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PLATFORM STRATEGIES FOR A SUPPLIER IN THE AIRCRAFT ENGINE INDUSTRY

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ABSTRACT

The utilization of a platform strategy has become a competitive priority in many industries, most notably in the automotive industry. Naturally, many firms in other industries are adopting this strategy with different modifications and degrees of implementation. However, little research covers the application of platform development in a supplier and/or small batch production environment. The adaptation of a platform strategy in these settings, by a supplier in the aircraft engine industry, is the focal point of this paper.

Based on platform development literature and the characteristics of the aircraft engine industry and the company studied advantages and hindrances for platform strategies have been ruled out. Interviews with involved people within the company studied have further clarified different perspectives on platforms and their possible utilization. Based on the analysis of collected information it is proposed that a possible platform strategy would include: a technology platform, incorporating general knowledge on core technology assets embodied in either humans, organizations, processes, information or methods; and a product platform, incorporating product specific elements that could be re-used when developing new components for a particular product line.

Keywords: Platform strategy, supplier, aircraft engine

1 INTRODUCTION

The utilization of a platform strategy has become a competitive priority in many industries, most notably in the automotive industry. Many firms in other industries are adopting this strategy with different modifications and degrees of implementation. This adaptation is the focal point of this paper. Key factors (motors) for utilizing platforms in a global organization includes: the *economies of scale* by reusing design solutions and minimizing bill-of-materials; *customer-oriented offers* with high degree of variety; the *responsiveness* in time-to-market; and the *flexible utilization of design and manufacturing resources*. It is however not a straightforward process to define a platform strategy, nor leverage an existing platform to achieve its expected benefits. This is no wonder since developing a platform strategy is a long term effort that has to be done while managing existing product portfolios and rapidly changing demands. Naturally, it also needs to be economically sound in both short and long terms. Consequently, defining a platform strategy is not only a technical decision but is also highly linked to how the business operates.

A common perspective taken on platforms is from a mass-producer of consumer-goods, often focusing on the product

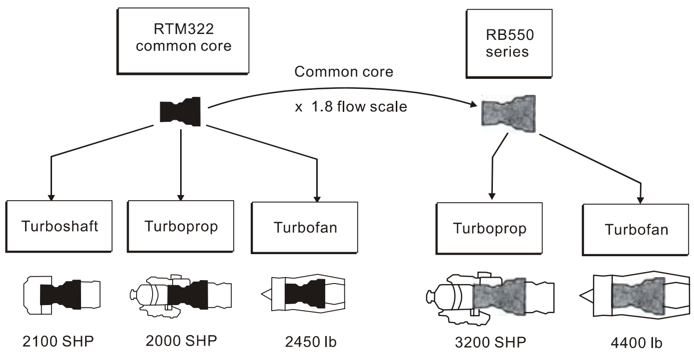

Figure 2. A scaled platform from Rolls Royce which realises a family of engines with different thrust output and specific fuel consumption [4]

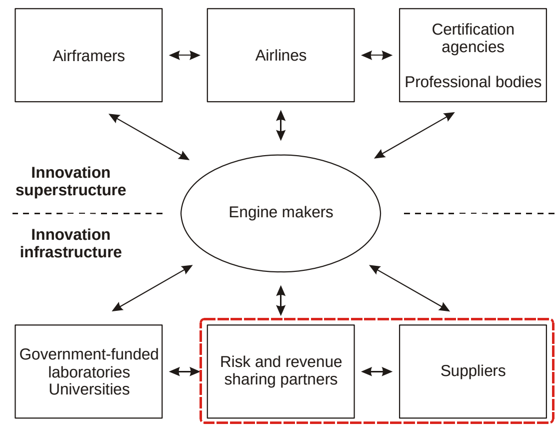

Figure 1. The aircraft engine industry meso-system [11] with VAC operations in red.

domain. However, a platform strategy has also significant benefits at other levels. A platform could be defined in terms of manufacturing processes. In this way, similar products could be produced and assembled in the same production line – with the possibility to develop product variations which have only limited impact on the manufacturing processes. It could also be defined in terms of organizational structures (e.g. cross-functional teams for the integration of product components considering a chosen platform). However, technological innovation or radical steps seldom arises from a pure platform organization: rather it arises from advanced engineering that could be focusing on a technological platform. In this sense, a technological platform focuses on knowledge assets in core areas with the aim to capitalize as much as possible on these technologies in various market niches.

The implementation of a platform strategy within an organization has been identified by researchers to enhance 'economies of scale' [1]. These enhanced economies of scale result from component/module standardization and design reuse. In this regard, the most detailed account of component standardization in literature to date is of Black and Decker. Black and Decker, a consumer power tool company, redesigned its basic universal motor such that a range of power options were possible by varying one design parameter – stack length [2, 3]. This new design with standardization across other major subsystems in their product offerings led to 85% savings in labor costs per unit [2]. These savings may tend to be magnified or some might argue justified due to the inherent large demand (in millions) for consumer products.

On the other, the aircraft engine industry is characterized by volumes that are several orders fewer in magnitude (in hundreds) and products that have high degree of engineering complexity. Even so, Rolls Royce RTM 322 aircraft engine is widely cited as an example for internal leveraging [4], see Figure 1. In the 1970s, Rolls Royce with the use of modularity simplified the design of the complex aircraft engine for a number of reasons including to realize economies of scale. Partitioning the engine into seven basic modules: fan (or low pressure compressor), high pressure compressor, combustion chamber, high pressure turbine, low pressure turbine, exhaust nozzle and control system enabled Rolls Royce to exploit economies of scale across engines and over time, as well as to facilitate ease of maintenance [5].

