Role of electronic measurement systems in new product development
by Adwait Prabhakar Ayare

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Industrial and Management Engineering
Montana State University

Abstract:
Firms increasingly compete on their ability to develop high quality products at lowest cost possible and introduce them into the market in the shortest possible time. Much has therefore been written about new product development (NPD) practices, but few researchers have attempted to highlight NPD issues related to electronic industries even though they are one of the major drivers of the US economy. Also few have investigated the role of test equipment in NPD, though it plays a crucial role in assessing design performance.

This thesis attempts to study NPD in electronic industries, especially understand the role of electronic measurement systems1 (EMS) in NPD. A qualitative research approach, namely grounded theory, was adopted to guide data collection and analysis. Four sites were chosen for collecting data, which were then analyzed using data coding techniques.

Rigorous data analysis uncovered two major themes, the Hardware-Firmware-Test integration triad and information transformation. The Hardware-Firmware-Test integration triad results from the common practice of breaking down the development effort into separate hardware and firmware development cycles that must then be integrated, often with great difficulty. This integration problem gets compounded because these two groups must also simultaneously develop EMS to test their designs.

Information transformation, the process by which test data is transformed into useable design knowledge, results from a complex interaction between the human design engineer and other participants in the development process. Information transformation activities consume 70% of testing time.

This thesis investigates these two deeply rooted issues that all electronics manufacturers face, and proposes alternative approaches. The new models hold significant potential to improve product development effectiveness by simplifying the integration problem and speeding up the transformation processes.

1EMS: system consisting of data acquisition, analysis, presentation and related tools.

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This thesis has been read by each member of the thesis committee and has been found to be satisfactory regarding content, English usage, format, citations, bibliographic style, and consistency, and is ready for submission to the College of Graduate Studies.

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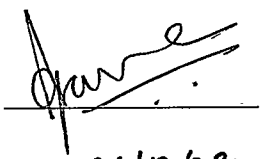
Signature 

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Dedicated to the people I love:

Mom, Dad and Yasuko

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ABSTRACT

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[1] EMS: system consisting of data acquisition, analysis, presentation and related tools.

CHAPTER 1

INTRODUCTION

New Product Development (NPD) activities, which involve conceiving new ideas, designing and testing them, then creating a manufacturing system to produce them are viewed as a major strategic competitive weapon (Wheelwright and Clark, 1992). Firms increasingly compete on their ability to develop new products faster and cheaper. Studies have shown that firms who are successful in NPD, irrespective of the industry type, set similar strategic goals: develop high *quality* products at lowest *cost* possible and introduce them into the market in the shortest possible *time*. The ultimate goal of this thesis is to help firms develop better product development (PD) systems and processes to meet these quality, cost and time (QCT) goals, as they are commonly referred to.

To help industries develop better PD systems and processes, numerous studies have been carried out and multiple streams of research have developed. But few researchers have viewed PD as a system and most of the studies tend to prescribe tools or techniques to improve some aspect of PD. Few studies provide a combinations of tools, techniques and processes that will optimize the PD system as a whole.

This research therefore takes a holistic view of the PD process and attempts to first understand NPD systems and processes at electronics industries. It then attempts to highlight issues related to design-test and manufacturing of electronic components in light of PD systems and processes. Understanding processes and trying to improve them is important, as Deming said, process control not product control. On a similar note the

basic premise of this thesis is to attempt to improve NPD processes so that the products therefore will be that much better, be made on time, involve minimal waste and ultimately be more profitable.

Why study NPD at electronic industries?

Much of the literature on PD has been born from case studies from automotive and software industries. Few researchers have attempted to address NPD issues related to electronics industries. Another reason for choosing this industry was many components in automobiles, airplanes, consumer electronics; PC's are electromechanical devices. The industry as a whole has also grown tremendously and is one of the major drivers of the US economy. Just like other industries it faces competition from firms from EU and Asia. Firms from all over compete on their ability to develop innovative products. Improvements in NPD systems and processes will potentially offer huge gains to these firms. Thus much could be gained from the study of NPD at electronic industries.

Contribution to recent NPD literature

Design, build and test (D-B-T) cycles have been given considerable importance in PD literature and some recent studies have also shed light on them (Loch, Terwiesch and Thomke, 2001; Thomke, 2001). But almost no one has attempted to look at the role that test equipment plays in the PD process. Studying this role is important because in a typical D-B-T cycle a design engineer designs the part, prototypes it and then tests it using test equipment, which then enables evaluation of the design performance against product requirements. Once a proper determination is made the design engineer can

improve the design and attempt to meet customer needs effectively. Carrying out such tests and making a determination of the design performance consumes a major part of the development time and engineering effort and therefore making this task simpler or faster could make the overall PD process faster.

