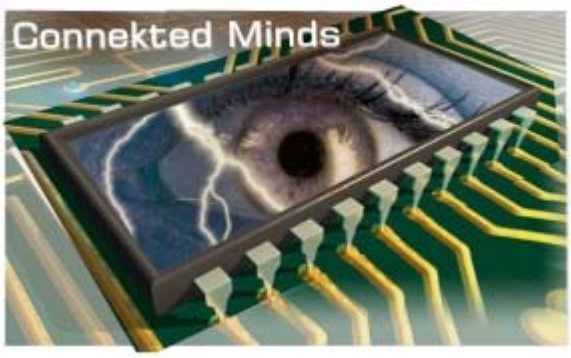
ConneKted Minds Inc.



Managing Development of Complex Systems in Products

Joanne Friedman
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Executive Summary

Embedded software has changed the face of product development from consumer electronics and high tech to automotive, aeronautics, life sciences and industrial markets. Today there are very few products involving mechanical and electrical design that are not dependent on embedded software - complicating matters across the product lifecycle from design to delivery and even into the aftermarket. If a company does not mitigate the risk of failure at the earliest stage of a product's design, the door is opened to increasing costs as a product progresses from early design stages through manufacturing.

Embedding software code in hardware as small as a cell phone to as large as an airplane is nothing new. What has changed is the degree of integration required in products between there mechanical, electrical and software components. The problem is that companies have focused on producing high volume, low cost mechanical and electrical products for more than 30 years and have little experience in creating and managing software development lifecycles.

Electrical and mechanical hardware typically do not involve much uncertainty about how the elements of a system work together - either it connects or not. On the other hand, software development is not as clear cut. Software involves more levels of connectivity and complex integrations with other systems. As a result, during the testing stage, it is often difficult to ascertain how a product will function or fail in diverse and unpredictable situations. It is not until later in the manufacturing process, when mechanical, electrical and software components are tested together, that specific issues can be identified.

Mechanical, electrical and software development teams work in parallel, but are typically isolated from each other. Without collaboration or synchronized changes, hardware and embedded software are completely disconnected until assembly and test stage. Data synchronization happens far later than it should to ensure that mechanical, electrical and software components function together properly.

As software becomes a key differentiator and more products are software driven or include embedded systems, change management processes are often:

- Not well defined or managed
- Not integrated with development
- Not synchronized to one product record
- Not compliant with increasing quality & regulatory requirements

These disconnects can expose a company to serious risk, including missing critical market windows; product quality and compliance issues; lower productivity and wasted resources; extra expenses that eat into profitability; and ultimately losing vital customer business.

To successfully deliver increasingly complex products, engineers from multiple disciplines need to have the ability to communicate efficiently and effectively. Top manufacturers - those who most consistently hit their product launch dates - use best-in-class tools that are integrated to ensure information and business processes flow freely across engineering disciplines and other parts of their organization that rely on product information.

Engineers, management, and quality personnel need an integrated change management solution that will provide visibility into issues that drive product change in sophisticated devices consisting of mechanical, electrical and software components.

Making the Connection with Integrated Change Management

The Integrated Change Management Solution combines Agile Product Lifecycle Management (PLM) with the IBM Rational Software Delivery Platform, providing an end-to-end solution that allows product development of both hardware and software in one integrated system - making management of the software lifecycle an integrated part of the product lifecycle.

The integrated solution combines two best-in-class products working in harmony to deliver a comprehensive, holistic and seamless solution for managing all product data – electrical, mechanical and software - across the entire product lifecycle via one unified product record. This powerful combination of world-class technologies also supports collaboration and information sharing across all functions within mechanical, electrical and software development.

Agile PLM is a broad suite of best practice, enterprise-class product lifecycle management solutions designed to help companies accelerate revenue, reduce costs, improve quality, ensure compliance and drive innovation throughout the product lifecycle. Agile is complemented by IBM's Rational ClearQuest™, an integral part of the IBM Rational Software Delivery Platform, which governs, integrates, and automates software development processes and workflow between product development teams and geographically disparate environments.

The Integrated Change Management solution provides mutual visibility across software and hardware development. The solution enables software developers using the ClearQuest environment to collaborate on solving issues and synchronize required code changes with mechanical and electrical engineers developing hardware in the Agile PLM environment. With this system, mechanical, electrical and software changes can be tracked in tandem and problems can be resolved to improve product quality in the early design stages.

The Integrated Change Management Solution enables companies to:

- Enhance embedded software collaboration and innovation
- Reduce turn-around-time in product design and defect resolution
- Improve product quality
- Minimize impact of warranty claims
- Reduce time to market
- Increase efficiency in change management
- Improve compliance to government regulations and industry certifications
- Strengthen communication with and responsiveness to customers

In proven installations, Agile customers have been able to cut NPI cycle time by as much as 22%; cut product design change cycle time by as much as 50%; cut time to volume by as much as 50%; and cut product development costs by as much as 25%. These results can be realized in any industry that requires concurrent mechanical, electrical and software development.

Table of Contents

Table of Figures

ConneKted Minds Inc.

