FOUNDATIONS OF ENGINEERING DESIGN
NSF / ASME STUDENT DESIGN ESSAY COMPETITION
GRADUATE CATEGORY

Achieving Success in 2030: Identifying Characteristics and Challenges for a High-Tech Global Manufacturing Enterprise

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Abstract

The success (or failure) of a high-tech manufacturer depends on its ability to establish business strategy roadmaps to predict as well as create next-generation products for its consumers. Moreover, with accelerating advances in technology as well as rapid changes in the political, social and economic landscapes of the world, long-term planning will be crucial for a company's continued success. Therefore, in this essay, the characteristics necessary for a company's success in 2030 are discussed. These characteristics can be categorized into a company's operational characteristics, and the partnerships and technologies that a company will need in 2030. In addition, the research challenges that exist for the realization of these characteristics are also presented. The research challenges are described in the context of two common underlying features, complexity and information management, with an emphasis on the use of models in the design process.

1 Introduction

In 1990, Alvin Toffler envisioned a future in which information and knowledge would radically alter the world's political and corporate landscape [1]. Twenty years later, globalization and widespread information availability have transformed the corporate environment by creating new competitors as well as global demand. Moreover, the internet has removed the limitations associated with geographic location, resulting in new competitors that run businesses in multiple countries while based in a different country. In the words of Thomas Friedman, author of *The World is Flat*, globalization will result in a "flattening" of the world economy, in which all competitors will have equal opportunities [2]. Due to the continuously changing landscape, the characteristics that define a successful company will be different in 2030 than they are now.

This essay presents a preliminary discussion on some of the characteristics that will be necessary for a company to be successful as well as some of the research challenges that will be encountered in the coming years. As shown in Figure 1, there are three main areas – operational characteristics, partnerships, and the use of technologies – that when combined, will lead to a successful high-tech manufacturing enterprise. However, there exist research challenges in each category that will affect the success or failure of a company in 2030. These research challenges are "drivers for success" that will differentiate a company from its rivals and enable it to achieve a competitive advantage. Accordingly, this essay is organized as follows. Section 2 discusses the forces that will impact the manufacturing industry in 2030. Section 3 then identifies the characteristics of a successful company in 2030 while setting up the research challenges that will be encountered. Section 4 then discusses the research challenges that will affect the product design process in the next twenty years. Finally, Section 5 summarizes the ideas presented in this essay for achieving success in 2030.

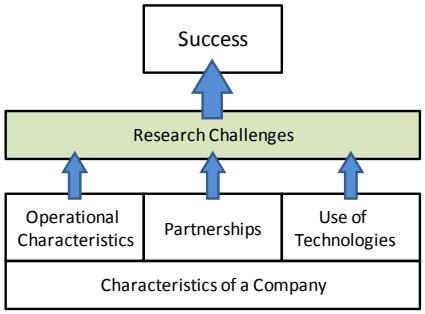


Figure 1 Path to success in 2030 will involve identifying the characteristics of a successful company as well as addressing the research challenges that will be faced in achieving these characteristics.

2 Manufacturing in 2030

In order to identify the challenges that will be faced in the next twenty years, we must identify the goal that is to be achieved before we can proceed towards it. The objective – to be a successful high-tech global manufacturing enterprise – can be decomposed into three main components:

- **Successful**: Create and maintain sustainable competitive advantage over its rivals
- **Global**: Have a worldwide presence in terms of engineering capabilities (design, manufacture) as well as customer base
- **High-tech manufacturing**: It is defined as a manufacturing segment which utilizes the latest technologies to create new products. According to OEDC, this segment includes nine main product groups such as aerospace, computers, non-electrical machinery, and armaments. Due to the risk involved in new technologies, correct investment decisions are crucial to maintain a competitive advantage [3].

Taken together, the objective for a company in 2030 will be:

> To achieve a competitive advantage in the manufacturing segment by using the latest technologies to deliver products to a global customer base.

To achieve this objective, it is necessary to understand the macroeconomic forces that will affect the company in 2030. Therefore, in Table 1, a PEST (Political, Economic, Social and Technological) analysis is presented, which provides indications of some of the trends that will impact the product design process in the manufacturing sector.

