Title: The NPI Process in Electronics Manufacturing

Course:
Year: 1994
Author(s): M. Greenwood, S. Kiesow, J.-L. Lim, R. Mazloomi and K. Ping

Report No: P94019

Abstract: This report recommends the structure and criteria for setting up a new product introduction (NPI) program within an electronics manufacturing company. The three design and manufacturing companies used to provide a basis for the study were Planar, Tektronix, and TriQuint. Planar and Tektronix have an NPI program in place, while the program at TriQuint is still being developed. This project was selected because of the potential to assist with the development of the NPI program at TriQuint, as well as the fact that each of the team members is familiar with the NPI program at their respective companies.

The NPI Process in Electronics Manufacturing

M. Greenwood, S. Kiesow, J.L. Lim,
R. Mazloomi, K. Ping

P9419

EXECUTIVE SUMMARY

There are numerous ways to introduce a new product into manufacturing, and some aspects are better than others. This report recommends the structure and criteria for setting up a New Product Introduction (NPI) program within an electronics manufacturing company. The three design and manufacturing companies used to provide a basis for the study were Planar, Tektronix, and TriQuint. Planar and Tektronix have an NPI program in place, while the program at TriQuint is still being developed. This project was selected because of the potential to assist with the development of the NPI program at TriQuint, as well as the fact that each of the team members is familiar with the NPI program at their respective companies.

The process of developing this report included interviews with key people within the NPI process at each of the companies (marketing, project manager, production line manager, manufacturing engineer, design engineer, finance representative) using a standard questionnaire (Appendix A, pg. 7), obtaining copies of the documented NPI processes (Appendix B and C), and attempting a literature search on other companies' NPI programs. Because of the proprietary nature, the literature search provided general information which was used to support the conclusions developed, rather than company specific information. The questionnaires that were completed from each company were analyzed to determine similarities and differences among the NPI programs. The success of the project, as referred to by the questionnaire, is based on the interviewees oppinion of what a successful project is. The differences were then looked at to determine if the difference was due to a company characteristic or an inherent difference in the NPI process. What was found was that most differences could be attributed to the company characteristics (size, age, type of product, etc.). Despite these differences, the NPI programs were very similar.

Each company's NPI program followed a basic framework of four distinct phases (see Appendix A, pg. 6). Within each there are recommended actions and criteria:

1. **Feasibility** – statement of problem, criteria for project selection, project manager and project team leaders assigned, alternatives proposed, project selected, project proposal developed. *Milestone - Product Proposal Approval.*

2. **Development Planning** – develop work schedules and budgets, identify required resources, develop project plan. *Milestone - Product Plan Approval.*
3. **Design** – product plan is executed, product proposal converted to actual product, prototyping begins (for inexpensive or individual build products). *Milestone - Design Release Approval.*
4. **Manufacturing Process Characterization** – characterization of process, determination of process times, ramp–up materials, first prototypes are built (for expensive or batch build products). *Milestone - Customer Product Release.*

The process for creating the above NPI structured program is rather straightforward. However, the efforts involved should not be underestimated. The recommended steps follow:

1. Standardize on and document an existing process. Don't try to create the perfect process. Some of the best lessons are learned through trial and error.
2. Define the phases and where the milestones should occur. The best place for a milestone is the point just before resources are needed or funds are to be expended.
3. Develop the milestone criteria. Examples of milestone checklists and questionnaires are in Appendix B and C.
4. Document responsibility and authority. Who is responsible for what activities, and what authority do they have? Do not overlook documenting who has the authority to approve the continuation of the project through approval of the milestones.
5. Get management support and buy–in on the documented NPI program. Upper management approval will greatly affect the level of acceptance or resistance from others.
6. Pilot the process. This will allow feedback and ease of change before the entire process is rolled out to the organization.
7. Roll out training to the entire organization. Although only a handful of people will actually be controlling the NPI process, everyone must be involved and aware of its focus.

During this time of developing the NPI program keep several things in mind: customer satisfaction is the ultimate goal, early involvement of team members is critical to a successful program, users of the system (or customers of the product) should participate in the development, and to be successful, the NPI process must be structured yet open to change.

TABLE OF CONTENTS

INTRODUCTION

The New Product Introduction (NPI) process varies from project to project in many companies. With each new project, the project managers finds themselves reinventing the wheel, trying to determine who should be involved, what documentation is needed and when, who will provide what, and what authority, if any, does anyone have!?! This report addresses these issues for electronics manufacturing companies and provides a recommendation on how to develop an NPI program suited to the particular circumstances of the business, such as size, age, type of product produced, etc.

The scope of the NPI program studied in this report covers product concept through transition to full-scale manufacturing. The report focuses more on the structure of the NPI program and less on the actual management, project selection, or project tracking techniques. What will be developed is the framework for a successful NPI program, including phase definition, milestone characteristics and examples of real world NPI programs. The three companies used as a baseline for this report were Planar, Tektronix, and TriQuint. A summary for each has been included in the Appendices.

This project was originated in an attempt to assist one of the team members in developing the NPI program at the company they are working for. Since all of the team members are familiar with the NPI program, and two of the companies included in the study have documented NPI programs, the topic was well suited to the group. The recommendations in this report were developed from interviews with various positions within each company (project manager, production line manager, manufacturing engineer, design engineer, finance representative, marketing), documented NPI programs supplied by the companies' quality systems, and a literature search of the NPI programs in other electronics companies. The data and questionnaires from each company were compiled and compared with those of the other companies studied. The results show that despite the differences between the companies, the NPI programs are very similar. Since most NPI programs are proprietary, very little information was provided through the literature search. However, general information on NPI programs was found and used to support the results.

RESULTS

Upon first glance at each company's NPI program they appeared to have little similarity. The phases in each of the programs were labeled differently, the milestones took on different forms, the business characteristics themselves varied greatly (Appendix A, pg. 8). Looking past the detail, however, the basic structure and functional roles within the NPI programs are very similar. Each of the companies had a different number of phases and milestones, and different labels for each. What was found was that despite the differences, four phases and milestones could be applied to each company. A phase can be divided into two or more sections, each with its own milestones, but overall only four phases are needed to describe any of the NPI programs looked at. We are suggesting any NPI program may also fit into these four phases.

Because none of the NPI programs clearly labeled the phases or milestones an NPI project goes through, we redefined them trying to capture the essence of the activities to be completed within them. The resulting phases are Feasibility, Development Planning, Design, and Manufacturing Process Characterization. Each phase is punctuated by the milestones of Product Proposal Approval, Product Plan Approval, Design Release Approval, and Customer Product Release respectively (see Appendix A, pg. 6). Each milestone must be approved (or a plan in place to meet approval) before the project continues on to the next phase.

Within each phase there are activities, deliverables, and resources assigned.

1. The Feasibility phase is where the project begins. Whether a customer approaches the company or marketing defines a market, assessment of a product opportunity is initiated. Data should be collected to define the customer base, customer needs need to be defined, and proposals for filling the need should be created. It is important in this phase that who the customer is and what their needs are be well researched. A product can be successfully designed around a definition, but if the need for the product was misconceived, there may be no customer to buy it. There also need to be criteria around project selection. The feasibility of each proposal should be analyzed and one of the proposals selected. There are numerous project selection techniques that may be used, several of which are described in the textbook "Managing Business and Engineering Projects" by John M. Nicholas (1). It is also important during this phase that the program manager be identified and involved in the customer definition and product proposal. Functional

team leaders should also be involved in this process (depending on the size of the company and available resources). The earlier the team is introduced to the project the better. The milestone for the feasibility phase is the Product Proposal Approval. This is the gating factor before initiating Development Planning, the next phase.

2. During the Development Planning phase, planning for the rest of the project is identified. Along with determining the customer base and product characteristics, this phase is the most important phase of the project. Decisions made at this stage have the greatest impact (≈70%) on the overall life cycle costs (2). Work schedules and budgets should be developed. If applicable, the Work Breakdown Structure (WBS) is set-up and work packages are supplied by the functional team leaders. Proper planning in this stage allows the program manager to focus on system objectives. If the environment changes, timely action can be taken to modify or terminate the project. The outcome of the development planning phase is the next milestone, Product Plan Approval. This milestone is important because approval allows the allocation of funds and resources to work on the project, which begin in the Design phase.
3. During the Design stage, specifications are converted into actual systems (engineering prototypes that closely resemble how the customer system will look and perform). This is also the phase where process steps differ depending on the business circumstances. In a company where the product can be built individually (Planar or Tektronix) or the production cost is minimal, prototyping should begin here. For companies where production is costly or can only be done in batches (TriQuint), prototyping may be delayed until the next phase, Manufacturing Process Characterization. The milestone to move from Design into the next phase is Design Release Approval. This releases the system to manufacturing, though the product is not yet salable. At this point the product should be meeting customer specifications, and there should be confidence in the consistency of performance, manufacturability, and reliability.
4. In the Manufacturing Process Characterization phase, products are built to meet customer requirements. This stage is also used to monitor the ability of the manufacturing process to deliver customer systems consistently over time and allow the manufacturing process to run as if in Full-Scale Manufacturing. The termination of the Manufacturing Process Characterization phase is the Customer Product Release milestone. At this point the product must meet all customer specifications, be acceptably repeatable by manufacturing, and have completed all requirements set out by the milestones in the process. Full scale manufacturing begins and it is here that the NPI process begins to wind down.

