ROLLS-ROYCE

A Circular Economy Business Model Case

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Executive Summary

This report presents the case study of Rolls-Royce's 'TotalCare' business model for widebody aircraft aero engines. It was chosen due to the commercially successful development of a whole lifecycle, servitised value proposition and associated business model.

Insights for business guidelines

This case study highlights the following key insights relevant to companies in similar industries or sharing a similar context:

- **Revenue mechanisms that align interests between a company and its customers can create powerful circular business models**. Although Rolls-Royce engines are sold to the aircraft owner, the TotalCare service package means Rolls-Royce retains responsibility for ensuring the product performs to customer requirements. The power-by-the-hour charging mechanism (revenues generated per engine flight hour) keeps incentives aligned by rewarding Rolls-Royce when the product is working as needed, and penalising it when it is not. This mechanism and alignment between the OEM and its customers encourages continuous improvement and collaboration. This also drives the extension of asset lifetime while optimising/reducing repair and maintenance costs. This results in reduced waste, increased resource efficiency, and enhances the asset's value over its lifetime.

- **Service-focused offerings that enable manufacturers to gain insight and intelligence on the use and performance of their products can lead to better customer service, improved product/service design, and resource efficiency**. TotalCare provides opportunities for constant insight and learning around customer requirements. This insight is enabled by the collection of engine usage and performance data, as well as through deep customer relationships. This produces ongoing improvements and evolution of the value proposition itself as well as expansion of value added services. This means that the customer is no longer buying 'just' a product, but gaining expanded value addressing a suite of needs and requirements. This provides greater flexibility for manufacturers to manage the underlying asset within a service contract, focusing on outcomes for the customer.

- **Servitised performance-based models can be important enablers for 'Resource Recovery' as well as 'Re-condition' / 'Re-make' circular business model patterns**. In the example of TotalCare, Rolls-Royce's service contract includes the provision of maintenance services which it has the responsibility and flexibility to deliver in an optimal way. This ensures that the 'life' and utility of the engine product is kept at the right level over its lifetime. Furthermore, the service contract gives the manufacturer visibility of the product throughout its lifecycle. This is especially relevant at the end-of-cycle where it creates an opportunity for product take-back and recovery of high value materials through close-loop recycling.

- **When transitioning from a product-focused to a service-focused business model, the installed base becomes a key asset and driver of revenue and profitability**. In product-focused business models, revenue is driven by the product sales price, and potentially some recurring revenue from maintenance services and sale of consumables and add-ons. In a service-focused business model, the installed base of products in use can become the driver

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of recurring revenue over the product's lifecycle. This aligns financial performance for the manufacturer (revenue and profits) with ensuring that products in use are kept at optimal performance for as long as possible. This in turn is a key enabler for resource efficiency and waste elimination.

Insights for policy recommendations

In this case study, issues related to policy primarily focus on the potential of product-service offerings being perceived as anti-competitive.

In order for many product-service or servitised business models to work, tight integration is required between the delivery of the product, the provision of services around the product, and the overall revenue model for charging the customer. In effect, products and services get tightly bundled and cannot be differentiated from the customer's perspective. As illustrated by the TotalCare case study, this can also require tight integration of an 'ecosystem' of partnerships and infrastructure (for example suppliers and providers of maintenance services). This integration is needed to align business models between partners, as well as processes and technology, in order to maximise efficiency and minimise risks.

This degree of 'lock-in' can create a perception of reduced choice and competition in the market. Competition policy may therefore need to adapt to account for new servitised approaches, and to ensure that unfair practices are properly distinguished from innovative and value-adding business models.

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1 Introduction

1.1 Background and context

R2π – Transition from Linear to Circular is a European Union Horizon 2020 project focused on enabling organisations and their value chains to transition towards a more viable, sustainable and competitive economic model in order to support the European Union's strategy on sustainability and competitiveness.

R2π examines the shift from the broad concept of a Circular Economy (CE) to one of Circular Economy Business Models (CEBM) by tackling market opportunities and failures (businesses, consumers) as well as policy opportunities and failures (assumptions, unintended consequences). Its innovation lies in having a strong business-model focus (including designing transition guidelines) as well as in the role of policy development (including designing policy packages).

The ultimate objective of the R2π project is to accelerate widespread implementation of a circular economy based on successful business models and effective policies:

- to ensure sustained economic development,
- to minimize environmental impact and
- to maximize social welfare.