Table 1 PEST (Political, Economic, Social and Technological) Analysis for 2030 [2, 4]

Political	**Economic**
• Improved macroeconomic policies • Political situation in Middle East & African countries • Increasing influence of China and India • Increase in Foreign Direct Investments (FDI) • Stricter environmental norms	• Globalization • Scarcity of natural resources • Rising prices • Global economic climate • Rate of growth in developing countries
Social	**Technological**
• Increased average education level • Large middle class in developing countries • Aging population in developed countries • Virtual social networks as proxy to physical contact • Increased collaboration due to global networks • Change in consumer behavior pattern	• Increases in computing power • Global high speed wireless internet • R&D Centers in developing countries • Advances in materials, manufacturing processes • Rise in capital expenditures

From the PEST analysis, the following trends will have an impact on product requirements and design for the manufacturing sector:

- **Competition**: Increasing globalization will lead to more competitors from developing countries such as China and India.
- **Consumer demand**: Due to increased competition, consumers will demand more features at lower costs. Depending on the industry, switching costs will be reduced and so companies will be forced to reduce dependence on brand loyalty.
- **Service-Oriented**: Product downtime will not be tolerated by customers. Therefore, services will need to be offered *before* the product fails. This will also contribute to added complexity of the product, due to requirement of sensors and controls that are not part of the actual product.
- **Manufacturing**: New materials and manufacturing technologies will need to be integrated into the design process to generate innovative solutions to product requirements.
- **Environmental Concerns**: Decreasing natural resources as well as stricter environmental regulations will require different designs that incorporate sustainable design as well as environmentally friendly materials.
- **Complexity**: The constant demand for more features, lower costs and smaller size all contribute to an increase in complexity of products. For instance, the integration of cell phones with mechanical sensors to provide advanced functionality increases the complexity of the product considerably. This trend of increasing complexity will be a key feature of next-gen high-tech products in 2030.

3 Characteristics of a Successful Company in 2030

Based on the trends outlined in the previous section, it is possible to determine some of the characteristics that a successful company will need in 2030. They can be classified in terms of the company's operational characteristics, necessary partnerships and its use of technologies that are likely to be prevalent twenty years from now. Moreover, these three categories are highly interconnected and a company will be successful if it is able to achieve a synergy between all of the categories. In Figure 2, a summary is provided for the characteristics of a successful company and the common research challenges that will be faced in all three categories.

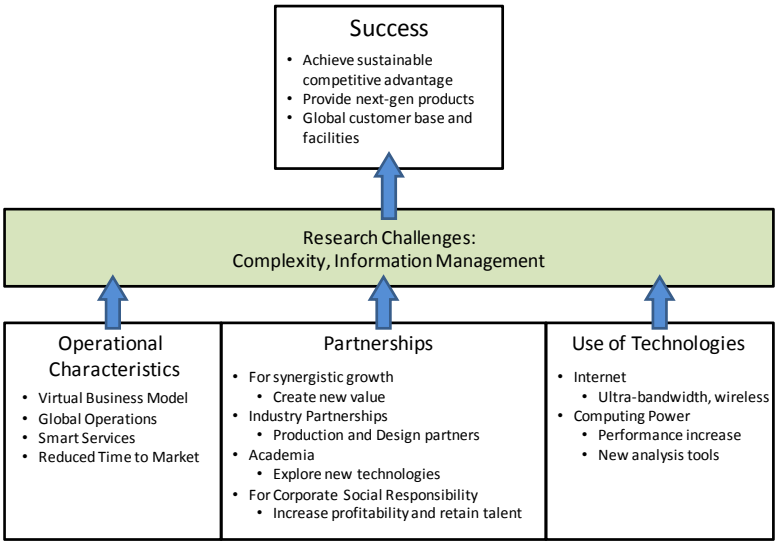


Figure 2 Summary of the characteristics and challenges of a successful high-tech manufacturing enterprise in 2030

3.1 Operational Characteristics

Operational characteristics of a successful company include its values, business strategy, type of product offerings, time involved in the product's lifecycle, and others. Only some of the key characteristics will be discussed in this section.