RECOMMENDATIONS

The process for creating the above NPI structured program is rather straightforward. However, the efforts involved should not be underestimated. The recommended approach to setting up an NPI program is:

1. Standardize on and document an existing process. Don't try to create the perfect process with the first attempt. Some of the best lessons are learned through trial and error. Also, trying to create the perfect system within a given time constraint results in some areas being more than adequate and others sorely lacking.

2. Define the phases and where the milestones should occur. There should be specific criteria and activities associated with each phase of the NPI project. These criteria and activities should then be translated into deliverables for the milestone checklist. The best place for a milestone is the point where the type of activities are changing, or just before resources are needed or funds are to be expended. We are recommending the previously described NPI program structure.

3. Develop the milestone criteria. Document the deliverables that must be met before the company is willing to expend more resources into the project. There should be some objective evidence that the project is worth pursuing. Examples of milestone checklists and questionnaires are in Appendix B and C.

4. Document who is responsible for what activities within the phases, and what authority they have. This is a very important part of the NPI process. Things flow much more smoothly when all of the departments involved understand their role and what they are expected to contribute. Do not overlook documenting who has the authority to approve the continuation of the project through approval of the milestones.

5. Get management support and buy–in on the documented NPI program. Upper management approval will greatly affect the level of acceptance or resistance from others. It is also important they recognize their role in guiding the NPI programs, and selecting ones that best fit the company strategy.

6. Select a project to pilot the process on. Although this could be considered an optional step, it is highly recommended. This will allow feedback and ease of change before the entire process is rolled out to the organization.

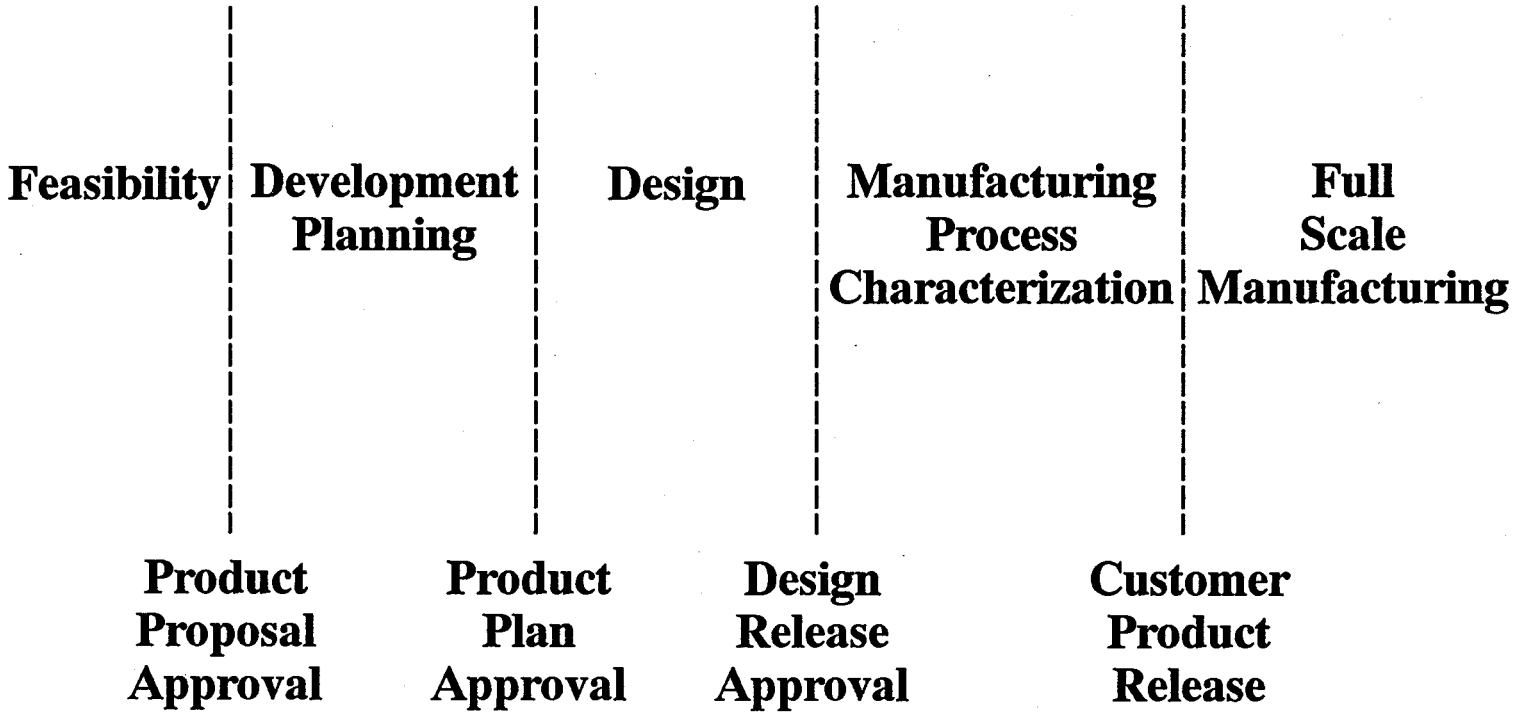
7. Roll out training to the entire organization. Even though only a handful of people will actually be controlling the NPI process, the success (or lack thereof) affects everyone. Everyone must see the importance of NPI and must be involved and aware of its focus.

CONCLUSION

In this report we have covered the four recommended phases of an NPI program and the associated milestones. We have also supplied a seven step process to follow when creating an NPI program. While designing the NPI program, though, a few things should be kept in mind. All successful NPI programs have customer satisfaction as the ultimate goal. Customers have cost/time/performance targets they have to meet and NPI programs that do not cater to these needs are doomed for failure. Customer requirements change and the NPI process needs to be sensitive to this moving target. Early involvement of team members is also critical to a successful program. Every team member's input is required to estimate, set schedules and budgets, help solve problems, and make decisions. Any crucial input that is late due to delayed involvement will jeopardize the project schedule. Also as important is user participation. Nonchalant participation is akin to not being there at all. Worse than that, it hurts the schedule due to lack of feedback. One of the more difficult to achieve characteristics of a successful program is an NPI process that is structured yet open to change. In this system, everything that is performed is very well documented and precise. Yet, if there are any improvements that should be done, a system should exist for changing the process.

Appendix A

PHASES OF NPI



INTERVIEW QUESTIONNAIRE

1. Do you have documentation on the NPI process in place at your company? Y N
   (if so get a copy)
2. Please rate the NPI process in your company: 1 2 3 4 5
3. What do you see as the phases of the NPI process? (i.e. concept, design, implementation, etc.)
4. What metrics are used to move the project into the next stage? (i.e. plan in place, certain goals are met, etc.)
5. What are the roles and responsibilities of the project manager during each of these phases?
6. How is the progress of the NPI process documented?
   Is this good or bad?
   (if there is no standard, what do they think would work best?)
7. What organizations are involved in the NPI process and when? (i.e. marketing at beginning and end, mfg at end, etc.)
8. How is the NPI process structured? (i.e. rotating mgmt, dedicated work force, etc.)
9. At what point in the NPI process does mfg. get involved?
10. Please list the positive aspects of your process? What works?
11. Please list the negative aspects of your process? What does not work?
12. In your opinion and from past experience, what makes an NPI process successful?
13. In your opinion and from past experience, what makes an NPI process unsuccessful?

COMPANY CHARACTERISTICS

Characteristics	PLANAR	TEKTRONIX	TRIQUINT
NPI Trigger	Customer Initiated	Marketing Initiated	Both
Size of Company	≈ 190 employees	≈ 9200 employees	≈ 160 employees
Type of Products	Flat Panel Displays	Oscilloscopes	Integrated Circuits
State of NPI System	Documented	ISO Certified	Documenting
Maturity	≈ 11 years	≈ 48 years	≈ 7 years

Appendix B

PLANAR

Background

Planar is an 11 year old company with 175 employees at the company's headquarters in Beaverton, Oregon (375 employees world wide). The company specializes in the sale and manufacture of electroluminescent displays, a light emissive flat panel display. As such, the company can primarily be considered a component manufacturer (versus Tektonix which is an OEM system manufacturer). Recently, Planar has moved into systems manufacturing by supplying complete and independent systems (primary for the medical market as a nurse bedside assistant or patient monitoring system). This type of system still only constitutes a small portion of the overall company's sales.

