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MANUFACTURING AS THE CUSTOMER OF DESIGN – AN INDUSTRIAL CASE STUDY.

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Abstract

This case study is based on Rolls-Royce plc (the Company), a significant global force in the provision of power systems for civil, defence, industrial and marine applications. During the near century of operations that the Company has survived, it has undergone many changes that have impacted the relationship between Design and Manufacturing. This paper sets out the state of the Company and the Product Definition Process within it (the process that captures the relationship between the two functions), identifying some of the principal issues that bear on it and, where the Company has embarked on improvements, what they are and what impact they have had.

Keywords: Process Management, Product Definition, Industrial Practice

1 Background & introduction

In the near one hundred years that Rolls-Royce plc has been a commercial enterprise, it has seen many changes. For a start, it no longer manufacture automobiles.

Instead, it has transformed itself into the only company in the world that is solely engaged in the provision of power generation systems. These products, predominantly based around the core technology of gas turbines, are principally sold into four distinct market sectors; civil aerospace, defence aerospace, energy power generation and oil and gas pumping and commercial and naval marine systems. In these market sectors, Rolls-Royce plc competes against extreme competition from large US manufacturers, such as General Electric, performing with a consistency that places it at number 1 or 2 within its markets.

This transformation has seen the Company change in many ways. It has successfully grown into a global organisation employing tens of thousands of people in over a hundred countries, offering a wide portfolio of products and services to a large and diverse group of customers. This growth has been through organic and inorganic means, when opportunities have presented themselves, acquiring companies that have products or services that are complimentary to the Company's power systems strategy. It is the scale of this change and the diversity now within the Company that has introduced issues into the relationship between Manufacturing and Design.

The most significant of these issues are as follows, each representing a section in the following paper:

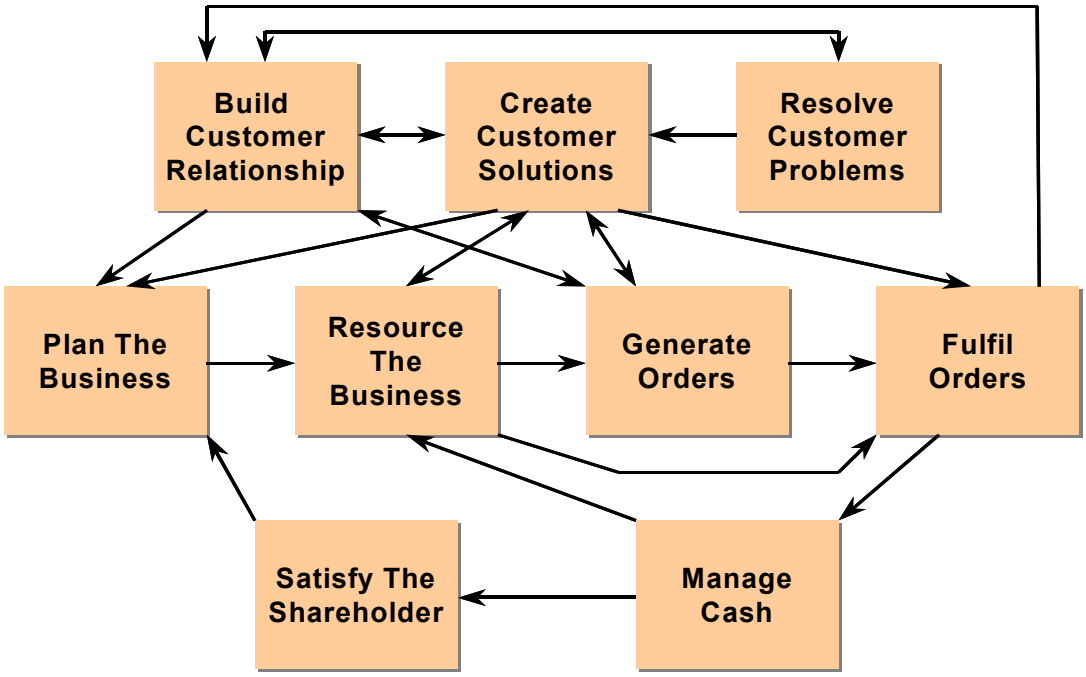
- Understanding the Product Definition Process
- The Company's organisation structure
- The need for Risk & Revenue Sharing Partners

- The physical and organisational separation of Design & Manufacture
- The complexity of the product

2 Understanding The Product Definition Process

The principle description of the processes that drive Rolls-Royce plc is recorded in the Company's Business Process Model (see figure 1 below). Each of these nine processes has an owner, typically a very senior director within the Company, accountable for the accurate definition and consistent implementation of their process.