In recent years, not only mass-producers of consumer-goods but other types of companies (e.g. suppliers) have identified platforms as a fruitful approach to create competitive advantages [6]. For instance, as presented in research, the usage of market segmentation grids for developing a product platform for yokes used to mount valve actuators in the nuclear power industry [7], the examination of how a robust standardization of components could be implemented during the design of an absorber-evaporator module for a family of absorption chillers [8], and various other implementations in industrial settings [9, 10]. However, little research covers the application of platform development strategies when it comes to specialized small batch production (as opposed to off-the-shelf components) in business-to-business relations. This paper will analyze the advantages and hindrances for the implementation of a platform strategy in such a situation. This will be done from the perspective of a supplier in the aircraft engine industry.

1.1 Background

An aircraft engine is a multi-technology, multi-component product involving high costs and intensive engineering. The complex nature of the aircraft engine is similarly reflected in the multi-tiered, multi-player aircraft engine industry. Unlike the traditional tiered buyer-seller model, the aircraft engine industry is characterized by six interdependent groups: the airlines, the airframers, the certification agencies and professional bodies, the government-funded laboratories and universities, the risk and revenue sharing partners, and the suppliers [11]. Figure 2 shows the industry relationships between a supplier and other groups influencing the aircraft engine industry. The functioning of these individual interest groups is coordinated through close linkages with the engine makers, also referred to as system integrators. Over the last decade, these business to business relationships (essentially between different groups) have reduced to fewer and fewer companies. Therefore it is not uncommon to find a supplier that works with different, even competing engine makers in multiple roles with varying responsibilities ranging from make-to-print to involvement in technology development.

The company studied, Volvo Aero Corporation (VAC), is based in Sweden and is primarily active in the aero engine industry. Its main operations are as a subcontractor supplying its customers with components in a business-to-business relationship. It is an old company, dating back to the 1930s, with a strong tradition of technology development intended primarily for military applications. The company was founded to support the Swedish Air Force. This focus remained unaltered for many years but, in the 1970s, the company management realized that, to continue growing and evolving, new markets and product areas had to be opened up. During the past 30 years, the company has gone through great changes and is today a component supplier for most major types of civilian aircrafts. The civilian component specialization has gradually evolved from make-to-print, without any design responsibility, to accepting design work under customer leadership, to taking on the full design responsibility for selected products. Today the strategy of the customers of the company has shifted towards that of system integrators who expect their suppliers to take on the full component or sub-system responsibility including developing innovative technologies within their respective specializations. The company is in many ways very typical for the aero engine industry. It has been a player in this particular market for a long time, has strong national roots but has transformed and become highly international. Business is done in all engine life cycle phases, and the company enters into business relationships both as a Risk-and-revenue-Sharing Partner (RSP) and as a make-to-print supplier through Long Term Agreements (LTA). The company has development capability in specific component specializations with an ambition to grow and take on a larger responsibility and expand its role in future engine development programs. VAC has chosen a design specialization on hot and cold static structures, such as turbine exhaust cases and fan hub frames, but also manufacture other components on make-to-print basis, such as shafts and discs, see Figure 3.

2 PROBLEM DEFINITION

Since VAC is a part of the aircraft engine industry at the first or second tier level, depending on their role in the program, they quite naturally want to take part in the foreseen aircraft engine industry growth. It is a company with a long history of cooperation with the major engine manufacturers around the world. Depending on business opportunities and company capabilities, they intend to enter different forms of future cooperations, both RSP and LTA as mentioned above. Financial restrictions will however limit the number, and share, of programs which can be entered. Access to personnel and competence is restricted and the company will have a problem engaging in too many new programs. It is therefore natural for the company to seek venues of synergy between different programs in order to utilize scarce resources with maximized efficiency. There is consequently a need to improve efficiency in the development programs in order to make it possible to accept larger program shares without increasing the financial investment. Additionally the company strives to develop technologies which can benefit as many products as possible and at the same time constitute a basis for enlarging the product portfolio. A platform strategy is thought to achieve these internal and external benefits.

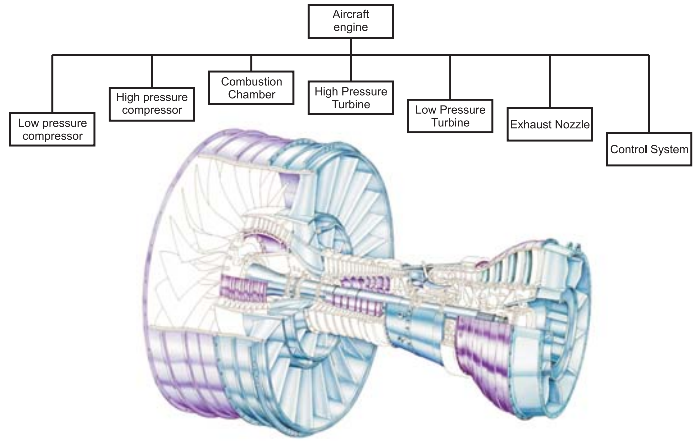

Figure 3. Civil aircraft engine structure, coloured components are typically designed and produced by VAC

Starting out from what has been reported in literature and combining with the particular needs of this company we want to explore the following research questions:

- What current best practices on platform formulation could be applicable to a company like VAC, a sub-supplier in a low batch production environment?
- Based on the needs from a company such as VAC, how could a suitable platform be formulated?

