BALANCING FLEXIBILITY AND FORMALITY IN PRODUCT DEVELOPMENT AT A HIGH GROWTH TECHNOLOGY COMPANY

by

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B.S. Electrical Engineering
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Submitted to the Sloan School of Management and the Department of Electrical Engineering and Computer Science in partial fulfillment of the requirements for the degrees of

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Abstract

In the competitive market of wireless telecommunications, time to market for new products can be a key strategic advantage. A short cycle-time product introduction process allows companies to respond more quickly to customer’s needs, incorporate a greater span of new technologies and improve product functionality and cost. This thesis presents a study on how balancing flexibility and formality in a New Product Introduction (NPI) process can increase time-to-market for large scale technology products.

This thesis begins with a background on the technology of wireless communication and Qualcomm Inc, the wireless equipment provider this thesis is developed in partnership with. Chapter 3 discusses the results of a post mortem conducted on the Qualcomm’s existing New Product Introduction (NPI) methodology. The results of the post-mortem are broken up into three categories: general working environment, communication between functional groups, and process concerns. Chapter 4 uses the results from the post-mortem to identify linkages between the design and manufacturing groups that are critical to balancing flexibility and formality in the NPI process. An extensive analysis is conducted of this critical link, including a discussion of Microsoft’s “synch-and-stabilize” process used to address this issue in software development. Finally, Chapter 6 presents specific recommendations to optimize the link between design and manufacturing for balancing flexibility and formality in the NPI process. The thesis concludes with a discussion covering issues relevant to the implementation of the recommendations made in Chapter 6.
Acknowledgments

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1.0 Introduction

The Strategic Importance of New Product Introductions

In the past decade, technology organizations have begun to realize the importance of time-to-market. Technology is evolving at such a pace that design, development and manufacturing are finding it difficult to keep up with the demands placed on them by growing customer expectations and increasing competition. Continuously shrinking product life cycles are making time-to-market a critical success factor for programs and for companies as a whole.

As technology products have market lives which are often less than a year, and strong competition is creating extremely thin margins, being late to market can significantly reduce the success and lifetime of a product.

Goals of the Thesis Project

This thesis represents the culmination of six months work at a wireless telecommunication equipment provider associated with MIT's Leaders For Manufacturing (LFM) program. The project was originally conceived of as an opportunity to improve the New Product Introduction process within one of the company's divisions. As this was a joint effort, the thesis had to satisfy both the academic requirements of MIT as well as the company's need for NPI process improvements, implemented into their systems. With this in mind, the thesis project was completed in three major phases. The first was performing a broad evaluation and analysis of the established NPI process. The second was to continue with more detailed research into a fundamental linkage within the greater process that was critical to the success of the overall NPI effort. The third was to implement specific well-defined improvements to the NPI process.

2.0 Background

2.1 Company

Qualcomm is a relatively "young" rapidly growing wireless telecommunications company in a hyper-competitive industry with many large and well-established competitors. Though the organization has been in existence for over a decade, only recently has it entered the wireless
communications market. Within the wireless technology market, this company is considered to be a relative newcomer, having only produced and sold products for approximately three years.

The company utilizes a standard matrix based management system, with operations, engineering, program management, product management and marketing in separate functional groups. Product based teams are coordinated by dotted-line assignments to cross-functional program managers. Though the structure is not unique, the corporate culture is. The environment is that of a “start-up” firm, implying incredible growth in both revenue and employee headcount, with relatively few entrenched business practices and procedures. The general philosophy has been to employ very intelligent people and place them into an environment that fosters creativity and drives products to the market quickly. Based on the revenue growth over the last three years, this formula has been very successful. However, this tremendous growth has added to the complexity of the corporation which demands more formal business processes. The employees recognize the necessity for this change, but adding structure and formality to the creative engineering core is a difficult change, especially when it is believed that their entrepreneurial spirit is the basis for success.

The company is engineering driven, in that both technical and business decisions are informally made and directed by engineering or by the Chief Executive Officer, who has always been an influential technical force in the corporation. As engineering often takes the lead in determining next generation products, marketing and other functional groups are forced to be responsive to those decisions. There is some movement within the organization to make the company more marketing driven, although that change has been slow to take hold. In general, these characteristics are systemic of a “start-up” corporation attempting to transition to the next stage of its evolutionary life.

2.2 Technology

There are several divisions of this corporation that produce a variety of wireless communication products. This thesis was written in conjunction with the Wireless Infrastructure Products Division (WIPD), which designs, develops and manufactures the support systems for wireless communication [See figure 1]. A brief explanation of this technology would be prudent.
2.2.1 Anatomy of a phone call

This is a rudimentary explanation of a very complex system that supports wireless communication. There are three different communication links that are established when a wireless phone call is placed. 1) The outgoing call placed on a cellular phone (subscriber unit) will first communicate to a Base station Transceiver Sub-system (BTS) via an wireless radio link. This BTS is responsible for communicating with multiple cellular phones simultaneously and is the primary component of the wireless infrastructure system that determines the overall capacity of the wireless network. Though there are many factors that determine the individual call capacity, a single BTS can usually handle upwards of 65 simultaneous phone calls. A network of BTS cells are deployed to cover an entire geographic region and demographic market to service all subscribers in that location. Figure 2 shows how multiple BTS’s (designated by the white circles) are positioned to provide coverage for the entire North County region of San Diego. These BTS’s are strategically placed to cover high caller density areas (city centers) and routes of transportation (highways) with secondary systems covering lower-priority areas. 2) The BTS takes the conversation encoded in the radio signal from the subscriber unit and passes it along to the Base Station Controller via a digital backhaul. There exists multiple BTS’s that simultaneously transmit signals back to a single BSC. 3) The BSC passes the signal along the Public Switched Telephone Network (PSTS) via a digital Trunk line. The BSC also provides electrical and signal

Figure 1

Figure 2
isolation as well as switching, billing and feature capabilities. A signal traveling to the cellular phone is communicated in reverse fashion. In the creation of a cellular system for a geographic location, multiple BSC’s and the corresponding BTS’s are located within that region to create the wireless infrastructure to support cellular communications. The art of determining where to place the BTS’s and BSC’s in order to optimize capacity and coverage is critical to planning the wireless network for any given city. The combination of the BSC’s and BTS’s represent the wireless infrastructure products.

Qualcomm Inc. is new player in the wireless infrastructure products market, having entered competition as of 1995. As of 1996, Qualcomm comprised only 1.5% of the $5.3B dollar domestic wireless infrastructure business [See Figure 3]. Being a new entrant in this market, their product portfolio is relatively small compared to the other big players such as Motorola, Nortel and Lucent. Presently, Qualcomm has two different BSC systems, called the QCore products, and six different BTS’s, called the QCell products. Products are differentiated by capacity (number of simultaneous calls that can be handled by the unit), operating frequency (Cellular or PCS band), installation location (inside or outside), and specific customer requirements. New products are launched according to the dramatically changing market and technology. Generally speaking, a completely new design for either a BSC or BTS, including changes to the silicon chips internal to the system would take on the order of 2-3 years. A minor revision of a product for reintroduction into a different market niche may take on the order of 10 to 15 months. Within the next 2 years, approximately 5 new products are expected to be launched, which will either add to the product portfolio or replace existing products. The purpose of this thesis is to propose ways of decreasing the cycle time for product introduction as a means to increase the competitiveness of Qualcomm.

### US Wireless Infrastructure Market

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<tr>
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<tr>
<td>Lucent</td>
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<td>Ericsson</td>
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<td>Motorola</td>
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<td>Nortel</td>
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<td>Qualcomm</td>
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<td>Others</td>
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2.3 Existing New Product Introduction Methodology

Though the absence of an official New Product Introduction (NPI) methodology is widely accepted within the corporation, an unofficial system has evolved. The organization generally hires only experienced people, many having developed products at competitive telecommunication companies. As such, an NPI process has naturally developed based on tribal
knowledge and past experiences from other organizations. As the process is informal, employees with different backgrounds evaluate their positions, roles and responsibilities inconsistently from each other. Moreover, the boundaries of those duties in relation to other employees and the rest of the organization are unclear, and therefore prone to either redundant action. The system has been successful thus far because generally speaking, the individuals are very pro-active and feel a strong connection between their job and the overall success of the company. However, repeated long hours over the last several years and the rapid growth of the company have left the workforce looking for more formality and structure to the NPI process.

2.3.1 Phases

Figure 4 below shows that there are five phases to the NPI process at Qualcomm. This is not to imply that this unofficial process is formalized to the point where there are distinct bounds on any of the phases, or that all employees are keenly aware of the existence of the individual. Figure 4 only attempts to describe the general approach to NPI that the company and its functional groups have taken.

