

# Concurrent Engineering in the 21st Century

Josip Stjepandić · Nel Wognum  
Wim J.C. Verhagen  
Editors

# Concurrent Engineering in the 21st Century

Foundations, Developments and Challenges



Springer

*Editors*

Josip Stjepandić  
3D Product Creation  
PROSTEP AG  
Darmstadt  
Germany

Wim J.C. Verhagen  
TU Delft  
Delft  
The Netherlands

Nel Wognum  
Social Sciences Department, Management  
Studies Group  
Wageningen University  
Wageningen  
The Netherlands

ISBN 978-3-319-13775-9

ISBN 978-3-319-13776-6 (eBook)

DOI 10.1007/978-3-319-13776-6

Library of Congress Control Number: 2014956561

Springer Cham Heidelberg New York Dordrecht London

© Springer International Publishing Switzerland 2015

This work is subject to copyright. All rights are reserved by the Publisher, whether the whole or part of the material is concerned, specifically the rights of translation, reprinting, reuse of illustrations, recitation, broadcasting, reproduction on microfilms or in any other physical way, and transmission or information storage and retrieval, electronic adaptation, computer software, or by similar or dissimilar methodology now known or hereafter developed.

The use of general descriptive names, registered names, trademarks, service marks, etc. in this publication does not imply, even in the absence of a specific statement, that such names are exempt from the relevant protective laws and regulations and therefore free for general use.

The publisher, the authors and the editors are safe to assume that the advice and information in this book are believed to be true and accurate at the date of publication. Neither the publisher nor the authors or the editors give a warranty, express or implied, with respect to the material contained herein or for any errors or omissions that may have been made.

Printed on acid-free paper

Springer International Publishing AG Switzerland is part of Springer Science+Business Media (www.springer.com)

*The editors of this book wish to dedicate its revenues to foundations that support high-potentials in achieving goals that would not have been possible otherwise. Referring to biographies of great scholars, with their achievements and contributions to humanity and science, we often do not realize that many of them experienced financial problems during their studies, which only could be solved with scholarships and grants. One of such foundations is the Foundation Fra Bonifacije Ivan Pavletić ([www.zaklada.biskupija-sisak.hr](http://www.zaklada.biskupija-sisak.hr)) from Sisak, Croatia, which is dedicated to financially aiding high-potentials with heavy financial needs.*



# Acknowledgments

The editors, Josip Stjepandić, Nel Wognum, and Wim J.C. Verhagen, sincerely thank the Board of Management of PROSTEP AG for its permission to produce the book by providing time and resources. Special thanks also go to PROSTEP colleagues who have provided support in adapting phrasing and English and improving graphical displays, in particular Ulrike Langer, Jonas Moeljadi, and Hannes Volz. They also thank their families for their support for spending so much time to the book.

# Contents

<b>1</b>	<b>Introduction to the Book</b> . . . . .	<b>1</b>
	Josip Stjepandić, Nel Wognum and Wim J.C. Verhagen	
<b>Part I Foundations</b>		
<b>2</b>	<b>The System of Concurrent Engineering</b> . . . . .	<b>21</b>
	Nel Wognum and Jacques Trienekens	
<b>3</b>	<b>Complex Engineering Programs as Sociotechnical Systems</b> . . . . .	<b>51</b>
	Bryan R. Moser and Ralph T. Wood	
<b>4</b>	<b>Technology Foundations</b> . . . . .	<b>67</b>
	Michael Sobolewski	
<b>Part II New Developments and Methods</b>		
<b>5</b>	<b>Requirements Engineering</b> . . . . .	<b>103</b>
	Stefan Wiesner, Margherita Peruzzini, Jannicke Baalsrud Hauge and Klaus-Dieter Thoben	
<b>6</b>	<b>Resolving Interoperability in Concurrent Engineering</b> . . . . .	<b>133</b>
	Nicolas Figay, Catarina Ferreira da Silva, Parisa Ghodous and Ricardo Jardim-Goncalves	
<b>7</b>	<b>Collaborative Engineering</b> . . . . .	<b>165</b>
	Milton Borsato and Margherita Peruzzini	
<b>8</b>	<b>Design of Complex Programs as Sociotechnical Systems</b> . . . . .	<b>197</b>
	Bryan R. Moser and Ralph T. Wood	

