

Preface

The creation of a novel technological product always starts with an idea, a collection of more or less imprecise conceptions of how it should work, what it should look like, and why the market would appreciate it and thus might turn it into an economic success. This idea is usually driven by a customer. But customer does not necessarily mean the end user or consumer. The supply chain in markets for technological products is typically quite long. So in this book the customer could be a different department of a single legal entity or a technological integrator like an electronics manufacturer. In any of these scenarios the customer is the only one who has all the required knowledge concerning functionality and the constraints of the application area. This makes the customer the natural instance to be in charge of leading and guiding the process that turns his/her idea into a marketable product.

Between the idea of the customer and millions of copies of the physical product or device ready for sale and use, a usually lengthy period of time goes by. This period is characterized by creativity, complex decision processes, setbacks, and lots of money spent. In the automotive industry in Europe, for example, it takes about 5 years from the idea of a new car to start of production. In consumer electronics, although a market with an extreme greed for innovation, this process still takes 6 months to 1 year. The increasing dynamics of modern markets for technological products and devices requires this process to be as short as possible, free of errors and yielding cost-effective, safe, secure, and optimized products. This is possible only if the path from the idea to the final product is accompanied by a systematic, controlled, and safe product creation/product engineering process.

Product Engineering is a term that denotes this sort of systematic processes guiding and controlling product creation from the very idea to the final devices ready for sale. The effort involved in a specific product engineering process is highly sensitive to the functional complexity of the intended product, the involved collaboration partners along the value chain, and the technological complexity of the required fabrication facilities.

Two aspects of modern high-tech products take influence on the composition and the complexity of the product engineering process. The first aspect is that the fabrication of one product frequently makes use of several very diverse fabrication

methods. Today, in many cases not all of these methods are available at a production facility. In this case one product requires the cooperation of several fabrication facilities, generally available only from different specialized companies. The second aspect is a direct consequence of this requirement for cooperative fabrication: Each of the partners involved in the fabrication effort has dedicated knowledge concerning their specific fabrication capabilities. But no one of the partners has sufficient knowledge of the overall requirements of the usually complex product. This role has to be taken and driven by the customer giving the customer a key role in the product engineering process.

Distributed, customer-oriented product engineering is the process required for innovative complex technological products. This type of products is found in all areas that are commonly regarded as “high tech” today. This covers, for example, automotive and aerospace industries, information technology, and more and more new fields like biomedical or micro- and nanotechnology. The field of micro- and nanotechnologies (MNT) is a particularly well-suited example for an industry where customer-oriented, distributed product engineering processes are needed. MNT needs to cope with the increasing demand for shorter product engineering cycles while at the same time production makes use of the leading edge of the fast-developing fabrication capabilities. The origin of MNT fabrication is in microelectronics. There, for the last 50 years, a centralized product engineering scenario has reached a very high level of maturity. In this “classical” scenario one company, an Integrated Device Manufacturer (IDM), was in charge of the whole product engineering process from the idea to the shipped products. Two strands of progression in the last 15 years made this scenario at least partially obsolete. The first one is the strict adherence of the semiconductor industry to the famous Moore’s Law driving the feature sizes of electronics devices continually deeper into the nanometer range. This calls for extremely sophisticated fabrication facilities that demand investments that are frequently beyond the capabilities of classical IDM microelectronics suppliers. The business model of pure play foundries at the rear end of the product engineering process has becoming more and more popular. In that model pure play foundries perform only high-volume fabrication using one manufacturing technology for diverse customers. The fabless (fablight) design houses at the front end turn product ideas into a set of appropriate inputs (specs, mask designs, etc.) for volume fabrication at the pure play foundries. This is the first step towards a distributed product engineering scenario. The second relevant progression is the increasing demand for heterogeneous integration. Many of today’s technological products offer functionality that requires sensors, electronics, and actors to be integrated into one single system. Products of this type are generally addressed as *micro electro mechanical systems (MEMS)*. The issue here is that sensors, actors, and electronics are usually based on different fabrication technologies. This leads to product engineering scenarios where fabrication is distributed among different companies, each one specialized in either sensors or actors or electronics fabrication. With assembly, packaging, and test of the products yet performed by other specialized companies, product engineering efforts are distributed among a large group of different parties.

Research and development efforts performed in the authors' companies and institutes during the last decade were dedicated to the problem of finding a generic methodology for customer-oriented, distributed product engineering of MNT products. The research effort culminated in the cooperative project Customer-oriented product engineering of micro and nano devices (CORONA). The project was funded by the European Commission in the 7th research framework programme (grant agreement CP-FP 213969-2). The project was conducted from 2008 to 2011 by 9 partners from 5 European countries as indicated in the acknowledgments. The goals of the project were threefold. First was defining, implementing, and optimizing a generic methodology for distributed, customer-oriented product engineering in MNT, based on established baseline methodologies from other fields and on first methodological results obtained from previous research by the authors. The second goal of the project was developing software tools to support the execution of the methodology. The third goal was to prove the applicability of the methodology by real-life demonstrators. This book is the central result of the methodology work done in the CORONA project.