![Phase Flow Chart]

**Phase 1: Product Definition**

As the organization transitions from being engineering-driven to more marketing-driven, the process by which products are defined is in flux. Previously, VPs of Technology or in some cases the CEO would dictate what products would be developed based on their knowledge of the market, trends and technology. As the company changes to become more market oriented, the product definition has begun to take on a more standard process as shown in Figure 5. This flow chart of information attempts to demonstrate the more logical procedure that the organization takes to determine what products should be included in the portfolio of the company. However,
this is not to imply that the company is this structured, but this is merely a general map of a very loose action and decision process.

1) From market research and information from existing and potential customers, marketing determines a potential product for the Wireless Infrastructure Group. Typically, this idea for a new product is in reference to bids that marketing/sales have made to potential customers for new business. 2) Product management takes the high level product concept and begins to derive a functional map of the product itself. 3) Armed with the functional definition of the product, sales develops a revenue forecast, as product management develops a more technical specification with the help of program management and systems engineering. From this technical Product Requirements Document (PRD), development costs and schedules are estimated. 4) Product management then develops a pro-forma P&L with which they sell the product to executive management. Once the product concept has been accepted, program management and engineering begin phase 2, Product Development. This very informal process is completely circumvented by those products that are defined and driven by the Engineering group or by the CEO.

Unfortunately, though phase 2 may have begun, the Product Definition phase has yet to end, as shown in Figure 3. It has been mentioned that the original idea for the product came from a sales bid for business with a potential customer. As the bidding process with customers continues, the definition of the product changes. For example, only when a contract is signed with the prospective customer is a network plan established for that individual market, dictating the size
and specific functional requirements of the system. As such, many features of the system remain in flux, even up until shipment. This process appears to be representative of the entire wireless infrastructure market, and is not necessarily specific to Qualcomm.

Phase 2: Product Design

The design of either a BTS or a BSC is a very complex process including electrical, mechanical and software engineering. In association with the actual product itself, is the corresponding testing systems which have a similar level of complexity and integration. Practicing concurrent engineering, the company designs and develops the electrical Circuit Card Assemblies (CCA) simultaneously with the mechanical racks and backplanes that will be used to connect and support them. Development on the testing systems are also done in parallel to the development of the actual product. It is the responsibility of program management to coordinate the design and development efforts in engineering with manufacturing, training and field engineering.

The longest lead-time for individual components for these systems has historically been cables. On any given system, there are over 300 cables of varying types, connectors and lengths which connect the individual subsystems and the various racks of electronics. In an attempt to define the cables as early as possible, manufacturing is extremely proactive in creating a mock-up system in parallel to the product design effort of the design engineers. This non-functioning system is used to determine the routing and lengths of any cables defined by the design engineers. NPI manufacturing engineers will usually begin development of the Mock-Up as soon as the base rack structure is designed, and the location and design of a few subsystems is determined. This is not meant to be a fully functional system, and in many cases, cardboard cutouts for shelves, components, etc. are used to determine cable specs. This Mock-Up is usually transitioned into the first functioning Prototype in phase 3. However, the point of transition from phase 2 to phase 3 is not defined by product maturity, and in almost all cases Prototyping begins before Product Design is completed. In fact, the design of the product continues to evolve and change well into the phase 4, Pre-Production.

Phase 3: Product Prototype

In this phase, manufacturing builds a few (anywhere from 1 to 10) functional units for internal hardware and software development. This is done primarily in the Manufacturing Development Lab (MDL), removed from the manufacturing floor, and away from the constraints of formal
manufacturing processes. The purpose of this phase is to prove out the design, and work through problems and issues while the design and corresponding processes are still flexible.

Phase 4: Pre-Production

The purpose of the Pre-Production phase is to prove out the manufacturing processes. At the beginning of phase 4, preliminary work instructions (documentation dictating how the product is to be put together) and shop floor control routes (map of the product’s movement across the production floor) are supposed to have been created and instituted by the beginning of the phase. All manufacturing processes are supposed to be finalized and validated before entering phase 5, Production. At least one of the Pre-Production units will be shipped to an external customer as a Beta trial unit.

Phase 5: Production

This phase should represent the point in the product’s life where both the design and manufacturing processes are mature and proven. This includes all product integrity testing intended to prove out functionality as well as regulatory approval. In reality, the product and processes continue to evolve and change through to Production phase.

2.3.2 Release Control of Documentation

In the development process, the revision levels of a document attempt to communicate and control the maturity of the drawings of parts, components and higher level assemblies of the products. There are two levels in the revision system. ‘X’ and ‘-’. Under the rules of the release system, a document is considered to be at Revision X, if the cognizant engineer has authorized that document to be under the control of Configuration Management (CM). This entails the engineer signing off on the document and turning it over to CM for archiving purposes. The advantage of having documents (and therefore parts) at Rev X, is that changes can be made quickly by the cognizant engineers, as only their signature is needed to enact changes to the documents under control by CM. The second level of the Revision System, Rev -, represents a much greater control over documentation. In order for documents to reach the Rev - level, they must be voted on by the Change Control Board (CCB), which includes the cognizant engineer, Project Manager, Program Manager, Manufacturing, Quality as well as other representatives whose inclusion in the CCB are at the discretion of the CM group. The intention of the CCB and the Rev - release level on documents is to control the risk associated with changing the
documents (and hence the product) arbitrarily. Notification of changes are made via email and
informally through “hallway conversations,” which is considered a significant and critical
communication medium within the organization. According to corporate ISO policies, an entire
product is supposed to be released to Rev - before it enters full production with unlimited release
to external customers. Corporate practice is much different, as several products studied in the
post mortem were launched into production while much of the product remained at Rev X.

3.0 Post Mortem on Previous Product Introductions

In an attempt to better understand the organization and previous successes and failures for this
thesis, post mortems were conducted on three different products launched over a period of three
years.

3.1 Process of Information Gathering

Thirty employees with experience in previous product launches were interviewed. Interviewees
included members from program management, product management, production, materials,
quality, executive management and marketing. After collecting the information, the opinions and
thoughts were scrubbed by using TQM practices including a KJ. In this process, the individual
thoughts and ideas were categorized into several general groups. These groups included general
working environment, communication between functional groups and process concerns.

3.2 General Working Environment

3.2.1 Start-up Culture

Almost unanimously, the employees described Qualcomm as an engineering driven organization
with a very unique culture. They directly attribute the company’s success to the start-up culture
that their founder, Irwin Jacobs, has instilled in the corporation and fights to keep alive. Despite
the tremendous influences to grow the organization, human resources has apparently resisted the
need to fill positions with whomever they can find. Instead, they have historically hired only the
best and the brightest of the engineers on the market, and gives them an equity stake in the
company. This has served to create a very strong engineering-entrepreneurial culture with a lot
of freedom and creativity afforded to the engineering community. This sort of organization has
been very successful in the past, but the employees recognize that the company is at a crucial
stage in its evolution, where they must become more mature with established business processes
and formal methodologies.
3.2.2 Power Hierarchy

There was a general feeling among the parties interviewed that a power hierarchy existed among the functional groups. Design engineering was perceived to be in control of projects, with manufacturing, program management and marketing playing subordinated roles. One of the program managers responsible for a product launch summarized it as follows.

My litmus test for doing anything on a product or project is whether I can get the support of design engineering. If they buy into the idea, it has a good chance of success. If design engineering does not buy into the idea, there is pretty much no chance of it getting off of the ground.

Not only did design engineering tend to wield most of the control, there was also the concern among the groups that design tended to drop support of the product much too early in the product launch. Historically, by the time the latest product was just entering the pre-production and production phases of the NPI effort, a newer and more exciting product was being defined by marketing. Design resources tended to be pulled off of the existing product too early, for the sake of staffing up for the new product coming down the pipe-line. As a result, other organizations felt that design was not very supportive of their needs in the latter stages of product launches.

For the most part, operations was highly regarded across the entire organization and throughout all levels. The general impression among other groups is that operations people are motivated, proactive individuals who take ownership of their problems and do what it takes to pull off miracles in getting the product to market. Almost all of the people within operations have extensive experience in manufacturing from other organizations including DEC, Motorola, General Dynamics, Unisys and others. Having come from a variety of backgrounds, these individuals all had different approaches to their jobs and philosophies on the roles and responsibilities of their respective assignments.

3.3 Communication between functional groups

3.3.1 Integration of Operations and Design

There was a tremendous effort on the part of operations to be part of the design process. There were no formal lines of communication across functional groups, so operations became very aggressive in how they “embedded” themselves into the design process. In order to aid in the
communication between the design engineers and operations, the manufacturing engineers and
the materials support organization were staffed in the same building as the design groups. This
served to close the communication gap between the designers and the individuals in operations
that were directly in contact with them. Operations did well is to integrate themselves informally
upstream into program management and the design activities so as to push engineering for the
deliverables that manufacturing needed to get the product launched. None of this was by formal
process, but almost entirely because operations was very proactive in getting what they needed to
accomplish their goals.