Synchronizing Product Lifecycle Management across Mechanical, Electrical and Software is a key Differentiator

Consider this. Thirty four operating companies, in 28 geographies produce electronic components, circuits and boards for no less than twelve and as many as twenty of the world's largest computer, telecomm, automotive, CPG, life science and aerospace companies, on any given day, in any week, in any year.

This is business as usual for one Electronic Manufacturing Services (EMS) company, which together with six of its closest co-opitors, form just a single thread, a segment, in a vast, global manufacturing ecosystem. A network of partners that now spans the globe, and has surpassed both steel and plastics as the largest producer of raw materials for remanufacture.

As if that were not enough complexity, more than half of all the hardware produced by these companies now relies on embedded software, (created by other companies, across geographies and segments) to make the hardware run.

Chaos it seems does have a name. It's called the Electronics and High Tech Manufacturing industry, and today, like its demand chain partner the automotive industry, it has serious and growing problems. It has outgrown its ability to effectively manage product development, manufacturing operations, or mitigate risk.

The purpose of this document is to introduce the Agile Software PLM and IBM Rational Integrated Change Management capability, a highly collaborative technology product, that offers manufacturers the opportunity to manage hardware and software development, mitigate risk and improve value.

The reality is, globalization, coupled with explosive growth in product complexity and an ever expanding value network have left manufacturing companies vulnerable and exposed to the impact of business process failure.

Questions like, what can they do to manage and mitigate risk across the ecosystem? Or more appropriately, "what tools and technologies can be deployed" to help prevent a recurrence of the catastrophic business losses that hit the high tech industry last year (Sonyism) are now being raised.

Introduction

Hardware and software development, globalization and risk go hand-in-hand -- yet now more than ever, manufacturing companies in high tech and automotive must find innovative solutions to synchronize hardware & software development processes.

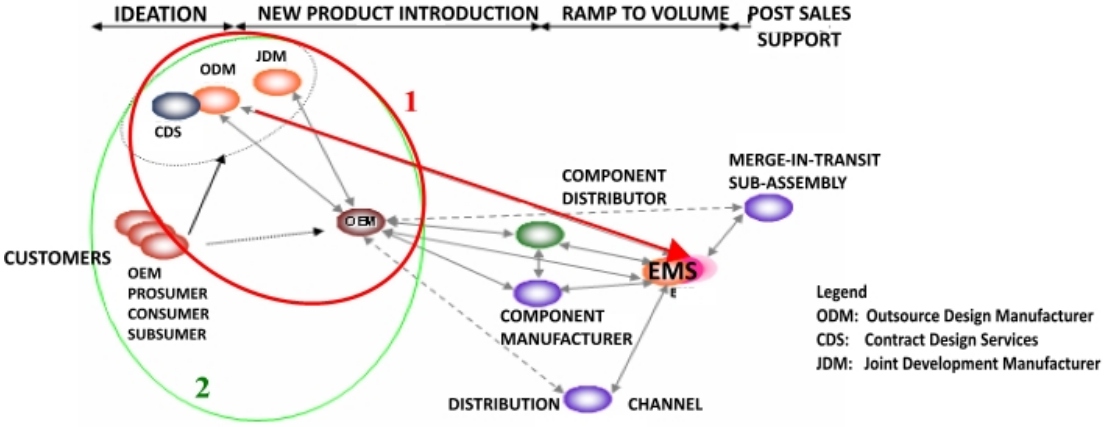
Massive increases in embedded software content, coupled with excessive process disaggregating, (decomposing business process into smaller and smaller chunks) and explosive growth in the number of design and outsourcing partners have all contributed to creating a manufacturing ecosystem that now resembles an un-seamed, patchwork quilt. While little if anything seems to be binding the network's segments together, even less binds the steps of its long running business processes. Gaps in activity streams, information silos, and uncoordinated business processes are rampant.

When one considers that electronics touch virtually every aspect of our daily lives, and now comprise more than 50% of the component parts in our cars, planes, and appliances, a single process failure anywhere in such a vast ecosystem can spiral out of control and have a very long lasting effects (e.g. Ford/Bridgestone Firestone, Sony Electric).

Together with the need to improve product development processes, manage increasingly complex product configurations, and meet customer requirements, the heavy reliance on embedded software exacerbates the need for companies to be far more collaborative so that hardware and software development processes are more synchronized, and synergized.

Software engineering continues to be the highest growth sector in the product development process and today, as much as 50% of all hardware devices require embedded software or firmware. Thus, while executives are looking at ways to apply governance and technology to resolve their immediate challenges, those charged with innovation and improving corporate value see software & hardware synchronization as a means to better manage product development, mitigate risk, improve overall product quality and ultimately increase customer satisfaction.

The relationship between an Original Equipment Maker (OEM) and its outsource design partners has become increasingly complex as it stretches over the span of a long running product development process . The diagram below indicates two sets of relationships and the points at which errors can occur.



