Engineering and Product Development Management

Engineering and Product Development Management is a practical guide to the components of engineering management, using a holistic approach. It will help engineers and managers understand what they must do to improve the product development process by deploying new technology and new methods of working in concurrent teams. The book takes elements from six well-known and understood bodies of knowledge and integrates them into a holistic approach: integrated product development, project management, process management, systems engineering, product data management, and organizational change management. These elements are framed within an overall enterprise-wide architecture.

The techniques discussed in this book work for both huge multinational organizations and smaller enterprises. The emphasis throughout is on practical tools that will be invaluable for engineers, managers, and consultants responsible for project and product development.

Stephen C. Armstrong is founder and president of AMGI Management Group Inc, an international operations and technology management consulting firm. He combines the business experience of a Certified Management Consultant and the technical rigor of a Professional Engineer with the practicality of a five year aeronautical engineering apprenticeship. Born in Belfast, he completed his apprenticeship in Northern Ireland with Short Brothers Aircraft, and completed a BSc Hons Mechanical Engineering degree in England at the University of Westminster – Polytechnic of Central London. Since 1981, he has worked as a design and manufacturing engineer and as a manufacturing engineering manager in North America, spending six years at KPMG as a principal management consultant specializing in advanced manufacturing systems. A consultant to some of the world's largest aerospace companies, including Lockheed Martin, de Havilland, British Aerospace, Bombardier, and Messier Dowty, Mr. Armstrong and his firm specialize in transforming business by focusing on Integrated Product Development/Collaborative Product Commerce. Their website can be found at www.amgimanagement.com. Mr. Armstrong's email address is amgi@amgimanagement.com.

Engineering and Product Development Management

The Holistic Approach

Stephen C. Armstrong
PEng, CEng, MIMechE, CMC
AMGI Management Group, Inc.

CAMBRIDGE UNIVERSITY PRESS

CAMBRIDGE UNIVERSITY PRESS
Cambridge, New York, Melbourne, Madrid, Cape Town, Singapore, São Paulo

Cambridge University Press
The Edinburgh Building, Cambridge CB2 2RU, UK

Published in the United States of America by Cambridge University Press, New York

www.cambridge.org
Information on this title: www.cambridge.org/9780521790697

First published 2001
This digitally printed first paperback version 2005

A catalogue record for this publication is available from the British Library

Library of Congress Cataloguing in Publication data
Armstrong, Stephen C.
Engineering and product development management : the holistic approach /
Stephen C. Armstrong.
p. cm.
ISBN 0-521-79069-7
1. Production management. 2. Production engineering. 3. New products. I. Title.
TS155 .A683 2001
658.5 – dc21 00-064218

ISBN-13 978-0-521-79069-7 hardback
ISBN-10 0-521-79069-7 hardback

ISBN-13 978-0-521-01774-9 paperback
ISBN-10 0-521-01774-2 paperback

Contents

List of Figures and Tables

Forewords

The vision of engineering management presented by Stephen Armstrong is one that is both broad in its context and deep in its coverage. He offers the engineering project manager an extensive set of management tools that, when used in total, will assure project success while improving overall project engineering effectiveness. Managers that employ this methodology will soon find this to be their indispensable desktop reference manual as they progress through the phases of product development.

The demands on the modern engineering manager are greater than they have ever been and the challenges to program success continue to grow exponentially. The rapid growth of technology has resulted in most of the products being developed by current and future companies – large and small – being inordinately complex systems of integrated technologies. This complexity is exacerbated by the complicated interdependencies among the technologies of the various product components. The availability of highly capable e-design, e-analysis, and e-prototyping tools and the growth in new methods that better integrate design and manufacturing are both wonderful benefits and potential burdens to the engineering teams using them. The move to virtual prototyping changes the planning and staffing profiles from that of the traditional project engineering organization. Added to these changes are the increasing demands for shorter and shorter engineering span times accompanied by the further expectation that engineering costs must be reduced by factors of 30 to 50 percent for businesses to remain competitive, and in some cases these reductions are expected to be recurring. These factors bring additional uncertainties and risk to an activity that has traditionally been risky.

