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**C a m b a s h i L i m i t e d**

## **Managing complexity to deliver competitive advantage**

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### Background

Cambashi researches the use of Information and Communication Technology. Our goal is to understand

- the business reasons that drive investment decisions,
- the technology that addresses these issues,
- the market mechanisms that bring users and vendors together, and
- the impact of deployment of applications and infrastructure.

IBM commissioned us to document our research on the effects of increasing complexity in the electrical component and industrial electronic OEM sectors, and the opportunity to develop competitive advantage by successfully managing it.

We thank IBM for the sponsorship of this white paper and the opportunity to investigate the effects of increasing complexity in products and processes.

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## 1 Introduction

Increasing complexity in products and their development processes drive business change.

Demand for increased product functionality, wider distribution of stakeholders and auditable regulatory compliance challenge companies to deliver quality products on time and to cost. Standing back from the complexity of today's products, processes and workflows is not a viable strategy. In order to improve results, companies must harness and capitalise on this increased complexity to deliver product and performance advantage.

Change is not optional; the problem is where to focus change to deliver best return. This has particular relevance to electrical component manufacturers and electronics industry OEM's such as specialist battery suppliers for mobile telecoms and medical device manufacturers.

This paper examines the issues of complexity that challenge current product development methodologies, and considers areas of opportunity to deliver competitive advantage from improved product and process management.

*"Product Lifecycle Management (PLM) systems support the management of a portfolio of products, processes and services from initial concept, through design, launch, production and use to final disposal. They co-ordinate product, project and process information throughout new product introduction, production, service and retirement among the various players, internal and external to the company, who must collaborate to bring the concept to fruition."*  
Cambashi

## 2 The changing competitive landscape causes increased complexity

Increasing customer expectation leads to operational and product complexity. To improve company profit in this environment requires continuous change.

*"The markets for high-speed telecommunications products are characterized by rapid technological developments, frequent enhancements to existing products and new product introductions, changes in customer requirements and evolving industry standards. Intense competition among numerous high-speed access technologies has further driven innovation and increasingly complex product requirements. We may be unable to improve the performance and features of our products as needed to respond to these developments. The introduction or market acceptance of products incorporating superior technologies or the emergence of alternative technologies or new industry standards could render our existing or potential future products less economical, obsolete and unmarketable. For example, if semiconductor, robotic or other technologies become effective alternatives for our product architecture, our products may become obsolete." Extract from 2001 annual report of a mid-sized electronics manufacturing company*

In many companies there is continuous cycle of product and process complexity growth. This is a natural result of enhancing product capabilities. In parallel to this, there are ongoing engineering and management efforts to simplify designs and procedures.



Manufacturing, supply and distribution and in-service support also follow similar cycles. Waiting for insight that replaces complexity with simpler products and processes will condemn a company to practice 'commodity business' strategies. If a company wants to differentiate itself from the competition it must be willing to accept complexity.

The challenge is to manage increasing product complexity whilst contending with increasing complexities in manufacturing, supply and after sales service processes.

To identify solutions which address these challenges it's important to understand the principal issues that drive changes in products and their development processes in electrical components and industrial electronic OEM businesses.

**The time products remain in the market** is decreasing yet demand for longevity and durability is increasing. This requires increase in the rate of innovation and improvements in quality and serviceability.

*"I'm all for progress it's  
change I don't like" – Mark  
Twain*

**Customers' demands** for increasingly complex deliverables and mass customisation remain unabated. Improvements must be made without sacrificing profit or delivery timescales.

**Trends towards more globally dispersed** manufacturing and design operations create opportunities and at the same time challenge current business practices. The challenge is how to exploit emerging markets whilst delivering greater value for all relevant stakeholders. Increased globalisation of enterprise value chains demands higher levels of cooperation and coordination. Using the most economic and suitable resource, wherever the location, is fundamental to competitiveness.

**Company and product value** comes not only from increased innovation and improved efficiency, but also from new methodologies and business alliances. More often than not last year's competitor is this year's partner and businesses have to adapt to manage this environment.

**Planning for service after sale and end of life retirement** are increasingly important considerations in product development. Market forces such as regulatory and environmental issues challenge industry to support products within increasingly stringent and globally varying parameters. This is exacerbated by the multinational nature of customers and extended supply and manufacturing partnerships.