The success of high-tech manufacturing based companies will depend on their ability to create next-generation products in time, so that the product does not become obsolete before its release [5]. Therefore, in the face of increasing competition, companies will be required to focus on their core competencies and existing core products in order to make proper investment decisions as well as to maintain a competitive advantage. In such situations, a "***Virtual Business Model***" business strategy will become popular due to the increasing costs associated with maintaining expertise in areas that are not part of their core competencies. As per the virtual business model, a company will maintain a limited number of employees for only its principal operations, such as design and R&D of its core products. The remaining tasks such as production, distribution and marketing will be outsourced to either subsidiaries or partners [6]. As a result of the lower overheads associated with this business model, a company will be able to remain agile as well as retain an entrepreneurial spirit by focusing on its core competencies. Consequently, it will be able to adapt faster to changing technology and demand as well as push the envelope of existing technologies. Finally, concentrating on core design and R&D will help in retaining strong control over Intellectual Property (IP) rights, which will be essential when faced with multiple competitors in high-investment, high-risk technology fields.

To adopt such a business strategy, it will be necessary to form partnerships with companies that can provide the required services at the lowest costs. With the increase in globalization, this will lead to a network of ***Global Operations***, with a majority of research centers and outsourcing operations in emerging economies such as China and India. Moreover, a network of global operations will improve the company's ability to provide local service support, such as maintenance and training, which will serve as a differentiator over competing products.

However, due to the increasing costs associated with product down-times, companies will have to focus more on providing "***Smart Services***", which are preemptive instead of reactive [7]. Smart services rely on real time sensor data to know *before* an event, such as machine failure or inventory stock-out, occurs. For instance, a high-tech manufacturer of jet engines cannot have its products fail during operation. Therefore, using sensors to provide real time monitoring will enable the manufacturer to monitor engine performance and provide service to the engines

before a failure will occur. Thus, smart services will prevent customers from switching to competitors' products, enabling a company to create a sustainable competitive advantage. Similar to smart services, another key differentiator will be the ability to provide such next generation products in the shortest possible time.

For a high-tech company, the product design period (conception to release for production) is one of the riskiest periods due to the uncertainty in technological innovation as well as the uncertainty in the amount of time required to design the product. There is danger of the product becoming obsolete if the product design process takes too long and newer technologies take its place. In addition, the threat of substitutes will also contribute to a need to reduce the ***Time to Market*** (TTM) for a product. The TTM for a product can be reduced by two approaches: improve the supply chain for products already designed, reduce the time involved in the design process, or both.

The supply chain is a critical component of manufacturing industries, which directly affects the profitability by determining the cost of the product. With global operations, the need for more efficient supply chains will be crucial. Moreover, with distributed design and production, the resultant supply chain for high-tech industries will be highly interdependent. The Joint Strike Fighter is an ideal example of a next generation product with a complex global supply chain that is highly interdependent [8]. Therefore, with so much variability in each link, establishing efficient supply chains with minimum variability to reduce TTM will be a major challenge in the coming years.

TTM can also be reduced by decreasing the time involved in the design process for the complete product lifecycle. However, TTM should not be improved by cutting corners in the design process, which can affect the resultant product quality, cost or feature set [9]. Therefore, improvements are needed in the actual design process, such as automatic component selection or the reuse of knowledge. With the increase in product complexity, scalable solutions will be required that can reduce the time in the design process.

In conclusion, a successful company in 2030 will require a different set of operating characteristics than currently needed. Some of these characteristics are: a virtual business model strategy to adapt quickly to changing demands, a global operations network to utilize the most effective talent and production, a focus on smart services in addition to the core product, and a minimum TTM that can be achieved through efficient supply chain as well as improved design processes. Each of these characteristics involves many different research challenges between now and 2030. However, all of these characteristics have two common features: **complexity** and **information management**, and their research challenges are discussed in Section 4.

Another common feature present in all of these characteristics is the need for partnerships. Partnerships are necessary for designing products with distributed teams, global operations, as well as for managing complex global supply chains. Therefore, partnerships will be essential for maintaining sustainable growth, and will be discussed in the next section.