Planar is a spin–off of Tektronix, and as a new company, management quickly recognized that to grow from the original start–up phase to a mature phase, it needed to standardize on processes which provide control and structure in all phases of the company. One of the areas identified in need of a common practice and streamlining, as mandated by a top down decision by the Chief Operating Officer (COO), was the NPI process.

Prior to the adoption of the standardized NPI process, each new product introduced required re–engineering the NPI process. The project managers tried to determine (usually without input) what functional groups ought to be involved or bought in. The lack of structure resulted in numerous oversights, overpriced displays, a lack or an excessive number of custom display features, inadequate marketing research, and several products were launched unsuccessfully. Fortunately, a lack of manufacturing involvement never was problem at Planar. The company was founded on its manufacturing strength.

NPI Process

The guidelines and specifications for the Planar NPI program evolved from a structure used at Texas Instruments (where the Planar COO had been a division president). They were developed personally by the COO, and therefore carried the appropriate weight. The structure of the program is fairly standard and consists of five phases and milestones to be met prior to full manufacturing. Buy

in from the various groups was easily achieved since everybody on the committee reported to the COO. Also a general agreement existed among these various groups as to the need for such a document. The responsible functional groups developed the questionnaires which must be satisfactorily addressed prior to moving to the next phase. The company strictly adheres to its guidelines. Changes in the process require the approval of the COO. A typical project can be fast tracked in eight months from concept definition to manufacturing.

Although in theory anyone could start an NPI project, Planar's NPI is usually driven by a demand from a customer. The customer, usually with a specific requirement in mind (size, resolution, format, etc.), requests a quote from the Sales group. Armed with preliminary numbers, Sales approaches Marketing and Design to establish a discussion. If everything is agreeable, the NPI process begins.

During the Product Concept Definition phase, Sales/Marketing, Design Engineering, and Finance gather to do a preliminary design checkoff and may return a quote to the customer. The second phase, usually accompanied by an approval from the customer, is called the Product Definition phase and involves Manufacturing and Quality Assurance (in addition to the original members). The committee usually addresses manufacturing costs and finalizes the specification. The third phase, usually followed by a customer non-recurring engineering (NRE) fund (i.e. the customer starts to pay for the design cost and special tooling), allows for the completion of the system's design through breadboard analysis. Materials management (purchasing) gets involved at this phase to plan for the long lead items and establishes the required vendors. A Critical Design Review punctuated by building a workable prototype is next. The customer must approve the design and at this stage has a workable system available for testing. The last phase usually involves building several hundred units for reliability testing, manufacturing process characterization, and building up marketing demo units prior to full fledge manufacturing.

Project Management System

The NPI process' main benefit is in providing the common structure (attention to detail, formal communication channels, milestones, etc.) to the product introduction. The project manager as well as all the supporting cast do not have to reinvent the wheel for each new product. The other benefit is in raising the visibility of the project company wide, across all functional groups, and facilitate the matrix organization required by the project manager to initiate the project. This process also requires that Sales and Marketing clearly understand the market direction and size (projected number of units to be sold) as well as the customer specific requirements/market and future plan. In turn, the usual NPI process also requires the customer to show serious intention and commit some resources (NRE and contract) in order to accelerate the process. Several projects have been delayed or canceled due to lack of focus from either the customer or Sales. In doing so, the process conserves the scarce engineering resources necessary for more urgent or more financially rewarding projects. The NPI process also takes away the personality ego and holy cow type of project (usually hyped up by the Marketing or Engineering) and places a stringent financial hurdle for projects to overcome. The company commitment to the process is also laudable and ensures its success.

Despite all the rigorous check points, some project managers still feel that some projects are allowed to bypass some of the milestones and hurdles, at the whim of upper management. In others cases, management may only pay a perfunctory glance at the contents of the NPI project, and pay more attention to the process itself (who's making the presentation, the forms, the format, etc.).

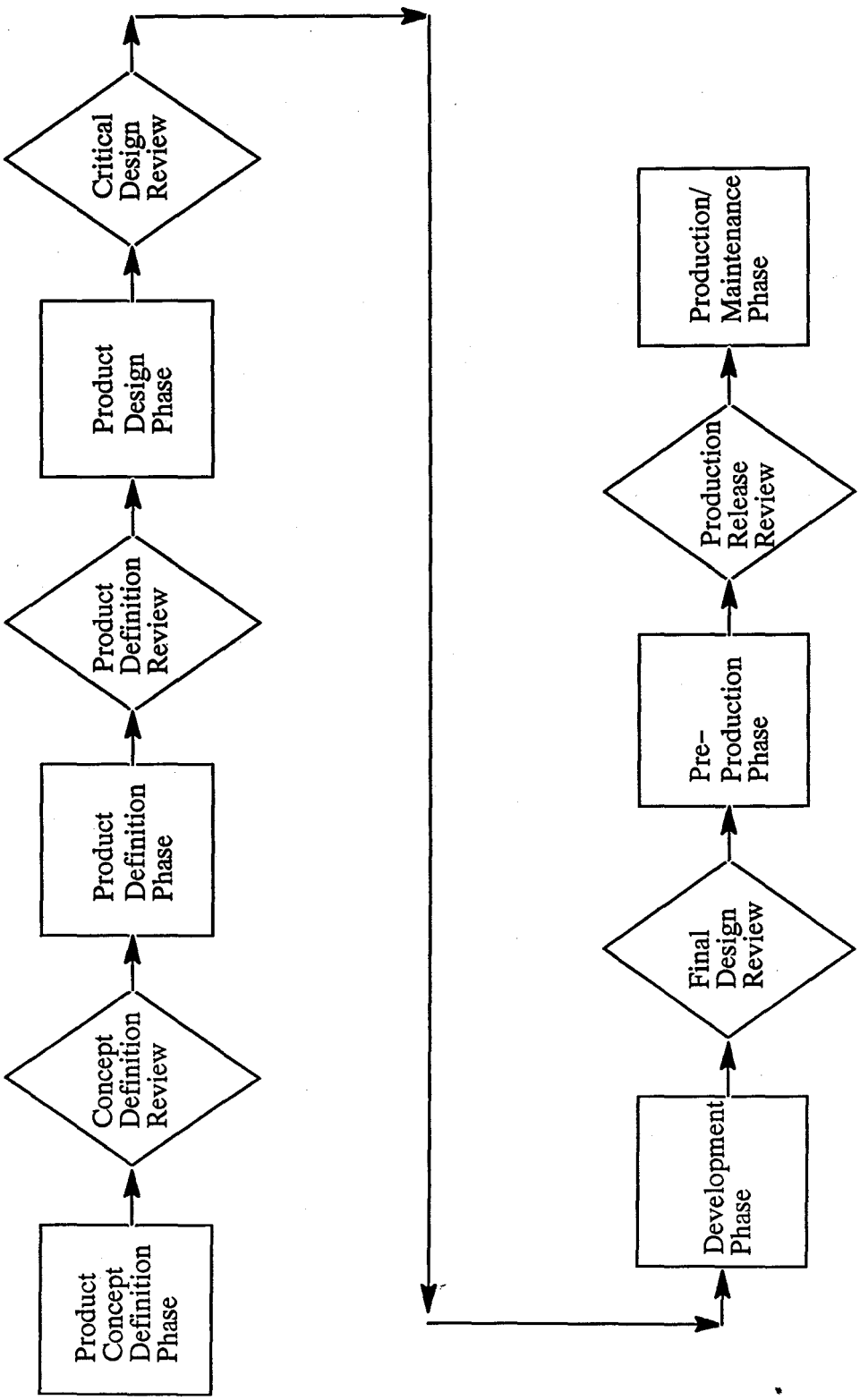
Another complaint is the process takes too long and takes away the company's ability to fast track projects, and quickly respond to the customer. Many projects also tend to be borderline. They do not become fast track, nor does they completely fail. In such cases, the project lingers on to a slow death or until someone rescues it. Fine-tuning the process may be required. This is difficult due to the rigid structure of the system. Because each project has to pass strict financial hurdles, the company may miss several opportunities by not addressing markets where the customers are already lined up. The present structure makes it difficult for the company to design a generic display, despite the known enormous potential in the market.