*"The speed of technology  
development, combined  
with increasing product  
complexity, requires  
creative approaches in  
keeping everyone rapidly  
and accurately informed."  
FDAMA plan for FY1999  
- U.S. Food and drugs  
administration*

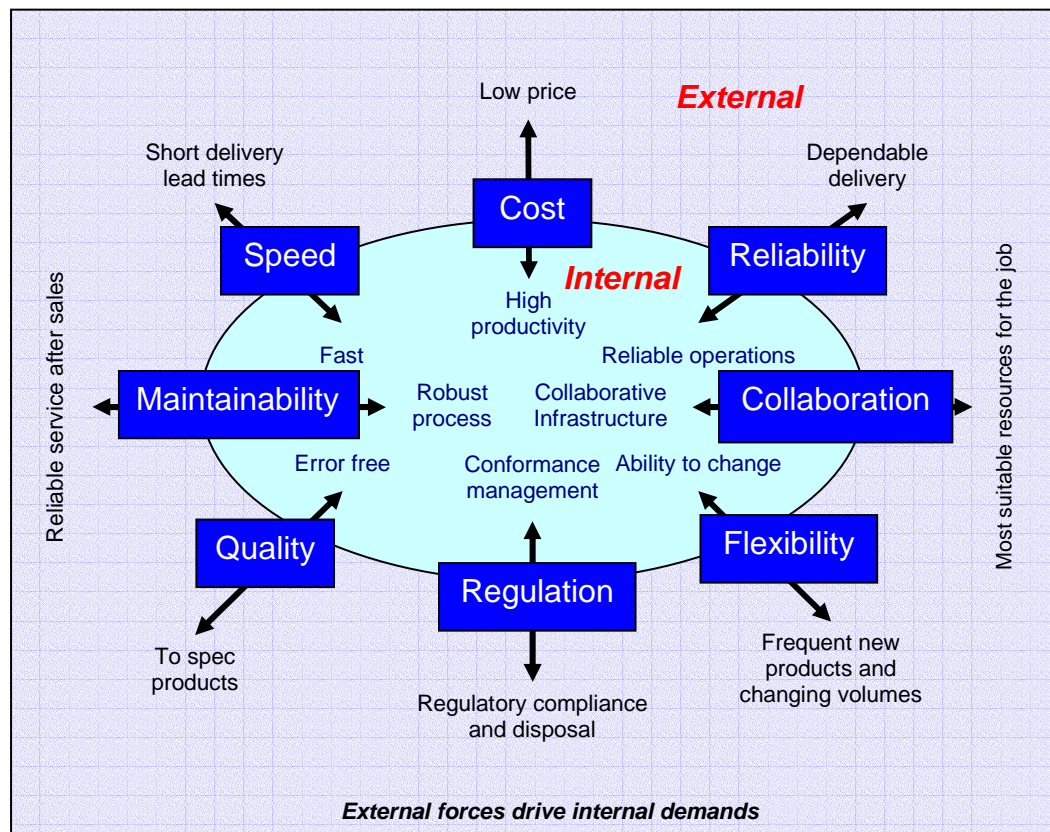
**As products and processes increase in complexity, risk increases.** Whilst it's impossible to eliminate risk, there is opportunity to manage it. "New" is inherently risky. Introducing techniques that expose and manage risk is a critical issue in the drive to better performance and profit.

All of these challenges make products and processes more complex. The root solution to managing these increasing complexities lies in the effective use and communication of accessible, consistent and up-to-date information for product and process through the complete product lifecycle. Fundamental to success is the application of IT solutions

such as Product Lifecycle Management. Application of these solutions to the challenges of increasing complexity will be discussed within the subsequent topics of this paper.

### 3 External challenges and internal change

External industry drivers coupled with assessment of a company's situation and aspiration result in the development of internal business initiatives. To be most effective, these must take advantage of the challenges and opportunities that result from internal forces as well as changes in the external environment.



Advancement and innovation require input from scarce and expensive specialist human resources. Ensuring that efficient use is made of this intellectual capital is a challenge in itself. As timescales shorten and complexity of products increases it is essential to both create and reuse tacit and implicit knowledge effectively. New methods and tools are required to deliver improved performance from limited resources.