Figure 1 The Rolls-Royce Business Process Model



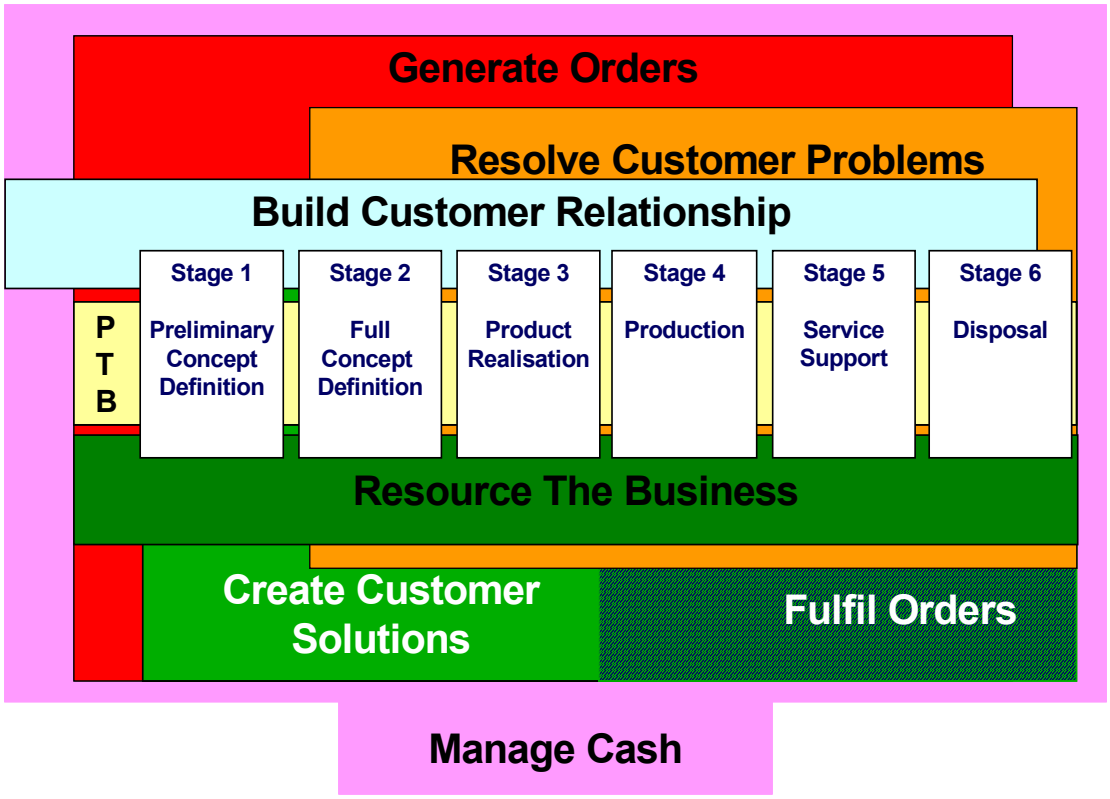
The process of Product Definition resides within Create Customer Solutions ([the process of producing] a complete and detailed description of a product, including its cost, functional characteristics and how to make, operate, maintain and support it in service and dispose of it . . . [encompassing the definition of] a fully functioning system for producing the product in the required volume), although, as can be seen in figure 1, Create Customer Solutions (and hence the Product Definition Process) takes inputs from and provides outputs to a number of the other processes in the BPM.

It is significant to notice in this definition that, whilst Design is predominantly active in Create Customer Solutions and that, even at this high level, there is the recognition that it is the Design activity that commits the way that Manufacturing will be achieved, it is within Fulfil Orders ([the process that] in response to, or in anticipation of customer orders [and] following confirmation that the required product or service can be delivered, supplies technology, delivers and manages power systems and provides services) that Manufacturing lives.

Further, what the BPM does not show is the concept of time, so Rolls-Royce plc uses a six-stage product life cycle model (called Derwent within the Company) to indicate the stages of

development through which a product passes. This life cycle model is illustrated in the diagram below (figure 2, overlaying another representation of the BPM – with the intentional exclusion of Satisfy the Shareholder on the basis that if everything else in the BPM is conducted well, the latter will be a natural occurrence) which should be examined with the understanding that to pass between each stage requires the product to successfully endure a rigorous independent audit from the Company's Technical & Quality Directorate.