The mission of the project is therefore to identify and develop sustainable business models and guidelines that will facilitate the circular economy, and to propose policy packages that will support the implementation of these sustainable models.

A core part of this project is to work with organisations who are on the journey towards developing circular economy business models, as well as those who have the ambition to do so but haven't yet begun. The project has conducted case studies of 18 selected organisations.

The 18 chosen cases covered all five priority areas highlighted in the EU Action Plan on the Circular Economy: plastics, food waste, biomass/bio-based, important raw materials, and construction & demolition. Additionally, the cases were selected to ensure learning in each of the seven business model patterns defined by the R2Pi project: re-make, re-condition, circular sourcing, co-product recovery, access, performance and resource recovery, and these will be discussed in more detail in this report. To gather wide-ranging lessons from differing company sizes and maturities, the following were selected: 7 large corporations, 8 small, medium enterprises, 1 public entity, 1 entire value chain with both public and private organisations and 1 ongoing social project.

This report presents the case study of Rolls-Royce's 'TotalCare' business model for widebody aircraft aero engines. It was chosen due to the commercially successful development of a whole lifecycle, servitised value proposition and associated business model.

The next section provides a more detailed overview of the case organisation's business.

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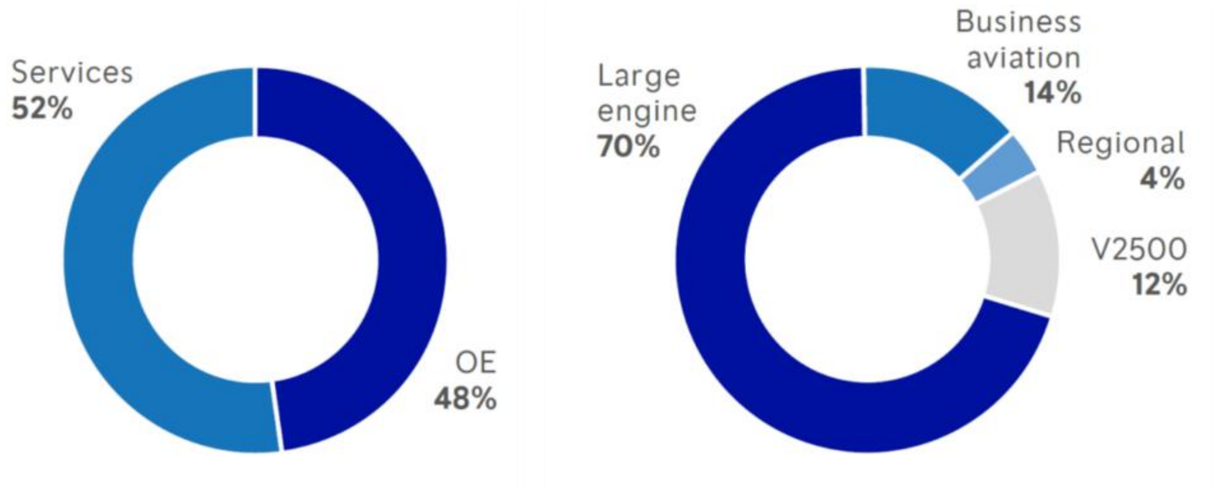
1.2 Business overview

Rolls-Royce's Civil Aerospace business is a leading manufacturer of aero engines for the large commercial aircraft, regional jet and business aviation markets. The business uses its engineering expertise, in-depth knowledge and capabilities to provide through-life support solutions for its customers. Rolls-Royce has a 35% market share of engines installed in the passenger fleet for widebody aircraft. Civil Aerospace is Rolls-Royce's largest business unit, accounting for over £7 billion of revenues in 2017. Figure 1 below shows the revenue mix within this business unit.

FIGURE 1 ROLLS-ROYCE CIVIL AEROSPACE BUSINESS REVENUE MIX



Source: Rolls-Royce plc Annual Report 2017

While engine manufacturing has traditionally been the core of Rolls-Royce's Civil Aerospace business, revenue from the provision of aftermarket services now dominates (as shown above). The key driver of service revenue is the TotalCare offering, which this case study focuses on. TotalCare provides services to Rolls-Royce's airline customers over the entire lifecycle of the engine.

