic used it; while it was present on four of the five corporate maps.

5.1.2.4 Qualitative Sorting Analysis Performed by Design Experts

After three different types of quantitative analyses were conducted on the inventor maps, two comparisons using qualitative methods were performed. Utilizing two engineering design experts, a sorting exercise was conducted on the 11 inventor maps. Recognizing that all the inventions resulted in a patent, it cannot necessarily be designated that a particular technology development process is incorrect; however, a sense of whether or not certain maps had more of a "process" orientation associated than did others (i.e., more of a process flow and overall organization) and whether or not this "process" orientation was related to the maps being academic or corporate based was necessary to establish. It was initially hypothesized that corporate maps may follow a more structured technology development process than academic maps. The two design theorists rank-ordered the maps, as shown in Table 13, and provided comments to their ratings. The design experts were then asked to further expand their rank-order along three dimensions – completeness, correctness, and organization (see Besterfield-Sacre[106] et al. for full definitions) via a rubric. A rubric rating of "3" was a high score; and a rating of “1” a poor rating. From Table 13, it can be seen that three of the five corporate maps were ranked the highest and three of the academic maps received the lowest scores on the three dimensions.

Table 13. Inventor Map Scores on Completeness, Correctness, and Organization

Rank Order	Inventor Map	Completeness	Correctness	Organization	Design Expert Selection
High	Corporate 5	3	3	3	Corporate
	Corporate 4	3	3	2	Corporate
	Corporate 3	3	3	2	Corporate
	Academic 2	2	3	2	Academic
	Academic 1	2	2	2	Academic
	Hybrid	1	2	2	Academic
	Corporate 2	2	2	1	Corporate
	Corporate 1	2	2	1	*Academic*
	Academic 3	1.5	2	1	*Corporate*
	Academic 5	1	1	1	Academic
Low	Academic 4	1	1	1	Academic

Finally, the experts were asked to identify for each map whether its origin was academic or corporate based. As shown in Table 13, the experts correctly designated nine of the 11 maps. At first, they had correctly identified all 11 maps, but upon further reflection, they relabeled Corporate 1’s map as academic and Academic 3’s map as corporate. When asked how they determined the origination, the experts settled on three primary factors. First, the overall organization of the map, particularly those elements that appeared early in the process often determined the inventor’s origin. For example, one map indicated *One, Three, and Five Year Product Plans* and it appeared early in the process. Not surprisingly, the design experts identified this map as being corporate. Their second rationale was based on the level of integration present between various elements. Specifically, maps with feedback loops and links between technological and strategic issues were often identified as being corporate in nature. Also, the maps that had a strong core structure with several surrounding areas were identified as being constructed by a corporate inventor. Lastly, the location in the process where *Patent Filing Initiated* or *Patent Prosecution* was mentioned differentiated academic and corporate maps. Maps that indicated patent filing near the beginning of the process were identified as academic inventors, while those that had substantial workings before the first mention of patenting were typically identified as corporate.

5.1.2.5 Common Elements used in the Technology Development Process

In this final investigation, those elements that were commonly used on the maps as well as those not used were identified. Table 14 provides those elements that were common to all the academic inventors (shown in orange); those common to all the corporate inventors (shown in blue); and those common to all 11 inventors (shown in green). Overall, the technology development model shown in Table 14 is heavily focused on the technological issues with some strategic and financial issues present. The first stage is primarily composed of strategic issues and human aspects with some societal and financial concerns. The second and third stages are heavily comprised of technological issues. Finally, technological and strategic issues and societal aspects make up the fourth, fifth and ongoing stages of the model.

Only five elements (highlighted in Table 14 in green) were present on all 11 maps collected. They included:

- *Define the Product Scope / Statement of Work* (Strategic)
- *Define the Product's Performance Requirements* (Technological)
- *Optimization of Detailed Design* (Technological)
- *Testing, Data Analysis, Evaluation and Reporting* (Technological) and
- *Schedule / Cost / Technical Performance Summaries* (Strategic)

Table 14. Elements Appearing in All Maps

Opportunity Identification	Design & Development	Testing & Preproduction	Introduction & Production	Life Cycle Management	Ongoing
Preliminary Research (T) Individual Brainstorming (H) Team Brainstorming (H) Multifunctional Team Development (H) Create Schedule For The Product (St) Define the Market and Its Growth Potential (St) Customer Needs Analysis (So) Target Customer Determination (So) Product Need Determination Based on Development Lead Time (So) Define the Product Scope / Statement of Work (St) Resource Requirements (H) Define Product's Performance Requirements (T) Product Feature Determination (So) Incorporate Available Technologies to Improve Functionality, Safety, Etc. (T) Funding Considerations (F) Determination of Product Cost (F) Evaluate Product's Mesh with Corporate Vision, Mission, and Objectives (St)	Produce 2-D & 3-D Drawings (T) Create Product Description (T) Product Functional Analysis (T) Evaluate Prior Art (Similar Patents) (So) Optimization of Detailed Design (T) Modeling and Simulation to Study Design (T) Patent Filing Initiated (St) Prototype Development (T) Regulatory Certification / Compliance (So)	Prototype Testing (T) Testing, Data Analysis, Evaluation, and Reporting (T) Alpha / In-house Testing (T) Beta Testing – Product Works in Customer Operations (T) Pilot / Prototype Review (T) Product Meets Actual User Needs (So) Product Use / Knowledge Dissemination (So) Quality and Process Reviews (St)	Actual Versus Planned Cost Evaluation (F)	Reaction to Customer Response (So)	Design Reviews (T) Design Modifications (T) Documentation of Design Work in Technical Memos (T) Determination of Changing Customer Needs / Market Requirements (So) Technical Problems Arising During Development (T) Schedule / Cost / Technical Performance Summaries (St) Concurrent Engineering Principles (T) Orange – Elements chosen by all 5 academic inventors Blue- Elements chosen by all 5 corporate inventors Green – Elements chosen by all 11 inventors **Legend** **T – Technological** **St – Strategic** **F – Financial** **So – Societal** **H – Human** **C – Competitor**

Clearly evident is the number of elements common across the corporate inventors. It can be observed that there is much more similarity among the corporate maps as opposed to the academic maps. For academic inventors there were only nine common elements (those highlighted in green or orange); and for corporate inventors there are 39 common elements (those elements highlighted in green or blue). Roughly 30% of the elements used on the corporate maps were common. This is in contrast to only seven percent common on the academic maps. This suggests that the corporate inventors are following a more formal method or model of technology development within their organizations, whereas the academic inventors clearly exhibit less consistency.

Viewing this from the opposite perspective, Table 15 provides those elements not appearing on any of the maps. As shown, between the five corporate inventors every element provided was used on at least one corporate map; whereas on the academic maps there were 26 elements that did not appear on any of the maps. Given their particular perspective, it is beneficial to understand why certain elements did not appear on the academic maps. Interestingly, four of these elements were found on all five corporate maps: *Define the Market and it Growth Potential* (Opportunity Identification) one corporate map even identified this as critical; *Product Use / Knowledge Dissemination* (Testing and Pre-Production); *Actual versus Planned Cost Evaluation* (Introduction and Production); and *Determination of Changing Customer Needs/Market Requirements* (Ongoing).

Table 15. Elements Not Appearing in Any Inventor Maps

Opportunity Identification	Design & Development	Testing & Preproduction	Introduction & Production	Life Cycle Management	Ongoing
Define the Market and Its Growth Potential (St) Construct a House of Quality (St) Create a Product Financial Plan (F) Develop a Human Resources Plan (H) Product Risk Assessment (St)	Reverse Engineering Protection (T) Create a Part Sourcing / Partnership Plan (St) Product Advertising Plan (St) Product Marketing 3 C's, 4 P's (St) Supply Chain Management (St) Sales Forecasting (F) Determination of Product Positioning / Segmentation (So) Identify Litigation Risks and How to Avoid Them (So)	Develop a Product Manufacturing Plan (T) Pretest / Pre-launch Forecasting (St) Evaluation of Insurance Risks due to Performance Errors (So) Product Use / Knowledge Dissemination (So)	Actual versus Planned Cost Evaluation (F) Consideration of Product Service Opportunities (T) Production Line Design and Setup (T) Final Financial Reviews (F)	Evaluation of Competitor Reactions (C) Life Cycle Cost Analysis (F) Product Warranty (So) Determination of Product Phase-out / Divestment (St)	Determination of Changing Customer Needs / Market Requirements (So) Orange – Elements not chosen by any of the 5 academic inventors Blue- Elements not chosen by any of the 5 corporate inventors **Legend** **T – Technological** **St – Strategic** **F – Financial** **So – Societal** **H – Human** **C – Competitor**

In addition to the four elements found above, this investigation was extended further to find the "gap" between the academic and corporate inventors. This was done by identifying elements that were present on the majority (four or more) of the corporate maps, but were not present at all on the academic inventors' maps. These elements were: *Construct a House of*

Quality (Opportunity Identification); *Product Risk Assessment* (Opportunity Identification); *Create a Product Financial Plan* (Opportunity Identification); *Determination of Product Positioning / Segmentation* (Design and Development); and *Evaluation of Competitor Reactions* (Life Cycle Management).

Of these nine elements that were used by a majority of the corporate inventors and none of the academic inventors, zero were of a technical nature; while three were strategic and three were societal. This agrees with the earlier speculation that the academics' primary focus in developing a new technology would be on technological issues. Surprisingly, four of the nine elements where a "gap" existed were from the Opportunity Identification stage and not later in the process after the inventor has disclosed their idea to the TTO.

5.1.3 Conclusions From the Concept Mapping Approach

This study investigated the differences in the technology development processes between academic and corporate inventors. A major catalyst for the overarching research is to understand how and why U.S. academic patents still wane to corporate patents 25 years after the signing of the Bayh-Dole act.

For the particular study presented in this section, the technology development process from idea generation to protection and beyond of 11 successful patents in the area of RFID was examined. To do this, 11 U.S. inventors each reflected and developed a map of the particular patent from its initial idea generation to the point of patent filing and beyond where applicable. To create these maps, inventors self-selected elements they used in the development of their invention from a conceptual model developed from the literature.

To investigate potential differences between academic and corporate inventors, five different investigations of the maps were conducted, of which three were quantitative and two were qualitative in nature. From these analyses, it is clear that academic and corporate inventors differ in their technology development processes. Although this may not be a surprising result, how and where these differences occur is of value. The participating academic inventors used, on average, significantly fewer elements in their process maps than did the corporate inventors. Further, there was little commonality between academic inventors in terms of the elements appearing on their maps (only seven percent commonality) as opposed to the corporate maps (nearly 30% of the elements were common). Twenty percent of all the elements were not used by any of the academic inventors. Most of these elements were non-technical in nature (i.e., they described strategic, societal, humanistic, financial and competitor issues and aspects). This led to the belief that academic inventors focused primarily on technological issues. However, when the maps were evaluated proportionally the only difference was that corporate inventors used statistically more financial elements than did the academic inventors. So although they used fewer elements on average, proportionally, academic inventors are similar to corporate inventors with respect to technological issues.

With respect to "challenges" (i.e. those elements that were critical, time consuming, or problematic) in the technology development process, it was found that overall the corporate inventors selected proportionally more societal issues as being time-consuming and problematic and proportionally more strategic issues as being problematic than did the academic inventors. Hence the supposition that there is a difference in the barriers between academic and corporate technology development was supported. The corporate inventors' emphasis on *Customer Needs Analysis* and *Product Meets Actual User Needs* were the main contributors to this difference. It is questionable though whether the academic inventors interviewed even considered certain issues and aspects in their technology development. As Table 15 indicates, there were many societal, strategic and financial aspects not considered in any of the academic maps, let alone classified as challenges in the technology development process. In terms of individual elements, the inventors' maps showed little similarity within or across the two groups. As previously mentioned, this analysis has led to the belief that the often troublesome technology development process is a unique experience for each inventor.

Utilizing two engineering design experts, a sorting exercise was conducted on the 11 inventor maps to see if certain maps exhibited more of a "process" orientation than the others (i.e., more of a process flow and overall organization) and whether or not this "process" orientation was related to the maps being academic or corporate-based. The hypothesis that corporate inventors would follow a more structured and complete technology development process than academic inventors was confirmed based first on the experts' rankings and then after they expanded their rank-order along three dimensions – completeness, correctness, and organization. The experts were able to correctly identify nine of the 11 maps as being academic or corporate, and again indicated that corporate maps were more structured and complete. In addition, corporate inventors tended to file for a patent later in the development process than did the academic inventors.

Although this study of 11 inventors is small and focused on RFID related technologies, it highlights some striking differences between academic and corporate based inventors. As Wright, Birley, and Mosey[107] mention "some universities have adopted approaches whereby TTOs work very closely with departments and academics to proactively identify opportunities …, we need to know more about these process of opportunity realization." This study has begun to investigate this process and the findings of this study can be used to inform university TTOs on focus areas to aid academic inventors in their development processes whereby stimulating the number of patents coming from academia. Specifically four such elements were identified as being important to all corporate maps but non-existent in academic technology development processes: *Define the Market and it Growth Potential, Product Use / Knowledge Dissemination, Actual versus Planned Cost Evaluation,* and *Determination of Changing Customer Needs/Market Requirements*. Support in these areas would allow academic inventors to emphasize the technological issues related to their innovation and possibly would lead to increased licensing agreements (as suggested by Mowery[108] et al.) and patents.

5.2 DISCUSSION FROM THE INVENTOR SURVEY APPROACH

Part II of Study One involved using the results from Part I to develop an online closed-form questionnaire to facilitate data collection from the larger database of inventors about the activities/elements of the technology development process. The questionnaire consisted of three sections: Inventor characteristics, Corporation/University characteristics, and Process characteristics.

It was intended to use the in-depth interviews and accompanying process maps to develop a thorough questionnaire; and the resulting data from the questionnaire was intended to be used to create and verify empirical models on the elements typically used in the technology development process. Unfortunately, the response rate for this population of inventors (4.6 % for both academic and corporate) was extremely inadequate (see following section). Although there is no agreed-upon standard for minimum acceptable response rate[109], a rule of thumb response rate greater than 30% is typically desired when surveying a population. In addition the inability of the survey participants to holistically reflect on their process limited the value and creditability of their responses in terms of the development process and the particular elements in question. Hence, statistical analyses of any sort would result in erroneous results and conclusions. Therefore, information presented in this section is for descriptive purposes only. No statistical analyses or conclusions are made.

5.2.1 Response Rate

The academic survey was administered via two separate rounds of emails followed by a third round of phone calls to solicit participation. Emails were sent to 222 academic inventors. 28 emails were returned undeliverable, 15 inventors responded that they were unable or unwilling to participate, and nine inventors fully completed the survey. Those that were unable or unwilling often cited time concerns due to the length of the survey, felt that they had little to add, or that the survey was irrelevant to their particular involvement in the development of the technology. Eliminating those inventors for whom an accurate email address or telephone number could not be located brought the total sample population down to 194 inventors. The overall response rate was 24 out of 194 or 12.4% and the usable response rate was nine out of 194 or 4.6%.

The corporate survey was administered via two separate direct mailings followed by a third round of phone calls. Letters were sent to 291 corporate inventors. 71 letters were returned to sender, four inventors had international addresses and the addresses were incomplete, five inventors responded that were unable or unwilling to complete, and ten inventors fully completed the survey. Those that responded but were unable to complete cited legal concerns, the overall length of the survey and the inability to answer all of the required questions. Eliminating the inventors whose letters were "returned to sender" and those for whom an accurate phone number could not be obtained, brought the total sample population down to 216 inventors. The overall response rate was 15 out of 216 or 6.9% and the usable response rate was ten out of 216 or 4.6%.

5.2.2 Presentation of Process Element Survey Data

Four separate data presentations were conducted on the inventors' responses: three quantitative in nature, and one qualitative. The first presentation of data is a series of categorical comparisons between inventor groups on the entire development process. The academic and corporate inventors are compared relative to their utilization of the elements throughout the entire process. The second data presentation compares the two inventor groups relative to how they designated elements as being critical, time-consuming and problematic. Following this, a qualitative analysis of the particular elements that were designated as most critical, time-consuming and problematic is provided. Third, categorical comparisons between inventor groups for each process stage as well as ongoing elements are presented. Finally, those specific elements used by all the inventors or none of the inventors are shown.

5.2.2.1 Categorical Comparisons of the Entire Development Process

The number of elements in each category was summed for both academic and corporate innovators and the percentages used from each category were highlighted, as shown in Table 16 below. Again, this is similar to the method used in Part I of Study One and by Mohr[110] in which both focused on element and process analyses.

Table 16. Inventor Survey Percent Utilization

	Inventor	Technological Issues (35)	Strategic Issues (14)	Financial Issues (4)	Societal Aspects (15)	Human Aspects (7)	Competitor Aspects (2)	Totals (77)
Academic	1	57.1	50	0	40	57.1	0	48.1
	2	85.7	78.6	100	93.3	85.7	0	84.4
	3	54.3	42.9	75	33.3	42.9	0	46.8
	4	80	71.4	75	53.3	71.4	0	70.1
	5	60	57.1	75	80	57.1	100	64.9
	6	54.3	35.7	0	53.3	42.9	100	48.1
	7	37.1	14.3	0	0	28.6	0	22.1
	8	42.9	85.7	75	53.3	85.7	100	59.7
	9	80	64.3	50	53.3	71.4	50	68.8
	A Average	61.3	55.6	50.0	51.1	60.3	38.9	57.0
	A St. Dev.	17.1	22.5	39.5	26.7	19.9	48.6	18.1
Corporate	1	65.7	57.1	75	66.7	71.4	100	66.2
	2	45.7	78.6	75	46.7	42.9	50	53.2
	3	68.6	85.7	75	60	71.4	100	71.4
	4	11.4	14.3	0	6.7	28.6	0	11.7
	5	74.3	78.6	100	73.3	85.7	100	77.9
	6	8.6	35.7	0	20	28.6	50	18.2
	7	65.7	21.4	50	53.3	28.6	50	50.6
	8	65.7	85.7	75	66.7	14.3	50	64.9
	9	25.7	35.7	25	6.7	28.6	0	23.4
	10	68.6	71.4	75	86.7	57.1	0	70.1
	C Average	50.0	56.4	55.0	48.7	45.7	50.0	50.8
	C St. Dev.	25.5	27.5	35.0	28.3	24.1	40.8	24.3

5.2.2.2 Comparisons in Critical, Time-Consuming and Problematic Elements

Upon completion of the process element section of the survey, the inventors were asked to identify the seven *most* critical and problematic elements which they encountered for their particular technology. (The seven most time-consuming elements were determined from the responses to the time spent on each of the elements that were utilized.)

In terms of the particular elements that the inventors classified as being critical, time-consuming and problematic, there was little similarity within or across the two groups as noted in Table 17 below. From the academic respondents, there was no consistency in the designation of the critical elements of the process. Five of the academic inventors did agree that *Prototype Development* was time-consuming and *Funding Considerations* and *Beta-Testing* were problematic. Five of the corporate inventors agreed that *Evaluating Prior Art (Similar Patents)* was critical and *Alpha / In-house Testing* was time-consuming. There existed no consistency in the corporate inventor's designation of the problematic elements in the process. Upon collapsing the two groups, no common critical, time-consuming or problematic elements in the processes were found.

Table 17. Elements Classified as Most Critical, Time-Consuming and Problematic

Inventor Group	Finding(s)
Academic *Noted by at least half the respondents*	• *Critical:* None • *Time consuming*: Prototype Development • *Problematic*: Funding Considerations, Beta Testing – Product Works in Customer Operations
Corporate *Noted by at least half the respondents*	• *Critical*: Evaluate Prior Art (Similar Patents) • *Time Consuming*: Alpha / In-house Testing • *Problematic*: none

5.2.2.3 Categorical Comparisons by Development Stage

For the third presentation, utilization of elements for each stage is presented. Table 18 provides an overview of the average element count per technology development stage.

Table 18. Inventor Survey – Percent Utilization per Technology Development Stage

	Stage 1 (26)	**Stage 2 (17)**	**Stage 3 (22)**	**Stage 4 (2)**	**Stage 5 (2)**	**Ongoing (8)**
Academic Inventors	56.9	61.2	56.8	30	40	56.3
Corporate Inventors	56.5	54.1	45.5	40	30	47.5

Similarly to what was done in Part I of this study, the proportion of elements used from each category relative to the total number of elements selected by the inventor in their survey is presented by stage. The results are shown in Table 19 below.

Table 19. Inventor Survey – Proportions of Elements Used by Stage

		Academic Mean	Corporate Mean
Stage 1	**Technological Issues (7)**	0.114	0.113
	Strategic Issues (5)	0.051	0.093
	Financial Issues (3)	0.034	0.041
	Societal Aspects (3)	0.031	0.05
	Human Aspects (7)	0.098	0.098
	Competitor Aspects (1)	0.008	0.005
Stage 2	**Technological Issues (10)**	0.131	0.136
	Strategic Issues (3)	0.053	0.055
	Societal Aspects (4)	0.05	0.064
Stage 3	**Technological Issues (13)**	0.191	0.137
	Strategic Issues (4)	0.052	0.055
	Financial Issues (1)	0.006	0.006
	Societal Aspects (4)	0.046	0.032
Stage 4	**Technological Issues (1)**	0.009	0.006
	Strategic Issues (1)	0.005	0.01
Stage 5	**Technological Issues (1)**	0.008	0.004
	Societal Aspects (1)	0.009	0.007
Ongoing	**Technological Issues (3)**	0.058	0.039
	Strategic Issues (1)	0.011	0.005
	Societal Aspects (3)	0.024	0.02
	Competitor Aspects (1)	0.01	0.02

5.2.2.4 Common Elements used in the Technology Development Process

In the final data presentation, those elements commonly used by all of the inventors as well as those not used by any of the inventors were identified. Table 20 provides those elements that were common to all the academic inventors (shown in orange) and those common to all the corporate inventors (shown in blue). As shown, there was only one common element for all ten corporate inventors, *Evaluate Prior Art (Similar Patents)*. The academic inventors also exhibited little commonality with only six (~7%) elements in common between the nine academic inventors; *Individual Brainstorming, Identify the Primary Innovation, Prototype Development, Prototype Testing, Testing, Data Analysis, Evaluation and Reporting* and *Alpha / In-house Testing*. No elements were utilized by all 19 survey participants.

Table 20. Elements Utilized by all Inventors in the Inventor Survey

Opportunity Identification	Design & Development	Testing & Preproduction	Introduction & Production	Life Cycle Management	Ongoing
Individual Brainstorming (H)	Evaluate Prior Art (Similar Patents) (So) Identify Primary Innovation (St) Prototype Development (T)	Prototype Testing (T) Testing, Data Analysis, Evaluation, and Reporting (T) Alpha / In-house Testing (T)			Orange – Elements chosen by all 9 academic inventors Blue- Elements chosen by all 10 corporate inventors Green – Elements chosen by all 19 inventors **Legend** **T – Technological** **St – Strategic** **F – Financial** **So – Societal** **H – Human** **C – Competitor**

Table 21 provides those elements not utilized by any of the inventors. As shown, only *Evaluate Potential Time to Market Requirements* was not used by any of the nine academics and *Forces of Nature Effect on Development* was not used by any of the ten corporate inventors.

Table 21. Elements Not Utilized by Any Inventor in the Survey

Opportunity Identification	Design & Development	Testing & Preproduction	Introduction & Production	Life Cycle Management	Ongoing
Evaluate Potential Time to Market Requirements (T)					Forces of Nature Effect (So) Orange – Elements chosen by none of the academic inventors Blue – Elements chosen by none of the corporate inventors Green – Elements chosen none of any of the inventors **Legend** **T – Technological** **St – Strategic** **F – Financial** **So – Societal** **H – Human** **C – Competitor**

5.2.3 Presentation of Inventor and Organizational Survey Data

As mentioned, there were three primary categories of survey questions. This section provides a data presentation of the questions related to the inventor's motivation / idea origination, the invention disclosure process, and invention ownership policies and concerns.

5.2.3.1 Inventor Motivation / Idea Origination

On the survey, questions pertaining to the inventors' motivation behind developing the particular technology were asked. Specifically, inventors were asked about: the type of rewards or incentives various companies and academic institutions offer for developing patentable ideas, how the inventors' rated their organization's "reward" policies, and the origination of the idea for the technology.

Amabile[111] indicates that motivations can be either extrinsic or intrinsic. Extrinsic being "driven by the desire to attain some goal that is apart from the work itself – such as achieving a promised reward or meeting a deadline or winning a competition" and intrinsic "driven by deep interest and involvement in the work, by curiosity, enjoyment, or a personal sense of challenge." She finds that combinations of these are common and that a primarily intrinsic motivation will be more conducive to creativity than a primarily extrinsic motivation. Cooper[112] found that 12 motivational descriptors were sufficient to cover the statements made by all persons interviewed in his study on motivations behind the development of new products and technologies. Of these 12, three in particular were most often mentioned; "creative buzz," "tangible benefits," and "excitement." He determined that all the innovators appreciated a creative environment and are motivated by value and tangible benefits in their work. In this study, the majority (seven out of the nine) of the academic inventors responded that their primary motivation was the advancement of the scientific body of knowledge (an intrinsic desire to further science). Two of the corporate inventors indicated that the advancement of the scientific body of knowledge was their primary motivation; while two said financial, four said it was simply part of their job description, and two said that it was a personal challenge for them to develop the technology. This is in contrast to the initial expectations of the research that the corporate inventors would be primarily motivated by financial matters.

In terms of the rewards or incentives offered to inventors, all academic inventors responded that their institutions offered some level of partial ownership or percentage share of royalty incomes. The corporate responses varied. Six of the corporate inventors answered that they are rewarded with some type of award or recognition; five responded that they are given cash bonuses or stock options, only one was given partial ownership or royalties and two received absolutely nothing at all. (The total is larger than ten as respondents were allowed to select more than one response.) When asked to rate how they felt about their organizations "reward" policy, the corporate respondents were critical of the process (i.e., unfairness). Eight of the ten rated their company's policy as highly unfair. The academic respondents tended to be neutral in their rankings. Three indicated that the policy was unfair, four were neutral to the institution's policy, and two felt the policy was fair.

Finally, the two groups appear to be similar in their selections for idea origination. Ten inventor respondents (five from each group) indicated that their ideas came from continuous improvement or investigating new solutions to existing problems. One of the academic and three of the corporate respondents' inventions originated from an opportunity or a need that was assigned to them to solve. Three of the academic and one of the corporate inventions originated from their research or personal interests. All questions and responses from this section are provided in Table 22.

Table 22. Motivation for Development and Origin of Idea

Question (*Responses*)	**Academic**	**Corporate**
What was your underlying motivation behind the development of this idea?		
Advancement of scientific body of knowledge	7	2
Financial	0	2
Part of my job description	1	4
Personal Challenge	1	2
What does your company / university offer to patent inventors that encourages generating and exploring new ideas?		
Awards/ other types of recognition	0	6
Cash bonuses / stock options	0	5
Partial ownership / royalties	9	1
Nothing	0	2
How would you rate your company / university's "reward" policies for a patentable/commercial product?		
Highly unfair (all of the royalties / ownership is maintained by the organization)	0	8
Unfair (a great percentage (~75%) of the royalties / ownership is maintained by the organization)	3	0
Neutral (50% of the royalties / ownership is maintained by the organization)	4	0
Fair (a small percentage (~25%) of the royalties / ownership maintained by the organization)	2	1
Highly generous (none of the royalties / ownership is maintained by the organization)	0	1
Where did the idea for this particular patent come from?		
As part of continuous improvement, investigating new solutions to existing problems	5	5
Opportunity (need) assigned to you to find a solution	1	3
Your own research (personal interests)	3	1
Idea given to you to technically develop	0	1

5.2.3.2 Invention Disclosure Process

A second segment of questions involved how inventors rated: their organization's "control" on invention disclosures once submitted and their organization's innovation policies. In addition, a valuation of the time between when the invention was disclosed and the patent application filed is presented.

Both groups indicated that once the invention was submitted, control of the invention process was, to some degree, taken from them. Only one academic and two corporate respondents indicated that they still had involvement. When asked about how encouraging their particular organization was towards innovation/patenting, only four of the nine academic innovators indicated that their institutions were encouraging. This appears to be in contrast to the corporate inventors where six of the corporations were rated as encouraging and two were rated as very encouraging.

The final questions related to when a patent was filed. Based on the stage in the development process, corporate inventors filed invention disclosures and patents sooner in the process than did academic inventors. From a time perspective, the academic inventors who responded to the survey filed the invention disclosure at an average of 1.38 years as opposed to 0.98 years for the corporate inventors (note, no statistical analyses were conducted). In terms of the time until a patent application was filed, the responding academic inventors averaged 2.2 years from the time the idea was first generated until when the patent was filed compared to 2.43 years for the responding corporate inventors. All questions and responses from this section are provided in Table 23 below.

Table 23. Invention Disclosure Survey Questions

Question (*Responses*)	**Academic**	**Corporate**
How would you rate your company / university's degree of control on invention disclosures?		
Once I submit my idea, what happens with it is totally out of my control	3	4
My input and involvement is very infrequent (~ 4x per year)	3	2
My input and involvement is still considered on a regular basis (~ 4x per month)	2	2
My involvement and input is still considered on a daily basis	1	2
How would you rate your company / university's innovation policies?		
Discouraging towards innovation	1	1
Neutral towards innovation	4	1
Encouraging towards innovation	4	6
Strongly encouraging towards innovation	0	2
To the best of your recollection, nearest to what point in the process was the invention disclosed to an office of technology management / technology transfer office? (Select One)		
Idea was generated and product description created	3	3
Brainstorming sessions were conducted	0	2
The product's performance requirements were defined	1	0
Product functional analysis was conducted	1	0
Conceptual design was optimized	1	2
Prototype development	2	0
Prototype testing	1	2
Final design approval granted	0	1
To the best of your recollection, nearest to what point in the process was the patent filed? (Select One)		
Idea was generated and product description created	0	2
Brainstorming sessions were conducted	0	1
The product's performance requirements were defined	1	1
Finalization of technical and physical requirements	1	1
Conceptual design was optimized	0	1
Product functional analysis was conducted	1	0
Prototype development	2	0
Prototype testing	3	3
Beta and gamma testing and ensuring that the product meets customer needs	1	1

5.2.3.3 Invention Ownership Policies and Concerns

The third set of questions pertained to the ownership of the technology. The questions included whether or not the inventor would withhold an invention because they thought the organization's "ownership" policy was unfair, if the inventor's decision to work at the organization was influenced by the "ownership" policy, and if the inventor left (or would ever leave) an organization because of "ownership" policy. Finally, inventors were asked to rate their organization's "ownership" policy.

Three of the nine responding academic inventors indicated that they would (or have) withhold an invention; while only one out of ten responding corporate inventors would (or have) withhold an invention because they felt their organization's "ownership" policy was unfair. None of the 19 respondents said that their decision to work at their present institute was affected by their "ownership" policy. One of the corporate inventors did indicate that they had left a company because of their policy. Finally, eight out of the ten corporate inventors' felt their companies were "highly unfair" with regards to the ownership policies. Three of the academic inventors rated the policy as "unfair," four felt their policy was "neutral," and two felt that the "ownership" policy was fair. All questions and responses from this section are available in Table 24 below.

Table 24. Invention Ownership Survey Questions

Question (*Responses*)	**Academic**	**Corporate**
Would you (have you) purposely withhold an idea or invention from submission because you feel that your company / university's "ownership" policy is unfair?		
Yes	3	1
No	6	9
Was your decision to work at your present company / university affected by their invention "ownership" policy?		
Yes	0	0
No	9	10
Have you ever left a company / university because you were unhappy with their invention "ownership" policy?		
Yes	0	1
No	9	9
How would you rate your company / university's "ownership" policies for a patentable/commercial product?		
Highly unfair (all of the royalties / ownership is maintained by the organization)	0	8
Unfair (a great percentage (~75%) of the royalties / ownership is maintained by the organization)	3	0
Neutral (50% of the royalties / ownership is maintained by the organization)	4	0
Fair (a small percentage (~25%) of the royalties / ownership maintained by the organization)	2	1
Highly generous (none of the royalties / ownership is maintained by the organization)	0	1

5.2.4 Summary from the Closed-Form Inventor Survey

The closed-form inventor questionnaire was intended to investigate the differences in the technology development processes for both academic and corporate inventors. The survey consisted of three sections: Inventor characteristics, Corporation/University characteristics, and Process characteristics. Only 19 responses were acquired through proper survey administration. Because of the poor sample size, no viable statistical comparisons or conclusions could be made; only summary descriptive measures could be presented. Further, no feasible comparisons can be made between Part I and Part II of this study. What follows is a summary of the data presentation from the closed-form inventor questionnaire.

The process section gathered information specifically pertaining to particular elements of the development process and to milestones such as first prototype being developed, invention disclosure and patent filing. Four data presentations were presented from the 19 responses (nine academic and ten corporate).

Additionally, the questionnaire delved into three secondary research areas: (1) inventor motivation / idea origination, (2) the invention disclosure process, and (3) the invention ownership policies and concerns. Inventor characteristics gathered information about the individual's motivation behind the technology's development and how the idea originated. The majority (seven out of nine) of the academic inventors responded that their primary motivation was the advancement of the scientific body of knowledge, an intrinsic motivation. The corporate respondents indicated less consistency. Two indicated that the advancement of the scientific body of knowledge (intrinsic) was their primary motivation, two specified financial (extrinsic); four designated that it was part of their job description (combination), and two pointed to it as a personal challenge (intrinsic) for them to develop the technology. This was in contrast to initial expectations and research that the corporate inventors would be motivated by financial matters. Finally, the two groups were similar in their selections for idea origination that of continuous improvement or investigating new solutions to existing problems.

The corporate/university section gathered information about the organization's control over invention disclosures once submitted and inventors' perceptions about their organization's innovation environment and reward policies. Both groups indicate that once the invention is submitted, the control of the invention is taken (to some degree). Overall, the responding academic inventors found their institution to be less encouraging towards innovation than did the corporate respondents; while the corporate inventors were more critical of their organizations reward policies. Three of the nine academic inventors indicated that they would (have) withhold an invention. In comparison, none of the corporate respondents would withhold an invention. However, none of the 19 inventors indicated that their decision to work at the organization was influenced by the "ownership" policy. One of the corporate inventors did indicate that they had left a company because of their former employer's policy. In terms of the rewards or incentives offered to inventors, all of the academic inventors responded that their institutions offered some level of partial ownership or some percentage share of royalty incomes, whereas corporate responses were scattered.

Though not intended, Part II of Study One yielded a sample size insufficient to determine any useful information with regards to the technology development process characteristics. Although the other two portions of the survey (Inventor and Corporation/University characteristics) did present some interesting summaries, again no viable conclusions can be established.

5.3 CONCLUSIONS FROM STUDY ONE

From the concept mapping (and to a diminutive extent the inventor survey) it was found that the academic and corporate technology development processes (in RFID and similar technologies) do differ, but not as substantially as initially speculated. In terms of the process itself, an initial speculation was that the academics would focus on technological issues and possibly societal aspects; while the corporate inventors would focus on strategic, financial and competitor aspects. The concept mapping approach resulted in the corporate inventors' using significantly more elements in the technology's development than did the academic inventors. Further, there existed some differences in the focus of the elements used and the particular elements that the two groups found to be critical, time-consuming and problematic. These differences will be examined below.

The concept mapping approach highlighted substantial findings. First, corporate inventors focused more on financial issues, in particular, *Creating a Financial Plan, Determining Product Cost and Funding Considerations*. The corporate inventors found strategic issues to be more critical and problematic. In particular, *Defining the Market and Its Growth Potential*, *Creating a Schedule* and *Defining the Scope of the Product* were more critical and problematic to the responding corporate inventors. The corporate inventors also found that societal issues were both more time-consuming and problematic as compared to the academic inventors. Completing a *Customer Needs Analysis* and verifying that the *Product Meets Actual User Needs* were more difficult for corporate inventors. An interpretation for this could be the fact that the academics may not have even considered these elements since their primary motivation is the advancement of scientific knowledge and not finding customers and markets for their technologies (as found in Part II of Study One). When examining the two groups by stage, the academic participants in the concept mapping showed a greater tendency to concentrate on technological issues in Stages 3 and 5; while the participating corporate inventors focused more on societal aspects in Stage 3 and financial issues in Stage 4. These findings further support the initial research expectations.

Overall, in terms of the designation of particular elements as critical, time-consuming, and problematic, there existed little similarity between the two inventor groups. There did exist more similarity in the corporate inventors' processes (and their concept maps were better organized with greater integration between elements), which would suggest that they might have been following some type of formal approach to technology development, but the overall commonality remained relatively small (~30%). The commonality that did exist for the responding academic inventors was in technological elements. Primarily, the areas where a "gap" existed between academic and corporate inventors were of a non-technical nature. This reverberates that the technology development process is unique and a single conceptual model may not be capable of summarizing technology development.

Secondary to the differences in the technology development process between academic and corporate inventors, are the underlying reasons why the two processes may differ. The technology development process begins with idea generation. Prior to idea generation, there typically exists some type of motivation. This motivation can be either intrinsic or extrinsic[113]. It was proposed that the academics would be more motivated by advancing scientific knowledge (intrinsic); while the corporate inventors would be more motivated by financial benefits (extrinsic). While no statistical analyses could be done, seven of the nine academic inventors were motivated by advancing the scientific body of knowledge; while the corporate inventors showed less consistency in their motivation; hence initial expectations were only partially supported. However, the two groups though did appear uniform in their idea originations. The majority indicated that continuous improvement or investigating new solutions to existing problems spawned their new technologies. In terms of organizational motivation, all academic respondents indicated some type of reward is given for licensable, patentable technologies. Whereas, only approximately half of the corporate inventors indicated some type of reward (i.e. cash bonuses and stock options); however, the corporate inventors did note that the climate for innovation in their companies was encouraging compared to the perceptions of the academic respondents.

Given the findings from this study, a second study was developed to investigate those technology development process elements that TTOs view as critical to helping academic inventors further their invention disclosures towards a licensable, patentable technology. Because academic inventors used less elements than corporate inventors (from the concept map study); Study Two investigated the TTO perspective of the use of elements to determine if elements that academic inventors did not use were being performed by the TTO and how they may differ or be the same as elements used by corporate inventors. If there are elements "neglected" by both the academic inventor and TTO, investing such elements may be important to TTOs to potentially improve the technology transfer process. This may be particularly true if corporate inventors have identified such elements as critical.

6.0 STUDY TWO – TECHNOLOGY TRANSFER INVESTIGATION

The overarching goal of a TTO is maximizing revenue with "close seconds" being the number of licenses executed and inventions commercialized[114]. The process by which this occurs is under-researched. In Study One, the idea generation and protection of an RFID patented technology was investigated from the inventor perspective. The overarching goal of Study Two was to investigate the idea protection (and possibly generation) process from the TTO perspective. In this study the following was questioned: what elements of the technology development model are viewed as critical responsibilities of the TTO? Further, from Study One it was found that there are elements that are commonly performed by corporate inventors, but rarely completed by academic inventors. This "gap" between academic and corporate inventors is investigated to determine if the TTO conducts certain elements that academic inventors do not, but corporate inventors do conduct. Specifically, can areas be identified where TTOs can contribute to the quantity and quality of technology emerging from academia? Coupling the results from Study One of this research with the study and analyses performed in this section will allow the researcher to address this question in greater detail below.

6.1 SURVEY OF TECHNOLOGY LICENSING OFFICE MANAGERS

While performing the concept mapping approach on the 11 inventors from Study One, maps for two TTO licensing managers were also collected. The pilot TTO maps formed the basis for an on-line TTO survey that examined the critical elements of the technology development process that TTOs conduct to aid their academic inventors in furthering invention disclosures towards licensable, patentable technologies. To evaluate the data, two quantitative and two qualitative analyses were conducted. The quantitative analyses investigated how various elements, identified as critical, compared to available factors obtained from the AUTM's annual licensing survey[115].

6.1.1 Survey Administration and Response Rate

The technology licensing manager survey was administered via three separate rounds of emails. Emails were sent to 199 technology licensing office managers. The first email distribution resulted in three undeliverable messages and 34 respondents. The second round of emails resulted in 21 additional respondents; and round three resulted in 26 new respondents. A total of 81 persons responded to the survey. Removing the three undeliverable emails, the response rate was 41.3%. Given the population of 199 technology license managers, this response rate is suitable for conducting data analyses.

6.1.2 Analyses and Results

Both qualitative and quantitative analyses were conducted on the results of the TTO licensing manager survey. The first qualitative analysis involved the identification of the percent utilization of the 70 elements provided to the licensing managers in the survey. Two quantitative analyses were then conducted. The first quantitative analysis involved a stepwise multiple logistic regression to determine a relationship between the university's Carnegie classification, the number of employees working full time for the TTO, and various other licensing and patenting statistics, and the elements identified by the licensing managers as critical to their duties in furthering invention disclosures. The second, but similar, quantitative analysis involved a general multiple linear regression. This was performed to determine if there was a relationship between the organizational characteristics and licensing and patenting statistics and whether or not specific elements were utilized in a particular TTO.

6.1.2.1 Technology Licensing Manager Survey – Qualitative Analysis

A summary of the responses of the 81 participants is available by category in Table 25 below. The values represent the percentage of participants that identified the elements as being a critical item in furthering invention disclosures in their TTO.

Table 25. Elements Chosen as Critical by the Technology Licensing Managers – By Category

Percent	Technological Issues
25.9	Create Product Description
21.0	Evaluate Potential Time to Market Requirements
9.9	Prototype Development
8.6	Technical Risk Assessment
4.9	Define Product's Performance Requirements
4.9	Prototype Testing
3.7	Optimization of Conceptual Design
1.2	Generate Multiple Product Alternatives
1.2	Product Functional Analysis
1.2	Reverse Engineering Protection
1.2	Optimization of Detailed Design
1.2	Beta Testing – Product Works in Customer Operations
1.2	Gamma Testing / Actual User Testing
1.2	Pilot Scale Operational Testing and Evaluation
	Design For Mfg, Assembly, Auto
	Finalization of Technical and Physical Requirements for
	Product Component Tradeoffs and Optimization
	Testing Data Analysis, Evaluation and Reporting
	Reliability Testing, Test to Failure, Limit Testing
	Design Manuals Written
	Site Surveys / Installation Considerations
	Design Modifications / Reviews

Percent	Strategic Issues
71.6	Intellectual Property Awareness
63.0	Licensing In / Out Considerations
50.6	Define the Market and Its Growth Potential
39.5	Identify Primary Innovation
17.3	Identify Potential Future Innovations
14.8	Product Marketing, 3 C's, 4 P's
4.9	Cost Estimate Projections
3.7	Product Advertising Plan
2.5	Schedule / Cost / Technical Summaries
1.2	Develop Peripheral Innovation(s)
	Product Risk Assessment
	One, Three and Five Year Product Plans
	Limited Rollout, Test Marketing
	Create a Schedule for the Product

Percent	Financial Issues
37.0	Funding Considerations
9.9	Determination of Investment Req. / Potential Profit
8.6	Financial Risk Assessment
6.2	Sales Forecasting
3.7	Create a Product Financial Plan
3.7	Determination of Product Cost
3.7	Estimate / Predict Customer ROI
1.2	Life Cycle Cost Analysis
	Proposed Design within Target Costs
	Actual Versus Planned Cost Evaluation
	Final Financial Reviews

Percent	Societal Aspects
71.6	Evaluate Prior Art (Similar Patents)
21.0	Target Customer Determination
21.0	Strength, Weakness, Opportunity, Threat Analysis
17.3	Sought Guidance From Outside Sources
12.3	Determination of Product Positioning
9.9	Customer Needs Analysis
9.9	Customer Feedback Evaluation
7.4	Product Feature Determination
7.4	Determination of Changing Customer Needs / Market
6.2	Product Meets Actual User Needs
4.9	Identify Litigation Issues and Ways to Avoid
4.9	Regulatory Certification / Compliance
4.9	Train / Transfer Technology, Actual User Training
2.5	Product Need Based on Development Time
2.5	Product Use / Knowledge Dissemination
1.2	Stakeholder Analysis
1.2	Reaction to Customer Response
	Design For Environment (Is Product Recyclable,
	Evaluation of Insurance Risks due to Errors

Percent	Competitor Aspects
11.1	Competitor Benchmarking
	Anticipate Competitor Responses
	Evaluation of Competitor Reactions
	Continuous Competitor Monitoring

Eight of the 22 (36%) technological elements were not selected by any of the licensing office managers; while only four of the 14 (29%) strategic issues and only two of the 19 (11%) societal issues were not selected by any of the licensing office managers. Conversely, none of the 22 technological elements were used by greater than one-third of the respondents; while four (*Intellectual Property Awareness, Licensing In/Out Considerations, Define the Market and Its Growth Potential*, and *Identify Primary Innovation*) of the strategic issues, one (*Funding Considerations*) of the financial issues and one (*Evaluate Prior Art / Similar Patents*) of the societal aspects were used by at least one-third of the respondents. This potentially indicates that the TTO personnel are concentrating more on strategic, financial and societal elements instead of technological issues, which from Study One Part I (concept mapping) was found to be a focus of the academic inventors particularly in Stages 3 and 5.

Overall, there were only two elements (*Evaluate Prior Art / Similar Patents* and *Intellectual Property Awareness*) identified as critical by more than two-thirds of the respondents and six identified as critical by at least one-third of the respondents (*Define the Market and Its Growth Potential, Evaluate Prior Art / Similar Patents, Funding Considerations, Identify Primary Innovation*, *Intellectual Property Awareness,* and *Licensing In/Out Considerations*). Similar to the results of Study One Part I that found the technology development process to be somewhat unique to each inventor, this study found the TTO process to exhibit variation and be unique to each university.

Correspondingly, the responses are also examined by the stage to determine where in the technology development processes the TTOs focus their efforts. A summary of the responses by stage of the 81 participants is available in Table 26 below.

Table 26. Elements Chosen as Critical by the Technology Licensing Managers – By Stage

Percent	Stage 1 - Opportunity Identification
71.6	Intellectual Property Awareness
50.6	Define the Market and Its Growth Potential
37.0	Funding Considerations
25.9	Create Product Description
21.0	Evaluate Potential Time to Market Requirements
21.0	Target Customer Determination
21.0	Strength, Weakness, Opportunity, Threat Analysis
11.1	Competitor Benchmarking
9.9	Determination of Investment Req. / Potential Profit
8.6	Technical Risk Assessment
8.6	Financial Risk Assessment
7.4	Product Feature Determination
4.9	Define Product's Performance Requirements
4.9	Cost Estimate Projections
3.7	Create a Product Financial Plan
3.7	Determination of Product Cost
2.5	Product Need Based on Development Time
1.2	Generate Multiple Product Alternatives
1.2	Stakeholder Analysis
	Create a Schedule for the Product
	Product Risk Assessment

Percent	Stage 2 - Design and Development
71.6	Evaluate Prior Art (Similar Patents)
63.0	Licensing In / Out Considerations
39.5	Identify Primary Innovation
17.3	Sought Guidance From Outside Sources
14.8	Product Marketing, 3 C's, 4 P's
12.3	Determination of Product Positioning
9.9	Prototype Development
9.9	Customer Needs Analysis
6.2	Sales Forecasting
4.9	Identify Litigation Issues and Ways to Avoid
4.9	Regulatory Certification / Compliance
3.7	Optimization of Conceptual Design
3.7	Product Advertising Plan
1.2	Optimization of Detailed Design
1.2	Product Functional Analysis
1.2	Reverse Engineering Protection
	Design For Mfg, Assembly, Auto
	Finalization of Technical and Physical Requirements for Design
	Product Component Tradeoffs and Optimization
	Design For Environment (IRecyclable, Reusable, etc.)