Figure 2 The Derwent life cycle model within the Business Process Model



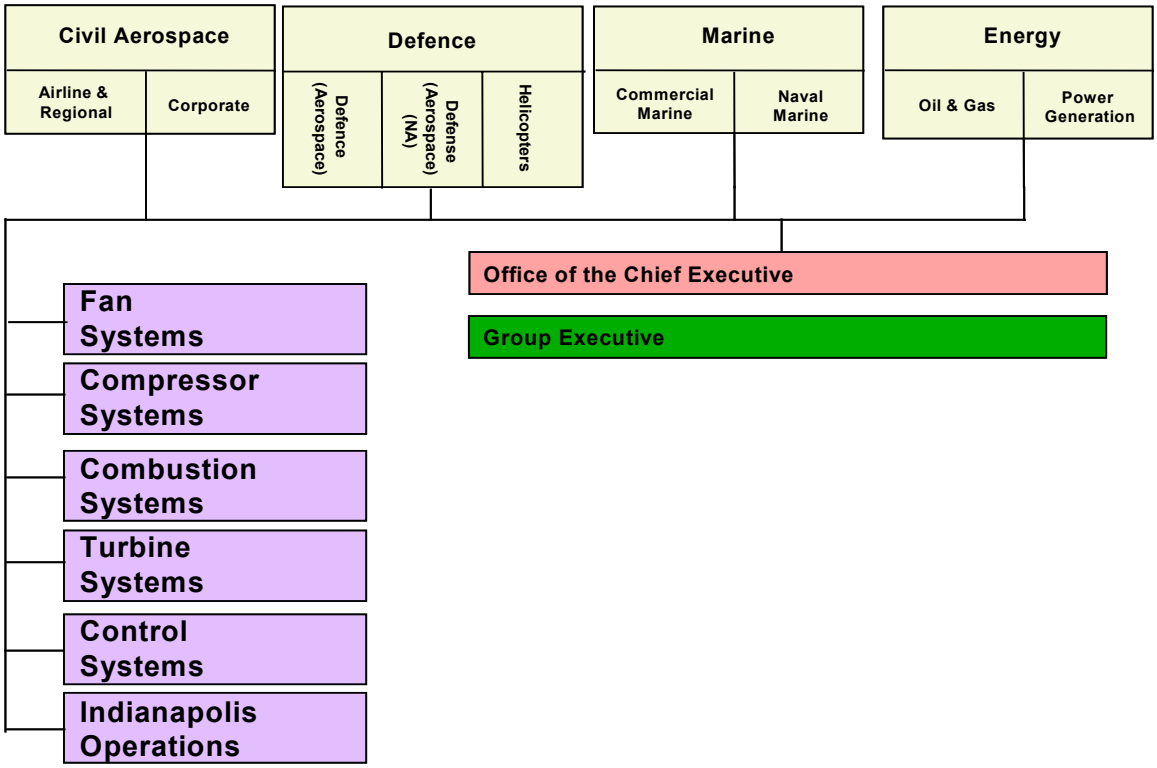
These two factors, the separation of Design and Manufacturing within processes in the BPM and the complication of multiple models, leaves the Company in the position that very few understand the totality of the Product Definition Process and what the significance of the relationships within it bear on the successful delivery of the Company's products. Rather, what the Company is left with is a number of people who are expert in their own process, but less informed about the interfaces between their and other processes and the implications for the greater whole should these interfaces be altered.

3 The organisational structure of Rolls-Royce plc

As described in the Background section above, there are four principal market sectors in which the Company operates. In order to better serve these sectors, in 1998 Rolls-Royce plc introduced a matrix organisation structure (see figure 3 below), with the intention that the organisations along the top were outward, Customer Facing Business Units (CFBUs), whist those down the left hand side were internally facing manufacturing and purchasing Operating Business Units (OBUs). The selection of the different OBUs is predominantly based on the sub-systems within a gas turbine, therefore, for instance, Turbine Systems is responsible for

the provision of all Turbine components and Combustion Systems all those components that appear in the Combustor.

Figure 3 The organisational structure within Rolls-Royce plc



The CFBUs are tasked with the identification of new business and the provision of after sales services for their markets, whilst the OBUs are tasked with the provision of world's best manufacturing capability and the delivery of an efficient supply chain. By organising in this way, the CFBUs are able to go to an OBU as a 'one stop shop' for both the Design and Manufacture of the components within the sub-system.

4 The physical and organisational separation of Design and Manufacture

When this change in the organisation structure was introduced, it brought with it a clear delineation between Engineering (and particularly Design) and Manufacturing. The CFBU, as described, is responsible for the identification of new business and the agreement of the requirements for the new product or system at a complete entity level. It then decides the breakdown of the sub-systems within this whole and cascades the functional (thrust, fuel consumption etc.) and physical (weight, cost etc.) requirements for each sub-system to the appropriate OBU.