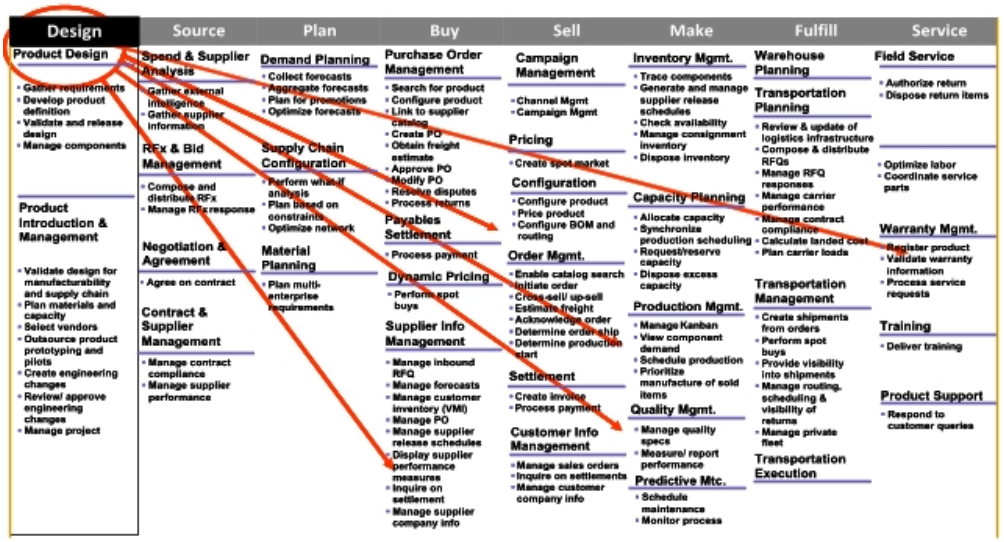
Scenario 1 (RED CIRCLE): Here information flows between the OEM and the design partners as well between an Outsource Design Manufacturer (ODM) and the Electronic Manufacturing Services company. The two streams of information may not be synchronized or contain the same data (ie.IP protection) leading to a process failure.

Scenario 2 (Green Circle): Electronics raw materials consumers (e.g. automotive or aerospace) may also engage an Outsource Design Partner (ODM) directly, increasing the number of information and process streams to be managed. Without data or process synchronization or a unified approach, the risk of process or infomation errors increases by orders of magnitude and may subsequently cascasde across industries.

Source: ConneKted Minds© 2006
for iNEMI 2006 Electronics and High Tech Industry Roadmap;PLIM Chapter

Figure 1: Complex Relationships & Activity Streams

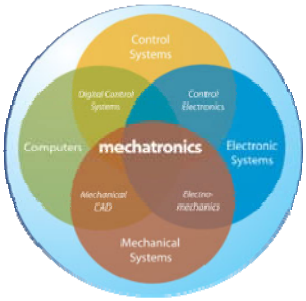
Delayed Reaction: Impact of Errors in Design across the Product Lifecycle Process



Source: ConneKted Minds ©2007

Disaggregating design processes (i.e. split for cost and time optimization) result in information silos as mechanical, electrical and software engineering groups work in isolation from each other. Without process or data synchronization, errors may not be recognized or resolved until much later in the product development process. The result is an increase in the frequency of Engineering Change Orders (ECO) which in turn leads to increasing product cost, and lengthens time to market.

Figure 2: Ramifications of Unsynchronized Data and Development Processes



Mitigating risk: Begin at the beginning of the lifecycle

While there's a very old joke that starts with "how many engineers does it take …" tomorrow, the answer may be one, the Mechatronics engineer.

Mechatronics is a system-level approach to designing electromechanical systems that merges mechanical, electrical, control system, and embedded software design. It represents an industry-wide effort to improve the design process by integrating the best available development practices and technologies to streamline design, prototyping, and deployment.

If you design industrial machinery, equipment, vehicles, or other devices with moving parts and electronically controlled actuators, Mechatronics technology can help drive lower development costs, reduce risk, and contribute to manufacturing of higher quality products.

Mechatronics technologies and development practices seek to deliver the following benefits:

- Increased efficiency due to automation, standardized processes, enhanced project visibility and communication, collaboration, and overall integration
- Improved environment for innovation, design and engineering resource utilization across domains
- Reduced time to market
- Higher profitability through faster, lower-risk, lower-cost development

While the upside of Mechatronics may be shorter cycle times for product development and reduced cost, the areas of concern are engineering silos, and with them, a greater need for synchronized business process and information flows that cascade across large complicated ecosystems.

Business processes starts and stops in odd ways at the early stage in a product's lifecycle. As aspects of a business process move from multiple organizations or across geographically disparate entities, and mechanical design is completed, other engineering tasks are beginning in serial fashion and parallel streams. Who's doing what, when and whether the threads can be woven together effectively is the challenge.

The resulting silos of information, black holes where data is lost, means information can be misinterpreted, and activities can get out of synch very quickly - events that could easily impact schedules, drive cost and add risk. This is where governance, collaboration and sophisticated collaborative technologies can help turn things around.