It is becoming increasingly difficult for companies to maintain competence in all areas. The decision to develop, partner or buy is critical to ongoing success. The onus is now on the company to focus on the task at hand and capitalise on core competence to improve their offerings. The key is to innovate where value can be added and use external resource to augment this.

Design using external specialists is now easier than before. There is a time and cost penalty to package a design sub-task and send it to a specialist. In the past, this often meant that an in-house generalist designed a less than satisfactory solution which led to



late rework. Modern computing and telecommunications have moved the trade-off in favour of the subcontractor.

Expansion of the value chain outside the company's historic boundaries necessitates closer third party collaboration and information sharing. This is complicated by the need to manage the valuable intellectual property, which is at the heart of most design and manufacturing organisations.

As product technology demands increase, companies require broader skills from existing personnel. As a result, individual specialist skill levels decrease. Capture and reuse of knowledge and intellectual property becomes more important and more difficult. Tools that deskill complex activities and provide mechanisms to reuse historical knowledge become key assets.

Increase in complexity isn't purely driven by new features or innovative design processes. New production methodologies and changes in materials usage may also increase complexity. New regulations regarding product disposal have resulted in significant re-design and process change. End of life issues now have to be considered at the design stage and affect the whole organisation from concept through design, manufacture, service and disposal.

Customisation for specific delivery inherently adds complexity and, potentially, cost to deliverables, yet customers demand price consistency. With increasing functionality comes the challenge of product validation. Companies cannot afford the luxury and cost of numerous prototype cycles. As sophistication increases, product validation becomes more complex and testability more difficult. New methods and mechanisms are required to ensure customer satisfaction is maintained and products are delivered right first time.

With all the above evolutionary and environmental factors, risk increases. The challenge to business is to continue to develop whilst maintaining or improving the certainty of success.

## 4 From problems to solutions

The ever increasing demand to continually innovate drives complexity into products. If this increasing complexity is left unmanaged it increases business risk.

*Many objectives + few methods + high rate of technology change = very high risk*

Companies need to apply all available resources to deliver better and more suitable products and services at lower cost in shorter time. The capability to accomplish these objectives exists, and is enabled by the application of new methodologies and tools that capitalise on the competence and experience in the organisation.



<i>Within component manufacturing, take as an example a mobile phone battery manufacturer. Customers' demands for extended talk time and phone features necessitate development of batteries with greater charge carrying capacity. This encouraged development of more efficient rechargeable batteries. This required redesign and new manufacturing processes. As technology advanced, customers demanded that vibrating alerts be built into the batteries. This further increased the batteries' complexity, and again changed the complexity within design and manufacturing.</i>	<i>Within design to order products market, take for instance a company developing sophisticated imaging and robotics technology for use in surgical applications. The increasing demands for quality tracking requirements for stringent medical regulatory compliance drive the demand for increased complexity for design and data management. As customer demand for more sophisticated products drives greater use of subcontractors to manufacture subassemblies, the challenges regarding their compliance management become significantly more complex.</i>
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Technology change will continue at an ever more prolific rate. Business objectives continually expand to take account of new challenges, including new regulations.

*"Acknowledging this complexity and embracing the new paradigm now available will provide the foundation and theoretical framework to practically evolve beyond ideologies and arguments based on obsolete methodologies and agendas."  
Joseph Kruth Sustainable Communities, Globalization and Increasing Complexity*

To deliver business improvement requires:

- Reduction of product and process risk
- Consistent and improved innovation
- Improved re-use of assets
- Increasing the performance and capability of available resources.
- Improving quality and testability
- Designing in conformance
- Ensuring effective collaboration amongst all stakeholders

The next sub-sections examine each of these requirements in turn. For all of them successful application of a Product Lifecycle Management solution creates an environment that allows companies to best capitalise on all assets and stakeholders. It encourages innovation and creative thinking and minimises the overheads that impede time to market and continuous profitability.



## 4.1 Reduction of product and process risk

The escalating complexity of products and processes increases risk. There are a number of areas where use of PLM technology can help to manage this.

- Re-use of existing product and parts within the design process
- Early validation of product concepts
- Ensuring valid and consistent data are provided to and shared by all parties
- Automation of the development workflow and engineering change process
- Integrating all concerned stakeholders in the development lifecycle, for example:
  - Market research
  - R&D
  - Partners
  - Manufacturing
  - Quality
  - Sales
  - Customers
  - Service

PLM methodologies and solutions can enhance operational performance by consistently managing the complexities of changing product and process demands.

