New Product Development for Engineers

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***Abstract*—**Success in new product development (NPD) execution has become ever more critical today due to the global competitive pressure and rapid changing technologies. Innovation is not a competitive advantage until a company can successfully commercialize it via new product introduction. Universities and professional training of NPD normally focus broadly on the marketing, operational, and process aspects, but not adequate on the technical roles and functions of engineers. In this paper, we propose a course to prepare specifically engineering students for NPD with emphasis on the engineering roles, practices, and deliverables. The motivation stems from recognizing when entering the workforce in the industry, the vast majority of engineers will be involved in designing products and systems for profit. In a framework of new product development, where products are developed from inception to mass production, students need to learn cross-functional activities and skills that are beyond their traditional design technical discipline. These skills will directly enable these graduates to operate effectively and successfully in such ubiquitous commercial environment.

***Keywords*—**New product development (NPD), innovations, DFx, engineering curriculum.

I. Introduction

THE NPD process is widely used in the industry to develop new products in a most reliable, effective, and manageable manner. It is often referred to as a stage-gate process, illustrated by the diagram in Fig 1. It consists of typically 6 stages with distinct entry and exit criteria. This process is standard and is well documented in [1], [2], [3] and [4]. The vast majority of major corporations employ this formal process to develop products and they constantly seek new ways to reduce cycle times and unit costs [8], [9]. It was shown empirically in [8] that using a cross-functional project team can improve time-to-market. However, this assumes that all members in the cross-functional team, such as shown in Fig. 2, are well trained in their respective discipline of product development. We assert that engineers and engineering students do not get adequate training for their technical role in the NPD process. Most existing NPD training programs focus too broadly on marketing, operation, and process, such as the program prescribed by the Product Development and Management Association (PDMA) shown in Fig. 3. This is most beneficial for marketing or program management professionals, but lack some key areas for engineers. For instance, it does not cover how design and manufacturing engineers work together to ensure the product design meets high reliability and can be manufactured in high volume, known as DFx. The ability to do this has direct impact to project execution success. Hence, we propose an engineering centric course to teach NPD to engineers.

There are two key outcome objectives of the course. The first is to enable students to understand the purpose and mechanism of the NPD process. This means they will understand the activities and deliverables of engineering at each phase. They will also understand the interdependencies with other cross-functional members, such as contributing to the plans developed by supply chain, marketing, and quality teams. The second objective is teach students the skills to develop a shippable product, which encompass technical aspects that are beyond the traditional curricular design scope. These include systems engineering, rapid prototyping, design for excellence (DFx), and cross-functional teamwork. An example of a pitfall is where an engineer completes a design is very far along in the process but then discovers that a critical single source component, used in the design, is not sufficiently available from the supplier at the volume forecasted by marketing, and therefore the design has to be modified and recertified with a different component. Needless to say, this causes a huge schedule delay. Had the engineer taken proactive steps early in the process and worked with the supply chain team to validate sourcing of all critical components then this situation would be avoided. This is an example of DFx - design for manufacturability.

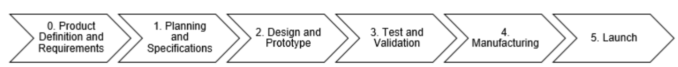

Fig 1. New product development (NPD) process

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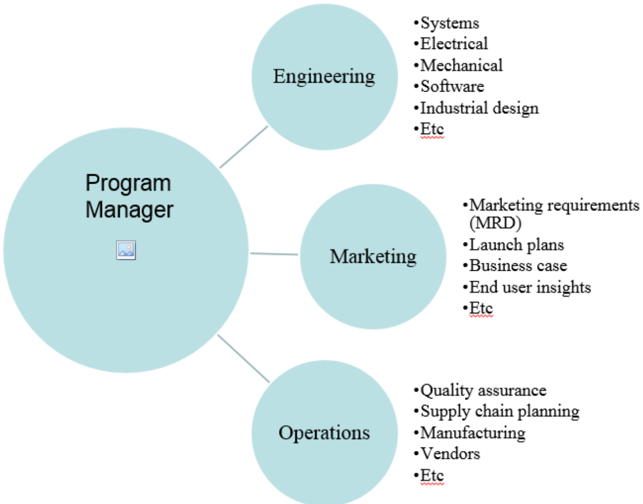

Fig. 2. Cross-functional NPD team structure

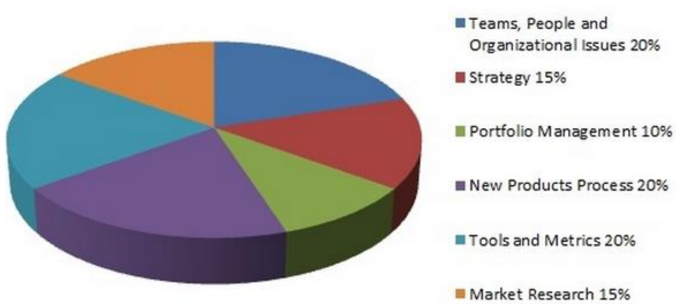

Fig 3. PDMA NPD training and certification subjects.