For these new products, the OBUs are then responsible for the definition of their individual sub-systems, before offering these back to the CFBU for integration into the whole. However, once the product has been certified as compliant with all its requirements (including those of a regulatory or legal nature) and passes into regular service, it is the responsibility of the CFBU to maintain this service operation through the completion of modifications (either

in response to service arisings or to reflect advances in technology).

However, this relationship is complicated by the fact that Design and Manufacture are interested in different 'views' of the component structure of a product. Design is interested in a design structure, groups of components that together deliver a given function; suck in air, transport fluids, provide thrust etc. Manufacturing on the other hand is interested in groups of components that go together when assembling the engine.

This issue is visible in the lack of clarity in Design Responsibility (DR) and Sub-System Accountability (SSA). As the whole product requirements are cascaded from the CFBU into the OBUs, they are passed Design Responsibility for the provision of a sub-system that will deliver against these questions. However, although an OBU is a manufacturing and purchasing organisation as well as a design one, they may not have manufacturing responsibility for all the components they design. This Sub-System Accountability for manufacture may reside in another OBU.

5 The need for Risk and Revenue Sharing Partners.

The complexity in the organisational structure described above is added to by the increasing number of Risk & Revenue Sharing Partners (RRSPs) in new product developments.

Risk and Revenue Sharing Partnerships are formed between Rolls-Royce plc and commercial organisations who wish to buy into a Rolls-Royce product, sharing the risk of development and sales in return for a proportion of the future revenues realised by the product. Typically the organisations that become RRSPs are either already involved in the Aerospace market or have complimentary skills and knowledge and wish to enter the market.

However, in terms of the Product Definition Process, aside from the geographical, cultural and temporal issues that are introduced by having more partners, the challenge of integrating all the new inputs, from organisations unfamiliar with the Company's processes and often using different IT systems, becomes another ingredient in a complex mix.

6 The Complexity of the Product

A modern gas turbine is both physically and functionally demanding. Typically, there are between 20 and 22,000 components in a large Trent engine, of which approximately 12,000 are separately different parts. The operating conditions inside the engine require that some components must operate in temperatures that, in normal conditions, would cause them to melt. Finally the product must be able to meet highly demanding and often conflicting performance characteristics; it must be a 'good neighbour', providing as little noise and noxious emissions as possible, yet able to produce take off thrust and levels of fuel consumption that make the product commercially viable for the customer.

When Rolls-Royce plc launched the RB211, it embarked on a strategy that, where appropriate, would see the future development of large gas turbines based around an architecture of 'three shafts'. By doing so, the Company would mitigate some of its future development costs by being able to offer a 'family' of engines, wherein it would be possible to trace the genealogy of the sub-systems within each offering. This strategy can be seen in the Trent family of engines, which was developed for civil aerospace, but has been modified to operate in marine and industrial applications, whilst sharing roughly an 80% commonality of components.

However, this architecture, whilst providing a stable platform for future development, forced the Company into clearly understanding and describing the interfaces between the sub-systems. If a sub-system is to be shared between applications, it is essential to know, both physically and functionally where the sub-system starts and finishes.

7 What has the Company done about this situation?

7.1 Co-location of design and manufacture

Acknowledging the inherent inefficiencies in separating Design and Manufacture, the Company has taken steps to bring them back together when there is a sound business need. This has typically led to the consolidation of complimentary activities into regional centres, although in some instances, the consolidation has been much tighter.

In 2000, the Company opened a new facility in Derby that had the single objective of becoming a Centre of Excellence for the production of turbine blades. These components are incredibly sophisticated, both in terms of their manufacture and operation and are considered part of the Company's 'crown jewels', representing a state of the art that conveys significant competitive advantage.

Part of the consideration in establishing such a venture, was the physical co-location of the Designers, Manufacturing Engineers and machines that are used in turbine blade production. Although there would still be some requirement to move the blades outside the facility, especially for the application of some of the coatings they have, for the first time, the majority of the knowledge and understanding behind these complex components was all in the same building.

7.2 Manufacturing buy off

When it is not possible or economically sensible to co-locate Designers with their Manufacturing counterparts, the Company has sought to formalise the input from Manufacturing into the reviews through which a design passes as it evolves.

This input ranges from a statement of agreement to the manufacturability of a component from the Manufacturing Engineer through to this person attending the design review to

represent the issues they have. Whatever form the buy-off takes though, it is now a necessary aspect of a successful review.

7.3 The deployment of statistical process control

An aspect of the interface between Design and Manufacture has always been the agreement of tolerances. From a Design point of view, there is great pressure to drive towards the tightest possible tolerance, as this is a driver of functional performance. However, in Manufacturing, the tighter the tolerance, the more difficult it is to make consistently.