3 RESEARCH APPROACH

This paper is a result of a collaborative industry-university study involving Chalmers University of Technology (Sweden), Michigan Technological University (USA), and Volvo Aero Corporation (Sweden). This study was performed during spring 2007 when empirical data was gathered through eight interviews with key managers and strategists at VAC. The interview material was then analyzed and discussed in workshops with participants from the three involved parties. In addition, there has been an intervention between the researchers and the actual work within the organization to formulate a product platform within the different product lines. Consequently, the action-research approach [12] has been flavored by participation and co-learning between inside and outside researchers. In order to map a research gap to current state of practice a literature review was also conducted in parallel to this study.

This approach is believed to have given a good view on the needs of VAC as well as the current state of practice. In order to assure validation of the study, workshops were conducted to allow discussion of the research findings between the researchers and company employees. The collaboration with two universities further enabled a broad view on the published material in related research, adding insights to ensure the validation of the study.

4 PLATFORM STRATEGIES FROM A VOLVO AERO PERSPECTIVE

Product platforms are recognized to offer a number of advantages in the marketplace as well as within the organization. As a result, researchers have studied and proposed suitable frameworks, methods, and mathematical tools to assist in the selection of the platform elements within different industries as summarized by Simpson [13], Simpson et al. [1], Jose and Tollenaere [14] and Yang et al. [15]. The aim of this section is to briefly summarize the potential benefits of platforms characterized from a VAC viewpoint. The benefits are viewed as directly resulting from two types of activities: leveraging within the organization (internal leveraging) and leveraging external to the organization (market leveraging). Such typology is adopted only to clarify and separate the organizational intents in carrying out platform development.

4.1 Internal Leveraging

When discussing the needs and benefits of a platform strategy with personnel within product development, the internal factors are not surprisingly highlighted. A platform for Volvo Aero is basically seen as a way to respond faster in the order delivery process. In the current situation, there could be 50 weeks between order and delivery of large casts from VAC suppliers, so the product development process has to be very fast, in order to reduce the total development lead-time. It is believed that the development of a platform would enable Volvo Aero to be better prepared with mature technologies and manufacturing processes, together with contracted suppliers. Hence a platform is mainly seen as a means to increase the organization's responsiveness. It is believed that with an effective platform, incorporating generic technologies, product elements, engineering methods and manufacturing processes, one could quickly and more accurately offer a potential customer an optimized product.

Technological perspective. Considering the high level of technological knowledge within VAC and their active work to conceive, asses and develop new technologies it is not farfetched to think of a technology platform. Today, new technologies are continuously developed for new engine programs and synergies are searched for in order to serve all business units. These technologies are often applicable in other settings than in aircraft engines, and in such cases the company actively searches for new applications and markets for their technologies. However, the technology portfolio is not really formalized, at least in the sense that it is formally communicated to customers. A technology platform as proposed by us is a set of capabilities organized around a macro-level product functionality or process ability that helps manage and optimize technology investments across multiple product lines across generations.

Product Perspective. Traditionally there used to be a lot of fabrication in the products that Volvo Aero supplied. Novel casting technologies introduced during the 1980s offered several advantages and quickly became the dominant manufacturing process. The main advantage is the ease of incorporating a large amount of features on cast parts, especially as the complexity of the structures has since risen dramatically, in fact to a point where only a few specialized suppliers have such capabilities. The integrated design of these casts makes it harder to implement a modular architecture within VAC. As a consequence, the interest in fabrication concepts has re-emerged and is being investigated as an alternative to large casts. This new approach would enable VAC to produce structures by fabricating individual elements, i.e., welding or brazing components together that used to be made with one large cast. Fabrication projects are currently in technology development with the goal to fabricate as many products as possible that are today cast as single pieces. There are several possible approaches, e.g., smaller casts that are welded together or simply replacing all casts with forged alternatives made from sheet metal. A fabricated alternative is believed to give advantages to the in-house production since similar manufacturing processes, materials and technologies can be reused almost down to a component level. The fabrication concept could allow a more standardized and modular architecture, where subcomponents actually could be manufactured separately and put together in different variants for different engines and engine manufactures.

Standardization and modularization in design and production are key to realizing internal leverage of platforms. Techniques for implementing standardization and modularity for resources within organizations are discussed in a number of publications including Baldwin and Clark [16] and Ericsson and Erixon [17]. In the aircraft industry, standardization and modularization are also necessary due to its multi-tiered multi-player nature. However, these industry level attributes are different from the ones within the organization and have evolved to support risk and revenue sharing partnerships and legal issues such as antitrust.

Although, a modular and fabricated architecture would have positive effects related to economies of scale, concerns have been raised whether such an approach would make it possible to optimize individual components to an extent needed in future jet engine programs. This corresponds to Hölttä et al. [18] conclusion that if technical constraints, such as power consumption or weight, are the main drivers of design, an integral system will provide a more suitable architecture than a modular system. An uncoupled modular design, on the other hand, is preferred, when business drivers, such as commonality and flexible design, are the main concern during design. Nevertheless, one can identify features that are re-usable in between different products. Furthermore, similar components in different applications originate from the same conceptual system solution. These concepts are often simulated with similar or scaled property and behavior models. So rather than having a modular product platform one could talk about a product platform more supporting the product realization. Roach and Cox [19] presents a product design generator, a knowledge-based-engineering application, for product platform customization applied in the aerospace engine industry.

Manufacturing Perspective. During platform development the goal is to optimize flexibility vs. efficiency in the manufacturing system and variety vs. commonality in the product family to achieve maximum profitability. Evidently, process and product aspects are correlated so they must be mutually considered and not treated as two separate problems. Considering that VAC has chosen and followed a product specialization they currently have manufacturing capabilities that corresponds to the treatment of large casts.