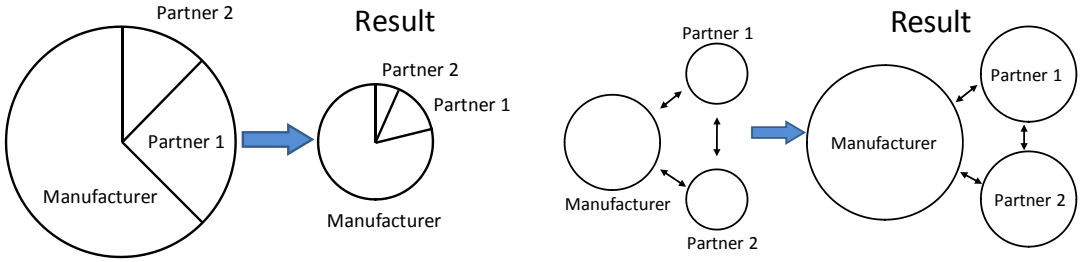
3.2 Partnerships

To achieve the operational characteristics outlined in the previous section, some of the key partnerships that will be required are presented below.

Value Creation Based Partnerships for Synergistic Growth:

For a company to be successful in 2030, it will have to focus on its core competencies to satisfy its consumer's demands. Consequently, in addition to manufacturer-supplier partnerships, partnerships in the design phase will also be necessary. For instance, a process control equipment manufacturer may possess a core competency of instrumentation and control. However, other aspects such as mechanical design and software design constitute an important, but not core, part of the complete product, without which the product fails to satisfy customer requirements. Therefore, instead of spending time and money to build up these secondary competencies, partnerships will need to be formed with other companies that possess them as their core competencies. These types of partnerships are of the win-win type, as opposed to conventional partnerships in which the manufacturer tries to

leverage more value at the expense of the less powerful supplier (or vice-versa). The key to such a partnership is *joint dependence,* in which dependence between the partners leads to new value creation, resulting in greater growth for *all* the partners involved, and not just the manufacturer [10]. This concept of value based partnerships is shown in Figure 3, in which the pie (circle) represents a company's relative value.



a) Conventional Partnership: Total value decreases over time.

b) Value based: New value is created over time. Everyone grows.

Figure 3 Need for value based partnerships instead of conventional partnerships

Moreover, due to globalized operations and the power of the internet, partnerships will be formed internationally with companies that have complementing competencies. Currently, developing countries are mainly used for labor intensive tasks such as manufacturing or service providers (call centers). This is likely to change in the next two decades, due to a "flattening" of the industrial and developing countries [2]. Factors such as improving education, presence of large skilled youth workforce, and rapidly growing economies will lead to partnerships being formed for design-related tasks as well, such as design consulting or R&D centers for innovation in new technologies.

However, with increasing partnerships, there is a risk associated with Intellectual Property (IP) violations and its consequences. Partnerships, both manufacturing and design related, will require a transfer of knowledge between all partners involved. This may lead to purposeful violations of IP rights, which can lead to copycat products from competitors, resulting in significant loss of business. On the other hand, inadvertent misuse of confidential information can lead to a loss of goodwill between partners, resulting in lost market share due to strained relations. Finally, international legal policies vary and therefore caution must be exercised when establishing new foreign partnerships, such as in China [11].

Despite the risks involved, the need for synergistic growth through partnerships will become increasingly important in the world of 2030, due to advances in technology that will make it more difficult to have competency in all of the required areas. In addition to partnerships with other companies, academic partnerships will also become more important in order for a company to be at the cutting edge of rapidly changing technology.

Academic Collaboration:

Since the high-technology sector employs the latest technologies to create next generation products, it therefore becomes imperative to identify the latest trends in technology in order to maintain a competitive edge. However, since the next hot technology trend is unknown, the primary concern for a company is the proper allocation of resources and time to upcoming technologies that are not yet clearly understood. For instance, in the video game industry, Nintendo adopted a radical shift in technology, resulting in huge dividends, while competitors such as Sony have struggled for the last three years. Thus, there is a tremendous payoff in selecting the right technology, but there is also a significant penalty involved in choosing the incorrect technology. This is where partnerships with academia come into the picture.