Operation’s attempt to move upstream into the process of design engineering was continuously
met with mixed reactions from the engineering community. There were apparently circles of
influence in the design groups which dictated how the design engineers reacted and behaved to
manufacturing’s role in phase 2: Product Design. If the VP of Technology or the Engineering
Director in charge of the design was sympathetic to the need for operation’s involvement,
integration upstream became much easier. On the products where the leaders of the design staff
were less understanding, operations was forced to find more creative ways to get their
job done.

One of the operations program managers in charge of a New Product Introduction spoke to this
issue:

The design community at Qualcomm can tend to have a very myopic view of
product development. They believe that all that matters is how long it takes them to
get the design done and working. They often don’t see the need for manufacturing’s
involvement in a project, and feel that we just slow them down. We may force them
to go more slowly in terms of just the design phase, but our involvement decreases
the total time-to-market of the entire project. We are getting better at this.

3.2.2 Integration of Marketing

There exists a large communications gap between marketing and both design engineering and
operations. As was mentioned previously, the perceived organizational hierarchy places
marketing on the bottom of the food chain at Qualcomm. Marketing’s relative position in the
organization leads to disconnects and mistrust with the rest of the corporation. On one product
launch, marketing had committed to sell a specific feature which it felt to be a non-issue and
easily developed. In reality, that specification represented a complete redesign of major systems
and months of development time on the part of both design and manufacturing. Marketing’s
lack of connection with the technical competence of the organization led to a decision that postponed the ultimate delivery date of the product by over a month. Their lack of power in the structure seemed to be amplified by the difficult position that they play in attempting to translate a very tumultuous market to product definitions and forecasts that drive design and operations. Marketing is responsible for developing forecasts for new products yet to be launched, as well as established products being shipped into the market. Because of the volatility of the bidding process necessary to win contracts, and the underlying volatility of the market, it was very difficult for marketing to develop accurate forecasts, making operations and design engineering even more skeptical of the information from marketing. This reinforced the relational gap between the functional groups, and caused the communication to become more dysfunctional. This marketing disconnect is not necessarily unique to Qualcomm, and is often found in a wide variety of high-tech companies.

3.4 Process Issues

3.4.1 Lack of Formality

There are no formal processes in place to direct or coordinate design, quality, manufacturing and procurement. When asked the question of what the New Product Introduction methodology was at Qualcomm, the common answer was “We have an NPI process?” Qualcomm is still developing its own methodologies, despite the fact they have over $2B in sales with over 9000 employees. Consequently, there are no formal lines of communication, and the exact roles and responsibilities of respective employees are not clearly known. This seems to work fairly well because the people in the organization are very proactive and work to cover all issues on a product launch, but the lack of structure and formality results in everyone working twice as hard as they should.

Design engineering was the main opponent to adding any formality or structure to the product development process. They felt that such constraints would inevitably turn into a “Gated” development philosophy, slowing down their individual development effort. Several of the interviewees from manufacturing jokingly referred to the corporate philosophy on a gated product development process.

If you mention the word “Gate” in this organization, you will be thrown out of Qualcomm.
This had an adverse effect on the rest of the organization where jobs had to be aligned with the design group’s efforts and the evolving product. As there were never any points where the design would be frozen, or any gates in the process that would allow the other parts of the organization to sync-up efforts with design, many of the other groups tended to lag behind the development effort.

The rest of the organization would have to scramble to stay abreast of the constantly changing design. It was described before that Qualcomm used such terms as Prototype, Pre-Production and Production to theoretically describe the state of a product or project. Unfortunately, there was not common agreement as to the real meaning of these terms across functional groups, or even internally within the vertical organizations. As design would dictate changes to the product even up to high volume manufacturing, Production or Pre-Production did not have much significance as far as the maturity of the product or processes. This ambiguity caused many problems within the manufacturing organization.

3.4.2 Project Scheduling

In Qualcomm’s process for defining products, detailed in Figure 4, there existed a breakdown in the flow of information that negatively affected operations. In the beginning of each product launch, program management was responsible for identifying resource needs from engineering and manufacturing in order to create a cost model and delivery schedule for the project. All told, the headcount for a larger BSC effort may include around 50 design and manufacturing engineers over a two year period. This is further broken up into smaller teams of 3-5 persons each, for electrical design, mechanical design, tester development, software and manufacturing. This represents only the those people directly staffed to a single product, as total headcount dealing indirectly with a product would be much more. Program management would work with engineering to understand design needs and conflicts, but would often leave operations out of the total schedule creation process. Program management would take their best guess as to the needs for manufacturing resources and time. Only until this budget and schedule had been accepted by executive management would operations get the opportunity to see and react to the schedule. By that point, they would be powerless to push back on a delivery schedule that had already developed momentum and expectations in the upper levels of the company and within marketing. In one specific case, operations was particularly frustrated with the schedule that was created. An operations program manager spoke to this.
Even from the beginning, we knew that the schedule was completely unrealistic, but nobody believed us. We fought with program management and marketing to convince them that the product would not be done, but they would not slip the schedule. Everyone expected us to pull off miracles, because we always did it before. The expectations for us to do the impossible became so great that ultimately the team dynamics started to break down within manufacturing, because we knew we couldn’t do it but no one would listen. Ultimately, we were not able to meet the really schedule that was set for us, but we still felt successful because we met the schedule we had created at the start.

Marketing and program management, however, felt that manufacturing was unsuccessful, having not met the original schedule that program management had created. This lack of alignment of goals and expectations between the groups occurred on other development projects as well.

3.4.3 Reliance on Operations
Operations had little control on project schedules, which were ultimately determined by marketing and program management. Being at the end of the product launch process meant that operations was often held accountable for making up time in the schedule that the design group had lost. On several occasions, despite the fact that design engineering slipped their schedule back due to unforeseen problems, manufacturing was still expected to launch the product on the pre-determined date. This served to force manufacturing to work extremely hard to “pull off miracles” and get the product to market. However, this served as a reinforcing dynamic loop for the design community. After the second product launch, operations was expected to always be able to execute miracles which became very detrimental to the attitude of the operations group.

An operations program manager spoke to this:

Operations is clearly under the gun. Design will consistently slip their schedule for delivering information and designs to us, but we are still expected by the organization to ship on time. We have pulled off miracles before, so that has now become the status quo. Our needs are rarely considered in the scheduling process, and it always kills us in the end.

3.5 General Conclusions
The post-mortem demonstrated several critical issues:

1. Qualcomm is an engineering-driven company whose heart and soul is based on talented engineers allowed a certain level of creativity and freedom to innovate. Anything that would be perceived to break this culture would be aggressively opposed by management and employees alike.
2. The organization is fighting the transition to a more structured and mature state with standardized business practices. Most of the corporation understands the need for formal business processes and is actively looking to create them, while attempting to keep the underlying culture alive.

3. The biggest problems that were highlighted in the post mortems were caused by a breakdown of communications between the functional groups whose coordination is the job of program management. This disconnect between the groups has led to a mis-alignment of goals and expectations as to the launch of the product.

4. The control hierarchy design at the top of the pyramid and operations and marketing at the bottom has led to a sub-optimization of communication and management of programs.

4.0 The Balance Between Flexibility and Formality

Throughout the NPI process there exists an inherent conflict between the culture of the design organization and the needs of manufacturing. Design represents creativity, independence and the lack of significant formality and structure. Dominant personalities within the organization have protected the autonomous environment of design engineering to the point where it is systemic throughout the company’s culture and philosophy. Evidence of this can be seen by the lack of any design freeze throughout the NPI Process: At no point in the New Product Introduction process does the hardware and/or software design mature to the point where the engineering and manufacturing community recognize the product as stabilized and frozen. Though the revision control system at Rev - could be construed as a product freeze, in reality such measures are rarely implemented, and the design continues to evolve throughout the prototype, pre-production and production phases. However, this lack of formality is widely viewed as an organizational core-competency, and something that should be protected at all costs.

The contrasting needs of operations and manufacturing ultimately clash with this philosophy. Manufacturing is a pursuit that strives for repeatability, stability and precision. The ideal situation for manufacturing would be to have a finished and stable design with which to establish a supply chain and manufacturing process. The standard gating process to product development, where the design must be finished and frozen before moving onto the next step, is inherently manufacturing friendly. If the design is stable and well validated, finding suppliers and creating manufacturing processes to build the product is substantially easier. The trade-off is time-to-market. However, waiting until the design is frozen to begin developing manufacturing
capability and a supply chain will lengthen the company’s time-to-market, and make the product and company less competitive. In the highly competitive market of wireless telecommunications, one of Qualcomm’s strongest competitive advantages has been time-to-market. As such, any recommendations that have been made to add structure to the NPI process have historically been quelled by engineering and management under the context that such formality would lengthen development cycle times.