One significant problem that is experienced within product development is a gap in manufacturing capabilities, as the factory shop floor is not able to meet the demands of what is possible in design. A plausible explanation is that the manufacturing organization is more focused on day to day operations (e.g., maximizing throughputs in cells). Hence a larger focus on integrating technology development and manufacturing engineering is necessary.

Concluding remarks. The example of consumer products but also modular jet engines is difficult to asses for a company like VAC. The supplier does not control system architecture which has a fundamental impact on needed component characteristics, and thus on component design. However, there are opportunities, for instance by increasing (and leading) the development of standardised interfaces for jet engines. However this is a very difficult task to achieve since the jet engine is an integrated product with several different architectures and legacy between the different jet engine manufacturers. Consequently, a fundamental challenge for a company like VAC is to develop a platform resulting in internal leveraging while at the same time maintaining flexibility to meet engine specific needs.

4.2 Market Leveraging

VAC has over the last decades developed into an important producer of components for the civilian aero engine market. The stability stemming from being part of the Volvo family combined with excellent production capabilities, experience from product development and broad and ambitious technology development makes VAC a suitable and reliable partner to the main engine manufactures in the world. This position has evolved over a long period and that initially relied heavily on experience gained from military and space programs. Experienced engineering and production personnel were moved from the military and space activities to support development of new civilian aero engine components. Competence and facilities which had been built in these “older” programs were used to build the new civilian product area. In recent years the different civilian components that are produced have increased in number and variety. The different types of components which are developed today have grown and draw heavily on previous civilian developments. A common pattern is that the company has often gained initial experience from a particular type of component through manufacturing on a make-to-print basis, without design responsibility. In later programs the company enters into shared development of the same type of product, or even accept full design responsibility. It was found that, within the organization, first technical experience was built to gain customer trust which in turn was used to increase the product portfolio.

Market leveraging refers to the advantage gained from understanding of customers, markets and distribution networks. Exploitation of such experiences and channels to proliferate existing or related or new markets with new products is termed as market leveraging. Such proliferation is also referred to (in the literature) as development of a product family. Meyer and Lehnerd [20] define a product family as a set of similar products that are derived from a common platform and yet possess specific features/functionality to meet particular customer requirements.

Market leveraging through development of product families offers several competitive advantages. Sanderson and Uzumeri [21] in their study of Sony Walkman product family found that Sony offered the greatest variety in market and coupled with rapid introduction of its new Walkman variants. As a result, Sony enjoyed the highest market share (as high as 50%) [21]. Over two decades, Sony launched over 260 models of Walkmans, either by bringing new (improved) products to the existing customer base or expanding into related markets (e.g. AM/FM market). A number of other examples of (in-time and over-time) product families can be found in Simpson et al. [1].

In the aircraft industry, Meyer and Lehnerd [20] point out that the product family approach was adopted in the Douglas DC-3 in mid 1900s. The DC-3 was first developed to carry passengers (commercial airline market) and later introduced in the military and cargo markets. Similar trends continue to be exploited by companies such as Boeing and Airbus in the airline industry. Standardization and modularization has offered companies tremendous advantages in leveraging

markets as well. The ability to mix and match modules to create product variants has increased the possibilities for greater market leverage. Modularization is further advantageous when considering market leveraging over-time – new requirements/technologies can be introduced easily.
As the market looks today there are several changes in how business is traditionally managed. The expected profitability of the aftermarket is expected to reduce as for example engines needs to be replaced or upgraded more often, but also since the market is being opened up for "pirate" manufacturers.

Scenarios on the future are connected to opportunities where a company in the forefront has the possibility to act quickly and increase market shares. For VAC, developing the fabrication concept of the future is one of these opportunities. Another opportunity is the new engine architectures and need for upgradeability and higher fuel economy connected to the rising fuel prices. Higher fuel prices is believed to lead to development of new more efficient engines, but also to offer upgrades to existing engines in the operational phase of the life cycle.

Concluding remarks. Modularization through components, where designs are reused, may be difficult to realize at component level. Rather, design concepts at the more abstract level can form a common platform. Most designs are optimized for the particular application but are based on some generic design concept with underlying technologies to support its realization.

4.3 Possible strategies for market leveraging

Generally the area of developing platforms consists of three main problem areas: (1) identify the optimal selection of products in a product line based on customer preferences; (2) define and evaluate one or more platforms that can serve this product line; and finally (3) develop flexible system solutions (product & process) that contributes to these platforms [22]. Translated to this actual case, the first problem area would more consider possible strategies for market leveraging, since the focus is not primarily delivering product variety. From a market perspective, a supplier in the aerospace industry may be presented with the following four strategies for expansion and change, see Figure 4.

Strategy I – Towards increased component development of similar category (knowledge domain, e.g. static structures or dynamic structures) in the same subsystem. A natural way to increase the responsibilities in an engine program would be to increase the number of components provided by VAC. The strategy, following the chosen specialization, is to take responsibility for as many static structures as possible, in line with their current knowledge domain. This could also mean that VAC supplying components for a sub-system developer strives to include more functionality in the components, thus increasing the level of complexity and share of a development program.