Research questions

One of the major goals of this research is therefore to understand the role of electronic measurement systems[2] (EMS) in NPD. The questions addressed by this research are:

- What is the role of EMS in PD processes especially D-B-T cycles?
  - What are the data usage patterns?
  - What is the relationship between the data generators and users?
  - What is the role of software used in testing? and
  - What is role of EMS in experimental strategies?
- What is the role of EMS in management of engineering information at these firms?

These findings will help to prescribe in a limited way what new capabilities should be and how EMS could help these firms improve their PD systems and processes.

The scope of this thesis was to understand the role of EMS in NPD, therefore data collection concentrated on understanding when and how the EMS are designed and used. This included understanding of how EMS are used to generate test data, analyze it, store

[2] EMS: system consisting of data acquisition, analysis, presentation and related tools.

it and transfer it. Also data about all engineering activities leading to and resulting from the use of EMS was also collected.

But to understand this data, contextual information was needed. Therefore data collection was broadened to include product development organizations and processes. This included information about the role of management, structure and communication within teams, PD phases, activities performed within the phases, milestones, and detailed information on D-B-T cycles.

Thesis overview

The backbone of this thesis is data collected about PD systems and processes from four firms involved in development and manufacturing of electronics. The first is a large corporation developing electronic test systems. Two of the firms are mid-size corporations, involved in manufacturing hybrid chips and fiber optics respectively. The fourth firm is a small company making dynamometers.

These four firms are diverse in terms of their products, size and competencies. Consequently the PD organization and processes they have in place to design, test and manufacture new products were also slightly different. But this diversity was advantageous because it made it possible to generalize across the firms and investigate PD issues that were common across all four firms. The themes that emerged and discussed in this thesis are grounded in PD issues common across all four firms.

Chapter 2 reviews PD literature, which serves two purposes. The first is to enable us to understand and appreciate current PD practices, including PD organizations, processes and strategies. The second purpose of reviewing current NPD literature was to

understand world-class PD practices pertaining to the goals of this research such as flexible PD systems, information and knowledge management strategies, Concurrent Engineering and Set-Based practices.

Chapter 3 describes the research methodology adopted to guide data collection and analysis. It justifies the choice of qualitative research methods over quantitative methods and describes the qualitative methods adopted, mainly grounded theory. It explains in depth how this research was carried out, including choice of sites, data collection through semi-structured interviews, and data analysis using various types of data coding.

Chapter 4 describes the four cases from a standpoint of PD organization, processes and experimental strategies adopted by these firms including and the use of EMS in D-B-T cycles. This chapter not only explains the subtle differences in the PD processes followed by these four firms, but also generalizes across the sample and highlights PD issues common across these firms. This chapter also provides the reader contextual information for understanding the two themes described in chapters 5 and 6.

Chapter 5 describes a major integration issue faced by management at these four firms. The Hardware- Firmware-Test integration problem occurs because these firms choose to break down the PD effort into hardware and firmware development groups and then have to integrate the efforts of these two groups. This problem gets further precipitated because these two groups have to develop EMS to test their designs and also coordinate development activities with manufacturing engineering. To resolve this issue

set-based concurrent engineering practice has been prescribed instead of the point based concurrent engineering approach.

Chapter 6 describes issues related to information transformation that occurs after testing a prototype. The most critical aspect of any design, build and test cycle is the transformation of test data into useful information so that design performance can be evaluated. This chapter explains the information transformation process, and shows how it consumes a significant amount of PD time. To improve the information transformation process a new information management system is proposed that supports NPD.

This thesis is a result of intensive data collection and rigorous data analysis but yet should be treated as a preliminary investigation into the research questions. There are still many issues to be investigated and many other themes might emerge if more data is collected from many more firms.

CHAPTER 2

LITERATURE REVIEW

Literature on new product development (NPD) is extensive, fragmented and ever growing. Several researchers have attempted to classify NPD literature into different streams. Brown and Eisenhardt (1995), for example, have classified literature into three streams: PD as a rational plan, communication web and disciplined problem solving. But in view of understanding the role of Electronic Measurement System (EMS) in NPD, no one stream of NPD literature was pursued, rather literature prescribing best practices in NPD was reviewed. As the grounded theory study progressed certain issues of NPD became more relevant to the research problems and so literature relating to information and knowledge management, new PD practices and experimental strategies was also reviewed.