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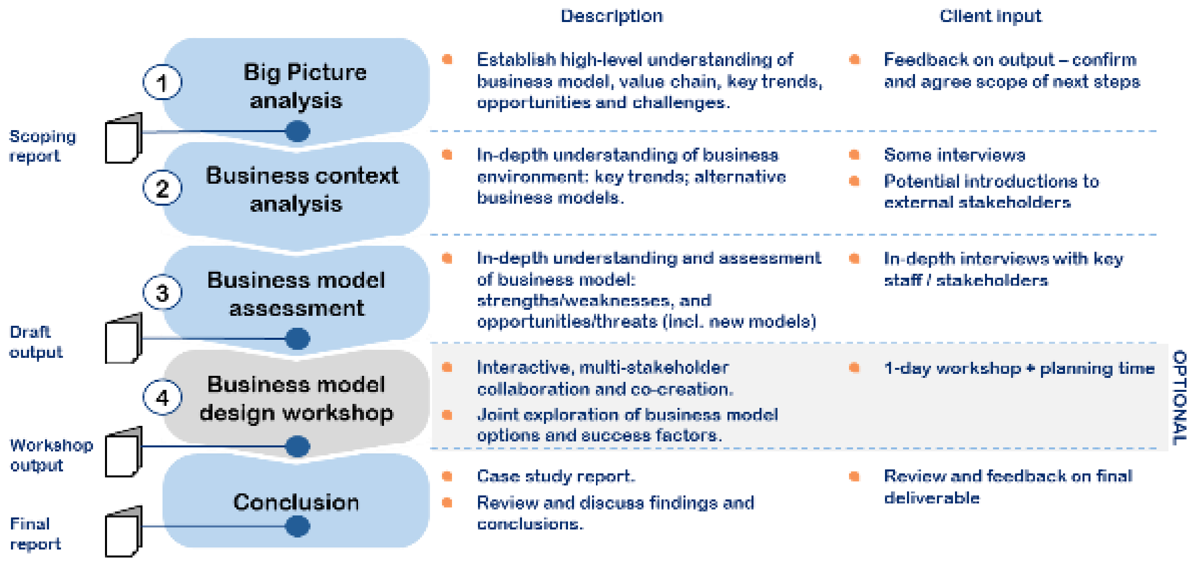
1.3 The case study analysis process

The case study process was structured in three main steps, plus an optional workshop, and concludes with this document as the final report (see diagram below).



1.4 Report outline

The first chapter introduction has provided a high-level overview of the case and case study process. Chapter 2 presents the big picture surrounding the business, showing the context in which it operates and the key external factors. Chapter 3 is an analysis of the business at the building block level of the business model, including the circularity of the business, the financials, and the strengths and weaknesses. Chapter 4 draws conclusions about the current state of the business and its future potential.

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Glossary of terms

AOG	Aircraft On Ground – where an aircraft is not able to take off due to a technical fault.
CSC	Customer Service Centre
EFC	Engine Flight Cycle. A complete flight cycle includes the following events: engine start; a take-off and landing; and engine shutdown.
EFH	Engine Flight Hour
EHM	Engine Health Monitoring
EIS	Entry Into Service
IP	Intellectual Property
LLP	Life Limited Parts. Life limited parts are parts that, as a condition of their type certificate, may not exceed a specified time, or number of operating cycles, in service. These types of parts cannot be feasibly repaired. *See also RP- Repairable Parts.*
MRO	Maintenance, Repair and Overhaul
OE	Original Equipment
OEM	Original Equipment Manufacturer
PBH	Power By the Hour
RP	Repairable parts. Some high value aircraft parts can be repaired using various re-manufacturing processes such as machining, welding, plating, etc. *See also LLP – Life Limited Parts.*
RRSP	Risk and Revenue Sharing Partnership
SV	Shop Visit
Time and Material	Traditional maintenance contracts where the client pays for labour hours and materials consumed during a maintenance check. The MRO shop does not take any risk of cost overruns.
$/EFH	Revenue ($) per engine flight hour (EFH)

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2 Rolls-Royce's business context analysis

2.1 Scope of the business context analysis

The objective of the context analysis is to identify the main external factors that are to be considered in order to explain the success (or failure) of Circular Economy Business Models (CEBM), as well as their potential role in accelerating the transition towards a Circular Economy.

The business context research included a combination of interviews with relevant key stakeholders of the case organisation as well as complementary desk research where required. The objective was to identify relevant factors (geographic or sector-specific) within which the business model operates today, as well as key trends that may influence how it evolves in the future.

