

# SEI PRODUCT LINE BIBLIOGRAPHY

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## Introduction

A product line is a set of products that together address a particular market segment or fulfill a particular mission. Product lines are, of course, nothing new in manufacturing. Airbus builds one, and so do Ford, Dell, and even McDonald's. Each of these companies exploits commonality in different ways. Boeing, for example, developed the 757 and 767 transports in tandem, and the parts lists for these very two different aircraft overlap by about 60%, achieving significant economies of production and maintenance. But software product lines based on interproduct commonality are a relatively new concept that is rapidly emerging as a viable and important software development paradigm. Product flexibility is the anthem of the software marketplace, and product lines fulfill the promise of tailor-made systems built specifically for the needs of particular customers or customer groups. A product line succeeds because the commonalities shared by the software products can be exploited to achieve economies of production. The products are built from common assets in a prescribed way.

Organizations are finding that this practice of building sets of related systems from common assets can yield remarkable quantitative improvements in productivity, time to market, product quality, and customer satisfaction. They are finding that a software product line can efficiently satisfy the current hunger for mass customization. Organizations that acquire, as opposed to build, software systems are finding that commissioning a set of related systems as a commonly developed product line yields economies in delivery time, cost, simplified training, and streamlined acquisition.

But along with the gains come risks. Using a product line approach constitutes a new technical strategy for the organization. Organizational and management issues constitute obstacles that are critical to overcome and often add more risk, because they are less obvious. Building a software product line and bringing it to market require a blend of skillful engineering as well as both technical and organizational management. Acquiring a software product line also requires this same blend of skills to position the supplier organizations, so they can effectively exploit the commonality of the incoming products, as well as lend sound technical oversight and monitoring to the development effort. These skills are necessary to overcome the pitfalls that may bring failure to an unsophisticated organization.

This bibliography lists SEI and non-SEI resources that have informed the SEI Product Lines efforts. It includes examples of real software product lines listed in the Catalog of Software Product Lines. The examples cover diverse domains and show the kind of improvements your organization can achieve using a product line approach.

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## Catalog of Software Product Lines

Description	Cited Improvements
<b>AKVAsmart ASA</b>	
Fish farm feed control and management software	<ul style="list-style-type: none"><li>• Reduction of code size by more than 70%.</li><li>• Uniform look and feel.</li><li>• Common technological platform and code style.</li></ul>

Description	Cited Improvements
	<ul style="list-style-type: none"> <li>• Easier reuse, maintenance and integration</li> </ul> <p><i>Reference</i></p> <p>Frank van der Linden, Klaus Schmid, &amp; Eelco Rommes. Software Product Lines in Action, Springer, 2007, Ch. 8.</p>
<b>Argon Engineering</b>	
<p>Design and development of communication systems that search, identify, and capture signals. Sensor development, data collection and decision support, analysis and design of information retrieval and visualization technique</p>	<ul style="list-style-type: none"> <li>• Shorter development schedules</li> <li>• Lower development and upgrade costs</li> <li>• Lower total ownership costs</li> <li>• Support for an incremental development model</li> <li>• Shared technology costs</li> <li>• Best-in-class COTS/government off-the-shelf (GOTS) components</li> <li>• Continuous technology insertion</li> </ul> <p><i>Reference</i></p> <p>John Bergey, Sholom Cohen, Lawrence Jones, &amp; Dennis Smith. Software Product Lines: Experiences from the Sixth DoD Software Product Line Workshop</p>
<b>Asea Brown Boveri (ABB)</b>	
<p>Gas turbines, train control, Semantic Graphics Framework</p>	<ul style="list-style-type: none"> <li>• Shorter development time, higher code quality, cost savings</li> </ul> <p><i>Reference</i></p> <p>Klaus Pohl, Günter Böckle, &amp; Frank van der Linden. Software Product Line Engineering, Springer 2005, ch. 21.</p> <p>C. Ganz &amp; M. Layes. "Modular Turbine Control Software: A Control Software Architecture for the ABB Gas Turbine Family," Proceedings of the Second Intl. ESPRIT ARES Workshop, Springer LCNS 1429, 1998, pp. 32-38.</p> <p>A. Rösel. "Experiences with the Evolution of an Application Family Architecture," Proceedings of the Second Intl. ESPRIT ARES Workshop, Springer LCNS 1429, 1998, pp. 39-48.</p>

Description	Cited Improvements
	<p>W. Eixelsberger &amp; H. Beckman. "The TCS Experience with the Recovery of Family Architecture," M. Jazayeri, A. Ran, &amp; Frank van der Linden (eds.), Software Architecture for Product Families - Principles and Practice, Addison Wesley 2000, pp. 209-231.</p> <p>P. Stoll, L. Bass, E. Golden, &amp; and B. John., "Supporting Usability in Product Line Architectures," Proceedings SPLC 2009, San Francisco, August 2009.</p>
<b>Axis Communications AB</b>	
<p>Computer printer servers, storage servers, network camera and scanner servers.</p>	<p><i>Reference</i></p> <p>Jan Bosch. Design &amp; Use of Software Architectures, Addison Wesley, 2000.</p>
<b>Boeing</b>	
<p>Bold Stroke Avionics</p> <p>Boeing is a member of the Product Line Hall of Fame.</p>	<ul style="list-style-type: none"> <li>• Improved affordability, quality, and system timeliness</li> </ul> <p><i>References</i></p> <p>David C. Sharp. "Reducing Avionics Software Cost Through Component Based Product Line Development," Patrick Donohoe (ed.) Proceedings SPLC1, Kluwer Academic Publishers, 2000.</p> <p>Bryan S. Doerr &amp; David C. Sharp. "Freeing Product Line Architectures from Execution Dependencies," Patrick Donohoe (ed.) Proceedings SPLC1, Kluwer Academic Publishers, 2000.</p> <p>David C. Sharp. "Avionics Product line Software Architecture Flow Policies," Gateway to the New Millennium. 18th Digital Avionics Systems Conference. Proceedings, 1999, pt. 2, 9.C.4/8 pp. vol.2 ISBN: 0 7803 5749 3.</p> <p>M. Schulte. "Model-Based Integration of Reusable Component-Based Avionics Systems - A Case Study," Proceedings, Eighth IEEE International Symposium on Object-Oriented Real-Time Distributed Computing, 2005, 62-71 ISBN: 0 7695 2356 0.</p>