<b>9</b>	<b>Systems Engineering</b> . . . . .	221
	Alain Biahmou	
<b>10</b>	<b>Knowledge-Based Engineering</b> . . . . .	255
	Josip Stjepandić, Wim J.C. Verhagen, Harald Liese and Pablo Bermell-Garcia	
<b>11</b>	<b>Product Lifecycle Visualization</b> . . . . .	287
	Alfred Katzenbach, Sebastian Handschuh, Rudolf Dotzauer and Arnulf Fröhlich	
<b>12</b>	<b>Reverse Engineering</b> . . . . .	319
	Goran Šagi, Zoran Lulić and Ivan Mahalec	
<b>13</b>	<b>Digital Mock-up</b> . . . . .	355
	Roberto Riascos, Laurent Levy, Josip Stjepandić and Arnulf Fröhlich	
<b>14</b>	<b>Modularity and Supporting Tools and Methods</b> . . . . .	389
	Josip Stjepandić, Egon Ostrosi, Alain-Jérôme Fougères and Martin Kurth	
<b>15</b>	<b>Multidisciplinary Design Optimization: Designed by Computer</b> . . . . .	421
	Cees Bil	
<b>16</b>	<b>Product Lifecycle Management</b> . . . . .	455
	Lutz Lämmer and Mirko Theiss	
<b>17</b>	<b>Variability Management</b> . . . . .	491
	Georg Rock, Karsten Theis and Patrick Wischnewski	
<b>18</b>	<b>Intellectual Property Protection</b> . . . . .	521
	Josip Stjepandić, Harald Liese and Amy J.C. Trappey	
 <b>Part III Applications</b>		
<b>19</b>	<b>Challenges to Digital Product and Process Development Systems at BMW</b> . . . . .	555
	Dietmar Trippner, Stefan Rude and Andreas Schreiber	
<b>20</b>	<b>Concurrent Engineering and Integrated Aircraft Design</b> . . . . .	571
	Richard Curran, Xiaojia Zhao and Wim J.C. Verhagen	

<b>21</b>	<b>Automotive</b> . . . . .	607
	Alfred Katzenbach	
<b>22</b>	<b>Concurrent Engineering in Machinery</b> . . . . .	639
	Jožef Duhovnik and Jože Tavčar	
<b>23</b>	<b>Shipbuilding</b> . . . . .	671
	Kazuo Hiekata and Matthias Grau	
<b>24</b>	<b>Consumer Goods</b> . . . . .	701
	Chun-Hsien Chen, Li Pheng Khoo and Nai-Feng Chen	
<b>25</b>	<b>The Application of an Integrated Product Development Process to the Design of Medical Equipment</b> . . . . .	735
	Osiris Canciglieri Junior, Maria Lucia Miyake Okumura and Robert Ian Marr Young	
<b>26</b>	<b>Carbon Emission Analysis for Renewable Energy Policies</b> . . . . .	761
	Amy J.C. Trappey, Charles V. Trappey, Jerry J.R. Ou, C.T. Hsiao, Kevin W.P. Chen and Penny H.Y. Liu	
<b>27</b>	<b>Sustainable Mobility</b> . . . . .	779
	Alain Biahmou	
 <b>Part IV Current Challenges</b>		
<b>28</b>	<b>Challenges of CE</b> . . . . .	807
	Wim J.C. Verhagen, Josip Stjepandić and Nel Wognum	
	<b>Author Index</b> . . . . .	835
	<b>Subject Index</b> . . . . .	837



# Editors and Contributors

## About the Editors

**Dr. Josip Stjepandić** is the Head of business unit 3D Product Creation at PROSTEP AG, the leading product data integration company worldwide. After receiving his grade as M. Eng. from the University of Zagreb and Ph.D. from the University of Technology of Graz, he worked for two automotive suppliers in the areas of engineering simulation and design methodology. From 1994 to 1996, he was Associated Professor for Applied Informatics in Mechanical Engineering at the University of Applied Sciences Dortmund. Since 1996, he has been in charge of consultancy and solution development at PROSTEP AG in the areas of design methodology, supplier integration, systems engineering, knowledge-based engineering, product data validation and visualization, configuration management, and CAD data exchange for many industries (automotive, aerospace, shipbuilding, machinery). One of his most important contributions is the multiply awarded global supplier portal [OpenDESC.com](http://OpenDESC.com). His current research is focused on systems engineering, modular design, and digital factory.