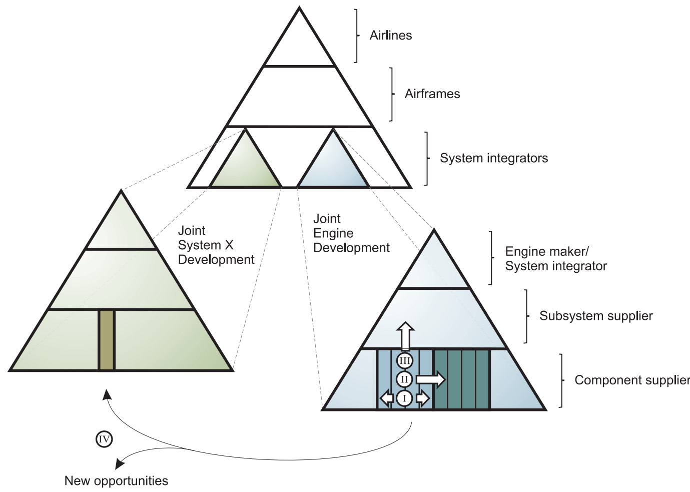

Figure 4. General strategies for market leveraging for VAC

An example is the GEnx development, the new engine developed by GE with the Boeing 787 Dreamliner as first application, where VAC took responsibility for the Front Hub Frame, a static structure in the forward section of the engine. Originally this was only intended to be a development of the structure. However, during the process GE asked VAC whether they could take responsibility for the air bleed valve. This is a mechanism for air bleed which in previous designs had been designed by GE. VAC had no previous design experience from this type of component but nevertheless accepted and in effect increased the functionality of the component and increased its level of responsibility.

Strategy II – Moving towards developing components needing knowledge in a new domain. Another possibility for a component supplier to grow is to add new components to its product portfolio that needs investments in new knowledge domains. This could be components which previously have been developed by other suppliers, completely new components due to architectural changes or they may also be the result of an out-sourcing strategy of an engine supplier.

An example is again the GEnx development. In the original contract VAC took responsibility on three components, the Front Hub Frame, the Turbine Rear Frame and the Booster Spool. When approaching engine certification on the GEnx 1B design, intended for the Boeing 787 Dreamliner, the company had added three additional components, however without design responsibility, to its portfolio and increased the effective share in the program. These added components were in some cases of a type in which earlier experience existed inside the organization, and in some cases the components were completely new to the company. The expansion into fan casings resulted 2005 in that VAC acquired a small company in Connecticut, Aero-Craft, specialized in manufacturing these

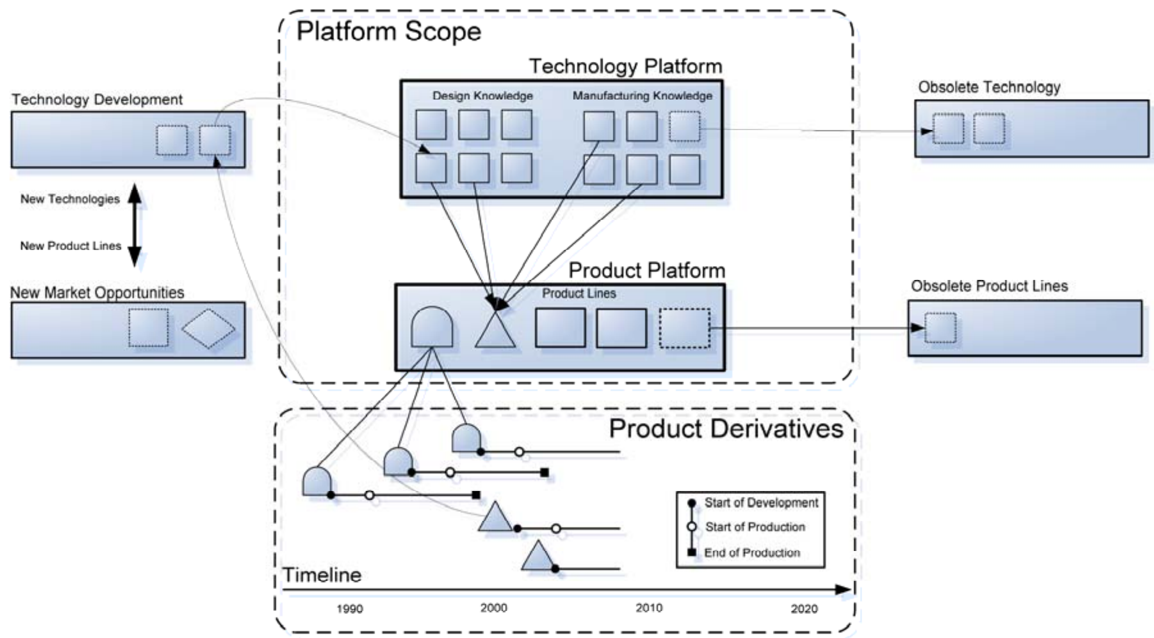

Figure 5. A proposed platform strategy, including a technology and product platform, serving different product derivatives.

types of components, which was already accepted as a supplier to GE and Pratt & Whitney. This strategy stresses the need for excellent forecasting abilities for product planning and technology management.

Strategy III - Towards sub-system development and systems integrator in same subsystem. A third possible growth strategy as a component specialist is to move from component supplier to sub-system supplier. Aircraft engines are modular products, and therefore it is possible to extend the current offerings and develop into a module supplier. Some companies within the aircraft engine industry have done this transformation, for example TechSpace Aero in Belgium. This company has a history that is very similar to VAC. They have specialized as a supplier of low-pressure compressor modules [23]. Another example is MTU in Germany, which has a main specialty of supplying low pressure turbine modules [24].

Strategy IV – Towards component development in another application (Capitalizing on your knowledge/platform in new markets). A final strategy is to capitalize on internal knowledge and resources by exploring new applications. Such a strategy could include developing new components within an aircraft programme, however, external to the aircraft engine. This strategy would take advantage of VAC's prevalent trust and reputation within the aircraft industry of developing, verifying and delivering robust solutions. However, Strategy IV could also include entering completely new markets that require competences in line with the chosen specializations at VAC. In fact, within VAC there is a department responsible for exploring the use of internal resources in new external markets.