Percent	Stage 3 - Testing and Preproduction
17.3	Identify Potential Future Innovations
6.2	Product Meets Actual User Needs
4.9	Prototype Testing
4.9	Train / Transfer Technology, Actual User Training
3.7	Estimate / Predict Customer ROI
2.5	Product Use / Knowledge Dissemination
1.2	Beta Testing – Product Works in Customer Operations
1.2	Gamma Testing / Actual User Testing
1.2	Develop Peripheral Innovation(s)
	Testing Data Analysis, Evaluation and Reporting
	Reliability Testing, Test to Failure, Limit Testing
	Design Manuals Written
	Site Surveys / Installation Considerations
	Limited Rollout, Test Marketing
	Proposed Design within Target Costs
	Evaluation of Insurance Risks due to Errors
	Anticipate Competitor Responses

Percent	Stage 4 - Introduction and Production
1.2	Pilot Scale Operational Testing and Evaluation
	One, Three and Five Year Product Plans
	Actual Versus Planned Cost Evaluation
	Final Financial Reviews

Percent	Stage 5 - Life Cycle Management
1.2	Life Cycle Cost Analysis
1.2	Reaction to Customer Response
	Evaluation of Competitor Reactions

Percent	Ongoing
9.9	Customer Feedback Evaluation
7.4	Determination of Changing Customer Needs / Market Reqs
2.5	Schedule / Cost / Technical Summaries
	Design Modifications / Reviews
	Continuous Competitor Monitoring

At least a third of the TTO respondents focused on elements in Stages 1 and 2 with three elements in each of these stages (*Intellectual Property Awareness, Define the Market and Its Growth Potential,* and *Funding Considerations* in Stage 1; and *Evaluate Prior Art / Similar Patents, Licensing In/Out Considerations,* and *Identify Primary Innovation* in Stage 2). Only one element, *Identifying Potential Future Innovations,* in Stage 3 was identified by 17% of the respondents as being critical for the TTO. No elements were identified in Stages 4 or 5 or in the "ongoing" stage by more than 10% of the respondents.

6.1.2.2 Technology Licensing Manager Survey – Quantitative Analyses

Two sets of empirical models were developed involving 31 of the variables identified as critical elements performed by TTOs[9]. The first analysis involved using stepwise logistic regression to establish if there was a relationship between the: institution's Carnegie classification, number of employees working full time for the TTO, and various other available licensing and patenting statistics, and those elements the university's office manager identified as critical. The purpose of the general linear regression (the second analysis) was used to determine if the elements identified by a TTO as being critical were related[10] to the various organizational characteristics and licensing and patenting success factors.

Analysis 1 – Stepwise Logistic Regression

The variables[11] used to evaluate the TTO survey responses are provided in Table 27.

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[9] These 31 elements were those that were identified as being critical by at least 5% of the respondents.
[10] These models will not be used to predict. If significant models are found, it will indicate that a relationship exists between the variable and whether or not a TTO performs the particular element.
[11] It is noted that the data is available for the licensing and patenting statistics for 2004, but the survey of critical elements identified by TTO licensing managers was performed in 2006. This research assumes that due to the mission of the TTO, their seven critical elements would have been the same in 2004 as in 2006.

Table 27. Variables Used in Evaluating TTO Survey Responses

Variable Name	Description	Data Type, Range
CARNEGIE	Carnegie classification of institution: Research University / Very High (RU/VH) Research University / High (RU/H) Master and Medical Specialty (Other)	Categorical, coded as CARNEGIE1 and CARNEGIE2 where (1,0) is Other, (0,1) is RU/H, and (-1,-1) is RU/VH
EMP	Number of employees at the TTO	Nominal, 0.2-35
YEAR	2006 less the year of inception of TTO[12]	Nominal, 2-66
ID	Invention disclosures filed in FY 2004	Nominal, 2-549
PAF	Patent applications filed in FY 2004	Nominal, 0-536
PI	Patents issued in FY 2004	Nominal, 1-159
SCF	Start-up companies formed since TTO's inception	Nominal, 0-20
LOE	Licenses and options executed in FY 2004	Nominal, 0-134
LOYI	Cumulative licenses and options yielding income	Nominal, 0-474

The number of invention disclosures, the number of patent applications filed, the number of patents issued, the number of start-up companies formed, the number of licenses and options executed, and the number of licenses and options yielding income data were only available via the AUTM's 2004 annual licensing survey[116]. Of the 81 respondent TTOs, data was available for 57 institutions. As a result, the analysis was split into two data sets depending on the number of independent variables available for each institution. Models for each of the 31 elements were constructed for both of the data sets available and are of the forms available in Table 28 below.

[12] This is defined as the year in which 0.5 Professional Full Time Employees was devoted toward technology transfer activities.

Table 28. Logistic Regression Model Forms for the TTO Survey Data

Full Data Set (n=81)	Partial Data Set (n=57)
$Logit[\pi_{hat}i] = \alpha + \beta_i x_i$ Where: $\pi_{hat\ i}$ = the 31 Technology Development Process Elements and x_1 = CARNEGIE and/or x_2 = EMP	$Logit[\pi_{hat}i] = \alpha + \beta_i x_i$ Where: $\pi_{hat\ i}$ = the 31 Technology Development Process Elements and x_1 = CARNEGIE and/or x_2 = EMP and/or x_3 = YEAR and/or x_4 = ID and/or x_5 = PAF and/or x_6 = PI and/or x_7 = SCF and/or x_8 = LOE and/or x_9 = LOYI

SAS statistical software version 9.1 was used to develop models for this study. The multiple logistic regressions[117] were performed using a stepwise procedure in which independent variables were entered into the model and removed from the model based on default significance levels of entry (α = 0.25) and exit (α = 0.10)[13]. Three of the 31 elements modeled were determined significant for the full data set; and three of the 31 elements resulted in significant models for the reduced data set, as shown in Table 29 below.

[13] These reflect the default values of SAS version 9.1 statistical software.

Table 29. Logistic Regression Models from the TTO Survey Data

Data Set	Critical Element	Model	R^2	p value
Full (n=81)				
	Evaluation of Potential Time to Market Requirements	–1.79 - 0.77 CARNEGIE 1 - 0.41 CARNEGIE 2	.156	.0160
	Funding Considerations	–0.42 + 0.42 CARNEGIE 1 + 0.29 CARNEGIE 2	.0796	.0923
	Target Customer Determination	–1.72 - 0.84 CARNEGIE 1 - 0.15 CARNEGIE 2	.1084	.0608
Partial (n=57)				
	Determination of Investment Required / Potential Profits	–3.64 + 0.07 YEAR	.1879	.0051
	Evaluation of Potential Time to Market Requirements	–1.99 + 0.03 LOE	.2042	.0023
	Financial Risk Assessment	1.06 - 0.40 YEAR + 0.38 SCF	.4385	.0043

Three significant models were found from the full data set. Although the models are significant (i.e., p-value < 0.10), they are relatively weak in terms of explaining variation (R^2 ranging from 0.0796 to 0.156). In general, the models presented in the table explain less than 16% of the variation. The first model (R^2 = 0.156) indicates that universities classified as RU / VH *Evaluate the Potential Time to Market Requirements* significantly more than those classified as Other with an odds ratio of 0.142 and RU / H with an odds ratio of 0.205. The odds ratios mean that the universities which are classified as RU / VH are 7.04 and 4.88 times more likely than Other and RU / H (respectively) to have *Evaluated the Potential Time to Market Requirements*. For the second model (R^2 = 0.0796), universities that are classified as RU / VH *Considered Their Funding Situation* significantly less than those classified as Other with an odds ration of 3.11 and RU / H with an odds ratio of 2.72. The odds ratios in this case indicate universities that are classified as Other and RU / H are 3.111 and 2.722 times, respectively, more likely than RU / VH to have chosen *Funding Considerations* as being one of their seven critical duties. For the third model (R^2 = 0.1084) constructed universities that are classified as RU / VH *Determined Their Target Customers* for the technology significantly more than those classified as Other with an odds ration of 0.16 and RU / H with an odds ratio of 0.321. These odds ratios mean that the universities which are classified as RU / VH are 6.25 and 3.12 times more likely than Other and RU / H, respectively, to have *Determined Their Target Customer* for the technology.

For the partial data set, three significant models emerged. The first of the three significant models (R^2 = 0.1879) indicated that the more established the TTO (YEAR) significantly influences whether or not the office *Determined the Investment Required and Potential Profits* after the invention's disclosure. The odds ratio for YEAR in this model was 1.069. This indicates that for each additional year of a TTO's existence the predicted odds of *Determining the Investment Required and Its Potential Profits* would increase by seven percent. The second significant model (R^2 = 0.2042) indicated that the number of licenses and options for FY 2004 (LOE) significantly influences whether an institution *Evaluated the Potential Time to Market Requirements*. The odds ratio for LOE in this model was 1.032. This indicates that for each additional license and option executed in 2004 the predicted odds of *Evaluation of Potential Time to Market Requirements* would increase by 3.2 percent. The third (and best) significant model (R^2 = 0.4385) indicated that YEAR and the number of start-up companies formed since the TTO's inception (SCF) significantly influenced whether the university *Performed a Financial Risk Assessment* on their technologies. The odds ratio for YEAR in this model was 0.673 and for SCF was 1.456. This indicates that for each additional year that the TTO has been existence the predicted odds of *Financial Risk Assessment* would decrease by 33 percent and that for each additional start up company formed the predicted odds of *Financial Risk Assessment* would increase by 45.6 percent.

Analysis 2 – Stepwise Linear Regression

A second set of regressions were investigated to determine if combinations of elements (additive in nature) had a relationship with the various organizational characteristics, and licensing and patenting statistics based on whether a particular office performs the specific elements. Again, the data sets were split into full and partial data sets depending on the number of dependent variables available for the participating TTOs. Models for both data sets are presented in Table 30 below.

Table 30. Linear Regression Model Forms for the Licensing and Patenting Statistics

Full Data Set (n=81)	**Partial Data Set (n=57)**
$y = \beta_0 + \beta_i x_i$ Where: y = CARNEGIE or y = EMP and x_1 - x_{31} = the 31 Technology Development Process Elements	$y = \beta_0 + \beta_i x_i$ Where: y = EMP or y = YEAR or y = ID or y = PAF or y = PI or y = SCF or y = LOE or y= LOYI and x_1 – x_{31}= the 31 Technology Development Process Elements

SAS statistical software version 9.1 was used to perform the analyses in this study. A stepwise procedure was used in which independent variables were entered into the model and removed from the model based on default significance levels for entry ($\alpha = 0.25$) and exit ($\alpha =$

0.10)[14]. Using the default significance levels; the following significant models resulted, as shown in Table 31 below.

[14] These reflect the default values of SAS version 9.1 statistical software.

Table 31. Linear Regression Models of the Licensing and Patenting Statistics

Data Set	Significant Variable	Model	Cum. R^2	p-value
Full (n=81)				
	EMP	7.65		
		– 3.90 Create Product Description	.0474	.0472
		+ 5.09 Evaluate Potential Time to Market Reqs.	.0897	.0657
Partial (n=57)				
	EMP	4.47		
		– 4.50 Create Product Description	.0742	.0306
		+ 8.17 Evaluate Potential Time to Market Reqs.	.1867	.0108
		+ 4.09 Evaluate Prior Art / Similar Patents	.2699	.0173
		– 9.44 Regulatory Certification / Compliance	.3296	.0360
	YEAR	11.50		
		+ 15.68 Determination of Investment Required / Potential Profits	.1375	.0045
		+ 9.34 Evaluate Potential Time to Market Reqs	.2238	.0176
		+ 8.19 Identify Primary Innovation	.3321	.0050
	ID	89.55		
		– 76.56 Create Product Description	.0810	.0205
		+ 155.82 Evaluate Potential Time to Market Reqs	.2323	.0028
		– 169.10 Regulatory Certification / Compliance	.2855	.0474
		– 94.57 Sales Forecasting	.3313	.0710
	PAF	87.69		
		– 65.77 Create Product Description	.0702	.0376
		- 48.99 Define the Market and its Growth Potential	.1159	.0793
		+ 132.94 Evaluate Potential Time to Market Reqs	.2121	.0195
		- 151.25 Regulatory Certification / Compliance	.2575	.0836
	PI	18.43		
		– 17.24 Create Product Description	.0620	.0435
		+ 38.28 Evaluate Potential Time to Market Reqs	.2159	.0025
		– 40.08 Regulatory Certification / Compliance	.2674	.0591
	LOE	18.89		
		+ 24.95 Determination of Investment Required / Potential Profits	.0419	.0785
		– 18.32 Determination of Product Positioning	.0845	.0700
		+ 28.48 Evaluate Potential Time to Market Reqs	.2476	.0018
		- 41.87 Regulatory Certification / Compliance	.3235	.0241
	LOYI	49.26		
		+ 72.91 Determination of Investment Required / Potential Profits	.0680	.0500
	SCF	2.30		
		+ 3.36 Evaluate Potential Time to Market Reqs	.0838	.0289
		– 5.17 Regulatory Certification / Compliance	.1365	.0751

For the full data set, only one model was created: EMP (the number of employees working at the TTO). Although the model is relatively weak ($R^2 = 0.0897$) it is still a significant model that explains ~9% of the variance using two elements. *Creating a Product Description* has a negative effect on the number of employees. (These models are identifying relationships, therefore, this indicates that universities that are *Creating a Product Description* have fewer employees that work in their TTO) and *Evaluating the Potential Time to Market Requirements* has a larger positive effect (meaning that universities that are *Evaluating the Potential Time to Market Requirements* have more employees that work in their TTO than those that do not identify this element as critical).

Models for each of the eight licensing and patenting statistics were constructed using the partial data set. For the number of employees in the TTO (EMP), a model was found with $R^2 = 0.3296$ that explains ~33% of the variance with four of the elements. *Creating a Product Description* and *Regulatory Certification / Compliance* have a negative effect on the number of employees and *Evaluating the Potential Time to Market Requirements* and *Evaluating Prior Art (Similar Patents)* have positive effects.

For the number of years that the TTO has been in existence (YEAR), a model was found with $R^2 = 0.3321$ that explains ~33% of the variance with three of the elements. *Determining the Investment Required / Potential Profit of the Product*, *Evaluating the Potential Time to Market Requirements* and *Identifying the Primary Innovation* all have positive effects indicating that the universities who are performing these three elements are typically TTOs that have been instituted for longer periods of time.

For invention disclosure filed (ID), a model was found with $R^2 = 0.3313$ (again, explaining ~33% of the variation) and consists of four elements. *Creating a Product*

Description, Regulatory Certification / Compliance and *Sales Forecasting* elements have a negative effect on invention disclosures and *Evaluating the Potential Time to Market Requirements* has a positive effect on the number of invention disclosures filed in FY 2004.

For patent applications filed (PAF), a model consisting of four elements was obtained with R^2 = 0.2575 (~26% of the variation in the number of patents applications is explained by the elements). *Creating a Product Description, Defining the Market and Its Growth Potential,* and *Regulatory Certification / Compliance* all have a negative effect and *Evaluating the Potential Time to Market Requirements* has a positive effect on the number of patent applications filed in FY 2004.

For patents issues (PI), a three element model was developed that that explains ~27% of the variance in the number of patents issued (R^2 = 0.2674). *Creating a Product Description* and *Regulatory Certification / Compliance* both have a negative effect and *Evaluating the Potential Time to Market Requirements* has a positive effect on the number of patent issued in FY 2004.

For the number of licenses and options executed (LOE), a four element model was found with R^2 = 0.3235. *Determination of Product Positioning* and *Regulatory Certification / Compliance* both have a negative effect and *Determining the Investment Required / Potential Profit of the Product* and *Evaluating the Potential Time to Market Requirements* have a positive effect on the number of licenses and options executed in FY 2004.

For the cumulative number of licenses and options (LOYI), a model was found with R^2 = 0.0680 (only ~7% of the explained variation) and consists of one element. Although the R^2 is low, explaining 7% of the variation with one parameter is worth mentioning. *Determining the Investment Required / Potential Profit of the Product* had a positive effect on the number of licenses and options yielding income in FY 2004.

Finally, for the number of start ups (SCF), a two element model explaining 14% of the variation was found (R^2 = 0.1365). Again, although the R^2 is low, explaining 14% of the variation with two parameters is notable. *Regulatory Certification / Compliance* has a negative effect and *Evaluating the Potential Time to Market Requirements* has a positive effect on the number of start-up companies formed since the TTO's founding.

6.2 CONCLUSIONS FROM STUDY TWO

Several conclusions can be made from Study Two. First, in bridging the "gap" between the TTO and academic inventors, the TTO survey revealed that the TTO does indeed fill the "gap" with respect to several critical elements that the academic inventors do not typically focus on, such as strategic issues and societal aspects (as found in Study One). However, of the 70 elements presented to the office managers, 20 were not indicated as critical to any respondents' offices. The majority (40%) of these elements was technological in nature (involving aspects of design and testing) and was found to be a focus of the academic inventor (Study One). Of the elements not indicated by the TTOs, only *Testing, Data Analysis, Evaluation and Reporting* (see Table 14, Chapter 5) was performed by all five academic inventors. *Product Risk Assessment, Actual Versus Planned Cost Evaluation, Final Financial Reviews, Evaluation of Insurance Risks due to Performance Errors,* and *Evaluation of Competitor Reactions* (see Table 15) were not performed by any of the academic inventors and were not identified as critical elements by any of the responding TTO managers.

Another area underutilized by the TTO was competitor aspects. Of the three competitor elements presented on the survey, few of the office managers considered the elements as critical.

Only *Competitor Benchmarking* was viewed as critical by ~11% of the respondents. Further, several strategic, financial issues and societal aspects were not selected by any respondents. Such items may be performed by a licensing company acquiring the technology, such as *One, Three and Five Year Product Plans, Final Financial Reviews,* and *Evaluation of Insurance Risks due to Errors*.

From the logistic regressions, several conclusions can be made. Three significant models were found from the full data set. They indicate that universities that are classified as RU / VH tend to *Evaluate the Potential Time to Market Requirements* and *Determine Their Target Customers* (both critical to 21%) for the technology more than the two other institution classifications; and such institutions also *Considered Their Funding Situation* (critical to 37%) less than the other two classifications. In addition, three significant models were found from the partial data set. They indicate that the longer a TTO's tenure the more likely they were to have *Determined the Investment Required and Potential Profits* (critical to ~10%) and the less likely they were to have *Performed a Financial Risk Assessment* (critical to 8.6%) after the invention's disclosure. The second significant model found the university's that *Evaluated the Potential Time to Market Requirements* had higher levels of licenses and options executed in FY 2004. The third model indicates that universities that *Performed a Financial Risk Assessment* on their technologies had larger numbers of start-up companies formed since the TTO's inception.

Further, investigation of the linear regression models reveals that four elements appeared in several of the models. *Evaluating the Potential Time to Market Requirements* appeared in eight of the nine models. Further, this element explained, on average, 11.5% of the variation in the models (minimum 4.2%, maximum 16.3%). This particular element appeared to contribute most, in comparison to the other elements, both in terms of the number of models, but also in the proportion of variation it contributed to the model. Interestingly, less than one-quarter (21%) of the respondents indicated that this element was critical to their TTO operations; yet, it had a positive effect on all but one of the success factors.

Three other elements are also worth discussion: *Creating a Product Description, Regulatory Certification / Compliance*, and *Determining the Investment Required / Potential Profit of the Product. Creating a Product Description* appeared in five of the nine models. This element was considered by over 25% of the respondents as a critical element, yet it has a negative effect on five of the TTO success factors. In addition, the average R^2 equaled 6.7% (minimum 4.2%, maximum 8.1%). Hence, this element, though present in over half the models, did not contribute to the same degree as the prior element, and it contributed negatively to the success factors; yet, it was considered by 25% of the respondents as critical to TTO operations. Similarly, *Regulatory Certification / Compliance* aspects of the product appeared in six of the nine models and also had a negative impact on the TTO success factors. Its average contribution to the variance in the success factors is 5.6% (minimum 4.5%, maximum 7.6%). However, unlike *Creating a Product Description,* only ~5% indicated the element critical to their TTO, so its importance is likely seen by the TTO as relatively non-critical. Finally, *Determining the Investment Required / Potential Profit of the Product* appeared in three of the models and has a positive impact on the TTO success factors. Its contribution to the variance in the respective success factors averages 8.3% (minimum 4.2%, maximum 13.8%). Roughly 10% of the TTOs considered this element as critical. Perhaps this element may be reconsidered as being more essential to TTO functions.

Further, 71% of all responding TTOs indicated that *Evaluating Prior Art (Similar Patents)* was critical to their organization. However, it appeared in only one of the nine models and in that model explained only eight percent of the variation in the number of employees, EMP. *Intellectual Property Awareness* was considered critical to ~72% of the responding TTOs, but did not contribute significantly to any of the models derived. This is also true for the *Licensing In/Out Considerations* element in which 63% of the respondents indicated it was a critical element. Though these two elements are widely used by more than half of the TTOs participating in the study, they do not appear to be contributing to factors associated as desired metrics by the AUTM.

7.0 DISCUSSION AND PRESENTATION OF ACADEMIC TECHNOLOGY DEVELOPMENT MODEL

This research investigated multiple perspectives of the academic technology transfer process utilizing a common technology development framework of elements. First, it examined the idea generation to protection process from the perspective of the inventor by investigating the differences and similarities between academic and corporate inventors. For this portion of the research, both interviewed sets of inventors had previously developed successfully patented inventions. Second, this research investigated the process from the perspective of the technology transfer office (TTO). In doing so, the elements selected by the TTOs were modeled to success factors and compared to the frequency in which they are used at institutions. A final perspective was to investigate the "gap" area between academic and corporate groups and how the TTO "fills" or does not "fill" this "gap." This section discusses this potential "gap" and provides a summary of the major conclusions and recommendations from the research through a model for academic technology transfer, as well as providing a discussion of the research contributions.

In addressing the first research question, the processes that the academic and corporate inventors utilized to develop an idea from opportunity identification to invention disclosure and beyond were clearly different, particularly in terms of the inventors' focus and their self-described "challenges". From the process maps (Study One Part I), corporate inventors focused more on the financial issues in the development process than did the academic inventors. In terms of technology development "challenges", the corporate inventors in the process mapping activity found strategic issues to be more problematic and societal aspects to be more time-consuming and problematic in the development of their invention.

Contrary to initial expectations, the underlying motivation for all the inventors investigated (Study One Part I and II) was to "advance the scientific body of knowledge". Secondary motivators included a personal challenge and performing their job description. This potentially reveals that a common intrinsic desire to pursue the advancement of science exists for both academic and corporate inventors and that the extrinsic financial or reward-based motivation is secondary. In this study, the majority of the technologies generated were of the continuous improvement type (or new solution to an existing problem). This finding parallels that of both Markides[118] and Reid & Brentani[119] who indicate that most innovations are incremental not radical.

Though most academic institutions and corporate organizations have offices for filing and previewing invention disclosures, Study One Part II found the entrepreneurial climate in the corporate setting to be more encouraging towards innovation than in the academic setting. The academic criticism possibly arises from "… the philosophy that universities are for teaching and research and not for the commercialization and financial benefits associated with developing new technology[120]."

Study Two highlighted that activities performed by the TTO were, indeed, not of the technical or competitive nature. These duties are primarily handled by the academic inventors' whose processes exhibit more technical elements as indicated from Study One Part I. Models were developed to establish potential relationships between the elements that the technology licensing managers use (and are critical to the functioning of their offices) and various organizational characteristics, as well as various patenting and licensing statistics (success factors) of the respondents' offices. From Table 25, it can be seen that the primary elements designated as critical by the TTO respondents are *Intellectual Property Awareness, Evaluate Prior Art (Similar Patents),* and *Licensing In / Out Considerations*. Surprisingly, none of these elements were identified by the regression models as having a significant influence on any of the success factors. These elements, although necessary to the mission and function of the TTO, where not found to be statistically critical to its success; rather they are core elements of any TTO. Although *Determination of Investment Required / Potential Profit* and *Evaluation of Potential Time to Market Requirements* were not widely cited as critical, they were found to have a positive effect in multiple success factor models. Further, *Creating a Product Description* was found to have a negative effect on a majority of the models; however, it was considered a critical element by a quarter of the TTO managers.

Recall from Table 14 and Table 15 (Study One, Section 5), only four elements were used by all corporate inventors but none of the academic inventors: *Defining the Market and Its Growth Potential, Product Use / Knowledge Dissemination, Actual Versus Planned Cost Evaluation*, and *Determination of Changing Customer Needs / Market Requirements*. This investigation found that the TTOs were focused on assisting the academic inventor or filling the "gap" in terms of strategic issues such as *Defining the Market and Its Growth* Potential. Half of the respondents (50.6%) identified this particular element as being one of their seven critical duties. However, little assistance was being offered in terms of the other three financial and societal elements (2.5%, 0%, and 9.9%, respectively); hence, TTOs are not contributing to the technology development process with regards to these elements. Roughly 15 percent of TTOs assisted their inventors in terms of *Product Marketing, 3 C's, 4 P's,* an area not utilized by any of the five academic inventors in Study One.

In addition, less than 5% of the respondents' offices performed *Creating a Product Financial Plan, a Product Risk Assessment, a Product Advertising Plan, Product Use / Knowledge Dissemination, Actual Versus Planned Cost Evaluation,* and *Evaluation of Competitor Reactions.* These were elements used by four or five of the corporate inventors, but none of the academic inventors. Certainly several of these elements are out of the intended scope of the mission of the academic process as some of the elements are directly related to physically selling a particular product and thus would be the responsibility of the licensing company. However, a few elements are worth discussion as to whether or not a TTO should include them in their scope of activities.

Tying together the two studies, there is an overall lack of commonality of the particular elements that the inventor groups (Study One Part I and II) identified as being critical, time-consuming and problematic. This leads to the belief that the technology development process is diverse in terms of how individual inventors traverse the process, but also in how certain aspects of the process can be perceived to be more important than others. The analyses conducted as part of this research revealed areas of similarity and differences between academic and corporate inventors in the process of technology development. Without question, the academic inventors used significantly less elements than their corporate counterparts. This by itself is not necessarily a problem as one could view comparing the technology development processes of academic and corporate inventors likened to comparing "apples to oranges". Inherently they are different based on their affiliated organization's mission and attitude towards innovation as addressed by some of the secondary research questions. However, it is important for the institution's TTO to aid academic inventors via those elements that are important to producing licenses, patents, etc.; hence, a purpose for this research. As noted from Study One Part I, their appears to be a "gap" in the overall academic process (both inventors and TTO) with regards to specific non-technical elements such as *Financial Risk Assessment*, *Determination of Investment Required / Potential Profit* and *Evaluation of Potential Time to Market Requirements*. (Coincidentally, these elements were rarely utilized by the academic inventors, but were found to have positive relationships to the success factors in Study Two). Two final elements, *Creating a Product Description* and *Regulatory Certification / Compliance*, were found by the corporate inventor as being "challenges" and found in Study Two to have a negative influence on the success factors. The underlying reason for the negative impact of *Creating a Product Description* is unclear, but it is possible that excessive time and energy is spent on this activity and possibly should be spent elsewhere. *Regulatory Certification / Compliance* is not an element that can be neglected, but perhaps better guidance from the TTO could alleviate some of the negative impact on the statistics.

The findings of the inventor studies coupled with the results revealed from the TTO study can provide TTOs with guidance to better facilitate academic inventors in their technology development ideas. The next section will provide an academic technology development model that can be utilized not only by academic inventors, but also by new and existing TTOs. Incorporating the elements available in the model into the development process will enhance the process potentially allowing more patentable technologies to arise from academia.

7.1 THE ACADEMIC TECHNOLOGY DEVELOPMENT MODEL

The primary objective of this research was to *determine the areas where university technology transfer offices can potentially aid the academic inventor in furthering his / her invention disclosure to the point where it is a licensable, patentable technology.* The results of this research reside in the creation of an academic technology development model, as provided in Table 32. This model can be used to assist the academic inventor and the university TTO possibly streamlining the development process; and hence, potentially advancing invention disclosures towards becoming licensable, patentable technologies.

Table 32. Academic Technology Development Model

Opportunity Identification	Design & Development	Testing & Preproduction	Introduction & Production	Life Cycle Management	Ongoing
Preliminary Research (T) Define the Product Scope / Statement of Work (St) Define Product's Performance Requirements (T) Intellectual Property Awareness (St) Funding Considerations (F) Determination of Investment Required / Potential Profit (F) Define the Market and Its Growth Potential (St) Evaluate Potential Time to Market Requirements (T)	Optimization of Detailed Design (T) Evaluate Prior Art (Similar Patents) (So) Licensing In / Out Considerations (St) Identify Primary Innovation (St) Customer Needs Analysis (So)	Testing, Data Analysis, Evaluation, and Reporting (T)	Actual Versus Planned Cost Evaluation (F)		Documentation of Design Work in Technical Memorandums (T) Schedule / Cost / Technical Performance Summaries (St) Determination of Changing Customer Needs / Market Requirements (So) Orange – Elements designated as responsibility of academic inventor Blue- Elements designated as responsibility of technology transfer office Green – Elements designated as responsibility of academic inventor and / or technology transfer office **Legend** **T – Technological** **St – Strategic** **F – Financial** **So – Societal**

This model represents the important elements established in Study One and Two – those found to be either critical by the academic inventors or positive influencers to licensing and patenting statistics. Because of its relatively small size (i.e. it contains less than 15% of the elements from the overall framework), it is feasible to implement; consequently it can be used independent of the size of the TTO. Further, the breadth of coverage contained by the model is manageable.

The highlighted orange elements in Table 32 are designated the responsibility of the academic inventor. The elements highlighted in blue would likely be the duties staffed by the TTO. Lastly, the green highlighted elements can serve as tasks that can be conducted by either the academic inventor or the TTO, as these elements potentially overlap between the two entities.

The justifications for including the elements in the academic technology development model are available in Table 33. The 18 elements present were found to be: (1) critical in the inventor concept mapping approach (used by all of the academic inventor or used by all the corporate inventors and none of the academic inventors), (2) critical to the corporate inventors, (3) critical to the responding TTO managers, and / or (4) significant to the licensing and patenting success factors. As indicated by the table, some elements have multiple justifications.

Table 33. Academic Model Element Justification

Stage	Element	All Academic Maps	All Corporate Maps; No Academic Maps	Critical to TTO Managers	Critical to Corporate Maps	Positive Impact to Success Models
1	Preliminary Research	X				
1	Defining the Product Scope/Statement of Work	X				
1	Define Product's Performance Requirements	X				
1	Intellectual Property Awareness			X		
1	Funding Considerations			X		X
1	Determination of Investment Required/Potential Profits			X		X
1	Defining the Market and Its Growth Potential		X	X	X	
1	Evaluate Potential Time to Market Requirements			X		X
2	Optimization of the Detailed Design, Testing	X				
2	Evaluating Prior Art (Similar Patents)			X		X
2	Licensing In/Out Considerations			X		
2	Identifying the Primary Innovation			X		X
2	Customer Needs Analysis				X	
3	Testing, Data Analysis, Evaluation and Reporting	X				
4	Actual versus Planned Cost Evaluation		X			
On-Going	Documentation of Design Work in Technical Memorandums	X				
On-Going	Schedule/Cost/Technical Performance Summaries	X				
On-Going	Determination of Changing Customer Needs/Market Requirements		X			

In order to abstract benefit from the model, the eighteen elements should be implemented in some fashion as both the academic inventor and TTO traverse the process from idea generation to protection. The following sections will provide recommendations for how to best implement the elements.

7.1.1 Implications for the Academic Inventor

Certainly, the academic technology development process is initiated with *Preliminary Research* performed by the academic inventor. Logically, *Preliminary Research* includes technical journal reviews to document the existing technologies to ensure that the idea or technology was not previously developed as well as other preliminary research conducted by the inventor. In many cases, if not all, the inventor is an expert in the particular technology and on the forefront of research in the area. A next step is to clearly *Define the Product Scope / Statement of Work*. By clearly scoping the work, the inventor defines aspects to advance the technology. If the technology is being funded by a funding agency such scope has already been created and likely needs to be culled for patenting purposes.

Definition of the Product's Performance Requirements includes a list of necessities generated for the potential technology and product to ensure that the technology can perform as intended. This list is coupled to *Testing, Data Analysis, Evaluation and Reporting* of the technology, as it documents and verifies that the technology is meeting the product's performance requirements. An outcome of the testing phase is the *Optimization of the Detailed Design*, which ensures the technology satisfies the performance requirement demands by effectively minimizing resources. *Schedule, Cost and Technical Performance Summaries* should be completed throughout the development process by the academic inventor. These periodic reviews guarantee that the technology is developed within the scheduled amount of time, under the initially proposed budget constraints while satisfying the product's performance requirements. The final suggested step for the academic inventor is the clear *Documentation of the Design Work in Technical Memorandums*. A primary goal of academic research and development is the advancement of the scientific body of knowledge (supported by this research). By documenting the work that is completed and publishing in technical journals, the technology is shared with the academic and related scientific community. As indicated, funded research often requires such elements be conducted via funding requirements.

7.1.2 Implications for the Technology Transfer Office

A new TTO potentially benefits from this model by assigning their limited resources to the elements provided above in blue. Existing TTOs can gain efficiency by reevaluating their existing process and, where necessary, incorporating the stated critical elements. The overall legal responsibility to *Evaluate Prior Art (Similar Patents)* is normally conducted by the TTO upon invention disclosure. This ensures that the development being performed is not infringing on any existing patents. Equally, the TTO is the entity at an institution that informs all parties on the *Awareness for Intellectual Property*. This will come into play once the technology is being discussed with resources outside of the university setting. Many times technologies are developed jointly from within the university and possibly outside of the university with local companies or other universities. The TTO is typically responsible for monitoring the situation to protect all parties. A critical element is the *Identification of the Primary Innovation.* Often the academic inventor is rightfully engrossed in the development to clearly define the primary innovation. One of the TTOs most important responsibilities is to determine what aspect of the technology is the most critical to protect. Combining the *Evaluation of Prior Art (Similar Patents)* and *Intellectual Property Awareness* with the *Identification of the Primary Innovation* is the key contribution of the TTO and is critical to its mission.

There also exists a financial side to the TTO's responsibilities. *Funding Considerations* must be acknowledged by the TTO; and is done by determining how much additional capital is required to further an invention disclosure to the point where it is ready for patenting and potential licensing. The *Determination of Investment Required / Potential Profits* should be done in accordance with *Funding Considerations* to determine if the potential profits will outweigh the investment required. Finally, *Licensing In / Out Considerations* should be completed to determine if additional technologies should be licensed in to better the technology or if the technology would be better licensed out and utilized by an existing company in their endeavors. The realization of these six elements will notably impact the overall success of the TTO.

7.1.3 Implications for Both the Academic Inventor and the Technology Transfer Office

Certainly, there exist elements that can be conducted by either the academic inventor or the TTO. For instance, in the development of a technology, some customer elements (*Customer Needs Analysis*, *Defining the Market and its Growth Potential*, and Determination *of Changing Customer Needs / Market Requirements*) should be considered during development to verify that there is or will be a market for the technology. By realizing who potentially would utilize the technology may be of use to the academic inventor. However, TTOs may become more proactive in their approach once an invention disclosure has been filed, at which time they can begin to assess the market and customer needs; while the academic inventor can begin to incorporate additional customer needs and requirements into the development of the technology. By *Determining the Market and its Growth Potential*, the TTO can assist academic inventors in meeting specific needs and desires of the prospective customer and market.

Evaluating the Potential Time to Market Requirements is critical for both the academic inventor and the TTO. If the development time is too lengthy to incorporate the technology into a viable upcoming product, competitors may likely challenge the technology's introduction.

Though a management function headed by the TTO, time to market is a critical patenting/licensure aspect that requires both party's involvement. Finally, an *Actual Versus Planned Cost Evaluation* should be completed by the TTO with the help of the academic inventor. The inventor is expectedly tracking some facets through their *Schedule*, *Cost and Technical Performance Summaries*, but actual cost of technology implementation might not be the same as the planned cost of implementation.

In summary, this eighteen element academic technology development model represents a baseline model for academic idea generation and protection. Obviously other elements may be necessary to the development process. As indicated, the process is unique to the inventor and invention; however, in meeting an objective goal of patenting and licensing, this model provides a set of critical elements necessary for the process.

7.2 CONTRIBUTIONS

There are two underlying areas of contribution resulting from this research. The first involves the descriptive study[121] comparing academic and corporate inventors in terms of the particular processes utilized in developing patentable technologies (specific to successful patented technologies in RFID). There is no question that the two processes are inherently different, but the determination of how and where they are different (and similar) is an essential outcome of Study One of this research. The second underlying contribution involves the investigation of particular elements acknowledged as critical to the function of the technology transfer office. The identification of relationships between the critical elements and the overall success of a university's TTO in terms of the patenting and licensing statistics provides new information about how certain TTOs achieve success.

Because both studies were conducted using a common framework of elements found in large part, from the literature surrounding product development, combining the contributions of the two studies (i.e., technology development and technology transfer) leads to a third contribution. There is a gap in the literature with respect to what particular activities TTOs effectively use to aid academic inventors that eventually lead to patent and the transfer of innovative technologies to the public sector. An *overarching* contribution of this research is the identification of critical elements needed for patenting and licensing. These are depicted through the academic technology development model. The incorporation of the elements present in the model into the processes of both new and existing TTOs potentially stimulates the quality and quantity of the number of licensable, patentable technologies arising from academia. *Evaluating*

Prior Art (Similar Patents), *Licensing In / Out Considerations* and *Identifying the Primary Innovation* are inherent and integral to the mission of the TTO. *Defining the Market and its Growth Potential* and *Evaluating Potential Time to Market Requirements* are not nearly as intuitive, but should certainly be a focal point of the academic inventor as well as the TTO. The proper implementation of these eighteen elements by the academic inventors with mentoring and guidance from the TTO will elevate the value of technologies and corresponding licensing agreements and options from academia. This, in turn, will have a potential influence on regional economic growth. Economic growth is a vital statistic for many cities; and several cities have experienced declines in population[122 & 123] that is attributed to poor local job markets[15]. Universities can be instrumental in promoting such regional economic growth.

[15] For example, the population of Baltimore has decreased by 11.5% between 1990 and 2000 and its unemployment rate ranks 3rd highest of the 50 largest metropolitan cities at 8.1%. In comparison, the population of Austin has increased by 41% during this same time, while its unemployment rate ranks lowest of the 50 largest cities at 2.2%.

8.0 FUTURE RESEARCH

Study One was small and focused on RFID and related technologies. The future of this body of research would benefit from expanding the study to more academic and corporate inventors whom are developing technologies residing in varying fields. This would be done in order to see if commonalities exist in terms of the elements utilized, focus and "challenges" across multiple disciplines. Cross-discipline similarities will add impact to the findings of this research and truly identify the elements that are the most significant to the technology development process regardless of the technological area.

The inventors whom participated in this research were all considered to be successful. They each obtained a patent on a technology that they developed. The next major step in this research would be to investigate the processes used by inventors that were unsuccessful in their development utilizing the literature based framework used in this research. A comparison between the elements utilized, the inventors' focus, and the elements identified as "challenges" by the successful and unsuccessful inventors could then be investigated. The identification of differences could be critical to the future "success" of inventors.

Critical to the findings of this research would be an in-depth examination of how TTOs can assist academic inventors in terms of *Financial Risk Assessment, Determination of Investment Required / Potential Profit, Evaluation of Potential Time to Market Requirements, Determining the Market and its Growth Potential and Evaluating Prior Art (Similar Patents),* to name a few. These elements were found to have significant impact on the success factors; and the incorporation of these elements into the idea generation/protection process could benefit the technology being developed.

APPENDIX A

DEFINITIONS OF PROCESS MAPPING TILES

Actual Versus Planned Cost Evaluation – Financial considerations comparing the planned cost of the product versus the actual cost of the product.

Alpha/In-house Testing – A crucial "first look" at the initial design, usually done in-house. The results of the Alpha test either confirm that the product performs according to its specifications or uncovers areas where the product is deficient.

Anticipate Competitor Responses – Being aware of what competitors may do in various situations.

Beta Testing – A more extensive test than the Alpha, performed by real users and customers. The purpose of Beta testing is to determine how the product performs in an actual user environment.

Choose Product Design From Multiple Alternatives – If multiple alternatives are conceived, one will be chosen to undergo further development.

Competitor Benchmarking – Evaluating similar (fulfills same purpose) products from your competitors.

Concurrent Engineering Principles – A systematic approach to the integrated, concurrent design of products and their related processes, including manufacture and support. This approach is intended to cause the developers, from the outset, to consider all elements of the product life cycle from conception through disposal, including quality, cost, schedule and user requirements.

Conjoint Analysis of Customer Needs - A methodology for exploring and describing subjective customer views of product features. Conjoint analysis avoids direct questioning, e.g., "what do you think of the price of our product?" Instead, the customer is asked what they are willing to pay for a particular product feature. Thus, the real buying situation with consideration of different cost-benefit alternatives is simulated.

Consideration of Product Service Opportunities – Will the product need regular maintenance, does it have replaceable parts, etc?

Construct a House of Quality - The House is divided into several rooms. Typically you have customer requirements, design considerations and design alternatives in a 3 dimensional matrix to which you can assign weighted scores based on market research information collected.

Continuous Competitor Monitoring – Constant monitoring of the competition to see if they are introducing a similar product.

Corporate Infrastructure Changes – Based on the product’s development, will the infrastructure change? Will the company create a new division based on this technology?

Corporate Strategy Change – The company’s strategy, mission or goals change during development therefore affecting product’s development.

Cost Estimate Projections – Part of a larger financial plan where costs are estimated for parts, personnel, facilities, etc.

Create a Part Sourcing / Partnership Plan – An element of supply chain management; this is the upstream end where product parts maybe outsourced instead of produced.

Create a Product Financial Plan – Full scale financial analysis, including personnel, facilities, other overhead, component costs, production and labor costs, warranty costs, additional funding required, and then the financial outcomes such as ROI, etc.

Create a Schedule for the Product – Adding the time element to the statement of work, the order in which things will be done, completion time, etc.

Create Communication Plan Among Team Members – Communication plan for the team so that all members are kept abreast of the product's design, features, etc.

Create Communication Plan For Briefing Management – How will product information be disseminated to upper management, how will approval be achieved, etc.

Create Product Description- Describing the intended product, its uses, and functionalities, physical and technical characteristics.

Creation of Operational Data Management System – Creating a database or file keeping system whereby all members of development team are kept up-to-date on the current design, features, functionality, etc.

Customer Feedback Evaluation – Gathering customer feedback on the product, what additional features would they like, what they dislike, this can be done both during and after development.

Customer Needs Analysis – Once the target customer has been established, the customers needs must be realized so the intended product will satisfy them and create a market for sales.

Customer Service and Logistical Support Development – Establishment of customer support channels whereby they can get feedback if they are having problems operating the product.

Define Product's Performance Requirements – Defining the various performance levels the product is to be able to withstand.

Define the Market and Its Growth Potential – Who will this product be marketed too and how will this market grow?

Define the Product Scope / Statement of Work – Defining all of the steps of the development process, what will be done, etc.

Design For Assembly – Refers to the principles of designing assemblies so that they are more manufacturable. DFA principles address general part size and geometry for handling and orientation, features to facilitate insertion, assembly orientation for part insertion and fastening, fastening principles, etc. The objective of DFA is to reduce manufacturing effort and cost related to assembly processes.

Design For Automation – Incorporating into the design, considerations so that the product could produced, assembled, packaged, etc via an automated process using machines instead of people.

Design For Environment (Is Product Recyclable, Reusable, Reducible, Disposable?) – Process for the systematic consideration during design of issues associated with environmental safety and health over the entire product life cycle. DFE can be thought of as the migration of traditional pollution prevention concepts upstream into the development phase of products before production and use.

Design For Manufacturability – Optimizing a product's design to make its parts more manufacturable (fabrication). DFM includes: understanding the organization's process capabilities, obtaining early manufacturing involvement, using formalized DFM guidelines, using DFM analysis tools, and addressing DFM as part of formal design reviews.

Design Manuals Written – Documentation for the design, how it works, with what parts, etc.

Design Modifications – Design changes occurring throughout the design process.

Design Review(s) – Design reviews are formal technical reviews conducted during the development of a product to assure that the requirements, concept, product or process satisfies the requirements of that stage of development, the design is sound, the issues are understood, and the risks are being managed. Typical design reviews include: requirements review, concept/preliminary design review, final design review, and a production readiness/launch review.

Determination of Changing Customer Needs / Market Requirements – Considerations for existing products to be updated and developed based on changing customer needs and market requirements and how in the future changing needs will impact the sales of the product.

Determination of Investment Req. / Potential Returns – Investigation into the investment required and the potential returns on investment (ROI).

Determination of Product Cost – This is the initial target cost whereby the design should meet or fall below this threshold.

Determination of Product Phase-out / Divestment- Considerations into when the product should be phased out of divested based on diminishing returns.

Determination of Product Positioning / Segmentation – How will this product be positioned against its competitors, does it fulfill any additional needs, is it segmented from the existing competitors/market?

Determination of Product Retail Price – Based on benchmarking, forecasting, marketing and advertising, determination of the product's retail price.

Develop a Human Resources Plan- Do additional people need to be hired, new positions created?

Develop a Product Manufacturing Plan – Development of the theoretical process by which the product could be produced in full scale production.

Develop a Work Breakdown Structure – Dividing the development into subsections whereby individual team members get smaller pieces to work.

Develop Peripheral Innovation(s) – Once the first innovation has been developed, further innovation can be incorporated to further the product's capabilities, etc.

Documentation of Design Work in Technical Memos – Formally documenting design work, testing, etc. in written communication to other members of the development team.

Documentation of Lessons Learned in Development – Refers to specific lessons that are experienced, learned, and captured or knowledge that is gained during the execution of a project or activity. Lessons learned are captured and documented for others in the organization to learn from, use to improve their performance on a project, and avoid repeating with negative consequences.

Ergonomic Evaluation – Considering if the product is ergonomically appropriate for the targeted customer in their application.

Estimate / Predict Customer ROI – Determining what the customer's return on investment will be based on the product, if applicable.

Evaluate Potential Time to Market Requirements – How long will it take to develop the product?

Evaluate Prior Art (Similar Patents) – Investigate to see if the technology or similar technologies have already been developed by others to avoid wasting time.

Evaluate Product's Mesh With Corporate Vision, Mission, and Objectives – Does the product being developed make sense given the companies vision, mission, and objectives?

Evaluation / Selection of CAD Tools – Studying and deciding which Computer Aided Drafting tools to utilize to develop the product.

Evaluation of Competitor Reactions – Being aware during development and as product is released, how the competitors are reacting.

Evaluation of Insurance Risks due to Performance Errors – Will the developer be held liable for any faulty products because the product has malfunctioned?

Final Design Approval – The point where the final design has been decided and pilot and full scale production considerations can begin.

Final Financial Reviews (Ratio, Overhead, etc.) – Design is chosen and product ready for full scale manufacturing, finances are re-evaluated to ensure economic viability including considerations for overhead, etc.

Finalization of Technical and Physical Requirements – Setting in stone all of the requirements (technical and physical) that the final product must adhere too.

Financial Risk Assessment- Evaluating the financial and risk possibilities of developing, introducing the product.

Forces of Nature, Effect on Development - Unforeseen natural disaster/problems that arose during development that caused a delay.

Full Scale Operational Testing and Evaluation - Testing to see how full scale production of the product works, identifying and ensuring that production would be possible within proposed cost targets.

Funding Considerations – How will the product be funded, internal, external, investors, angels, etc.

Gamma Testing / Actual User Testing – An evaluation of the product itself and its marketing plan through placement of the product in a field setting. Another way of thinking about this is to view it as an in-market test using a real distribution channel in a constrained geographic area or two, for a specific period of time, with advertising, promotion and all associated elements of the marketing plan working.

Generate Multiple Product Alternatives – Based on customer needs, various product alternatives can be generated fulfilling the needs in different manners.

Identify Litigation Issues and How to Avoid Them – If there are elements of the product that are already patented, can you work with the other inventor to license the technology to avoid litigation.

Identify Primary Innovation – Establish the primary innovation of the idea or concept.

Identify Potential Future Innovations – From the first innovation, looking ahead into the future to see how the current innovation can be expanded to other applications.

Incorporate Available Technologies to Improve Functionality, Safety, Etc. **–** Using computer based software packages to improve design, rapid prototyping, etc.