Conclusions

More than anything, success in an NPI project requires strong commitment from upper management. The company must view the entire process as a way of doing business. Without such a commitment, the process can degenerate into just more paperwork, and become viewed as an obstacle for the project manager to overcome, rather than an aid. Due to the complex and time consuming process, the project manager must also be allowed adequate time and resources to complete the process.

Failures of the NPI are few in Planar's case. The failures have been derived mainly from trying to shortcut the NPI process. The project may be perceived as a holy cow, or may receive major backing from upper management. Lack of interest or attention by one of the supporting team members can drag the process on longer than required and undermine the process. The company must address guidelines to deal with NPI projects which are stuck in limbo.

PLANAR NEW PRODUCT FLOW CHART



CONCEPT DEFINITION REVIEW CHECKLIST

WHO	WHAT	DESCRIPTION / COMMENTS
Marketing	Market Target	Who will be the customer(s)? Market segments? Expected life of the product? Will it cut into demand of any current product? How much? When?
Marketing	Unit Volume Forecast	Based on typical ramp–up or customer defined need.
Marketing	Functional Definition	Feature list weighted per QFD (or equivalent) approach based on survey results.
Marketing	Competitive Analysis	What is expected competition and what is required for success? Similar products and their cost? Expected new developments by competition?
Marketing	Price Range Target	Based on projected or expected competition at introduction and production.
Engineering	Design Issues	Based on prior design and developing enabling technologies.
Engineering	Design Project Size	$\pm$20% estimate of design cost based on similar projects.
Engineering	Engineering Resources	Appoint a project manager. Identify engineering resources required for next phase.
Finance	Financial What If's	Based on various volumes, design cost, product GPMs, etc. – define the requirements for success: minimum volumes, GPM, etc.

PRODUCT DEFINITION PHASE CHECKLIST

WHO	WHAT	DESCRIPTION / COMMENTS
Marketing	Unit Forecast	Update ramp–up and run rate if new information is available.
Marketing	Seed Units	Specify number of Marketing seed units required (Prototypes built in Engineering).
Marketing	Functional Spec	List of all target specs and / or QFD charts or equivalent. Clearly define customer desired options to be evaluated.
Engineering	Functional Design	Functional block diagrams, mechanical sketches, interface timing, etc.
Engineering	Design Issues	Written discussion (outline) of all design issues. Data showing breadboard results or analysis of critical circuits or parameters.
Engineering	Subassemblies	Identify potential purchased subassemblies such as power supplies, interface boards and identify design issues.
Engineering	Risk Issues	Identify spec or designs that represent high risk to the program.
Engineering	New Parts Issues	Identify any new uncommon parts or potential critical vendor issues.
Engineering	Preliminary Budget	Hard engineering budget for the next phase – preliminary schedule and estimate for total project (±20%).
Engineering	Project Resources and Preliminary Schedule	Identify engineering resources to assign to next phase. Identify all other team members. Define preliminary schedule. Use Microsoft Project program software.
Engineering	Preliminary Product Design–to–Cost (DTC)	Cost estimate using applicable portion of the standard format based on similar products and projects.
Manufacturing	Preliminary Product (DTC)	Same as above
Manufacturing	Glass Design	Preliminary layout to prove feasibility.

Mtls. Management	Vendor Issues	Identify possible long lead or other vendor problems for new uncommon parts and purchased subassemblies. Identify potential vendors for each.
Manufacturing	Build Issues	Identify preferred assembly and interconnect approaches based on past experience. identify potential problems in any new design approaches. Identify any tooling, testing, etc. problems associated with any new approaches.
Manufacturing	Testing Concepts	Written statement as to the general approach to temperature cycling and testing.
Manufacturing	Tooling Concepts	Define tooling required and make preliminary estimate. Begin checklist.
Quality Assurance	Reliability Issues	Identify reliability and serviceability problems experienced in similar products. Recommend changes to correct past problems.
Quality Assurance	Agency Issues	Outline critical issues in meeting agency requirement and / or decision that agency approvals not required.
Quality Assurance	Testing Concepts	Written statement as to general approach to reliability testing.
Finance	Financial Analysis	Based on Design–to–Cost–Target and engineering development cost, determine ASP and quantity required for success. Calculate ROI based on marketing and engineering forecasts. Assign project number if decision is to proceed. (Negotiate contract if customer funded)

CRITICAL DESIGN REVIEW CHECKLIST

WHO	WHAT	DESCRIPTION / COMMENTS
Marketing	Unit Forecast	Update ramp–up and run rate.
Marketing	Preliminary Product Launch Plan	No. of demos required (level of testing required) beta sites, list of marketing material to be generated, schedule. Update seed units required.
Marketing	Product Spec	Complete spec signed off by engineering and marketing – last opportunity for change.
Engineering	Eng. Design Confirmation	Breadboard data and analysis to prove that design specs can be met – possibly include PWB layout and assembly – reliability estimate – outline dimension and mounting drawings – Timing diagrams and worse case analysis.
Engineering	Schematic	Full schematic which represents current design.
Engineering	Bill of Material (BOM)	Detailed adequately to get hard quote on high cost or first time used parts. Create Parts Master(s).
Engineering	Reliability Risks	Identify any parts used that has a history of prior reliability and assert that no options are available.
Engineering	DVT detailed Plan	What will be tested and the data sheets which will be filled out during the test.
Engineering	Documentation Plan	List of documents that must be generated.
Engineering	Project Budget	Firm project budget and schedule for the remainder of the project.
Engineering	Design–to–Cost (DTC)	Final update. Cost estimates on standard format backed with hard quotes or current purchase prices for currently used devices. This is the final check that Design–to–Cost Target will be met and assures all areas of manufacturing and engineering are in agreement.
Manufacturing	Design–to–Cost (DTC)	Same as above.

Manufacturing	Documentation Plan	General list of documents that must be generated.
Mtls. Management	Vendor Plan	New and critical vendors selected and contacted. Critical specs discussed. Cost and lead time established. Vendor tooling requirements and cost established.
Manufacturing	Manufacturability	Analyze mechanical assembly and testing for manufacturability.
Manufacturing	Testing Plan	List test equipment, hot mockups, etc. required for manufacturing testing. Generate budget ($, MM, Schedule).
Manufacturing	Tooling Plan	List of type and quantity of tooling required. Generate budget ($, MM, Schedule).
Manufacturing	Glass Tooling	Thin Film Coater tooling required to build Glass for breadboards (Prototypes) designed.
Quality Assurance	Reliability Test Approach	Statement of number units, hours of test, manpower, budget estimate, schedule.
Mtls. Management	Preproduction MRP	Load preproduction quantities into MRP.
Finance	Payback Analysis	Update financial analysis using new estimates.

FINAL DESIGN REVIEW CHECKLIST

WHO	WHAT	DESCRIPTION / COMMENTS
Marketing	Unit Forecast	Update ramp up and run rate.
Marketing	Final Launch Plan	No. of demos, pricing, PR timing.
Marketing	Documentation: Handbook PR Release	 Complete draft – Outline of contents
Marketing	Customer Service Plan	Statement of level of repair anticipated. List of critical issues or requirements which must be planned. Estimates of cost and time to repair. (Service technicians trained in prototypes are going to be sent to the field).
Engineering	Prototypes	Must be representative of final design, i.e., limited number of modifications.
Engineering	Seed Units	Hand build seed units for Marketing (Prototypes quality).
Engineering	DVT Results	Test results proving specifications are met. Step stress testing to find weak parts.
Engineering	Parts Qualification	All new parts qualified and parts masters updated.
Engineering	Final BOM / Bid Pkgs.	Final bid packages for PWB, assembly and mechanical parts.
Engineering	Design–to–Cost (DTC)	Update
Engineering	Cost Reduction	Identify potential areas to reduce cost in a future project.
Manufacturing	Documentation Plan	Detailed list of documents required.
Mtls. Management	Vendor Agreements	Negotiate annual purchase agreements with key vendors.
Mtls. Management	Vendor Qualifications	In factory qualification of key vendors.
Mtls. Management	MRP	Load MRP. Commit to early production parts.
Manufacturing	Testing	Special test equipment designed (Hot mock-ups, etc.).

Appendix B

Manufacturing	Tooling	Tool design complete and ready for fabrication (Burn in, cycle rack, etc.).
Quality Assurance	Parts and Vendor Qual	Participate with Engineering and Materials management in qualifications.
Quality Assurance	Agency Approval	Schedule and budget to get approvals.
Quality Assurance	Reliability Test Plan	Completed plan that tells how many units, how long tested, and test to be run.
Quality Assurance	Failure Analysis	Failure analysis database created.
Finance	Payback Analysis	Update all analysis with latest numbers.