Given this backdrop, Stephen Armstrong urges us to view the engineering management problem from a different perspective from what has been offered before. Engineering managers should adopt a total perspective of the problems that they have facing them. Even though they divide the work along the logical lines of work breakdown, they must also undertake the effort with the right tools and processes to ensure success. At the core of these processes are the ones that provide a logical and systematic definition of workflow and that provide the mechanisms to control and manage risk. Because an engineering effort is simply

the maturation of information, understanding the flow of information and the management of it is critical to success. We are also cautioned that the answers to good engineering management are more than just technical or administrative. The engineering manager must recognize that his or her primary resource is people and must provide a human side to the management of engineering teams.

The managers who read this book will find the formula for successful projects. They will find useful management methods – a pattern starts to unfold and the powerful concept of an integrated technical management will form. Their approach to successful engineering management will never be the same.

Dr. Woody Sconyers, PhD
Director, Virtual Product Development
Lockheed Martin Tactical Aircraft Systems
Fort Worth, Texas

Stephen Armstrong has presented a holistic and structured approach to engineering management. It is customer focused, dealing with processes, people, communication, and their working relationships. This approach is comprehensive and offers the engineering executive an extensive and structured methodology that brings together an integrated team to enable extraordinary project success in terms of quality, cost, and schedule.

I was introduced to a holistic view of engineering management through Stephen Armstrong. This approach was first implemented at Bombardier de Havilland on the Lear 45 Wing Program with great success. Later, Bombardier Aerospace used a holistic philosophy and applied it corporation-wide. With the implementation of this management methodology, it has developed into their superb Bombardier Engineering System. It is currently being applied on new Bombardier programs such as the BD100 Continental jet.

Twenty-first-century customers are becoming significantly more sophisticated and are demanding shorter and shorter product development times, higher quality, more product performance, and lower cost. This is an ongoing challenge. The product must meet design expectations the first time. Today, customers are virtually demanding zero tolerance. To add to this challenge, new products are being developed more and more by corporate consortiums and partnerships that are faced not only with developing their components but with integrating them into the final product. Most of this is now being done with e-tools. Not only are e-tools subject to their own continuous development, but they must also be integrated with partners who are faced with a continuous training program to use these tools. The risks are increasing dramatically, and the complexity of managing all of this has become formidable indeed.

In this book, Stephen Armstrong presents a management methodology that will enable success with programs of all sizes. He takes the disciplines of integrated product development, project management, process management, systems engineering, product data management, and organizational change management and integrates them into a holistic approach for managing engineering and product development. He treats the most important constituent of a program – the people and the organizational culture. This methodology is documented in a simplified

way that can be easily understood and employed by all levels of management. Knowing and understanding the information flow, workflow, and human aspect is paramount for the success of any team.

Success will come to those who read and implement the methodologies presented in this book. The material is presented with a logical flow. It provides the breadth of knowledge and the tools needed. It will lead one to the structure, organization, and effective management of a team that will make the changes required.

Carl Gerard, P Eng, MSc Eng (Cranfield)
Vice-president Engineering 1992–7 (Retired)
Bombardier Aerospace de Havilland

Preface

As the frontiers of technology advance and the work of engineers takes on an increasingly important role in our economy, companies with effective product development and engineering processes will be poised to create value for their shareholders. Those without the will to improve engineering and product development processes will be destined to lag behind.

Our university engineering programs focus on graduating technically sound engineers. Students study the disciplines of structural design or fluid mechanics. However, in both North America and Europe, little attention is paid to teaching the practice of engineering management. Engineering programs typically contain a fourth-year course on engineering economics, where students are taught the mechanics of discounted cash flows and budgets. The courses do not deal with the challenges of managing complex engineering-driven companies. With this gap in the training of engineers, it should come as no surprise when a graduate engineer practices engineering for two or three years and then leaves the profession to take an MBA. Many of these bright young engineers cut all ties to engineering. However, MBA programs are not designed to create engineering managers. The best of them teach the integration of management disciplines to teach general management; however, the worst provide the engineer with little more than a few specialized tools to apply in the area of marketing or finance. Generally speaking, the practice of engineering management is not taught in our universities. It is not a major area of research and learning, but it is vitally important to the success of today's technically driven enterprises. This problem is being addressed. Courses are being added, and enrollment is strong. The research base is lean, but certainly this book will help to fill the void.