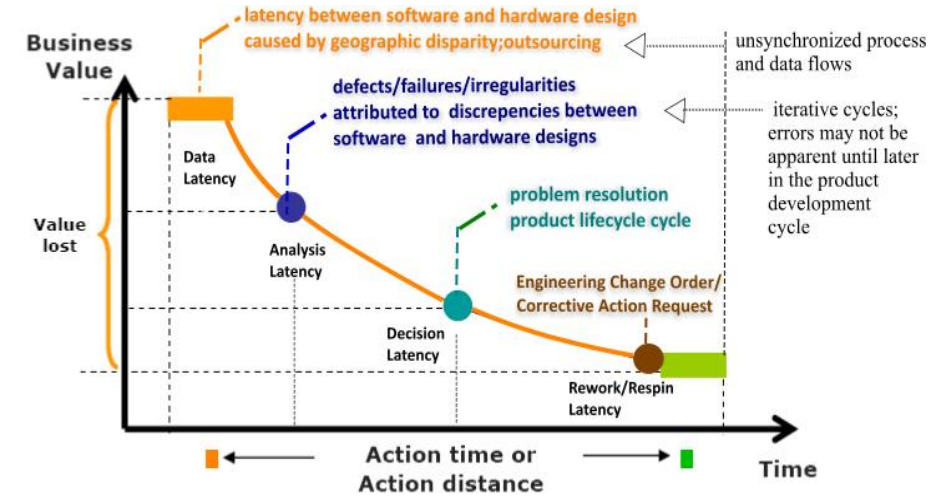
While it is well established that unsynchronized data causes latency (time delay) in decision cycles, where and when latencies occur and the impact on business value is another matter.

Figure 3 below illustrates the low hanging fruit, those process steps where data and information flows are likely out of synch and business value is being lost.

Collaborative technology can help to reduce or eliminate latencies by enabling disparate teams to share information and enable companies to make more informed decisions. Similarly as latency is reduced or eliminated during the early stage of the product development process, the likelihood that time to market improvements can be made over the entire product lifecycle increases.

Although latency is a term normally used to define the amount of time it takes for a data packet to move across a network connection, latency metrics can also be used to measure how long it takes for data to move between process steps and disparate teams.

As companies become more collaborative and employ non-disruptive technology to synchronize and manage data, they can begin to focus on more granular issues, that lead to improving product quality and product cost. In short, synchronization improves time-to-decision, and the quality of decision making, both of which factor in achieving time to market and customer satisfaction.



Disaggregated business process creates time and information gaps; out of synch process creating opportnity for increased risk of a business process failure;

Unsynchronized data means no cross check between SW/HW engineering teams; errors then increase cycle time and product cost; may reduce product quality and time to market across the ecosystem;

Lack of synchronized information increases frequency of respin/rework, ECO and Corrective action resolution cycles; iterations add cost which then aggregates;

Respin cost, time to value and risk increase with each additional cycle needed

Source ConneKtedMinds ©2007

Figure 3: The Impact of Process Latency

Agile's PLM Software Integrated with IBM's Rational ClearQuest Integrated Change Management Connector

The combination of IBM Rational's Integrated Hardware & Software Change Management Solution and Agile PLM software tackles the problem of removing process and information silos at the earliest point in the product lifecycle. By enabling engineers from different disciplines and geographies to collaborate, and quickly address issues and resolve problems that arise when hardware and software are created in complex and often isolated teams, companies can more effectively manage product development, realize substantial cost benefits while mitigating potential risks that stem from process failure.

Collaborative solutions such as the Agile Software PLM and IBM Rational ClearQuest Integrated Change Management remove the complexity and ease the communication hurdles (people, process and technology) that are common in today's complex and globally dispersed product development organizations.

In combining the governance and discipline enhancing features of software engineering (from IBM's market leading ClearQuest) with the holistic process control and product data management of Agile's robust Product Lifecycle Management, IBM and Agile have created a new software category – solutions that are "designed for business outcome". Designed for business outcome is a premise that enables the enterprise to better align software and hardware engineering processes, and synchronize the flow of data. In doing so, the solution removes the risk that hardware produced by one organization, will not function with the software created by another organization. IBM & Agile's products help connect the dots between software, hardware and cause and effect. In doing so the solution enables the enterprise to fill a void long needed to offset delays, cost and risk - the womb to tomb track and trace on product information previously unavailable to the industry.

In creating a shared pool of information (software engineering data, together with product record and its artifacts), IBM and Agile have connected more than the disparate engineering groups responsible for product design and development. Indeed, perhaps unwittingly, they've connected the dots between the stages of manufacturing processes that are often siloed (i.e. due to disparate teams, processes, outsourcing, etc.), but ironically contain the kind of information needed to help clients avoid catastrophic business process failures the industry has all too often experienced.

From initial product development to tracking and tracing causes of product defects, between hardware and software, to leveraging the information to reduce the cost of test, repair and warranty caused by defective products, the integrated solution sets the stage to apply insight, governance and to long running processes that would otherwise be near impossible to control.

Lastly, the highly collaborative product provides engineers and enterprises in the discrete manufacturing community with the means to overcome historical obstacles, cultural boundaries, localization issues and many lesser known hurdles that impact time to value and cost - everything from lag times due to different time zones, to differences in engineering environments, and tools used by each specialty.