The quality organization is another internal group that historically pushed for more formality and structure to the products and processes. Quality assurance recognizes the risk of shipping product without more well established processes within the design phase, and has attempted to impose those beliefs upon the engineering community with gradual success. Up until the time of this thesis, Qualcomm had not encountered any major quality issues with products in the field, making it more difficult for the quality group to justify constraining checks and balances on the system.

4.1 NPI process - Critical Link

The critical link in the NPI process is where the organizational culture of design engineering clashes with the organizational needs of manufacturing. This transition from phase 2 (Product Design) to phase 3 (Product Prototype) represents this critical point for Qualcomm’s product introduction strategy. At this point, manufacturing is pulling into their organization as much information about the design and development as possible. That information is the base from which operations is establishing a short-term supply chain for the Prototype and Pre-production builds, long-term supply chains for the Production builds and establishment of their internal manufacturing capabilities and processes. Engineering’s continuous iteration of the design through the Prototype and Pre-Production phases, forces operations to continually re-evaluate and change all work done up until that point. The sooner the majority of the iterations and changes in design are completed, the less potential impact they will have on manufacturing and the supply chain. Changes in the
design that occur while manufacturing is in the prototype phase will impact the functional prototype and the short-term supply chain. Any changes in the design that occur while manufacturing is in the pre-production phase will impact not only the functional prototype and short-term supply chain, but also the pre-production units, the long-term supply chain and formalized manufacturing processes. Manufacturing would prefer to delay its actions as long as possible to allow the design to stabilize, but their ultimate deadline for product launch is rarely flexible. As such, manufacturing pushes up-stream into the design process in attempt to get information upon which to act, running the risk of having to adapt to massive changes in the design later on.

The reality of technology development is that there will always be a number of changes that occur to the design well past the design phase, caused by customer concerns, hardware and software limitations and general market dynamics. Many of these influences cannot be controlled by the company at large. Though the engineering groups would like to “finish” the design before manufacturing get involved, time would not allow such a separation of tasks and inevitably changes will occur. These problems are not at all uncommon among organizations that practice concurrent engineering.

4.2 The Present Organizational Structure

Qualcomm functionally organized with engineering and operations in two independent vertical structures. In the New Product Introduction process, the interaction and communication between the respective members of the engineering and operations group is critical to the success of the NPI effort. As described in the previous chapter, design engineering is perceived to be “in control,” whereby other groups within the company must cater to design, pulling information from them in order to accomplish their own independent jobs. Recognizing the necessity to be close to the design engineers, the operations group has staffed the Engineering Planner and NPI Manufacturing Engineer in the same building as the engineering design team in hopes of closing the information gap between the functional groups. This has met with mixed success. The design
engineering groups tend to be very territorial, and the operations team members must work hard to foster long-term relations in hopes of gaining the trust and cooperation of the design engineers.

4.2.1 The Engineering Planner

As presently defined in the organizational structure, the Engineering Planner is responsible for integrating changes in the product design, into the supply chain. This person's job begins as the design engineers start development on a product, and the design of certain electrical components or mechanical assemblies starts to take form. It is the responsibility of the Planner to drive the procurement and sourcing of the materials and components needed by the engineers. It is the responsibility of the Materials Planner to have visibility over all changes in the design as they occur, understand the implications to the supply chain and feed information back to the engineers on pricing and availability to the design engineer. Typically there are two Engineering Planners staffed on a given product, one specifically for the electrical Circuit Card Assemblies (CCAs) and one the mechanical assemblies and systems. Though these individuals are located in the same building as the design engineers, their offices are separated by approximately 200 yards and 2 flights of stairs.

4.2.2 The NPI Manufacturing Engineer

The NPI Manufacturing Engineer (ME) is the liaison between the design engineers and the manufacturing community. The NPI ME is tasked with influencing the design for manufactureability. There is one NPI ME for each product being launched. This person is staffed in the same building the design engineering staff, and is primarily responsible for integrating operations with design engineering. They must keep abreast of any changes in the product design, understand their implication to the manufacturing process and capabilities, and communicate that information up-stream to the design team as well as down-stream to the manufacturing community. In phase 2 (Prototype) their job is to coordinate the development of the mock-up unit, and the subsequent Prototype units. As phase 2 comes to a close and Pre-Production is ramping-up the NPI ME is responsible for developing and documenting the preliminary manufacturing processes for production. During the Prototype and Pre-production phases of the NPI process, the Engineering Planner and the NPI ME are critical to the speed with which operations is able to setup the manufacturing capabilities for the product.
4.2.3 The Manufacturing Development Lab

The Manufacturing Development Lab (MDL) is a 400 sq. ft. room off of the main manufacturing floor where the mock-up and prototype versions of the new BTS and BSCs are assembled. There are approximately 13 assemblers and technicians who work in the MDL and are dedicated to assembling the first functional units of any new product. Having the units created in the MDL allows manufacturing a certain amount of freedom, away from the constraints of shop floor controls, work instruction and specific routes. It also gives manufacturing the flexibility to rapidly change and manipulate the product as it takes form out of the design stages. At any given time, there can be up to four different products being built within this room. After there have been around 10 copies of the same product built in the MDL, the production is rolled out to the manufacturing floor with formally established and documented processes.

4.3 Definition of Optimization of the NPI critical Link

Before making recommendations for the improvement of the NPI process or the critical link, a definition should be made as to what “improve” actually means in the context of New Product Introduction and specifically Qualcomm.

Considering the contradictory cultures between design and manufacturing, the goal of an established NPI process is two fold. In one dimension, the NPI process should allow the engineers the creativity and independence that they desire, while giving manufacturing the formality and structure that they need. In the second dimension, the NPI process should be able to fully integrate the two functional groups and their respective attitudes to facilitate a quick transition from design to manufacturing. Considering Qualcomm’s position in the wireless telecommunications market, the ultimate goal of the NPI process is to decrease the overall time to market of products for the Wireless Infrastructure Products Division (WIPD).

5.0 The Sync and Stabilize Model

It is sometimes helpful to make comparisons between the organizational processes despite glaring differences in the products and markets. The Microsoft Corporation, based in Redmond Washington, and maker of software that runs on 95% of all personal computers, implements a model of design and development, called “Sync and Stabilize.” This method of organizing development teams is used extensively in software companies, and has been implemented effectively by Microsoft in the rapid development of large scale software programs. Though this
methodology is used extensively by software companies, several significant comparisons can be made with Qualcomm’s culture and NPI process.

5.1 Sync and Stabilize and the Microsoft Corporation

Microsoft, the world’s largest producer of PC software with over $8.7 billion in 1996 revenue, has had to gradually reorganize their methodology for developing software to accommodate the changing products. Microsoft Windows 95 or Windows NT consists of millions of lines of code written and tested by hundreds of people over multiple years. The process that they have adopted avoids many of the more structured software design philosophies while remaining true to their flexible, entrepreneurial heritage. Michael Cusumano and Richard Selby speak to this product development process in the article *How Microsoft Builds Software*.

The objective is to get many small parallel teams (three to eight developers each) or individual programmers to work together as a single relatively large team in order to build large products relatively quickly while still allowing individual programmers and teams freedom to evolve their designs and operate nearly autonomously. These small parallel teams evolve features and whole products incrementally while occasionally introducing new concepts and technologies. However, because the developers are free to innovate as they go along, they must synchronize their changes frequently so product components all work together.

Cusamano and Selby call Microsoft’s product development process “sync and stabilize.” The basis of this process is the continuous synchronization of the work of individual programmers and the smaller parallel teams, with periodic stabilization of the product throughout the cycle of development. This process addresses a problem, faced by most technology firms who build complex, rapidly changing systems. Qualcomm’s Wireless Infrastructure Products Division is a perfect example of this.

The development teams for Qualcomm’s BTS and BSC products have hundreds of employees on staff, including electrical and mechanical hardware, software engineers, testing engineers and manufacturing people. The definition of the product continually changes through the development cycle as a function of customer and market demands, forcing the entire group to react to the evolving product requirements. The problem is how to get such a large group to work efficiently together, and incorporate the rapid changes that occur to the product design.

Microsoft addresses this big problem by breaking it up into smaller chunks. Firstly, they prioritize all of the features that are to be included in the next release of the program. These
features get grouped into three or four major sequential milestones for the project. The large development team is then broken up into smaller groups which work in parallel, developing the interdependent features of the larger program. The “synch and stabilize” philosophy acts as the glue, providing a structure and coordination between the individuals and teams, while allowing them enough flexibility to be creative. This allows the product definition to iteratively change, as the development process continues.