Description	Cited Improvements
	<p>Timothy J. Popp. "Software Architecture Development for Product Line Software," AIAA/IEEE Digital Avionics Systems Conference, October 1999.</p> <p>Klaus Pohl, Günter Böckle, &amp; Frank van der Linden. Software Product Line Engineering, Springer 2005, ch. 21.</p> <p>David C. Sharp. "Object Oriented Real-Time Computing for Reusable Avionics Software," Proceedings, ISORC 2001.</p> <p>Don Winter. "Modular, Reusable Flight Software for Production Aircraft," 15th AIAA/IEEE Digital Avionics Systems Conference, p. 40106, 1996.</p> <p>David C. Sharp. "Reducing Avionics Software Cost through Component Based Product Line Development," Software Technology Conference, 1998.</p>
<p><b>CelsiusTech</b></p> <hr/>	
<p>ShipSystem 2000 naval command and control</p> <p>CelsiusTech is a member of the Product Line Hall of Fame.</p>	<ul style="list-style-type: none"> <li>• Improved time to delivery, productivity, cost.</li> </ul> <p><i>References</i></p> <p>Len Bass, Paul Clements, &amp; Rick Kazman. Software Architecture in Practice, 2nd edition, Addison Wesley, 2003, Chapter 15.</p> <p>Lisa Brownsword &amp; Paul Clements. A Case Study in Successful Product Line Development (CMU/SEI-96-TR-016).</p> <p>Klaus Pohl, Günter Böckle, &amp; Frank van der Linden. Software Product Line Engineering, Springer 2005, ch. 21.</p>
<p><b>Cummins</b></p> <hr/>	
<p>Diesel engine controls</p> <p>Cummins is a member of the Product Line Hall of Fame.</p>	<ul style="list-style-type: none"> <li>• Greatly reduced time to market (~1 year vs. ~1 week).</li> <li>• Ability to quickly and effectively enter new markets.</li> <li>• Increased productivity.</li> <li>• Higher quality.</li> <li>• Higher responsiveness to customer needs.</li> </ul>

Description	Cited Improvements
	<p><i>References</i></p> <p>J. C. Dager. "Cummins' Experience in Developing a Software Product Line Architecture for Real-time Embedded Diesel Engine Controls," Patrick Donohoe (ed.) Proceedings SPLC1, Kluwer, 2000. Page: 23-46. ISBN: 0792379403.</p> <p>Paul Clements &amp; Linda Northrop. Software Product Lines: Practices and Patterns, Addison Wesley, 2001.</p> <p>Klaus Pohl, Günter Böckle, &amp; Frank van der Linden. Software Product Line Engineering, Springer 2005, ch. 21.</p>
<b>Danfoss Drives</b>	
<p>Frequency converters</p>	<ul style="list-style-type: none"> <li>• Simplified product production</li> <li>• Rapid introduction of new features; greater development efficiency</li> </ul> <p><i>References</i></p> <p>H. Jepsen, J. Dall, &amp; D. Beuche. "Minimally Invasive Migration to Software Product Line," Proceeding, SPLC 2007, Kyoto, September 2007, IEEE Computer Society.</p> <p>H. Jepsen &amp; D. Beuche. "Running a Software Product Line – Standing Still Is Going Backwards," Proceedings SPLC 2009, San Francisco, August 2009.</p>
<b>Deutsche Bank</b>	
<p>Financial global transaction and settlement</p>	<ul style="list-style-type: none"> <li>• \$4M/year cost savings</li> </ul> <p><i>Reference</i></p> <p>David Faust &amp; Chris Verhoef. "Software Product Line Migration and Deployment," Software - Practice and Experience 33, 10, Aug. 2003, 933-55.</p>
<b>Dialect Solutions</b>	
<p>Internet payment gateway infrastructure products</p>	<ul style="list-style-type: none"> <li>• Quality and predictability, development efficiency.</li> <li>• Defect fixes only developed once.</li> <li>• More rapid improvements in product quality.</li> </ul>



Description	Cited Improvements
	<ul style="list-style-type: none"> <li>• Configuration control branching reduced, productivity increased.</li> <li>• Customers upgraded to new major versions more efficiently.</li> <li>• New functionality added across whole family</li> </ul> <p><i>Reference</i></p> <p>M. Staples &amp; D. Hill. "Experiences Adopting Software Product Line Development Without a Product Line Architecture," Proceedings. 11th Asia-Pacific Software Engineering Conference, 2004, 176-83 ISBN: 0 7695 2245 9.</p>
<p><b>DNV Software</b></p> <hr/> <p>Software products and customized solutions for transportation industries</p>	<ul style="list-style-type: none"> <li>• Reduction of service needs.</li> <li>• Elimination of administrative tasks.</li> <li>• Uniform look and feel.</li> <li>• Easier reuse, maintenance and integration.</li> </ul> <p><i>Reference</i></p> <p>Frank van der Linden, Klaus Schmid, &amp; Eelco Rommes. Software Product Lines in Action, Springer, 2007, Ch. 10.</p>
<p><b>E-COM Technology Ltd.</b></p> <hr/> <p>Medical imaging workstations</p>	<ul style="list-style-type: none"> <li>• Improved cost, time to market, productivity</li> <li>• Developing and deploying a system in a week</li> </ul> <p><i>Reference</i></p> <p>Liang Liang, Zhiqiang Hu, &amp; Xiangyun Wang. "An Open Architecture for Medical Image Workstation," Progress in Biomedical Optics and Imaging - Proceedings of SPIE, v 5748, Medical Imaging 2005 - PACS and Imaging Informatics, 2005, p. 470-479, ISSN: 1605-7422.</p>
<p><b>Enea</b></p> <hr/> <p>OSE real-time operating system for telecom and automotive applications and Element middleware</p>	<p><i>Reference</i></p> <p>J. Andersson &amp; J. Bosch. "Development and Use of Dynamic Product-Line Architectures," IEE Proceedings-Software 152, 1, 7 Feb. 2005, pp. 15-28 ISSN: 1462-5970.</p>