Rather than presenting a comprehensive review of the literature this chapter highlights important issues and concepts considered for this research. The first section of this chapter establishes the need for NPD and outlines measures of successful NPD. The second section explains how these success factors contribute towards establishing world-class PD systems. The third section outlines how this research contributes the current body of knowledge on effective NPD practice.

Need and measures for successful NPD

The current electronics environment is perhaps best described as 'turbulent', very intense and dynamic. The major factors or forces causing this are (Wheelwright and Clark, 1992):

- Intense competition: Just like in all other businesses the numbers of competitors that are capable of competing on a world class level in electronics and hi-tech have increased multifold. The list of a firm's toughest competitors now includes firms from Europe and Asia thus making the competition is more intense and less forgiving.
- Fragmented and demanding markets: The target markets for electronics are not limited to developed nations but also developing nations, which have now become more accessible and hold huge potential. Firms now have to serve customers with diverse expectations who need quick and easy solutions to their problems.
- Diverse and rapidly changing technology: Rapidly developing and changing technology also creates options to meet the needs of the changing markets. The challenge lies not only in the development of these technologies but also in being able to commercially harness them.

To survive and grow in this turbulent environment firms compete on their ability to meet customer needs faster and efficiently. NPD has therefore become a focal point of competition and a potential source of competitive advantage (Clark and Fujimoto, 1991,

as quoted in Brown and Eisenhardt, 1995; Anderson, Tushman and Reilly, 1991). Designing, developing and marketing a new product involves an integrated effort from all functions within the firm and also its customers and suppliers. Management also has to radically rethink the firm's systems, structures and values and establish NPD systems and processes that can help meet customer needs effectively and efficiently (Wheelwright and Clark, 1992).

Measures of successful NPD

Success in the market is judged by how well a new product meets cost, quality and time (CQT) goals. Quality refers to total product quality encompassing reliability, functionality and customer satisfaction. Developmental processes have a great bearing on the budget needed for developing the product which taken together with cost of manufacturing the product makes up the total cost of the product. The total cost of the product should be competitive with that offered by other firms. Consideration of time to market is crucial to the success of the product because there is always a window of opportunity within which the market needs can be fulfilled profitability. The time span from product concept to market should therefore be as short as possible to enable a firm to take advantage of the opportunity.

Conventional thinking would call for tradeoffs between the three imperatives, but that is no longer feasible in the current environment. All three imperatives need to be optimized to succeed in NPD and ultimately in the marketplace.

Factors associated with successful NPD

Figure 2.1 depicts the key factors that research has shown to be associated with highly effective NPD. The center box represents the transformation process (PD process) from customer needs to a finished product. The transformation process is facilitated by five sets of supporting systems: customers, suppliers, manufacturing, technology and organizational structure and leadership. Many critical and revolutionary issues have been included in the transformation process including flexible stage gate PD process, early and rapid prototyping, set based concurrent engineering and use of engineering checklists.