Rolls-Royce stakeholders interviewed for this report were the Sustainability Manager for Engineering and Design; and the Marketing Manager for Services, Civil Aerospace. Additional stakeholders were consulted internally by these direct counterparts to provide input and review findings.

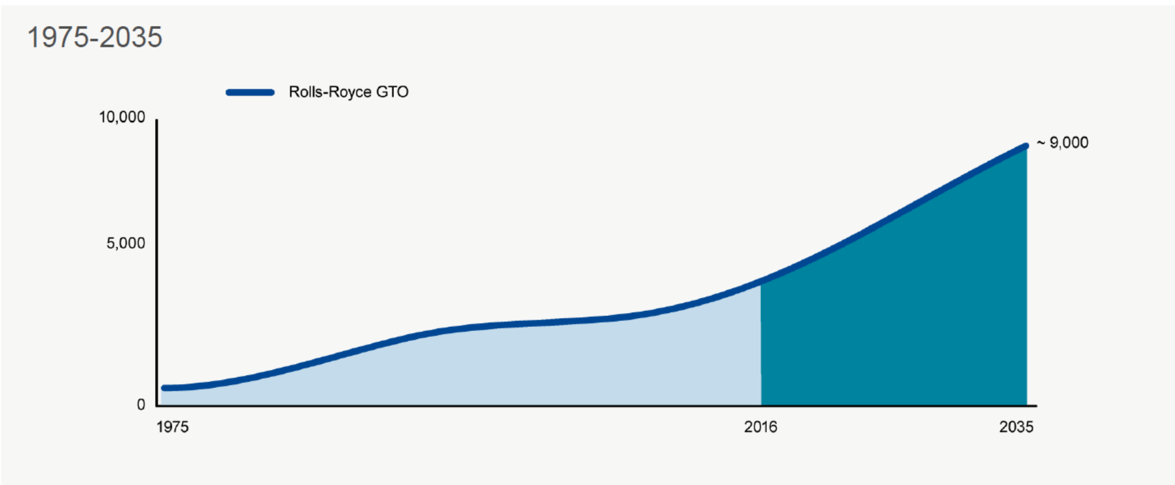
2.2 Contextual factor analysis

2.2.1 Demographic trends

Growth of air travel continues to grow, with consensus forecasts of air traffic (revenue passenger kilometres) growth of approximately 5% compound annual growth rate over the next 20 years. A significant amount of growth is forecast to come from Asian carriers in particular.

The underlying factors behind this trend are economic growth as well as demographic and socio-economic trends where the global middle class is forecast to double over a similar time period. This spending power will generate additional demand for flying.

FIGURE 2 PASSENGER WIDEBODY AIRCRAFT IN SERVICE FORECAST



Source: Rolls-Royce (2017) – Rolls-Royce Services – Pioneering Care for the widebody market

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2.2.2 Rules and regulations

Environmental regulation

ACARE and industry standards

The aviation sector has a growing environmental impact including direct carbon emissions, noise pollution and hazardous material waste. To tackle some of these issues the Advisory Council for Aeronautics Research in Europe (ACARE) has set goals to limit these negative externalities. These include the target for all aircraft to be designed and manufactured in a way that enables them to be recycled at their end-of-life by 2050.

EU-ETS

Aircraft operating within the EU fall within the carbon emissions trading scheme (EU-ETS). While EU-ETS carbon prices have been relatively low, future pressure from this and other types of carbon regulation will put pressure on airlines, who in turn will look to airframe and engine manufacturers such as Rolls-Royce to address this through greater fuel efficiency and new technologies. ACARE has also set carbon emission targets for the industry which directly impacts Rolls-Royce as supplier of aircraft engines.

REACH

The EU REACH regulation (Registration, Evaluation, Authorisation and Restriction of Chemicals) aims to improve the protection of human health and the environment through better and earlier identification of the intrinsic properties of chemical substances. This is done by four processes, namely the registration, evaluation, authorisation and restriction of chemicals.

Aero-engine manufacturing includes chemicals falling within the REACH regulations, and will require compliance within own operations as well as that of suppliers. This will include requiring authorisation for continued use where alternatives are not feasible. However future changes to authorisation creates risks for companies such as Rolls-Royce: if a chemical incorporated into engines or manufacturing processes is further restricted, this may put at risk the re-use of parts and materials from used engines as required in their business model.