Cusamano and Selby describe it in this way:

What Microsoft tries to do is allow many small teams and individuals enough freedom to work in parallel yet still function as a single large team, so they can build large-scale products relatively quickly and cheaply. The teams adhere to a few rigid rules that enforce a high degree of coordination and communication.

Each of the feature teams go through the following synchronizing process with their code.

1) In order for programmers to develop specific product features, they check out individual copies of the source code from a centralized master version [See Figure 8]. This checking out process is conducted by multiple programmers at the same time.

2) The programmers make independent changes to their code, implementing their specific product feature.

3) The programmers develop, and test a private build of the product including the individual feature they were implementing.

4) The programmers then check in their altered code into the master version of the source code, which includes extensive regression testing to flush out incompatibilities with other parts of the master program. One of the rigid rules imposed on this system is that the every programmers must check in their code on specific days (3 to 5 times a week), by a pre-determined time. [See Figure 8]

5) A designated developer, called a build master, creates a complete build every day of the centralized source code. This entails running of specific scripts which result in the creation of a new internal release of the product that will be further tested and iterated by the programmers.
Every one of the programmers who develop code for the software applications are paired up with a testing “buddy,” who acts as an advanced beta tester of the private releases of their software (step 3 above). This buddy system between programmers and testers is used to bullet proof the individual functions that the developers are building into the program. If a tester crashes their code due to incompatible changes, the respective programmer is responsible for fixing the bugs before the code is checked in (step 4).

Everyone of the feature teams go through a similar process of development, integration, testing and problem fixing, while synchronizing their efforts with those of other teams or programmers. At the end of the every milestone, the programmers “stabilize” the product by finding and fixing all bugs in the code. Once the product is fully stabilized, the group of developers may then move onto the next milestone and the next group of features.

The Sync and Stabilize model of software development has proven to be advantageous for Microsoft in several distinct ways.

1. The synch and stabilize model breaks down large-scale projects into smaller prioritized pieces, which can be worked on in parallel by multiple teams.

2. Product ship dates are more deterministic. Typically, software development had followed the “Code, Test and Ship” model, where there is an extensive testing process after the code has been completed. Quite often the amount of time necessary to find and fix all of the bugs in this style of product development is estimated incorrectly. As such, it always difficult to determine when the actual ship date of the program will be. With the “Sync and Stabilize” model it is fairly straightforward to determine how far along the application is and when it will be completed. This is a tremendous advantage to marketing as well as quality assurance.

3. The development program is always in a theoretically shipable state. Upon completion of the first milestone, the developers have a source code that has been fully tested with most important features designed in. These intermediate products that emerge after the completion of each milestone stabilization is a huge advantage to marketing, even though the product as a whole may not be fully functional. If the competition releases a comparable product with little advanced notice, marketing can respond in turn by launching a product that was actually in the midst of its development. Incomplete features that are not critical
can be cut out or postponed to the next release. Though the Microsoft product may not have the features of the competitor's product, it will still serve to stave off a first mover's advantage in the market place.

4. As Program Management and the Development team can readily see how far each of the features are from total completion, they can make a determination as to what features are truly necessary for a specific release of the product versus the timing of the release in the market place. Features can be quickly moved-up to an earlier version or postponed to a later one based on the constant information from the development effort and the market.

5.2 \textit{Sync and Stabilize at the Qualcomm Corporation}

Philosophically, Qualcomm is in a similar situation as Microsoft despite the hardware component to their business. Let's consider the concept that the synch-and-stabilize model could be performed at Qualcomm at two different levels by the engineering planner and the NPI manufacturing engineer as described earlier. Any change made by the design group, must be implemented within the supply chain, as well as the functional hardware as it take form in the mock-up and prototype units.

The engineering planner is responsible for syncing up the supply chain with the continuously evolving product design. In this case, a "bug" would refer to any change whose implementation by internal or external suppliers does not support specific build dates for the Prototype and Pre-Production units. Just as the developers and testers at Microsoft identify software bugs in the code through their continuous daily builds, the engineering planner is responsible for determining where there are material shortages, and then work with engineering and procurement to "fix the bugs," which in the case of Qualcomm entails re-engineering of the product, or finding alternate components or suppliers.

Continuing the analogy, the NPI Manufacturing Engineer also plays a similar role as compared to Microsoft's tester in the buddy system. Just as the testers are responsible for finding the problems with the private builds of the software code, the NPI ME is also responsible for "testing" the daily iterations of the design with the rest of the unit from a standpoint of manufactureability and assemblebility. In this case, hardware products are clearly more difficult
to sync-up and stabilize, as compared to software code. The daily build, integration and testing of code at Microsoft typically takes around 3-4 hours or less, whereas the creation of prototypes for such things as Circuit Card Assemblies (CCA) and sheet metal may take on the order of weeks. Clearly, it is unreasonable for Manufacturing to be synching-up their processes with weekly prototypes of designs as they evolve to maturity as this would be severely time consuming and expensive. Within the scope of Qualcomm and the NPI Manufacturing Engineer, a bug would be defined as anything that causes the designer engineers to revisit a design after it was released to Rev X.

The complaint of the design community is that manufacturing makes recommendations after it is too late to change the design, or after the engineers have committed to going in a particular direction. Manufacturing’s perspective is that they rarely have visibility over the product in the design phase, and can only make recommendations after the product has “emerged” from the designer’s hands. By the time that manufacturing provides feedback to the design team, it is already too late in the process for the recommendations to be adequately dealt with.

6.0 Recommendations for NPI Improvement

6.1 High Level Organization - Phase Review Management

Even at a high level within specific product groups, very little formal structure exists. There is a tremendous amount of reluctance and fear within the organization to add formality to the organization, as the employees feel that most of their success comes from their ability to creatively improvise solutions. As such, any methodology that even hints of instituting gates within the process is immediately frowned upon by most of the corporation and specifically the engineers. However, the organization is at a state in its growth where the number of employees and the scope of the programs are so large, that there must be some overriding framework to the process of New Product Introductions (NPI).

One approach to creating a flexible structure would be to establish phase Review Management (PRM). By breaking up the entire NPI process into distinct and separate phases, a general flow to the development process can be identified. In Qualcomm, the natural phases that have been identified: Product Definition, Design, Prototype, Pre-Production and Production, which provides a good starting place.
In attempting to institutionalize this PRM concept, the manufacturing executive staff for the Wireless Infrastructure Products Division was asked to identify high-level definitions for each phase. The process took many iterations over two months to drive agreement with the executive directors of process engineering, quality, supply and demand\(^1\) as to what Prototype, Pre-Production and Production meant for each of their functional groups. Figure 9 shows a high-level description of these definitions.

In Figure 9, the “Y” axis represents time and the maturity of the product as it passes from phase 2: Prototype, to phase 3: Pre-production and finally phase 4: Production. For each of those phases, the corresponding tasks or milestones for each of the functional groups are listed across the “X” axis, including: process engineering, design, quality, supply and demand. Process engineering represents the group of NPI manufacturing engineers tasked with bringing new products on-line in the manufacturing facility. Supply constitutes the sourcing and procurement organizations that are responsible for establishing the supply-chains for those new products. Demand is the group that is responsible for translating marketing’s demand forecasts into a build plan for manufacturing.

The intention for this high-level framework is to establish a benchmark NPI development process plan for the sake of visibility and ease of management. The discussion undertaken to create the information documented in Figure 9 forced the executive management of manufacturing to resolve differences in definition and vocabulary as to what each of the phases represented. At the beginning of the conversations to establish this process, even the vocabulary used to describe the state of a particular project was different between the functional groups and their management. Figure 9 represents the first point where the groups had come to convergence on describing the NPI process at a high level.

This framework was presented to other parts of the organization including program management, documentation and field engineering. All three of these groups recognized the need for such a

\(^1\) In these discussions, Design was not explicitly involved although their information is included in Figure 7. Design’s definition for Prototype, Pre-Production and Production were developed in further discussions after the Executive Directors had come to agreement within their Manufacturing.
high-level framework across an entire project, not just within manufacturing. Program management sponsored similar discussions with other supporting groups to create a program-wide NPI process framework, which they would use to coordinate program-specific activities.