These strategies are akin to expanding product offerings in the current market, foraying in related and new markets respectively as described in the book by McGrath [6].

5 POSSIBLE PLATFORM APPROACHES

This section proposes some possible platform approaches that VAC can consider based on the strategies outlined in the previous section. VAC could employ a combined technology platform and product platform (discussed in detail in the next sections) as illustrated as in Figure 5. The core competences are classified as technologies. For VAC a suitable distinction between design technologies and manufacturing technologies could be effective due to the different approaches in doing business. For a make-to-print order, manufacturing is central, but for a risk-and-revenue-sharing project both design and manufacturing technologies are important.

The technologies in Figure 5 are seen as disconnected from a specific implementation and examples of these technologies are more generic "Laser Welding" or "Aerodynamic Simulations". These core technologies are then connected to product lines. In the product lines the technologies are applied to specific problems, e.g. "Laser welding of titanium fins for a fan hub frame". This knowledge is however not the same thing as the actually produced fan hub frame for customer A, since the laser welding technology could be reused for the same component for customer B. The Platform Scope is hence separated from the actual produced derivatives of each product line. Thus, the platform strategy is similar to the "platform power tower" put

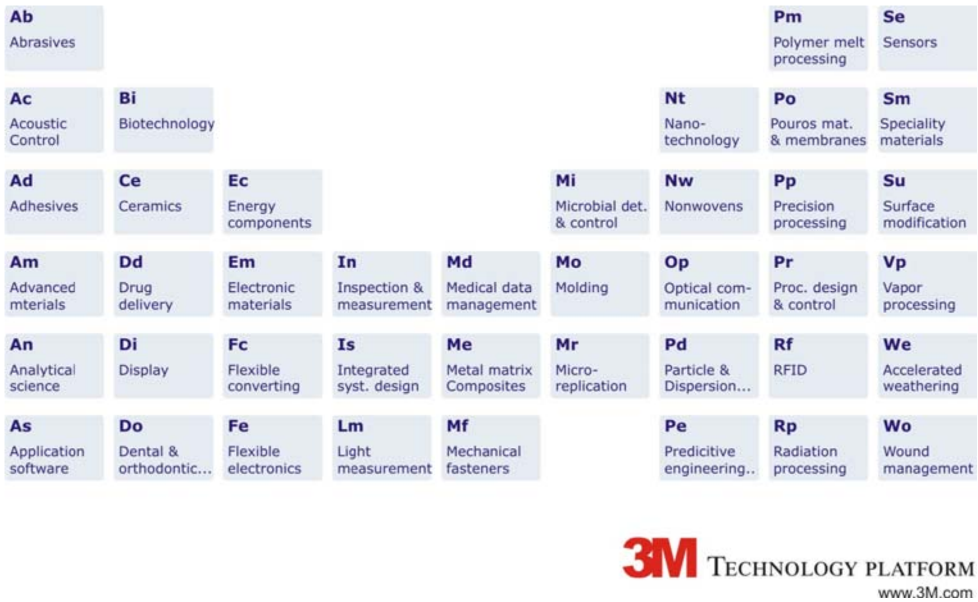

Figure 6. 3M technology platforms range from Abrasives to Wound Management, adopted from Shapiro [30] and 3M [25].

forward by Meyer and Lehnerd [2], although in this case the primary focus is on technologies and internal leveraging.

Outside of the platform new technologies are continuously developed. Also new market opportunities that could result in a new product line have to be monitored in order to assure the platform for future improvements. New technologies and product lines could be identified from a variety of different inputs, including demonstrator development projects together with potential customers to actual manufacturing problems that are fed back from production to enhance the platform. Likewise, old and obsolete product lines and technologies can become obsolete, and therefore they need to be removed from the active platform. There are however examples from VAC where retired technology has been re-invented and been introduced again in the company. It is therefore important to keep the retired technologies in a repository if they should be needed again in the future.

It is believed by the researchers that the platform approach in Figure 5 will give a good picture of the current, past and future products that are being produced, which is very important in the aero engine business. Evolution of products are illustrated with a timeline in order to understand and better see opportunities for scalability and “component” like reuse between currently produced products. Also the overtime issues within a product line are easily visualized. The focus with this kind of platform is on reuse in several layers, where the component level is not central (actually outside of the platform). It is believed that this approach enables reuse on a higher level where actual product and production knowledge is central and reused across the current and future products.

5.1 Technological Platform

A technology platform captures all the elements (physical and non-physical) of a platform unlike a product platform. Technologies within a technology platform can then be combined to develop new products and product lines. A well known example of a company that uses a technology platform to yield innovations is 3M [25]. Their core strength is derived from technology platforms such as adhesives, abrasives, and vapour processing as shown in Figure 6. When referring to the theory and the empirical material it can be shown that the technology platforms can be based on several bases. Two popular approaches described in the interviews is to connect the technologies either to the product lines or the materials. From these approaches it can then be extracted a third approach which makes it possible to connect the technologies to anything, by creating several views on the technologies and other product information within the company. Such a third example of information based technology platform can be created. However, a fundamental aspect of a technology platform is that they do not focus on a particular implementation (e.g., the simulation of a weld sequence on a specific component) but rather on a more general implementation (e.g., the simulation of weld sequences on hot structures.