Description	Cited Improvements
<b>Ericsson</b>	
<p>AXE family of Telecommunications Switches</p> <p>Ericsson is a member of the Product Line Hall of Fame.</p>	<ul style="list-style-type: none"> <li>• Adaptability to change and evolution.</li> </ul>
<b>Ericsson</b>	
<p>Telecom network nodes providing packet data services for mobile networks</p>	<ul style="list-style-type: none"> <li>• Significantly lower number of defects and code modifications</li> </ul> <p><i>Reference</i></p> <p>Parastoo Mohagheghi &amp; Reidar Conradi. "An Empirical Investigation of Software Reuse Benefits in a Large Telecom Product," ACM Transactions on Software Engineering and Methodology 17, 3, 2008.</p>
<b>Ericsson Mobile Data Design</b>	
<p>DPE systems for packet based mobile communication</p>	<p><i>Reference</i></p> <p>J. Andersson &amp; J. Bosch. "Development and Use of Dynamic Product-Line Architectures," IEE Proceedings-Software, 152, 1, 7 Feb. 2005, pp. 15-28 ISSN: 1462-5970, IEE, UK.</p>
<b>Eurocopter</b>	
<p>Avionics software for multi-role NH90 helicopter</p>	<ul style="list-style-type: none"> <li>• Ability to cope with high number of software variants and technology (platform) variations</li> </ul> <p><i>Reference</i></p> <p>F. Dordowsky &amp; W. Hipp. "Adopting Software Product Line Principles to Manage Software Variants in a Complex Avionics System," Proceedings SPLC 2009, San Francisco, August 2009</p>
<b>General Motors Powertrain</b>	
<p>Software for engines, transmissions, and controllers</p> <p>General Motors Powertrain is a member of the Product Line Hall of Fame.</p>	<ul style="list-style-type: none"> <li>• Supporting product variation</li> <li>• Reduced time to market</li> <li>• Eliminating redundant resources</li> </ul> <p><i>Reference</i></p> <p>Cheryl Williams. "Algorithms, Algorithm Modeling, Software, and Software Architecture."</p>

Description	Cited Improvements
	Viewgraph presentation, www.eecs.umich.edu/courses/eecs486 /win03/notes/GMVisit.pdf
<b>Hewlett Packard</b>	
<p>Firmware for computer peripherals Hewlett Packard is a member of the Product Line Hall of Fame.</p>	<ul style="list-style-type: none"> <li>• Products built with 1/4 of the staff, in 1/3 of the time, and with 1/25 the number of bugs of earlier products.</li> <li>• Complexity up 10x, number of products up 10x, time to market decreased by factor of 2.</li> </ul> <p><i>References</i></p> <p>Peter Toft, Derek Coleman, &amp; Joni Ohta. "A Cooperative Model for Cross-Divisional Product Development for a Software Product Line," Patrick Donohoe (ed.) Proceedings SPLC1, Kluwer Academic Publishers, 2000.</p> <p>Klaus Pohl, Günter Böckle, &amp; Frank van der Linden. Software Product Line Engineering, Springer 2005, ch. 21.</p> <p>Mebane, H., Ohta, J. "Dynamic Complexity and the Owen Firmware Product Line Program," Proceeding, SPLC 2007, Kyoto, September 2007, IEEE Computer Society.</p>
<b>Hitachi</b>	
<p>Clinical analyzer product line, plus product lines across various divisions</p>	<p><i>Reference</i></p> <p>Y. Takebe, N. Fukaya, M. Chikahisa, T. Hanawa, &amp; O. and Shirai. "Experiences with Software Product Line Engineering in Product Development Oriented Organization," Proceedings SPLC 2009, San Francisco, August 2009.</p> <p>Van der Linden, F., Schmid, K., Rommes, E. Software Product Lines in Action, Springer-Verlag, 2007.</p> <p>Yoshimura, K., Shimabukuro, J, Atarashi, Y., Koizumi, S., Watanabe, S., Funakoshi, K. "Key Activities for Introducing Software Product Lines into Multiple Divisions: Experience at Hitachi, Proceedings SPLC 2011, Munich, pp. 261-266.</p>