PRODUCTION RELEASE REVIEW

WHO	WHAT	DESCRIPTION / COMMENTS
Marketing	Unit Forecast	Update with hard customer information.
Marketing	Final Launch Plan	PR, Ad, Demo schedules, etc.
Marketing	Handbook & Flier	Final Document
Marketing	PR & Ad	Written Press Release, Ad concept
Marketing	Price List	Final version ready to mail
Marketing	Customer Service	List of parts and test equipment required by customer service.
Engineering	Design-to-Cost (DTC)	Verify the DTC was met.
Engineering	Documentation Package	Documentation complete.
Manufacturing	Design-to-Cost (DTC)	Verify the DTC was met.
Manufacturing	Documentation Package	Documentation complete.
Manufacturing	Testing	Test procedures and test equipment proven by testing preproduction models successfully.
Manufacturing	Tooling	All tooling in place and first Articles accepted.
Manufacturing	Training	All operators trained.
Mtls. Management	MRP	Load MRP. Production parts ordered.
Mtls. Management	Vendor Tooling	First articles built on vendor tooling and accepted.
Quality Assurance	Agency Approval	Agency Approvals Obtained
Quality Assurance	Reliability Testing	Reliability testing started using the preproduction units and initial results show no problems. Plans in place for Ongoing-Reliability-Testing (ORT).
Finance	Financial Performance Analysis	Review Design-to-Cost actuals and all project costs vs. original budgets.
Team	Cost Reduction, Value Engineering	Identify potential cost savings through a value engineering effort. Establish the cost reduction team and schedule with estimate of $ saved and schedule.

Appendix B

Appendix C

TEKTRONIX

Background

Tektronix is the largest of the three companies surveyed with approximately 9200 employees. It is also, at forty-eight years, the oldest of the companies studied. The company manufactures a wide variety of products, from test equipment to displays to color printers. For this report, the Test and Measurement division was looked at with particular emphasis on the NPI processes of oscilloscope development.

Tektronix was founded on oscilloscope production and the "scope" business is still the bread and butter product for the company. Prior to ISO certification, the NPI process was dependent upon the experience of the particular project manager running the project. Although this suffered from a lack of structure, these disparate NPI processes worked sufficiently well to introduce a stream of quite successful oscilloscope lines. However, each product development cycle was an exercise in reinventing the NPI process. Part of the success can be attributed to program managers that have done NPIs over and over again and have ideas in their heads or on pieces of paper about what to do and what not to do. However, new project managers or other project managers do not have these guidelines available.

ISO documentation has provided Tektronix with an invaluable baseline to standardize the NPI process. Even though modifications continue to be made, these changes are documented, approved incremental steps that improve the existing process, not attempts to re-invent a brand new NPI process with each new product.

NPI Process

Tekronix's NPI process consists of four phases and five milestones. Upon completion of any phase, milestone review is conducted. The primary focus of the process is to enhance customer satisfaction by quality product planning. The four phases are:

1. Feasibility
2. Project Planning
3. Design
4. Ramp-up

The Criteria For Phase Completion respectively are:

1. Product Proposal
2. Implementation Plan
3. Engineering Release
4. Product Shipment Release

Phases

1. Feasibility: The focus of the Feasibility phase is to identify the market/customer requirements; assess market, technical, functional and process risks; evaluate its financial expectations against other opportunities; describe a product that directly addresses the market/customer requirements; develop detailed risk reduction plans; develop detailed risk reduction plans; establish a product core team; develop a product proposal document for review, approval and later reference.

The makeup of product core teams can vary depending on project content, but the NPI team is consisted of program manager and functional leaders. The functional leaders are expected to manage work package commitments made between functional areas and the project.

During the feasibility phase, functional area managers are expected to provide detailed plans and resource commitments for project planning phase activities and preliminary plans but not resource commitments for design and ramp-up phase activities.

2. Project Planning: Upon the completion of the feasibility phase, Project Planning will start. The following goals are to be established during this phase:

a. Implement the risk reduction plans;
b. Complete detailed product definition consistent with that of the approved Product Proposal (EIS & UIS complete enough to put under change control);
c. Develop detailed resource and schedule plans for engineering and manufacturing process development;
d. Complete preliminary plans for production, sales, service, customer support setup and the marketing launch;
e. Define completion criteria for deliverables from each functional area;
f. Firm up the financial analysis;
g. Solicit resource commitments from all functional areas to complete the project through PSR.

3. Design Phase: The goals of the Design Phase are to:

a. Complete the product design;
b. Complete engineering verification of product maturity;
c. Complete new process design;
d. Complete production, service and support ramp–up plans;
e. Reassess market viability (with particular emphasis on any deviations in product content from original detailed product definition).

Note: In the event product content or market conditions change in a significant way, it is the responsibility of the program manager to recall the Implementation Plan milestone review for reassessment of product viability.

4. Ramp–Up: During this phase, process capabilities and quality goals such as process yield and reliability are investigated. Sales and service setup and user documentation are completed. After marketing plan approval is reviewed, it will be implemented.

Milestones

There are five milestones associated with the process:

1. Product Proposal Approval (PPA)
2. Implementation Plan Approval (IPA)
3. Engineering Release Approval (ER)
4. Marketing Plan Approval (MPA)
5. Product Shipment Release (PSR)

PPA, IPA, ERA and PSR trigger phase changes and are reviewed and approved. MPA does not trigger phase change. The marketing action plan is developed by marketing and reviewed by the General Manager and approved by the Product Line manager.

Milestone Review Process Steps

1. The required documentation for Phase Change Process are listed on page 29.
2. The Program Manager will collect and distribute the required milestone documentation to the list of reviewers at least one week prior to program core team review meeting. (See page 34 for list of recommended reviewers.)
3. The Program Manager will schedule and announce the milestone review meeting.
4. The Program Manager will collect all issues and recommendations, from reviewers prior to the core team review meeting.
5. The Program Manager will convene a program core team meeting dedicated to the development of responses to reviewers' comments.
6. The milestone review meeting will be held to discuss the product core team's responses to reviewers issues and recommendations. The meeting attenders should include the product core team and interested reviewers.
7. The program manager will present a summary of the reviewers comments and the product core team's responses at the milestone review meeting.
8. The Approver will chair the milestone review meeting.
9. The Approver will document and send the results of the review meeting to the product core team and the list of reviewers.
10. The Program Manager must ensure that the review package, his/her presentation material, and approvers memo documenting the results of the review are filed in the Master Program Files.

Project Management System

Due to the size of Tek, nature of the projects, and the involvement of many different organizations in the NPI process, the need to define and establish a project management system was inevitable. As is illustrated below, the roles and responsibilities of the organizations and individuals are defined in great detail. The overall project management is broken into the responsibility and authority of the program manager, functional managers and functional leaders. In addition, to provide a specific authority matrix, a list of all the reviewers for all the milestones has been created (page 34). As it is stated, different managers have the authority to approve, or make recommendations at the specific milestone.

The program manager is responsible for:

1. Identification of program core team needs
2. Negotiation of core team resources
3. Assigns core team members their overall program and functional responsibilities
4. Cross functional planning
5. Overall control of the program

The program manager will approve of all milestone check–list affirmative answers and action plans for milestone check–list negative answers.

Functional Managers are responsible for:

- Selection of functional leaders and Work package commitments made between their direct functional areas during the planning phase.
- Approval of all internal functional milestones.

Functional leaders are responsible for:

- Work package commitments made between their direct functional area(s) and the program during the implementation phase and All answers to milestone checklist questions and their associated action plans.

Details of responsibility matrix is illustrated on page 34.

Product proposal and implementation plans are listed on pages 30 and 31 respectively.