Individual Brainstorming – A creativity technique in which a person thinks of ideas related to a particular topic, listing as many possible ideas as possible before any critical evaluation of the ideas is performed.

Intellectual Property Awareness – Being aware that what is being developed may contain intellectual property.

Interaction With Support Groups – Meeting or Interacting with external groups that could aid in the development or bring to mention items not previously considered.

Licensing In Considerations – If elements of other products can be incorporated, consideration of licensing the technology to better the product.

Licensing Out Considerations – If elements of the product can be better utilized if you license the technology to someone else or if you decide that you no longer want to pursue the technology, it might be beneficial to license to someone interested in taking it further.

Life Cycle Cost Analysis – The total cost of acquiring, owning, and operating a product over its useful life. Associated costs may include: purchase price, training expenses, maintenance expenses, warrantee costs, support, disposal, and profit loss due to repair downtime.

Limited Rollout / Test Marketing – Introducing the product to various potential markets to see how the product is received, if users like it, want other functions, etc.

Modeling and Simulation to Study Design – Computer based modeling to study various situations the product might encounter, e.g. Stress, strain, fatigue, pressure.

Multifunctional Team Development – Gathering a team of various backgrounds and expertise's to aid in the development of the product.

One, Three and Five Year Product Plans – Plans for where the product should be in one, three and five years from the present. Including whether the technology can be expanded to a full business line, etc.

Operator/Training/Assembly/Maintenance Documentation – Preparation of documentation for production line workers, assemblers, packagers, and maintenance personnel for pilot and full scale production.

Optimization of Conceptual Design – Ensuring all features of conceptual design are theoretically optimized for performance.

Optimization of Detailed Design - Ensuring all features of detailed design are optimized for performance, cost.

Part/Product Cost Reduction – Analyzing design to see if the product can be make for less money. This may include reducing piece thickness while maintaining the same performance characteristics.

Patent Filing Initiated – Legal course of action has begun for filing of the patent application

Patent Prosecution – Work involved applying and obtaining the patent.

Pilot Scale Operational Testing and Evaluation – Testing to see how small scale production of the product works, identifying and ensuring that full scale production would be possible.

Preliminary Research – Initial research into possible technology areas.

Pretest/Pre-Launch Forecasting – Prior to product launch, further sales forecasting is conducted to establish market and sales estimates.

Produce 2-D and 3-D Drawings – Includes hand sketches up to un-scaled CAD drawings.

Product Advertising Plan – Developing an advertising plan that will promote the product and its functionality.

Product Bill of Materials – A hierarchical list of subassemblies, components and/or raw materials that make up a higher-level component, assembly, product or system. An engineering BOM represents the assembly structure implied by the parts lists on drawings and drawing tree structure. A manufacturing BOM represents the assembly build-up the way a product is manufactured.

Product Component Tradeoffs and Optimization – Optimizing the product component materials to minimize cost without losing any of its technical performance qualities.

Product Design to Meet Government Mandate / Requirements – Product is being designed to satisfy a new government mandate or new regulatory requirements.

Product Feature Determination – Determination of features necessary to satisfy customer needs.

Product Functional Analysis - Testing either an element of or the complete product to determine whether it will function as planned and as actually used when sold.

Product Marketing 3 C's, 4 P's – The process of planning and executing the conception, pricing, promotion, and distribution of ideas, goods, services, organizations, and events to create and maintain relationships that will satisfy individual and organizational objectives, Product, Place, Promotion, Price and Cost, Convenience, Communication and Customer Satisfaction.

Product Meets Actual User Needs – Considerations for whether the product being developed actually meets the customers needs.

Product Need Determination Based on Development Lead Time – Based on the product's development time, will there still be a need for the product when it is ready to be introduced.

Product Packaging and Protection – Considerations into how the product will be packaged and protected while being delivered to the customer.

Product Quality Reviews TQM, SQC – Incorporating into the production process quality control techniques to ensure that the products that are being produced are of expected quality.

Product Risk Assessment – Analyzing other ways in which the product could be used and ensuring that the user could not get hurt by the product.

Product Use / Knowledge Dissemination – If the product is new or unfamiliar, how will the product be introduced to the customer, e.g. tradeshow, word of mouth, demonstrations, etc.

Product Warranty – Considerations about what the product's warranty will cover and how it returns will be handled.

Production Line Design and Setup – After pilot scale production has been completed, physically setting up the production facilities layout, number of machines and personnel considerations.

Production Pilot Review – Pilot scale production is reviewed to see if changes should be made in the design/product based on physically producing (greater than one is created) the product.

Proposed Design within Target Costs – Check to ensure the design is within target cost estimates.

Prototype Development – Creating computer based models of the product that can be transferred into a physical prototype via any prototyping technique (soft, hard, rapid).

Prototype Review – Prototype is reviewed to see if changes should be made in the design/product based on physically creating (one is created) the product.

Prototype Testing – Preliminary testing to see if the product works.

Quality and Process Reviews – Once production has begun, ensuring that product quality is up to standards and that the process is functioning as intended.

Quality Function Deployment - A structured planning and decision-making methodology for capturing customer requirements (voice of the customer) and translating those requirements into product characteristics, part characteristics, process plans, and quality/process control requirements using a series of matrices.

Reaction to Customer Response - Being aware after market introduction how the customers are reacting, do they like it, do they want it to do more/less.

Refine Tests and Models – Changing testing methods and models to incorporate new elements in the design.

Regulatory Certification / Compliance- If the product being developed has certain impacts on humans, certification or governmental compliance may be necessary.

Reliability Testing, Test to Failure, Limit Testing – Testing that includes trying to make the product fail, making sure the product doesn't fail upon x number of uses, and that the product functions safely under all possible operating conditions.

Re-scope Development Team – During development the adding or subtracting of team members after the requirements have changed.

Resource Requirements – How many people, how much money, how much time are necessary to develop this product to its full requirements and specifications.

Reverse Engineering Protection – Incorporating elements into the design to aid in the prevention of outsiders being able to reverse engineer the product.

Sales Forecasting – Predicting the future sales of the product so manufacturing processes can be determined; finances can be calculated such as break even point, etc.

Schedule / Cost / Technical Performance Summaries – Periodic examinations into whether the schedule, product cost and the product's technical performance are within desired specifications.

Site Surveys / Installation Considerations – Visiting sites where the product will be utilized or installed and verifying that the product will work once installed.

Situational Analysis - The process of examining the environment for which a product is to be developed and the application of that product in that environment.

Software Development – Developing software for product or computer interface.

Sought Guidance From Outside Sources (Experts) – Consultation with experts about product design choices/options.

Staffing Level and Turnover Considerations – Considering whether development could be completed with current staffing levels and whom should become part of the development team.

Stakeholder Analysis – Considering all persons involved (both directly and indirectly) in the introduction of the product.

Strength, Weakness, Opportunity, Threat (SWOT) Analysis – Process where by a group of people determine: a) what strengths do we have? (how can we take advantage of them?); b) what weaknesses do we have? (how can we minimize them?); c) what opportunities are there? (how can we capitalize on them?); d) what threats might prevent us from getting there? (consider technical obstacles, competitive responses, values of people within the organization, etc.). For every obstacle identified, what can we do to overcome or get around it?

Supply Chain Management – The procurement, stocking and distribution of components, subassemblies and products throughout the design, manufacturing, and distribution stages, ensuring that the correct components, subassemblies and products are delivered to their appropriate destination at the proper time, the lowest overall cost, and acceptable quality levels.

Target Customer Determination – Selecting the target customer for the product.

Team Brainstorming- A creativity technique in which a group of people think of ideas related to a particular topic, listing as many possible ideas as possible before any critical evaluation of the ideas is performed.

Technical Problems Arising During Development – Unforeseen technical problems that arose during development that caused a delay.

Technical Risk Assessment – Ensuring that the product fulfills its purpose without endangering the user.

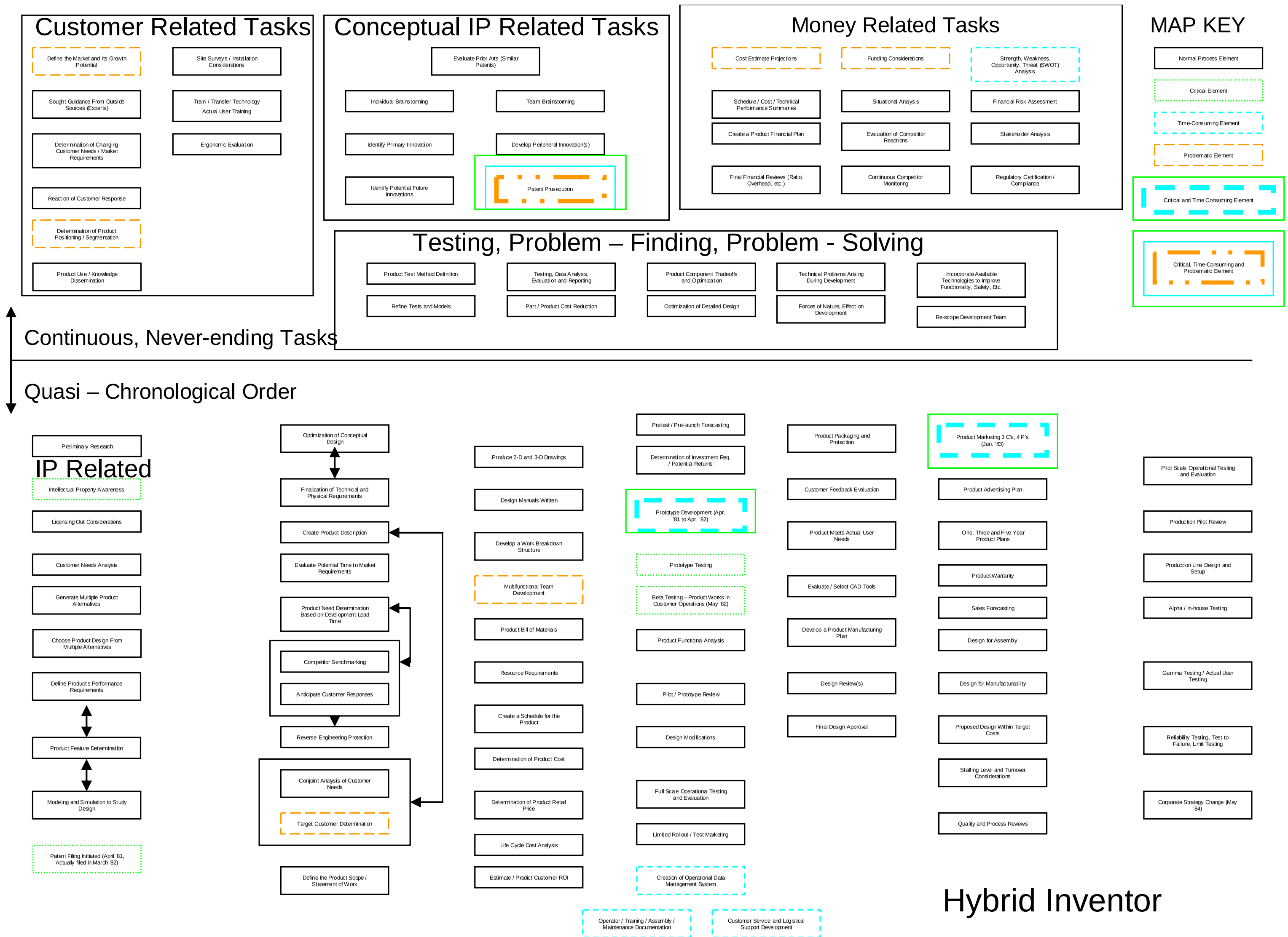
Testing, Data Analysis, Evaluation and Reporting – Physical testing of the product by any of the various testers (alpha, beta, gamma), analyzing the results of the test, evaluating, reporting to the designers and then making appropriate changes to design if necessary.

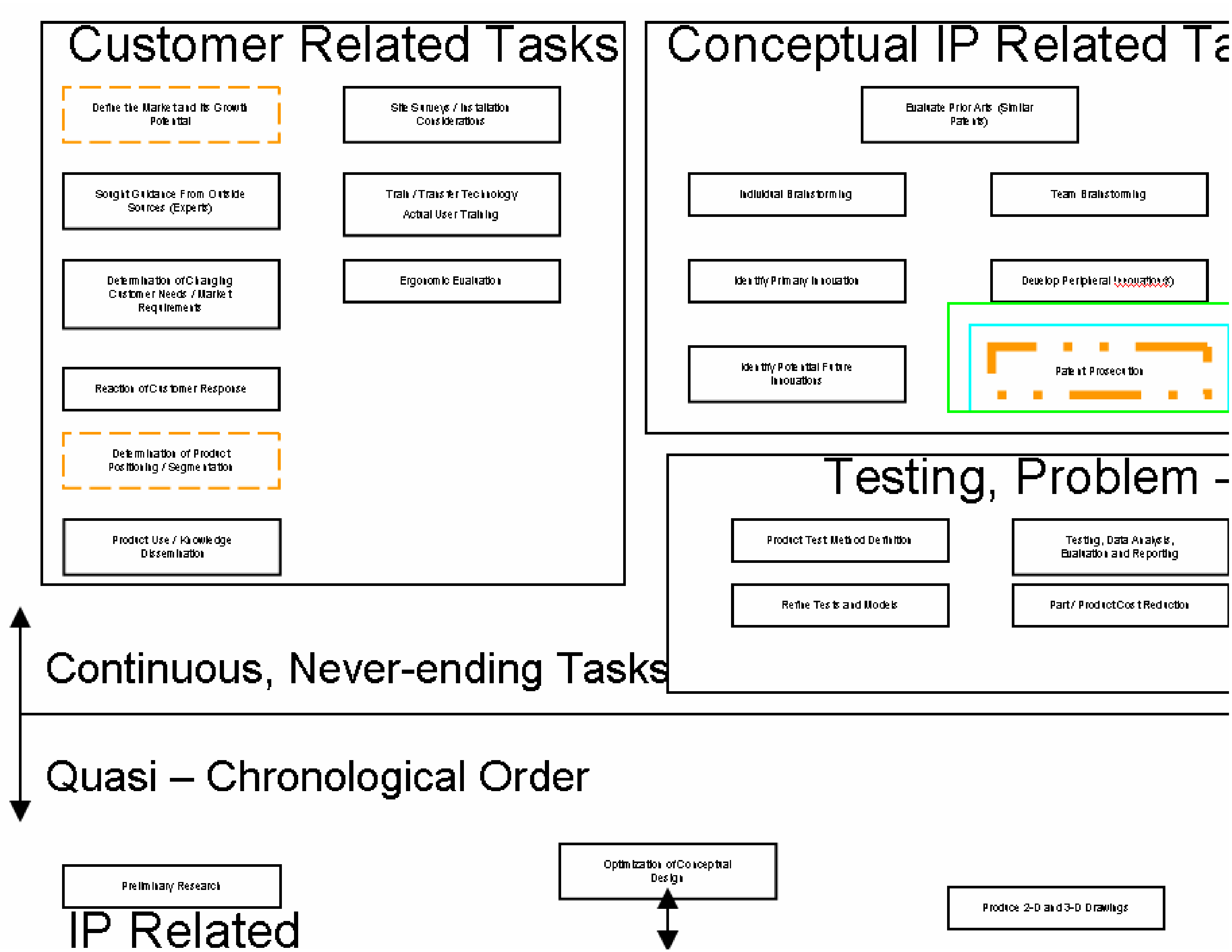
Test Method Definition – Defining the test that will be used to evaluate whether the product performs to desired requirements.

Train / Transfer Technology Actual User Training – Further training than simply preparing documentation and training manuals. Physically training the users on how the product works.

APPENDIX B

STUDY ONE PART I PARTICIPANT CONCEPT MAPS


Customer Related Tasks
Define the Market and Its Growth Potential
Site Surveys / Installation Considerations
Sought Guidance From Outside Sources (Experts)
Train / Transfer Technology Actual User Training
Determination of Changing Customer Needs / Market Requirements
Ergonomic Evaluation
Reaction of Customer Response
Determination of Product Positioning / Segmentation
Product Use / Knowledge Dissemination
Conceptual IP Related Tasks
Evaluate Prior Arts (Similar Patents)
Individual Brainstorming
Team Brainstorming
Identify Primary Innovation
Develop Peripheral Innovation(s)
Identify Potential Future Innovations
Patent Prosecution
Money Related Tasks
Cost Estimate Projections
Funding Considerations
Strength, Weakness, Opportunity, Threat (SWOT) Analysis
Schedule / Cost / Technical Performance Summaries
Situational Analysis
Financial Risk Assessment
Create a Product Financial Plan
Evaluation of Competitor Reactions
Stakeholder Analysis
Final Financial Reviews (Ratio, Overhead, etc.)
Continuous Competitor Monitoring
Regulatory Certification / Compliance
MAP KEY
Normal Process Element
Critical Element
Time-Consuming Element
Problematic Element
Critical and Time Consuming Element
Critical, Time-Consuming and Problematic Element
Testing, Problem – Finding, Problem - Solving
Product Test Method Definition
Testing, Data Analysis, Evaluation and Reporting
Product Component Tradeoffs and Optimization
Technical Problems Arising During Development
Incorporate Available Technologies to Improve Functionality, Safety, Etc.
Refine Tests and Models
Part / Product Cost Reduction
Optimization of Detailed Design
Forces of Nature, Effect on Development
Re-scope Development Team
Continuous, Never-ending Tasks
Quasi – Chronological Order
Preliminary Research
IP Related
Intellectual Property Awareness
Licensing Out Considerations
Customer Needs Analysis
Generate Multiple Product Alternatives
Choose Product Design From Multiple Alternatives
Define Product's Performance Requirements
Product Feature Determination
Modeling and Simulation to Study Design
Patent Filing Initiated (April '81, Actually filed in March '82)
Optimization of Conceptual Design
Finalization of Technical and Physical Requirements
Create Product Description
Evaluate Potential Time to Market Requirements
Product Need Determination Based on Development Lead Time
Competitor Benchmarking
Anticipate Customer Responses
Reverse Engineering Protection
Conjoint Analysis of Customer Needs
Target Customer Determination
Define the Product Scope / Statement of Work
Produce 2-D and 3-D Drawings
Design Manuals Written
Develop a Work Breakdown Structure
Multifunctional Team Development
Product Bill of Materials
Resource Requirements
Create a Schedule for the Product
Determination of Product Cost
Determination of Product Retail Price
Life Cycle Cost Analysis
Estimate / Predict Customer ROI
Pretest / Pre-launch Forecasting
Determination of Investment Req. / Potential Returns
Prototype Development (Apr. '81 to Apr. '82)
Prototype Testing
Beta Testing – Product Works in Customer Operations (May '82)
Product Functional Analysis
Pilot / Prototype Review
Design Modifications
Full Scale Operational Testing and Evaluation
Limited Rollout / Test Marketing
Creation of Operational Data Management System
Operator / Training / Assembly / Maintenance Documentation
Customer Service and Logistical Support Development
Product Packaging and Protection
Customer Feedback Evaluation
Product Meets Actual User Needs
Evaluate / Select CAD Tools
Develop a Product Manufacturing Plan
Design Review(s)
Final Design Approval
Product Marketing 3 C's, 4 P's (Jan. '83)
Product Advertising Plan
One, Three and Five Year Product Plans
Product Warranty
Sales Forecasting
Design for Assembly
Design for Manufacturability
Proposed Design Within Target Costs
Staffing Level and Turnover Considerations
Quality and Process Reviews
Pilot Scale Operational Testing and Evaluation
Production Pilot Review
Production Line Design and Setup
Alpha / In-house Testing
Gamma Testing / Actual User Testing
Reliability Testing, Test to Failure, Limit Testing
Corporate Strategy Change (May '84)
Hybrid Inventor



Customer Related Tasks
Define the Market and Its Growth Potential
Site Surveys / Installation Considerations
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Reaction of Customer Response
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Produce 2-D and 3-D Drawings
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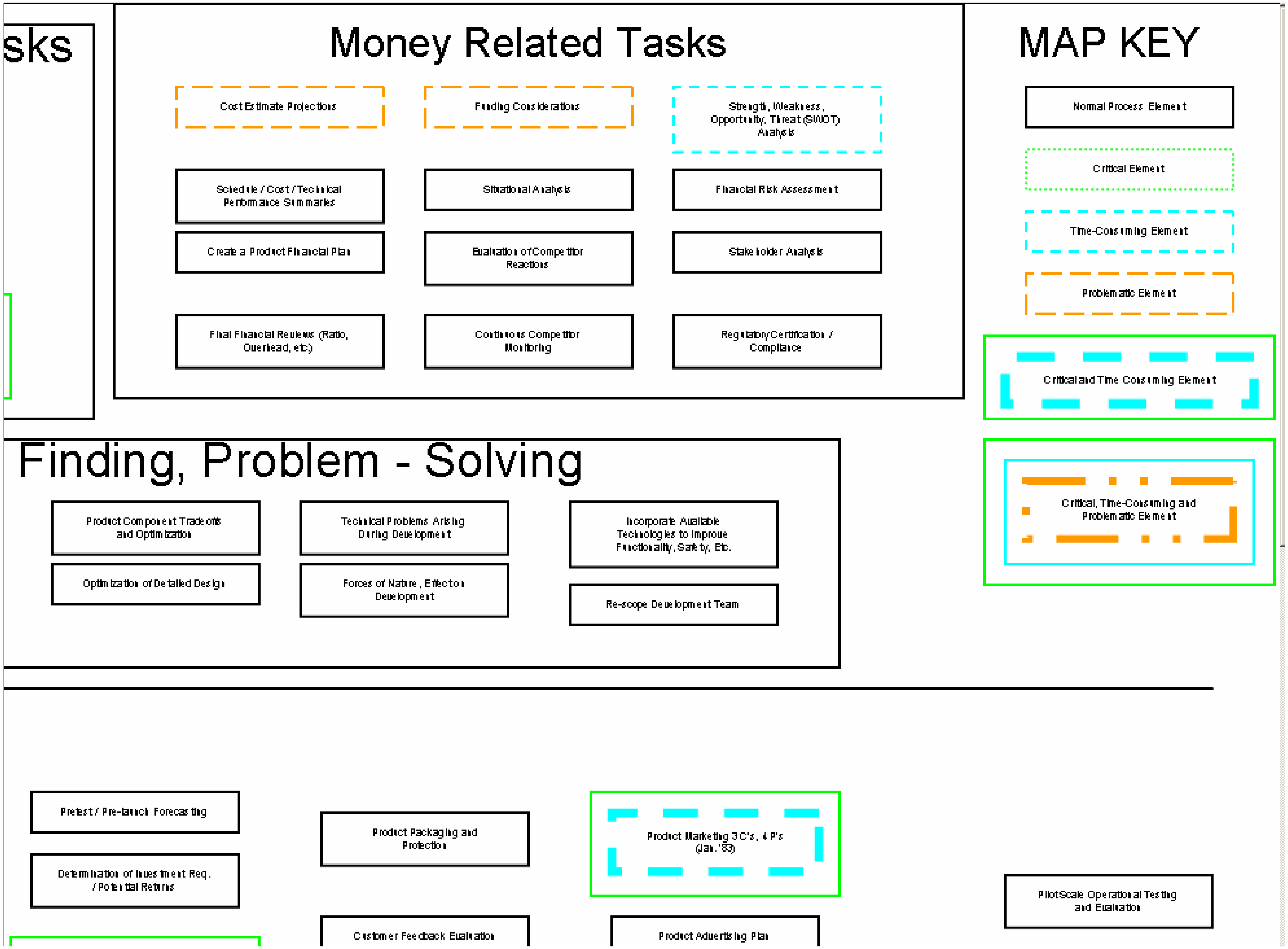
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Finding, Problem - Solving
Product Component Tradeoffs and Optimization
Technical Problems Arising During Development
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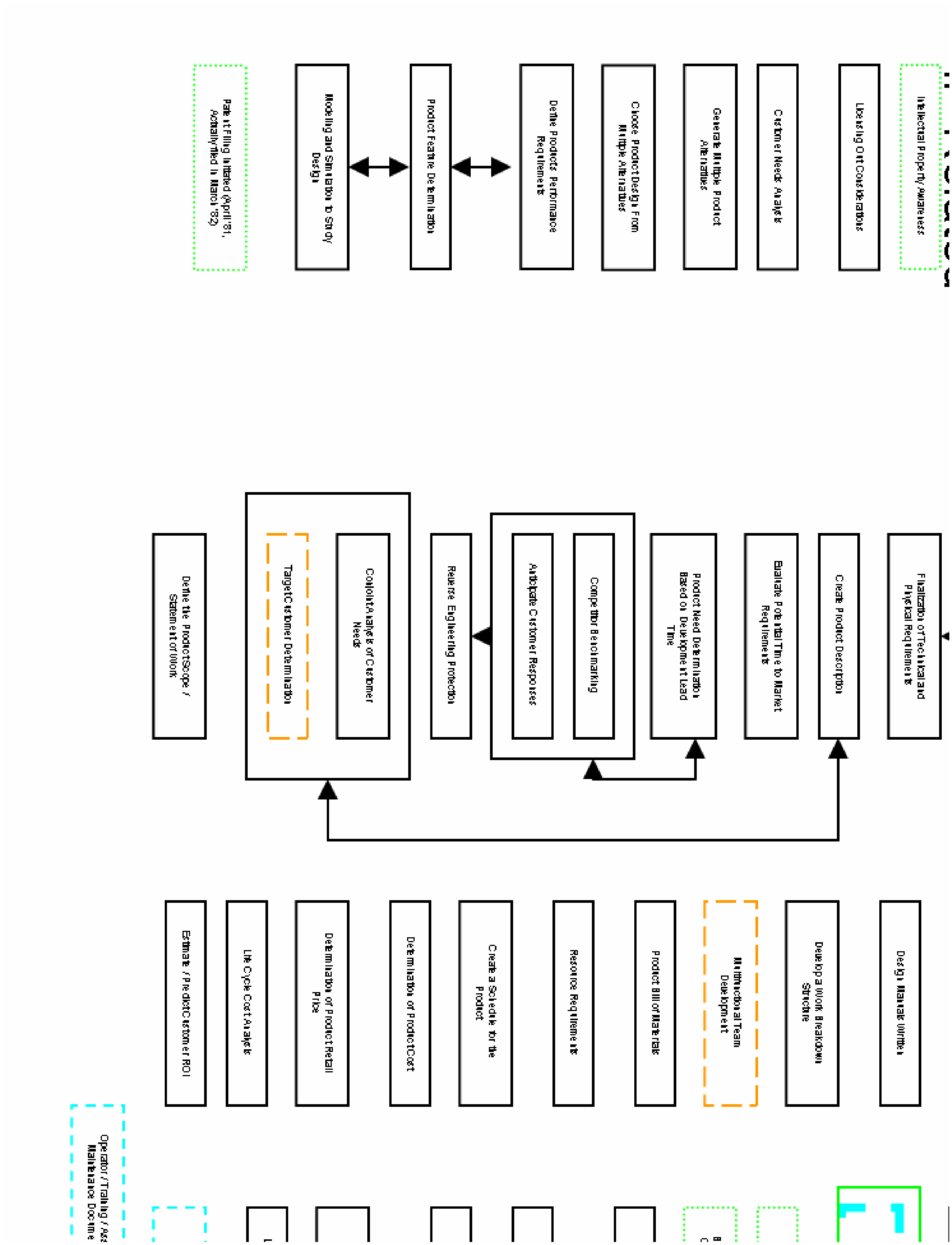
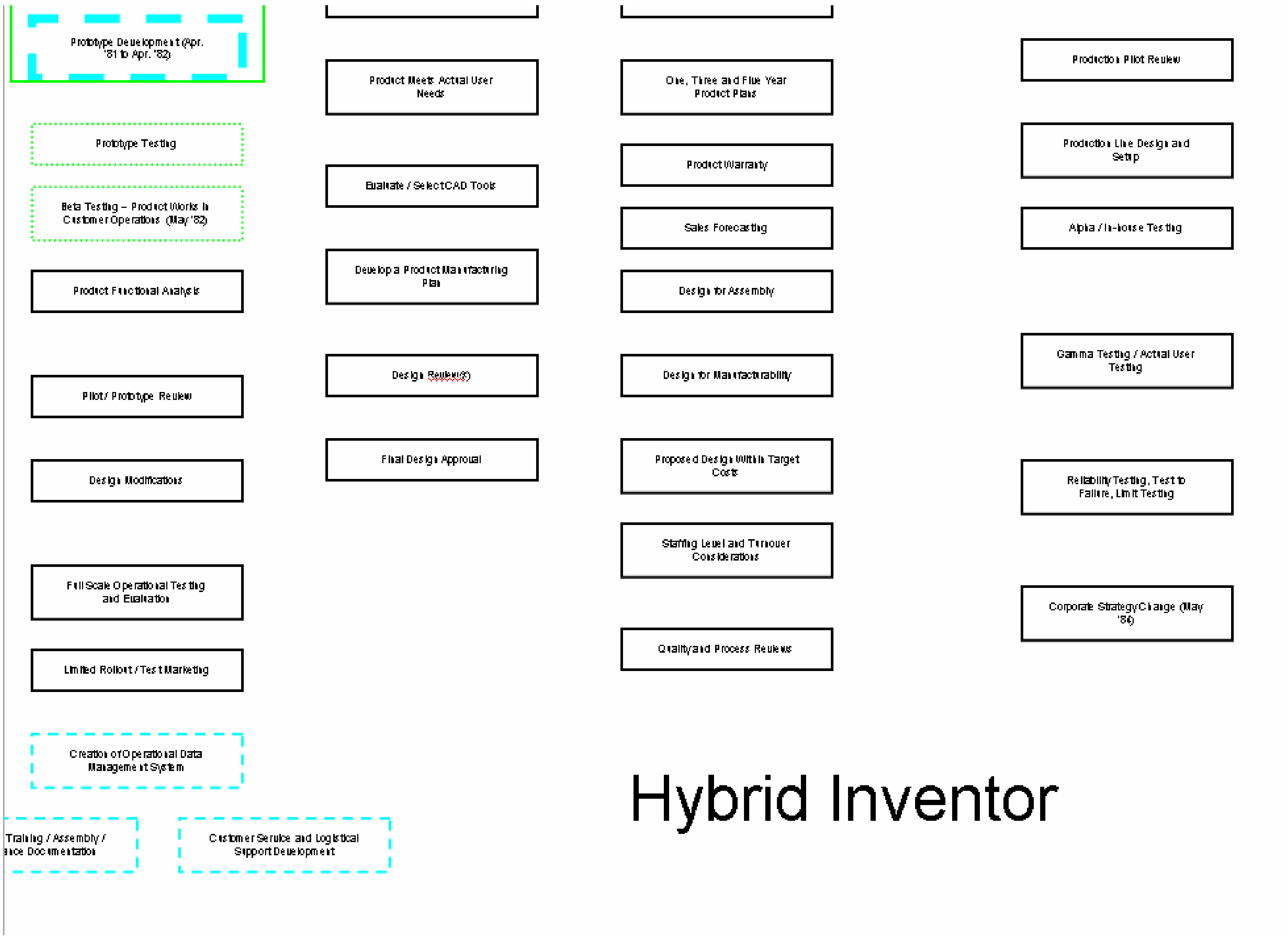


Intellectual Property Awareness
Licensing Out Considerations
Customer Needs Analysis
Generate Multiple Product Alternatives
Choose Product Design From Multiple Alternatives
Define Products Performance Requirements
Product Feature Determination
Modelling and Simulation to Study Design
Finalization of Technical and Physical Requirements
Create Product Description
Evaluate Potential Time to Market Requirements
Product Need Determination Based on Development Lead Time
Competitor Benchmarking
Anticipate Customer Responses
Reverse Engineering Protection
Conjoint Analysis of Customer Needs
Target Customer Determination
Define the Product Scope / Statement of Work
Design Manuals Written
Develop a Work Breakdown Structure
Multifunctional Team Development
Product Bill of Materials
Resource Requirements
Create a Schedule for the Product
Determination of Product Cost
Determination of Product Retail Price
Life Cycle Cost Analysis
Estimate / Predict Customer ROI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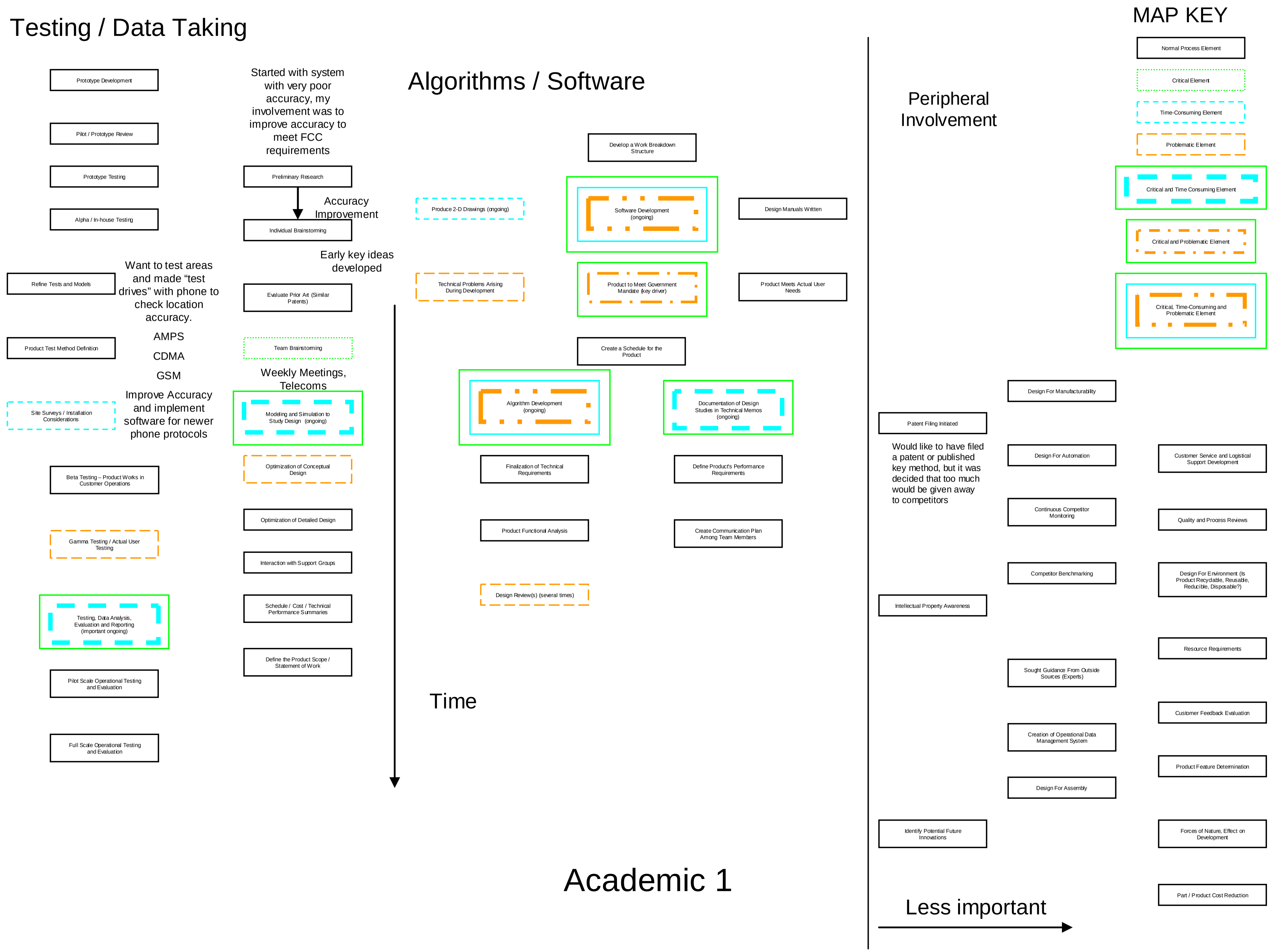
Testing / Data Taking
Prototype Development
Pilot / Prototype Review
Prototype Testing
Alpha / In-house Testing
Refine Tests and Models
Want to test areas and made "test drives" with phone to check location accuracy.
Product Test Method Definition
AMPS
CDMA
GSM
Site Surveys / Installation Considerations
Improve Accuracy and implement software for newer phone protocols
Beta Testing – Product Works in Customer Operations
Gamma Testing / Actual User Testing
Testing, Data Analysis, Evaluation and Reporting (important ongoing)
Pilot Scale Operational Testing and Evaluation
Full Scale Operational Testing and Evaluation
Started with system with very poor accuracy, my involvement was to improve accuracy to meet FCC requirements
Preliminary Research
Accuracy Improvement
Individual Brainstorming
Early key ideas developed
Evaluate Prior Art (Similar Patents)
Team Brainstorming
Weekly Meetings, Telecoms
Modeling and Simulation to Study Design (ongoing)
Optimization of Conceptual Design
Optimization of Detailed Design
Interaction with Support Groups
Schedule / Cost / Technical Performance Summaries
Define the Product Scope / Statement of Work
Time
Algorithms / Software
Produce 2-D Drawings (ongoing)
Technical Problems Arising During Development
Develop a Work Breakdown Structure
Software Development (ongoing)
Product to Meet Government Mandate (key driver)
Create a Schedule for the Product
Design Manuals Written
Product Meets Actual User Needs
Algorithm Development (ongoing)
Finalization of Technical Requirements
Product Functional Analysis
Design Review(s) (several times)
Documentation of Design Studies in Technical Memos (ongoing)
Define Product's Performance Requirements
Create Communication Plan Among Team Members
Academic 1
Peripheral Involvement
Patent Filing Initiated
Would like to have filed a patent or published key method, but it was decided that too much would be given away to competitors
Intellectual Property Awareness
Identify Potential Future Innovations
Design For Manufacturability
Design For Automation
Continuous Competitor Monitoring
Competitor Benchmarking
Sought Guidance From Outside Sources (Experts)
Creation of Operational Data Management System
Design For Assembly
Customer Service and Logistical Support Development
Quality and Process Reviews
Design For Environment (Is Product Recyclable, Reusable, Reducible, Disposable?)
Resource Requirements
Customer Feedback Evaluation
Product Feature Determination
Forces of Nature, Effect on Development
Part / Product Cost Reduction
Less important
MAP KEY
Normal Process Element
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Problematic Element
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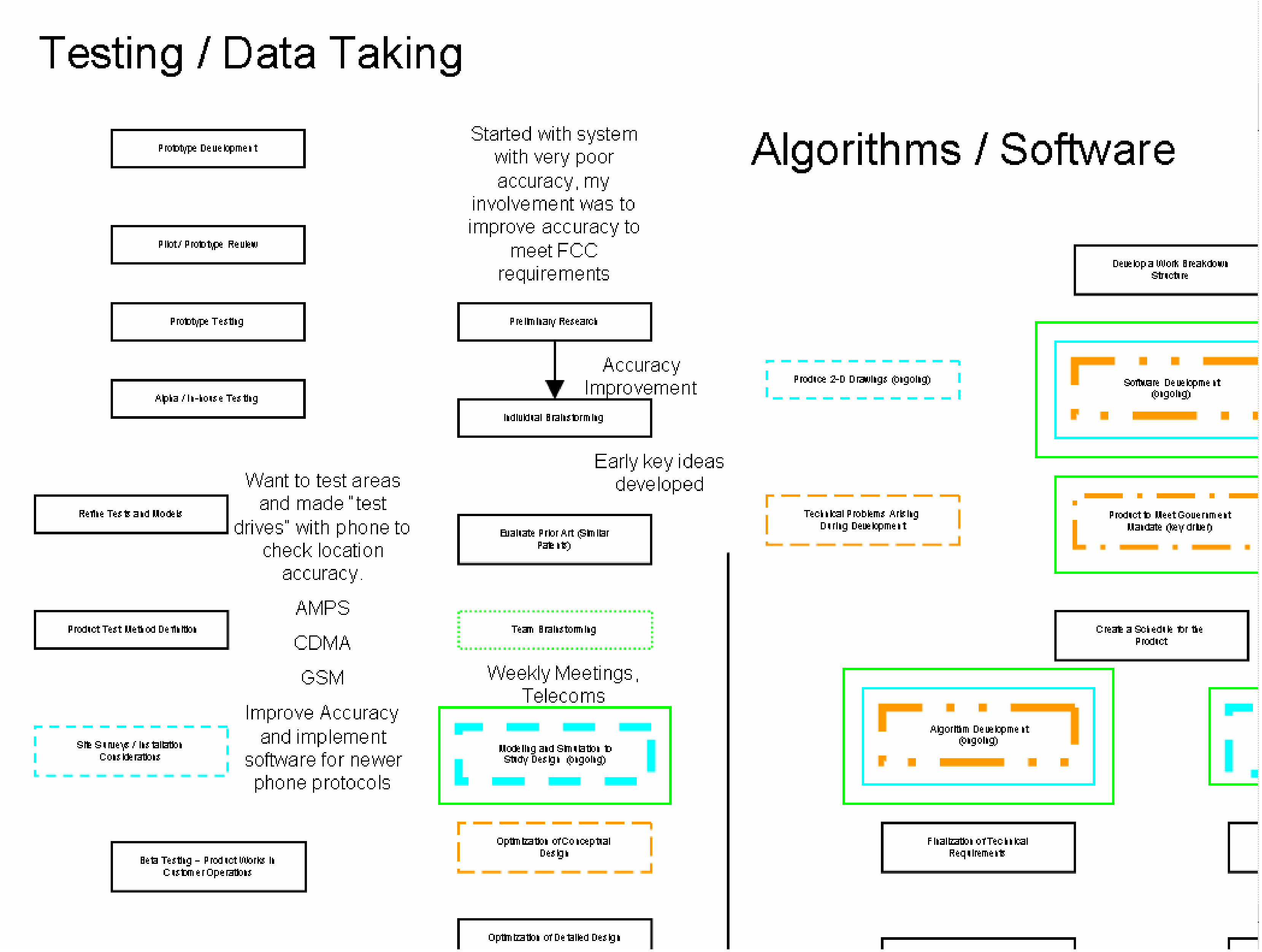
Critical and Problematic Element
Critical, Time-Consuming and Problematic Element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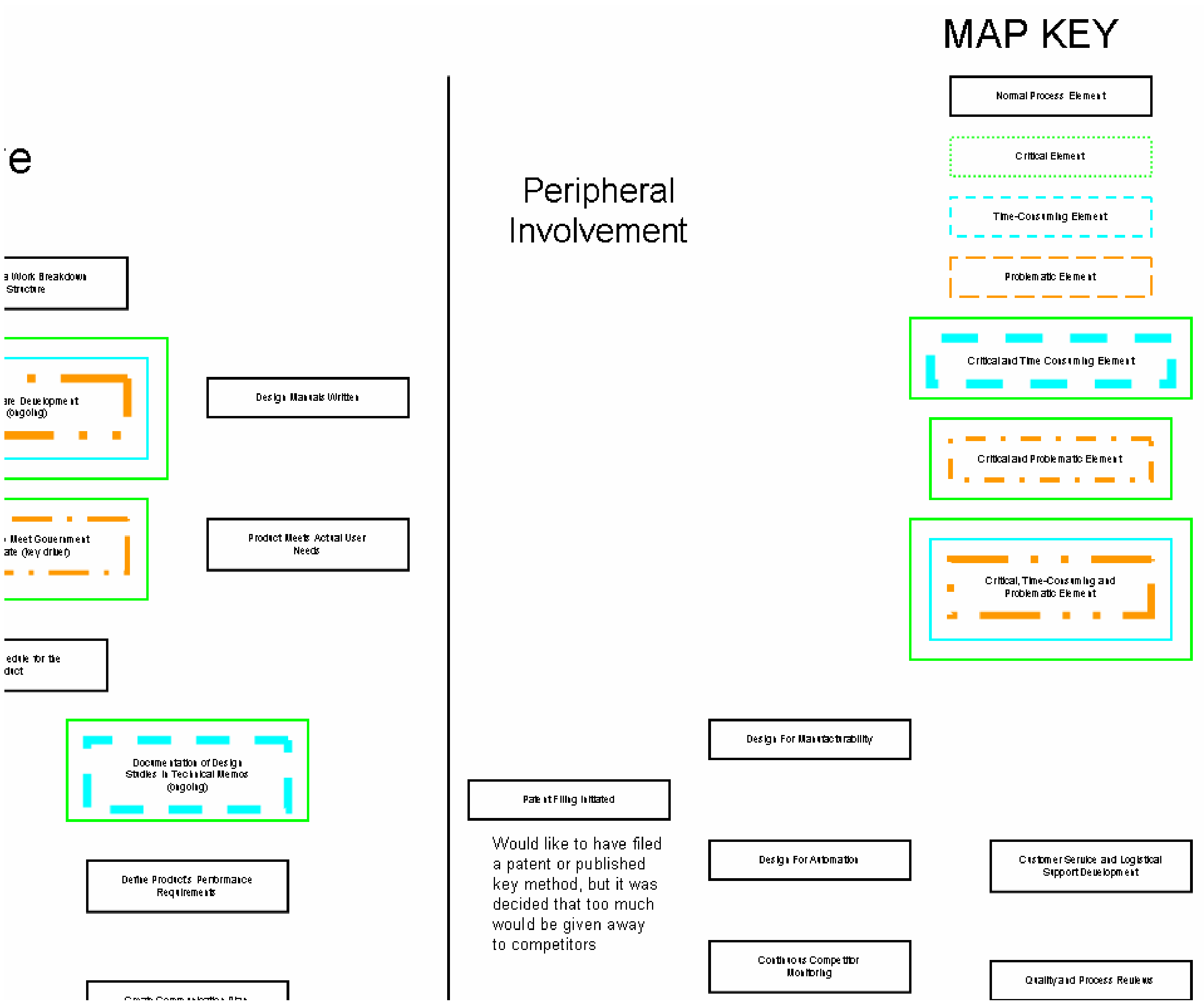