Competition regulation

The recent period of 2015-16 saw increasing scrutiny by the European Commission of OEM practices in the aftermarket for parts and services following complaints from airlines and the IATA industry body. This stemmed from perceptions of anti-competitive practices of OEMs such as restricting information and access to IP by third party independent MRO providers; requiring the use of OEM-sourced parts and components; and locking customers into using designated MRO shops.

While this probe has not resulted in further action, it highlights potential challenges that companies such as Rolls-Royce may face in capturing value from aftermarket services.

"[Airlines] have little alternative but to sign on to long-term maintenance and parts agreements containing pricing escalations that are often above the inflation rate."

Tony Tyler, ex-CEO, IATA

Source: Financial Times

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2.2.3 Economy and environment

New Airline customers

Growth in the airline industry is creating new entrants in the airline (aircraft operator) sector. New entrants may not have the depth of technical capability to conduct their own MRO planning and execution, and will likely value the outsourcing of aftermarket services to engine OEMs who can provide an integrated and competitive service.

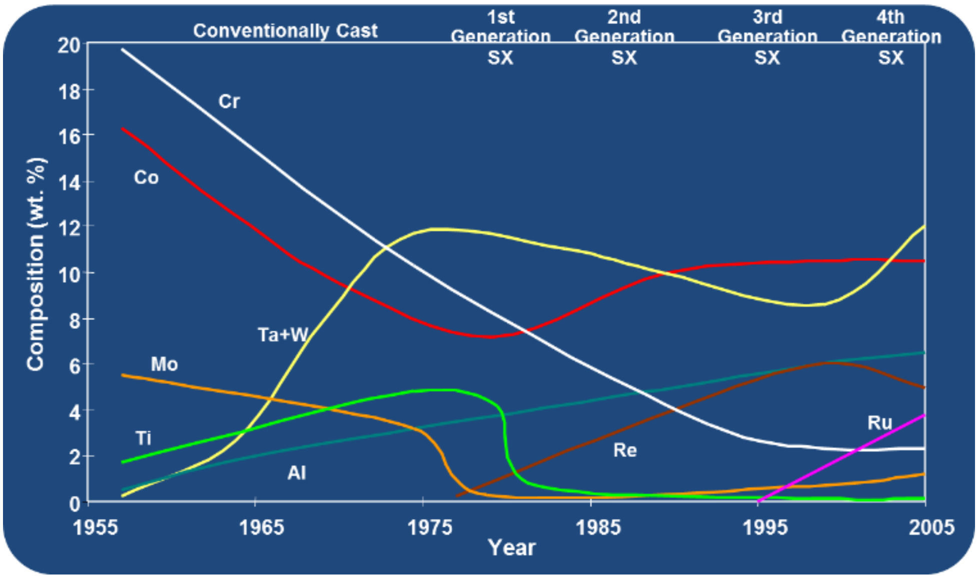
New entrants in the airframe manufacturing sector

The market for widebody airframe manufacturing is dominated by Airbus in Europe, and Boeing in the US. Russia and China are developing both their own as well as joint manufacturing capabilities for widebody aircraft: China's COMAC and Russia's UAC have joined forces to establish the China Russia Commercial Aircraft International Corporation (CRAIC). This will create at least one new customer for engine manufacturers.

Materials costs and scarcity

Aircraft engines incorporate exotic alloys and rare metals such as Rhenium (Re), Cobalt (Co), Tantalum (Ta), and Rhenium (Re). Global demand from multiple sectors for these metals is leading engine manufacturers to consider price and security of supply in future design and supply chain decisions.

FIGURE 3 EVOLVING COMPOSITION OF TURBINE BLADE ALLOYS



Source: Rolls-Royce (2013), Material Challenges for the Aerospace Sector

2.2.4 Competition

The business of commercial aircraft engines is characterised by high upfront investment in technology development, very long business cycles, and a high degree of regulatory and performance standards – which creates high barriers to entry for any new competitor. Nevertheless, the market for widebody aircraft engines is very competitive among the three key OEM players: GE, Rolls-Royce, and Pratt & Whitney.

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From the perspective of airframe manufacturers and airline customers there is increasingly a strategic option between multi-vendor sourcing to ensure competitive pricing and choice, and forming deeper and exclusive relationships with a single engine supplier. Currently, most aircraft models can be fitted with engines from multiple vendors, while some exclusive relationships are developing (e.g. between Airbus and Rolls-Royce for the A350 and Trent XWB engine).