The engineering manager at all levels has a very complex task. Just as the general manager must integrate marketing, engineering, operations, and finance, the engineering manager has an equally broad, equally complex task. Many engineering departments have specialists who have developed knowledge of a specific element of technical management. However, in today's environment, the management team must be able to look at problems from a broad, holistic perspective. To be truly successful, engineering managers must learn to integrate the concepts of a broad area of technical management disciplines. The engineering manager

will need to mobilize his or her organization around this new approach. Only then will the goal of delivering new programs cheaper, faster, and with higher quality than ever before be realizable. In this book, the author takes elements from six well-known and understood bodies of knowledge and integrates them into a holistic approach for managing engineering. The disciplines of Integrated Product Development, Project Management, Process Management, Systems Engineering, Product Data Management, and Organizational Change Management are usually considered distinct, and often their implementation winds up with disastrous consequences. Never before has one integrated system been proposed to manage an engineering department from a holistic standpoint. The approach described in this book will help managers develop new products or improve existing ones faster, more cheaply, and with higher quality than ever before.

We believe that this book will provide you with the breadth of knowledge and the practical tools necessary to lead just such a change. Is this a daunting task? Perhaps, but we will address the changes required, with the same structured approach that we will learn to use to manage your new product development programs. Large problems will be broken down into manageable chunks, and suddenly they will seem very manageable indeed.

The author has been able to put a fine point on the problem after more than ten years as a consultant to large engineering organizations. In this practice, he has worked with the engineers on the CAD system improving a single workstep, all the way to the CEO in the boardroom setting a vision for an entire organization. This experience has given him a unique perspective on the problem we have just described. He knows intimately the individual management tools, but he also knows how to make them fit into a cohesive holistic plan that executives can describe but don't know enough details to implement.

The author has been involved in process management and integrated product development pretty much from its inception. In 1988–9 as a consultant for Ernst & Whinney, he facilitated the team that designed and implemented the integrated product development approach at McDonnel Aircraft in St. Louis, Missouri. McAir utilized this approach to conduct product improvements on both the Harrier and F-18 programs.

In 1991, Ernst & Whinney merged with KPMG Peat Marwick in Canada. And this led to a major business transformation assignment at Boeing de Havilland in Toronto. Bombardier Aerospace acquired de Havilland in 1992. The author received further assignments, which tended to be fundamental improvement projects to deliver step changes in organizational performance. During this time, the author left KPMG to found AMGI, the organization of which he is president today. His work at Bombardier led to the creation of the Bombardier Engineering System or BES. Building on the earlier work at McAir, the BES brought integrated cross-functional design teams to a traditional "over the wall" design engineering process. The greatest challenge on the BES was the aspect of managing organizational change within the project. The BES team fostered

a common process across three countries and four cultures. Each company had the pride of its engineering heritage, bolstered by a nationalistic pride that comes from being a "national aerospace company." Today, Bombardier has applied the BES successfully on the Regional Jet RJ700, on major components of the Lear 45 business jets, and on the new Dash 8–400 regional commuter aircraft.

The author completed several assignments at the world's major military aircraft manufacturers in the period from 1996 to 2000. He assisted in the development and deployment of integrated product development to several military aircraft programs. The concept of concurrent product and process development stuck with him and has helped set the basis of the processes surrounding collaborative projects involving several partners working on a single design.

Being involved with integrated product development from its inception provides a unique perspective. The U.S. defense industry moved quickly to implement IPD, with mixed results. Typically they were trying to drive IPD separate from the other dynamics within their organization.

AMGI switched focus and began to develop a holistic approach to engineering management. Many companies will pick an initiative from one of the common management approaches. They will attempt to implement integrated product development, project management process management, systems engineering, or product data management, often with disastrous consequences because the rest of the organization actively resists the change. The holistic approach described here is unique, however, because it makes sense. Of course, new cross-functional processes are needed to support the implementation of cross-functional teams, but change of this magnitude takes vision and leadership to implement successfully. We believe that this book will provide the breadth of knowledge and the practical tools necessary to lead such a change. Top executives in most of the companies that the author has consulted have expressed their neglect of the human issues when deploying IPD or process management.

The approach documented here is a proven winner. It integrates the best thinking in the field of engineering management. Over the past ten years, we have had tremendous success putting our mark on the engineering processes of such successful engineering enterprises as Lockheed Martin Tactical Aircraft, British Aerospace Military Aircraft, Bombardier Aerospace, McDonnell Douglas, and Messier Dowty, as well as many smaller enterprises such as Ontario Store Fixtures.

This book aims to describe a straightforward model for organizing and running an engineering program and to suggest guidelines for selecting and dealing with the most important ingredient in any program, its people, and the collective organizational culture.