How it Works: Integration, Hardware and Software, Change Control…..lions and tigers and bears Oh My!

One of the most important features of the Integrated Hardware/Software Change Management Solution enables engineers to collaborate internally or externally while remaining in their own familiar environment, whether it is IBM's ClearQuest, or Agile's Product Lifecycle Management.

ClearQuest™ is one tool within the comprehensive Rational Software Delivery suite of products. ClearQuest governs, integrates, and automates the software development, delivery and workflow processes. IBM Rational ClearQuest orchestrates collaboration, change control and work transfer between distributed team members and partners.

Combined, the Integrated Change Management solution allows customers to accomplish tasks faster, with greater accuracy, provides cross-functional insight to project activity, better predictability and control over product development processes.

Agile Product Lifecycle Management focuses on managing the business processes and data for a product's manufacture and enables the enterprise to model, measure and manage the entire design through delivery process.

The approach used is to view a product's information, in context, and incorporates artifacts beginning from its Bill of Materials root – the parts, engineering specifications, test results, changes, project management – for a holistic view of the product information that is used to manufacture product.

Although the processes of software engineering are entirely different than hardware, the two now must be aligned, synchronized and synergized. The integrated solution accomplishes this objective by providing a common issue resolution screen which is integrated into both ClearQuest and Agile product environments.

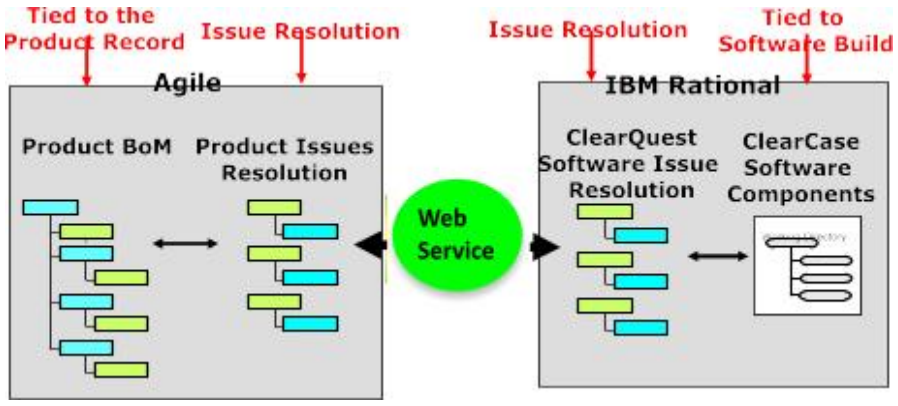


Figure 4: Integrated Change Management

Mutual benefit: The impact to Hardware Design Cycles

Reducing hardware design spins is critical to achieving cost and time to market efficiencies for all manufacturing industries. Companies that are able to remove even one design cycle gain a host of benefits ranging from being first to market, to cost avoidance, and, true cost reduction. The ability for mechanical and software engineers to collaborate will reduce frequency of respins.

DESIGNERS AND ENGINEERS STRUGGLE TO REDUCE SPIN, YET WITHOUT VALUE BASED COLLABORATION, THE VALUE OF BUSINESS PROCESS INTEGRATION, COST REDUCTION AND EARLIER TO MARKET GO OUT THE WINDOW.

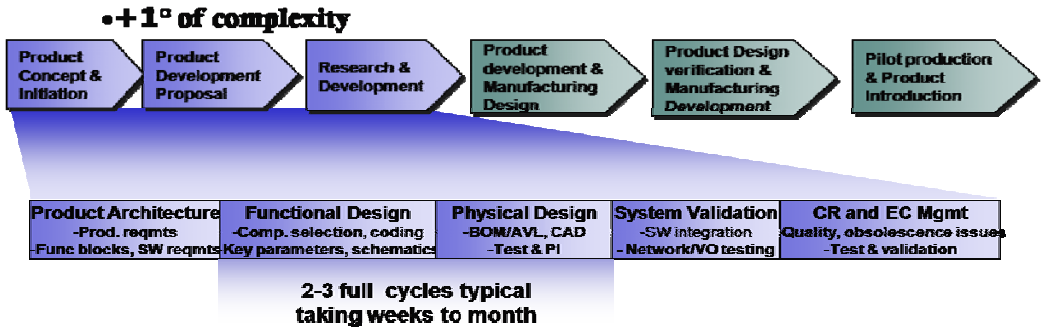


Figure 5: Effect of Increasing Complexity

Cause and Effect

What causes a design respin varies – In some cases it is a change in customer requirements, in others a shortage in the supply chain, and in other cases, its errors and discrepancies - issues that often arise because of a lack of collaboration between disparate engineering groups.

A Hardware Design Survey (2007) conducted across 25 R&D teams in telecomm illustrates the value highly collaborative technologies can bring to manufacturers. As noted, thirty-three percent of the respondents surveyed indicated the cause of hardware design spins is errors which escape review processes –errors that are attributable to information silos and black holes created by the massive increases in embedded software, disaggregated business processes and outsourcing.