Description	Cited Improvements
<b>HomeAway</b>	
<p>Vacation property rental</p> <p>HomeAway is a member of the Product Line Hall of Fame.</p>	<ul style="list-style-type: none"> <li>• Smaller footprint</li> <li>• Better performance</li> <li>• Higher test coverage</li> <li>• Improved quality</li> <li>• Faster time to market</li> <li>• Lower cost maintenance</li> </ul> <p><i>References</i></p> <p>Charles W. Krueger. HomeAway: A Software Product Line Case Study, BigLever Technical Report 20070630, June 2007, BigLever Software, www.biglever.com</p> <p>Charles W. Krueger, Dale Churchett, &amp; Ross Buhrdorf. "HomeAway's Transition to Software Product Line Practice: Engineering and Business Results in 60 Days," Proceedings, SPLC 2008, Limerick, pp. 297-306.</p>
<b>LG Industrial Systems</b>	
<p>Elevator control systems</p>	<ul style="list-style-type: none"> <li>• Decreased complexity of software base; functions reduced by half</li> <li>• Reduced cost of making changes</li> </ul> <p><i>Reference</i></p> <p>Klaus Pohl, Günter Böckle, &amp; Frank van der Linden. Software Product Line Engineering, Springer 2005, ch. 21.</p>
<b>LSI Logic - Engenio Storage Group</b>	
<p>RAID controller firmware product line for disk storage units</p> <p>LSI Logic - Engenio Storage Group is a member of the Product Line Hall of Fame.</p>	<ul style="list-style-type: none"> <li>• Product variation</li> <li>• Rapid time to market</li> </ul> <p><i>References</i></p> <p>BigLever Software Case Study: Engenio (Report# 2005-06-14-1) 2005.</p> <p>William Hetrick, Charles Krueger, &amp; Joseph Moore. "Incremental Return on Incremental Investment: Engenio's Transition to Software Product Line Practice." OOPSLA Proceedings 2006. Portland, Oregon. October 2006.</p>

Description	Cited Improvements
<b>Lucent Technologies</b>	
<p>5ESS telecommunications switch</p> <p>Lucent Technologies is a member of the Product Line Hall of Fame.</p>	<ul style="list-style-type: none"> <li>• Productivity improved 3x-5x</li> <li>• High reliability and performance</li> </ul> <p><i>References</i></p> <p>M. Ardis, N. Daley, D. Hoffman, H Siy, &amp; D. Weiss. "Software Product Lines: A Case Study," <i>Software - Practice and Experience</i> 30, 7, June 2000, 825-47 ISSN: 0038-0644 CODEN: SPEXBL Publisher: Wiley, UK.</p> <p>W. Howard, editor. "The 5ESS Switching System," <i>AT&amp;T Technical Journal</i> 64, July-August, 1985, Special Issue on the 5ESS Switch.</p> <p>Klaus Pohl, Günter Böckle, &amp; Frank van der Linden. <i>Software Product Line Engineering</i>, Springer 2005, ch. 21.</p>
<b>Lufthansa Systems</b>	
<p>Integrated sets of services for airline operations</p>	<p><i>Reference</i></p> <p>Chastek, G., Donohoe, P., McGregor, J., Muthig, D. "Engineering a Production Method for a Software Product Line," <i>Proceedings SPLC 2011, Munich</i>, pp. 277-286.</p>
<b>Market Maker Software AG</b>	
<p>Stock market data and financial news management</p> <p>Market Maker Software AG is a member of the Product Line Hall of Fame.</p>	<ul style="list-style-type: none"> <li>• Time to market improvement - systems installed in a few days.</li> <li>• Small development team able to support entire product line.</li> <li>• Reduction of time to market: 2-4.</li> <li>• Break-even: after about five products.</li> <li>• Reduction of maintenance costs: ~60%.</li> <li>• Reduced cost of quality (reliability in the field).</li> </ul> <p><i>References</i></p> <p>Paul Clements &amp; Linda Northrop. <i>Software Product Lines: Practices and Patterns</i>, Addison Wesley, 2001.</p> <p>Martin Verlage &amp; Thomas Kiesgen. "Five Years of Product Line Engineering in a Small Company," 27th International Conference on</p>

Description	Cited Improvements
	<p>Software Engineering (IEEE Cat. No. 05CH37673), 2005, 534-43. ISBN: 1-59593-963-2.</p> <p>C. Gacek, P. Knauber, K. Schmid, &amp; P. Clements. Successful Software Product Line Development in a Small Organization. A Case Study, Technical Report, Fraunhofer Institut for Experimental Software Engineering (IESE), 013.01/E, 2001.</p> <p>Frank van der Linden, Klaus Schmid, &amp; Eelco Rommes. Software Product Lines in Action, Springer, 2007, Ch. 11.</p> <p>Klaus Pohl, Günter Böckle, &amp; Frank van der Linden. Software Product Line Engineering, Springer 2005, ch. 21.</p>
<p><b>Mondragón Sistemas de Información (MSI)</b></p> <hr/>	
<p>Metal processing</p>	<ul style="list-style-type: none"> <li>• Reduction in development time</li> <li>• Reduction in product heterogeneity</li> <li>• Better controlled product evolution</li> <li>• Improved product understanding by stakeholders</li> </ul> <p><i>Reference</i></p> <p>D. Sellier, M. Manion, G. Benguria, &amp; G. Urchegui. "Introducing Software Product Line Engineering for Metal Processing Lines in a Small to Medium Enterprise," Proceeding, SPLC 2007, Kyoto, September 2007, IEEE Computer Society.</p>
<p><b>NASA Goddard Space Flight Center</b></p> <hr/>	
<p>Core Flight Software, future flight software platform for NASA missions</p>	<p><i>Reference</i></p> <p>D. Ganesan, M. Lindvall, C. Ackermann, D. McComas, &amp; M. Bartholomew. "Verifying Architectural Design Rules of the Flight Software Product Line," Proceedings SPLC 2009, San Francisco, August 2009.</p>