II. NPD for Engineers Course

To develop a suitable course content, we listed out the key activities and deliverables [3] at each stage of the NPD process shown in Table 1 columns 1 and 2. From this, we derive the key appropriate subject areas that would be taught in the course, as shown column 3. Again, note here that the subjects are engineering centric to achieve the objectives described in previous section. The sequence of the subjects can conveniently follow the order of the stages 0 to 4. The course can also be based on team projects where each team selects a product project from a list of reference projects to put through the NPD process. These reference projects are pre-qualified and pre-determined by the instructor to ensure that they are not overly complex nor simplistic, but adequate to put through the NPD process. Next, we elaborate on the purpose and motivation of some of the key subject areas.

TABLE I
NPD Process Deliverables and Key Subject Areas for Engineers

Stage	Key Deliverables	Syllabus Topics
0	-Business case -Marketing requirements document (MRD) -Feasibility assessment	-NPD process -MRD -Program management
1	-Project plan -MRD Response -Product functional specifications	-Systems engineering (subsystems, requirements analyses) -Writing product specifications -Project planning -Cross functional teamwork
2	-System specifications -Design specifications -Designs (industrial, hardware, software) -Test plan -Quality plan -Manufacturing plan	-Develop design specifications -DFx (design for cost, performance, quality, manufacturability, and regulatory) -Rapid prototyping -Intellectual property development -Content of test, quality, and manufacturing plans
3	-Request for quote (RFQ) package -Design verification testing -Regulatory submissions	-Design and verification testing process -RFQ process -Defect management -Regulatory process
4	-Launch plans -Manufacturing verification testing	-Manufacturing and verification testing process

A. NPD Process

The process, in Fig 1, spans from conception to the production and market launch of the product. Stage 0 is defining the concept and market requirements of the product. This stage usually involves vetting out the business case and deciding if the product concept is commercially viable. Stage 1 involves sizing the project from the technical and project resource standpoint. At the end of this phase, the R&D team has a reasonable estimate of the achievable requirements and associated trade-offs, and hence, the systems specifications. The program manager also develops a cross functional project plan that includes tasks, resources, timeline, and risks. At the end of this stage 1 is where management stake-holders approve the significant investment to proceed to actual development of the product/service. The next stages 2 and 3 are mainly design, test, and validation that will result in a set of alpha or beta prototypes that demonstrate meeting the functional requirements. The manufacturing stage 4 is transferring the design into the factory floor with the goals of demonstrating volume production capability, quality, and compliances. The last stage 5 is launching the product into the market with promotions, sending out evaluation samples, sales preparation, ect. The overall purpose of the NPD process is to meet the three major objectives of achieving the target cost, schedule, and performance of the new product [9].

A typical structure of the cross-functional product team is shown in Figure 2. Here, there are typically four key groups: program manager, engineering, marketing, and operations. The program manager is the person responsible for managing the project schedule and communications with upper management and the rest of the team. The engineering group consists of technical development individuals from various design and integration disciplines. For instance, if the product is a mobile cell phone, the industrial designer works closely with marketing to create a 3D visual design that looks and feels functional and attractive to the end users. The mechanical engineer transforms the industrial design into a 3D CAD design that has proper structure and support for all the components. The electronic engineer designs the electronic and printed circuit board that fits inside the phone. The systems engineer, who normally acts as the engineering team lead, is responsible for engineering requirements and how all subsystems are tied together. It is important to note that engineers need to understand their role outside of the design and test stages 2 and 3. For example, they need to work closely with marketing team in stage 0 to formulate a product definition that is technical feasible and offer competitive advantage.