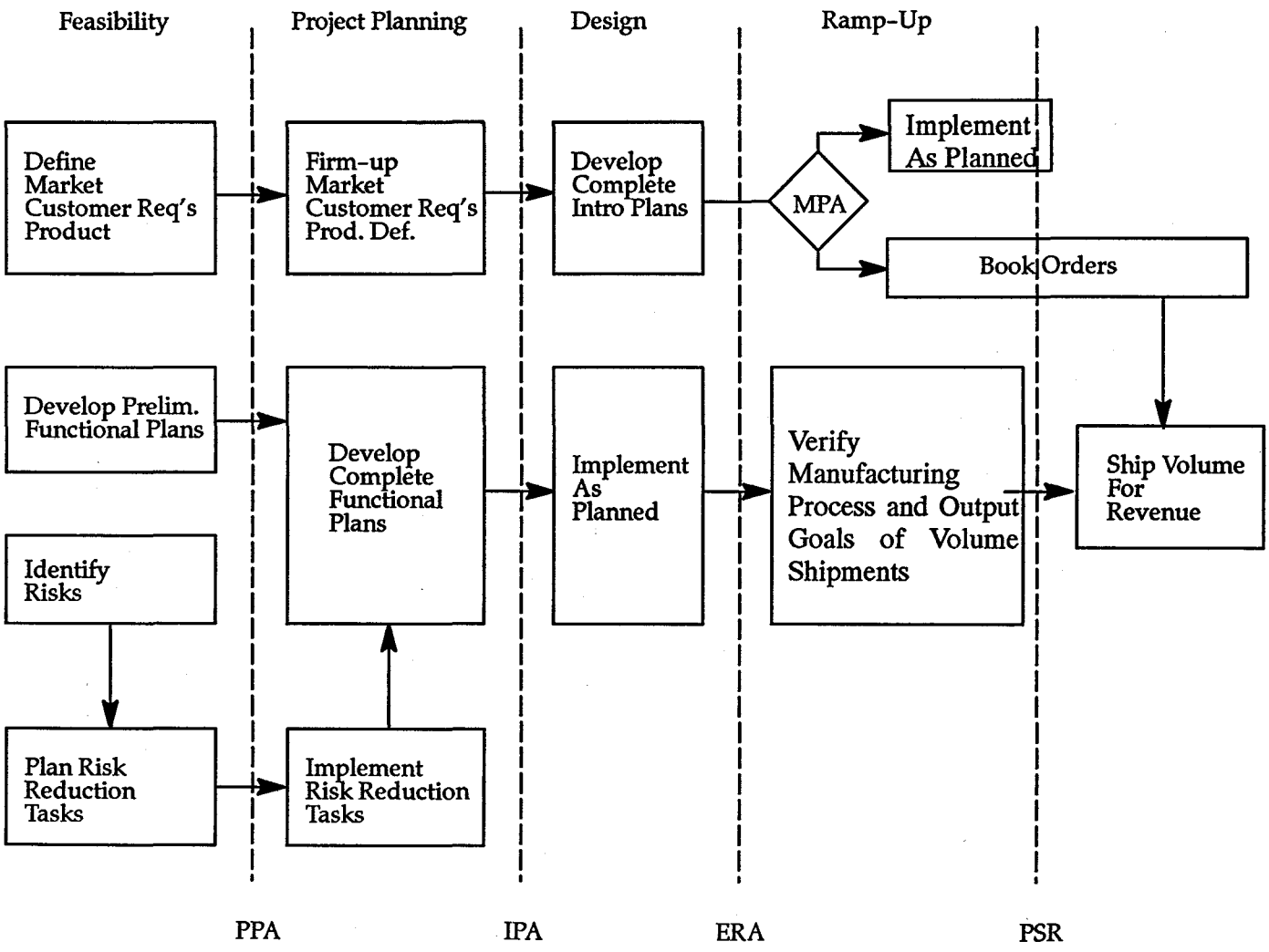
Conclusions

As may be the case with other organizations, some of the NPI projects at Tektronix have lead to great success, and some still carry the burden of a poor NPI process. In the interviews, an attempt

was made to examine and compare at least one "very successful" NPI against a "bad one". The goal was to pinpoint the key issues leading to these two different outcomes. Factors such as late involvement of Manufacturing, commitment of individuals, and many others were identified. It appears that Tektronix has already recognized the elements of failures and has gone to great lengths to avoid the reoccurrence of these problems. The overall feelings of the individuals (Manufacturing Managers, Line Managers, Project Managers, etc.) indicates that Tektronix is moving in the right direction. In addition, certification of ISO has contributed to the enhancement of the customer satisfaction and quality of the NPI process. In sum, completion of many successful NPI projects is a good indicator that the system is capable of producing good outcome.

Appendix C

TEKTRONIX NEW PRODUCT FLOW CHART



Appendix C

REQUIRED DOCUMENTATION FOR PHASE CHANGE REVIEWS

DOCUMENTATION ELEMENTS	PRODUCT PROPOSAL REVIEW	IMPLEMENTATION PLAN REVIEW	ENGINEERING RELEASE REVIEW	PRODUCT SHIPMENT RELEASE REVIEW
1) Program Code Name	Required	Changes	NR	NR
2) Product Nomenclature	NR	Required	Changes	Changes
3) Product Core Team List	Required	Changes	Changes	NR
4) Market Analysis	Appendix B-1	Appendix B-2	Changes	Changes
5) Product Description	Appendix B-1	Appendix B-2	Changes	Changes
6) Project Plans	Appendix B-1	Appendix B-2	Changes	Changes
6.1 Risk Identification and Reduction Plans	Appendix B-1	Appendix B-2	Changes	NR
6.2 Implementation Plans By Function	Appendix B-1	Appendix B-2		
6.2.1 Marketing			Firm	NR
6.2.2 Engineering			NR	NR
6.2.3 Manufacturing				
6.2.3.1 Process Dev.			Changes	NR
6.2.3.2 Production			Firm	NR
6.2.4 Materials			Firm	NR
6.2.5 Sales			Firm	NR
6.2.6 Service			Firm	NR
6.2.7 Customer Support			Firm	NR
6.2.8 Internal Support Groups			Changes	NR
7) Checklists With Explanations Of "No" Answers			Required	Required
8) Minutes: Previous Review	NR	Required	Required	Required
9) Forecast Date of Next Review	Required	Required	Required	NR

Note: REQUIRED means the item must be part of the documentation package. This also applies for UPDATE, PRELIMINARY, and FIRM. CHANGES means that only deviations from previous milestone documentation should be part of the documentation package (along with explanations). The normal expectation is that these areas will not change during the project. NR means the item is not required in the documentation package.

Note: All references to standards, policies or procedures must identify the name, revision number and the date of reference document, e.g., T&M New Product Policy, Revision 2, 2JUN93. This will clearly identify the compliant reference document(s).2. Each of the individual functional organizations has a plan to complete the steps identified in their individual processes and procedures for Public Announcement. Y/N

PRODUCT PROPOSAL OUTLINE

Cover: Include project name, date and list of product core team members with signatures.

1. Executive Summary
2. Market Analysis
   - 2.1 Opportunity Description
   - 2.2 Product Concept
   - 2.3 Phase 1 QFD Matrix
   - 2.4 Customer Purchase Criteria (Economic Value to the Customer)
   - 2.5 Market Description
     - 2.5.1 Size
     - 2.5.2 Growth
     - 2.5.3 Customers
     - 2.5.4 Competition
     - 2.5.5 Alternatives
   - 2.6 Fit to T&M and Product Line Business Strategy
   - 2.7 Product Tactics
     - 2.7.1 Configurations, Pricing, and Forecasts
     - 2.7.2 Displacement (including identification of products requiring phase-out)
     - 2.7.3 Promotion
     - 2.7.4 Distribution
3. Product Description
   - 3.1 Features and Market Critical Specs
   - 3.2 Concept Design (H/W, S/W, Packaging)
   - 3.3 Program/Product Dependencies
   - 3.4 MTBF Goals
   - 3.5 MCOS Goals
4. Project Plan
   - 4.1 Project Planning Phase
     - 4.1.1 Identified Risks and Risk Reduction Plans (for all functional areas)
     - 4.1.2 Schedule
     - 4.1.3 Project Planning Costs
   - 4.2 Implementation Phases (Design & Ramp-Up)
     - 4.2.1 Top-Level PERT
     - 4.2.2 Functional Contributions (Highlight the unusual)
       - 4.2.2.1 Marketing
       - 4.2.2.2 Engineering
       - 4.2.2.3 Manufacturing
       - 4.2.2.4 Sales
       - 4.2.2.5 Service
       - 4.2.2.6 Customer Support
       - 4.2.2.7 Internal Services Groups
         (CAD, Customer Documentation, NPI Support, ICO, HCO, BBO, etc.)
5. Financial Plans (Preliminary)
   - 5.1 Detailed Project Costs (Firm to IP, Preliminary to PSR)
   - 5.2 Perform a Financial Analysis
   - 5.3 Recovery Map

IMPLEMENTATION PLAN OUTLINE

Cover: Include project name, date and list of product core team members, with signatures.

1. Executive Summary

2. Market Update

   Describe changes since product proposal.

3. Product Update

   Describe changes since product proposal.

   Add detail where needed but not full EIS/UIS. See Reference documents.

4. Project Plan

   4.1 Risk Reduction Results

   Describe results of risk reduction work for each functional area.