## 4.2 Innovation

Innovation is achieved by individuals and teams who have the tools and environment to allow them to be creative. Inflexible practices and lack of pertinent information stifle the innovation process. To enhance innovation companies must enable engineers to focus on creative tasks by making administrative and routine tasks easier.

Reducing the process management burden enables more time to be spent on solving problems. Engineers enjoy challenges and dislike process. Automating the underlying infrastructure allows them to work on more motivational creative tasks. Non-value added activities such as searching for specifications and documents stifles the creative process and can be avoided by using modern computer search technologies. PLM methodologies and solutions such as SMARTEAM from IBM and Dassault Systèmes automate the design flow and deliver valuable knowledge on demand, freeing up time for creative activities.

## 4.3 Improved re-use of assets

Lack of information and inefficient or incorrect use of it make complex problems more difficult to solve. The ability to search historic data for similar projects, products and data allows engineers to re-use information efficiently. The ideal case is

*“..We investigated registering a new patent only to find that it had already been registered by us a few years ago” Manager of a medium sized component company*





where an engineered part is replaced by an existing item already used in other designs. This delivers products to market quicker, and with higher quality. Non value added tasks such as redevelopment and information gathering can be kept to a minimum.

The ability to “design from” as opposed to “design again” increases efficiency and

*“...it was the case that it was easier to reinvent than to find” George Valaitis – Manager, Mechanical Engineering, MDS SCIEX*

delivers higher quality products. It is generally accepted that a significant proportion of new products are essentially similar to previous designs. This necessitates more modular and coordinated storage of product information. Reuse reduces risk, improves quality, and increases the return on previously expended development costs. PLM

solutions enable rapid development of variants and new products based on known and valid products, assemblies and parts.

Consideration must also be given to the multitude of originating data sources. These may include product and part design data, analysis information, test results, regulatory information, service history, and project management and design workflows. It is important that all relevant data be available for reuse to deliver maximum return on past efforts. This can be achieved by successful implementation of an ‘open systems’ based PLM solution which allows for storage and retrieval of data from multiple applications.

The old saying “garbage in equals’ garbage out” still holds true. Clear descriptions and categorisation of stored information result in effective reuse. Companies can reduce implementation risk by including appropriate professional service in both design and implementation of PLM solutions and processes. Experience of attribute and process design as well as “best practice” advice from suppliers help achieve both efficiency and effectiveness.

#### 4.4 Increasing the performance and capability of available resources

Improving returns from existing assets means making better use of all available resources. It's commonly known that great products come from great people. The challenge is how to make great people more efficient.

The first step is to remove mundane, yet critical tasks and procedures, such as configuration management, from skilled staff. Modern data management solutions deliver this capability. These tasks are critical to the effective and efficient development of quality products, but are seen as low value-add by engineers who prefer to spend their effort solving problems. The performance and transparency within modern configuration management solutions deliver a high degree of confidence and control to the product development process, and reduce the administration overheads that burden engineers and their management.

*Innovative capabilities such as ‘morphing’, found in Dassault Systèmes CATIA V5 product, take existing product designs and modify them into new variants. This saves time and reduces the need for engineers to reverse engineer past developments to create new variants.*



*“...the hurdles in developing this capability are purely emotional, but the benefits will be significant” George Valaitis – Manager, Mechanical Engineering, MDS SCIEX*

The second step is to provide powerful functions that fit specific design tasks more naturally. Embedding captured knowledge into design tools such as CATIA allows greater use of proven best practices and procedures. This enables customers to make better, more accurate decisions earlier in the design process.

*One mid-sized manufacturer has an objective to increase the use of sub-contractors to allow them to grow their business at a significantly greater rate than in the past. This includes specialist skills such as finite element analysis, where their demand cannot justify the expense of an internal resource. Extensive use is now being made of external design operations where the deliverables are not seen as core to the business.*

By using these capabilities organisations can accomplish a higher level of capability with lesser skilled individuals. This capability adds greatly to the productivity and quality of the design environment, but adds challenges in managing personnel issues involved in decentralising learnt knowledge.