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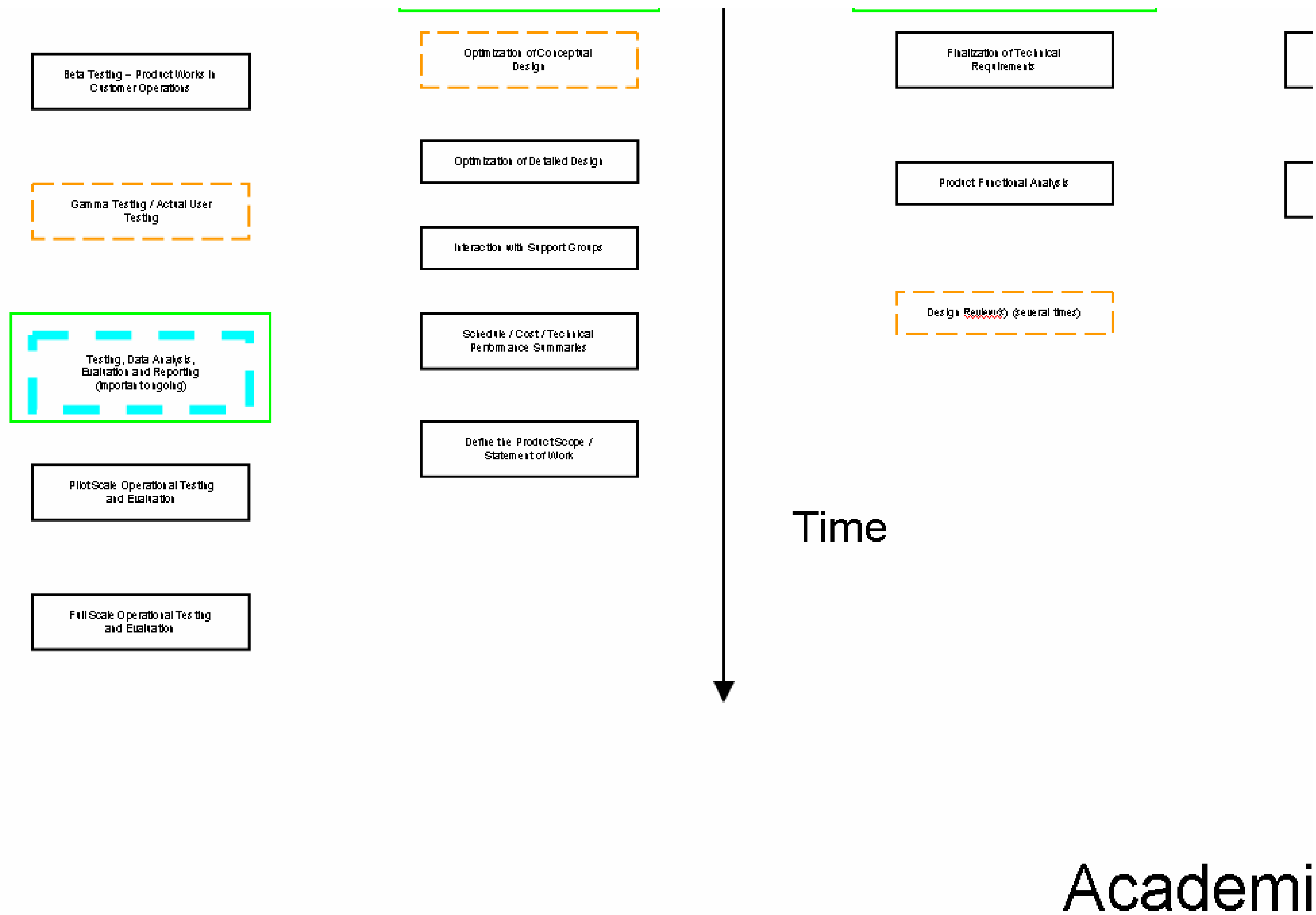
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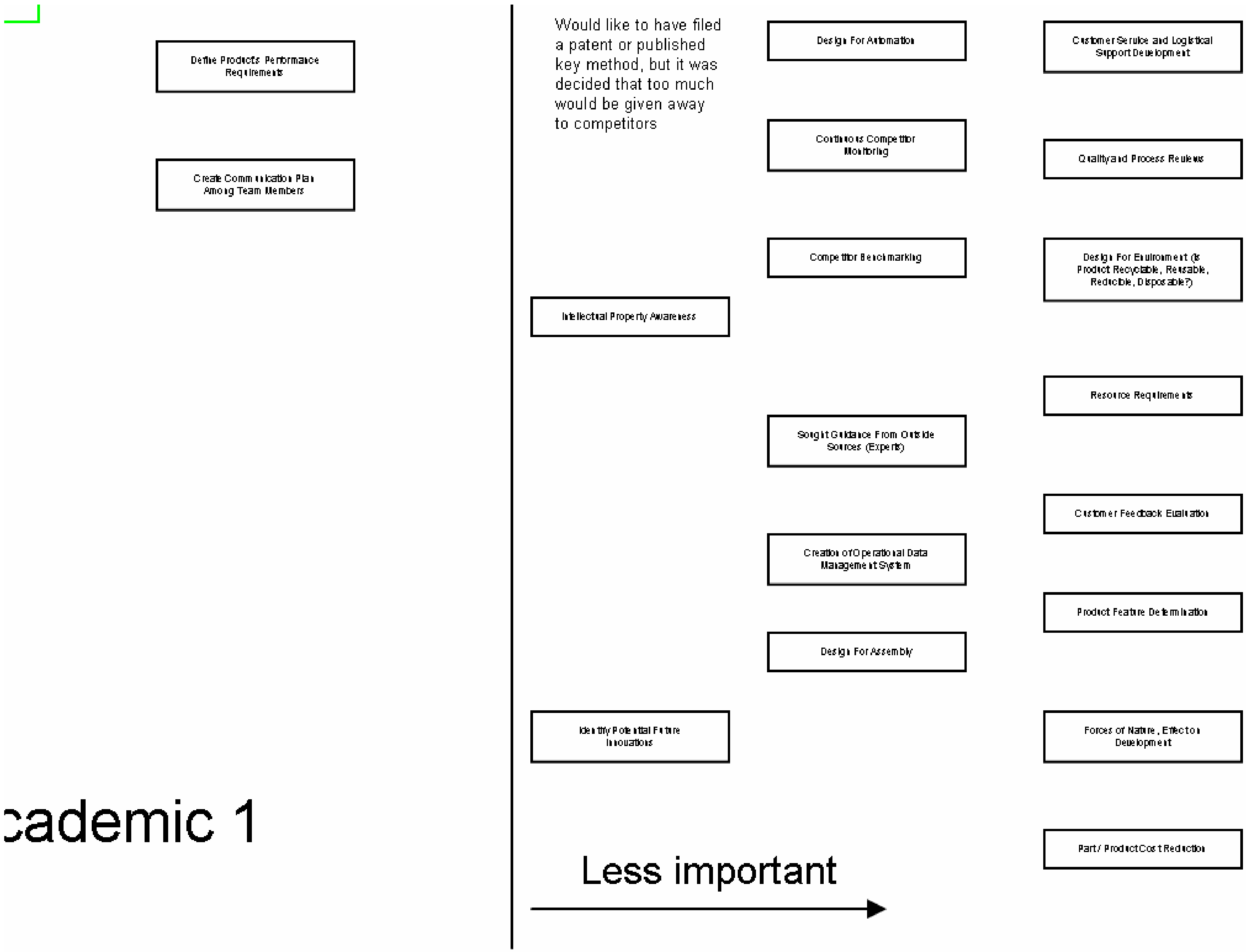
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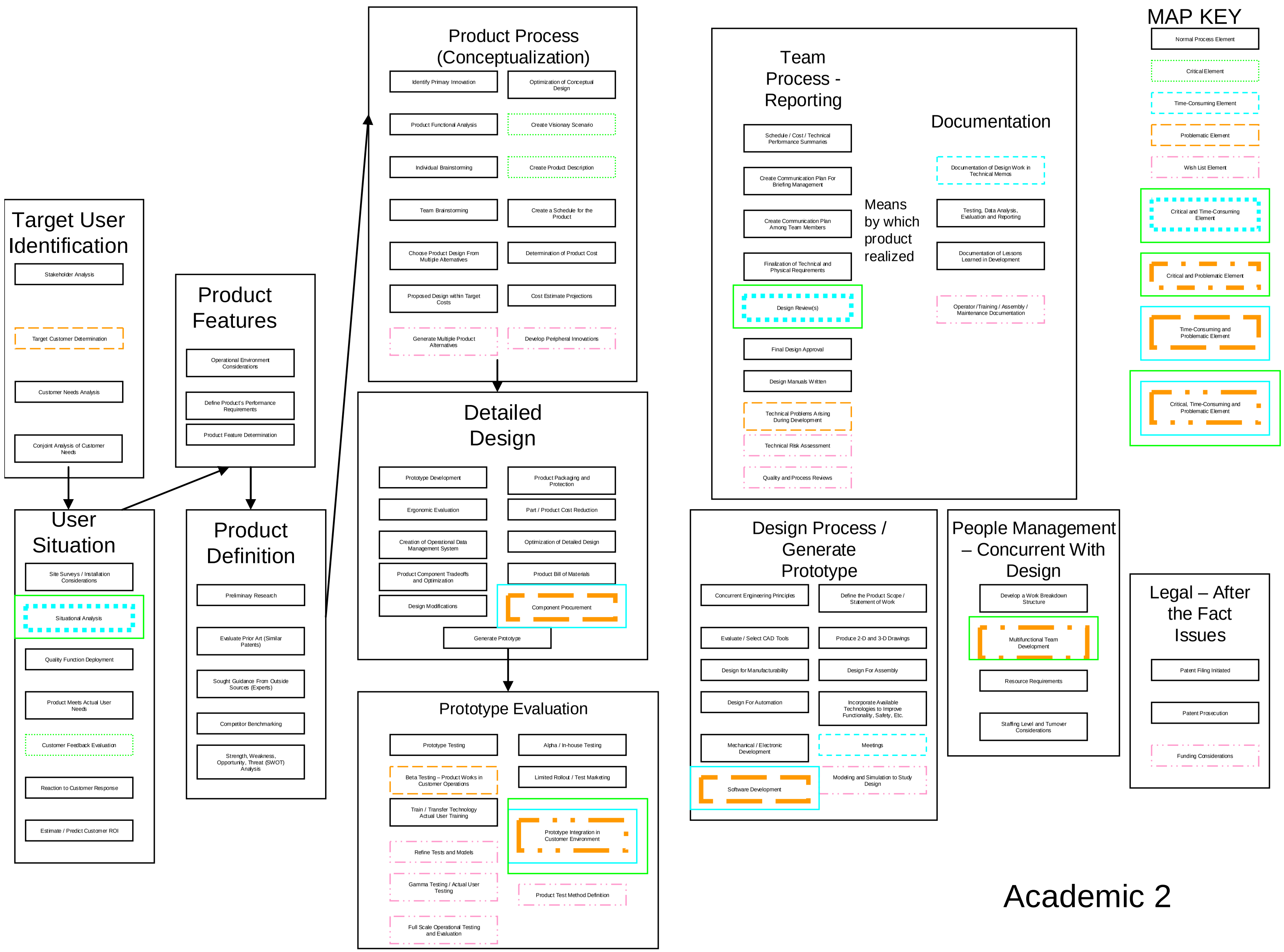
Forces of Nature, Effect on Development
Part / Product Cost Reduction



Target User Identification
Stakeholder Analysis
Target Customer Determination
Customer Needs Analysis
Conjoint Analysis of Customer Needs
User Situation
Site Surveys / Installation Considerations
Situational Analysis
Quality Function Deployment
Product Meets Actual User Needs
Customer Feedback Evaluation
Reaction to Customer Response
Estimate / Predict Customer ROI
Product Features
Operational Environment Considerations
Define Product's Performance Requirements
Product Feature Determination
Product Definition
Preliminary Research
Evaluate Prior Art (Similar Patents)
Sought Guidance From Outside Sources (Experts)
Competitor Benchmarking
Strength, Weakness, Opportunity, Threat (SWOT) Analysis
Product Process (Conceptualization)
Identify Primary Innovation
Optimization of Conceptual Design
Product Functional Analysis
Create Visionary Scenario
Individual Brainstorming
Create Product Description
Team Brainstorming
Create a Schedule for the Product
Choose Product Design From Multiple Alternatives
Determination of Product Cost
Proposed Design within Target Costs
Cost Estimate Projections
Generate Multiple Product Alternatives
Develop Peripheral Innovations
Detailed Design
Prototype Development
Product Packaging and Protection
Ergonomic Evaluation
Part / Product Cost Reduction
Creation of Operational Data Management System
Optimization of Detailed Design
Product Component Tradeoffs and Optimization
Product Bill of Materials
Design Modifications
Component Procurement
Generate Prototype
Prototype Evaluation
Prototype Testing
Alpha / In-house Testing
Beta Testing – Product Works in Customer Operations
Limited Rollout / Test Marketing
Train / Transfer Technology Actual User Training
Prototype Integration in Customer Environment
Refine Tests and Models
Gamma Testing / Actual User Testing
Product Test Method Definition
Full Scale Operational Testing and Evaluation
Team Process - Reporting
Schedule / Cost / Technical Performance Summaries
Create Communication Plan For Briefing Management
Create Communication Plan Among Team Members
Finalization of Technical and Physical Requirements
Design Review(s)
Final Design Approval
Design Manuals Written
Technical Problems Arising During Development
Technical Risk Assessment
Quality and Process Reviews
Means by which product realized
Documentation
Documentation of Design Work in Technical Memos
Testing, Data Analysis, Evaluation and Reporting
Documentation of Lessons Learned in Development
Operator / Training / Assembly / Maintenance Documentation
Design Process / Generate Prototype
Concurrent Engineering Principles
Define the Product Scope / Statement of Work
Evaluate / Select CAD Tools
Produce 2-D and 3-D Drawings
Design for Manufacturability
Design For Assembly
Design For Automation
Incorporate Available Technologies to Improve Functionality, Safety, Etc.
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Meetings
Software Development
Modeling and Simulation to Study Design
People Management – Concurrent With Design
Develop a Work Breakdown Structure
Multifunctional Team Development
Resource Requirements
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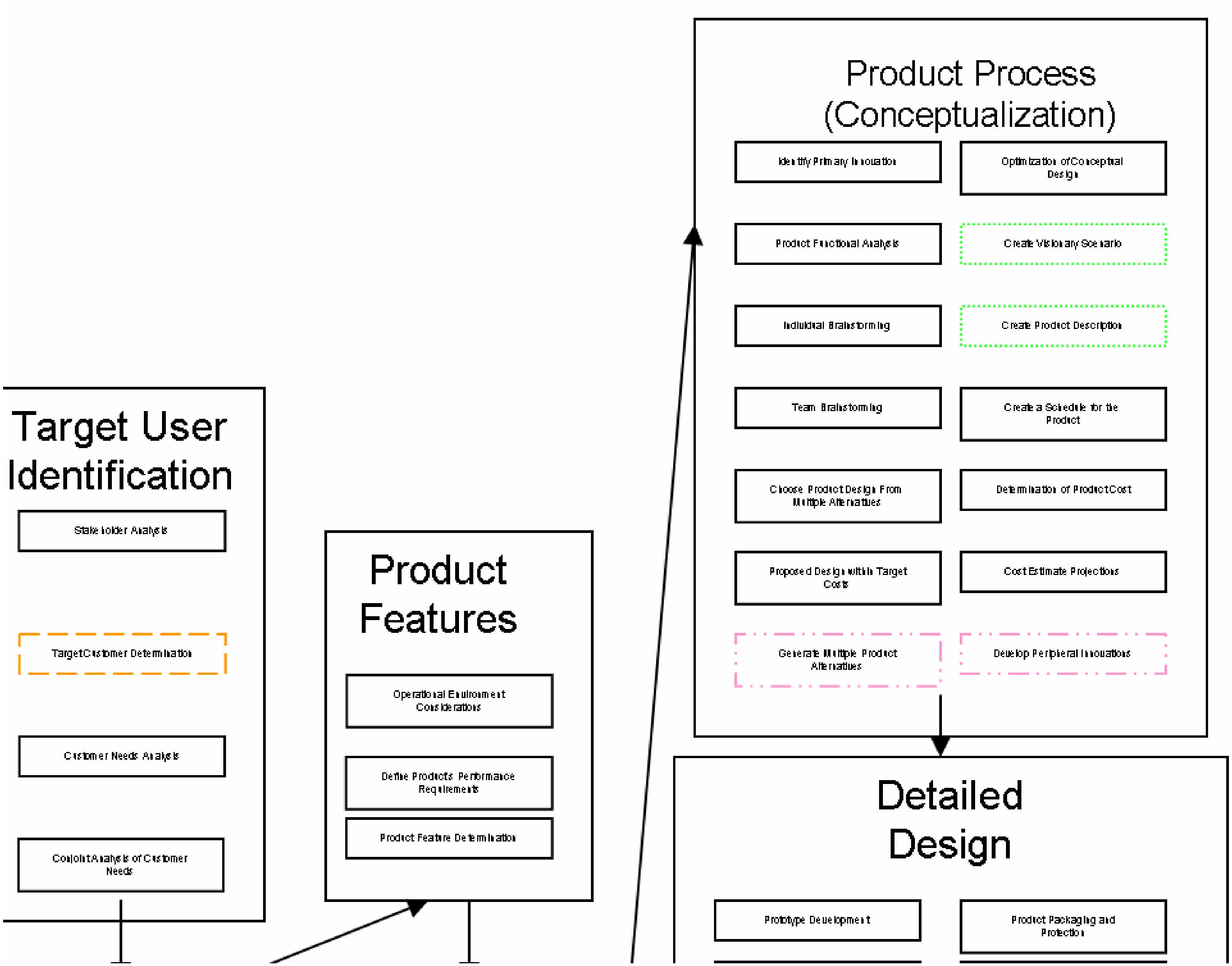
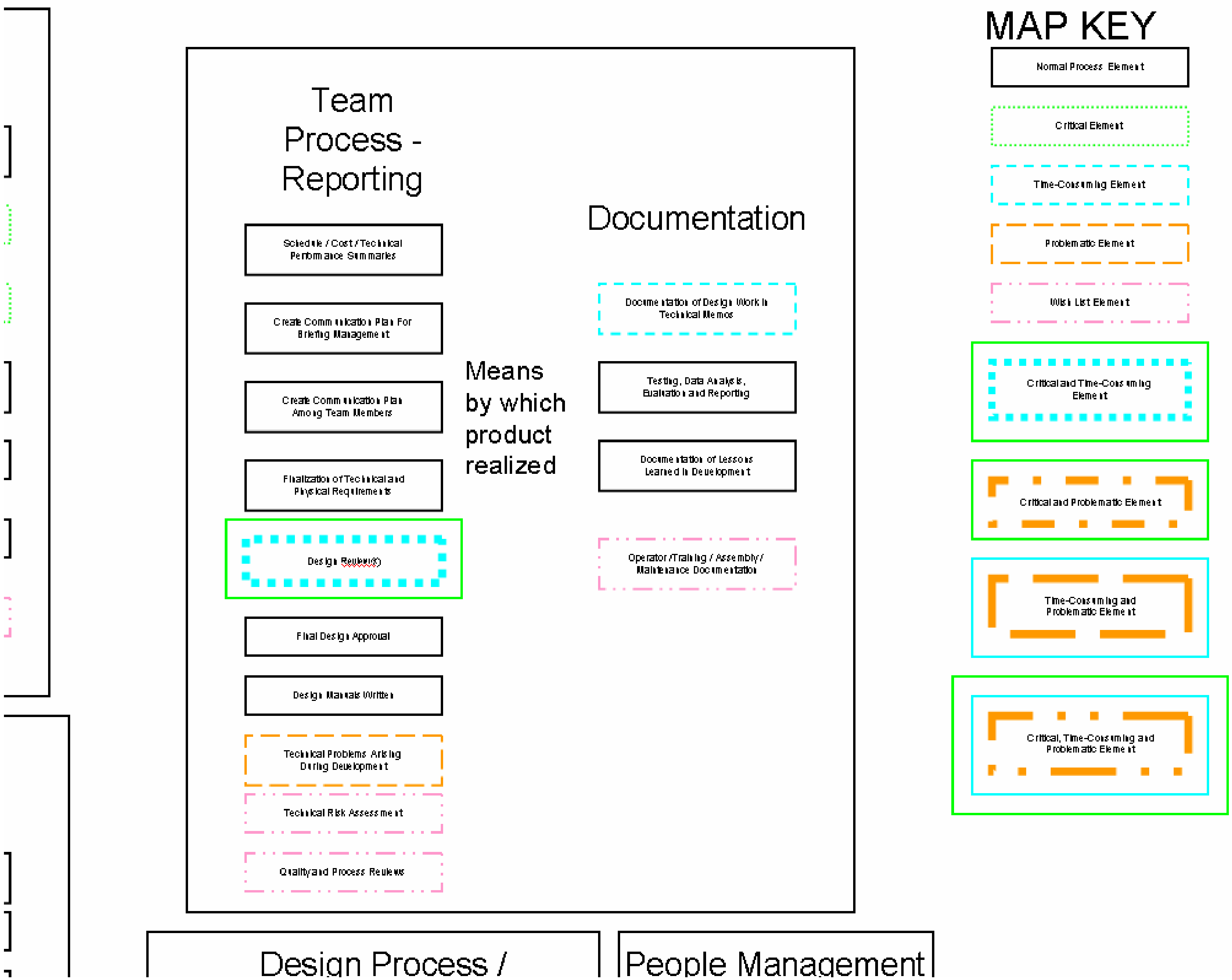
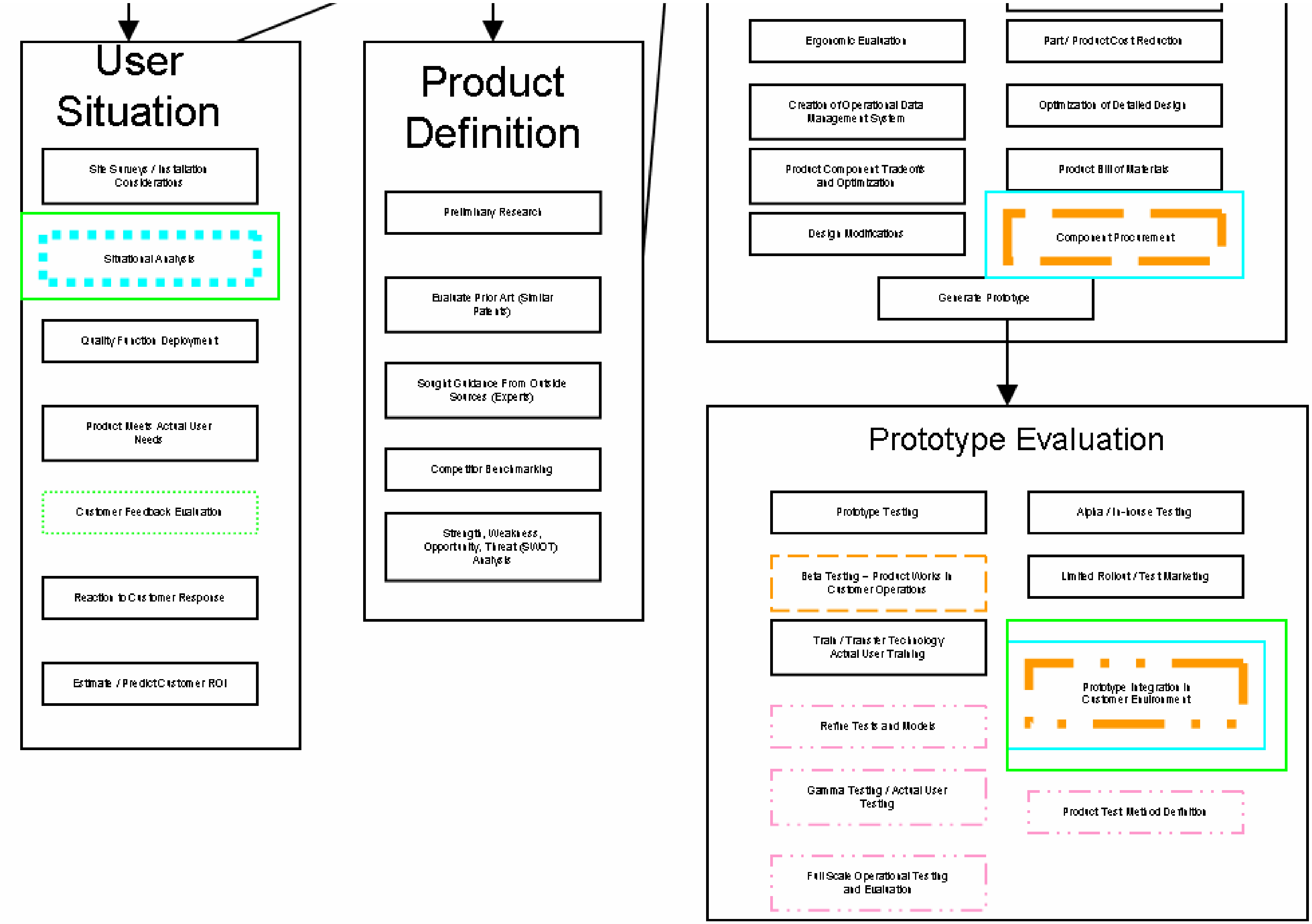
Patent Prosecution
Funding Considerations
MAP KEY
Normal Process Element
Critical Element
Time-Consuming Element
Problematic Element
Wish List Element
Critical and Time-Consuming Element
Critical and Problematic Element
Time-Consuming and Problematic Element
Critical, Time-Consuming and Problematic Element
Academic 2

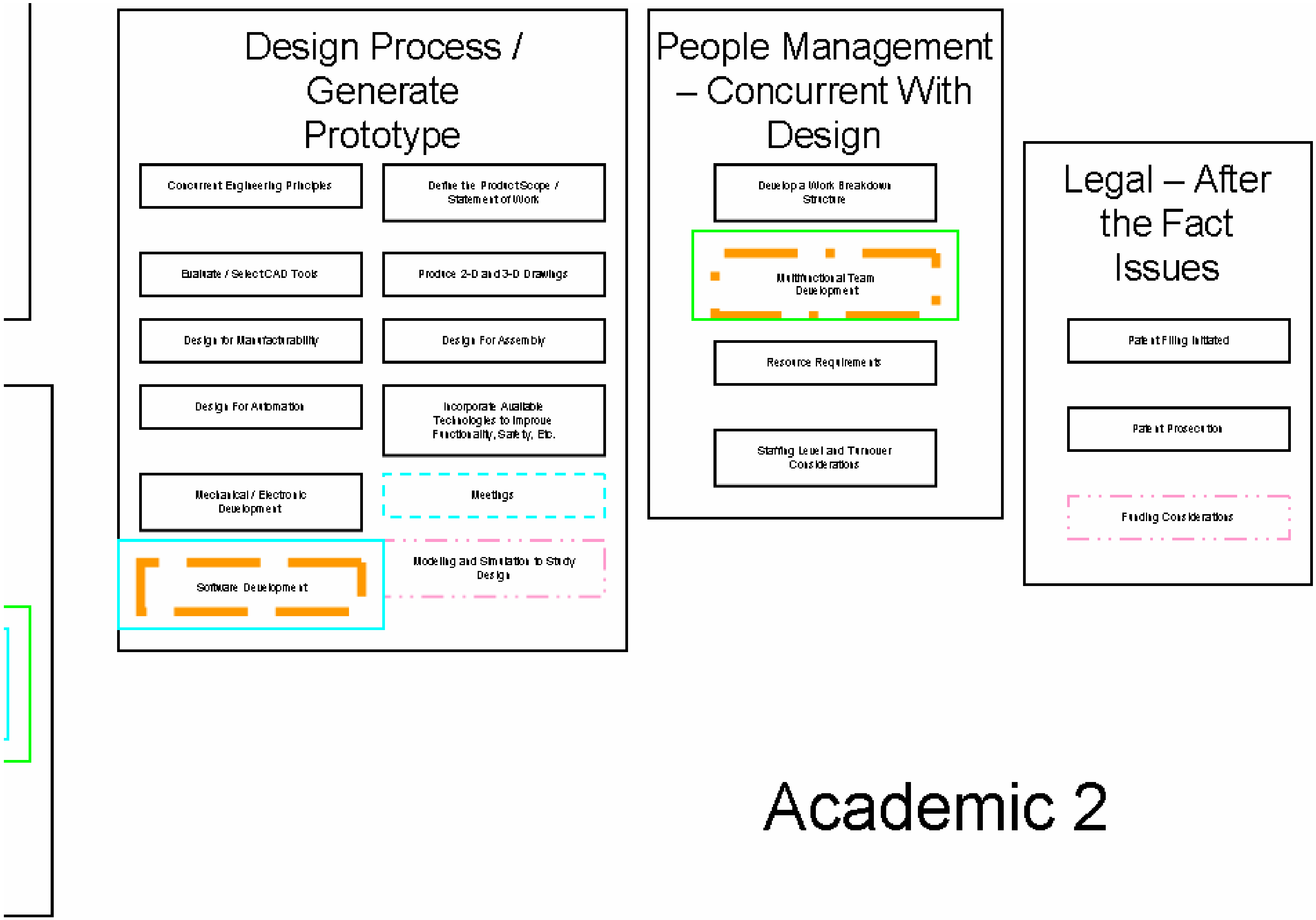


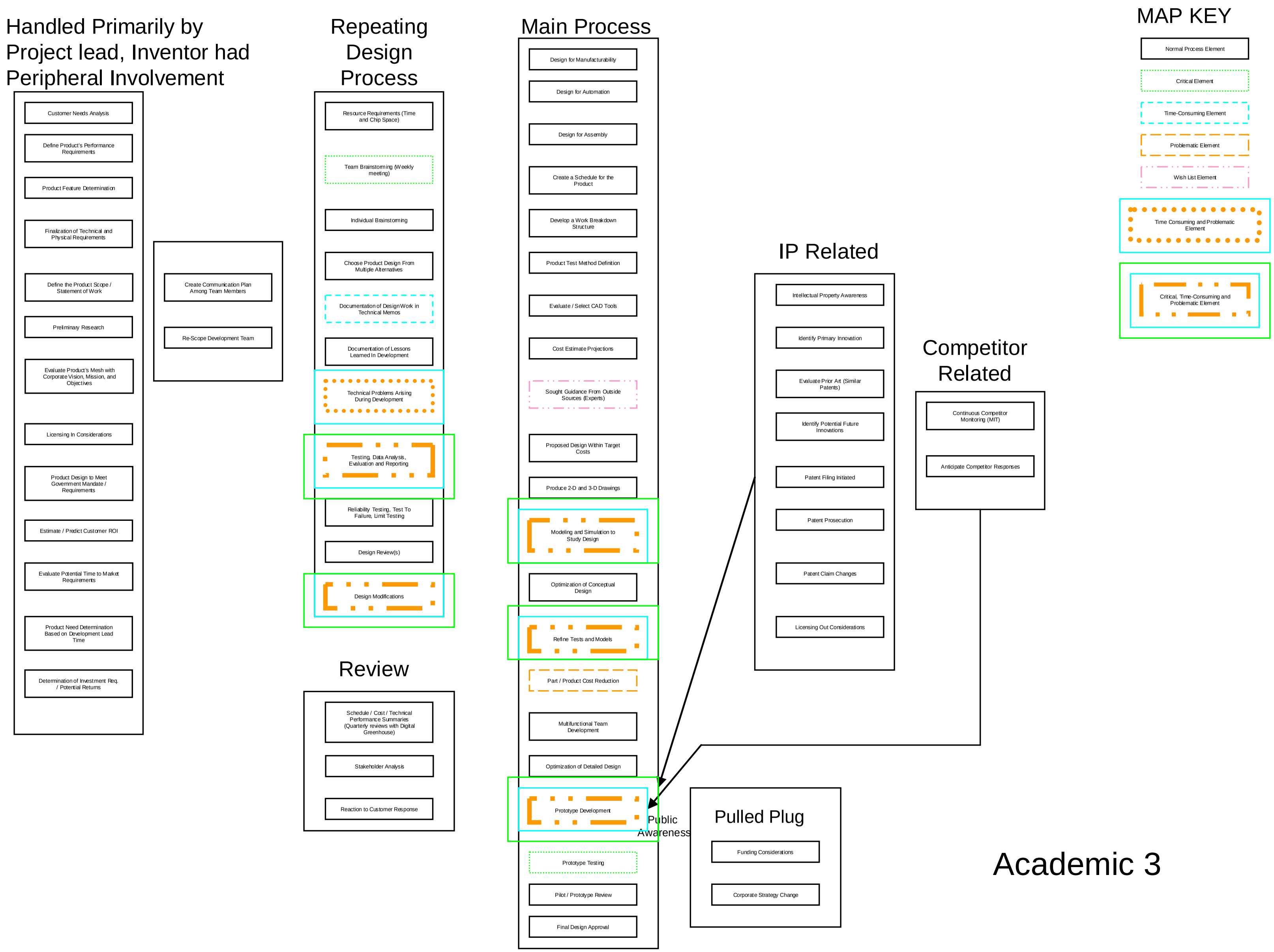
Target User Identification
Stakeholder Analysis
Target Customer Determination
Customer Needs Analysis
Conjoint Analysis of Customer Needs
Product Features
Operational Environment Considerations
Define Products Performance Requirements
Product Feature Determination
Product Process (Conceptualization)
Identify Primary Innovation
Optimization of Conceptual Design
Product Functional Analysis
Create Visionary Scenario
Individual Brainstorming
Create Product Description
Team Brainstorming
Create a Schedule for the Product
Choose Product Design From Multiple Alternatives
Determination of Product Cost
Proposed Design within Target Costs
Cost Estimate Projections
Generate Multiple Product Alternatives
Develop Peripheral Innovations
Detailed Design
Prototype Development
Product Packaging and Protection



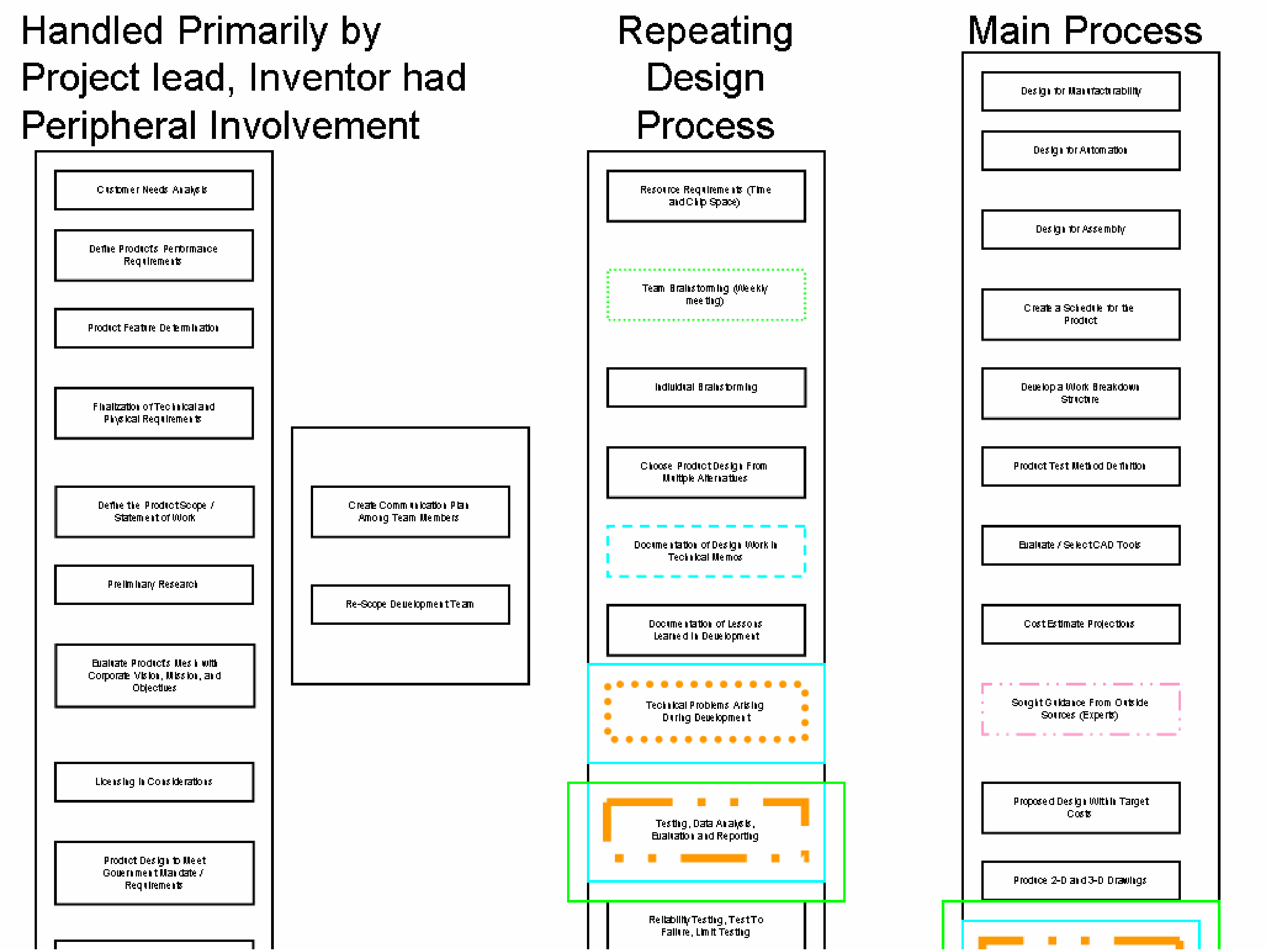
Team Process - Reporting
Schedule / Cost / Technical Performance Summaries
Create Communication Plan For Briefing Management
Create Communication Plan Among Team Members
Finalization of Technical and Physical Requirements
Design Review(s)
Final Design Approval
Design Manuals Written
Technical Problems Arising During Development
Technical Risk Assessment
Quality and Process Reviews
Means by which product realized
Documentation
Documentation of Design Work in Technical Memos
Testing, Data Analysis, Evaluation and Reporting
Documentation of Lessons Learned in Development
Operator / Training / Assembly / Maintenance Documentation
Design Process /
People Management
MAP KEY
Normal Process Element
Critical Element
Time-Consuming Element
Problematic Element
Wish List Element
Critical and Time-Consuming Element
Critical and Problematic Element
Time-Consuming and Problematic Element
Critical, Time-Consuming and Problematic Element

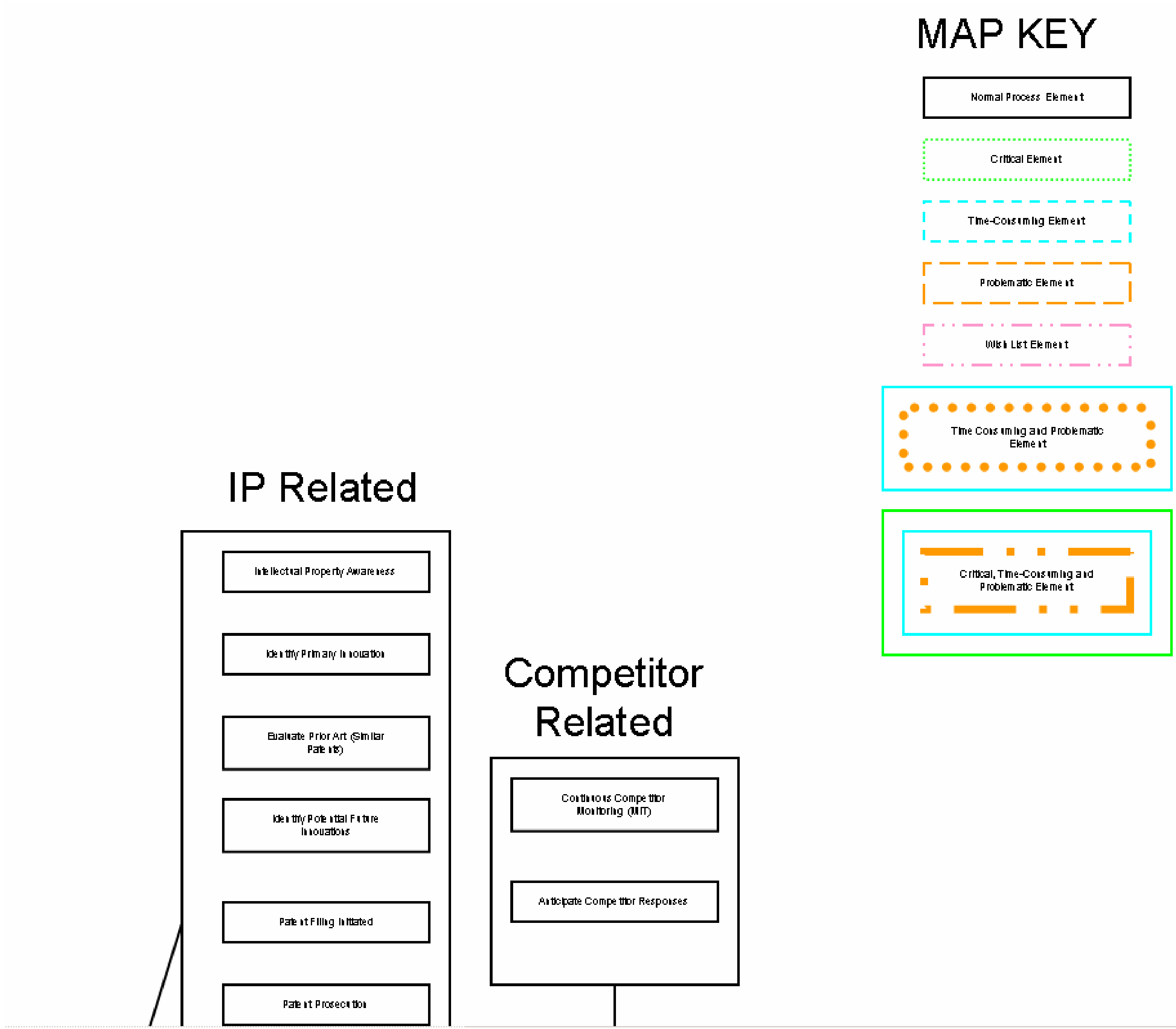

User Situation
Site Surveys / Installation Considerations
Situational Analysis
Quality Function Deployment
Product Meets Actual User Needs
Customer Feedback Evaluation
Reaction to Customer Response
Estimate / Predict Customer ROI
Product Definition
Preliminary Research
Evaluate Prior Art (Similar Patents)
Sought Guidance From Outside Sources (Experts)
Competitor Benchmarking
Strength, Weakness, Opportunity, Threat (SWOT) Analysis
Ergonomic Evaluation
Part / Product Cost Reduction
Creation of Operational Data Management System
Optimization of Detailed Design
Product Component Tradeoffs and Optimization
Product Bill of Materials
Design Modifications
Component Procurement
Generate Prototype
Prototype Evaluation
Prototype Testing
Alpha / In-house Testing
Beta Testing – Product Works in Customer Operations
Limited Rollout / Test Marketing
Train / Transfer Technology Actual User Training
Prototype Integration in Customer Environment
Refine Tests and Models
Gamma Testing / Actual User Testing
Product Test Method Definition
Full Scale Operational Testing and Evaluation

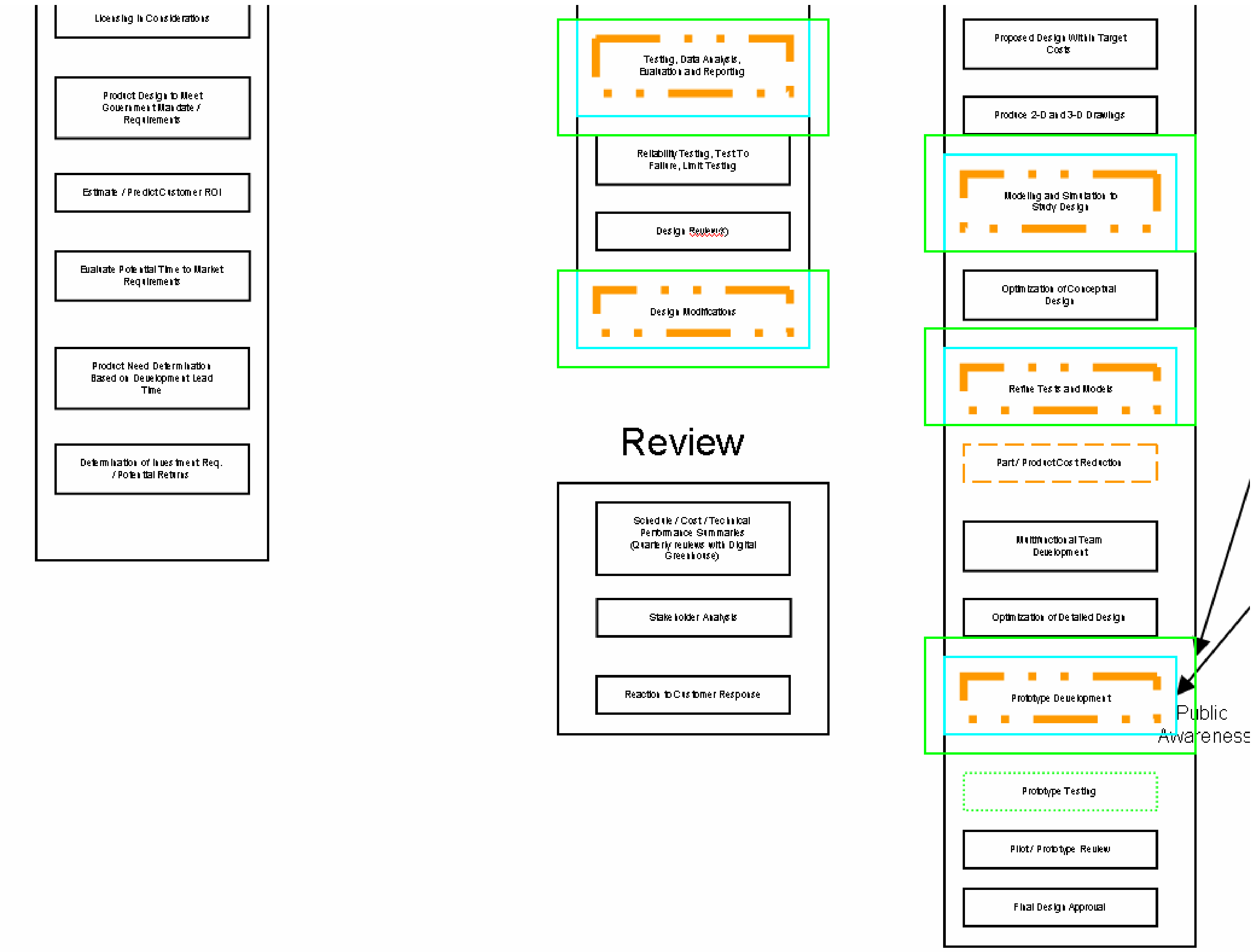

Design Process / Generate Prototype
Concurrent Engineering Principles
Define the Product Scope / Statement of Work
Evaluate / Select CAD Tools
Produce 2-D and 3-D Drawings
Design for Manufacturability
Design For Assembly
Design For Automation
Incorporate Available Technologies to Improve Functionality, Safety, Etc.
Mechanical / Electronic Development
Meetings
Software Development
Modeling and Simulation to Study Design
People Management – Concurrent With Design
Develop a Work Breakdown Structure
Multifunctional Team Development
Resource Requirements
Staffing Level and Turnover Considerations
Legal – After the Fact Issues
Patent Filing Initiated
Patent Prosecution
Funding Considerations
Academic 2