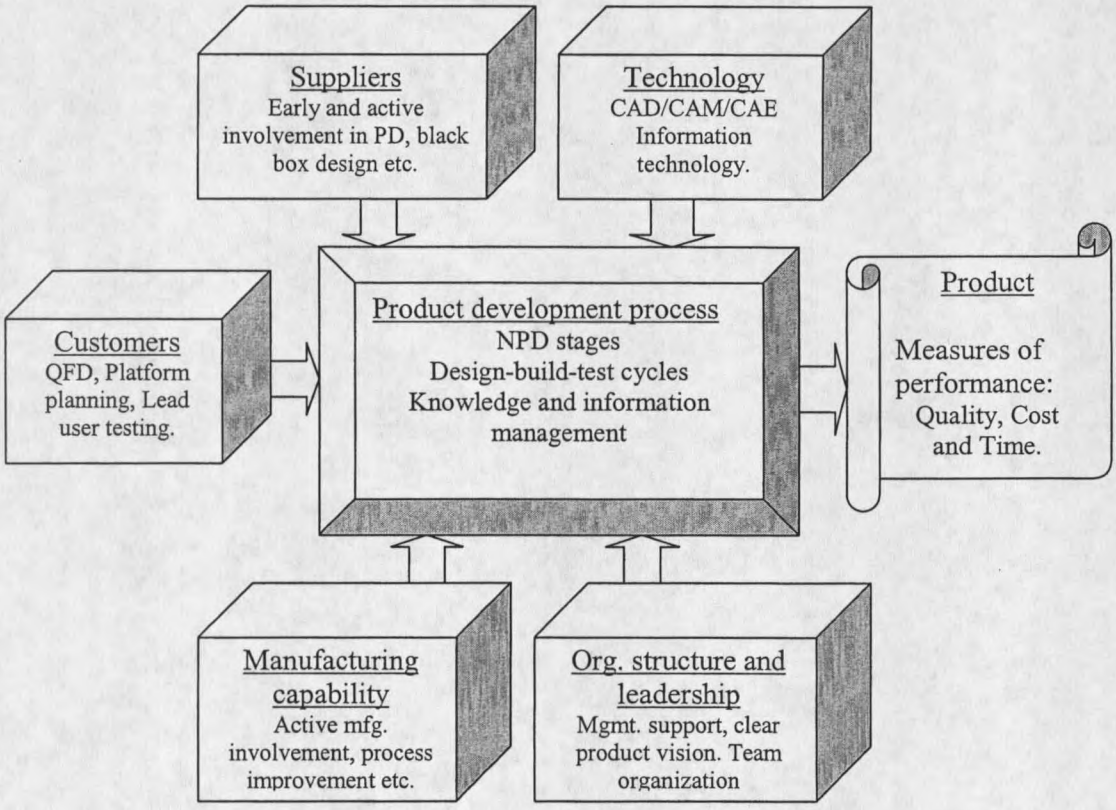

Figure 2.1: Transformation model

Organizational structure and leadership

The organizational structure for NPD commonly consists of top management providing the vision and resources and middle management directing and coordinating the activities of a cross-functional team that carries out the design and development activities.

Top management: Top management plays the primary role in the development of organizations and has a similar role to play in the NPD effort. If any firm has to position itself in a way that it is capable of designing and developing products that meet QCT goals consistently, then the change should happen first at the organizational level. This organizational redesign has to be led and managed by top management (Nadler and Tushman, 1997).

New role of top management: Literature in NPD directs top management towards two crucial tasks in organizing for NPD. They are defining a clear vision and communicating that vision through the organization.

- Clear vision and charter: Every effort needs a clear vision and the best way to capture the mission precisely is to have an explicit and measurable project charter. This charter should set broad performance based goals and a timeline for these goals (Clark and Wheelwright, 1992). Every function or development team should be able to translate the overall goals into targets, work plans and set their own evaluation criteria.
- Communication of the vision: Communication of the vision to each individual in the firm (or development team) is important and this should be done through

multiple media, and should be thought of as both a telling and selling activity. The vision should be communicated as real, visible and concrete long-term goals and not as the program of the month. This provides leverage points for changing individual behavior. The communication should not be a one-time event but should occur repeatedly to prove the commitment of top management towards the set goals.

Role of Middle management: The role of middle management also changes with the change in the organization structure. From being heads of functional groups in the past, middle level managers faces new challenges as team and project leaders.

- Link between customer and team: The team leader should be the direct link between the market/customer and the development organization. This involves knowing the market well, studying market data and being a multilingual translator (Fleischer and Liker, 1997). Multilingual translator means being able to translate the market data to information understood by all functions involved in development effort.
- Project management: The team leader should be able to translate the overall goals into team goals and accordingly initiate, direct and coordinate team activities, and maintain schedules.
- Concept champion: Success stories at many leading firms have highlighted a new role for project managers; that of a concept champion. Team leaders have been found to be most effective when they were working engineers and

guardians of the new idea or concept under development (Clark and Wheelwright, 1992). They should ensure that decisions made are consistent and harmonious with the concept goals and themselves act like mentors to the other engineers involved in the development effort. This requires team leaders to have a blend of leadership, engineering and mentoring skills, which not only ensure that the goals are met but also that the other engineers grow in experience.

The new roles of top and middle management discussed above are consistent with a new concept called 'compressive management' (Nonaka, 1988). In compressive management, top management is responsible for determining the overall direction of the firm, establishing the vision and setting time limits. They also select the middle managers to head the projects and lay the foundation for the lower organizational structure (teams). The middle management organizes the project team, breaks the overall goals into team goals and sets a timeline. The team is given autonomy in its working while being constrained by targets and a timeline (Nonaka, 1988). The team organization, working, tools used and the process of design and development is explained in detail in the following sections.

Team organization: Most engineering organizations can be classified into several types of structures:

- Functional organization: Management organizes the employees according to the functions that they serve in the organization. The functional departments for