2.2.5 Technology trends

Evolution of engine performance and hardware

Aircraft engines are staying on-wing for longer due to improved reliability and durability with each new generation of engine technology. This is a trend that is expected to continue with next-generation engines.

New and emerging engines such as Rolls-Royce's Trent XWB and Trent 7000 employ new technologies to optimise reliability and efficiency, such as 3D-printed components, composite materials, and bladed discs ('blisks'). This has implications for MRO provision as they require different repair and inspection processes.

Digitisation

Digitisation is a trend that pervades multiple aspects of aero-engines: from design through to engine data analysis; supply chain materials management; and integration with other digital sources for better in-flight performance – and associated value-added services.

As indicated by Rolls-Royce: "Advances in sensors, communication, data storage, processing power, machine learning, artificial intelligence, robotics and additive layer manufacturing are all combining to create new insights, processes, and opportunities".

Electrification of power

The overarching trend towards a lower carbon economy is creating a need to develop new propulsion technologies that rely less on – and eventually eliminate – the use of fossil fuels through electrification. As the jet engine technology of Rolls-Royce and other OEMs is based on mechanical technology, the move towards electrical technology will be a significant discontinuity.

While this is a longer-term trend, the aero engine industry is actively looking at developing new electrical technology, beginning with hybrid and electro-mechanical solutions. This will likely require new capabilities, new partnerships, and potential changes to business models.

2.2.6 Customer needs

Environmental performance and scrutiny

Airline customers are continuously looking for improved engine performance in terms of fuel efficiency, carbon emissions, NOx emissions, and noise pollution. Airlines themselves are under pressure from carbon regulations such as the European emissions trading scheme (EU-ETS) for the airline sector. With regards to noise, engine technology has reached a point where the airplane's airframe itself is the constraint on further improvements. This may shift the focus for Rolls-Royce engines on other environmental KPIs.

Airframe customers are increasingly requiring Rolls-Royce to provide greater information and transparency on the environmental performance of engines, including their supply chain impacts, through full lifecycle analysis.

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3 Business model assessment

The business model assessment has been conducted through a combination of publicly available information, interviews with employees and stakeholders of the case organisation and internal documents provided by the organisation. Rolls-Royce stakeholders interviewed for this report were the Sustainability Manager for Engineering and Design; and the Marketing Manager for Services, Civil Aerospace. Additional stakeholders were consulted internally by these direct counterparts to provide input and review findings.

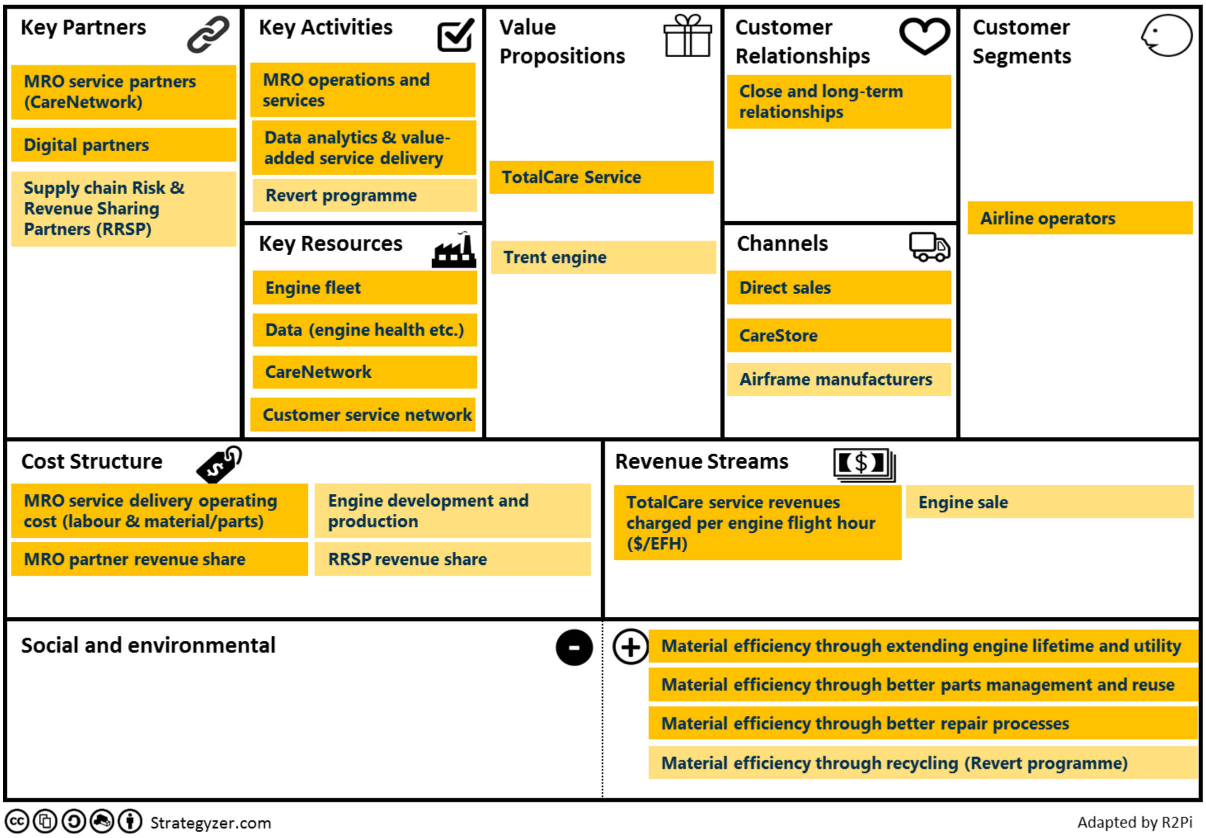
The objectives were to gain a deeper understanding of the circular business model and to map out the value chain and interactions in more detail in order to enable an analysis of the strengths and weaknesses as well as to consider the replicability and transferability of such a model to other entities and sectors.