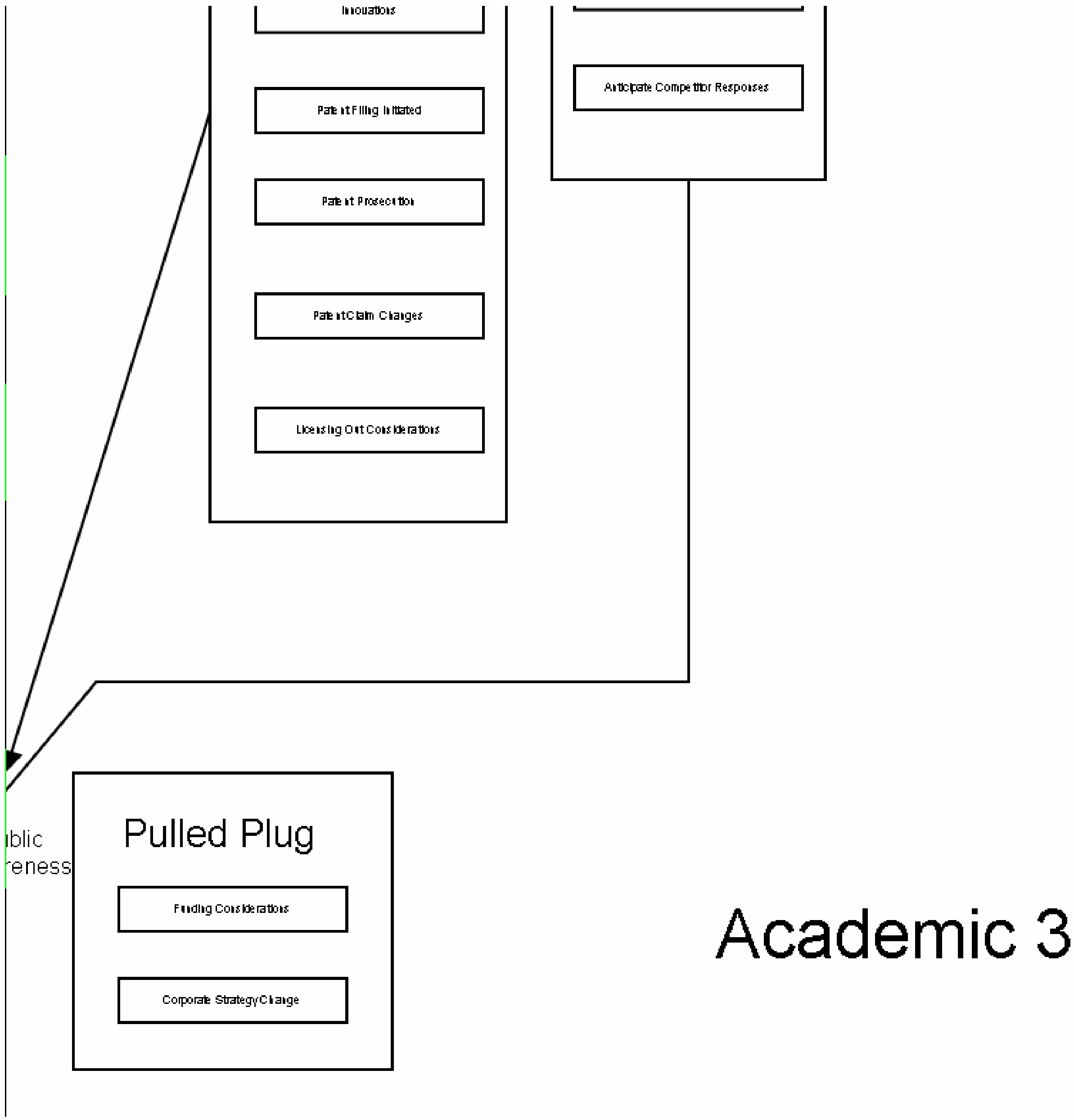
Handled Primarily by Project lead, Inventor had Peripheral Involvement
Customer Needs Analysis
Define Product's Performance Requirements
Product Feature Determination
Finalization of Technical and Physical Requirements
Define the Product Scope / Statement of Work
Preliminary Research
Evaluate Product's Mesh with Corporate Vision, Mission, and Objectives
Licensing In Considerations
Product Design to Meet Government Mandate / Requirements
Estimate / Predict Customer ROI
Evaluate Potential Time to Market Requirements
Product Need Determination Based on Development Lead Time
Determination of Investment Req. / Potential Returns
Create Communication Plan Among Team Members
Re-Scope Development Team
Repeating Design Process
Resource Requirements (Time and Chip Space)
Team Brainstorming (Weekly meeting)
Individual Brainstorming
Choose Product Design From Multiple Alternatives
Documentation of Design Work in Technical Memos
Documentation of Lessons Learned In Development
Technical Problems Arising During Development
Testing, Data Analysis, Evaluation and Reporting
Reliability Testing, Test To Failure, Limit Testing
Design Review(s)
Design Modifications
Review
Schedule / Cost / Technical Performance Summaries (Quarterly reviews with Digital Greenhouse)
Stakeholder Analysis
Reaction to Customer Response
Main Process
Design for Manufacturability
Design for Automation
Design for Assembly
Create a Schedule for the Product
Develop a Work Breakdown Structure
Product Test Method Definition
Evaluate / Select CAD Tools
Cost Estimate Projections
Sought Guidance From Outside Sources (Experts)
Proposed Design Within Target Costs
Produce 2-D and 3-D Drawings
Modeling and Simulation to Study Design
Optimization of Conceptual Design
Refine Tests and Models
Part / Product Cost Reduction
Multifunctional Team Development
Optimization of Detailed Design
Prototype Development
Prototype Testing
Pilot / Prototype Review
Final Design Approval
Public Awareness
IP Related
Intellectual Property Awareness
Identify Primary Innovation
Evaluate Prior Art (Similar Patents)
Identify Potential Future Innovations
Patent Filing Initiated
Patent Prosecution
Patent Claim Changes
Licensing Out Considerations
Competitor Related
Continuous Competitor Monitoring (MIT)
Anticipate Competitor Responses
Pulled Plug
Funding Considerations
Corporate Strategy Change
MAP KEY
Normal Process Element
Critical Element
Time-Consuming Element
Problematic Element
Wish List Element
Time Consuming and Problematic Element
Critical, Time-Consuming and Problematic Element
Academic 3

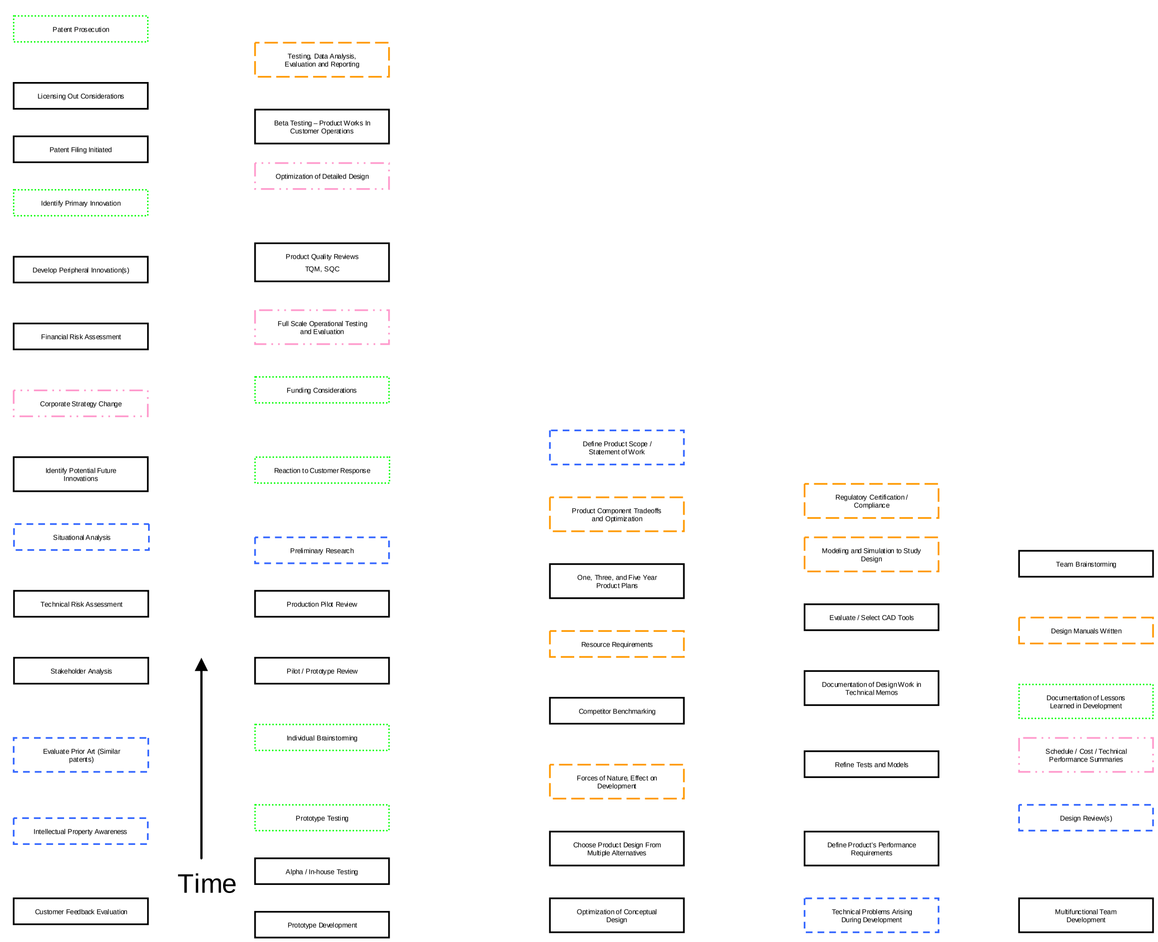

Handled Primarily by Project lead, Inventor had Peripheral Involvement
Customer Needs Analysis
Define Products Performance Requirements
Product Feature Determination
Finalization of Technical and Physical Requirements
Define the Product Scope / Statement of Work
Preliminary Research
Evaluate Products Mesh with Corporate Vision, Mission, and Objectives
Licensing In Considerations
Product Design to Meet Government Mandate / Requirements
Create Communication Plan Among Team Members
Re-Scope Development Team
Repeating Design Process
Resource Requirements (Time and Chip Space)
Team Brainstorming (Weekly meeting)
Individual Brainstorming
Choose Product Design From Multiple Alternatives
Documentation of Design Work in Technical Memos
Documentation of Lessons Learned in Development
Technical Problems Arising During Development
Testing, Data Analysis, Evaluation and Reporting
Reliability Testing, Test To Failure, Limit Testing
Main Process
Design for Manufacturability
Design for Automation
Design for Assembly
Create a Schedule for the Product
Develop a Work Breakdown Structure
Product Test Method Definition
Evaluate / Select CAD Tools
Cost Estimate Projections
Sought Guidance From Outside Sources (Experts)
Proposed Design Within Target Costs
Produce 2-D and 3-D Drawings

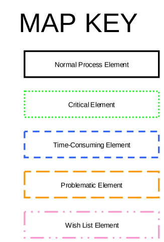

MAP KEY
Normal Process Element
Critical Element
Time-Consuming Element
Problematic Element
Wish List Element
Time Consuming and Problematic Element
Critical, Time-Consuming and Problematic Element
IP Related
Intellectual Property Awareness
Identify Primary Innovation
Evaluate Prior Art (Similar Patents)
Identify Potential Future Innovations
Patent Filing Initiated
Patent Prosecution
Competitor Related
Continuous Competitor Monitoring (MIT)
Anticipate Competitor Responses



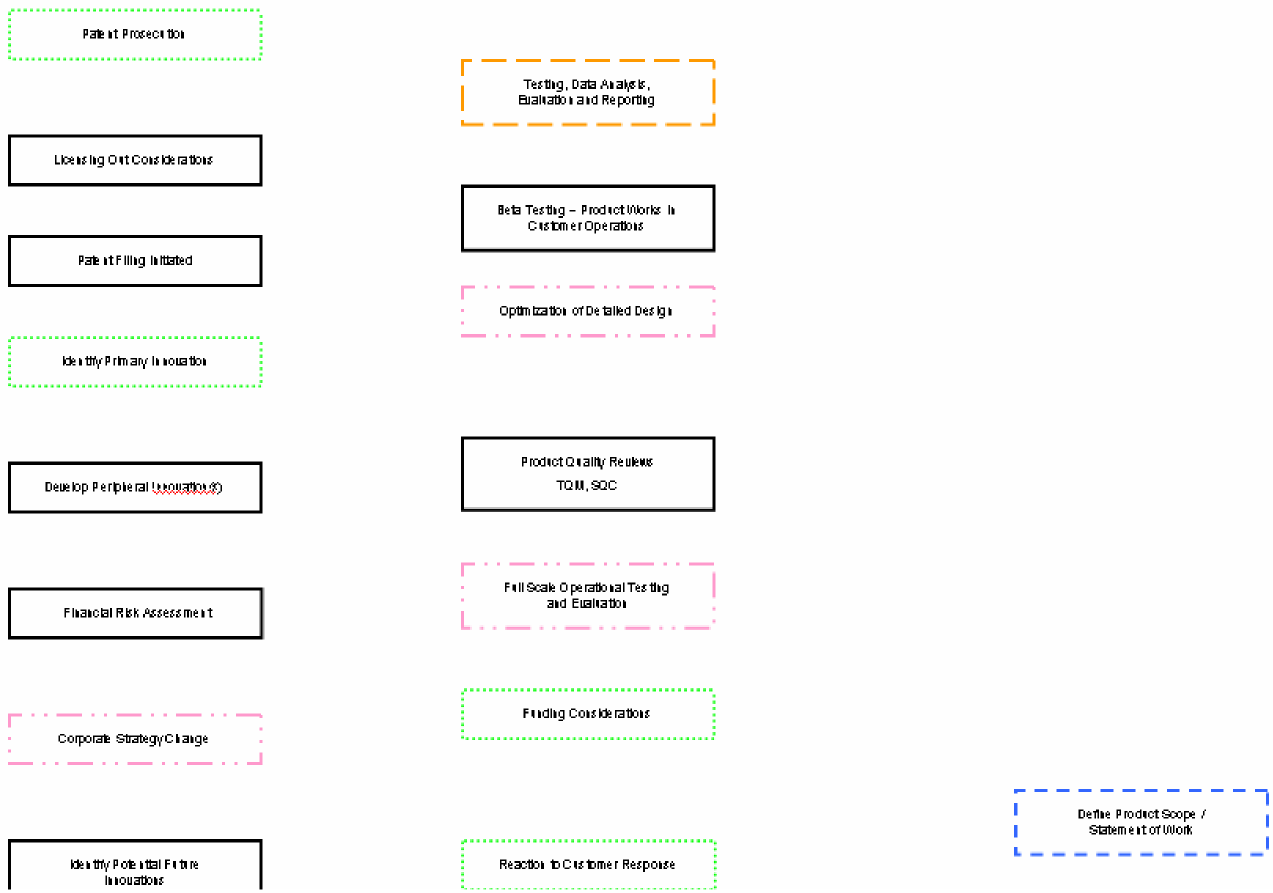
Licensing In Considerations
Product Design to Meet Government Mandate / Requirements
Estimate / Predict Customer ROI
Evaluate Potential Time to Market Requirements
Product Need Determination Based on Development Lead Time
Determination of Investment Req. / Potential Returns
Testing, Data Analysis, Evaluation and Reporting
Reliability Testing, Test To Failure, Limit Testing
Design Review(s)
Design Modifications
Review
Schedule / Cost / Technical Performance Summaries (Quarterly reviews with Digital Greenhouse)
Stakeholder Analysis
Reaction to Customer Response
Proposed Design Within Target Costs
Produce 2-D and 3-D Drawings
Modeling and Simulation to Study Design
Optimization of Conceptual Design
Refine Tests and Models
Part / Product Cost Reduction
Multifunctional Team Development
Optimization of Detailed Design
Prototype Development
Public Awareness
Prototype Testing
Pilot / Prototype Review
Final Design Approval


Innovations
Patent Filing Initiated
Patent Prosecution
Patent Claim Changes
Licensing Out Considerations
Anticipate Competitor Responses
blic
reness
Pulled Plug
Funding Considerations
Corporate Strategy Change
Academic 3


Customer Feedback Evaluation
Intellectual Property Awareness
Evaluate Prior Art (Similar patents)
Stakeholder Analysis
Technical Risk Assessment
Situational Analysis
Identify Potential Future Innovations
Corporate Strategy Change
Financial Risk Assessment
Develop Peripheral Innovation(s)
Identify Primary Innovation
Patent Filing Initiated
Licensing Out Considerations
Patent Prosecution
Time
Prototype Development
Alpha / In-house Testing
Prototype Testing
Individual Brainstorming
Pilot / Prototype Review
Production Pilot Review
Preliminary Research
Reaction to Customer Response
Funding Considerations
Full Scale Operational Testing and Evaluation
Product Quality Reviews TQM, SQC
Optimization of Detailed Design
Beta Testing – Product Works In Customer Operations
Testing, Data Analysis, Evaluation and Reporting
Optimization of Conceptual Design
Choose Product Design From Multiple Alternatives
Forces of Nature, Effect on Development
Competitor Benchmarking
Resource Requirements
One, Three, and Five Year Product Plans
Product Component Tradeoffs and Optimization
Define Product Scope / Statement of Work
Technical Problems Arising During Development
Define Product's Performance Requirements
Refine Tests and Models
Documentation of Design Work in Technical Memos
Evaluate / Select CAD Tools
Modeling and Simulation to Study Design
Regulatory Certification / Compliance
Multifunctional Team Development
Design Review(s)
Schedule / Cost / Technical Performance Summaries
Documentation of Lessons Learned in Development
Design Manuals Written
Team Brainstorming

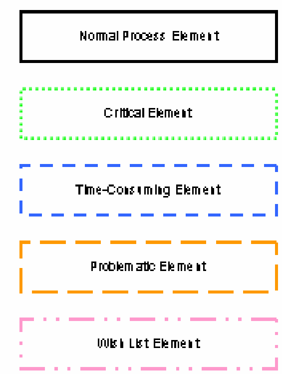

MAP KEY
Normal Process Element
Critical Element
Time-Consuming Element
Problematic Element
Wish List Element

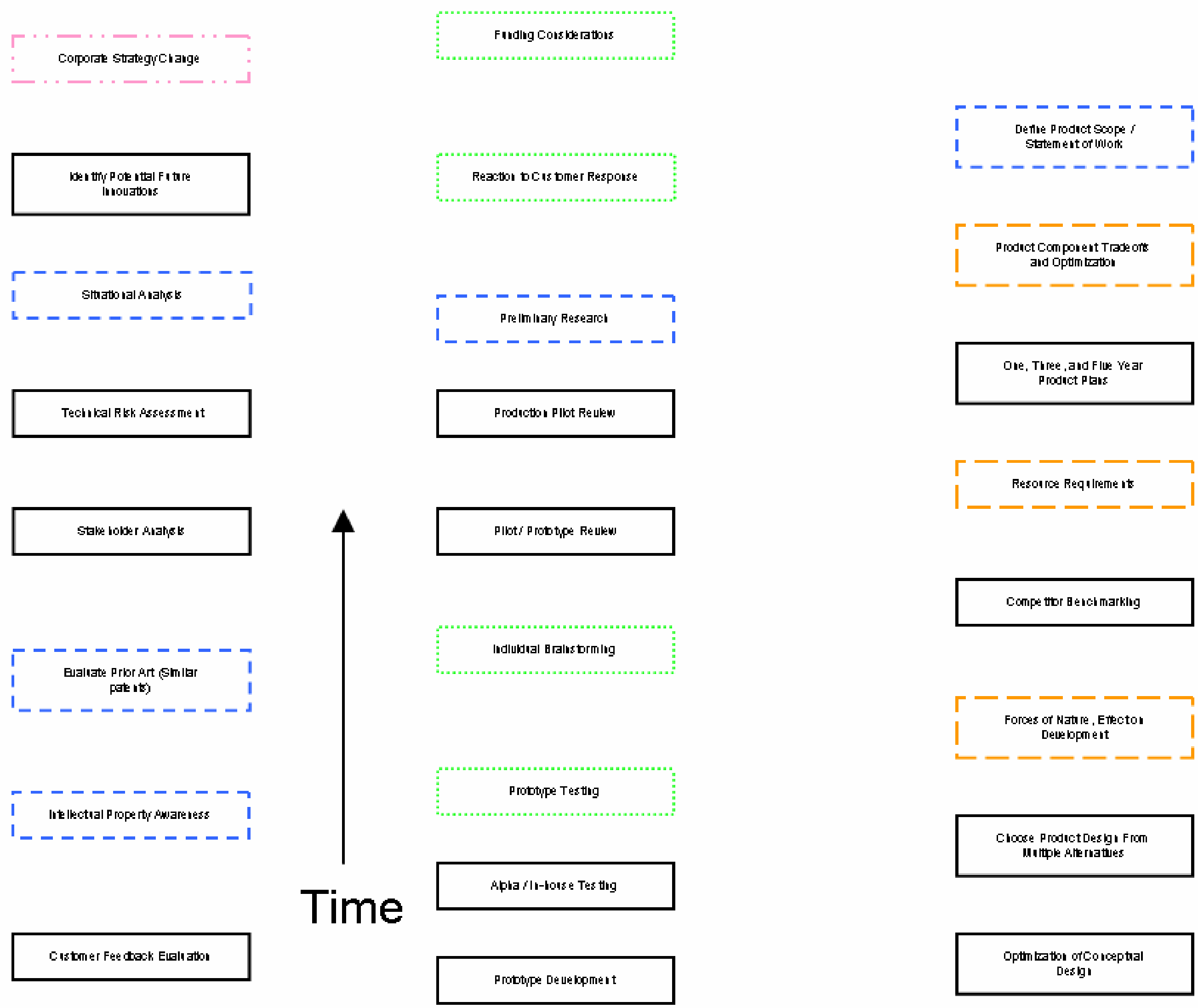
Academic 4

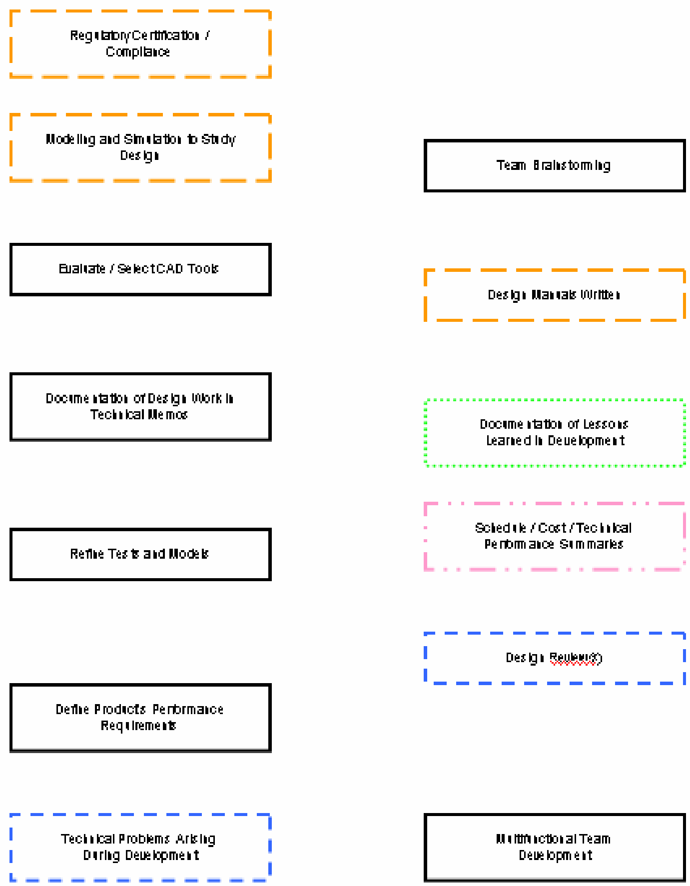


Patent Prosecution
Licensing Out Considerations
Patent Filing Initiated
Identify Primary Innovation
Develop Peripheral Innovation(s)
Financial Risk Assessment
Corporate Strategy Change
Identify Potential Future Innovations
Testing, Data Analysis, Evaluation and Reporting
Beta Testing – Product Works in Customer Operations
Optimization of Detailed Design
Product Quality Reviews
TQM, SQC
Full Scale Operational Testing and Evaluation
Funding Considerations
Reaction to Customer Response
Define Product Scope / Statement of Work

MAP KEY

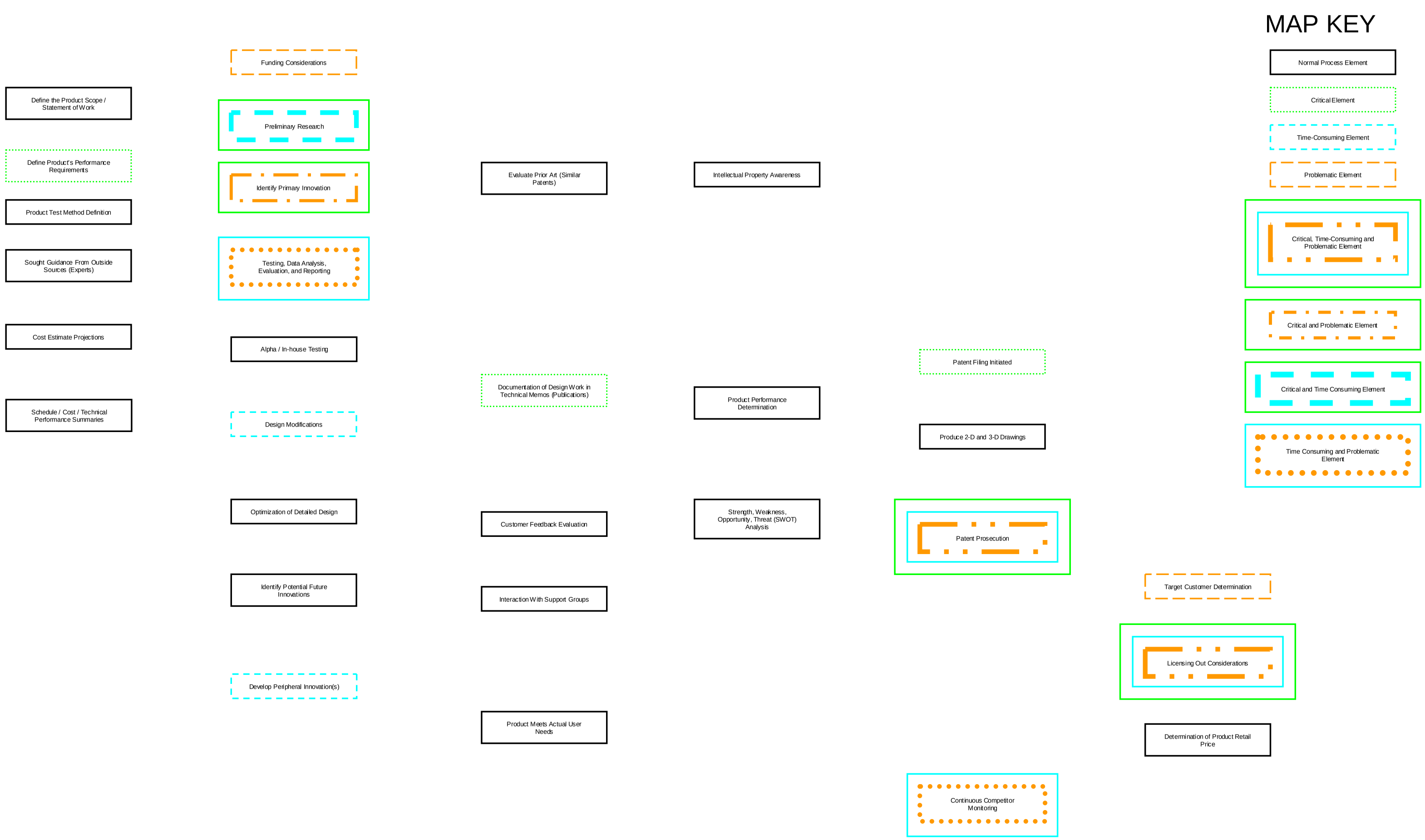

Normal Process Element
Critical Element
Time-Consuming Element
Problematic Element
Wish List Element


Corporate Strategy/Change
Identify Potential Future Innovations
Situational Analysis
Technical Risk Assessment
Stakeholder Analysis
Evaluate Prior Art (Similar patents)
Intellectual Property Awareness
Customer Feedback Evaluation
Time
Funding Considerations
Reaction to Customer Response
Preliminary Research
Production Pilot Review
Pilot / Prototype Review
Individual Brainstorming
Prototype Testing
Alpha / In-house Testing
Prototype Development
Define Product Scope / Statement of Work
Product Component Tradeoffs and Optimization
One, Three, and Five Year Product Plans
Resource Requirements
Competitor Benchmarking
Forces of Nature, Effect on Development
Choose Product Design From Multiple Alternatives
Optimization of Conceptual Design



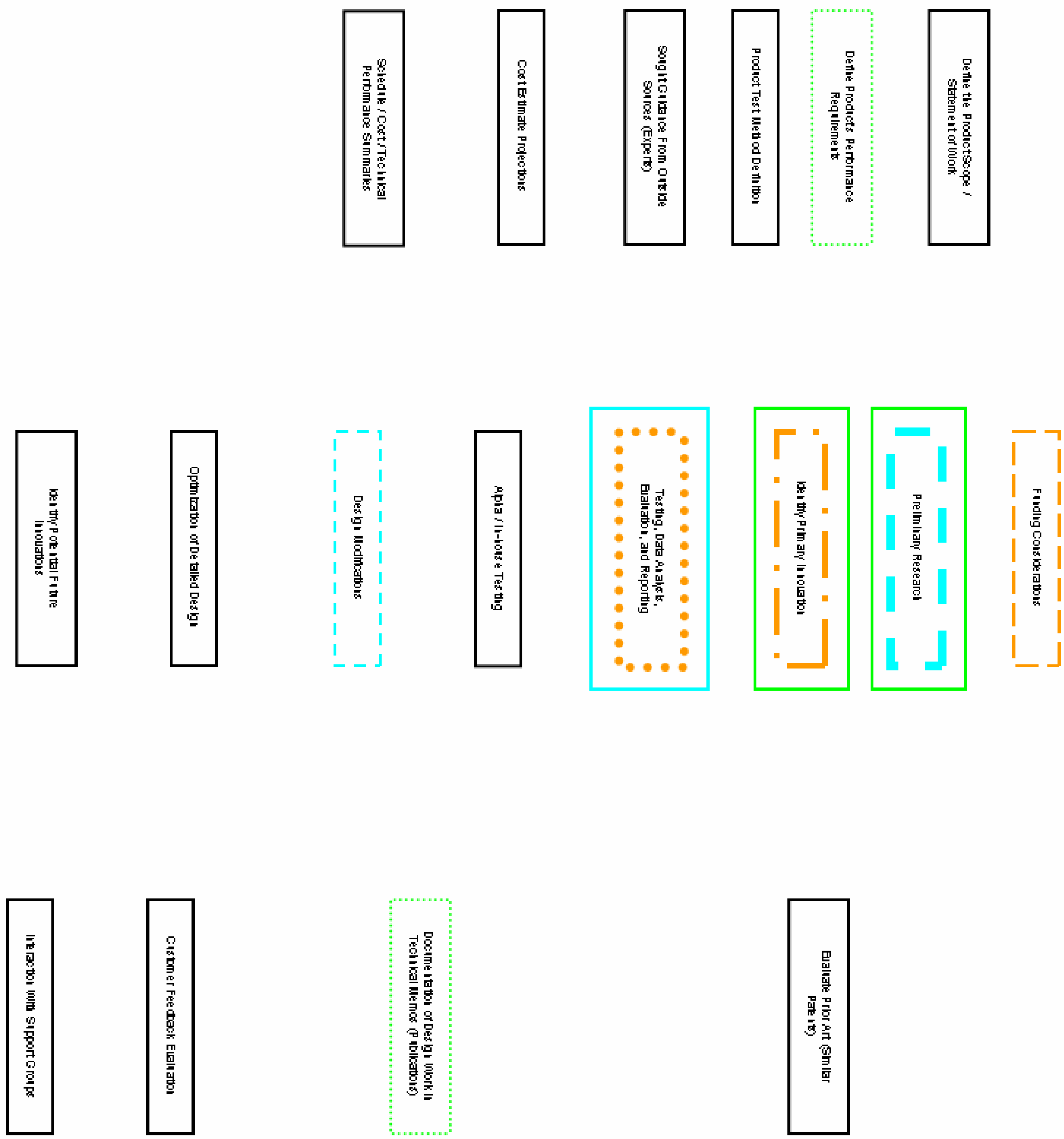
Regulatory Certification / Compliance
Modeling and Simulation to Study Design
Evaluate / Select CAD Tools
Documentation of Design Work in Technical Memos
Refine Tests and Models
Define Products Performance Requirements
Technical Problems Arising During Development
Team Brainstorming
Design Manuals Written
Documentation of Lessons Learned in Development
Schedule / Cost / Technical Performance Summaries
Design Review(s)
Multifunctional Team Development

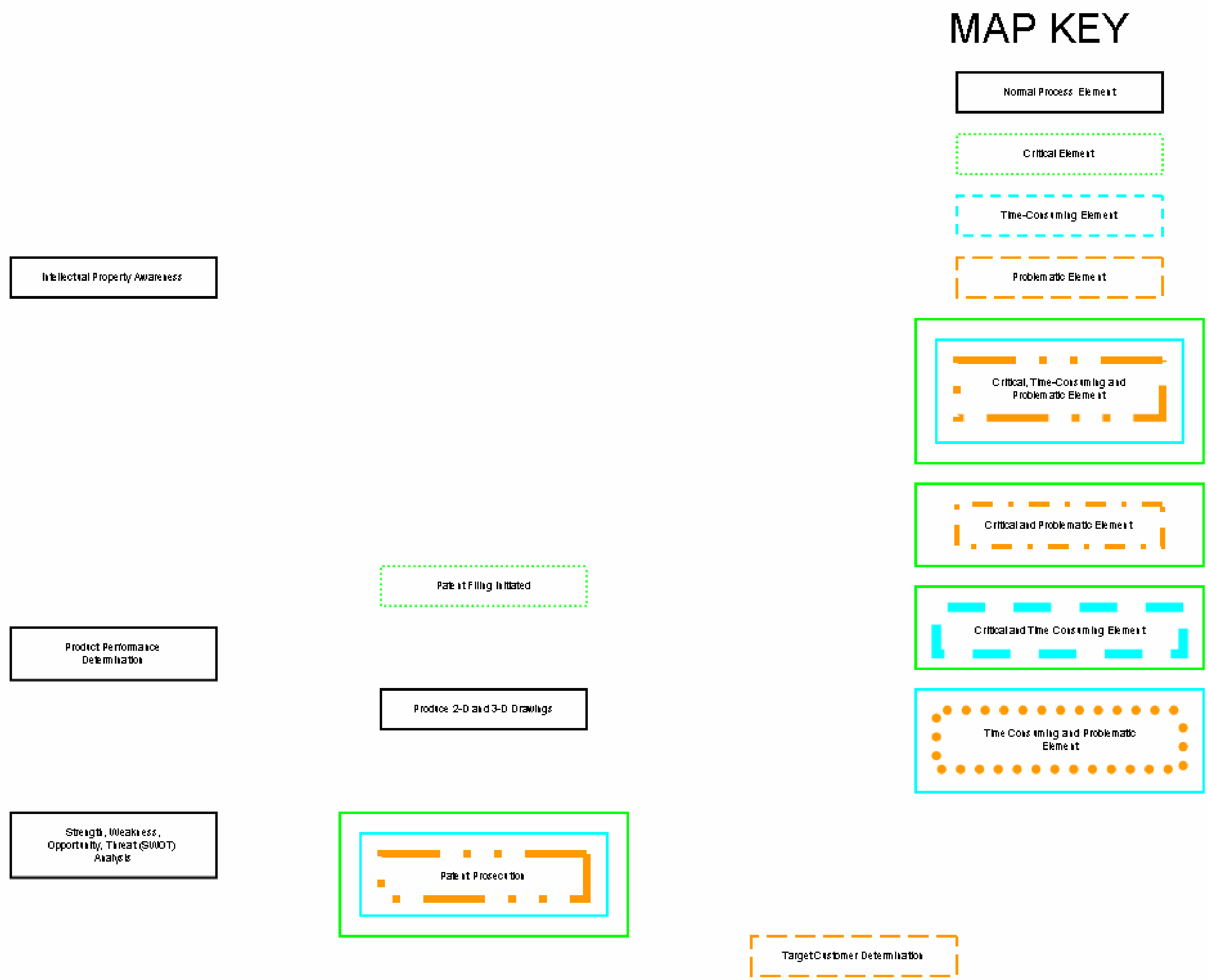
Academic 4

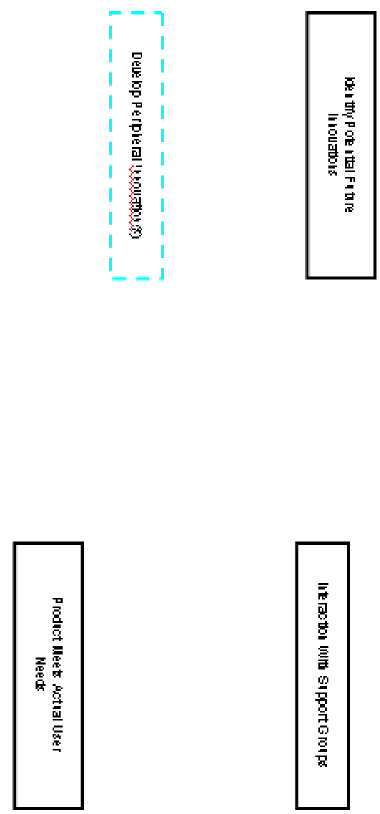


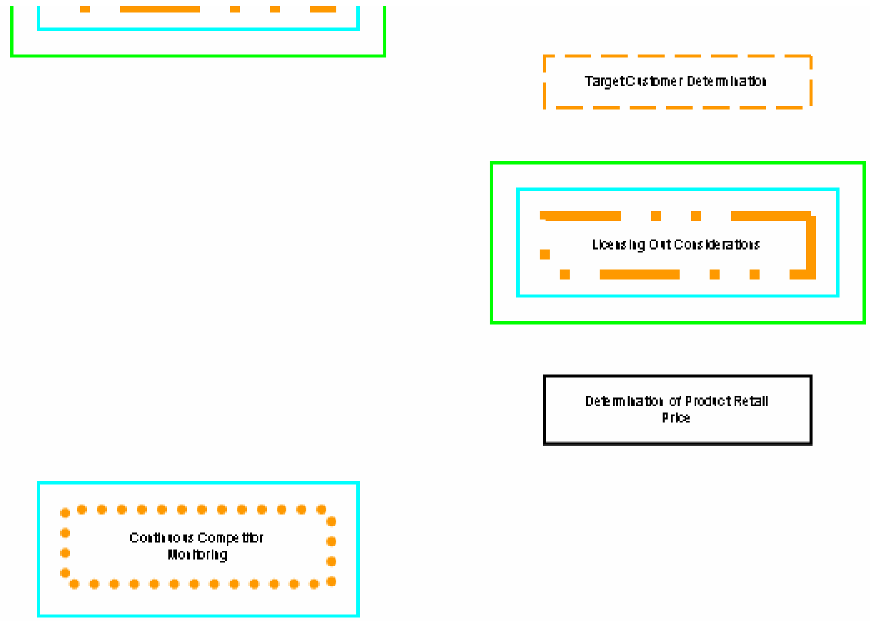
MAP KEY
Normal Process Element
Critical Element
Time-Consuming Element
Problematic Element
Critical, Time-Consuming and Problematic Element
Critical and Problematic Element
Critical and Time Consuming Element
Time Consuming and Problematic Element
Define the Product Scope / Statement of Work
Define Product's Performance Requirements
Product Test Method Definition
Sought Guidance From Outside Sources (Experts)
Cost Estimate Projections
Schedule / Cost / Technical Performance Summaries
Funding Considerations
Preliminary Research
Identify Primary Innovation
Testing, Data Analysis, Evaluation, and Reporting
Alpha / In-house Testing
Design Modifications
Optimization of Detailed Design
Identify Potential Future Innovations
Develop Peripheral Innovation(s)
Evaluate Prior Art (Similar Patents)
Documentation of Design Work in Technical Memos (Publications)
Customer Feedback Evaluation
Interaction With Support Groups
Product Meets Actual User Needs
Intellectual Property Awareness
Product Performance Determination
Strength, Weakness, Opportunity, Threat (SWOT) Analysis
Patent Filing Initiated
Produce 2-D and 3-D Drawings
Patent Prosecution
Continuous Competitor Monitoring
Target Customer Determination
Licensing Out Considerations
Determination of Product Retail Price

Academic 5

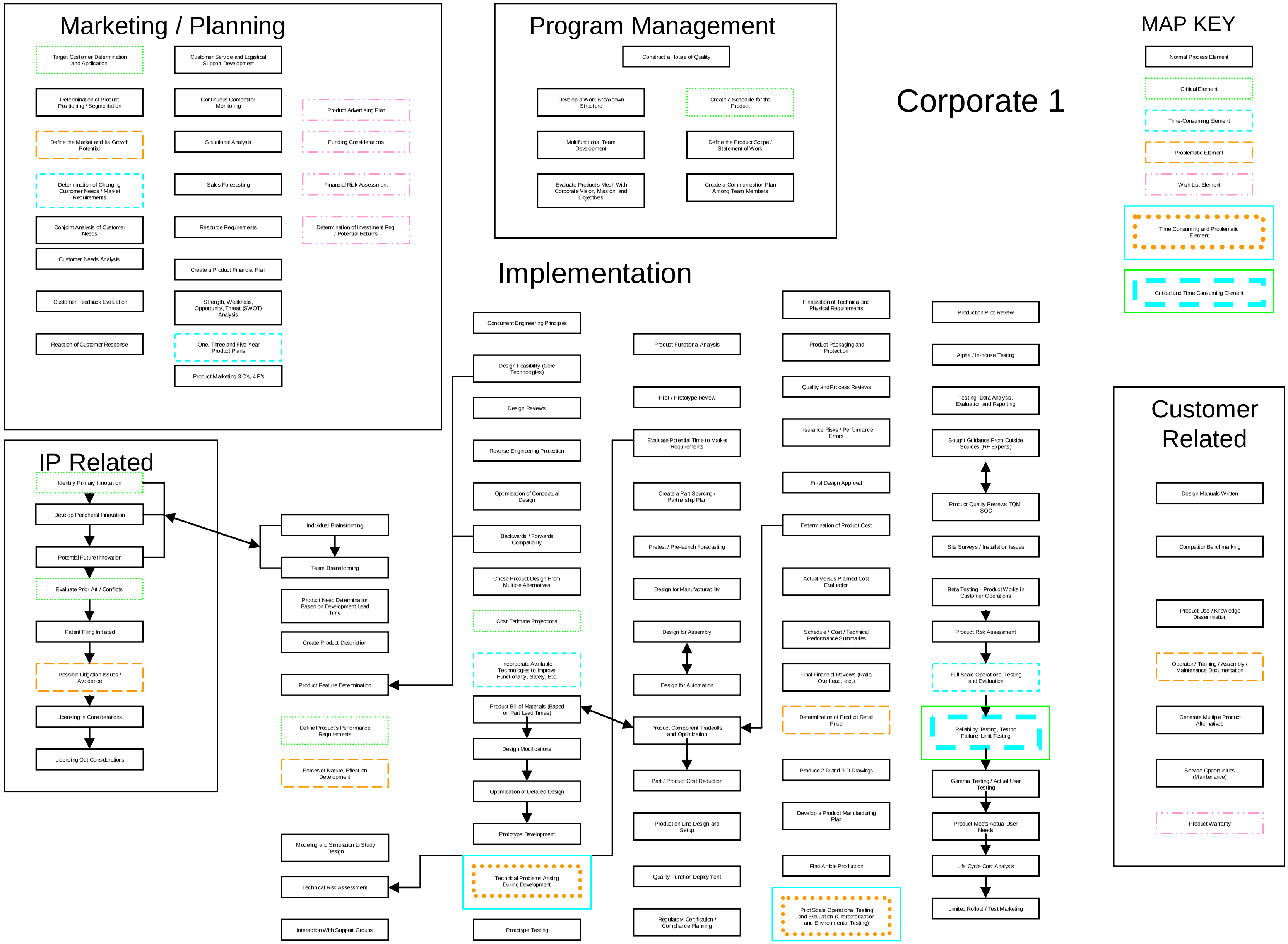

Define the Product Scope / Statement of Work
Define Products Performance Requirement
Product Test Method Definition
Sought Guidance From Outside Sources (Experts)
Cost Estimate Projections
Schedule / Cost / Technical Performance Summaries
Funding Considerations
Preliminary Research
Identify Primary Innovation
Testing, Data Analysis, Evaluation, and Reporting
Alpha / In-house Testing
Design Modifications
Optimization of Detailed Design
Identify Potential Future Innovations
Evaluate Prior Art (Similar Patents)
Documentation of Design Work in Technical Memos (Publications)
Customer Feedback Evaluation
Interaction with Support Groups

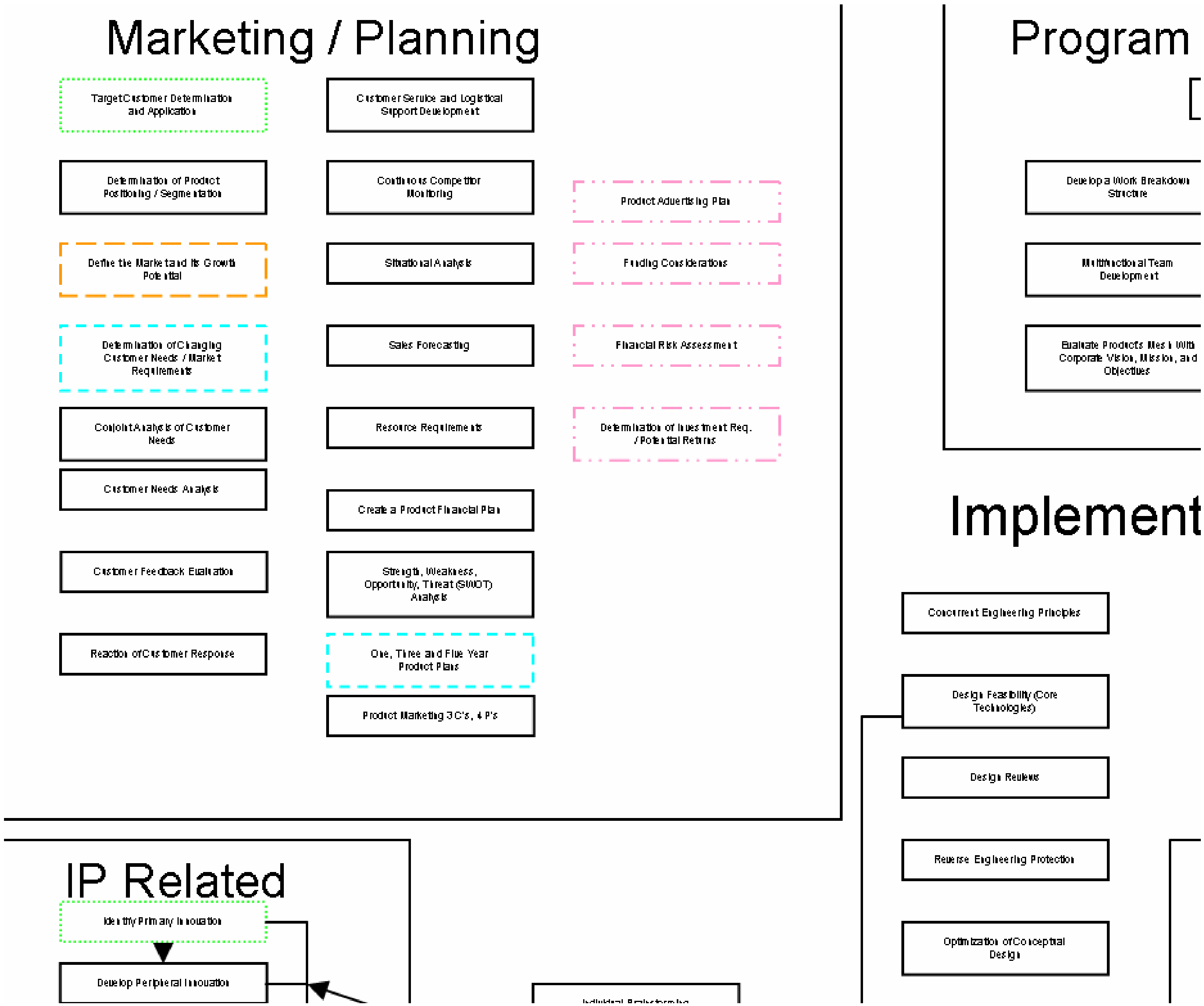

MAP KEY
Normal Process Element
Critical Element
Time-Consuming Element
Problematic Element
Critical, Time-Consuming and Problematic Element
Critical and Problematic Element
Critical and Time Consuming Element
Time Consuming and Problematic Element
Intellectual Property Awareness
Patent Filing Initiated
Product Performance Determination
Produce 2-D and 3-D Drawings
Strength, Weakness, Opportunity, Threat (SWOT) Analysis
Patent Prosecution
Target Customer Determination


Develop Peripheral Innovation(s)
Identify Potential Future Innovations
Product Meets Actual User Needs
Interaction With Support Groups


Target Customer Determination
Licensing Out Considerations
Determination of Product Retail Price
Continuous Competitor Monitoring