Design had serious misgivings about such a global framework for New Product Introductions that would govern their activities. They expressed their concern that such an established methodology would “eventually lead to a gated process in product development,” in the words of one of the technical engineering leads. The design group truly believed that their core-competency of fast-cycle time development was dependent on “eliminating as much bureaucracy as possible.”
<table>
<thead>
<tr>
<th>Process Engineering</th>
<th>Design</th>
<th>Quality</th>
<th>Supply</th>
<th>Demand</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prototype</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Manufacturing and Test processes neither defined nor implemented.</td>
<td>Preliminary parts list, and Indentured Drawings List are controlled by Manufacturing Engineering, possibly under CM control.</td>
<td>Quality issues are being tracked and corrective actions are being driven. Supplier quality programs are initiated</td>
<td>Purchases through DMAR, MR, engineering stock room and SOW</td>
<td>Manufacturing driven by DMAR</td>
</tr>
<tr>
<td>Pre-Production</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>The Manufacturing and Test processes are preliminarily defined and implemented. (Typically on Manufacturing floor)</td>
<td>All drawings, schematics, and parts lists are under CM control. 89- is at Preliminary release</td>
<td>Quality issues are being tracked and corrective actions are being driven. Quality Plan is being developed. Suppliers are being qualified.</td>
<td>MRP Driven</td>
<td>Manufacturing is driven by DMAR or SO</td>
</tr>
<tr>
<td>Production</td>
<td></td>
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</tr>
<tr>
<td>The Manufacturing and Test processes are defined, validated and under CCB control.</td>
<td>All drawings, schematics, and parts lists are under full CCB control. Regulatory approval from all governing bodies, PI testing done</td>
<td>There are no “Open” Quality issues or items with out a corrective action plan. All suppliers are qualified. Qual Plan is in place.</td>
<td>All purchases being driven by MRP Supply Pipe Line is well established. LTA contracts signed</td>
<td>Manufacturing is driven by DMAR, SO or forecast</td>
</tr>
</tbody>
</table>

Figure 9
**Recommendation 1:** Institute reviews between each of the identified phases, to be conducted by the development Project Engineer, Program Manager and the NPI Team Leader.

Without any form of established process or methodology, programs ramp-up at full speed without a tremendous amount of conscious thought. Very often, problems occur in development or in manufacturing that can impact the commercial success of the product, but without a formal process that allows those problems to be adequately dealt with they may go unresolved before product launch. Agreeably, a full gating mechanism in the NPI methodology can potentially slow down the development effort, especially as the criteria for those gates often take on a life of their own and become overly stringent.

The “phase review” takes the place of the more formalized gate. The primary purpose for the phase reviews is to provide a venue for the managers whereby they can judge the development effort in comparison to a previously defined benchmark. Its purpose is not to stop the process or slow its progress to the next phase. The three primary people listed, as well as their respective staffs, should have sufficient knowledge about the technical development, manufacturing readiness and the business needs to be determining the risks involved with continuing down the NPI path despite the fact that all of the requirements of the phases may not have necessarily been met. Wielding this information, they can make informed conscious decisions to move forward in the program while understanding the risks involved, and putting into place processes to mitigate the outstanding risk.

The matrix displayed in Figure 9 only includes the NPI operations effort in relation to design. In order for this to be a complete program-wide NPI process, documentation, field engineering, training, system integration and system test would need to be included as well. All of these groups serve as support to the product development effort, but can significantly impact the overall delivery time and overall level of customer satisfaction if they are not coordinated with the central NPI effort. At the time of full installation of a BTS or BSC at a customer site, not only must the hardware and software be finished and fully assembled, the documentation and
training manuals must be written, and the customer and field engineering training must be conducted.

Currently, when problems occur in the NPI effort for a new BTS or BSC product, at no point in time does there occur a process where the risk (financial, market or otherwise) is evaluated and a decision is made to continue with the product launch with or without modifications to the plan. The phase reviews give management the opportunity to formally evaluate the outstanding risk at timely points in the product development effort, and consciously make the decision to move forward.

The design group originally objected to the idea of phase reviews, arguing that they were gates in disguise. Through numerous discussions with the VP of Engineering and the Director of Corporate Business Processes, the lead engineering managers began to accept the concept of phase reviews.

### 6.2 Manufacturing Requirements Document

At the end of the product definition phase, product management publishes a Product Requirements Document (PRD). This report translates customer needs and requirements, into a high-level functional specification, driving the engineering development of a product. Presently, the PRD only includes the technical needs of the customer. However, there are many other issues pertaining to the design of the product that are not customer related, that could be highlighted early on in the process in order for design to be able to react to them.

**Recommendation 2:** A Manufacturing Requirements Document (MRD) should be written by operations, detailing strategic issues for manufacturing that need to be designed into the product. This MRD should be included as part of the Product Requirements Document that drives design activity.

There are several problems that this recommendation would address. Historically, manufacturing has had the reputation of feeding information back to the design group too late in the development process for their ideas to be implemented into the design easily. This happens, not only on the day to day iterations of the design, but also on the more strategic manufacturing issues. Case in point: On one recent program, manufacturing began discussions with design about the potential of shipping a product with all of the racks of electronics assembled in the
metal cabinet enclosures (normally they are shipped independently). These suggestions were proposed well into the prototype phase and were brought to light much too late for design to implement them in the existing product. The MRD would provide manufacturing the opportunity to create Design for Manufactureability (DFM) or Design For Assembleability (DFA) guidelines which can then drive the design process. Furthermore, having such a channel for manufacturing to provide up-front input to the design group would allow the opportunity for Operations to create a manufacturing road map that could be integrated in the design over successive products. The purpose of this MRD is not necessarily to increase the work load of the design engineers, but rather to provide them with all the information they need to design the product, up-front in the process were it can be acted upon easily.

Secondly, the MRD would also provide operations with greater visibility up-stream in the process. manufacturing is continuously battling to gain visibility over new programs as they are coming on-line. One of the biggest problems highlighted in the post-mortems discussed earlier was that operations has not been part of the schedule creation process for the previous products, and would get pulled into a program only after design had begun the development stage. A perfect example of this is involves the recent bidding for Mexican wireless frequencies.

Marketing was in the midst of bidding for frequency ownership in the Mexican wireless auction. As part of that process, marketing had to develop and deliver a deployment plan to the Mexican customer for the proposed network of BTS and BSCs. This was occurring without operations knowledge or input into that plan. This reinforces what was found in the post-mortems. On two product launches, operations felt that they were incapable of meeting the first customer shipment date set by marketing and program management, but were still powerless to influence those dates once they had already established momentum at the higher levels of management.

Manufacturing’s involvement in the development effort would be initiated by their development of the MRD for the design group early on in the definition phase. Their inclusion into the early stages of the program would enable them to gain visibility of programs as they are still within their infancy, allowing manufacturing to be part of the up-front schedule development process. This would also provide an opportunity for manufacturing to provide early input to the design group, and avoid the situation where manufacturing’s ideas force the engineers to go back and revisit the high-level product description.
6.3 Supply Chain Management

Perhaps the biggest departure between Qualcomm and the “Sync and Stabilize” methodology as used by Microsoft, is the existence of a supply chain and the time necessary for trial of prototypes. In any one of the BTS or BSC products there are approximately 10,000 individual piece parts, 60 different suppliers and 15 major sub contractors that need to be brought on-line and coordinated for each of the short-term builds in the mock-up, prototype and pre-production stages, as well as the steady-state production activity.

As mentioned in the post-mortem section of this thesis, one of the biggest problems with time-to-market has been getting all of the suppliers to deliver good quality material in time for all of the respective builds. The biggest hindrance to this, has been design engineering’s lack of visibility of lead times associated with specific components and assemblies. The engineers continue to keep components or sub-assemblies “hidden” behind the closed doors of the design phase, long after the point where the materials organization should have placed those parts on order. The implemented philosophy of concurrent engineering is both an advantage and a detriment in this case. Qualcomm practices concurrent engineering between design, manufacturing and procurement. Unfortunately, as the design is never frozen, the product builds in the prototype and pre-production phases occur where the product design is still very much in flux. Consequently, the supply chain must be very responsive to continuous changes in the design.

The Engineering Planners are staffed to facilitate the proactive supply chain development for the early prototype builds, and to pull the necessary information out of the design engineers needed to begin development of the supply chain. The Engineering Planner begins driving the Indentured Drawing List (IDL)as the design begins to take form. From the IDL, they will start driving the ordering process for material or components that have been released by design. This happens very early on in the design phase and usually 85% of the material is handled within these first IDLs. The problem occurs when engineering is continuously changing the design and new parts are added, or stable ones are changed. The Planners are known to be overly proactive, in that as soon as a part or change becomes is identified, they will drive the ordering process. On occasion, the planners have moved too quickly, driving the ordering process for parts that the engineers had not finalized, resulting in the purchase of thousands of dollars of unnecessary parts. As such the design engineering group has become reluctant to give out information on parts and components that are still within the design process, and yet to be released.
The result of the dynamics of this relationship is that engineering receives input from the engineering planning, procurement, quality and manufacturing groups too late in the process. e.g. after the design engineers have already been through the conceptual iteration of a design, have made a decision, releasing the parts to Rev X. Oppositely, operations and procurement complain of not having enough early visibility of the components and subassemblies that could potentially have long lead times.