With the birth of e-engineering, many smaller companies are examining their product development processes. The danger is that they will fall into the trap of developing a purely electronic process. We believe that the approach we outline in this book is a prerequisite for making the move to electronic, collaborative projects. The book does not dwell on technology. Instead, it deals with people,

politics, processes, and management. No technological solution will succeed if it does not consider the impact that solution will have on people. Electronic file sharing is useless if no one knows who has the authority to approve a drawing, or worse yet if the previous signatory is upset that a "team" now triggers the sign-off. These are the issues we deal with in this book. Software teams will get the electronic system up and running. Only a leader with a broad vision can make it work.

Acknowledgments

This book is based on the experience the author gained from apprenticeship in the 1970s through to the management consulting assignments performed from 1988 to 2000. Many special people have influenced, inspired, and encouraged the author to improve constantly both personally and professionally. And others in senior executive leadership positions have had the courage to risk adapting new management systems. They did this despite resistance from the established culture. Many years after an innovation is launched the original pioneers are often forgotten in the politics of change, but they are the true leaders. The following people deserve special thanks for their efforts. I am a better person for knowing them.

Technical Editing

Jim Saunders, Professional Engineer and Business Executive, for editing the book through three versions since 1997. His in-depth practical understanding of IPD and engineering management made the book possible. Jim led the original design of the Bombardier Engineering systems as an employee at de Havilland and fostered the adaptation of BES to the corporate level (1993–6).

Manuscript Typing and Layout

Jaswinder Dehal for typing endless modifications to the manuscripts from 1998 to 2000. Her precision, dedication to get the job done on time, and quality of work have been a blessing.

Jan Bowins for typing the manuscript from 1996 to 1998.

Marlene Warnysky for typing the initial manuscript from 1993 to 1996.

Consulting Assignments

Messier Dowty, Toronto, Canada, 1995–2000

Ken Laver, President, for being an executive with vision and the wisdom to adapt advanced process management methods throughout the Canadian operations of the Messier Dowty enterprise. As President of de Havilland

in 1993, he sowed the original seed that led to the Bombardier Engineering System. This was later sponsored by the new President Gaston Hebert. The original sponsors of a successful change initiative are often forgotten years after it has become a way of life in a company.

Lockheed Martin Tactical Aircraft Systems, Fort Worth, Texas, 1997–2000

Dr. Woody Sconyers, Director, Virtual Product Development, and Dr. Jack Garner, Manager, Engineering Processes, for leadership in pushing the integration of process management with Virtual Product Software tool development. Dr. Sconyers provided valuable input into this book as a reviewer.

Computer Science Corporation, Cincinatti, Ohio, and Dallas, Texas, 1996–8

David Howells, Partner, for having faith in my work by introducing me to two major aerospace clients and supporting my work. In addition, Dave provided valuable input into this book as a reviewer. My work with Dave originated on the McDonnel Aircraft IPD project in 1989. And since then he has become an authority in engineering systems in the United States.

Bombardier Aerospace – de Havilland, Toronto, Canada, 1991–6

Carl Gerrard, Vice President, Engineering, for demonstrating leadership and adapting process management in engineering and product development for the first time in the company's history. This was so successful it became a corporate initiative and later an institutionalized system.

Jan McDonald, BES Coordinator, for her commitment, enthusiasm, and process excellence and for coordinating the development of BES in the early stages.

Jim Schwalm, President, for outstanding leadership in operations management and for initiating a business transformation program. His vision and hands-on approach have had an impact on Bombardier long after he was gone.

British Aerospace, Military Aircraft Division, Warton, Lancashire, UK, 1996–9

Ross Bradley, Director, Eurofighter and the OEI Transformation Program, for showing leadership in questioning the status quo and for embracing the need to address the softer human issues in process management, particularly with the Integrated Product Development initiative.

McDonnel Aircraft, St. Louis, Missouri, 1988–9

Bob Riley, Chief Program Engineer, AV8B Harrier Program, for being an inspiration when we developed the IPD approach for McAir. This was a first in the aerospace industry. The work at McDonnel Aircraft was the seed for the development and implementation of integrated product

development systems at both British Aerospace Military Division and Bombardier Aerospace.

Employers

KPMG – Peat Marwick Stevenson and Kellogg (formerly Ernst & Whinney), Toronto, Canada, 1988–93

George Russel, Partner, for coaching me in the practice of management consulting and through the Certified Management Consulting (CMC) process. He is a truly outstanding mentor in the profession and I was blessed to have worked with him.