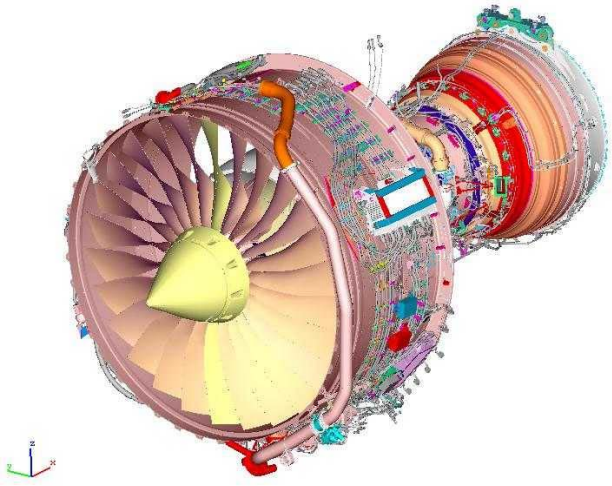
The way in which statistical process control (SPC) has been deployed in Rolls-Royce provides a very useful two way communication mechanism across the Design and Manufacture interface. The Company has taken the traditional approach of using SPC to prove that a manufacturing process is capable of consistent output and augmented this by the use of Conformance Control Features (CCFs).

By applying SPC in Manufacturing, the Company has been able to drive improvement in reducing scrap and rework rates by getting consistent and capable processes. This information can then be fed back to Design so that the Designer selects these proven processes over ones that are less reliable. At the same time, the Designer can identify those features in the design that are key to its performance as CCFs, thereby informing Manufacturing that the process that delivers this feature needs to be targeted for stable capability through the use of SPC.

7.4 Visualisation

In the Company's attempts to address the disparate Computer Aided Design and Computer Aided Manufacture (CAD and CAM) tools both it, its customers and its suppliers have, Rolls-Royce plc has invested in the use of visualisation software, (an example of the output from which can be seen in figure 4 below).

Figure 4 An example of the output from visualisation software.



Visualisation is the 3-dimensional representation of components to create an electronic view of what they will look like when made. Powerfully, these representations can then be pulled together up to a level where the whole engine is depicted in this way. From this, many lessons can be learnt about the way the product has been designed – will components clash with their neighbours when assembled, will a maintenance engineer have easy access to components when conducting an overhaul? However, a significant benefit of the use of

visualisation is that it is a ‘neutral’ format, capable of integrating geometry from several different CAD or CAM packages, rather than requiring a full translation into a native code.

By having such a neutral format, Designers and Manufacturers can communicate and collaborate with each other regardless of which software they are using themselves.

8 Conclusions and thoughts on the future

During its existence, Rolls-Royce plc has been through significant change. Technically, the products the Company offers are extremely advanced and new developments to them are exceptionally challenging. Commercially, the Company is recognised as being a major supplier to the markets in which it operates. It has over 55,000 engines in service with an order book in excess of £16bn that will see this number of engines in service added to. Organisationally, Rolls-Royce plc has a presence in many tens of countries around the world and a customer base and supply chain of a comparable nature.

However, growth never occurs without associated strains on the business. In the case of Rolls-Royce plc, one of these strains has been in the dislocation of the Design and Manufacturing activities. When the Company was young and small, the designs were undertaken by 'craftsmen', people who designed for manufacture because they were intimately involved in it, either making components themselves or being in easy reach of the manufacturing activity. Over time, as the knowledge required to design and manufacture something became too much for one person to hold, Designers and Manufacturing Engineers evolved as separate people. Finally, as the Company itself grew in size and entered into partnerships with other organisations, the Design and Manufacturing activity became physically separated.

For the foreseeable future, the transformation within the Company will continue. The challenges facing the business are to organise the supply chain so that it can deliver an engine more quickly and to secure more of the aftermarket, both to realise the revenue stream of servicing all the engines the Company has produced, as well as to protect its expensively generated intellectual property rights.

These challenges will require the Company to revisit its understanding of the processes it operates; Product Lifecycle Management (PLM) is already being wrestled with as a framework under which such a change may hang. Technology may come the Company's aid as collaborative tools and internet technology rapidly reduce the impact of distance between organisations, perhaps allowing Rolls-Royce plc to 'follow the sun', operating the Product Definition Process 24 hours a day depending on who is awake!

It is however, the people who Rolls-Royce plc employs that will ultimately be required to rise to the challenge of the Company's growth and it is their consideration that will need to be addressed.

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