What takes the most time in the cycle?[1]

- 30% of respondents listed documentation and submission to DDME
- 22% of respondents listed component selection
- 20% of respondents listed component coding intervals
- 20% of respondents listed various elements of PCB layout
- 7% of respondents listed collaboration between EE&ME to complete common feature processes

What Causes design spins: (combinations)

- 60% of respondents listed changing requirements
- 47% of respondents listed component supply (performance, availability, price)
- 33% of respondents listed component library quality issues
- 33% of respondents listed errors which escaped review processes
- 20% of respondents listed aggressive timelines

[1] Hardware Design Survey in Telecomm, ConneKted Minds© 2007

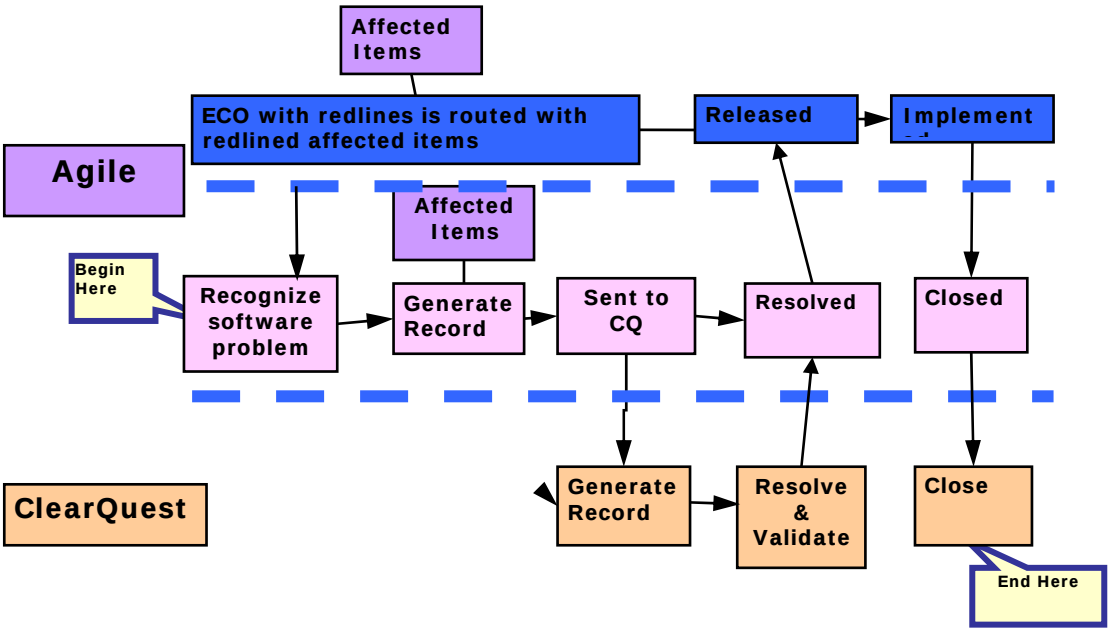


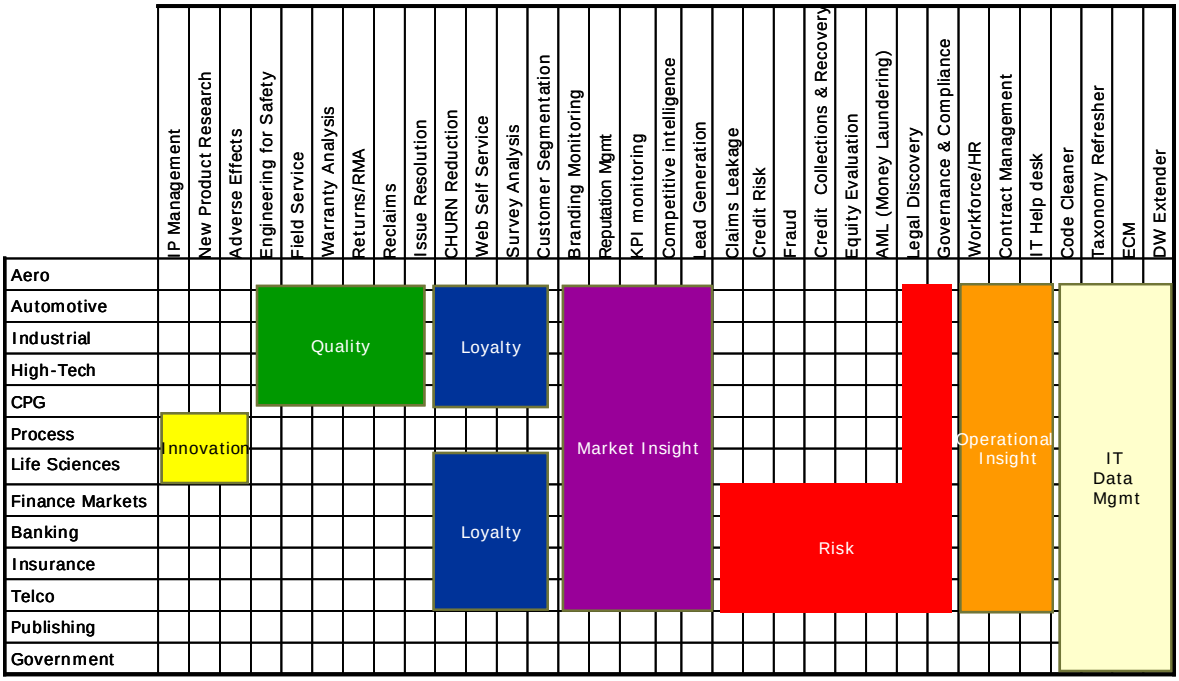
Figure 6: Integrated Change Management

In this example, a software issue is found by a mechanical engineer. He/she routes a Problem Report in Agile. Since it is determined to be a software issue, ICM generates a defect in ClearQuest which is routed for resolution. After the change is made and verified, an Engineering Change Notice is sent out and released in Agile

Benefits that cross Industries

Agile's PLM integration to IBM Rational's ClearQuest Integrated Change Management tool will provide organizations with significant enhancements in the areas of software development, cycle times, and improvements in product quality for a wide range of materials and products that are provided to a myriad of industries, thus shortening time to market across the board. Additional benefits include:

- Increased collaboration among product development engineers, partners and suppliers
- Greater process synchronization and visibility within the enterprise, early in the development process
- Improved change management control, efficiency and traceability
- Compliance with governmental and industry regulations and initiatives including ISO-9001:2000 and CMMI.



Source: ConneKted Minds©2005

Figure 7: Collaboration reduces the impact of cascading design errors (by industry)

By pairing IBM's Rational Software Delivery Platform, (ClearQuest) together with Agile's market leading Product Lifecycle Management software, companies can leverage and extend the value of existing engineering and PLM infrastructure and build the governance needed to close the gaps between engineering silos and across hardware and software in complex manufacturing environments.

Conclusion

The viral expansion of global manufacturing ecosystems brings untold opportunity for growth and profitability, but industry ecosystems such as electronics and high tech, automotive, aerospace and others have each become unwieldy beasts in need of standardization, governance, management controls and technologies that can reduce design cycles, cost, risk and the potential for and impact of even minor business process failures.