Ernst & Whinney, Cleveland, Ohio, 1988–9

Larry Michaels, Senior Manager, for coaching me in my first major aerospace consulting assignment at McDonnel Aircraft. This was truly an inspiring project and my first at applying the IPD philosophy in engineering and product development.

BBC Brown Boveri, Toronto, Canada, 1983–6

Roland Knoblauch for coaching and mentoring me in my first job in manufacturing systems and for learning the MRP II philosophy. This was a major career shift from engineering design to management.

Short Brothers Ltd., Belfast, Northern Ireland, 1972–7

Liam Begley, Senior Tool Development Engineer, for mentoring me through my apprenticeship when I moved from the shop floor into the manufacturing engineering technical department.

A. B. Treacher, Chief Planning Engineer, and Ernie Crone, Planning Engineer, for encouraging me to continue my studies and inspiring me to study engineering at the university level. I am indebted.

Publishers

Dr. Philip Meyler, Senior Commissioning Editor, Cambridge University Press, Cambridge, England, for helping me through the initial preparation phase of the publishing process.

Milicent Trealor, Editor, Society of Manufacturing Engineers, for encouraging me to approach Cambridge University Press and for coaching me through the process.

Family

Various family members in both Northern Ireland and the United States for providing me with a solid foundation in which to carry out my work and for showing faith in me throughout the years. Many are deceased but will never be forgotten.

Layout of Book at a Glance

Part 1 – Learn the underlying body of knowledge
Part 2 – Learn the tools and techniques of engineering management
Part 3 – Learn how to make use of this knowledge in your organization and overcome resistance

PART 1 – UNDERSTANDING ENGINEERING PROCESS MANAGEMENT

1 – THE HOLISTIC APPROACH TO MANAGING ENGINEERING OPERATIONS
- Bodies of Knowledge
- The Holistic Approach
- IPD Philosophy
- The Integrated Enterprise Framework

2 – AN OVERVIEW OF ENGINEERING PROCESS MANAGEMENT
- Process Decomposition
- Customer Deliverables
- Maturity Gates
- Process Maturity

3 – ORGANIZATION OF ENGINEERING TASKS
- Tracking System
- Integrated Master Plan
- Integrated Master Schedule
- Work Plan Templates

PART 2 – APPLYING ENGINEERING PROCESSES TO PROGRAM MANAGEMENT

4 – ROLES AND RESPONSIBILITIES
- Customer
- Sponsor
- Project Manager
- Partner
- Functions
- IPTs

5 – APPROACH TO PROGRAM AND PROJECT MANAGEMENT
- Program Office
- Framework
- Success Factors
- Soft Side
- Program Modules
- Hard Side

6 – AN INTEGRATED TEAM MEMBER'S GUIDE TO PERFORMING A TASK
- IPT Member Responsibilities
- Work Products
- Performing Tasks

7 – PROGRAM STRUCTURING AND PLANNING
- Approach/Benefits
- Integrated Master Plan
- Structuring
- Tailoring
- Review Plan

8 – RISK ASSESSMENT
- Performing an Assessment
- Strategies for Risk Management

9 – PROGRAM INITIATION AND EXECUTION
- Setting Goals
- Environment
- Training
- Work Management
- Team Management
- Re-planning

10 – PROGRAM REVIEWS
- Q & A Factors
- Q & A in IPD
- Tailoring
- Review Process
- Measuring Quality
- Review Board

11 – ENGINEERING CHANGE AND PDM
- Engineering Change Concepts
- Engineering Change Process
- PDM Concepts/Benefits/Justification

PART 3 – DEPLOYING ENGINEERING PROCESS MANAGEMENT

12 – ORGANIZING FOR DEPLOYMENT
- Program Organization
- Charter & Objectives
- External Consultant
- Budgeting
- IPD Plan
- Sector v. Corporate

13 – OVERCOMING RESISTANCE TO CHANGE
- Political Management
- Overcoming Resistance to Change Approach
- Adapting Teams
- Leadership Behaviors
- Obstacles to Effectiveness

14 – IMPLEMENTING IPD – LESSONS LEARNED CASE STUDY
- Leadership
- Roles & Responsibilities
- IPT Setup
- Communications
- Decision Making
- Team Skills & Training