**Recommendation 3: Synchronize and Stabilize as much information as possible, pertaining to the supply chain with design engineering, by distinguishing finished from unfinished or unstable components, early on in the design process and before concrete decisions are made.**

Microsoft’s model entails that programmers continuously sync up their individual changes to the common source code of a product, enabling multiple people to have simultaneous impact on the product. Though Qualcomm’s supply chain deals with specific pieces, components, racks and sub-assemblies, the critical item to be “synced-up” is information. The design engineers need information on price, lead-time, component quality, supplier quality and capacity constraints while making the decisions within the conceptual design. Once they release the design to Rev X, much of their thought process is done, and their effort and time is moved onto the next step in the design. Receiving ancillary information too late, means that entire decisions and designs will need to be revisited, which is both painful and time-consuming. The design engineer should have all the information necessary to be able to make a decision once, and be able to immediately recognize the impact to operations, the supply chain, and the build schedule. Presently, all of this information is returned to design weeks after they have made decisions and have moved on, creating a “bug” in the process by forcing the engineers to re-evaluate previous decisions and designs.

The implementation of Microsoft’s “Sync and Stabilize” process begins with absolute openness between the design groups and the engineering planners, tempered by a few simple rules. At present the planners only have visibility of parts that have been identified to them by engineering and have been placed on the IDL. If all the parts and components that design was working on were visible, the planners could supply the engineers with all of the necessary information in a
timely manner commensurate with the needs of the design group. However, the efforts of the engineering planners must be aligned with those of the designers. The planners should not be spending a significant amount of time collecting information on parts that are in a constant state of flux. In the past, the planners have spent exorbitant amounts of time on parts that the Design engineers were not focusing on due to miscommunication and disconnects. In order to communicate the design engineer’s relative level of completeness concerning specific parts, the IDL should be segmented into distinct groups, with specific rules governing the behavior of the planners for each group. These rules are meant to align the efforts of the planners with the expectations and needs of the designers. A three-tiered, all-inclusive IDL would allow for both engineering and the planners (and hence Operations) having total visibility for those parts and components that are presently in the design phase, as well as align the level of effort spent of any given part.

**Tier 1:** This represents parts, sub-components, assemblies that engineering has completed its design, and have released to Rev X. The engineering planner is charged with driving demand for these parts through the normal channels of sourcing and purchasing.

**Tier 2:** This represents parts, sub-components and assemblies that engineering has not completed design on. These parts may or may not be present on the final design, and there may exist multiple exchangeable parts from which only one will be chosen for the final design. The engineering planner, having visibility of these parts, is charged with obtaining information from purchasing and quality and can feed back information to the design engineers on a weekly basis for pricing, lead-times and specific quality issues associated with a part or a supplier. As these are Tier 2 parts, the planner will not drive the purchasing of these items, except for engineering samples.

**Tier 3:** Similar to Tier 2, these are also parts, sub-components and assemblies that design engineering has not completed, or has not officially designed into any product. Tier 3 parts are a lower priority than Tier 2. The distinction between Tier 2 and Tier 3 is meant to help communicate the priorities of the design engineers to the engineering planners. The engineering planner, having visibility to these parts, will feed back information to the design engineers on a weekly basis for pricing, lead-times and specific quality issues associated with that part or
supplier. As these are Tier 2 parts, the Planner will not drive the purchasing of these items, except for engineering samples.

The distribution of parts in the Tier 1, Tier 2, and Tier 3 categories is at the discretion of the design engineers. The engineering planner will act as the point-person for all information pertaining to the three classification of parts, and will communicate that information to the design engineering group.

The added benefit of the tiered IDL concept is that the design engineers should no longer feel the need to “hold-back” information from the engineering planner and the procurement group, for fear of initiating overly risky purchases. Conversely, since operations will have visibility over all parts that are in the midst of their design, they will be able to sync-up all information back to the engineers early enough in the process to affect their design decisions while they are being made, avoiding a “bug” in the development process.

6.4 Functional Design and Development

Within the critical NPI Link, the connection between design engineering and manufacturing engineering is also of great significance. The NPI Manufacturing Engineer is staffed close to the design group in order to facilitate the communication and transfer of information. Though this has been met with limited success, the NPI ME represents a critical link with the design group, and all steps should be taken to facilitate their further integration.
There are actually two different NPI ME roles that have been defined within Qualcomm which are graphically depicted in Figure 10. Though the difference may seem trivial, the result is significant. The primary difference between the definition of the two groups is the role of the NPI manufacturing engineer at the extremities of the position. In Role A, the NPI ME is involved in the design process from the start, and has specific deliverables to the design engineering group very early on in the process. These include conducting tolerance stack-ups and checking the drawings of the design engineers which is done in advance of the drawings and designs rolling to Rev X.

95% of my job is done by the time the design has been rolled to Rev X.

- NPI ME acting in Role A

As the NPI MEA has specific deliverables to the design group, the tendency is for the design engineers to pull the NPI ME into the development and make sure that all of the drawings are passed to them for their approval. Since the NPI ME is pulled further up-stream into the design phase, they have greater visibility on the product earlier on and they are more capable of...
influencing the design for manufactureability. In fact, much of what the NPI ME brings to the
design organization is background and knowledge of the overall product building process. Most
of the design engineers tend to very theoretically oriented and do not have extensive practical
background in assembly and manufacturing. This weakness is supported by the more practical
and application-oriented experience of the NPI MEA. Furthermore, the active involvement of the
NPI ME's so early on in the design process, leads to greater ownership over the product as it
passes into manufacturing, and tends to eliminate the feelings on the part of the NPI ME of
having the product thrown over the wall. The drawback to the NPI MEA is that the back-end
manufacturing process development often gets dropped, and must be covered by another NPI
operations team member.

Role B of the NPI ME covers perhaps the same amount of work, but is shifted down-stream in
the process. The NPI MEB tends to do more traditional manufacturing work, including writing
Work Instructions (WI) and creating Shop Floor Control (SFC) Routes. As this NPI MEB's do
not have specific deliverables to the design engineers, they are not pulled into the design process.
As such the NPI MEB count on being extremely proactive and pushing themselves into the design
group. They spend much of their time constantly working to just get the information that they
need to accomplish their jobs. In all of the relationships between the NPI MEB and design
engineer that were studied, there were no issues of distrust from either side and generally the two
groups work well together. In fact, the design engineers believes the NPI MEB people were very
proactive and they enjoyed a good working relationship.

However, it was clear that the design engineers appreciated the NPI MEA more than Role B. The
designers believed that the engineers in those roles clearly provided a value added service to the
engineering process. It appeared that the engineers were theoretically strong and very design
oriented and the NPI MEA added a level of realism and applicability to their designs that could
not have otherwise been incorporated. When working with the NPI MEA engineers, the designers
not only looked to them to screen for manufactureability, but also provide input on a host of
other issues such as supplier quality and lead time concerns. The designers were using the NPI
MEA as their point person for all of the information they needed from the manufacturing world.

It is clear that the NPI staff was split between the two philosophies of the roles of the NPI ME.
Both sides agreed that it is the responsibility of the NPI ME to be involved with the design from
the beginning. The issue was in the execution. The Role B players, as well as the director of the group believed that it was not the responsibility of the NPI ME to be doing tolerance stack-ups and checking the drawings. However, they did agree that the design engineers pulling the NPI ME into the design phase was a desirable proposition.

**Recommendation 4:** Give the NPI Manufacturing Engineer formal sign-off on the engineering drawings as they are rolled to Rev X status.

Based on the above analysis of the established relationships between these two groups, and the results from the post-mortems, it is clear that early involvement of the NPI ME into the design process is advantageous in decreasing time-to-market of new designs. The issue at hand is the method for institutionalizing this up-front interaction between of the NPI ME with the design group. The “sign-off” mentioned in the recommendation entails that the design engineering must get approval from the NPI MEs before they roll documents and drawings to a Rev X status. This will establish a specific point of interaction between the two groups. Allowing the NPI MEs courtesy sign-off, will formalize the process by which the of the designer’s get information from manufacturing. This will also facilitate early incorporation of this information and feedback into the design during the iterative stages of development, and before the design begins to take on a level of formality.

Furthermore, hard-coding of the interaction between design engineering and manufacturing will, in part, standardize the interface between the two groups. Design management had been wanting a stable interface with operations. Every time a new NPI MEs was staffed on a specific, the duties and expectations of the design engineers would also change to compensate for the difference in philosophies between the different NPI MEs. Clearly identifying the interface between design and manufacturing will help in streamlining projects as personnel rotate in and out of the program.