Areas in which the company has deep knowledge or even a leading position can be made fairly long. Some of the key areas which have been pointed out in the study are given in Table 1, where we have chosen to categorize them either as related to design or manufacturing. These capabilities are used in different programs and on different products. In several cases one or more of such key technology areas have been

Design Capability
Aerodynamic & aeromechanical simulations
Weld & heat treatment simulations
Forge & casting simulations
Low noise design methods and tools

Manufacturing Capability
Robotic welding and deburring
Robust fixturing design
Metal deposition
Automated machining
High pressure assisted machining
Ultrasonic controlled milling
Thermal spraying
Automated non-destructive testing
Wide chord fan blisk technology

Table 1. Examples of technologies developed and leveraged at VAC

instrumental in generating new business to the company. One often cited example is when the first make-to-print contracts on the Ariane 4 launcher main combustion chambers were captured in the 1970's due to the company capability regarding electron beam (EB)-welding. A more recent example is how the company captured the re-design contract of the turbine exhaust case on the GP7000 engine, in large part due to manufacturing process simulation technology.

Looking at VAC it is evident that their technologies and chosen specialization has been a major reason for entering new programs. Table 1 shows some core design and manufacturing technologies that would make up a technology platform at VAC. However, in order to have an effective technology platform one cannot only rely on a set of identified core technological abilities within the company. In addition, one needs a process to finance, conceive, prioritize, develop, and implement new technologies, and a corporate culture where innovation and platforms are an organizational idea as a whole. Following a previous study [26] it is evident that VAC essentially have these assets, for instance:

- A strong belief and commitment in the organization that technology development is essential to enter future development programs.
- A technology plan is to a large extent established in dialogue between the marketing and engineering departments according to the business plan.
- A strong tradition to fund development activities through research foundations both nationally and internationally.
- Cross-functional teams act as decision bodies to govern technology development activities.
- They have a very successful long-term strategy to involve universities in competence build-up.

From a technology platform perspective, VAC lacks a process to formally document the track-record of technology implementations. This probably originates from the difficulty to assess in what way technology efforts have supported past and on-going product development projects.

5.2 Product Platform

A product platform, a traditional definition of a platform focused on components is quite common and can be found in various industries, e.g. the automotive industry. These product platforms could be developed for a finite planned life, or be evolutionary in design to incorporate changes over time. The main focus in a product platform is on the reuse of components and subsystems.

In the case at VAC, a product platform based on components is very difficult to achieve. Especially since many components of an aero engines are integrated and cast as one piece. In the case of a middle house all five (functionally different) components are often integrated and cast together. However, if VAC is moving towards a fabrication-based manufacturing concept these components could be made independently and later welded together. Still there are few similarities between these components on a level that would enable reuse of the component for different purposes or in different engine architectures or thrust ranges.

When describing the product platform as in Figure 5, the product platform is situated one abstraction level above the actual components. This means that the product platform should hold the knowledge to develop and manufacture a product within this product line. This implies that technologies are connected to a generic product line, and each technology developed to a point where they are no longer solution independent, but still generic enough to be reused for different products within the product line, i.e. allowing different architectures, scales and fabrication concepts. This means that the product platform in the VAC case consists of applied technologies to a specific line of products, e.g. middle house.

In this sense, the product platform approach suggested is similar to both (1) Generic Bill-Of-Materials-and-Operations proposed by Jiao et al. [27], and (2) Configurable Components proposed by Claesson [28].

The product derivative level of Figure 5 refers to the actually manufactured products, and is therefore highly application dependent. The possibility of sharing components and subcomponents at this level is seen as highly unlikely due to the different customer's requirements. This is why the actual "component level" is excluded from the platform scope. However the component level is important in finding synergies within the product lines, and also between product lines, and should therefore be mapped towards the platform in order to identify and evaluate possible expansions and additions to both the product and the technology platform. The possibility to find

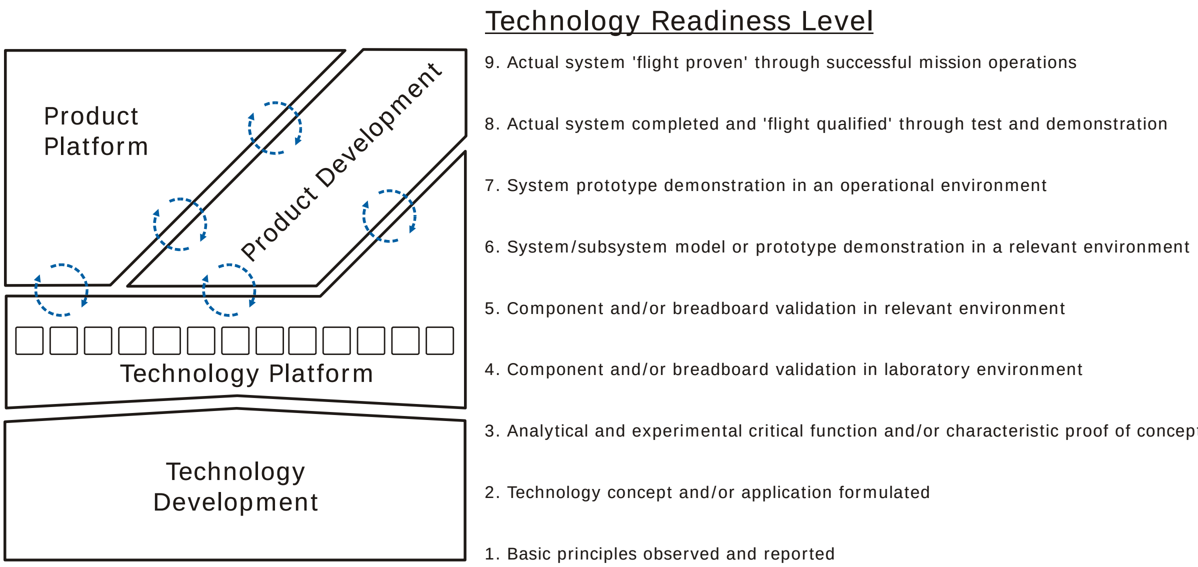

Figure 7. Technology/product development and technology/product platforms in relation to the technology readiness level

similarities lies in a level below the subcomponents referred to as features, fins etc. In a future it could be possible to create fins by the meter that is adjusted according to the size of the intended component. The business potential and actual benefit with such a "component based" platform is to current date very difficult to assess.