Academia is always interested in pushing the envelope of current technologies, and commercial implications are given lower priorities. Exposing dead-ends or limitations of technologies are also important research areas that cannot be performed in industry, since the objective there is to minimize the uncertainty involved in allocating resources to upcoming technologies that are not yet clearly understood. Therefore, partnerships with academia can act as incubators for new technologies, thereby providing a company with the crucial guidance of how to allocate resources to new technologies. Moreover, academia can also explore solutions to the research questions that are associated with the success of a company, such as improving current design process methodologies. A flow chart for conducting academic collaboration is presented in Figure 4. Academic collaboration will lead to new breakthrough which will then be implemented by a company for improving its design process or for creating new products. Moreover, academia will also help in determining limitations of technologies or technology dead-ends, which will help prevent a company from making wrong technology investments. For instance, the use of incorrect statistical formulas for financial predictions was one of the causes for the huge losses in the financial markets in 2008 [12]. In the future, the likelihood of similar technology failures could be reduced by academic partnerships, by providing companies with better indicators for technological feasibility.

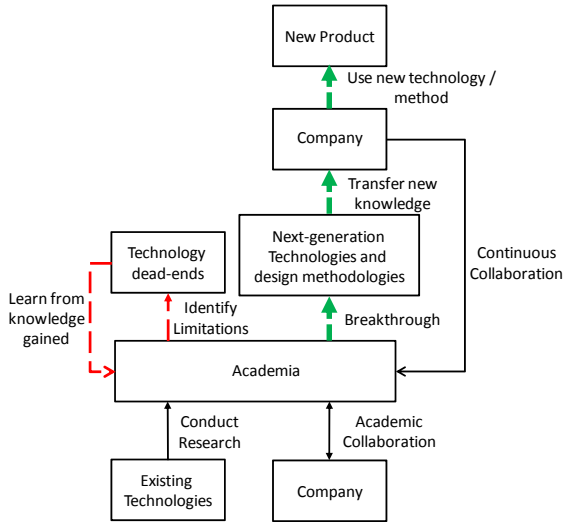


Figure 4 Academic Collaboration to identify new technologies and design methodologies for creation of next-gen products

In addition to academic partnerships, a company's social activities and partnerships will also play an important role in maintaining sustainable growth.

Corporate Social Responsibility (CSR):

For a company to be successful in 2030, it will have to form partnerships to concentrate on providing value to its customers and society, in addition to maintaining profitability. Such activities, which serve the community, represent a company's level of corporate social responsibility (CSR). In the coming years, CSR will shift from its present state of being a secondary branch of a company's operations to becoming an integral part of a company's primary operations and value systems. For instance, twenty years ago, only a few companies practiced CSR since it was considered to be detrimental to profits. However, this has changed in recent years and will continue to become more important due to a number of factors, such as rise in energy prices, scarcity of natural resources and stricter environmental regulations. Moreover, high-tech companies will be at the forefront of this new change towards CSR, in order to minimize product costs and increase profitability [13]. Consequently, CSR activities such as zero-waste manufacturing and using alternatives to oil will become a core part of a successful company's value chain.

In addition to increasing profitability, CSR-based activities will help in retaining skilled employees, which will be an important factor for high-tech companies in 2030 [14]. Companies that practice CSR will gain a positive brand image, both from consumers and employees, by positioning itself as a company that serves its customers and the world community. Moreover, CSR activities in developing countries will promote economic and social development, thereby leading to more potential for future demand and customers. This will also help build brand loyalty, which will be important when facing increased competition from a global market.

Similar to the operating characteristics, establishing the partnerships outlined in this essay also share certain common research challenges, namely **complexity** and **information management**. Multiple partnerships, within industry as well as with academia, will require free flow of information and knowledge in both directions. In

addition, this will require next generation information management systems, which will be able to handle the rapid changes in technology. Moreover, partnerships in the design process as well as supply chain will create additional complexity related to managing consistency between information that is held by the partners involved. Both of these issues carry with them a number of research challenges, which are discussed in Section 4. In order to solve such research challenges and successfully deliver next-gen products, companies will need to use external technologies that will develop concurrently in the years between now and 2030. Two such evolving technologies are discussed in the next section.

3.3 Technology

In order to achieve the operational characteristics as well as partnerships outlined in the previous sections, the following are two of the many technologies that will play an important role in the next two decades. A successful company in 2030 will need to use these technologies in order to design and deliver products with advanced features in the most efficient manner.