Academic 5


Marketing / Planning
Target Customer Determination and Application
Determination of Product Positioning / Segmentation
Define the Market and its Growth Potential
Determination of Changing Customer Needs / Market Requirements
Conjoint Analysis of Customer Needs
Customer Needs Analysis
Customer Feedback Evaluation
Reaction of Customer Response
Customer Service and Logistical Support Development
Continuous Competitor Monitoring
Situational Analysis
Sales Forecasting
Resource Requirements
Create a Product Financial Plan
Strength, Weakness, Opportunity, Threat (SWOT) Analysis
One, Three and Five Year Product Plans
Product Marketing 3 C's, 4 P's
Product Advertising Plan
Funding Considerations
Financial Risk Assessment
Determination of Investment Req. / Potential Returns
Program Management
Construct a House of Quality
Develop a Work Breakdown Structure
Multifunctional Team Development
Evaluate Product's Mesh With Corporate Vision, Mission, and Objectives
Create a Schedule for the Product
Define the Product Scope / Statement of Work
Create a Communication Plan Among Team Members
Corporate 1
MAP KEY
Normal Process Element
Critical Element
Time-Consuming Element
Problematic Element
Wish List Element
Time Consuming and Problematic Element
Critical and Time Consuming Element
IP Related
Identify Primary Innovation
Develop Peripheral Innovation
Potential Future Innovation
Evaluate Prior Art / Conflicts
Patent Filing Initiated
Possible Litigation Issues / Avoidance
Licensing In Considerations
Licensing Out Considerations
Implementation
Individual Brainstorming
Team Brainstorming
Product Need Determination Based on Development Lead Time
Create Product Description
Product Feature Determination
Define Product's Performance Requirements
Forces of Nature, Effect on Development
Modeling and Simulation to Study Design
Technical Risk Assessment
Interaction With Support Groups
Concurrent Engineering Principles
Design Feasibility (Core Technologies)
Design Reviews
Reverse Engineering Protection
Optimization of Conceptual Design
Backwards / Forwards Compatibility
Chose Product Design From Multiple Alternatives
Cost Estimate Projections
Incorporate Available Technologies to Improve Functionality, Safety, Etc.
Product Bill of Materials (Based on Part Lead Times)
Design Modifications
Optimization of Detailed Design
Prototype Development
Technical Problems Arising During Development
Prototype Testing
Product Functional Analysis
Pilot / Prototype Review
Evaluate Potential Time to Market Requirements
Create a Part Sourcing / Partnership Plan
Pretest / Pre-launch Forecasting
Design for Manufacturability
Design for Assembly
Design for Automation
Product Component Tradeoffs and Optimization
Part / Product Cost Reduction
Production Line Design and Setup
Quality Function Deployment
Regulatory Certification / Compliance Planning
Finalization of Technical and Physical Requirements
Product Packaging and Protection
Quality and Process Reviews
Insurance Risks / Performance Errors
Final Design Approval
Determination of Product Cost
Actual Versus Planned Cost Evaluation
Schedule / Cost / Technical Performance Summaries
Final Financial Reviews (Ratio, Overhead, etc.)
Determination of Product Retail Price
Produce 2-D and 3-D Drawings
Develop a Product Manufacturing Plan
First Article Production
Pilot Scale Operational Testing and Evaluation (Characterization and Environmental Testing)
Production Pilot Review
Alpha / In-house Testing
Testing, Data Analysis, Evaluation and Reporting
Sought Guidance From Outside Sources (RF Experts)
Product Quality Reviews TQM, SQC
Site Surveys / Installation Issues
Beta Testing – Product Works in Customer Operations
Product Risk Assessment
Full Scale Operational Testing and Evaluation
Reliability Testing, Test to Failure, Limit Testing
Gamma Testing / Actual User Testing
Product Meets Actual User Needs
Life Cycle Cost Analysis
Limited Rollout / Test Marketing
Customer Related
Design Manuals Written
Competitor Benchmarking
Product Use / Knowledge Dissemination
Operator / Training / Assembly / Maintenance Documentation
Generate Multiple Product Alternatives
Service Opportunities (Maintenance)
Product Warranty



Marketing / Planning
Target Customer Determination and Application
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Customer Needs Analysis
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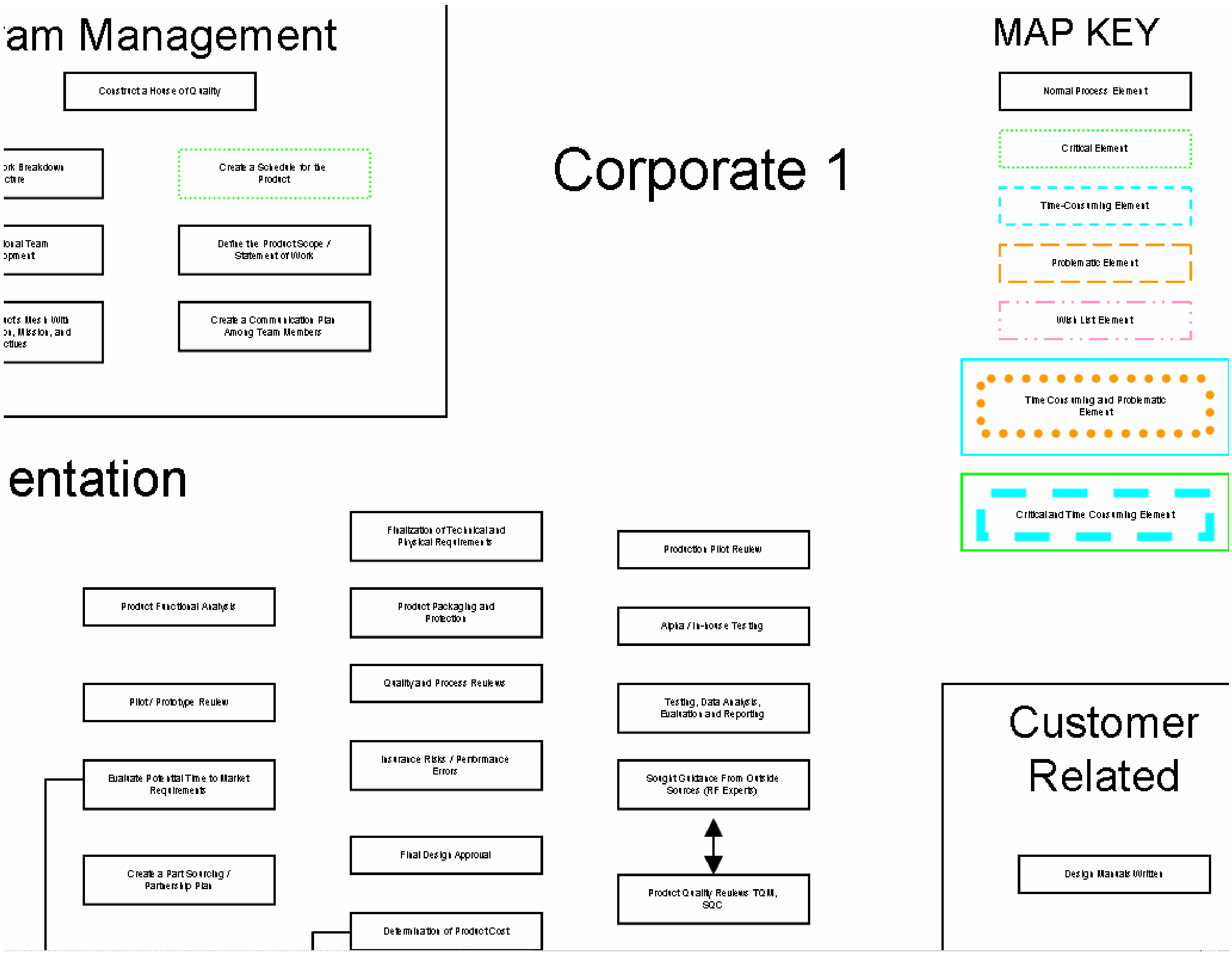
Sales Forecasting
Resource Requirements
Create a Product Financial Plan
Strength, Weakness, Opportunity, Threat (SWOT) Analysis
One, Three and Five Year Product Plans
Product Marketing 3 C's, 4 P's
Product Advertising Plan
Funding Considerations
Financial Risk Assessment
Determination of Investment Req. / Potential Returns
Program
Develop a Work Breakdown Structure
Multifunctional Team Development
Evaluate Products Mesh With Corporate Vision, Mission, and Objectives
Implement
Concurrent Engineering Principles
Design Feasibility (Core Technologies)
Design Reviews
Reverse Engineering Protection
Optimization of Conceptual Design
IP Related
Identify Primary Innovation
Develop Peripheral Innovation



am Management
Construct a House of Quality
ork Breakdown cture
Create a Schedule for the Product
ional Team opment
Define the Product Scope / Statement of Work
ucts Mesh With on, Mission, and ctives
Create a Communication Plan Among Team Members
Corporate 1
MAP KEY
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Problematic Element
Wish List Element
Time Consuming and Problematic Element
Critical and Time Consuming Element
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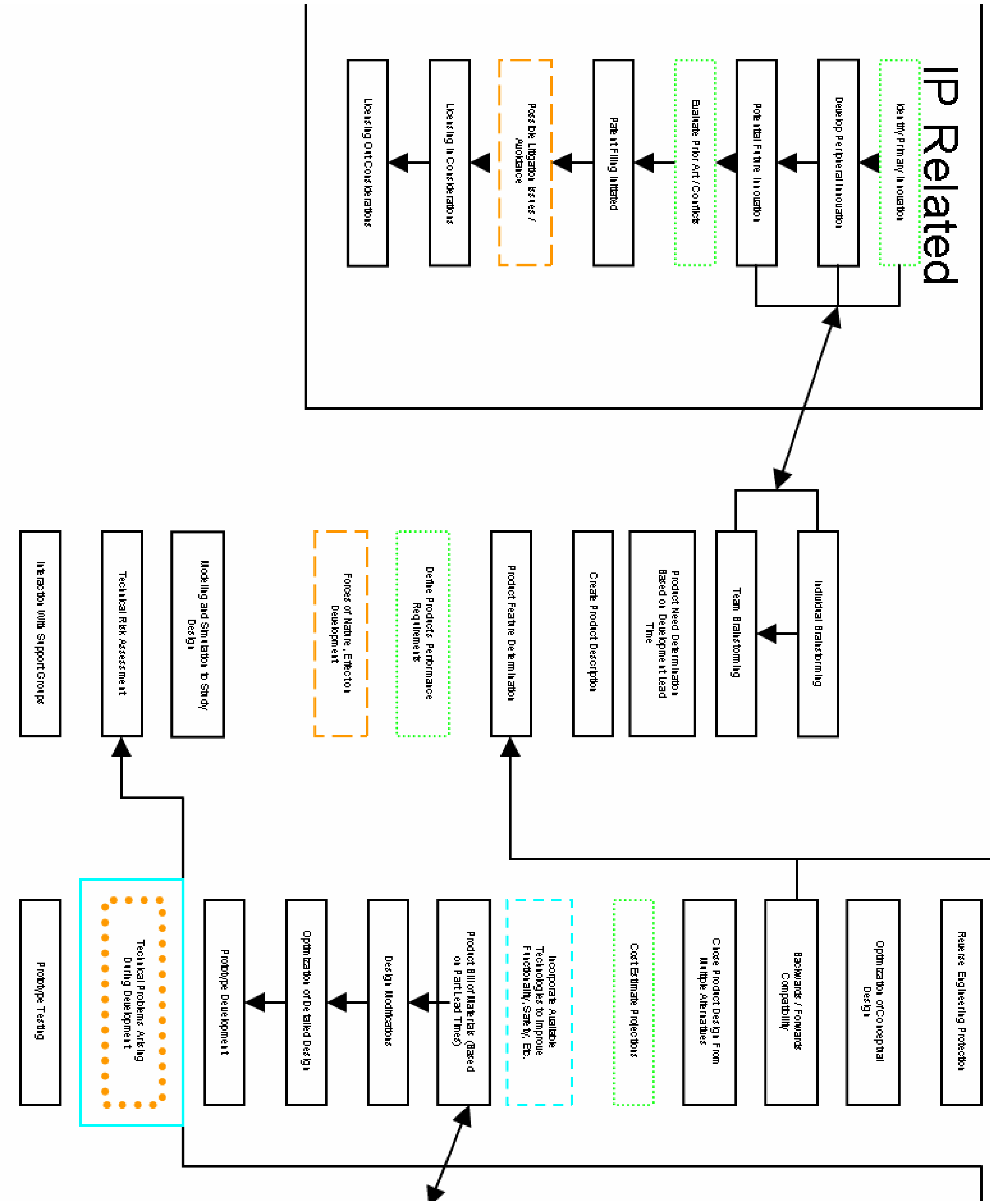
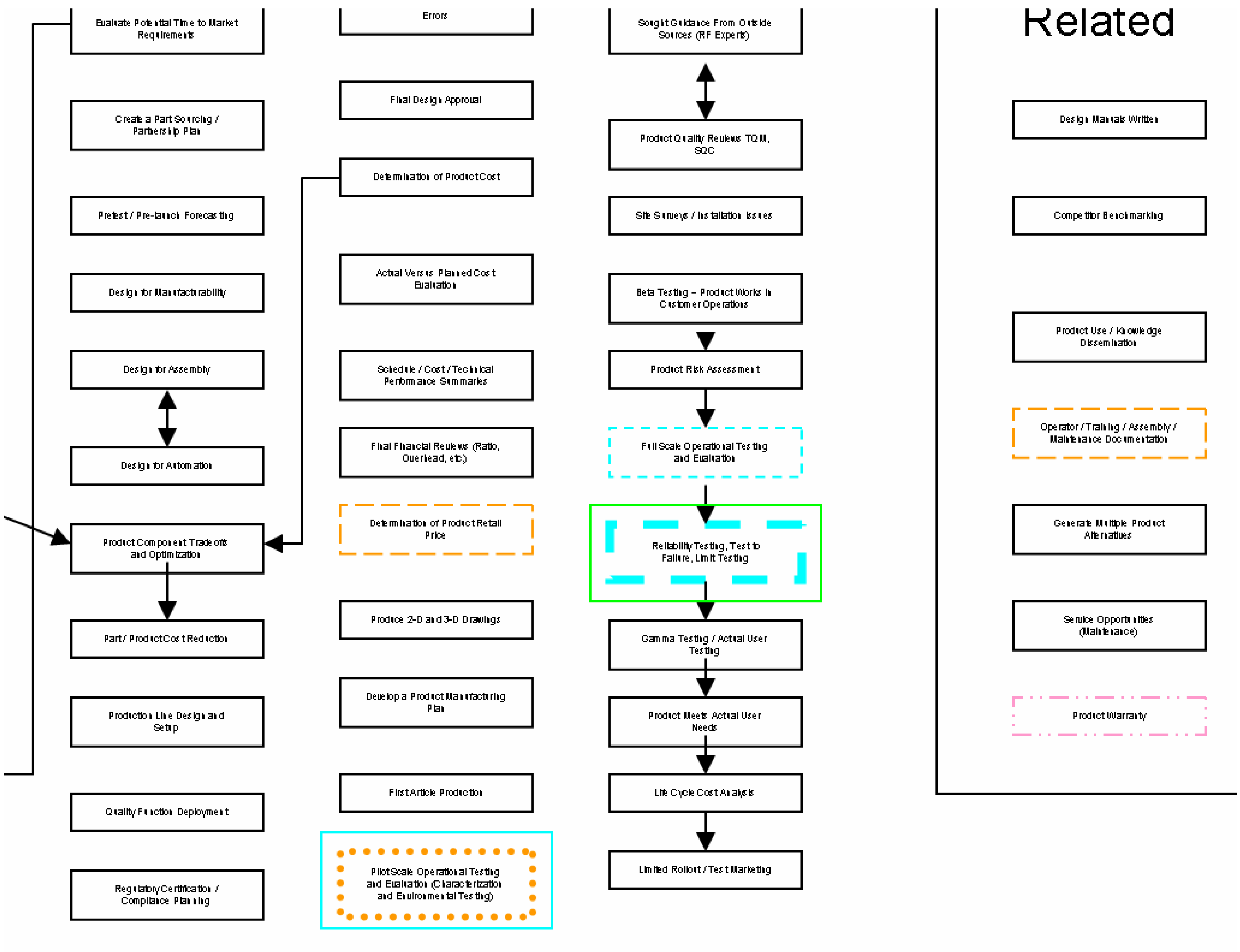
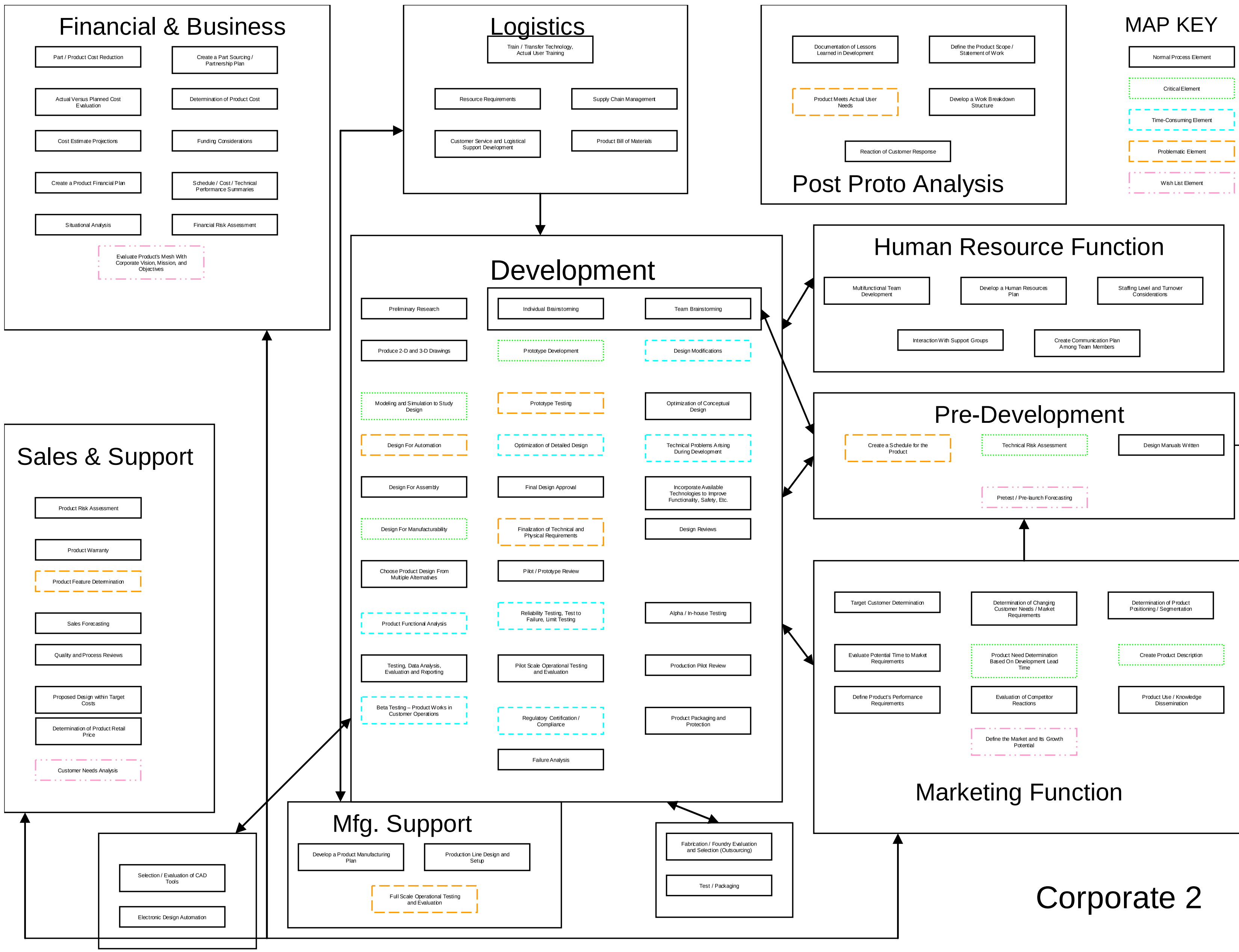
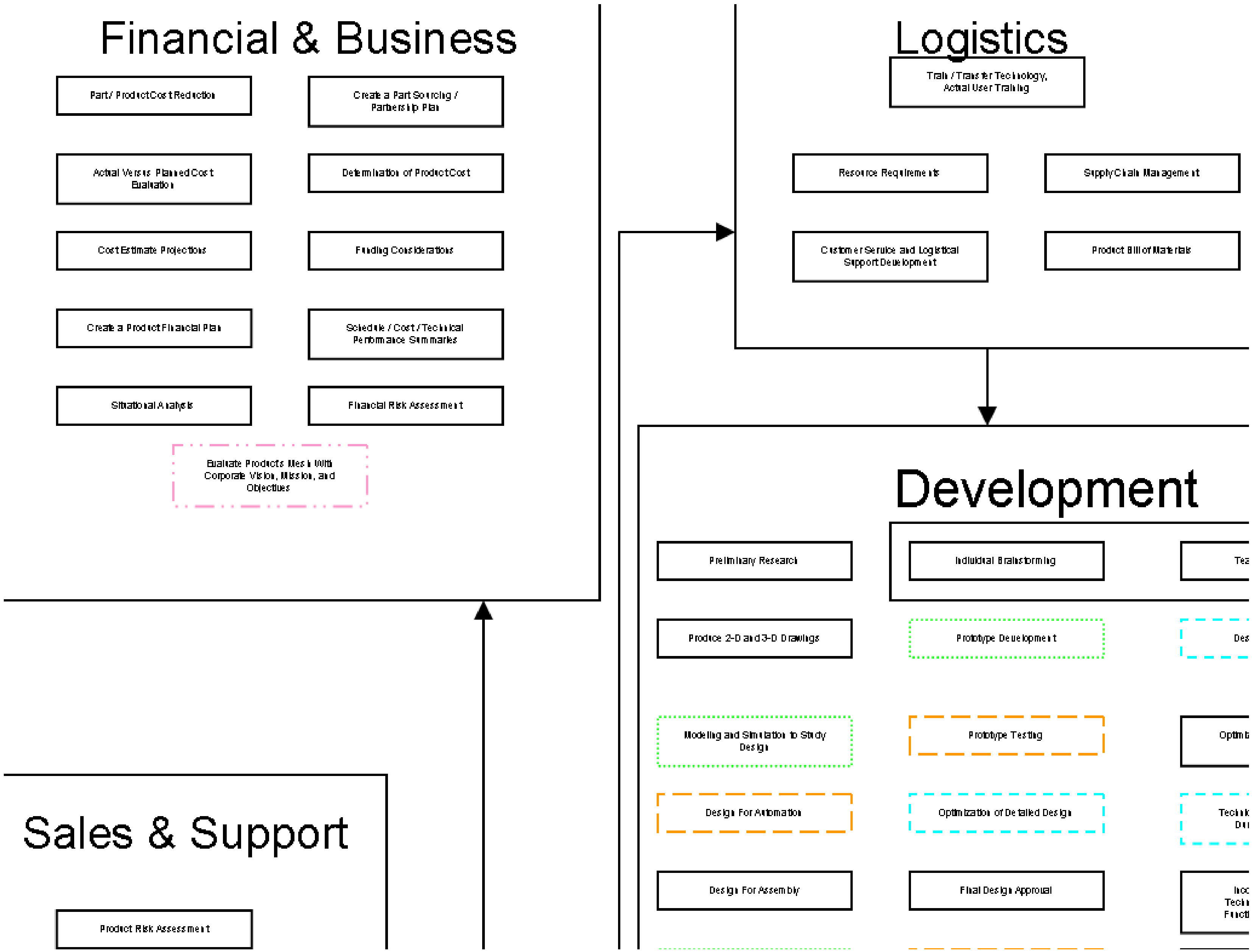
Finalization of Technical and Physical Requirements
Production Pilot Review
Product Functional Analysis
Product Packaging and Protection
Alpha / In-house Testing
Quality and Process Reviews
Pilot / Prototype Review
Testing, Data Analysis, Evaluation and Reporting
Insurance Risks / Performance Errors
Evaluate Potential Time to Market Requirements
Sought Guidance From Outside Sources (RF Experts)
Customer Related
Final Design Approval
Create a Part Sourcing / Partnership Plan
Product Quality Reviews TQM, SQC
Design Manuals Written
Determination of Product Cost


IP Related
Identify Primary Innovation
Develop Peripheral Innovation
Potential Future Innovation
Evaluate Prior Art / Conflicts
Patent Filing Initiated
Possible Litigation Issues / Avoidance
Licensing In Considerations
Licensing Out Considerations
Individual Brainstorming
Team Brainstorming
Product Need Determination Based on Development Lead Time
Create Product Description
Product Feature Determination
Define Products Performance Requirements
Forces of Nature, Effect on Development
Modelling and Simulation to Study Design
Technical Risk Assessment
Interaction With Support Groups
Reverse Engineering Protection
Optimization of Conceptual Design
Backwards / Forwards Compatibility
Choose Product Design From Multiple Alternatives
Cost Estimate Projections
Incorporate Available Technologies to Improve Functionality, Safety, Etc.
Product Bill of Materials (Based on Part Lead Times)
Design Modifications
Optimization of Detailed Design
Prototype Development
Technical Problems Arising During Development
Prototype Testing



Related
Evaluate Potential Time to Market Requirements
Create a Part Sourcing / Partnership Plan
Pretest / Pre-launch Forecasting
Design for Manufacturability
Design for Assembly
Design for Automation
Product Component Trade offs and Optimization
Part / Product Cost Reduction
Production Line Design and Setup
Quality Function Deployment
Regulatory Certification / Compliance Planning
Errors
Final Design Approval
Determination of Product Cost
Actual Versus Planned Cost Evaluation
Schedule / Cost / Technical Performance Summaries
Final Financial Reviews (Ratio, Overhead, etc)
Determination of Product Retail Price
Produce 2-D and 3-D Drawings
Develop a Product Manufacturing Plan
First Article Production
Pilot Scale Operational Testing and Evaluation (Characterization and Environmental Testing)
Sought Guidance From Outside Sources (RF Experts)
Product Quality Reviews TQM, SQC
Site Surveys / Installation Issues
Beta Testing – Product Works in Customer Operations
Product Risk Assessment
Full Scale Operational Testing and Evaluation
Reliability Testing, Test to Failure, Limit Testing
Gamma Testing / Actual User Testing
Product Meets Actual User Needs
Life Cycle Cost Analysis
Limited Rollout / Test Marketing
Design Manuals Written
Competitor Benchmarking
Product Use / Knowledge Dissemination
Operator / Training / Assembly / Maintenance Documentation
Generate Multiple Product Alternatives
Service Opportunities (Maintenance)
Product Warranty


Financial & Business
Part / Product Cost Reduction
Create a Part Sourcing / Partnership Plan
Actual Versus Planned Cost Evaluation
Determination of Product Cost
Cost Estimate Projections
Funding Considerations
Create a Product Financial Plan
Schedule / Cost / Technical Performance Summaries
Situational Analysis
Financial Risk Assessment
Evaluate Product's Mesh With Corporate Vision, Mission, and Objectives
Logistics
Train / Transfer Technology, Actual User Training
Resource Requirements
Supply Chain Management
Customer Service and Logistical Support Development
Product Bill of Materials
Documentation of Lessons Learned in Development
Define the Product Scope / Statement of Work
Product Meets Actual User Needs
Develop a Work Breakdown Structure
Reaction of Customer Response
Post Proto Analysis
MAP KEY
Normal Process Element
Critical Element
Time-Consuming Element
Problematic Element
Wish List Element
Development
Preliminary Research
Individual Brainstorming
Team Brainstorming
Produce 2-D and 3-D Drawings
Prototype Development
Design Modifications
Modeling and Simulation to Study Design
Prototype Testing
Optimization of Conceptual Design
Design For Automation
Optimization of Detailed Design
Technical Problems Arising During Development
Design For Assembly
Final Design Approval
Incorporate Available Technologies to Improve Functionality, Safety, Etc.
Design For Manufacturability
Finalization of Technical and Physical Requirements
Design Reviews
Choose Product Design From Multiple Alternatives
Pilot / Prototype Review
Reliability Testing, Test to Failure, Limit Testing
Alpha / In-house Testing
Product Functional Analysis
Testing, Data Analysis, Evaluation and Reporting
Pilot Scale Operational Testing and Evaluation
Production Pilot Review
Beta Testing – Product Works in Customer Operations
Regulatory Certification / Compliance
Product Packaging and Protection
Failure Analysis
Human Resource Function
Multifunctional Team Development
Develop a Human Resources Plan
Staffing Level and Turnover Considerations
Interaction With Support Groups
Create Communication Plan Among Team Members
Pre-Development
Create a Schedule for the Product
Technical Risk Assessment
Design Manuals Written
Pretest / Pre-launch Forecasting
Target Customer Determination
Determination of Changing Customer Needs / Market Requirements
Determination of Product Positioning / Segmentation
Evaluate Potential Time to Market Requirements
Product Need Determination Based On Development Lead Time
Create Product Description
Define Product's Performance Requirements
Evaluation of Competitor Reactions
Product Use / Knowledge Dissemination
Define the Market and Its Growth Potential
Marketing Function
Sales & Support
Product Risk Assessment
Product Warranty
Product Feature Determination
Sales Forecasting
Quality and Process Reviews
Proposed Design within Target Costs
Determination of Product Retail Price
Customer Needs Analysis
Selection / Evaluation of CAD Tools
Electronic Design Automation
Mfg. Support
Develop a Product Manufacturing Plan
Production Line Design and Setup
Full Scale Operational Testing and Evaluation
Fabrication / Foundry Evaluation and Selection (Outsourcing)
Test / Packaging
Corporate 2


Financial & Business
Part/ Product Cost Reduction
Create a Part Sourcing / Partnership Plan
Actual Versus Planned Cost Evaluation
Determination of Product Cost
Cost Estimate Projections
Funding Considerations
Create a Product Financial Plan
Schedule / Cost / Technical Performance Summaries
Situational Analysis
Financial Risk Assessment
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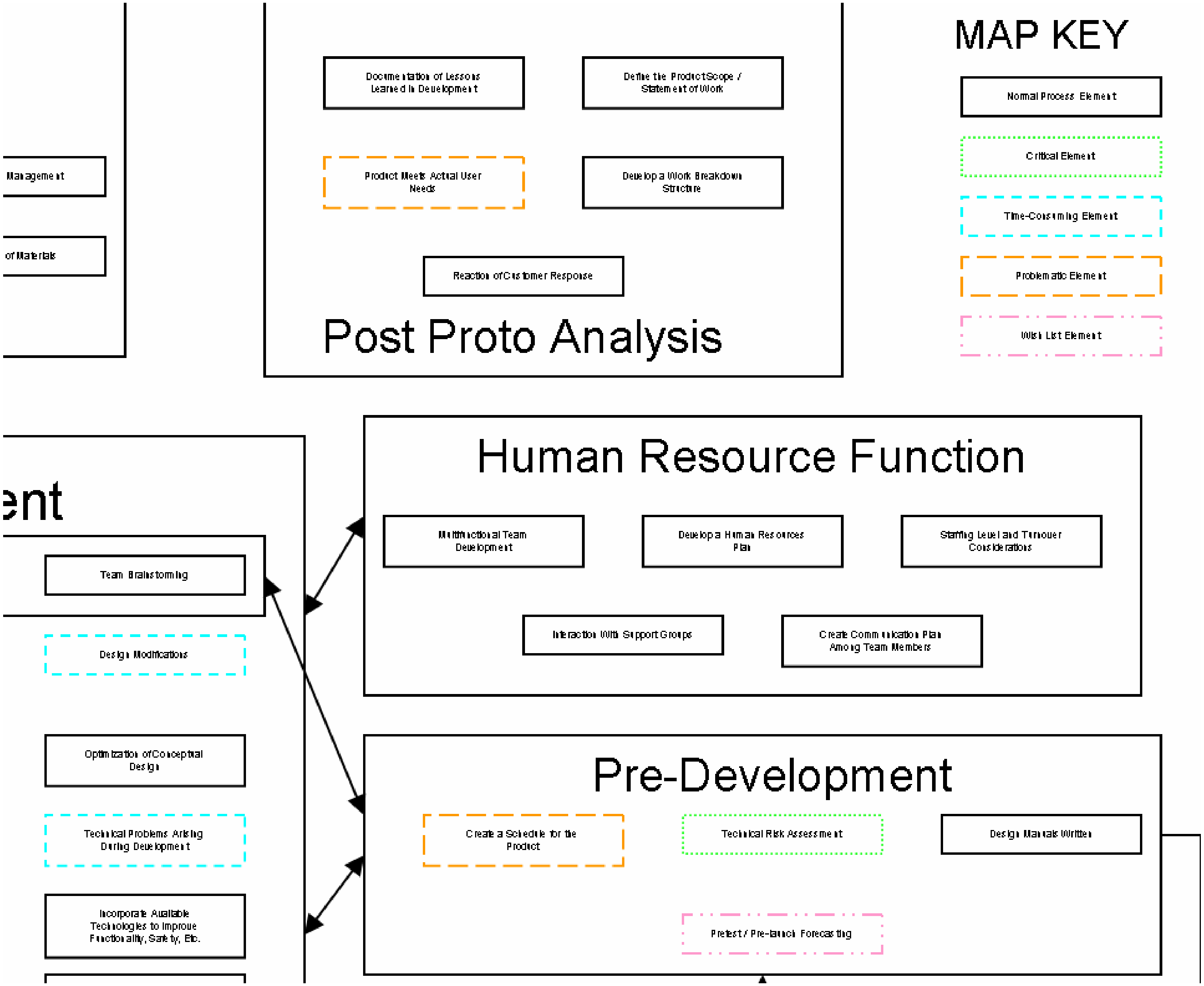
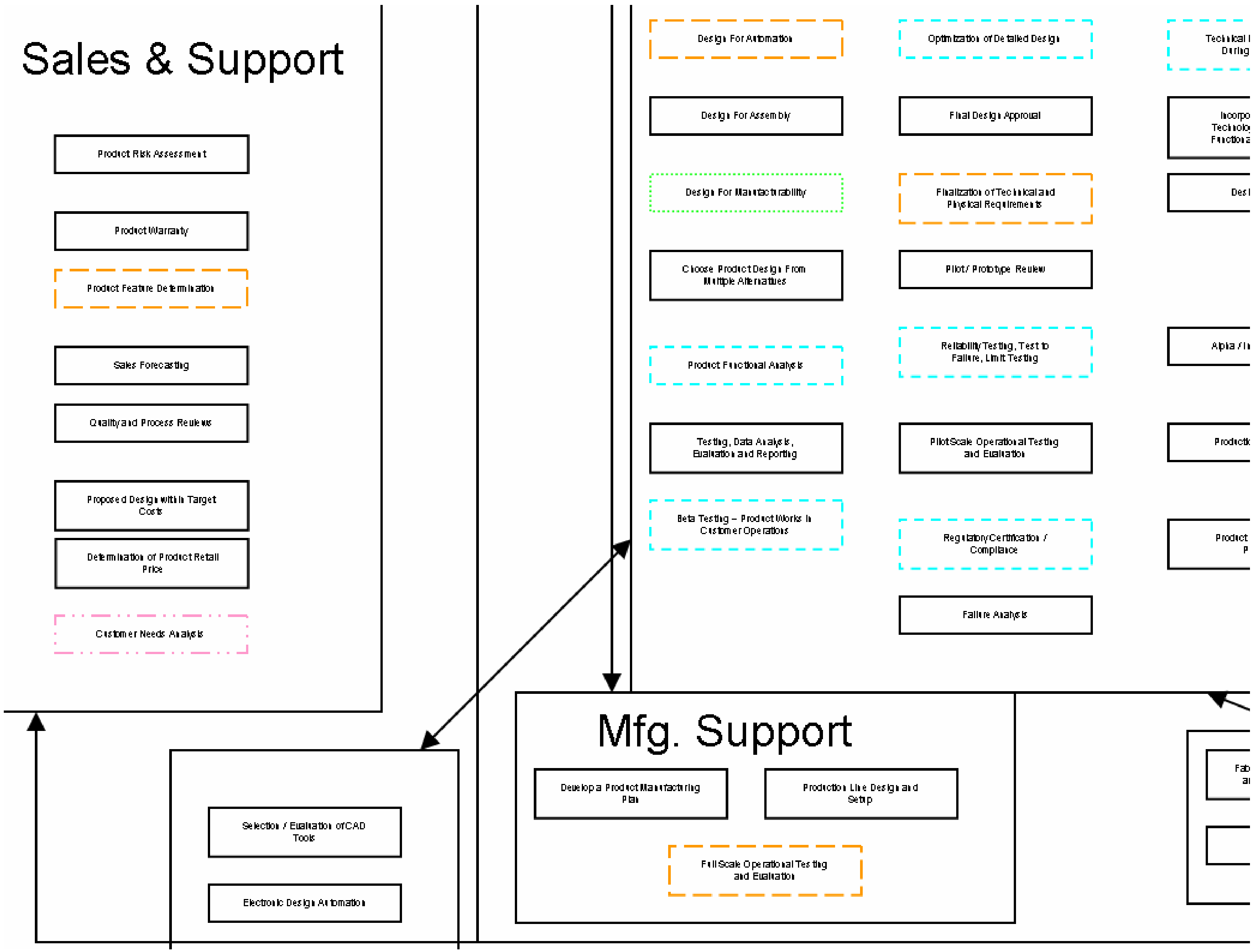
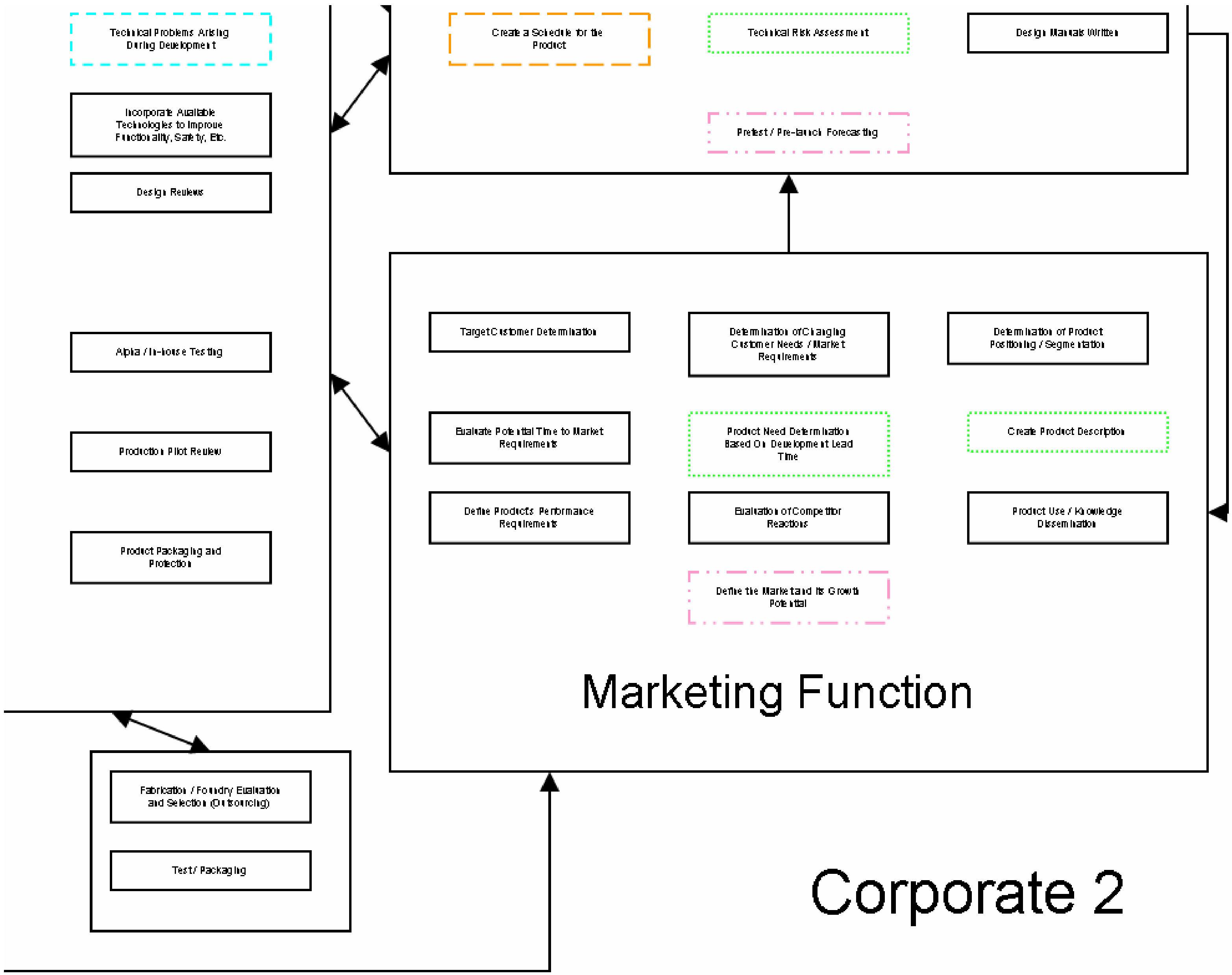
Logistics
Train / Transfer Technology, Actual User Training
Resource Requirements
Supply Chain Management
Customer Service and Logistical Support Development
Product Bill of Materials
Development
Preliminary Research
Individual Brainstorming
Produce 2-D and 3-D Drawings
Prototype Development
Modeling and Simulation to Study Design
Prototype Testing
Design For Automation
Optimization of Detailed Design
Design For Assembly
Final Design Approval
Sales & Support
Product Risk Assessment

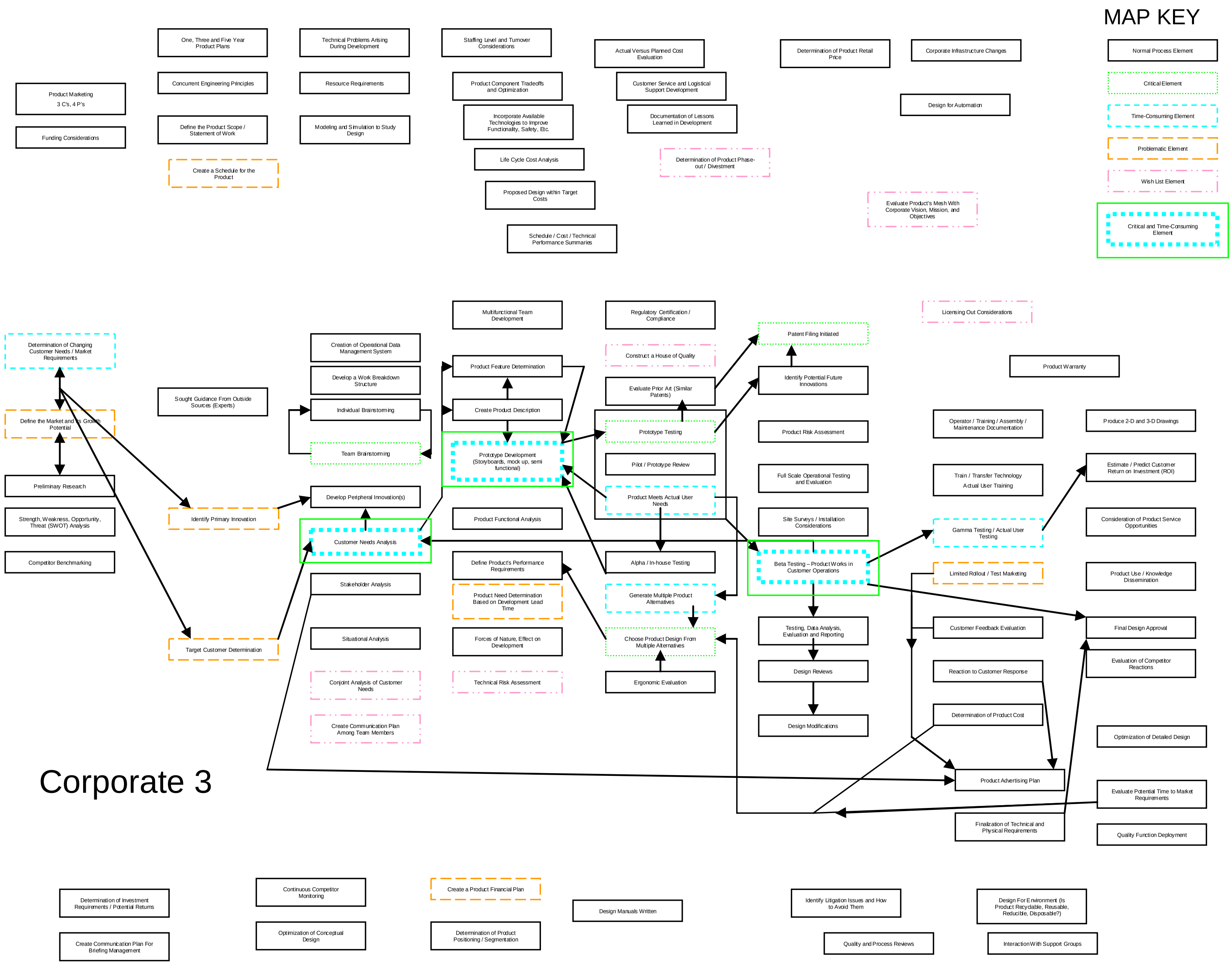


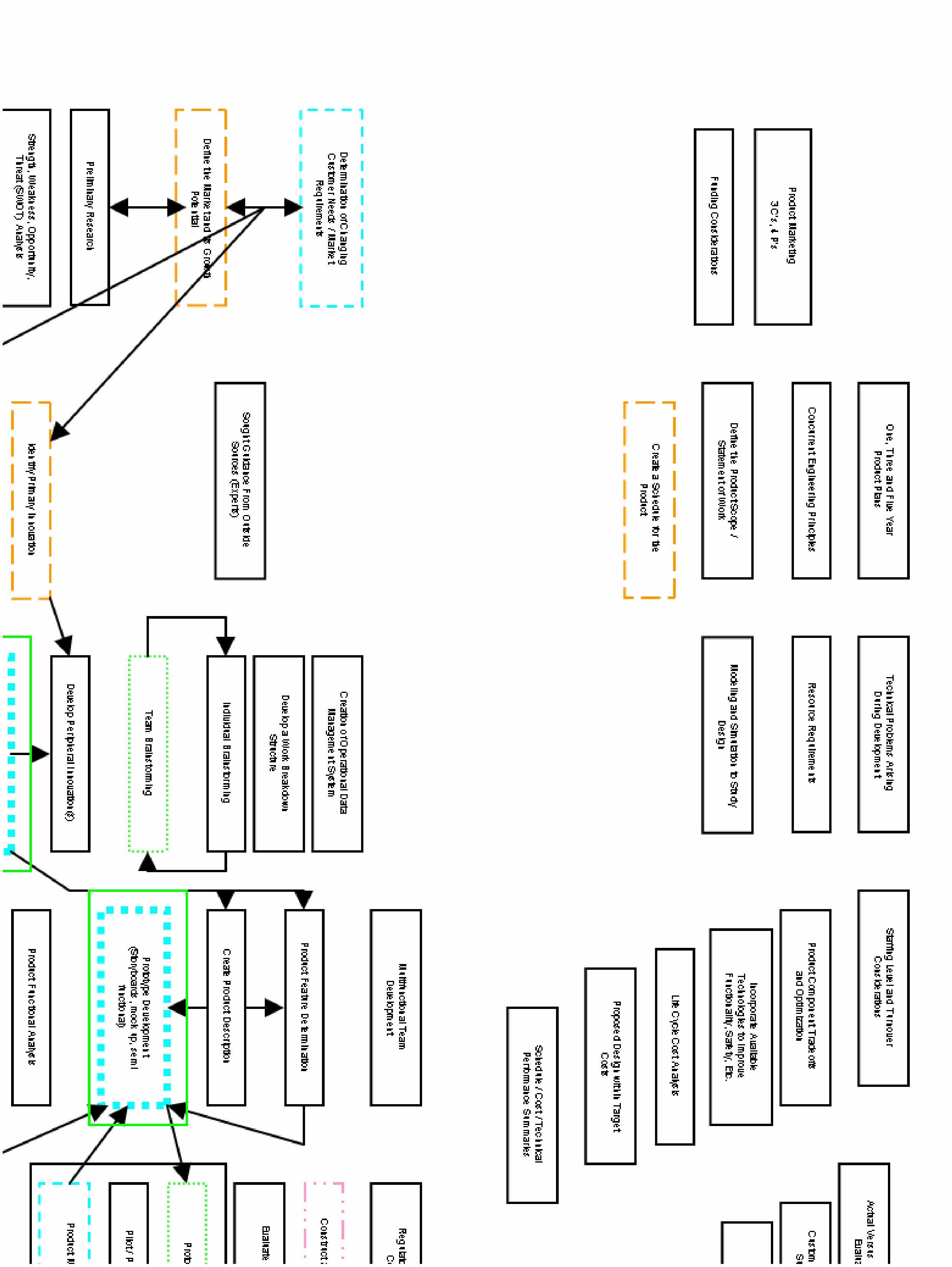
Management
of Materials
ent
Team Brainstorming
Design Modifications
Optimization of Conceptual Design
Technical Problems Arising During Development
Incorporate Available Technologies to Improve Functionality, Safety, Etc.
Documentation of Lessons Learned in Development
Define the Product Scope / Statement of Work
Product Meets Actual User Needs
Develop a Work Breakdown Structure
Reaction of Customer Response
Post Proto Analysis
MAP KEY
Normal Process Element
Critical Element
Time-Consuming Element
Problematic Element
Wish List Element
Human Resource Function
Multifunctional Team Development
Develop a Human Resources Plan
Staffing Level and Turnover Considerations
Interaction With Support Groups
Create Communication Plan Among Team Members
Pre-Development
Create a Schedule for the Product
Technical Risk Assessment
Design Manuals Written
Pretest / Pre-launch Forecasting