The marketing team shown in Figure 2 is sometimes called product management. They are responsible for understanding the market landscape, customer needs, and business objectives such that they can formulate a new product proposal. This work is normally completed and approved in stage 0 of the NPD process. The marketer works closely with the NPD team throughout the process to ensure that the product is developed to meet the requirements in the MRD. If there is any trade-off needed to be made along the way, the marketer needs to weigh in and agree to the trade- off. For example, if the engineering team discovers that the product cost is going to end up higher than the projected cost, then the marketer has to decide to whether allow this higher cost, or compromise another requirement, such as a feature or performance specification. The marketing team is also heavily involved in stages 3 and 4 to promote the products and prepare to launch the new product into the market. The last key group is the operations team, which covers the functions of quality assurance, supply chain, and manufacturing. This team is responsible for ensuring that the product meets the quality standard. They select vendors to supply the parts with the best possible cost and schedule. They work closely with the engineering team to transfer the product from the design lab to the production floor. In cases where the product is to be manufactured externally, the operations team is responsible for selecting the contract manufacturer and negotiating the best possible terms. Overall, it is of great importance that engineers understand the NPD process as they require to be active in all the phases to be successful.

A. Systems Engineering

The defense and aerospace industry have used systems engineering (SE) [5] for several decades to manage the requirements, design, and integration of highly complex projects, such as a fighter jet. Although most commercial products are not as complex as a fighter jet, there are benefits to employing SE, especially when a project consists of a combination of electrical, mechanical, and software subsystems. SE breaks the high level product requirements into subsystem specifications. A systems engineer works closely with all the design functions to ensure that their subsystems are specified properly such that the combined subsystems meets the overall product requirements. For example, for a disk drive to deliver a certain read/write data rate, the servo-mechanical subsystem has to be fast enough to seek to the data track to read/write the data, the recording subsystem has to meet the minimum bit density, and the firmware subsystem has to be optimize the encode/decode the data sufficiently fast. SE plays a central role in facilitating the optimization and trade-offs amongst the subsystems such that best overall performance can be achieved. One important method to teach is the quality-function-deployment (QFD) [6], which captures the contributions of subsystems for each and every functional and performance requirement. Its role is most critical in phases II, III, and IV of the NPD process. Because engineers will inevitably have to deal specifying design requirements and trade-offs, learning SE is very beneficial.

B. Design for Excellence (DFx)

Designing a circuit or subsystem to function and perform to the specification is only part of the overall design objective. Engineers need to know the peripheral and consequential effects of their designs. If an engineer uses a sole-sourced component in his circuit that is scheduled to end of life in the near future, then the product will surely suffer when that time comes because of lack of availability, meaning the product would have to be redesigned and recertified with another part. This is an example of a design-for-manufacturing (DFM) issue-- if the engineer understands DFM and works with the supply chain team up front to select a part that is sourceable, then he could avoid the situation. This is one of several DFx [7] aspects that need to be considered during the early design phase. The x could stand for manufacturing, reliability, cost, performance, and compliance. Some of the requirements sometimes are captured in the MRD, but not always. Therefore, the engineering team needs to establish a set of criteria to ensure that their design will meet these potentially overlooked requirements. In DFR (reliability), the team needs to understand the heavy use scenarios of the product and formulate criteria to ensure that the product can be tested and survive those vigorous conditions. In DFC (cost), the team needs to be able to size the design and select components that lead to the most cost effective solution. Why use a quad-core processor when a single core processor can do the job, unless there is a long term platform goal of leveraging the design for bigger more capable versions of the product. Regarding DFc (compliance), normally there is a whole host of compliance that need to be met in order for the product to be sold in certain countries. Some examples are FCC, CE, RHOS, CCC, and so on. More and more green and sustainability regulations are introduced every year. Therefore, the engineering team needs to work with a compliance expert to determine all the compliances the product will need to be certified and consequently the constraints placed on the design. The systems or lead engineer is normally a suitable person that maps out the DFx requirements to design and integration requirements.

C. Team Project

High performance teamwork is critical to successfully executing the plans and following the process. Therefore, students must learn and demonstrate teamwork ability. In class, each team will determine the product idea and manage it through the NPD process. There will be a list of reference projects that each team can choose from. This is ensure that the product is not too complex or simplistic such that it serves as reasonable vehicle for the team to progress it through the development phases and gates. If the class doesn't have students in marketing or operations, then the instructor can act in such role, or invite members from other department or industry to serve as stake holder members. The goal here is to simulate the NPD process and dynamics as closely to real world as possible while recognizing limitation of a class room environment.

III. CONCLUSIONS

Product development is ubiquitous and engineers need to understand the process and their roles beyond technical design. The process depicted in Figure 1 is fundamental and represents an industry-standard. We propose the NPD for Engineers course. Some of the key subjects covered are NPD process, systems engineering, DFx, and team projects. The complete syllabus is suggested in Table 1. The students will work in teams to take product ideas through the stage-gate process. By providing exposure and insight to product development best practices, we better prepare students for their role in the industry.

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