3.1 Business model overview

> ***"We care about the performance of our solutions throughout their lives. Our whole-life capabilities maximise availability and enable us to meet changing customer needs"***
>
> **Rolls-Royce 2017 Annual Report**

This section describes the building blocks of Rolls-Royce's TotalCare business model. These are summarised in the business model canvas (Figure 4) below.

FIGURE 4 BUSINESS MODEL CANVAS



Source: R2Pi Project analysis, company interviews

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In the above diagram, elements of the business model which are not directly covered by the scope of this case study, but are relevant to Rolls-Royce's overall business model or contribute to circularity, are shown in a lighter shade. This are also described in the sections below.

It should be noted that the traditional nine-block canvas for circular business models outlined above has been adapted to include an additional building block – Social and Environmental. This is designed to capture key social or environmental benefits or costs which arise from the application of the circular business model. Discussion of non-financial outcomes is covered in Section 3.14.

3.2 Customer segments

Rolls-Royce serves airline operators around the world. Companies will typically buy Rolls-Royce engines as part of an aircraft purchase deal. For widebody aircraft, these will be purchased from either Boeing or Airbus Industries, the two dominant players in that market. A separate deal is made for purchasing the engines which are then fitted onto the aircraft delivered.

Buyers of new aircraft and engines are either airline companies themselves, or airplane leasing companies. The latter purchase airplanes and lease them to airline operators. Approximately 40% of aircraft in service are leased. Airline operators and airplane leasing companies are therefore the two key customer segments for engine sales.

However with respect to aftermarket services (maintenance, repair and other support services), the main customer segment for Rolls-Royce is airline operators. For the purpose of this case study, airline operators are the key customer segment we will focus on.

In addition to whether they operate owned or leased aircraft, other factors distinguish sub-segments within airline operators. One of the relevant factors is the degree to which the operator has in-house engine asset management and maintenance capabilities. For instance, large established airline companies may have their own MRO shops and capabilities, or existing commercial relationships with third party MRO service suppliers. On the other hand, more recent or start-up airline operators (a significant source of growth for new airplane deliveries or buyers of used aircraft) may not have these in-house capabilities. This can influence the degree to which airline operators value aftermarket services provided by OEMs such as Rolls-Royce.

3.2.1 Customer needs

To understand how Rolls-Royce's TotalCare creates value for customers it is important to understand the implications that engine maintenance and performance has on key areas of value-at-stake for an airline.

Direct maintenance costs are about 4% of an airline's total operating costs. However the proper maintenance and operation of aircraft engine has implications on a much wider set of factors that influence value to the airline operator (illustrated in Figure 5).