Internet:

The internet has revolutionized the way business has been conducted over the past twenty years and it will play a similar role in the next two decades as well. Increasing speeds and bandwidth, coupled with high-speed wireless access will enable information exchange on an unprecedented level. For instance, high-speed wireless access will create new opportunities for smart services that can be provided by connecting products wirelessly across the world. More importantly, high-speed internet will allow for greater real time information transfer between distributed design teams, such as complex simulations and models. Another benefit of high-speed wireless internet is that large amounts of design information can be stored and used online, removing the need for local storage as well as providing access anywhere in the world at any time. In addition, it will help a company secure its intellectual property by restricting duplication of important design knowledge.

However, along with the advances in internet technologies, increases in computing power will also play an important role in the product lifecycle process.

Computing Power:

Computing power has changed the way design is conducted over the last half century by allowing the designer to more accurately describe the complexities involved in the products. Greater computing power has led to more complex, detailed simulations, which has resulted in products with much higher performance and safety. This trend is likely to continue. Over the next twenty years, processing capabilities will increases to an order of magnitude greater than that available today. In addition, new computing platforms such as cloud computing will transform the way in which tools are used to aid in the design process. For instance, in 2009, a computer program was able to self-discover certain laws of physics from large experimental data-sets [15]. Over the next twenty years, advances in these areas combined with increasing computing power will provide new tools to analyze the complex phenomena involved in high-technology areas. As a result, the design process itself will need to adapt to incorporate these new methods and tools available to the designer. However, to support these new design methods and tools, there will be an increased need for frameworks that will bring together the large quantities of interrelated knowledge that will exist for the different disciplines involved during the product design process.

From the discussion on operational characteristics, necessary partnerships and the use of technologies, a common thread emerges that ties them all together. This common thread is that the success of a company in 2030 will depend on its ability to handle the increasing **complexity** in the product and design process, as well as put in place an **information management** system that will enable a company to design and manage its next-gen products efficiently. The research challenges involved in this will be discussed in the next section.

4 Research Challenges for 2030

Based on the characteristics discussed in the previous section for a successful company in 2030, it is clear that complexity and information management will be two critical areas that will determine the success (or failure) of a company. Therefore, this section discusses some of the research challenges that will need to be addressed by academia in the coming years.

4.1 Handling complexity in the design process

As products become more complex due to increasing feature sets and smaller sizes, the product design process correspondingly becomes more complex. Complexity in the design process arises due to an increase in the number of parameters that influence system behavior as well as due to a lack of understanding of the behavior of the physical phenomena involved. This will be the case for the next generation products that will be produced in the coming years. Due to the multiple disciplines involved, such as mechanical, electrical, electronics, and software, the product must be designed from all aspects.

Therefore, designers will have to ask questions such as:

a. How to translate large number of requirements into system and subsystem models?
b. To what level of detail should these models be developed and how to determine required level of detail?
c. How to incorporate different levels of analysis for different parameters involved in a system?

Such questions are non-trivial; with a large number of requirements arising due to a demand for more features, translating the requirements into models that accurately represent them will be a challenge. Towards this end, approaches such as utility theory, which combine multiple requirements into a single metric of total utility, can be used.

Along with creating system and subsystem models, it will be necessary to know the level of detail that each model should contain, since different stages of design require different accuracies. For instance, in the conceptual design phase, creating detailed models for all of the different configurations is a waste of time and effort, since only a particular configuration will be taken forward in the next phase. Therefore, new techniques will be required that can quickly analyze different configurations and aid in selecting the appropriate one. This will be made more challenging due to the large number of different subsystems and domains involved in the product.

Due to the varied disciplines and subsystems involved, there will be many design parameters that will affect the performance of the entire system. However, not all parameters are equally important. Therefore, different parameters will require models of varying complexity. For instance, an actuator may be modeled using dynamic behavioral simulations while conductors may be modeled using heuristics or other low-level analyses. Therefore, new methodologies will be required that can quickly analyze systems with models of different types as well as similar models with varying levels of detail.

On top of all of these questions, the need for global operations with distributed design teams adds another layer of research challenges that will need to be addressed by academia. Different design teams, in various locations, focused on different but ultimately related aspects, increase the complexity associated with the design process. This is where the need for an integrated information management system arises.