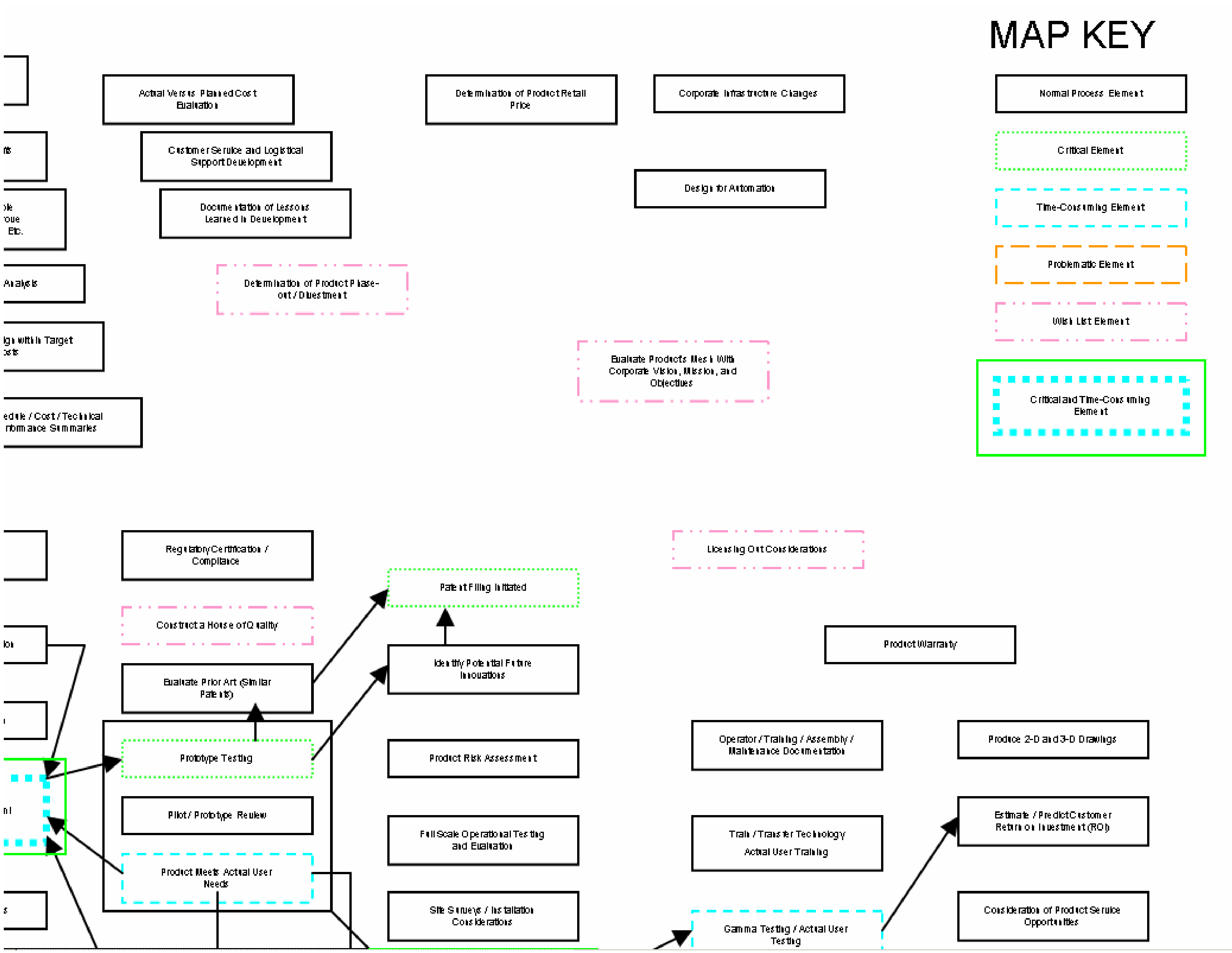


Sales & Support
Product Risk Assessment
Product Warranty
Product Feature Determination
Sales Forecasting
Quality and Process Reviews
Proposed Design within Target Costs
Determination of Product Retail Price
Customer Needs Analysis
Selection / Evaluation of CAD Tools
Electronic Design Automation
Design For Automation
Design For Assembly
Design For Manufacturability
Choose Product Design From Multiple Alternatives
Product Functional Analysis
Testing, Data Analysis, Evaluation and Reporting
Beta Testing – Product Works In Customer Operations
Optimization of Detailed Design
Final Design Approval
Finalization of Technical and Physical Requirements
Pilot / Prototype Review
Reliability Testing, Test to Failure, Limit Testing
PilotScale Operational Testing and Evaluation
Regulatory/Certification / Compliance
Failure Analysis
Mfg. Support
Develop a Product Manufacturing Plan
Production Line Design and Setup
FullScale Operational Testing and Evaluation

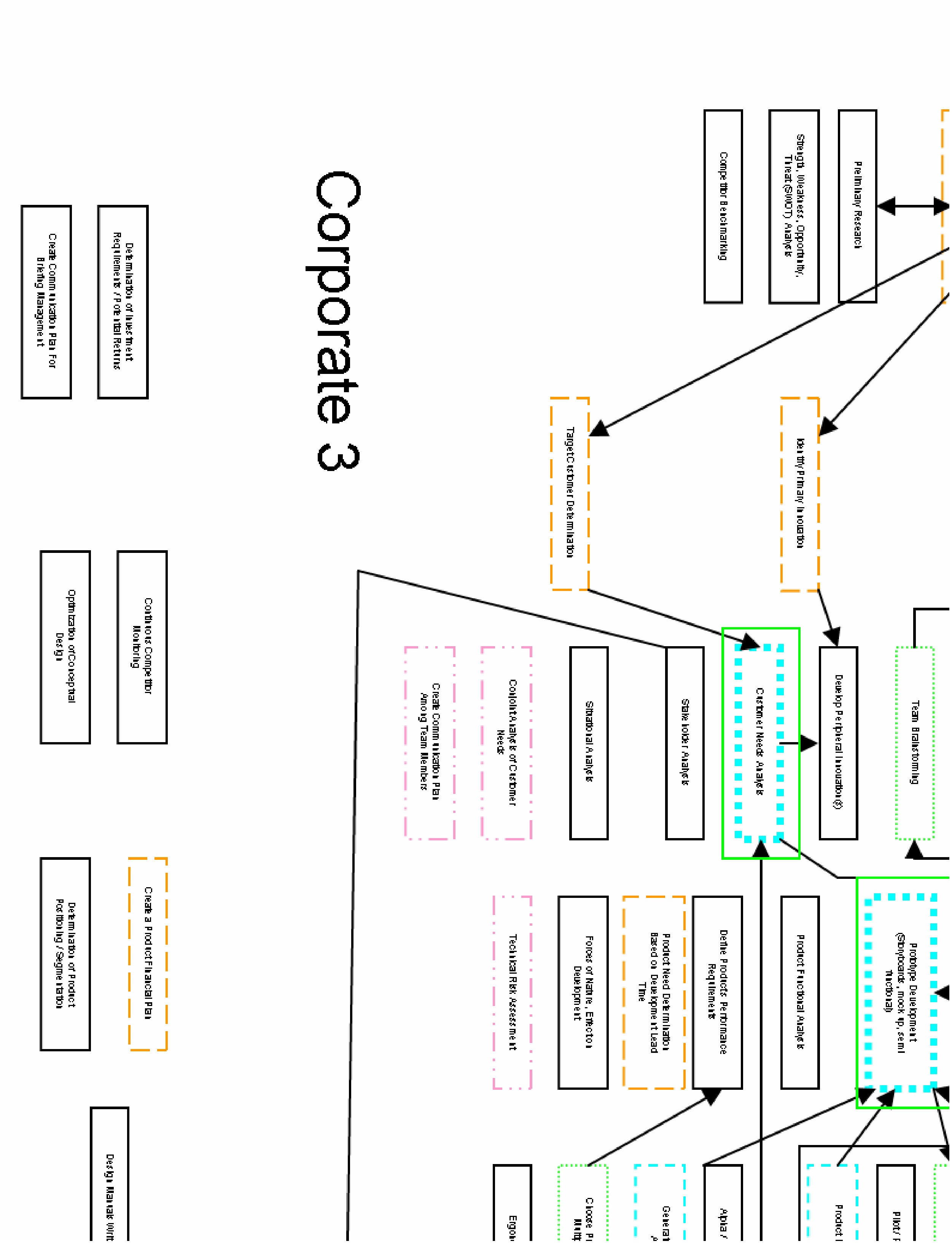

Technical Problems Arising During Development
Incorporate Available Technologies to Improve Functionality, Safety, Etc.
Design Reviews
Alpha / In-house Testing
Production Pilot Review
Product Packaging and Protection
Fabrication / Foundry Evaluation and Selection (Outsourcing)
Test / Packaging
Create a Schedule for the Product
Technical Risk Assessment
Design Manuals Written
Pretest / Pre-launch Forecasting
Target Customer Determination
Determination of Changing Customer Needs / Market Requirements
Determination of Product Positioning / Segmentation
Evaluate Potential Time to Market Requirements
Product Need Determination Based On Development Lead Time
Create Product Description
Define Products Performance Requirements
Evaluation of Competitor Reactions
Product Use / Knowledge Dissemination
Define the Market and Its Growth Potential
Marketing Function
Corporate 2

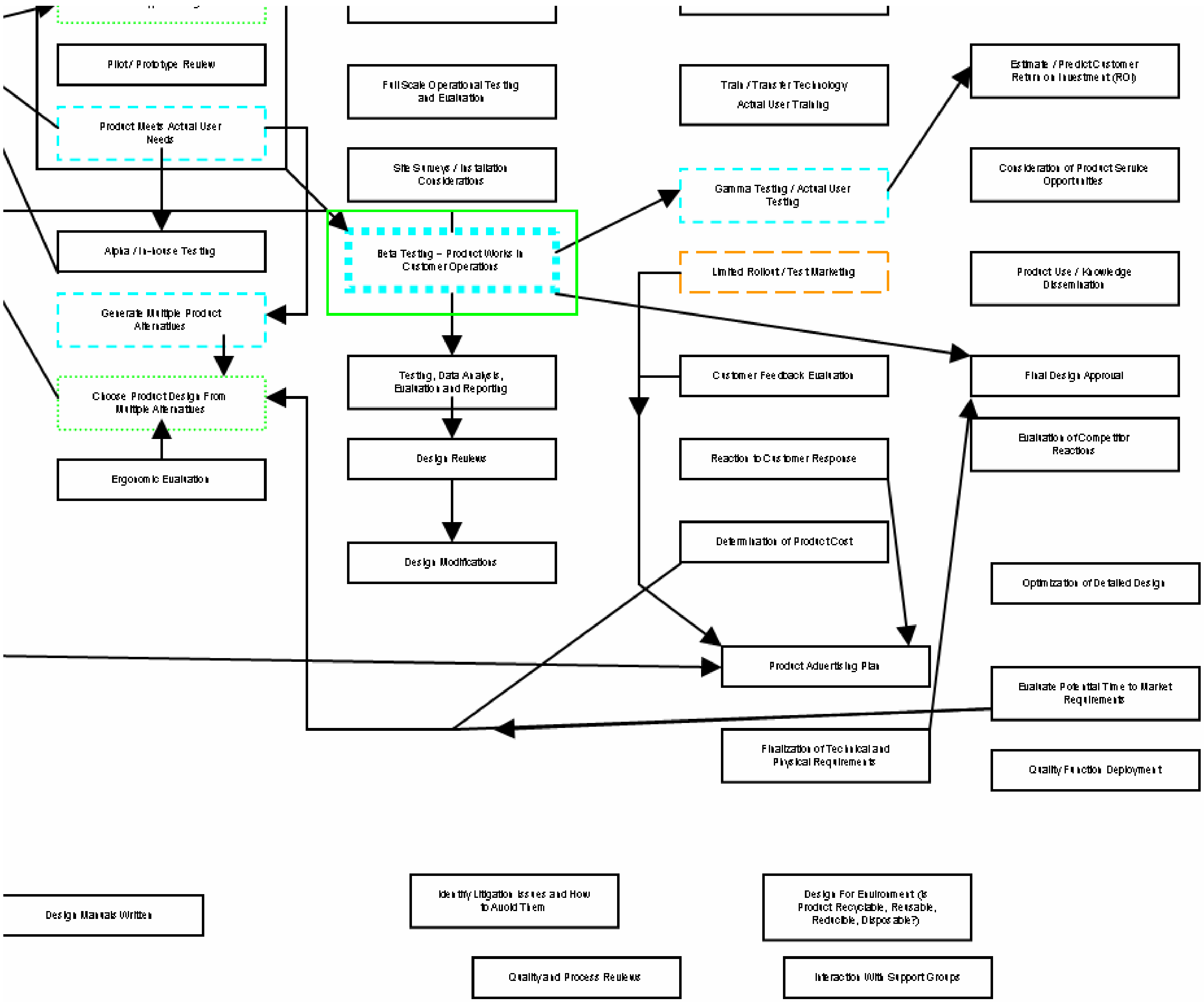

Corporate 3
MAP KEY
Normal Process Element
Critical Element
Time-Consuming Element
Problematic Element
Wish List Element
Critical and Time-Consuming Element
Product Marketing 3 C's, 4 P's
Funding Considerations
One, Three and Five Year Product Plans
Concurrent Engineering Principles
Define the Product Scope / Statement of Work
Create a Schedule for the Product
Technical Problems Arising During Development
Resource Requirements
Modeling and Simulation to Study Design
Staffing Level and Turnover Considerations
Product Component Tradeoffs and Optimization
Incorporate Available Technologies to Improve Functionality, Safety, Etc.
Life Cycle Cost Analysis
Proposed Design within Target Costs
Schedule / Cost / Technical Performance Summaries
Actual Versus Planned Cost Evaluation
Customer Service and Logistical Support Development
Documentation of Lessons Learned in Development
Determination of Product Phase-out / Divestment
Determination of Product Retail Price
Corporate Infrastructure Changes
Design for Automation
Evaluate Product's Mesh With Corporate Vision, Mission, and Objectives
Determination of Changing Customer Needs / Market Requirements
Define the Market and its Growth Potential
Preliminary Research
Strength, Weakness, Opportunity, Threat (SWOT) Analysis
Competitor Benchmarking
Sought Guidance From Outside Sources (Experts)
Identify Primary Innovation
Target Customer Determination
Creation of Operational Data Management System
Develop a Work Breakdown Structure
Individual Brainstorming
Team Brainstorming
Develop Peripheral Innovation(s)
Customer Needs Analysis
Stakeholder Analysis
Situational Analysis
Conjoint Analysis of Customer Needs
Create Communication Plan Among Team Members
Multifunctional Team Development
Product Feature Determination
Create Product Description
Prototype Development (Storyboards, mock up, semi functional)
Product Functional Analysis
Define Product's Performance Requirements
Product Need Determination Based on Development Lead Time
Forces of Nature, Effect on Development
Technical Risk Assessment
Regulatory Certification / Compliance
Construct a House of Quality
Evaluate Prior Art (Similar Patents)
Prototype Testing
Pilot / Prototype Review
Product Meets Actual User Needs
Alpha / In-house Testing
Generate Multiple Product Alternatives
Choose Product Design From Multiple Alternatives
Ergonomic Evaluation
Patent Filing Initiated
Identify Potential Future Innovations
Product Risk Assessment
Full Scale Operational Testing and Evaluation
Site Surveys / Installation Considerations
Beta Testing – Product Works in Customer Operations
Testing, Data Analysis, Evaluation and Reporting
Design Reviews
Design Modifications
Licensing Out Considerations
Product Warranty
Operator / Training / Assembly / Maintenance Documentation
Train / Transfer Technology Actual User Training
Gamma Testing / Actual User Testing
Limited Rollout / Test Marketing
Customer Feedback Evaluation
Reaction to Customer Response
Determination of Product Cost
Product Advertising Plan
Finalization of Technical and Physical Requirements
Produce 2-D and 3-D Drawings
Estimate / Predict Customer Return on Investment (ROI)
Consideration of Product Service Opportunities
Product Use / Knowledge Dissemination
Final Design Approval
Evaluation of Competitor Reactions
Optimization of Detailed Design
Evaluate Potential Time to Market Requirements
Quality Function Deployment
Determination of Investment Requirements / Potential Returns
Create Communication Plan For Briefing Management
Continuous Competitor Monitoring
Optimization of Conceptual Design
Create a Product Financial Plan
Determination of Product Positioning / Segmentation
Design Manuals Written
Identify Litigation Issues and How to Avoid Them
Quality and Process Reviews
Design For Environment (Is Product Recyclable, Reusable, Reducible, Disposable?)
Interaction With Support Groups

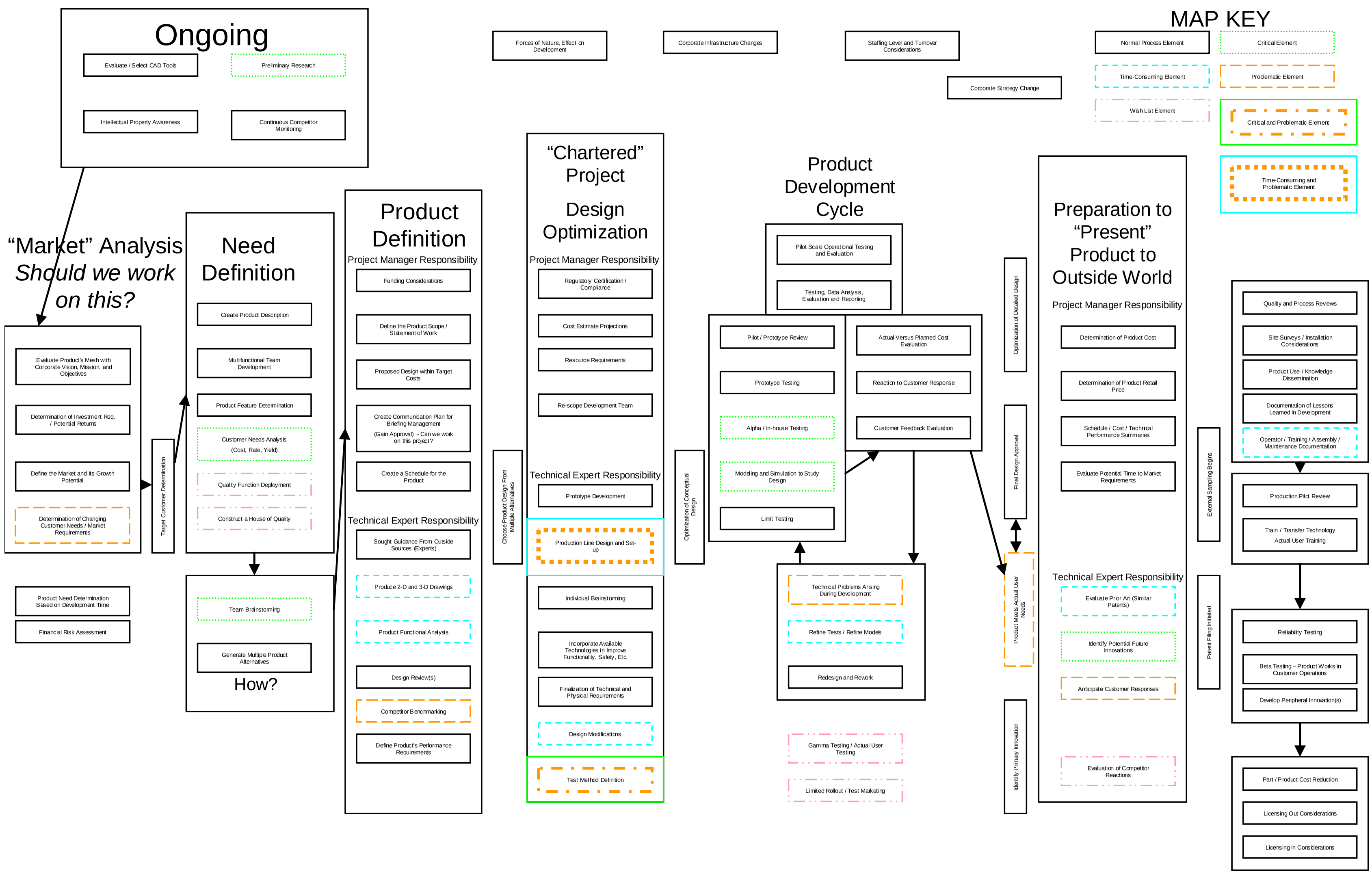

Strength, Weakness, Opportunity, Threat (SWOT) Analysis
Preliminary Research
Define the Market and its Growth Potential
Determination of Changing Customer Needs / Market Requirements
Product Marketing 3C's, 4 P's
Funding Considerations
Identify Primary Innovation
Sought Guidance From Outside Sources (Experts)
Create a Schedule for the Product
Define the Product Scope / Statement of Work
Concurrent Engineering Principles
One, Three and Five Year Product Plans
Develop Peripheral Innovation(s)
Team Brainstorming
Individual Brainstorming
Develop a Work Breakdown Structure
Creation of Operational Data Management System
Modeling and Simulation to Study Design
Resource Requirements
Technical Problems Arising During Development
Product Functional Analysis
Prototype Development (Storyboards, mock up, semi functional)
Create Product Description
Product Feature Determination
Multifunctional Team Development
Schedule / Cost / Technical Performance Summaries
Proposed Design within Target Costs
Life Cycle Cost Analysis
Incorporate Available Technologies to Improve Functionality, Safety, Etc.
Product Component Tradeoffs and Optimization
Staffing Level and Turnover Considerations



MAP KEY
Normal Process Element
Critical Element
Time-Consuming Element
Problematic Element
Wish List Element
Critical and Time-Consuming Element
Actual Versus Planned Cost Evaluation
Customer Service and Logistical Support Development
Documentation of Lessons Learned in Development
Determination of Product Phase-out / Divestment
Determination of Product Retail Price
Corporate Infrastructure Changes
Design for Automation
Evaluate Products Mesh With Corporate Vision, Mission, and Objectives
Analysis
Regulatory/Certification / Compliance
Construct a House of Quality
Evaluate Prior Art (Similar Patents)
Prototype Testing
Pilot / Prototype Review
Product Meets Actual User Needs
Patent Filing Initiated
Identify Potential Future Innovations
Product Risk Assessment
Full Scale Operational Testing and Evaluation
Site Surveys / Installation Considerations
Licensing Out Considerations
Product Warranty
Operator / Training / Assembly / Maintenance Documentation
Train / Transfer Technology
Actual User Training
Gamma Testing / Actual User Testing
Produce 2-D and 3-D Drawings
Estimate / Predict Customer Return on Investment (ROI)
Consideration of Product Service Opportunities

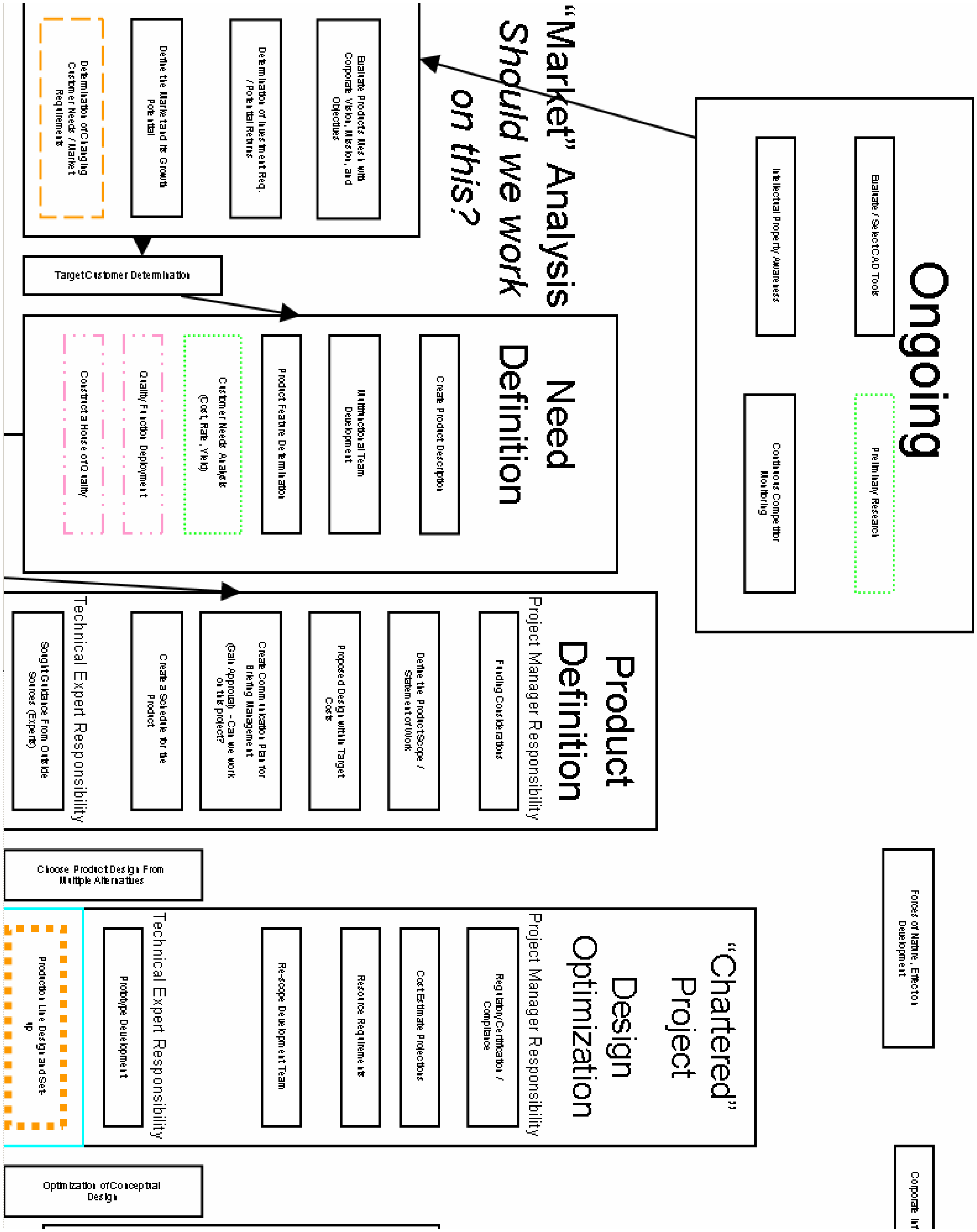

Corporate 3
Preliminary Research
Strength, Weakness, Opportunity, Threat (SWOT) Analysis
Competitor Benchmarking
Identify Primary Innovation
Target Customer Determination
Team Brainstorming
Develop Peripheral Innovation(s)
Customer Needs Analysis
Stakeholder Analysis
Situational Analysis
Conjoint Analysis of Customer Needs
Create Communication Plan Among Team Members
Prototype Development (Storyboards, mock up, semi functional)
Product Functional Analysis
Define Products Performance Requirements
Product Need Determination Based on Development Lead Time
Forces of Nature, Effect on Development
Technical Risk Assessment
Determination of Investment Requirements / Potential Returns
Create Communication Plan For Briefing Management
Continuous Competitor Monitoring
Optimization of Conceptual Design
Create a Product Financial Plan
Determination of Product Positioning / Segmentation

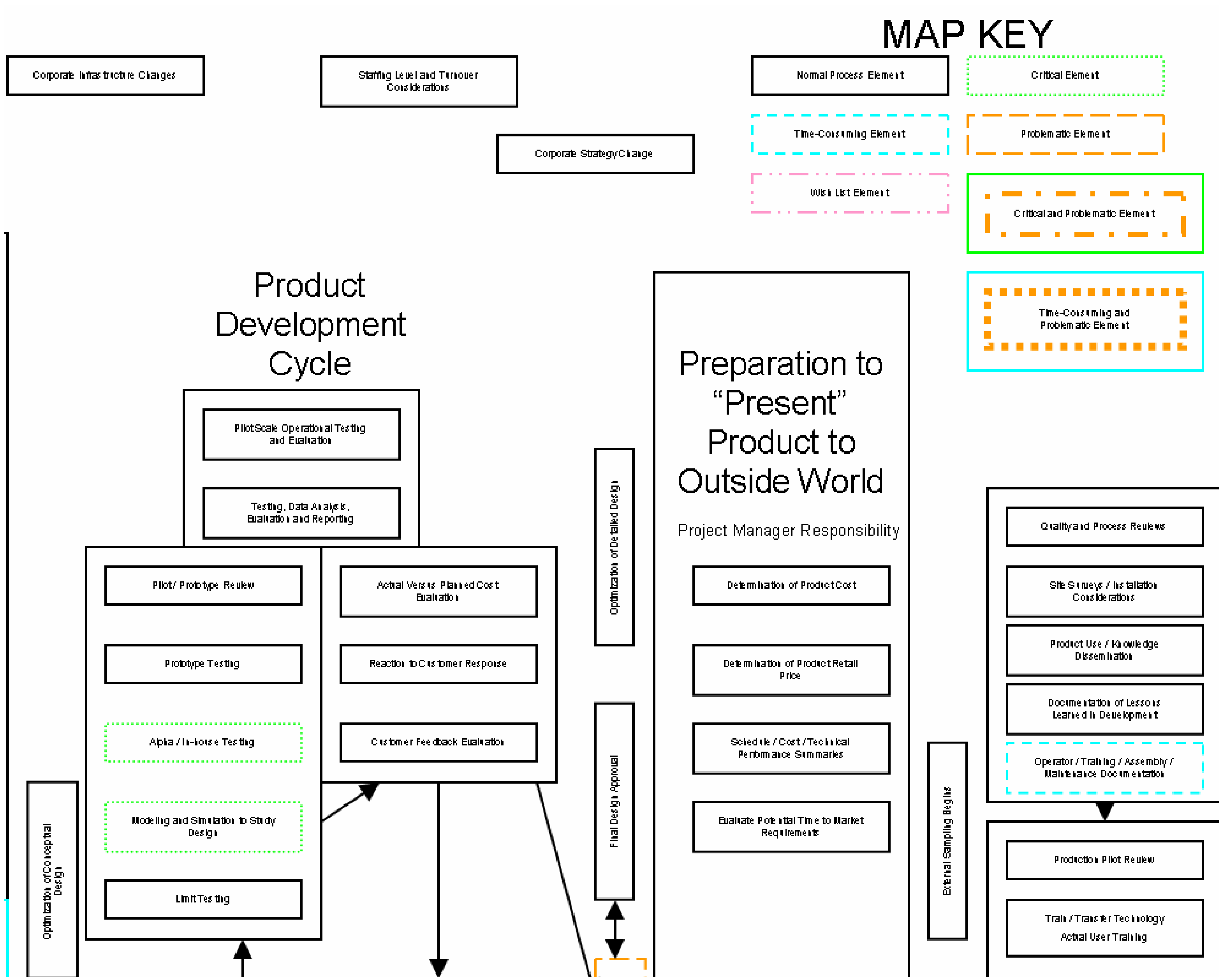

Pilot/ Prototype Review
Product Meets Actual User Needs
Alpha / In-house Testing
Generate Multiple Product Alternatives
Choose Product Design From Multiple Alternatives
Ergonomic Evaluation
Full Scale Operational Testing and Evaluation
Site Surveys / Installation Considerations
Beta Testing – Product Works In Customer Operations
Testing, Data Analysis, Evaluation and Reporting
Design Reviews
Design Modifications
Train / Transfer Technology Actual User Training
Gamma Testing / Actual User Testing
Limited Rollout / Test Marketing
Customer Feedback Evaluation
Reaction to Customer Response
Determination of Product Cost
Product Advertising Plan
Finalization of Technical and Physical Requirements
Estimate / Predict Customer Return on Investment (ROI)
Consideration of Product Service Opportunities
Product Use / Knowledge Dissemination
Final Design Approval
Evaluation of Competitor Reactions
Optimization of Detailed Design
Evaluate Potential Time to Market Requirements
Quality Function Deployment
Design Manuals Written
Identify Litigation Issues and How to Avoid Them
Quality and Process Reviews
Design For Environment (Is Product Recyclable, Reusable, Reducible, Disposable?)
Interaction With Support Groups

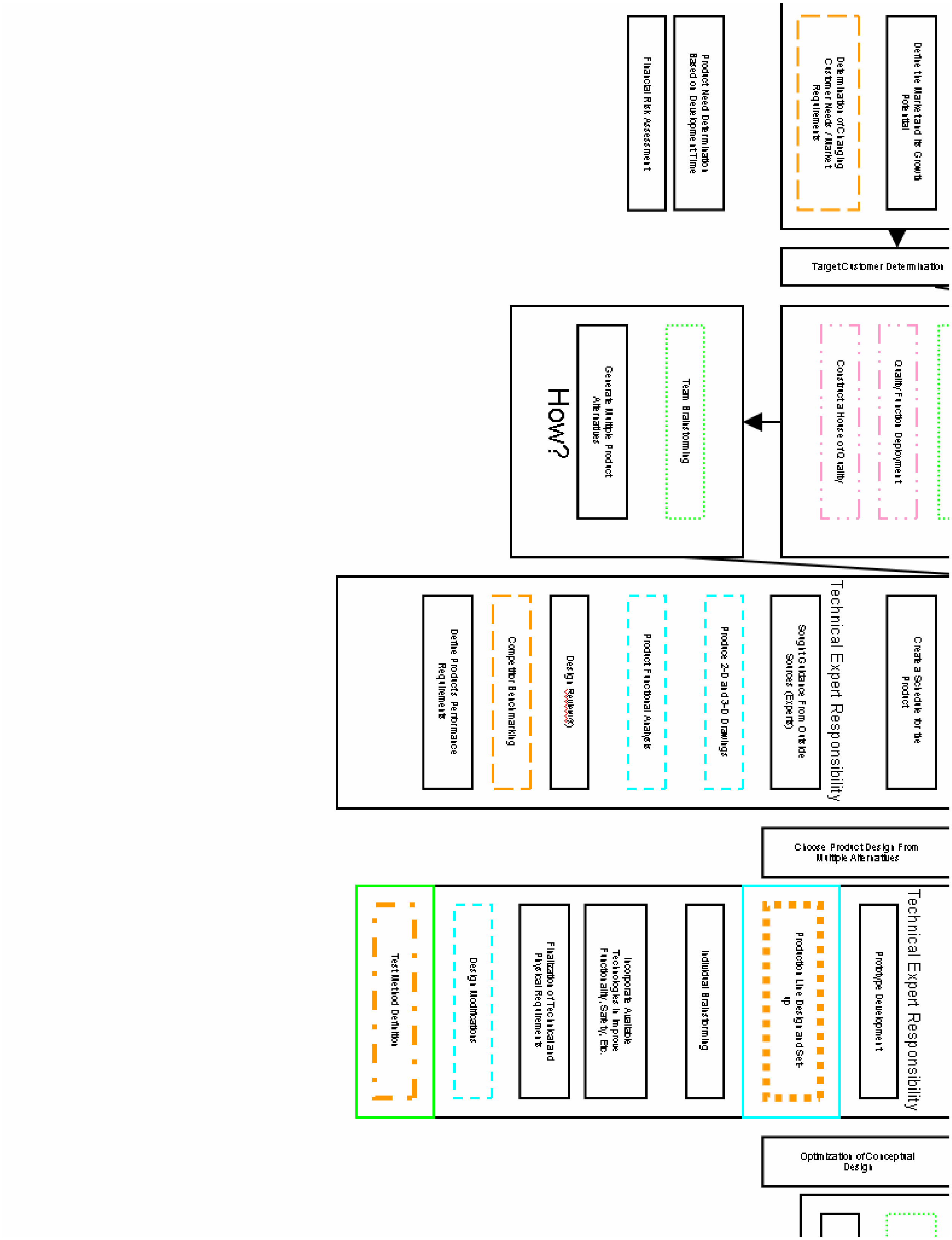


Ongoing
Evaluate / Select CAD Tools
Preliminary Research
Intellectual Property Awareness
Continuous Competitor Monitoring
"Market" Analysis
Should we work on this?
Evaluate Product's Mesh with Corporate Vision, Mission, and Objectives
Determination of Investment Req. / Potential Returns
Define the Market and Its Growth Potential
Determination of Changing Customer Needs / Market Requirements
Product Need Determination Based on Development Time
Financial Risk Assessment
Target Customer Determination
Need Definition
Create Product Description
Multifunctional Team Development
Product Feature Determination
Customer Needs Analysis (Cost, Rate, Yield)
Quality Function Deployment
Construct a House of Quality
Team Brainstorming
Generate Multiple Product Alternatives
How?
Product Definition
Project Manager Responsibility
Funding Considerations
Define the Product Scope / Statement of Work
Proposed Design within Target Costs
Create Communication Plan for Briefing Management (Gain Approval) - Can we work on this project?
Create a Schedule for the Product
Technical Expert Responsibility
Sought Guidance From Outside Sources (Experts)
Produce 2-D and 3-D Drawings
Product Functional Analysis
Design Review(s)
Competitor Benchmarking
Define Product's Performance Requirements
Choose Product Design From Multiple Alternatives
Forces of Nature, Effect on Development
"Chartered" Project
Design Optimization
Project Manager Responsibility
Regulatory Certification / Compliance
Cost Estimate Projections
Resource Requirements
Re-scope Development Team
Technical Expert Responsibility
Prototype Development
Production Line Design and Set-up
Individual Brainstorming
Incorporate Available Technologies in Improve Functionality, Safety, Etc.
Finalization of Technical and Physical Requirements
Design Modifications
Test Method Definition
Optimization of Conceptual Design
Corporate Infrastructure Changes
Product Development Cycle
Pilot Scale Operational Testing and Evaluation
Testing, Data Analysis, Evaluation and Reporting
Pilot / Prototype Review
Prototype Testing
Alpha / In-house Testing
Modeling and Simulation to Study Design
Limit Testing
Actual Versus Planned Cost Evaluation
Reaction to Customer Response
Customer Feedback Evaluation
Technical Problems Arising During Development
Refine Tests / Refine Models
Redesign and Rework
Gamma Testing / Actual User Testing
Limited Rollout / Test Marketing
Staffing Level and Turnover Considerations
Corporate Strategy Change
Optimization of Detailed Design
Final Design Approval
Product Meets Actual User Needs
Identify Primary Innovation
Preparation to "Present" Product to Outside World
Project Manager Responsibility
Determination of Product Cost
Determination of Product Retail Price
Schedule / Cost / Technical Performance Summaries
Evaluate Potential Time to Market Requirements
Technical Expert Responsibility
Evaluate Prior Art (Similar Patents)
Identify Potential Future Innovations
Anticipate Customer Responses
Evaluation of Competitor Reactions
External Sampling Begins
Patent Filing Initiated
Quality and Process Reviews
Site Surveys / Installation Considerations
Product Use / Knowledge Dissemination
Documentation of Lessons Learned in Development
Operator / Training / Assembly / Maintenance Documentation
Production Pilot Review
Train / Transfer Technology Actual User Training
Reliability Testing
Beta Testing – Product Works in Customer Operations
Develop Peripheral Innovation(s)
Part / Product Cost Reduction
Licensing Out Considerations
Licensing In Considerations
MAP KEY
Normal Process Element
Critical Element
Time-Consuming Element
Problematic Element
Wish List Element
Critical and Problematic Element
Time-Consuming and Problematic Element

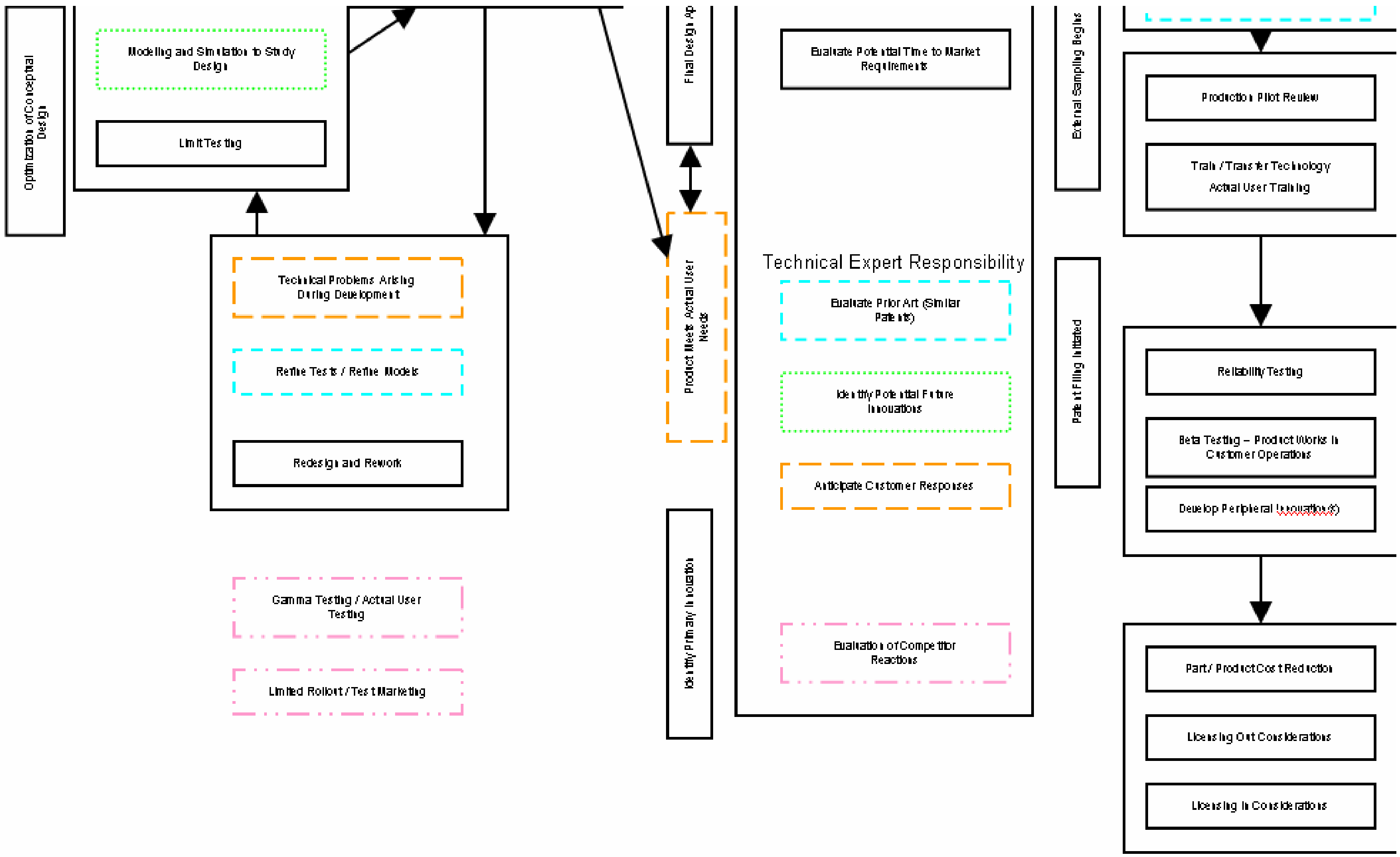
Corporate 4


Ongoing
Evaluate / Select CAD Tools
Preliminary Research
Intellectual Property Awareness
Continuous Competitor Monitoring
Forces of Nature, Effect on Development
Corporate In
"Market" Analysis
Should we work on this?
Evaluate Products Mesh with Corporate Vision, Mission, and Objectives
Determination of Investment Req. / Potential Returns
Define the Market and its Growth Potential
Determination of Changing Customer Needs / Market Requirements
Target Customer Determination
Need Definition
Create Product Description
Multifunctional Team Development
Product Feature Determination
Customer Needs Analysis
(Cost, Rate, Yield)
Quality Function Deployment
Construct a House of Quality
Product Definition
Project Manager Responsibility
Funding Considerations
Define the Product Scope / Statement of Work
Proposed Design within Target Costs
Create Communication Plan for Briefing Management
(Gain Approval) - Can we work on this project?
Create a Schedule for the Product
Technical Expert Responsibility
Sought Guidance From Outside Sources (Experts)
Choose Product Design From Multiple Alternatives
"Chartered" Project
Design Optimization
Project Manager Responsibility
Regulatory/Certification / Compliance
Cost Estimate Projections
Resource Requirements
Re-scope Development Team
Technical Expert Responsibility
Prototype Development
Production Line Design and Set-up
Optimization of Conceptual Design

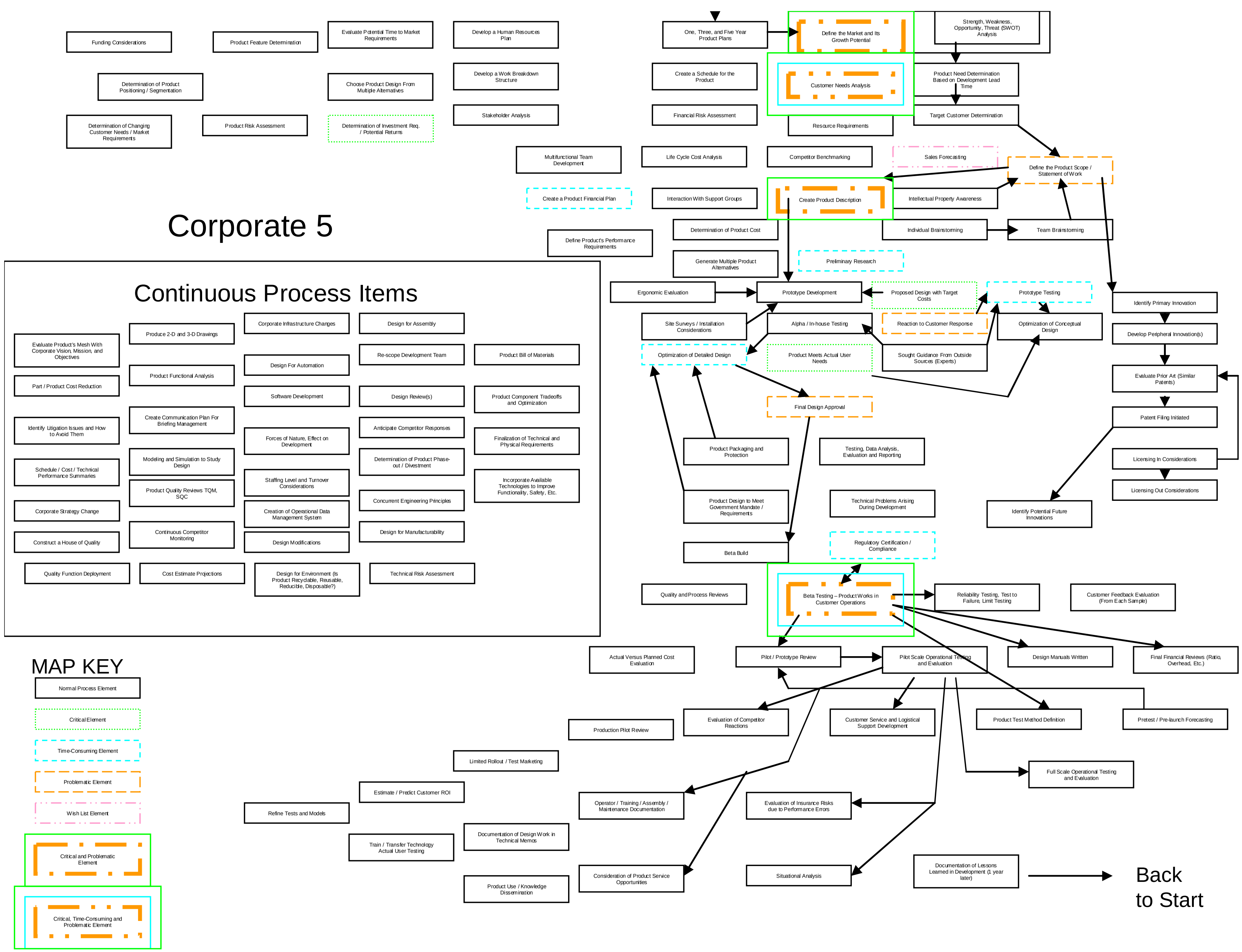

MAP KEY
Normal Process Element
Critical Element
Time-Consuming Element
Problematic Element
Wish List Element
Critical and Problematic Element
Time-Consuming and Problematic Element
Corporate Infrastructure Changes
Staffing Level and Turnover Considerations
Corporate Strategy Change
Product Development Cycle
Pilot Scale Operational Testing and Evaluation
Testing, Data Analysis, Evaluation and Reporting
Pilot / Prototype Review
Prototype Testing
Alpha / In-house Testing
Modeling and Simulation to Study Design
Limit Testing
Actual Versus Planned Cost Evaluation
Reaction to Customer Response
Customer Feedback Evaluation
Optimization of Conceptual Design
Optimization of Detailed Design
Final Design Approval
Preparation to "Present" Product to Outside World
Project Manager Responsibility
Determination of Product Cost
Determination of Product Retail Price
Schedule / Cost / Technical Performance Summaries
Evaluate Potential Time to Market Requirements
External Sampling Begins
Quality and Process Reviews
Site Surveys / Installation Considerations
Product Use / Knowledge Dissemination
Documentation of Lessons Learned in Development
Operator / Training / Assembly / Maintenance Documentation
Production Pilot Review
Train / Transfer Technology
Actual User Training