Description	Cited Improvements
<b>NASA Jet Propulsion Laboratory</b>	
Interferometer product line	<p><i>Reference</i></p> <p>G. C. Gannod, R. R. Lutz, &amp; M. Cantu. "Embedded Software for a Space Interferometry System: Automated Analysis of a Software Product Line Architecture," Conference Proceedings of the 2001 IEEE International Performance, Computing, and Communications Conference (Cat. No.01CH37210), 2001, 145-50 ISBN: 0 7803 7001 5.</p>
<b>Nokia</b>	
<p>Mobile phones</p> <p>Nokia is a member of the Product Line Hall of Fame.</p>	<ul style="list-style-type: none"> <li>• "Nokia Mobile Phones is the world's largest mobile phone manufacturer, and they believe that software product line engineering has helped it to reach that position."</li> <li>• Unprecedented feature variation and product to market capability.</li> </ul> <p><i>References</i></p> <p>A. Heie. "Global Software Product Lines and Infinite Diversity."</p> <p>J. Kuusela. "Architectural evolution: Nokia Mobile Phone Case Study," Software Architecture. TC2 First Working IFIP Conference on Software Architecture (WICSA1), 1999, 471-8 ISBN: 0 7923 8453 9.</p> <p>A. Maccari &amp; C. Riva. "Architectural Evolution of Legacy Product Families," F. van der Linden (Ed.): Proceedings PFE-4 2001, LNCS 2290, Springer-Verlag Berlin Heidelberg 2002.</p> <p>M. Jazayeri, A. Ran, &amp; F. van der Linden. Software Architecture for Product Families. Addison Wesley, 2000. pp. 169-176.</p> <p>Frank Van der Linden, Klaus Schmid, &amp; Eelco Rommes. Software Product Lines in Action, Springer, 2007, Ch. 12.</p>
<b>Nokia</b>	
Nokia: Mobile Browsers	<p>"...increased efficiency through reuse as well as accelerated product implementation, lowered cost, and increased quality."</p>

Description	Cited Improvements
	<ul style="list-style-type: none"> <li>• “We could not have developed four different products and six annual releases with our given resources without a product line.”</li> <li>• Led to improved working conditions - less than 3% turnover, product line highly rated in Nokia’s internal survey of working conditions.</li> </ul> <p><i>Reference</i></p> <p>Ari Jaaksi. “Developing Mobile Browsers in a Product Line,” IEEE Software 19, 4, July/August, 2002, p 73-80. Institute of Electrical and Electronics Engineers Computer Society.</p>
<b>Nokia Networks</b>	
<p>Telecommunication network products for public, private, and cellular networks</p>	<ul style="list-style-type: none"> <li>• Improved management of very complex systems.</li> <li>• Improved visibility and reuse of available assets.</li> <li>• Improved ability to evaluate system level quality properties.</li> <li>• Improved decision-making based on fact.</li> <li>• Architectural trade-offs are more concrete.</li> </ul> <p><i>References</i></p> <p>M. Jazayeri, A. Ran, &amp; F. van der Linden. Software Architecture for Product Families. Addison Wesley, 2000. p. 165 - 169.</p> <p>Frank van der Linden, Klaus Schmid, &amp; Eelco Rommes. Software Product Lines in Action, Springer, 2007, Ch. 13.</p>
<b>Nortel</b>	
<p>Digital loop carriers for telecommunications</p>	<ul style="list-style-type: none"> <li>• Reduced cycle time by 45%.</li> </ul> <p><i>Reference</i></p> <p>D. Dikel, D. Kane, S. Ornburn, W. Loftus, &amp; J. Wilson. “Applying Software Product Line Architecture,” Computer 30, 8, Aug. 1997, 49-55. IEEE Computer Society.</p>
<b>ORisk Consulting</b>	
<p>Risk management software</p>	<ul style="list-style-type: none"> <li>• Reduced time for changes</li> <li>• Increased quality</li> <li>• User customization</li> </ul>



Description	Cited Improvements
	<ul style="list-style-type: none"> <li>• Increased market share</li> </ul> <p><i>Reference</i></p> <p>Quilty, G., Cinneide, M. "Experiences with Software Product Line Development in Risk Management Software," Proceedings SPLC 2011, Munich, pp. 251-260.</p>
<b>Overwatch Textron Systems</b>	
<p>Multi-discipline analysis software</p>	<ul style="list-style-type: none"> <li>• Time to market for at least one product improved by factor of ~2.5</li> <li>• Anecdotal improvements in quality, cost, integration speed, and customer satisfaction</li> </ul> <p><i>Reference</i></p> <p>Paul Jensen. "Experiences with Product Line Development of Multi-Discipline Analysis Software at Overwatch Textron Systems," Proceedings, SPLC 2007, Kyoto, September 2007, IEEE Computer Society.</p>
<b>Philips</b>	
<p>High-end televisions</p> <p>Philips is a member of the Product Line Hall of Fame.</p>	<ul style="list-style-type: none"> <li>• Reduced faults during integration.</li> <li>• "Today, there are 20 different software releases per year, where each release serving 1-5 different product types. The product line supports three different hardware platforms.</li> <li>• "When we started, diversity was one of the top three issues on the agenda of architects. Now, diversity has disappeared as issue entirely."</li> <li>• A single product line of software for all of Philips' mid-range and high-end television products.</li> <li>• Able to produce the variability desired by marketing.</li> <li>• Software development not on critical path.</li> <li>• Variability no longer on architect's priority issue list.</li> </ul> <p><i>References</i></p> <p>Tim Trew. "Enabling the Smooth Integration of Core Assets: Defining and Packaging Architec-</p>