For electronics and high tech, the most recent example of a call to action was Sonyism -— the bad battery scourge that impacted the entire industry and cascaded the havoc it caused across many of its demand partners. (e.g. telecomm, consumer electronics). Although it may not have been the first business process failure of its kind, to-date it was the most significant.

Innovative, highly collaborative solutions such as Agile Software PLM integration to IBM Rational ClearQuest for Integrated Change Mangement enables stakeholders across manufacturing industries to improve software development processes while mitigating risks of recurring failures. By addressing software development process issues early in the process, enterprises can close the gaps in business process and information flows that lead to increasing cost, extend time to value, and eliminate a significant source of business process failures

About the Author:

Joanne Friedman is the Chief Executive Officer at ConneKted Minds Inc., an outsource provider of technology value management products and services. She is a respected IT industry analyst specializing in enterprise architecture, Business Process Integration,Ebusiness, SCM and Product Llifecycle Management. Ms Friedman has more than 21 years of experience in managing IT organizations in high tech manufacturing and life sciences industries. Previously, she was the Vice President, Electronic Business Strategies at META Group and responsible for leading its manufacturing and PLM research practice areas. Ms. Friedman is a co-founder of the Virtual Factory Information Interchange Project and a domian author of multiple technical standards including PDX, for the exchange of Electronic BOM , IPC series 2570, Materials Compliance Declarations Exchange and Green Tech. Most recently Ms. Friedman was Co-Chair of the 2006 iNEMI Electronics&High Tech Manufacturing Industry Roadmap PLIM Chapter and continues to help define the technical standards and business models for the industry . Her books include Business Bites Back, Zen and Art of Ebusiness and the Technology Value Management Framework for which she received the American Business Award (Stevie) for Technology Innovation in 2005 . Ms. Friedman hold degrees in business and technology from Universities in Canada, the United States and Europe..

Appendix I: Growth Rates and Statistics on Embedded Software and Operating Systems

Embedded Software

The embedded software market continues to enjoy steady growth. While market expansion is occurring across many industries, the growth in consumer electronics, especially in mobile and wireless, continues to have a significant impact on the embedded software market as a whole. VDC estimates that the market for embedded operating systems, bundled tools, and related services reached 905$ million in 2004 - an increase of 20.9% over the previous year[2]. This is driven by strong growth in consumer electronics, as well as continued increases in spending in the military/aerospace, industrial automation, and telecom/datacom segments.

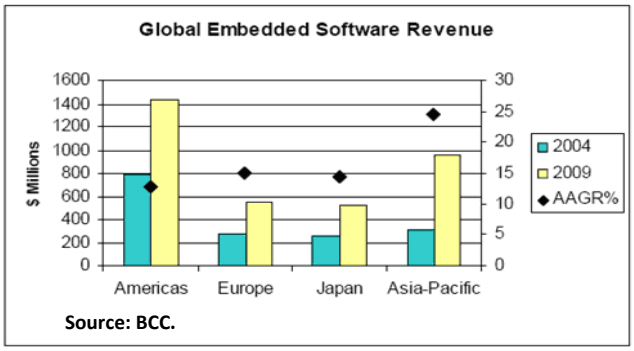
The estimated Average Annual Growth Rate (AAGR) between 2004 and 2009 are 16% for embedded software[3] .