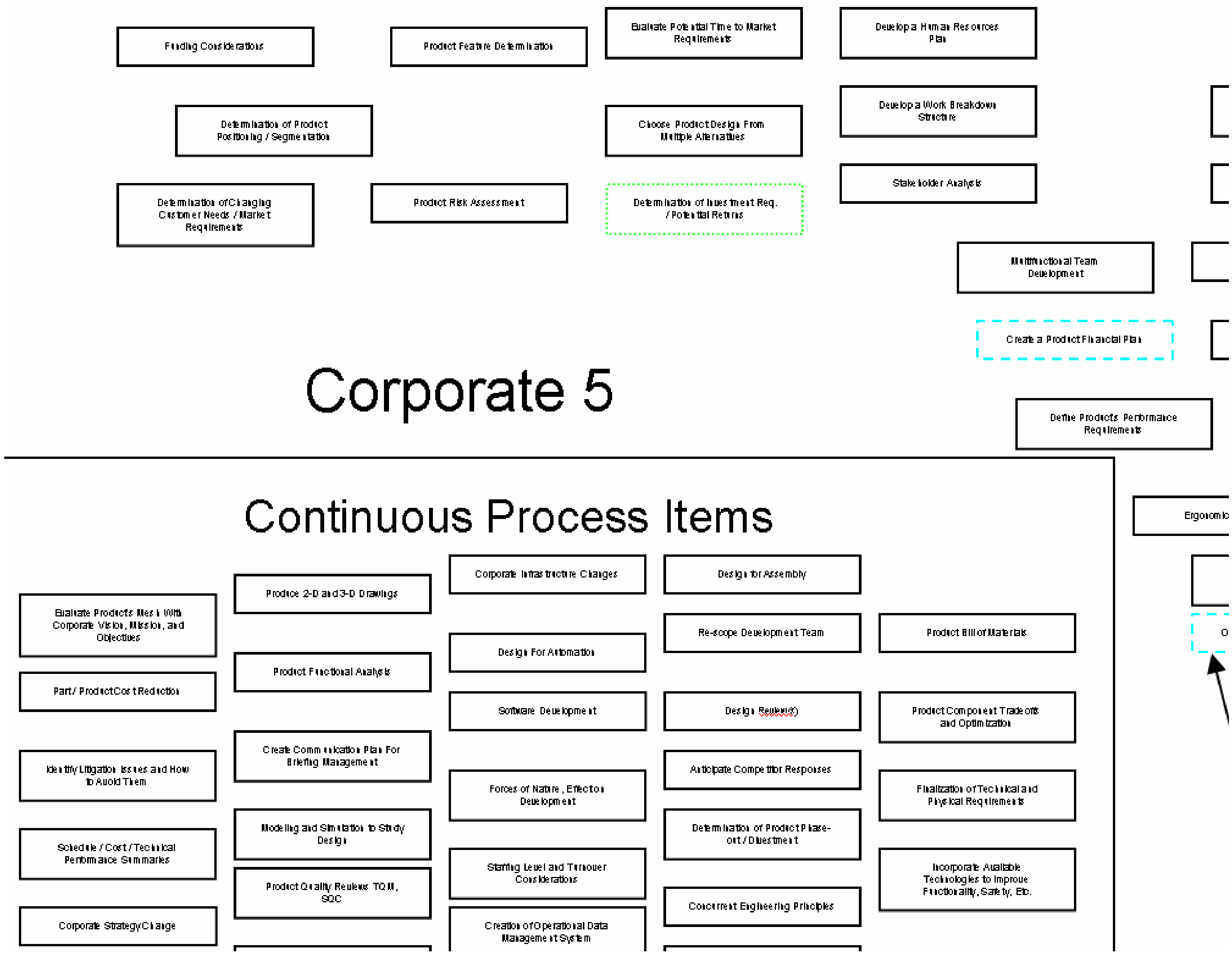


Define the Market and Its Growth Potential
Determination of Changing Customer Needs / Market Requirements
Product Need Determination Based on Development Time
Financial Risk Assessment
Target Customer Determination
Quality Function Deployment
Construct a House of Quality
Team Brainstorming
Generate Multiple Product Alternatives
How?
Create a Schedule for the Product
Technical Expert Responsibility
Sought Guidance From Outside Sources (Experts)
Produce 2-D and 3-D Drawings
Product Functional Analysis
Design Review(s)
Competitor Benchmarking
Define Products Performance Requirements
Choose Product Design From Multiple Alternatives
Technical Expert Responsibility
Prototype Development
Production Line Design and Set-up
Individual Brainstorming
Incorporate Available Technologies to Improve Functionality, Safety, Etc.
Finalization of Technical and Physical Requirements
Design Modifications
Test Method Definition
Optimization of Conceptual Design


Optimization of Conceptual Design
Modeling and Simulation to Study Design
Limit Testing
Technical Problems Arising During Development
Refine Tests / Refine Models
Redesign and Rework
Gamma Testing / Actual User Testing
Limited Rollout / Test Marketing
Final Design Ap
Product Meets Actual User Needs
Identify Primary Innovation
Evaluate Potential Time to Market Requirements
Technical Expert Responsibility
Evaluate Prior Art (Similar Patents)
Identify Potential Future Innovations
Anticipate Customer Responses
Evaluation of Competitor Reactions
External Sampling Begins
Patent Filing Initiated
Production Pilot Review
Train / Transfer Technology
Actual User Training
Reliability Testing
Beta Testing – Product Works in Customer Operations
Develop Peripheral Innovation(s)
Part / Product Cost Reduction
Licensing Out Considerations
Licensing In Considerations

Corporate 4


Corporate 5
Continuous Process Items
Funding Considerations
Product Feature Determination
Evaluate Potential Time to Market Requirements
Develop a Human Resources Plan
Determination of Product Positioning / Segmentation
Choose Product Design From Multiple Alternatives
Develop a Work Breakdown Structure
Determination of Changing Customer Needs / Market Requirements
Product Risk Assessment
Determination of Investment Req. / Potential Returns
Stakeholder Analysis
Multifunctional Team Development
Create a Product Financial Plan
Define Product's Performance Requirements
One, Three, and Five Year Product Plans
Define the Market and Its Growth Potential
Strength, Weakness, Opportunity, Threat (SWOT) Analysis
Create a Schedule for the Product
Customer Needs Analysis
Product Need Determination Based on Development Lead Time
Financial Risk Assessment
Resource Requirements
Target Customer Determination
Life Cycle Cost Analysis
Competitor Benchmarking
Sales Forecasting
Define the Product Scope / Statement of Work
Interaction With Support Groups
Create Product Description
Intellectual Property Awareness
Determination of Product Cost
Individual Brainstorming
Team Brainstorming
Generate Multiple Product Alternatives
Preliminary Research
Ergonomic Evaluation
Prototype Development
Proposed Design with Target Costs
Prototype Testing
Identify Primary Innovation
Site Surveys / Installation Considerations
Alpha / In-house Testing
Reaction to Customer Response
Optimization of Conceptual Design
Develop Peripheral Innovation(s)
Optimization of Detailed Design
Product Meets Actual User Needs
Sought Guidance From Outside Sources (Experts)
Evaluate Prior Art (Similar Patents)
Final Design Approval
Patent Filing Initiated
Product Packaging and Protection
Testing, Data Analysis, Evaluation and Reporting
Licensing In Considerations
Licensing Out Considerations
Product Design to Meet Government Mandate / Requirements
Technical Problems Arising During Development
Identify Potential Future Innovations
Beta Build
Regulatory Certification / Compliance
Quality and Process Reviews
Beta Testing – Product Works in Customer Operations
Reliability Testing, Test to Failure, Limit Testing
Customer Feedback Evaluation (From Each Sample)
Actual Versus Planned Cost Evaluation
Pilot / Prototype Review
Pilot Scale Operational Testing and Evaluation
Design Manuals Written
Final Financial Reviews (Ratio, Overhead, Etc.)
Production Pilot Review
Evaluation of Competitor Reactions
Customer Service and Logistical Support Development
Product Test Method Definition
Pretest / Pre-launch Forecasting
Limited Rollout / Test Marketing
Full Scale Operational Testing and Evaluation
Estimate / Predict Customer ROI
Refine Tests and Models
Operator / Training / Assembly / Maintenance Documentation
Evaluation of Insurance Risks due to Performance Errors
Documentation of Design Work in Technical Memos
Train / Transfer Technology Actual User Testing
Consideration of Product Service Opportunities
Situational Analysis
Documentation of Lessons Learned in Development (1 year later)
Product Use / Knowledge Dissemination
Back to Start
Evaluate Product's Mesh With Corporate Vision, Mission, and Objectives
Produce 2-D and 3-D Drawings
Corporate Infrastructure Changes
Design for Assembly
Part / Product Cost Reduction
Product Functional Analysis
Design For Automation
Re-scope Development Team
Product Bill of Materials
Identify Litigation Issues and How to Avoid Them
Create Communication Plan For Briefing Management
Software Development
Design Review(s)
Product Component Tradeoffs and Optimization
Schedule / Cost / Technical Performance Summaries
Modeling and Simulation to Study Design
Forces of Nature, Effect on Development
Anticipate Competitor Responses
Finalization of Technical and Physical Requirements
Corporate Strategy Change
Product Quality Reviews TQM, SQC
Staffing Level and Turnover Considerations
Determination of Product Phase-out / Divestment
Incorporate Available Technologies to Improve Functionality, Safety, Etc.
Construct a House of Quality
Continuous Competitor Monitoring
Creation of Operational Data Management System
Concurrent Engineering Principles
Design Modifications
Design for Manufacturability
Quality Function Deployment
Cost Estimate Projections
Design for Environment (Is Product Recyclable, Reusable, Reducible, Disposable?)
Technical Risk Assessment
MAP KEY
Normal Process Element
Critical Element
Time-Consuming Element
Problematic Element
Wish List Element
Critical and Problematic Element
Critical, Time-Consuming and Problematic Element


Corporate 5
Funding Considerations
Product Feature Determination
Evaluate Potential Time to Market Requirements
Develop a Human Resources Plan
Determination of Product Positioning / Segmentation
Choose Product Design From Multiple Alternatives
Develop a Work Breakdown Structure
Determination of Changing Customer Needs / Market Requirements
Product Risk Assessment
Determination of Investment Req. / Potential Returns
Stakeholder Analysis
Multifunctional Team Development
Create a Product Financial Plan
Define Products Performance Requirements
Ergonomic
Continuous Process Items
Evaluate Products Mesh With Corporate Vision, Mission, and Objectives
Part / Product Cost Reduction
Identify Litigation Issues and How to Avoid Them
Schedule / Cost / Technical Performance Summaries
Corporate Strategy Change
Produce 2-D and 3-D Drawings
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Design For Automation
Software Development
Forces of Nature, Effector Development
Staffing Level and Turnover Considerations
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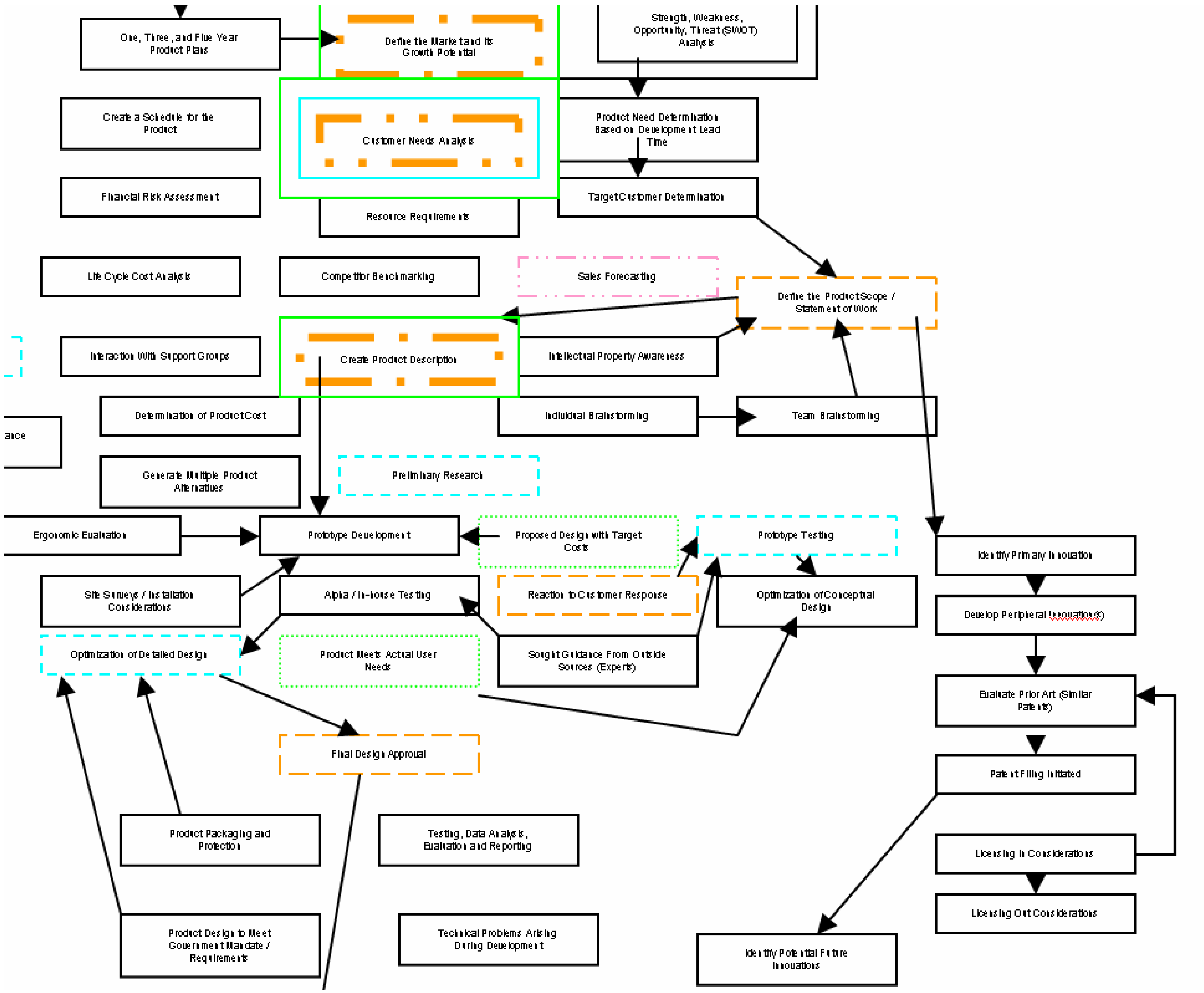
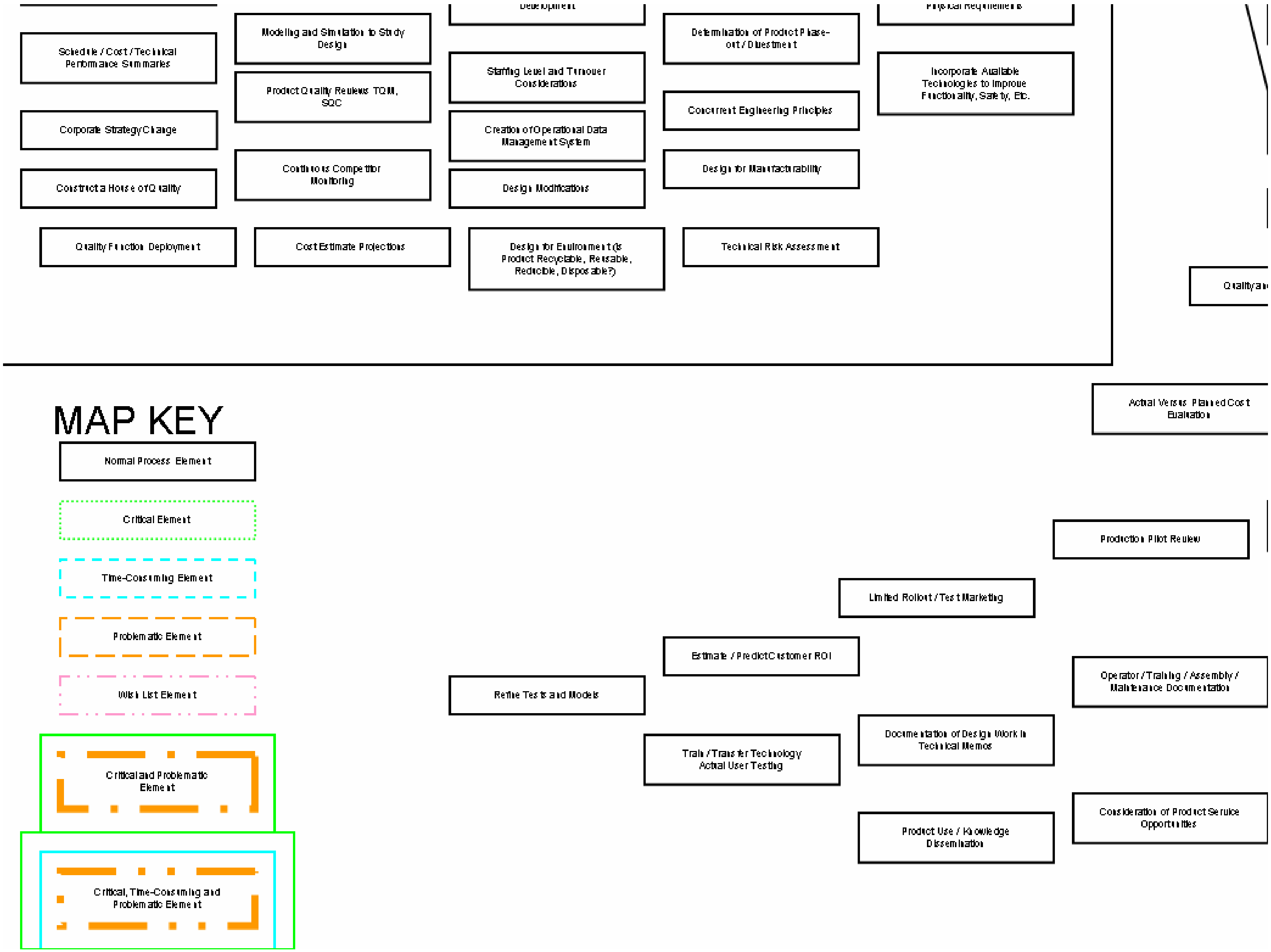
Concurrent Engineering Principles
Product Bill of Materials
Product Component Tradeoffs and Optimization
Finalization of Technical and Physical Requirements
Incorporate Available Technologies to Improve Functionality, Safety, Etc.


One, Three, and Five Year Product Plans
Define the Market and its Growth Potential
Strength, Weakness, Opportunity, Threat (SWOT) Analysis
Create a Schedule for the Product
Customer Needs Analysis
Product Need Determination Based on Development Lead Time
Financial Risk Assessment
Resource Requirements
Target Customer Determination
Life Cycle Cost Analysis
Competitor Benchmarking
Sales Forecasting
Define the Product Scope / Statement of Work
Interaction With Support Groups
Create Product Description
Intellectual Property Awareness
Determination of Product Cost
Individual Brainstorming
Team Brainstorming
Generate Multiple Product Alternatives
Preliminary Research
Ergonomic Evaluation
Prototype Development
Proposed Design with Target Costs
Prototype Testing
Identify Primary Innovation
Site Surveys / Installation Considerations
Alpha / In-house Testing
Reaction to Customer Response
Optimization of Conceptual Design
Develop Peripheral Innovation(s)
Optimization of Detailed Design
Product Meets Actual User Needs
Sought Guidance From Outside Sources (Experts)
Evaluate Prior Art (Similar Patents)
Final Design Approval
Patent Filing Initiated
Product Packaging and Protection
Testing, Data Analysis, Evaluation and Reporting
Licensing In Considerations
Licensing Out Considerations
Product Design to Meet Government Mandate / Requirements
Technical Problems Arising During Development
Identify Potential Future Innovations



Schedule / Cost / Technical Performance Summaries
Corporate Strategy Change
Construct a House of Quality
Quality Function Deployment
Modeling and Simulation to Study Design
Product Quality Reviews TQM, SQC
Continuous Competitor Monitoring
Cost Estimate Projections
Development
Staffing Level and Turnover Considerations
Creation of Operational Data Management System
Design Modifications
Design for Environment (is Product Recyclable, Reusable, Reducible, Disposable?)
Determination of Product Phase-out / Divestment
Concurrent Engineering Principles
Design for Manufacturability
Technical Risk Assessment
Physical Requirements
Incorporate Available Technologies to Improve Functionality, Safety, Etc.
Actual Versus Planned Cost Evaluation
MAP KEY
Normal Process Element
Critical Element
Time-Consuming Element
Problematic Element
Wish List Element
Critical and Problematic Element
Critical, Time-Consuming and Problematic Element
Production Pilot Review
Limited Rollout / Test Marketing
Estimate / Predict Customer ROI
Refine Tests and Models
Train / Transfer Technology Actual User Testing
Documentation of Design Work in Technical Memos
Product Use / Knowledge Dissemination
Operator / Training / Assembly / Maintenance Documentation
Consideration of Product Service Opportunities

APPENDIX C

STUDY ONE PART II INVENTOR SURVEY QUESTIONS

The online inventor survey questions are available below with the optional responses indicated below.

How would you describe your role in this patent's development?
Development Manager (Oversaw Patent's Development)
Patent Inventor (Physical / Technical Development)
Inside Assistance (Within the Corporation/University, Indirect Involvement, ex. Office of Development Personnel)
Outside Assistance (Outside of Corporation/University, Indirect Involvement, ex. Technology Expert)
Inside Counsel (Within the Corporation/University, Intellectual Property / Legal Issues)
Outside Counsel (Outside of Corporation/University, Intellectual Property / Legal Issues)

What was your underlying motivation behind the development of this idea?
Personal recognition (Awards/Acknowledgment)
Advancement of scientific body of knowledge
Financial
Personal Challenge
Part of my job description

Are you the inventor on any other patents either granted or filed (be it with your university or on your own)?
Yes/No

If yes, how many?

Define yourself in terms of product development / design experience?
Novice (less than 1 year experience)
One to four years experience
Intermediate (Four to seven years experience)
Seven to ten years experience
Expert (Ten+ years of experience)

Prior to the development of this patent, how would you have rated yourself in terms of innovative abilities?
Very unoriginal
Unoriginal
Neutral
Innovative
Very innovative

How many invention disclosures have you submitted individually or as part of a group? Invention Disclosure is defined as the formal submission of an invention or innovative idea to your corporation/university's office of development / technology transfer office.

Have you ever either had your own company or worked privately on your inventions?
Yes/No

What are the primary funding sources of your research?
Corporation/University internal funds

External funding (federal, state, foundation, or industry funding)
Personal funding
Private investors (venture capitalists, angel investors)

Upon completion of the development of this patent, how would you have rated yourself in terms of innovative abilities?
Very unoriginal
Unoriginal
Neutral
Innovative
Very innovative

In Part II, we'd like to ask some questions that pertain to your corporation/university and their policies towards innovation and intellectual property.

What does your corporation/university offer to patent inventors that encourages generating and exploring new ideas?
Cash bonuses / stock options
Awards/ other types of recognition
Partial ownership / royalties
Nothing

How would you rate your corporation/university's innovation policies?
Highly discouraging towards innovation
Discouraging towards innovation
Neutral towards innovation
Encouraging towards innovation
Strongly encouraging towards innovation

Are employees at your corporation/university given "flexible / free" time to investigate creative projects or work on their own personal interests?
Yes/No

Does your corporation/university have a formal process of invention disclosure? Invention Disclosure is defined as the formal submission of an invention or innovative idea to your corporation/university's office of development / technology transfer office.
Yes/No

Does your corporation/university have an office of development / technology transfer office or any formal group of persons who decide if a submitted idea or invention should be further developed?
Yes/No

Does this office or group encourage you to submit your ideas or inventions by promoting themselves and what it is that they do?
Yes/No

Would you (have you) purposely withhold an idea or invention from submission because you feel that your corporation/university's "ownership" policy is unfair?

Yes/No

Was your decision to work at your present corporation/university affected by their invention "ownership" policy?

Yes/No

Have you ever left a corporation/university because you were unhappy with their invention "ownership" policy?

Yes/No

How would you rate your corporation/university's degree of control on invention disclosures?

Once I submit my idea, what happens with it is totally out of my control
My input and involvement is very infrequent (~ 4x per year)
Control is equally shared
My input and involvement is still considered on a regular basis (~ 4x per month)
My involvement and input is still considered on a daily basis

How would you rate your corporation/university's "reward" policies for a patentable/commercial product?

Highly unfair (all of the royalties / ownership is maintained by the corporation/university)
Unfair (a great percentage (~75%) of the royalties / ownership is maintained by the corporation/university)
Neutral (50% of the royalties / ownership is maintained by the corporation/university)
Fair (a small percentage (~25%) of the royalties / ownership maintained by the corporation/university)
Highly generous (none of the royalties / ownership is maintained by the corporation/university)

In Part III, we would like to turn your attention to the development process that was utilized in the development of your particular technology. In this section, we will be trying to establish a time frame for when various milestones in the development were accomplished.

Where did the idea for this particular patent come from?

Your own research (personal interests)
Opportunity (need) assigned to you to find a solution
Idea given to you to technically develop
As part of continuous improvement, investigating new solutions to existing problems

Approximately when did the development of this invention begin (when was the idea for this patent first conceived or was the opportunity first identified)?

Approximately when was the conceptual product design chosen (or design selected from multiple alternatives)?

Approximately when was the first prototype developed?

Approximately when was the product testing completed (up to and including the product's performance satisfies customer needs)?

To the best of your recollection, nearest to what point in the process was the invention disclosed to an office of technology management / technology transfer office?

Idea was generated and product description created
Brainstorming sessions were conducted
The product's performance requirements were defined
2-D and 3-D drawings were produced
Finalization of technical and physical requirements
Product functional analysis was conducted
Conceptual design was optimized
Prototype development
Prototype testing
Final design approval granted
Beta and gamma testing and ensuring that the product meets customer needs

When was the invention disclosed?

To the best of your recollection, nearest to what point in the process was the patent filed?

Idea was generated and product description created
Brainstorming sessions were conducted
The product's performance requirements were defined
2-D and 3-D drawings were produced
Finalization of technical and physical requirements
Product functional analysis was conducted
Conceptual design was optimized
Prototype development
Prototype testing
Final design approval granted
Beta and gamma testing and ensuring that the product meets customer needs

When was the patent application filed?

Did this invention ever become a commercial product?

Yes/No

If yes, approximately when was the product first introduced to the market?

Was the invention completed ... ?

Ahead of planned schedule
On time
Behind planned schedule
Not completed / discontinued

If you answered ahead of schedule above, what was the main reason the project was completed ahead of schedule?

Multiple product design alternatives were generated
Initial product design / prototype functioned properly for customers' needs
Modeling and simulation tools were used to study design
Schedule, cost, and technical performance summaries were conducted on a regular basis
An extensive customer needs analysis was conducted
Brainstorming sessions utilized to improve communication amongst team members
Multifunctional team assembled to improve knowledge base
Continuous competitor monitoring to keep ahead of the competition

If you answered behind schedule above, what was the main reason the project was completed behind schedule?
Product was not functioning correctly in customer operations
Multiple design modifications were necessary
Customer needs' changed during development process
Satisfying regulatory compliance / certification caused delays
Lack of funding
Reliability / Limit Testing exposed concerns over product design
Product test method definition / refinement of product tests took longer than expected
Modeling and simulation of product design took longer than expected
Preparation of drawings, design manuals, and operator / training / maintenance documentation took longer than expected

Was the invention completed ... ?
Under proposed budget
Within proposed budget
Over proposed budget

For your corporation/university, what level of sales was realized from this invention (either by your corporation/university or any licensing company)?
None
$1 - $10K
$10K - $100K
$100K - $1M
$1M - $10M
> $10M

In Part IV, we are going to focus on individual elements of the process that you may or may not have utilized. This section will focus on 78 elements of the product development process. This is the longest section of the survey and should take approximately 20 minutes to complete.

Did you perform Alpha / In-house Testing during this patent's development? This is defined as a crucial "first look" at the initial design. The results of the alpha test either confirm that the product performs according to its specifications or uncovers areas where the product is deficient.
Yes/No

Approximately how much time did you spend working on alpha testing, in terms of weeks? (1 day = 0.2)

During what phase did you perform the Alpha Testing?
Phase 1 - Opportunity Identification
Phase 2 - Design and Development
Phase 3 - Testing and Preproduction

Phase 4 - Introduction and Production
Phase 5 - Life Cycle Management

This section included the same three questions repeated for each of the 78 selected elements.

BIBLIOGRAPHY

[1] United States Patent and Trademark Office, http://www.uspto.gov/web/offices/ac/ido/oeip/taf/univ/org_gr/all_univ_ag.htm, May 22, 2007.

[2] The Association of University Technology Managers, www.autm.net, 2004

[3] Wright, M., S. Birley, S. Mosey, "Entrepreneurship and University Technology Transfer." *Journal of Technology Transfer*, volume 29, pages 235-246, 2004.

[4] Meredith, R., "Giant Sucking Sound," *Forbes.com*, 10/06/03.

[5] Engardio, P., A. Bernstein and M. Kripalani, "The New Global Job Shift," *BusinessWeek Online*, February 3, 2003.

[6] U.S. Department of Labor, Bureau of Labor Statistics, http://stats.bls.gov/oes/2003/may/oes172072.htm, August 2004.

[7] United States Patent and Trademark Office, http://www.uspto.gov/web/offices/ac/ido/oeip/taf/apat.pdf, April 2002.

[8] Siguaw, Judy A., Penny M. Simpson, Cathy A. Enz, "Conceptualizing Innovation Orientation: A Framework for Study and Integration of Innovation Research." *Journal of Production and Innovation Management*, volume 23(6), pages 556-574, 2006.

[9] Stefflre, Volney, "Organizational Obstacles to Innovation: A Formulation of the Problem." *Journal of Production and Innovation Management*, volume 2(1), pages 3-11, 1985.

[10] Khilji, Shaista E., Tomasz Mroczkowski, Boaz Bernstein, "From Invention to Innovation: Toward Developing an Integrated Innovation Model for Biotech Firms." *Journal of Production and Innovation Management*, volume 23(6), pages 528-540, 2006.

[11] Knight, R., "Corporate innovation and entrepreneurship: a Canadian study", *Journal of Production and Innovation Management*, volume 4, pages 284-297, 1987.

[12] Meredith, R., Op. cit.

[13] Deutschman, Alan, "Offshoring Creativity." *Fast Company*, Issue 89, page 29, December, 2004.

[14] U.S. Department of Labor, Bureau of Labor Statistics, http://stats.bls.gov/oes/2003/may/oes172072.htm, August 2004.

[15] Scott, G., "Critical Technology Management Issues of New Product Development in High-Tech Companies", *Journal of Production and Innovation Management*, volume 17, pages 57-77, 2000.

[16] Jensen, R., M. Thursby, "Proofs and Prototypes for Sale: The Licensing of University Inventions." *American Economic Review*, volume 91, 240-259, 2001.

[17] Urban, G., J. Hauser, Design and marketing of new products, 2nd edition, Englewood Cliffs, N.J.: Prentice Hall, 1993.

[18] Kahn, K., Product planning essentials, Thousand Oaks, Calif.: Sage Publications, 2001.

[19] Kmetovicz, R., New product development: design and analysis, New York: Wiley, 1992.

[20] Armstrong, S., Engineering and product development management: the holistic approach, New York: Cambridge University Press, 2001.

[21] Molina, A., J.M. Sanchez, A. Kusiak, Handbook of life cycle engineering: concepts, models, and technologies, Boston: Kluwer Academic Publishers, 1998.

[22] Ravasi, D., C. Turati, "Exploring Entrepreneurial Learning: A Comparative Study of Technology Development Projects." *Journal of Business Venturing*, volume 20, 137-164, 2005.

[23] Cooper, R., E. Kleinschmidt, "An investigation into the new product process: steps, deficiencies, and impact", *Journal of Production and Innovation Management*, volume 3, pages 71-85, 1986.

[24] Calantone, Roger J., C. Anthony di Benedetto, "An Integrative Model of the New Product Development Process: An Empirical Validation." *Journal of Production and Innovation Management*, volume 5(3), pages 201-215, 1988.

[25] Novak, J., D. Gowin, Learning How to Learn, United Kingdom, Cambridge University Press, 1984.

[26] Conway, H.A., N. McGuinness, “Idea generation in technology-based firms”, *Journal of Production and Innovation Management*, volume 4, pages 276-291, 1986.

[27] Chukumba, C., R. Jensen, ‘University invention, entrepreneurship, and start-ups,” NBER Working Paper Series, Working paper 11475, National Bureau of Economic Research, June 2005.

[28] Chukumba, C., Op. cit.

[29] Lee, Y., R. Gaertner, “Technology transfer from university to industry: A large-scale experiment with technology development and commercialization”, *Policy Studies Journal*, volume 22, number 2, pages 384-399, 1994.

[30] Erkal, N., “Policy Forum: Intellectual Property Rights, On the Interaction between Patent Policy and Trade Secret Policy”, *The Australian Economic Review*, volume 37, no. 4, pages 427-435, 2004.

[31] The Association for Automatic Identification and Data Capture Technologies, “What is Radio Frequency Identification (RFID)?” http://www.aimglobal.org/technologies/rfid/what_is_rfid.htm, April 2004.

[32] “RFID and Your Supply Chain,” 2003 Catalyst International, Inc., http://www.knowledgestorm.com/collateral/WTP/4162_78108_81159_CAT179-RFID_Whitepaper.pdf.pdf, May 2004.

[33] United States Patent and Trademark Office, http://www.uspto.gov/web/offices/pac/doc/general/index.html#patent, January 2005.

[34] Coombs, R., P. Narandren, A. Richards, “A Literature-Based Innovation Output Indicator.” *Research Policy*, volume 25(3), pages 403-413, 1996.

[35] McAleer, Michael, Daniel Slottje, “A New Measure of Innovation: The Patent Success Ratio.” *Scientometrics*, volume 63(3), pages 421-429, 2005.

[36] Zoltan, J. Acs, Luc Anselin, Attila Varga, “Patents and Innovation Counts as Measures of Regional Production of New Knowledge. *Research Policy* volume 31(7), pages 1069-1085, 2002.

[37] Watanabe, C., Y. Tsuji, C. Griffy-Brown, “Patent Statistics: Deciphering a ‘Real’ Versus a ‘Pseudo’ Proxy of Innovation”, *Technovation*, volume 21, pages 783-790, 2001.

[38] Golish, B., M. Besterfield-Sacre, L. Shuman, "Comparing the Technology Development Processes in Academic and Corporate Settings," under third round review for a special issue of *Journal of Product Innovation Management on Technology Commercialization and Entrepreneurship*.

[39] Office of Technology Management, University of Pittsburgh, http://tech-link.tt.pitt.edu/about_overview.html, 2006.

[40] *Office of Technology Management Handbook*, University of Pittsburgh, 2003.

[41] Office of Technology Management, University of Pittsburgh, Op. cit.

[42] Lee, Y., Op. cit.

[43] Matkin, G., "Technology transfer and public policy: lessons from a case study", *Policy Studies Journal*, volume 22, number 2, pages 371-383, 1994.

[44] Lowe, R., "Who develops a university invention? The impact of tacit knowledge and licensing policies", *Journal of Technology Transfer*, volume 31, pages 415-429, 2006.

[45] Polanyi, M., Personal Knowledge: Towards a Post-Critical Philosophy, Chicago: University of Chicago Press, 1958.

[46] Jensen, R., J. Thursby, M. Thursby, "Disclosure and licensing of university inventions: 'the best we can do with the s**t we get to work with'", *International Journal of Industrial Organization*, volume 21, pages 1271-1300, 2003.

[47] Owen-Smith, J., W. Powell, "To patent or not: faculty decisions and institutional success at technology transfer", *Journal of Technology Transfer*, volume 26, pages 99-114, 2001.

[48] Thursby, J., R. Jensen, M. Thursby, "Objectives, Characteristics and Outcomes of University Licensing: A Survey of Major U.S. Universities", *Journal of Technology Transfer*, volume 26, pages 59-72, 2001.

[49] Markman, G., P. Gianiodis, P. Phan, D. Balkin, "Entrepreneurship from the Ivory Tower: Do Incentive Systems Matter?", *Journal of Technology Transfer*, volume 29, pages 353-364, 2004.

[50] Friedman, J., J. Silberman, "University Technology Transfer: Do Incentives, Management, and Location Matter?", *Journal of Technology Transfer*, volume 28, pages 17-30, 2003.

[51] Lach, S., M. Schankerman, "Incentives and Invention in Universities", working paper, May 8, 2003.

[52] Coupe, T., "Science Is Golden: Academic R&D and University Patents", *Journal of Technology Transfer*, volume 28, pages 31-46, 2003.

[53] Powers, J., "R&D Funding Sources and University Technology Transfer: What is Stimulating Universities to Be More Entrepreneurial?" *Research in Higher Education*, volume 45, number 1, February 2004.

[54] United States Patent and Trademark Office, http://www.uspto.gov/web/offices/ac/ido/oeip/taf/univ/org_gr/all_univ_ag.htm, May 22, 2007.

[55] Mowery, D., R. Nelson, B. Sampat, A. Ziedonis, "The growth of patenting and licensing by U.S. universities: an assessment of the effects of the Bayh-Dole act of 1980", *Research Policy*, volume 30, pages 99-119, 2001.

[56] Nelson, R., "Observations on the Post-Bayh-Dole Rise of Patenting at American Universities", *Journal of Technology Transfer*, volume 26, pages 13-19, 2001.

[57] Verspagen, B., "University research, intellectual property rights and European innovation systems," *Journal of Economic Surveys*, volume 20, number 4, pages 607-632, 2006.

[58] Sampat, B., D. Mowery, A. Ziedonis, "Changes in university patent quality after the Bayh-Dole act: a re-examination," *International Journal of Industrial Organization*, volume 21, pages 1371-1390, 2003.

[59] Ndonzuau, F., F. Pirnay, B. Surlemont, "A stage model of academic spin-off creation", *Technovation*, volume 22, pages 281-289, 2002.

[60] Lewis, M., "Success, failure, and organizational competence: a case study of the new product development process", *Journal of Engineering and Technology Management*, volume 18, pages 185-206, 2001.

[61] Balachandra, R., J. Friar, "Managing New Product Development Processes the Right Way", *Systems Management*, volume 1, pages 33-43, 1999.

[62] Wakasugi, R., F. Koyata, "R&D, Firm Size and Innovation Outputs: Are Japanese Firms Efficient in Product Development?", *Journal of Production and Innovation Management*, volume 14, pages 383-392, 1997.

[63] Radnor, Z., J. Robinson, "Benchmarking Innovation: A Short Report", *Creativity and Innovation Management*, volume 9, number 1, 2000.

[64] Oltra, M., M. Flor, "The impact of technological opportunities and innovative capabilities on firms' output innovation", *Creativity and Innovation Management*, volume 12, number 3, pages 137-144, September 2003.

[65] Knight, R., Op. cit.

[66] Bonner, Joseph M., Robert W. Ruekert, Orville C. Walker, Jr., Orville C., "Upper Management Control of New Product Development Projects and Project Performance." *Journal of Production and Innovation Management*, volume 19(3), pages 233-245, 2002.

[67] Wind, Yoram, Vijay Mahajan, Vijay, "New Product Development Process: A Perspective for Reexamination." *Journal of Production and Innovation Management*, volume 5(4), pages 304-310, 1988.

[68] Droge, C., J. Jayaram, S. Vickery, "The Ability to Minimize the Timing of New Product Development and Introduction: An Examination of the Antecedent Factors in the North American Automobile Supplier Industry", *Journal of Production and Innovation Management*, volume 17, pages 24-40, 2000.

[69] Mabert, V., J. Muth, R. Schmenner, "Collapsing New Product Development Times: Six Case Studies", *Journal of Production and Innovation Management*, volume 9, pages 200-212, 1992.

[70] Kessler, E., A. Chakrabarti, "Speeding Up the Pace of New Product Development", *Journal of Production and Innovation Management*, volume 16, pages 231-247, 1999.

[71] McGuiness, N., "New product idea and activities in large technology based firms," *Journal of Production and Innovation Management*, volume 7, pages 173-185, 1990.

[72] Cooper, R., Op. cit.

[73] Zirger, B., M. Maidique, "A model of new product development: an empirical test", *Management Science*, volume 36, number 7, pages 867-883, July 1990.

[74] Cunha, M., J. Gomes, "Order and Disorder in Product Innovation Models", *Creativity and Innovation Management*, volume 12, number 3, pages 174-187, September 2003.

[75] McCarthy, Ian P., Christos Tsinopoulous, Peter Allen, Christen Rose-Anderson, "New Product Development as a Complex Adaptive System of Decisions." *Journal of Production and Innovation Management*, volume 23(5), pages 437-456, 2006.

[76] March-Chorda, I., A. Gunasekaran, B. Lloria-Aramburo, "Product development process in Spanish SMEs: an empirical research", *Technovation*, volume 22, pages 301-312, 2002.

[77] Spivey, W., J. Munson, J. Wolcott, “Improving the New Product Development Process: A Fractal Paradigm for High-Technology Products”, *Journal of Production and Innovation Management*, volume 14, pages 203-218, 1997.

[78] Smith, R., J. Morrow, “Product development process modeling”, *Design Studies*, volume 20, pages 237-261, 1999.

[79] Veryzer, Jr. Robert W., “Discontinuous Innovation and the New Product Development Process.” *Journal of Production and Innovation Management*, volume 15(4), pages 304-321, 1998.

[80] Knight, R., Op. cit.

[81] Iwamura, Akira, Vijay M. Jog, “Innovators, Organization Structure and Management of the Innovation Process in the Securities Industry.” *Journal of Production and Innovation Management*, volume 8(2), pages 104-116, 1991.

[82] Scott, G., Op. cit.

[83] Product Development Management Association, Op. cit.

[84] Rouse, W., Design for success: a human-centered approach to designing successful products and systems, New York: Wiley, 1991.

[85] Rouse, W., Strategies for innovation: creating successful products, systems, and organizations, New York: Wiley, 1992.

[86] Sage, A., Systems Engineering, New York: J. Wiley, 1992.

[87] Urban, G., Op. cit.

[88] Kahn, K., Op. cit.

[89] Kmetovicz, R., Op. cit.

[90] Armstrong, S., Op. cit.

[91] Molina, A., Op. cit.

[92] Mohanty, R, “Analysis of Justification Problems in CIMS: Review and Projections.” *International Journal of Production Planning and Control*, volume 4(3), 260-271, 1993.

[93] Ignizio, J., Introduction to Expert Systems: The Development and Implementation of Rule-Based Expert Systems, New York, McGraw-Hill, Inc., 1991.

[94] Novak, J., Op. cit.

[95] Bernard, H.R, Social Research Methods: Qualitative and Quantitative Approaches, Thousand Oaks, California, Sage Publications, Inc., 2000.

[96] Walker, J., P. King, "Concept mapping as a form of student assessment and instruction in the domain of bioengineering", *Journal of Engineering Education*, April 2003.

[97] West, D., J. Park, J. Pomeroy, J. Sandoval, "Concept mapping assessment in medical education: a comparison of two scoring systems", *Medical Education*, volume 36, pages 820-826, 2002.

[98] Radnor, Z., Op. cit.

[99] Hoare, R., M.E. Besterfield-Sacre, L.J. Shuman, R. Shields, J. Gerchak, D. Eartman, and T. Johnson "Cross-institutional assessment: development and implementation of the on-line student survey system," *Computer Applications in Engineering Education*, 10(2), September 2002, pp. 88-97.

[100] http://www.autm.net/directory/search_org.cfm

[101] Gartner, W.B., S. Birley, "Introduction to the Special Issue on Qualitative Methods in Entrepreneurship Research". *Journal of Business Venturing*, volume 17, 387-395, 2002.

[102] Mohr, L.B., Explaining Organizational Behavior. San Francisco, CA: Jossey Bass, 1982.

[103] Livesay, Harold C., Marcia L. Rorke, David S. Lux, "Technical Development and the Innovation Process." *Journal of Production and Innovation Management*, volume 6(4), pages 268-281, 1989.

[104] Pavia, Teresa M., "The Early Stages of New Product Development in Entrepreneurial High-Tech Firms." *Journal of Production and Innovation Management,* volume 8(1), pages18-31, 1991.

[105] Slater, S., J. Mohr, "Successful Development and Commercialization of Technological Innovation: Insights Based on Strategy Type." *Journal of Product Innovation Management*, volume 23, 26-33, 2006.

[106] Besterfield-Sacre, M., J. Gerchak, M. Lyons, L.J. Shuman, and H. Wolfe, "Scoring Concept Maps: Development of an Integrated Rubric for Assessing Engineering Education." *Journal of Engineering Education*, volume 93 (2), 105-116, 2004.

[107] Wright, M., Op. cit.

[108] Mowery, D., Op. cit.

[109] Fowler, F. J., Survey Research Methods. Thousand Oaks, CA. Sage Publications, 2002.

[110] Mohr, L., Op. cit.

[111] Amabile, T., "Motivating creativity in organizations: on doing what you love and loving what you do", *California Management Review*, volume 40, number 1, pages 39-58, Fall 1997.

[112] Cooper, P., "A study of innovators' experience of new product innovation in organizations", *R&D Management*, volume 35, number 5, pages 525-533, 2005.

[113] Amabile, T., Op. cit

[114] Jensen, R., M. Thursby, "Proofs and Prototypes for Sale: The Licensing of University Inventions." *American Economic Review*, volume 91, 240-259, 2001.

[115] http://www.autm.net/about/dsp.publications.cfm.

[116] http://www.autm.net/about/dsp.publications.cfm.

[117] Allison, P. Logistic Regression Using SAS: Theory and Application. Cary, NC. SAS Institute, 1999.

[118] Markides, C., "Disruptive Innovation: In Need of Better Theory." *Journal of Product Innovation Management*, volume 23, 19-25, 2006.

[119] Reid, S., U. Brentani, "The Fuzzy Front End of New Product Development for Discontinuous Innovations: A Theoretical Model." *Journal of Product Innovation Management*, volume 21, 170-184, 2004.

[120] Personal Communication with Hybrid Inventor from Study One Part I, October 2005.

[121] Golish, B., Op. cit.

[122] U.S. Department of Labor, Bureau of Labor Statistics, http://stats.bls.gov/lau/lacilg00.htm, July 2004.

[123] US Cities Over 300,000 Ranked: 2000 Census, http://www.demographia.com/db-2000uscityr.htm.