Description	Cited Improvements
	<p>tural Rules for a Family of Embedded Products,” H. Obbink &amp; K. Pohl (Eds.), Software Product Lines: 9th Intl. Conf, SPL 2005, Lecture Notes in Computer Science, v 3714 LNCS, 2005, p 137-149. ISSN: 0302-9743. Springer.</p> <p>Rob van Ommering. Building Product Populations with Software Components, Dissertation, University of Groningen, 2004.</p> <p>Rob van Ommering, Frank van der Linden, Jeff Kramer, &amp; Jeff Magee. “The Koala Component Model,” Ivica Crnkovic, Magnus Larsson (eds.), Building Reliable Component-Based Software Systems, Aretch House, 2002.</p> <p>Frank van der Linden, Klaus Schmid, &amp; Eelco Rommes. Software Product Lines in Action, Springer, 2007, Ch. 14.</p> <p>Klaus Pohl, Günter Böckle, &amp; Frank van der Linden. Software Product Line Engineering, Springer 2005, ch. 21.</p>
<p><b>Philips</b></p> <hr/>	
<p>PKI telecommunications switching system</p> <p>Philips is a member of the Product Line Hall of Fame.</p>	<ul style="list-style-type: none"> <li>• Improved time to market</li> <li>• Improved reuse</li> </ul> <p><i>References</i></p> <p>Jan Gerben Wijnstra. “Critical Factors for a successful Platform-based Product Family Approach,” Gary J. Chastek (ed.) Proceedings SPLC2, Springer LNCS 2379, (2002).</p> <p>Frank van der Linden &amp; Jürgen K. Müller. “Creating Architectures with Building Blocks,” IEEE Software, Nov. 1995.</p> <p>Frank van der Linden &amp; Jürgen K. Müller. “Composing Product Families from Reusable Components,” Bonnie Melhart, Jerzy Rozenblit (eds.), Proceedings 1995 International Symposium and Workshop on Systems Engineering of Computer Based Systems, IEEE, pp. 35 - 40 (1995).</p> <p>Jürgen K. Müller. “Integrating Architectural Design Into The Development Process,” Bonnie</p>

Description	Cited Improvements
	<p>Melhart and Jerzy Rozenblit (eds.), Proceedings 1995 International Symposium and Workshop on Systems Engineering of Computer Based Systems, IEEE, pp. 114 - 121 (1995).</p> <p>Jürgen K. Müller. "Feature-Oriented Software Structuring," Proceedings CompSAC'97, pp. 552-555, (1997).</p>
<p><b>Philips Medical Systems</b></p> <hr/>	
<p>Diagnostic imaging equipment Philips is a member of the Product Line Hall of Fame.</p>	<ul style="list-style-type: none"> <li>• Time to market, consistent and integrated behavior of applications.</li> <li>• 2-4 times effort reduction.</li> <li>• Reduction to less than 50% time-to-market.</li> <li>• Product defect density to 50% of original rate.</li> <li>• Ease of feature propagation from one product to others.</li> <li>• Common look-and-feel.</li> <li>• Better product planning &amp; use of roadmaps.</li> </ul> <p><i>References</i></p> <p>B. J. Pronk. "Medical Product Line Architectures," Software Architecture. TC2 First Working IFIP Conference on Software Architecture (WICSA1), 1999, 357-67. ISBN: 0 7923 8453 9.</p> <p>Frank van der Linden, Klaus Schmid, &amp; Eelco Rommes. Software Product Lines in Action, Springer, 2007, Ch. 15.</p> <p>Klaus Pohl, Günter Böckle, &amp; Frank van der Linden. Software Product Line Engineering, Springer 2005, ch. 21.</p>
<p><b>Raytheon; U.S. National Reconnaissance Office</b></p> <hr/>	
<p>Control Channel Toolkit, satellite ground control station software</p>	<ul style="list-style-type: none"> <li>• Improved cost, time to delivery, quality</li> </ul> <p><i>References</i></p> <p>Paul Clements &amp; Linda Northrop. Software Product Lines: Practices and Patterns, Addison Wesley, 2001.</p> <p>Paul Clements, Sholom Cohen, Patrick Donohoe, &amp; Linda Northrop. Control Channel Toolkit: A Software Product Line Case Study</p>

Description	Cited Improvements
	<p>Klaus Pohl, Günter Böckle, &amp; Frank van der Linden. Software Product Line Engineering, Springer 2005, ch. 21.</p>
<p><b>Ricoh</b></p> <hr/>	
<p>Office appliances</p>	<p><i>References</i></p> <p>R. Kolb, D. Muthig, T. Patzke, &amp; K. Yamauchi. "A Case Study in Refactoring a Legacy Component for Reuse in a Product Line," Proceedings of the 21st IEEE International Conference on Software Maintenance, 2005, 369-78.</p> <p>R. Kolb, D. Muthig, T. Patzke, &amp; K. Yamauchi. "Refactoring a Legacy Component for Reuse in a Software Product Line A Case Study," Journal of Software Maintenance and Evolution Research and Practice 18, 2, March-April 2006, 109-32. Wiley, UK.</p> <p>R. Carbon, S. Adam, &amp; T. Uchida. "Towards a Product Line Approach for Office Devices – Facilitating Customization of Office Devices at Ricoh Co.," Proceedings SPLC 2009, San Francisco, August 2009.</p>
<p><b>Robert Bosch Corp.</b></p> <hr/>	
<p>Automotive gasoline systems</p> <p>Robert Bosch Corp. is a nominee in the Product Line Hall of Fame.</p>	<ul style="list-style-type: none"> <li>• 25% less memory consumption.</li> <li>• Reduction of calibration effort (-20%) and maintenance.</li> <li>• Reduction of the resource consumption: 20%-30%.</li> <li>• Product line definition reflecting market variance.</li> </ul> <p><i>References</i></p> <p>M. Steger, C. Tischer, B. Boss, A. Muller, O. Pertler, W. Stolz, &amp; S. Ferber. "Introducing PLA at Bosch Gasoline Systems: Experiences and Practices," Nord, R. (ed.), Proceedings SPLC3, Lecture Notes in Computer Science 0302-9743, vol. 3154. Springer, 2004. Page: 34-50. Boston. ISBN: 3540229183.</p> <p>C. Tischer &amp; A. Mueller. "Bosch Gasoline Systems: Engine Control Software Product Line."</p>