   4.2 Functional Implementation Plans

   4.2.1 Marketing

   4.2.2 Engineering

   4.2.3 Manufacturing

   4.2.4 Materials

   4.2.5 Sales

   4.2.6 Service

   4.2.7 Customer Support

   4.2.8 Internal Services Groups

   (CAD, Customer Documentation, NPI Support, ICO, HCO, BBO, etc.)

   4.3 Preliminary Production Ramp-up Plans

   4.4 Top Level Project PERT

5. Financial Plan (Firm)

   5.1 Detailed Project Costs to finish (through PSR)

   5.2 Perform a Financial Analysis

   5.3 Recovery Map

Reference Documents

- EIS (Under Change Control)
- UIS (Under Change Control)

Appendix C

ER MILESTONE CHECKLIST

1.	Each of the individual functional organizations has successfully completed the steps identified in their individual processes and procedures for Engineering Release.	Y/N
2.	Each of the individual functional organizations has successfully completed the tasks and activities in the implementation plan for Engineering Release.	Y/N
3.	Design Verification is complete and the results meet the requirements defined in the Implementation Plan.	Y/N
4.	Compliance with all required safety & regulatory standards has been certified.	Y/N
5.	All required manufacturing process documents (Board Build and Final Assembly & Test) are in place.	Y/N
6.	Operators are sufficiently trained to start the pilot build.	Y/N
7.	Manufacturing has identified sufficient capacity for the pilot build (Automatic Test, Environmental Stress Screening (ESS), assembly).	Y/N
8.	The Bill of Material and routing are in place.	Y/N
9.	All parts are PreProd (PP)or Current status (CR).	Y/N
10.	The pilot build schedule has been reviewed and approved.	Y/N
11.	The pilot build plan is loaded in MRP and the material is available to support it.	Y/N
12.	There is a forecast for all orderable products, options and accessories.	Y/N
13.	Demand is loaded for all orderable products, options and accessories.	Y/N
14.	All service processes and procedures have been documented for worldwide service.	Y/N
15.	A written plan exists, approved by Marketing, Manufacturing and Service on how to handle service on demos shipped prior to PSR.	Y/N
16.	A written plan exists, approved by Marketing and Customer Documentation on how to handle the documentation that will accompany demo units shipped prior to PSR.	Y/N
17.	All new T&M, 067-xxxx-xx, 020 and 040 kits are identified.	Y/N
18.	Service demand is forecast and loaded.	Y/N
19.	All new or unique replaceable parts have been identified.	Y/N
20.	S/W and H/W stress testing has been completed with documented results.	Y/N
21.	Environmental qualification has been completed and passed	Y/N
22.	Transportation Simulation has been completed and passed.	Y/N
23.	User Misuse Testing has been completed and passed.	Y/N
24.	Reliability testing has been completed and passed.	Y/N
25.	Software/Firmware testing (functional testing, stress testing, expert user tests) has been completed and all priority 1 and 2 bugs are fixed and verified.	Y/N
26.	All outstanding issues from Implementation Plan Approval have been resolved.	Y/N

PSR MILESTONE CHECKLIST

1.	All outstanding issues from Engineering Release Approval have been resolved.	Y/N
2.	Each of the individual functional organizations has successfully completed the steps identified in their individual processes and procedures for Product Shipment Release.	Y/N
3.	Each of the individual functional organizations has completed the tasks and activities identified in the Implementation Plan for Product Shipment Release.	Y/N
4.	Service process / procedure documents are in place for worldwide service.	Y/N
5.	Service training is complete.	Y/N
6.	Service logistics (new T&M, 067-xxxx-xx, 020 and 040 kits, and/or service S/W) is in place worldwide.	Y/N
7.	Unique parts and spares are in place worldwide.	Y/N
8.	Yields at each manufacturing step from the pilot build meet or exceed those projected in the Implementation Plan.	Y/N
9.	All manufacturing operators are trained.	Y/N
10.	The monthly operations process is now controlling the output plan loaded in the MRP system.	Y/N
11.	Manufacturing has sufficient capacity to support the output plan (scope cal, ESS, assembly).	Y/N
12.	Material to support the output plan is in place.	Y/N
13.	The full bill of materials is current status (CR). If not, list all parts not current status and define target dates and person responsible.	Y/N
14.	The specification audit (CPK's results of qualification as defined in IP) is complete and satisfactory.	Y/N
15.	An updated financial analysis using the current BOM, yields from the pilot build, the approved selling price, projected discounts and the current project costs has been performed and filed in the project file.	Y/N
16.	The following items have been included in the PSR review package.	Y/N

- Yields at each step from the pilot build.
- CPK's from the pilot build.
- Current reliability test results.
- The output plan.
- The specification audit results.
- The updated financial analysis.
- Product assurance and quality test results.

RECOMMENDED REVIEWERS

The following table lists the reviewers (blank, typically not needed at this milestone; A, approver; R, recommended for this milestone). All recommended reviewers may delegate review activities to appropriate experts within their functional area. Each reviewer is expected to provide written or oral comments if any.

Milestone	PP	IP	ER	MPA	PSR
Business Unit General Manager	A	A	R	R	R
Product Line Manager	R	R	A	A	A
Product Marketing Manager	R	R	R	R	R
T&M Quality Manager	R	R	R	R	R
Manufacturing Line Manager	R	R	R	R	R
Mfg. Engineering Manager	R	R	R	R	R
Materials Manager		R	R		R
Service Support Manager	R	R	R	R	R
Customer Support Center Manager				R	
Hardware Design Manager	R	R	R		R
Software/Firmware Design Manager	R	R	R		R
Mechanical Design Manager	R	R	R		R
Sales Support Manager	R	R		R	
Product Line Controller	R	R			R

- Check List with Explanation On Incomplete Items from Current and Previous Milestones
- Program Manager presentation materials used at the review meeting.
- Approver's (Product Line Manager) Minutes containing Decision from Reviewer

Product Shipment Release (PSR):

- Cover Memo (from the Program Manager) with Distribution List
- Check List with Explanation On Incomplete Items from Current and Previous Milestones.
- Program Manager presentation materials used at the review meeting.
- Approver's (Product Line Manager) Minutes containing Decision from Reviewer
- Closure on ALL open items from this or previous milestones.

Appendix D

TRIQUINT

Background

TriQuint Semiconductor (TQS), the third company studied, was formed as an independent corporation in 1991 from the former TriQuint Semiconductor, a subsidiary of Tektronix, in a merger with Gazelle Microcircuits and GigaBit Logic. The company manufactures gallium arsenide (GaAs) integrated circuits, which compete with silicon (Si) integrated circuits in niche markets where material properties of GaAs give it an electrical performance advantage over Si. The company's major product areas are Wireless Communications, Telecommunications, and Computing & Networking.

TriQuint markets its products and services in three ways. Originally, the company primarily provided its manufacturing process and computer-aided design models to customers and fabricated the customer's design, in a "build-to-print" type of arrangement. The company then added a few standard products and Application Specific Integrated Circuits (ASICs or "design-to-spec" chips) to its repertoire. TQS is now in the process of filling out its standard products line and in the meantime, supplementing its income with ASICs and foundry (fab of customer designs) work. Consequently, new products at TQS can result from either a specific customer request (ASICs and foundry) or from marketing research (standard products).

Because building semiconductors is a batch process (the ability to build large numbers of ICs on a single wafer is the driving factor in pushing the price of the product lower), it is very difficult and expensive to build small quantities of a given product. This leads to TQS having a New Product Development process which is somewhat different from companies who are able to build single-item prototypes. For TQS, the first fabrication is a relatively costly step in terms of material and resources, so TQS probably places more emphasis on insuring that the product is viable before ever making the first article.

NPI Process

TriQuint is made up of three divisions which represent different segments of the GaAs IC market, plus an administrative group and the manufacturing operations (or fab) area. The Wireless Communications Division (WCD) is one of the market segment divisions, and is responsible for products which are used in communications devices transmitting and receiving signals via radio waves. Within the Wireless Communications Division, there are five sub-groups. Three of the groups are made up of design engineers and technicians, and are divided according to the sub-segment of the wireless communications market they address. The fourth group is product engineering, made up of product engineers and technicians. This group addresses characterization, production test, yield improvement, and sustaining engineering for all of WCD's product line. The fifth group is the marketing and applications engineering group. This group performs all the market research and applications engineering support for WCD.