This book is intended for every person who takes an active role in either doing product engineering or teaching how to do it. This includes project and product management staff or program management offices in companies practicing innovation projects, every person active in doing innovation, as well as professors and students in engineering and management.

The book covers customer-oriented, distributed product engineering in the area of MNT. The methodology, however, is generic in wide areas and is also applicable to high-tech industries other than MNT. With some domain-specific modifications the methodology even appears useful as a baseline in other industrial areas where distributed and/or customer-oriented engineering is or becomes common.

Guide to the Book

This book addresses all persons interested in product engineering no matter what their professional background is. However, the book presents product engineering in a very specific setting. It thus consists of an introductory part that attempts to provide all the necessary background knowledge for everyone to be able to understand and appreciate the further chapters that treat the methodology and its application. In detail the book is organized as follows:

Part I is intended to pave the path to the book for every interested reader, especially for those who are not familiar with the field of MNT. It introduces the application area that has been selected to develop the product engineering methodology presented in the further chapters.

- *Chapter 1* gives an introduction to the MNT industry, market, and supply chain. It shows the specific properties of the market, shows, in a comprehensive manner, how MNT product engineering basically works, and introduces the challenges

and goals of a formal product engineering methodology for this area. In this manner a lean and comprehensive introduction to all areas touched in the remaining chapters is given.

- *Chapter 2* is dedicated to the term “product engineering” as it is understood by the authors. It gives definitions of terms and describes the essentials of how to perform innovation and the engineering of new products. The methodology that will be described in detail in Chap. 5 is derived from several baseline methods. Some of them like Stage-Gate® or PRINCE2® are common and have been in use in other application areas than MNT for quite some time, other ones like the T²M methodology have been introduced by the authors. The chapter gives a very brief introduction to various possible baseline methods and to the original literature that covers these methods in all required detail. It furthermore gives reasons why specific baseline methods have been selected as foundations for the new methodology presented in Chap. 5.
- *Chapter 3* covers micro and nano systems. This chapter is essential for readers with little or no background in this field. Micro- and nano systems have been used as the application area for which the methodology presented in this book has been optimized. To be able to fully understand and appreciate the specifics of the new methodology, a minimum understanding about MNT is necessary. The chapter gives a brief and easy-to-understand introduction to micro- and nano systems, how they work, how they are produced, and who is involved in creating this sort of products. The interested reader is guided to more elaborate texts on this topic in a comprehensive reference to the relevant literature.

Part II of the book covers MEMS product engineering in detail from three different perspectives. It is the central part of the book that introduces the reader to all relevant details of MEMS engineering processes and the formal methodology on how to conduct them, which the authors developed and implemented in their research work.

- *Chapter 4* addresses MEMS product engineering from the teams’ point of view. It introduces the reader to the various tasks that have to be performed during a typical product engineering process. It covers the aspects of device design, technology design, and quality management. It shows why MEMS require a distributed product engineering approach and why it is essential to put the customer in charge of this process. It furthermore gives examples of how and why software support is utilized when conducting MEMS product engineering projects.
- *Chapter 5* gives a thorough introduction to the product engineering methodology developed by the authors during the CORONA project. After an overview of the method and how it is composed from various building blocks it dives deep into all the details that are necessary to understand the methodology and to use it as a blueprint to set up an arbitrary product engineering project in the area of MNT.
- *Chapter 6* again changes the point of view and takes the perspective of the practical application of the methodology. It gives an overview of where and why it is required to have extensive tool support to perform product engineering

projects based on the methodology. It describes the main ingredients that are necessary to build up an appropriate software infrastructure for MEMS product engineering. However, it does not give recommendations to specific software packages to be used. This decision is intentionally left to the reader and user of the methodology as it is usually dependent on company policies and given software infrastructures.

Part III of the book is dedicated to the industrial product engineering practice. It only consists of *Chap. 7* that gives an overview of a practical product engineering endeavor that has been performed in a real-life distributed product engineering project by the authors. This project has served as a demonstrator within the CORONA project. It gives a very clear indication of the usefulness of distributed engineering for real-life MNT products with the customer in charge of the product engineering process. In this manner it can serve at the same time as evidence for the efficiency and effectiveness of the methodology presented in *Chap. 5* and as a practical guide on how to set up a product engineering endeavor based on this methodology.

Sect. 8 finally complements *Chap. 5* by giving more details of the project management sequences, the steps of the processes and their dedicated inputs, and outputs required when conducting a MEMS product engineering project.

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MEMS Product Engineering

Handling the Diversity of an Emerging Technology. Best
Practices for Cooperative Development

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