4.2 Information management

As discussed in the previous section on complexity, information management will be essential when dealing with distributed design teams as well as multiple stakeholders, representing the large number of requirements. Since the various domains and subsystems involved interact with each other, information exchange between the teams will be crucial. Combined with the various analysis tools available for each domain, the multi-disciplinary nature of the

product design process will result in large quantities of data, managed separately for each domain. In such cases, an information management framework will be crucial to efficiently integrate as well as maintain consistency between the large quantities of design data.

However, the complexities associated with such frameworks are such that project organization will be as complex as the challenges faced in designing the system [5, 16]. Therefore, some of the research challenges that will be faced are:

a. How to maintain consistency between models in different domains and subsystems?
b. How should the models be stored?
c. What levels of standardization are required, and how should standards be defined to adapt to changing technologies?
d. Are new product lifecycle development frameworks needed?

These issues are non-trivial, due to the inertia within each of the individual disciplines. Due to different conventions and techniques in each domain, integrating them to allow for information exchange is difficult and many times not possible. Moreover, standards established in each discipline are unlikely to change. Therefore, academia will need to define new methodologies that will be able to integrate between different models as well as maintain consistency between them. Frameworks such as Model Based Systems Engineering (MBSE), shown in Figure 5, provide a good starting platform, in which models are used at every step in the design process.

However, when dealing with models that are interconnected, the question of model storage becomes an issue. How and where should information about consistency and relations between models be stored? When attempting to answer such questions, standardization will be an important factor to be considered. What kind of standardization will be required in order to support different disciplines, and more importantly, be able to support changing technology requirements? Current research involves the use of general purpose modeling languages such as Systems Modeling Language (SysML^{TM}) [17] as a unifying language that can integrate the multiple disciplines involved as well as provide a mechanism for systems-level design.

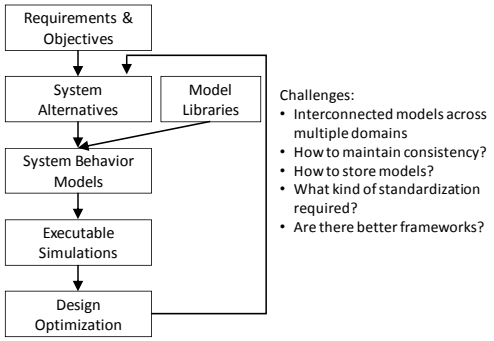


Figure 5 Model Based Systems Engineering Framework for Product Development

Finally, in addition to considering models and their relations, the framework in which product development is done will need to be revisited. We will need to determine whether there exist more efficient lifecycle development frameworks than those currently used, such as the Waterfall, Spiral or Vee methods [18]. Thus, addressing these research challenges will play a key role in designing high-tech next generation products in the coming years as well as in 2030.

5 Conclusion

In this essay, characteristics that will define the success for a high-tech company in 2030 have been identified as well as the associated research challenges. Some of the core challenges lie in addressing the increasing complexity involved in the product design process as well as incorporating an information management framework that can integrate across the entire design process. In terms of operating characteristics for a successful company, adopting a virtual business model will allow a company to focus more on creativity, resulting in greater opportunities for innovation. Companies will also have to focus on smart services, in order to reduce the threat from competing substitutes. A changing business model and focus on services will necessitate a global network of

partners for both design and production. However, challenges involving complexity and information management will act as hurdles to designing next generation products on schedule. Addressing these research challenges will help in decreasing the time to market for products as well as stay "ahead of the curve". Therefore, partnerships with academia will be necessary for a successful company. Partnerships that increase a company's CSR activities will also be important in determining success or failure of the company.

With the rapid advances in technology that are occurring daily, it is impossible to predict with any amount of certainty what the future will hold in 2030. However, the characteristics outlined in this essay represent general guidelines for any company that wants to succeed in today's global competitive economy. Finally, it is important to remember that "the more things change, the more they stay the same[1]." It means that no matter how much technology changes and becomes more complex, the fundamentals for successful product design will remain the same – satisfy the customer's needs.

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[1] A literal translation of the French proverb: *plus ça change, plus c'est pareil*