U.S.A. owns the major portion of the embedded software revenue (48%) as it is shown in the next figure. Europe, Japan and Asia share the remaining revenue almost equally having 274, 264 and 315 $ millions revenue, respectively. An interesting fact of this market research is that although USA, Europe and Japan have an aggregated annual growth rate of 15%, Asia (mainly because of the proliferation of China) has a growth rate of almost 25%. Hence, by 2009 the revenue of Asia is estimated that will be close to the one of the USA and almost double of the revenues of Europe and Japan[4].

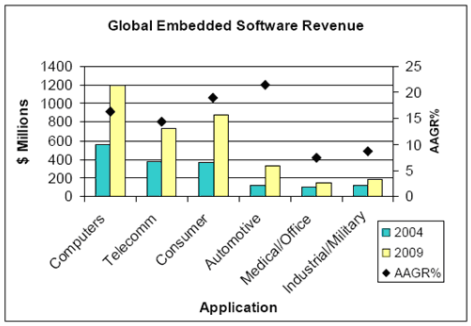
Global Embedded Software Revenue by Region,

(*)"The Hipeac Roadmap on Embedded Systems". Source: "Future of Embedded Systems Technology". BCC Report G-229R.

The graph illustrates a strong increase in the value of embedded systems across all sectors. The most prominent examples are telecommunications (with the number of mobile phones rising and added functionalities), logistics, automation, or automotive where further softwareization" is predicted.



Global Embedded Software Revenue by Application



(*)"The Hipeac Roadmap on Embedded Systems". Source: "Future of Embedded Systems Technology". BCC Report G-229R.

2 Venture Development Corporation. White Papers 2005 Embedded Software Strategic Market Intelligence, Vol. VIII Embedded Systems Market Statistics

3 Eurostat: "GDP and main components – Current Prices". Retrieved August, 19th, 2005

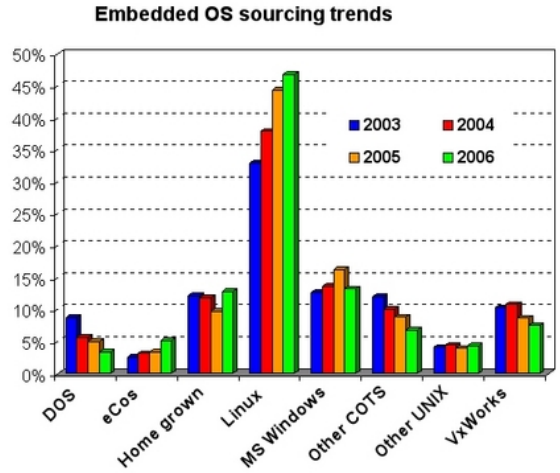
4 The Hipeac Roadmap on Embedded Systems. European Network of Excellence on High-

Embedded Operating Systems

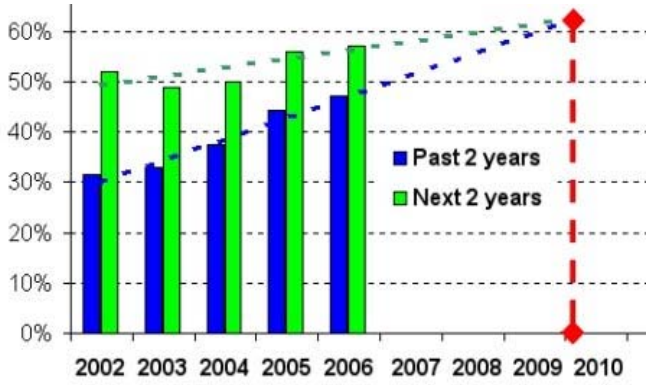
Venture Development Corporation estimates worldwide shipments of embedded devices to be over 2 billion in 2004. Talking about current project statistics, this company says that Linux continues to penetrate the embedded market. In a survey done by VDC, nearly **13 percent of respondents indicated that Linux was the primary OS being used for the current project** [5]

But in the LinuxDevices.com's sixth annual Embedded Linux Market Survey, **47 percent** of their survey's respondents affirmed to **have used Linux in embedded projects and/or products** – a growth of about two percentage points over the previous year's results.

While Linux continues to gain popularity, traditional embedded Operating Systems and Real-Time Operating Systems may be losing market share. Trend lines on the chart below suggest that **by decade's end, actual and planned Linux use will converge, at about 60 percent.**



The vast majority of embedded Linux developers do not pay anything for their OS, with only 17 percent actually purchasing Linux from a commercial vendor; the survey shows that is unlikely to change much over the next two years.



5 Venture Development Corporation. White Papers 2005 Embedded Software Strategic Market Intelligence, Vol. VIII Embedded Systems Market Statistics