## 4.5 Improving quality and testability

Customers continually demand greater quality and longevity and the costs of warranty repairs directly affect bottom line profit. The challenge is to develop more reliable, durable products without extending the design and test process, and without increasing product cost through over-design.

To do this, companies must validate developments early in the design cycle, and build in manufacturability and testability at an early stage. Early virtual prototyping and analysis is a fundamental benefit of modern design solutions. Errors can be trapped at an early stage which reduces the delays incurred in engineering change at production or assembly stages.

As product complexity increases, the ability to conceptualise prior to manufacture and test, in a virtual world, becomes more fundamental to improving cycle time. Users can assemble and validate complex assemblies at an early stage to investigate function and performance. Not only does this assist in up-front “form and fit” validation, it also provides an opportunity to try out new concepts. This is done without the risks and development delay involved in prototype build and helps to ensure that quality is maintained.

*“The trend towards increasing product complexity seems certain to make the environmental evaluation of products more difficult and expensive in the future” Georgia Institute of Technology, systems realisation laboratory*

*One manufacturing company cites, as an example, the challenges creating a wire harness for a complex electromechanical assembly. When the harness design was a separate process to the mechanical development, assumptions were made about the lengths and positioning which were only validated at final product assembly. Estimates made for length; routing and shielding often resulted in reengineering the harness after*



*the final mechanical assembly. This led to late engineering changes and subsequent delays in product delivery.*

Designing products that met specification was historically a trade-off between cost and confidence. By early evaluation of part and assembly analysis and simulation, companies are able to validate designs at a much earlier phase in the development process. Designing right first time is now possible, and has been proven in both large and small scale projects. This does not always eliminate the need to develop prototypes for testing, but significantly reduces the number of prototype cycles.

Up-front integration and management of testability data from design forms a key role in leading PLM solutions. Data for test, manufacturing and assembly can be managed and distributed to all relevant parties with minimal overhead through the product's lifecycle.

#### 4.6 Designing in conformance

Increasing pressures from customer specifications, governments and standards bodies drive increasing complexity in product lifecycles. This affects design, manufacturing, regulatory compliance and service after sales processes. To manage this demand, companies are being forced to change their products and working practices.

Advanced design solutions provide the ability to deliver specification driven design. This ensures that delivered products meet up-front requirements and work to specification first time.

Quality management standards such as ISO 9001 and demands for traceability require documentation which proves that procedures are followed. This is a particularly critical part of operations in the scientific, food processing and medical equipment markets. Managing access, process and enabling automatic audit trails are key attributes of PLM. Electronic signoff, a basic constituent of the audit process, forms part of the workflow process.

*"Designed-in reliability and conformance to international standards assures world-class products" Danaher Controls Web site, subsidiary of Danaher Corporation*

Compliance with environmental regulations often means changes to materials used. Rapid understanding of the impact on products and part portfolios enables companies to replace parts efficiently. This is a common feature of many PLM solutions.