**Dr. Nel Wognum** received her Master's degree in Medical Informatics from Leiden University and her Ph.D. in Knowledge-Based Systems from University of Twente in The Netherlands. She has been Assistant Professor in University of Twente, first in knowledge-based systems, later in organization and management studies. Her field of interest has since long been the interaction between various dimensions, disciplines, and functions, as in Concurrent Engineering. She was the President of ISPE from 2004 till 2006. Since 2007 she worked as a researcher in Wageningen University in the Management Studies Group in the field of supply chain management in the food area. Concurrent Engineering principles also apply to this field of study. She has authored and co-authored various publications in this field. Since the end of 2014, Nel Wognum is enjoying her retirement.

**Dr. Wim J.C. Verhagen** is Assistant Professor at the section of Air Transport and Operations, Faculty of Aerospace Engineering, Delft University of Technology. He obtained his M.Sc. and Ph.D. degrees at the same university. The focus of his early research has been on knowledge-based engineering systems in aircraft lifecycle

processes. In recent years, Dr. Verhagen's research has focused on aircraft maintenance research, including the development of Maintenance Information System (MIS) functionality using knowledge-based techniques. Furthermore, maintenance execution, spare parts management and logistics, as well as maintenance scheduling optimization are specific topics of interest. He has authored and co-authored a range of publications in the fields of knowledge-based engineering systems and aircraft maintenance.

## Contributors

**Pablo Bermell-García** EADS Innovation Works, Bristol, UK

**Alain Biahmou** EDAG Engineering AG, Fulda, Germany

**Cees Bil** RMIT University, Melbourne, VIC, Australia

**Milton Borsato** Federal University of Technology, Parana, Brazil

**Osiris Canciglieri Junior** Polytechnic School, Graduate Program in Production Engineering and Systems (PPGEPS), Pontifical Catholic University of Paraná (PUCPR), Paraná, Brazil

**Chun-Hsien Chen** School of Mechanical and Aerospace Engineering, Nanyang Technological University, Singapore, Singapore

**Kevin W.P. Chen** Department of Industrial Engineering and Management, National Taipei University of Technology, Taipei, Taiwan

**Nai-Feng Chen** School of Mechanical and Aerospace Engineering, Nanyang Technological University, Singapore, Singapore

**Richard Curran** Faculty of Aerospace Engineering, Air Transport and Operations, Delft University of Technology, Delft, The Netherlands

**Catarina Ferreira da Silva** LIRIS, UMR5205 CNRS, University of Lyon 1, Villeurbanne, France

**Rudolf Dotzauer** Continental, Ingolstadt, Germany

**Jožef Duhovnik** Faculty of Mechanical Engineering, University of Ljubljana, Ljubljana, Slovenia

**Nicolas Figay** EADS, Suresnes, France

**Alain-Jérôme Fougères** Université de Technologie de Belfort-Montbéliard, Belfort, France

**Arnulf Fröhlich** PROSTEP AG, Darmstadt, Germany

**Parisa Ghodous** LIRIS, UMR5205 CNRS, University of Lyon 1, Villeurbanne, France

**Matthias Grau** PROSTEP AG, Darmstadt, Germany

**Sebastian Handschuh** Daimler AG, Böblingen, Germany

**Jannicke Baalsrud Hauge** Bremer Institut für Produktion und Logistik GmbH (BIBA), University of Bremen, Bremen, Germany

**Kazuo Hiekata** University of Tokyo, Kashiwa, Chiba, Japan

**C.T. Hsiao** Department of Economics, Tunghai University, Taichung, Taiwan

**Ricardo Jardim-Goncalves** New University of Lisbon, Uninova, Lisbon, Portugal

**Alfred Katzenbach** Katzenbach Executive Consulting, Gaienhofen, Germany; University Stuttgart, Stuttgart, Germany

**Li Pheng Khoo** School of Mechanical and Aerospace Engineering, Nanyang Technological University, Singapore, Singapore

**Martin Kurth** RAYCE EURL, Lörrach, Germany

**Lutz Lämmer** PROSTEP AG, Darmstadt, Germany

**Laurent Levy** Airbus SAS, Toulouse, France

**Harald Liese** PROSTEP AG, Darmstadt, Germany

**Penny H.Y. Liu** Department of Industrial Engineering and Engineering Management, National Tsing Hua University, Hsinchu, Taiwan

**Zoran Lulić** Faculty of Mechanical Engineering and Naval Architecture, University of Zagreb, Zagreb, Croatia; Adolo 7 d.o.o., Zagreb, Croatia