Description	Cited Improvements
	<p>Viewgraph presentation,  <a href="http://www.sei.cmu.edu/splc2006/bosch_gs.pdf">http://www.sei.cmu.edu/splc2006/bosch_gs.pdf</a>            Frank van der Linden, Klaus Schmid, &amp; Eelco Rommes. Software Product Lines in Action, Springer, 2007, Ch. 9.</p>
<b>Rockwell Collins</b>	
<p>Commercial flight control system avionics</p>	<p><i>Reference</i>            Stuart R. Faulk. "Product Line Requirements Specification (PRS): An Approach and Case Study," Proceedings Fifth IEEE International Symposium on Requirements Engineering, 2000, 48-55 ISBN: 0 7695 1125 2, IEEE Comput. Soc, Los Alamitos, CA, USA.</p>
<b>Rockwell Collins</b>	
<p>Common Army Avionics System (CAAS), avionics for U.S. Army helicopters</p>	<ul style="list-style-type: none"> <li>• Eliminating duplicative maintenance contract (saving \$3-4M).</li> <li>• Expected to save \$4M per year in integration cost.</li> <li>• Reduced cost to develop new fleet-wide functionality. - Reduced documentation cost.</li> <li>• Simplified training, reduced training costs (\$1M per platform vs. \$50K per platform).</li> <li>• Reduced flight test costs.</li> <li>• Reduced time to deployment (10 years vs. 5 years).</li> <li>• Reduced system development costs (\$30-45M vs. \$10-15M).</li> <li>• Shorter time to airworthiness certification.</li> <li>• Increased competitiveness.</li> </ul> <p><i>References</i>            Paul Clements &amp; John Bergey. The U.S. Army's Common Avionics Architecture System (CAAS) Product Line: A Case Study            Mario Barbacci, Paul Clements, Anthony Lattanze, Linda Northrop, &amp; William Wood. Using the Architecture Tradeoff Analysis Method (ATAM) to Evaluate the Software Architecture for a Product Line of Avionics Systems: A Case Study</p>

Description	Cited Improvements
<b>Rolls-Royce</b>	
<p>Aerospace engine monitoring systems</p>	<p><i>Reference</i></p> <p>Ibrahim Habli, Tim Kelly, &amp; Ian Hopkins. "Challenges of Establishing a Software Product Line for an Aerospace Engine Monitoring System," Proceedings, SPLC 2007, Kyoto, September 2007, IEEE Computer Society.</p> <p>A. Nolan. "Building a Comprehensive Software Product Line Cost Model," Proceedings SPLC 2009, San Francisco, August 2009.</p> <p>Nolan, A., Abrahão, S., Clements, P., Pickard, A. "Requirements Uncertainty in a Software Product Line," Proceedings SPLC 2011, Munich, pp. 223-231.</p>
<b>Salion, Inc.</b>	
<p>Revenue acquisition management systems</p> <p>Salion, Inc. is a member of the Product Line Hall of Fame.</p>	<ul style="list-style-type: none"> <li>• Time to market</li> <li>• Scalability of product portfolio</li> </ul> <p><i>References</i></p> <p>Paul Clements &amp; Linda Northrop. Salion, Inc.: A Software Product Line Case Study</p> <p>Ross Buhrdorf &amp; Dale Churchett. Product Line Agility in the Face of Turbulence - The Salion Success Story.</p> <p>Charles W. Krueger &amp; Dale Churchett. "Eliciting Abstractions from a Software Product Line," in Proceedings of the OOPSLA 2002 PLEES International Workshop on Product Line Engineering. Seattle, Washington. November 2002, pages 43-48.</p> <p>Ross Buhrdorf, Dale Churchett, &amp; Charles W. Krueger. "Salion's Experience with a Reactive Software Product Line Approach," in Proceedings of the 5th International Workshop on Product Family Engineering. Siena, Italy. November 2003.</p> <p>Klaus Pohl, Günter Böckle, &amp; Frank van der Linden. Software Product Line Engineering, Springer 2005, ch. 21.</p>

Description	Cited Improvements
<b>Securitas Larm AB (now Matsushita Electric Works Fire &amp; Security Technology ASB)</b>	
Safety and security systems	<p><i>Reference</i></p> <p>Jan Bosch. Design &amp; Use of Software Architectures, Addison Wesley, 2000.</p>
<b>Siemens</b>	
Metals technologies: Sales support for electrode control systems for electric furnaces	<ul style="list-style-type: none"> <li>• Improved customer satisfaction</li> </ul> <p><i>References</i></p> <p>Vierhauser, M., Holl, G., Rabiser, R., Grünbacher, P., Lehofer, M., Stürmer, Uwe, "A Deployment Infrastructure for Product Line Models and Tools," Proceedings SPLC 2011, Munich, pp. 287-294.</p>
<b>Siemens</b>	
Software for viewing and quantifying radiological images	<ul style="list-style-type: none"> <li>• Reduction of unplanned dependencies.</li> <li>• Resilience to unanticipated changes.</li> <li>• Reduction of Development Cycle Time: ~25%.</li> </ul> <p><i>References</i></p> <p>Klaus Pohl, Günter Böckle, &amp; Frank van der Linden. Software Product Line Engineering, Springer 2005, ch. 21.</p> <p>R. W. Schwanke &amp; R. R. Lutz. "Experience with the Architectural Design of a Modest Product Family," Software - Practice and Experience, 34, 13, 10 Nov. 2004, 1273-96. ISSN: 0038-0644 CODEN: SPEXBL. Wiley, UK.</p> <p>Frank van der Linden, Klaus Schmid, &amp; Eelco Rommes. Software Product Lines in Action, Springer, 2007, Ch. 16.</p> <p>Barrtholdt, J., Becker, D. "Re-Engineering of a Hierarchical Product Line," Proceedings SPLC 2011, Munich, pp. 232-240.</p> <p>Sinha, S., Dasch, T., Ruf, R. "Governance and Cost Reduction through Multi-Tier Preventive Performance Tests in a Large-Scale Product</p>