The NPI process in TriQuint's Wireless Communications Division follows a series of phases and milestones which are quite similar to other electronics manufacturers, and notably to the two other companies addressed in this study. The Product Assessment phase is the initial phase in the development process. This phase includes performing a market assessment (in the case of a standard product) or a feasibility assessment (if the product is an ASIC), determining if the product fits with the division's strategic objectives, and initiating Product Development Planning if the decision is made to continue development. Product Development Planning includes the assignment of a project leader and project team members, the drafting of a project schedule, resource planning, and the assessment of manufacturing capacity and capability. The approval of the Product Development Plan leads to the Design phase. During design, the project team proposes alternative designs which have the potential to satisfy the end requirements. Computer simulation and 'breadboarding', a technique by which circuit performance is simulated by using discrete components rather than monolithic ICs, are usually employed to limit the number of alternatives under investigation. When the potential designs have been reduced to a few promising options, a Design Review is held with the customer, and the design is released (assuming customer approval is obtained). Note that other

design reviews are held during the course of development, but they do not have the same impact as the major milestone culminating in Design Release. If Design Release goes well, the design (or the small number of promising options) will be fabricated. Engineering Evaluation will insure that the design is capable of meeting the customer's requirements, or adverse results will trigger a revisiting of the planning and design phases. With Evaluation Release, the product is viable as it stands and can be shipped to the customer as a prototype or sold in small quantities. The next phase, Product Characterization, takes analysis of the product's performance one step further and demonstrates that in addition to satisfying performance requirements in one production run, the product can be manufactured in the company's fabrication facility over a period of time without adverse effects on the part's technical parameters. After Product Characterization, engineers and production personnel finalize the logistical structures which allow the product to be manufactured in volume. These include writing company specifications and work instructions, setting test specifications, bringing additional test capacity on line if necessary, and coordinating information with production control. When these requirements are satisfied, the Manufacturing Acceptance milestone is passed and the product enters full production. At this point, or shortly thereafter, the product's engineering effort enters the sustaining phase and the NPI process is complete.

Responsibilities for various portions of the NPI process are assigned to project team members which are drawn from functional groups. For example, design engineering representatives are responsible for the majority of the technical performance analysis, the investigation of the different circuit options, the layout of the IC, and negotiating specifications. Product engineers are responsible for developing test capabilities for evaluation, characterization, and production test, for establishing yield estimates, and for contributing to spec negotiations. Manufacturing operations has responsibility for developing and characterizing new manufacturing processes if they are required for the particular product, for implementing production control logistics, and providing support for initial production runs for evaluation and characterization. Marketing is consistently involved in order to maintain focus on the market targets and to track changes in those targets. The various responsibilities are occurring simultaneously, although emphasis shifts as the project progresses:

design has heavier responsibilities during the initial stages (along with marketing), product engineering during the middle stages, and manufacturing operations near the Manufacturing Acceptance milestone and on into production. Despite the shift in emphasis, there is still strong parallelism in the efforts. The emphasis on design near the beginning (along with the small size of the marketing staff) is probably what leads to the usual choice of the lead design engineer as the project leader.

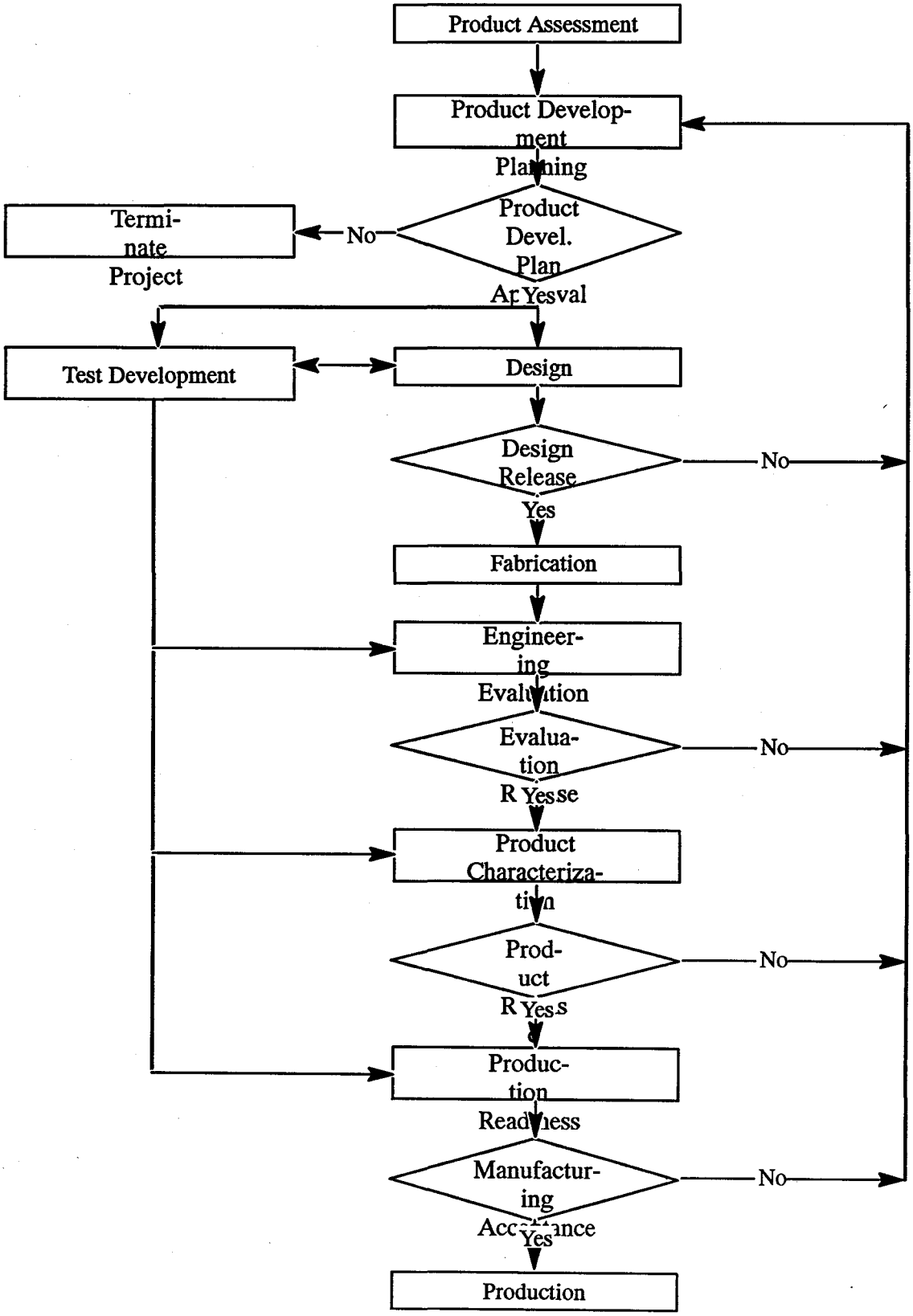
Project Management System

Because of TriQuint's size and recent history, formal project management was not espoused in the company until the New Product Development process was developed. The company and its projects were small enough that most communication took place without much need for formal procedures. As the company grew and took on larger projects, stress levels rose and some painful experiences occurred which indicated that communication was no longer as easy as it once was. The management of the Wireless Communications Division has since supported the use of project management techniques commensurate with the company's size and product complexity. Above all, the need for clearly designating a project leader for a particular project early in the program has been recognized.

Conclusions

Interviews with members of TriQuint's Wireless Communications Division indicated that past new product developments have been only marginally successful. Since the effort to implement a New Product Development process began, however, a few products have been introduced which have differed from past products in the effectiveness with which they were brought to market. The New Product Development process is also viewed as incorporating solutions to most of the perceived weaknesses of the past procedures (or lack thereof). The overall conclusion is that the marginal success of past products, when viewed in perspective with recent successes and the perception of a good product development process now in place, indicates that TriQuint WCD currently has the makings of a successful New Product Development process.

NEW PRODUCT FLOW CHART



Appendix D

References

1. Nicholas, John M., Managing Business and Engineering Projects: Concepts and Implementation, Prentice-Hall, Inc., 1990.
2. Shina, Sammy G., Concurrent Engineering and Design for Manufacture of Electronics Products, Van Nostrand Reinhold, 1991.

Interviewees

Planar

1. Larry Lewis, Project Manager and Design Engineer
2. Ken Ping, Manufacturing Engineer and R&D
3. Terry Roberts, Application Engineer and Marketing Support
4. Marc Ceciliani, Finance

Tektronix, Test and Measurement Division

1. Jim Larsen, Project Manager
2. Jit-Loke Lim, Manufacturing Engineer
3. Terry Norman, Manufacturing Line Manager
4. Ann Witkowski, Manufacturing Engineering Manager
5. John Hengeveld, Marketing Manager
6. Steve Harris, Project Manager (hardware)

TriQuint

1. Dennis Kruger, Project Leader
2. Ed Knapp, Design Engineer
3. Joe Skovron, Marketing
4. Terry Wilson, Product Engineering Manager
5. Mark Greenwood, Product Engineer