DISCUSSION

Developing or adopting a platform strategy is naturally not a goal in itself; there needs to be some underlying reason for the work. In this case, the driving factors would be to increase the responsiveness in the organization (i.e. internal effectiveness) and reducing risks by re-using common elements in various processes, the organization or the products being developed. This research work has analyzed the prerequisites for VAC and has suggested that a possible platform strategy could include a technology platform – incorporating general knowledge on core technology assets embodied in either humans, organizations, processes, information or methods; and a product platform, incorporating product specific elements that could be re-used when developing new components for a particular product line.

In this sense new technologies are developed to some degree of certainty before it is incorporated in a technology platform, see Figure 7. In relation to technology readiness levels (TRL) (see for instance [29]) this would mean TRL 3 or higher. A core technology would be developed further before it is accepted to be the foundation of a new product development program. But, for instance, manufacturing technologies could be incorporated earlier since it most often has a longer lead time to implementation. Thus, the technology platform feeds the development projects with general technological information and the development projects feeds the technology platform with specific knowledge on the application of a technology. Consequently, the technology platform is fed from to ways, bottom-up with new technologies from technology development efforts, and top-down with experiences of technology applications in different fields. The top-down approach of documenting experiences, seems to be a key characteristic of companies working with technology platforms as a corporate commitment [30]. A technology platform could in this sense also be a channel for technology prioritization and financing.

Although the main focal point at VAC for a platform strategy is internal leveraging, a proposed strategy must be in line with overall company market strategies. Table 2 summarizes possible benefits of proposed platform approaches in regards to strategies for market leveraging at VAC, as presented in section 4.3.

CONCLUSION

Platforms have been used in industry as an approach both to expand market and to reduce internal cost and complexity. A company like Volvo Aero Corporation differs significantly from common examples of the companies with developed platforms. Several case studies have reported on the advantages gained from applying platforms, however mostly from system integrator and architect perspective and not from the perspective of their suppliers. This led us to formulate the research questions explored in this study.

Research question 1: What in current best practice on platform formulation could be applicable to a company like VAC, a sub-supplier in a low volume business-to-business?

	Technology Platform	Product Platform
Strategy 1 *Increased component share within chosen specialisation*	Vital criteria to join new development programs aimed at a demonstrator. Supports the first implementation in an engine program.	Increased responsiveness in both tender and development processes. Increased quality assurance in both tender and development processes. Would act as a generic "white book" for a development project.
Strategy 2 *Increased component share outside chosen specialisation*	Communicates core technology assets that would fit into other development domains. Implemented technologies with an excellent track-record increase the credibility.	Better internal efficiency releases development resources.
Strategy 3 *Towards subsystem development/ system integrator*	Communicates core technology assets that would fit into other development domains. Implemented technologies with an excellent track-record increase the credibility.	Better internal efficiency releases development resources.
Strategy 4 *Towards component development in another application*	Open and communicated technology portfolio that would attract new customers. Creates a commitment in the organisation to innovate. Creates a mind-set to capitalise on innovations	

Table 2. Possible benefits of proposed platform approaches in regards to strategies for market leveraging

This paper has shown that current platform theory is applicable to sub-supplier companies in the low volume high technology segment. The reuse and commonality between products and product lines are however found at a higher abstraction level at these types of companies. A technology platform is seen as a fundamental basis for a company like VAC, because attractive and verified technologies are essential for being selected for new engine programs. In addition, the company needs to have the ability to design and manufacture many various components utilizing different technologies to minimize their risk, since the selection of partners is made fairly late. Formulating a product platform as one consisting of common modules or components is not seen as a fruitful strategy. The products are normally custom designed for a particular application, primarily due to important design drivers such as minimizing mass or optimizing overall system performance. In addition, since VAC does not control the system architecture there is always a risk of investing too much into methods and tools enabling design re-use connected to a specific architecture. Thus, one needs to balance this approach with more generic capabilities.

Research question 2: Based on the needs from a company of the type represented by VAC, how could a suitable platform be formulated?

Based on our findings from VAC we propose a platform strategy where a product platform, based on product lines, and a technology platform co-exist. The difference between the two platform descriptions is that the technology platform is not connected to a specific implementation, while the product platform is the application of that technology to a specific product line. Therefore, the product platform is viewed as application-specific.

REFLECTIONS

This study has been exploratory and has resulted in a platform formulation which is believed to be suitable to a supplier like VAC. However further work is needed, both to generalize results, and to show benefits from applying a platform formulation as proposed. Some of the remaining difficulties lie in the classification of core company technologies, and to make the suitable connections to product lines and manufactured products. Future studies will have to elaborate more on these concepts, for example by tracing a specific product line through its lifecycle and seeing how technologies have been used and reused across product lines and over time.

There is a potential risk that platforms define a filter that blinds the company to opportunities or needs to create new products or incorporate new technologies. The platform description has to provide both internal and market leverage through re-use and commonality but at the same time allow for innovation and renewal. How these aspects can be managed in the proposed formulation will be further explored in coming work.

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