Description	Cited Improvements
	Line Development,” Proceedings SPLC 2011, Munich, pp. 295-302.
<b>Symbian</b>	
EPOC operating system	<p><i>Reference</i></p> <p>Jan Bosch. Design &amp; Use of Software Architectures, Addison Wesley, 2000.</p>
<b>Telvent</b>	
Industrial supervisory control and business process management systems	<ul style="list-style-type: none"> <li>• Server platform extended to other markets.</li> <li>• Introduction of run-time variability.</li> </ul> <p><i>Improved Reference process framework.</i></p> <ul style="list-style-type: none"> <li>• Centralised roadmaps for platforms.</li> </ul> <p><i>Reference</i></p> <p>Frank van der Linden, Klaus Schmid, &amp; Eelco Rommes. Software Product Lines in Action, Springer, 2007, Ch. 17.</p>
<b>Testo</b>	
Climate, emission, and flue gas measurement devices	<ul style="list-style-type: none"> <li>• Ability to develop more complex products addressing new market segments.</li> <li>• “...these products would not have been possible without product line engineering.”</li> <li>• Increased developer satisfaction.</li> <li>• All projects on time and of high quality.</li> </ul> <p><i>References</i></p> <p>Ralf Carbon, Jens Knodel, &amp; Dirk Muthig. “Providing Feedback from Application to Family Engineering-The Product Line Planning Game at the Testo AG,” pp 180-192. 12th International Software Product Line Conference 2008. Limerick, Ireland, 8-12 September 2008.</p> <p>R. Kolb, I. John, J. Knodel, D. Muthig, U. Haury, &amp; G. Meier. “Experiences with Product Line Development of Embedded Systems at Testo AG,” 10th International Software Product Line Conference, 2006, 10 pp. ISBN: 0 7695 2599 7.</p>



Description	Cited Improvements
	<p>Klaus Pohl, Günter Böckle, &amp; Frank van der Linden. Software Product Line Engineering, Springer 2005, ch. 21.</p> <p>Klaus Schmid, Isabel John, Ronny Kolb, &amp; Gerald Meier. "Introducing the PuLSE Approach to an Embedded System Population at Testo AG," 27th International Conference on Software Engineering. ICSE'2005 (2005), 544-552.</p>
<b>TomTom Automotive</b>	
<p>Product line of embedded automotive navigation systems</p>	<ul style="list-style-type: none"> <li>• Reduced time to market</li> </ul> <p><i>Reference</i></p> <p>W. Slegers. "Building Automotive Product Lines around Managed Interfaces," Proceedings SPLC 2009, San Francisco, August 2009.</p>
<b>Toshiba</b>	
<p>Toshiba Software Factory: Electrical power generation, steel, traffic control, factory automation</p>	<ul style="list-style-type: none"> <li>• Increased productivity</li> </ul> <p><i>Reference</i></p> <p>Yoshihiro Matsumoto. "A Guide for Management and Financial Controls of Product Lines," Proceedings, SPLC 2007, Kyoto, September 2007, IEEE Computer Society.</p>
<b>U.S. Naval Undersea Warfare Center</b>	
<p>Test range facilities</p>	<ul style="list-style-type: none"> <li>• Cost of new products at least 50% lower.</li> <li>• Development time reduced from years to months.</li> <li>• Staff resources reduced by up to 75%.</li> <li>• High customer satisfaction.</li> <li>• Increased competitiveness.</li> </ul> <p><i>References</i></p> <p>Sholom Cohen, Ed Dunn, &amp; Albert Soule. Successful Product Line Development and Sustainment: A DoD Case Study</p> <p>Sholom Cohen, Dave Zubrow, &amp; Ed Dunn. Case Study: A Measurement Program for Product Lines</p>

Description	Cited Improvements
	<p>Klaus Pohl, Günter Böckle, &amp; Frank van der Linden. Software Product Line Engineering, Springer 2005, ch. 21.</p>
<b>U.S. Army</b>	
<p>Command and control simulator for Army fire support</p>	<ul style="list-style-type: none"> <li>• Time to add a mission reduced from about one month to about 3 days.</li> <li>• Able to add, remove, replace missions independently of each other.</li> <li>• Reduced code complexity.</li> </ul> <p><i>Reference</i></p> <p>Don Batory, Clay Johnson, Bob MacDonald, &amp; Dale von Heeder. "Achieving Extensibility through Product Lines and Domain-Specific Languages: A Case Study," ACM Transactions on Software Engineering and Methodology 11, 2, April 2002, 191-214. ACM, USA.</p>
<b>Wikon GmbH</b>	
<p>Remote monitoring and controlling devices</p>	<p><i>Reference</i></p> <p>D. Pech, J. Knodel, R. Carbon, &amp; C. Schitter. "Variability Management in Small Development Organizations – Experiences and Lessons Learned from a Case Study," Proceedings SPLC 2009, San Francisco, August 2009.</p>
<b>Unnamed</b>	
<p>Legal expert systems</p>	<ul style="list-style-type: none"> <li>• Increased modifiability, testability, usability (through uniform behavior), and adaptability.</li> </ul> <p><i>Reference</i></p> <p>C. Fritsch &amp; B. Renz. "Four Mechanisms for Adaptable Systems: A Meta-Level Approach to Building a Software Product Line," R. Nord (ed.), Proceedings SPLC3, Lecture Notes in Computer Science 0302-9743, vol. 3154. Springer, 2004. Page: 34-50. Boston. ISBN: 3540229183. Revised and extended in Software Process Improvement and Practice, v 10, n 2, April-June 2005, 103-24, ISSN: 1077-4866 CODEN: SPIPFL. Wiley, UK.</p>

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