This recommendation is not without drawbacks. If the NPI ME only looks at the drawings as they are about to be rolled to Rev X, it is possible that the they will become a gating item to the progress of design. The purpose of the NPI ME’s role in this is not to put design control into the hands of manufacturing. Rather the purpose is to guarantee manufacturing the opportunity to provide feedback to the engineers. If this feedback comes early enough in the iterative design
process, it will resemble the "synchronizing and stabilizing" of information as in the Microsoft model.

**Recommendation 5:** Co-locate the Design group, NPI Manufacturing Engineers, Engineering Planning and the Manufacturing Development Lab.

The original premise about the "Critical NPI Link" was that there is a small integral number of people around which the success or failure of the NPI effort is based. If this is true, then the key issue in the NPI process is to tighten the circles of communication between groups of people and their required resources. The engineering planners rely heavily on information from the design engineers to conduct their jobs. The NPI MEs also depend on information (designs, schedules, drawings, etc) that emerge from the design group in order to do their job. These three groups of people are located on three different floors, in three different parts of a 70,000 sq. ft. building. Furthermore, the mock-up and prototype systems that these groups of people are developing, exist in a completely different building 200 yards away. The lines of communication that exist between these three groups, and the feedback they receive from the evolving prototypes are delayed by distance and inconvenience. The present structure of the company means that each functional group is very tied-into other members of their organization. Referring back to Figure 6, we can see that the design engineers are aligned with their own group, facilitating transfer of knowledge and experience between the designers. Unfortunately, the NPI MEs and the engineering planners are staffed far away from their design engineer counterparts, and in a totally different building than their respective support staffs in Operations. The positioning of the NPI MEs and planners are not optimized for either communication with the designers, nor with their own staffs. Communally locating all three of these groups that are part of the NPI critical link would shorten the lines and loops of communication between them, decreasing the number of design iterations as well as the time for each iteration to be implemented.

In defense of this point, a different division the company developed the prototype units in two locations. One unit is assembled in the same building as the design engineers, and the second was assembled in a completely different building that was inconvenient to get to. The results were very clear from both the standpoint of design and manufacturing. The design engineers had much greater visibility over problems occurring in the systems developed within their building. It was extremely easy for them to see the issues that they needed to fix, and the approach they
should take. This resulted in faster cycle times in iterating the product design. In the case of the prototype developed in the other building, the results were equally as obvious. Manufacturing complained that the design engineers would never come to see the product that they were actually creating. Ultimately, the NPI MEs would have to communicate what was wrong with the evolving design, and were forced to describe what the problems looked like to the designers. The result was a much slower iterative design process with the prototype that was geographically removed from the design team. Co-locating the teams of individuals (design engineers, NPI MEs and engineering planners) associated with the development of these systems as well as the actual prototype system will facilitate visibility over the problems that occur, and decrease the time to fix them. Again, this concept of rapid “Sync and stabilization” of information related to design changes and problems is critical for decreasing the time-to-market of new product.

The disadvantage of moving the Manufacturing Development Lab (MDL) out of the manufacturing building is that operations loses visibility over the product will ultimately be placed on the manufacturing floor. The assembly line people would not get exposed to the product until it is finally transitioned on to the manufacturing floor, making up-front training very difficult.

However, one way to avoid this problem is to rotate assembly line workers into the MDL to work on the prototypes of the products that they would be building on the floor. Once the prototypes were completed, and the NPI process launched the pre-production phase in manufacturing, the workers would follow their product, transitioning into assembly line work again.

7.0 Implementation

Though the above conclusions may seem appropriate and could potentially add value to Qualcomm in decreasing the time to market of new products, the implementation of any of the recommendations is always difficult.

Much of the time over the internship was spent not merely gathering data and information for the sake of the thesis, but working with groups within the organization to drive acceptance of a more formalized NPI process. Figure 9 represents an NPI process that the manufacturing directors had committed to, and were working to implement in their respective organizations. This work was continued by driving this process down to the executional level. Each person in operations...
responsible for New Product Introductions was asked to detail their individual role, including specific responsibilities, deliverables and tasks. This information was collected from several people within each job category in order to identify differences of definitions and expectations. Meetings were held to discuss those differences within each position, and create a global definition for each role associated with the NPI process. These roles included: NPI team lead, NPI manufacturing engineer, materials program manager, engineering planner, NPI quality engineer, production manufacturing engineer and production quality engineer. Extensive effort was made to coordinate the various roles, and define the transition of information between the people at specific points in the product development. A tremendous amount of time was spent driving these common definitions with each employee, so that their roles and responsibilities would be are well known and understood. This proved to be effective because each employee was experienced in the methodology of their previous employer, and this exercise served to synch-up their respective ideas about their positions and the positions of others. Mid-way through the internship the role of “Director of New Product Introductions” was created and staffed with a seasoned individual, well respected by both the operations and design communities. This person proved instrumental in driving the discussions to flush out job descriptions as discussed above. This Director was also tasked with executing the recommendations made in this thesis.

Recommendation 1: Phase reviews
At the end of the six months of the internship, the operations organization was beginning to accept and use the general framework of the Phases system as described earlier. Individuals through-out the cross-functional teams assigned to each product launch began to establish consistent vocabulary, expectations and understanding of the NPI process. The Director of NPI furthered this by establishing post mortems after each phase as an evaluation of previous actions as well as a preemptive planning session for the next phase. Upper management also began to develop a common understanding of the NPI process across the various directors.

Recommendation 2: Manufacturing Requirements Document
As far as implementation was concerned, this was the recommendation for which the least progress was made. Continuing work should focus on getting acceptance by product management to incorporate an MRD into their Product Requirements Document, as well as getting manufacturing to develop Design For Manufactureability (DFM) guidelines for the design group.
Recommendation 3: Synchronize and stabilize information for the supply chain
Both engineering and procurement felt that this recommendation would be mutually beneficial to the development effort. The head of procurement had committed her team’s time and effort to making this recommendation a reality. Engineering’s only concern was to ensure that the time requirements for execution were not overly constricting. The pertinent groups have accepted this concept and merely need a champion to drive the execution of this recommendation.

Recommendation 4: Sign-off on design documents for NPI manufacturing engineer.
In order for this recommendation to become a reality, it must be incubated in a small subset of the design engineering community. The mechanical engineering group was response to the concerns that this recommendation addressed, and also had their own reasons for giving such control to the NPI manufacturing engineer. The Director of the mechanical engineering group was also sympathetic to this recommendation and was willing to support it in his group. Execution should originally be limited to this design engineering group and remain as low-visibility as possible so as to not incur the attention of unsupportive individuals elsewhere in the organization.

Recommendation 5: Co-location of the NPI groups
The rapid growth of the organization and the limitation on space makes this recommendation difficult to execute. One idea that is worthwhile pursuing is the access of CAD/CAM files across the functional groups. Nearly all of the electrical and mechanical design is done in an electronic medium using a multitude of software programs. A central database holds the electronic versions of the constantly iterating designs. Allowing groups like manufacturing and quality read-only access to these files would facilitate the visibility that co-location was intended to foster.

8.0 Conclusions
In the fast-paced wireless communications world, time-to-market is a critical metric for the success of products as well as the overall success of the company. Having talented and motivated employees if often not enough to create and sustain a competitive advantage against world-class competition like Lucent, Motorola and Nortel. The organizational structure and business processes must also be in place to support that strength. What was observed at
Qualcomm was that the organization was optimized for performance (as measured by fast design cycle-time) within the design organization. This was born out the organization’s roots and power structure. The post-mortem showed that such a system does not necessarily optimize for the more encompassing goal of getting products to market more quickly. Miscommunication and disconnects occur between the vertical division, and there exists mis-alignment between the groups. This is especially prominent at the intersection of the design, manufacturing and supply-chain management.

In preparation for the implementation of the recommendations made in this thesis, a base of understanding was driven into the organization over the six month internship. This understanding included a common vocabulary, expectations and knowledge of other peoples roles and responsibilities for New Product Introduction. Without this base of understanding any strategic recommendations would inevitably fail.

The recommendations presented are rooted in common sense, and represent an attempt to find simple solutions to complex organization behavior issues. Recognizing the expanse of the problems and the momentum behind them, the recommendations are meant as levers that can easily be turned, but are situated at the center of the issues so as to provide a catalyst for change.
8.0 Bibliography

1 A New American TOM, Shoji Shiba, Dave Walden, Alan Graham,
2 Microsoft Secrets, Michael Cusumano and Richard Selby, 1995 Simon and Shuster Inc.
3 Communications of the ACM, Michael Cusumano and Richard Selby, June 1997/Vol 40 No.6