**Ivan Mahalec** Faculty of Mechanical Engineering and Naval Architecture, University of Zagreb, Zagreb, Croatia; Adolo 7 d.o.o., Zagreb, Croatia

**Bryan R. Moser** Engineering Systems Division, Massachusetts Institute of Technology, Cambridge, MA, USA; Global Project Design, Boston, MA, USA

**Maria Lucia Miyake Okumura** Polytechnic School, Graduate Program in Production Engineering and Systems (PPGEPS), Pontifical Catholic University of Paraná (PUCPR), Paraná, Brazil

**Egon Ostrosi** Université de Technologie de Belfort-Montbéliard, Belfort, France

**Jerry J.R. Ou** Department of Business Administration, Southern Taiwan University, Tainan, Taiwan

**Margherita Peruzzini** Indesit Company S.p.A, Fabriano AN, Italy; Department of Industrial Engineering and Mathematical Sciences, Università Politecnica delle Marche, Ancona, Italy

**Roberto Riascos** PROSTEP AG, Darmstadt, Germany

**Georg Rock** Trier University of Applied Sciences, Trier, Germany

**Stefan Rude** BMW AG, Munich, Germany

**Goran Šagi** Faculty of Mechanical Engineering and Naval Architecture, University of Zagreb, Zagreb, Croatia; Adolo 7 d.o.o., Zagreb, Croatia

**Andreas Schreiber** BMW AG, Munich, Germany

**Michael Sobolewski** United States Air Force Research Laboratory, WPAFB, Dayton, OH, USA; Polish-Japanese Institute of Information Technology, Warsaw, Poland

**Josip Stjepandić** PROSTEP AG, Darmstadt, Germany

**Jože Tavčar** Faculty of Mechanical Engineering, University of Ljubljana, Ljubljana, Slovenia

**Karsten Theis** PROSTEP AG, Darmstadt, Germany

**Mirko Theiss** PROSTEP AG, Darmstadt, Germany

**Klaus-Dieter Thoben** Bremer Institut für Produktion und Logistik GmbH (BIBA), University of Bremen, Bremen, Germany

**Amy J.C. Trappey** Department of Industrial Engineering and Engineering Management, National Tsing Hua University, Hsinchu, Taiwan

**Charles V. Trappey** Department of Management Science, National Chiao Tung University, Hsinchu, Taiwan

**Jacques Trienekens** Social Sciences Department, Management Studies Group, Wageningen University, Wageningen, The Netherlands

**Dietmar Trippner** dreiconsult GbR, Landsberied, Germany

**Wim J.C. Verhagen** Faculty of Aerospace Engineering, Air Transport and Operations, Delft University of Technology, Delft, The Netherlands

**Stefan Wiesner** Bremer Institut für Produktion und Logistik GmbH (BIBA), University of Bremen, Bremen, Germany

**Patrick Wischnewski** Logic4Business GmbH, Saarbrücken, Germany

**Nel Wognum** Social Sciences Department, Management Studies Group, Wageningen University, Wageningen, The Netherlands

**Ralph T. Wood** Global Project Design, Boston, MA, USA

**Robert Ian Marr Young** Wolfson School of Mechanical and Manufacturing Engineering, Loughborough University, Loughborough, Leicestershire, UK

**Xiaojia Zhao** Faculty of Aerospace Engineering, Air Transport and Operations, Delft University of Technology, Delft, The Netherlands

# Used Trademarks

3CAD evolution	3CAD Consortium
Actify SpinFire	Actify
Altair Data Manager	Altair
ANSYS Engineering Knowledge Manager	ANSYS
Autodesk Streamline	Autodesk
CATIA	Dassault Systemes
Creo	Parametric Technology
DomusPlanner	Domus Planner
Enovia	Dassault Systemes
Google Sketch-up	Google
Google Sketch-up PRO	Google
iSIGHT	Dassault Systemes
LMS OPTIMUS	Siemens PLM Software
MATLAB/SIMULINK	MathWorks
Metron	Tesy Software
Mobilia	CE soft
NX	Siemens PLM Software
Oracle Autovue	Oracle
Pro/ENGINEER	Parametric Technology
SAP PLM	SAP
SimManager	MSC
SolidEdge	Siemens PLM Software
SolidWorks	SolidWorks
Sweethome3D	eTeks
Teamcenter	Siemens PLM Software
Windchill	Parametric Technology