#### 4.7 Ensuring effective collaboration amongst all stakeholders

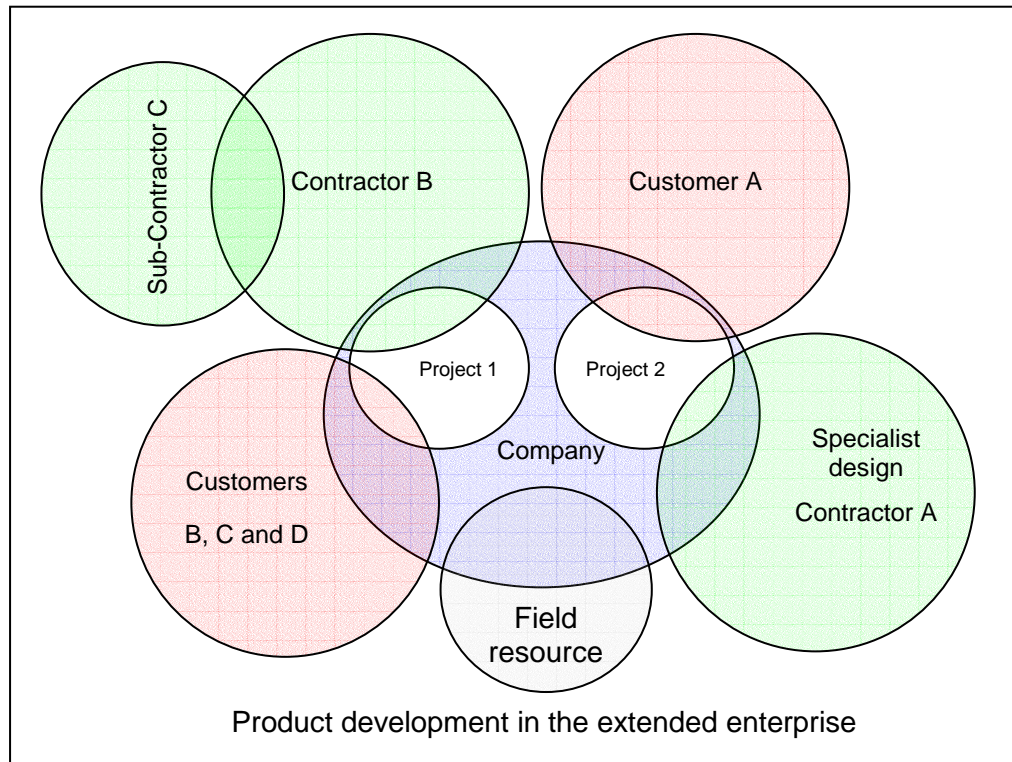
The network of stakeholders is increasingly complex. New mechanisms are required to manage the security and processes that enable a virtual project team. This is a fundamental constituent of PLM.

Modern PLM environments allow for multiple project relationships and information to be managed internally and externally.

These environments allow for:

- Shared workflows and project management between internally dispersed team members and external parties

- Common and proprietary data – distinguished between internal and external consumption
- Generally available information for public consumption



PLM solutions generally provide access to centrally stored data through desktop client software and web browsers. To protect confidential and proprietary intellectual property, these systems include comprehensive security management schemes. More comprehensive solutions, such as SMARTEAM, allow restricted parties to access pertinent information as it is approved or made available through the development workflow. It can be augmented by restrictions enabling variant or subset project data to be accessed by selected data consumers as the product development workflow progresses.

By capitalising on the common data stored and managed by these systems, companies can extend selected information access to the general public through linkages from their web sites. This ensures that information such as service and specification information is always up to date.

## 5 Managing compromises in the development process

Trade-offs are a fundamental part of modern business. The key is to optimise their time, cost and risk. PLM provides an infrastructure which enables this to happen.

Misinformation, incomplete information, poor judgement and poor communication can all lead to non-optimal trade-offs. To minimise this risk it is necessary to develop strategies to ensure that upfront decisions and assertions are made with the right information at hand. Quality can be maintained by managing workflows and enabling



valued collaboration between stakeholders to deliver products right first time and support them after sale.

Should a trade-off be required, PLM based solutions deliver the ability to validate alternates rapidly and understand the consequence of change. This enables users to efficiently analyse alternate solutions before committing them to manufacturing. Early validation of product capability, and production methods and processes by using tools such as thermal, stress and virtual assembly simulation deliver early confidence and reduce late engineering changes and rework.

## **6 Visions of the future**

It would be wrong to assume that demands from customers will abate. Indeed the opposite is true. Customers will continue to want improvements in performance, efficiency and price of products. And they will continue to demand that these are delivered in shorter timescales.

More rapid and prolific uptake of technologies such as PLM will produce tangible benefits in disparate product development environments. Affordability, simplicity of implementation and ease of use will enable all businesses to improve their productivity.

A move to “smarter” design and engineering and the more intelligent use of knowledge and people will offer the next step in productivity and responsiveness. Knowledge based PLM solutions are already in use in the market and numerous aerospace and automotive organisations cite improvements of 50% and higher. It's only a matter of time before these tools are more commonly applied by the wider engineering community.

## **7 Conclusions**

The demands of the market will continue to drive higher levels of product and process complexity.

Companies that look to take advantage of new developments in solutions such as product lifecycle management tools will be better positioned to manage this increasing complexity.

To accomplish this they must focus on applying solutions to capitalise on:

- Reducing product and process risk
- Delivering consistent and improved innovation
- Improving re-use of people and knowledge assets
- Delivering improved productivity from available resources.
- Improving product quality and testability
- Ensuring specification and regulatory conformance
- Enabling valued collaboration amongst all stakeholders