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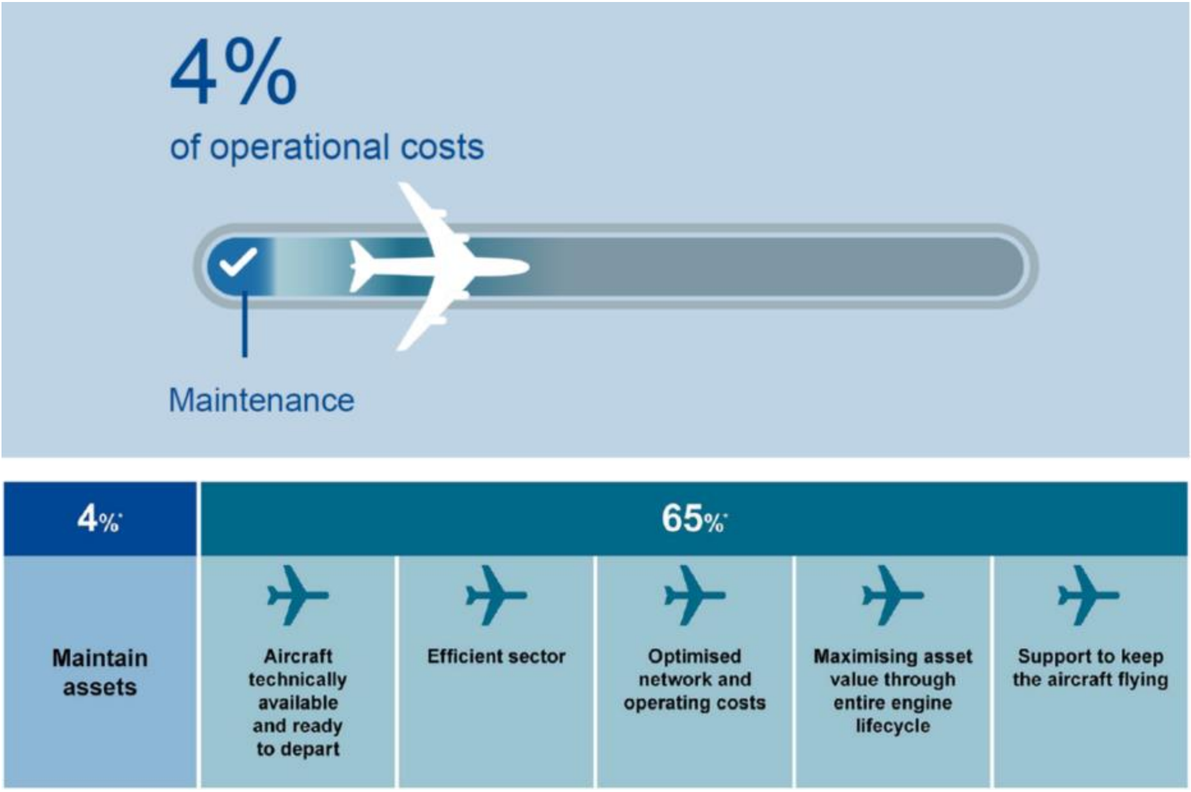
FIGURE 5 TOTAL VALUE AT STAKE IMPACT OF ENGINES



Source: Adapted from Rolls-Royce plc (2017) – Rolls-Royce Services – Pioneering Care for the widebody market

In relation to engines, key 'jobs-to-be-done' for airline operators include:

- **Optimising maintenance costs and time on wing**: *Airlines want predictability and control of engine maintenance costs and operational impacts*. Direct maintenance costs are about 4% of an airline's total operating costs, although they vary and increase over time with engine age. When an engine is taken off-wing for maintenance it is not available to power the aircraft which may need to be grounded. Timing of planned engine maintenance therefore needs to be balanced with operational and cost considerations. Furthermore there is a risk of either planned maintenance being more costly than anticipated, or unplanned maintenance being required (with additional cost and operational implications).
- **Maximising aircraft availability**: *Airlines want aircraft to take off as planned and avoid the risk of delays and cancellations impacting costs and reputation*. Airlines need to ensure that their aircraft are available to fly when required without disrupting quality of passenger experience.
- **Maximising operational efficiency**: *Fuel consumption is a significant operational cost to airlines that needs to be managed*. Airlines seek to enhance fuel efficiency of aircraft through better flight practices as well as flight routing based on weather and other atmospheric conditions.
- **Managing asset value**: *Engines are transferable assets that maintain their value compared to the airframe, exceeding 70% of total aircraft value as it matures*. Aircraft owners seek to optimise the value of engine assets over their lifetime and to maximise recovery of this value if it is sold and transferred to another party, or through residual value at end of life.

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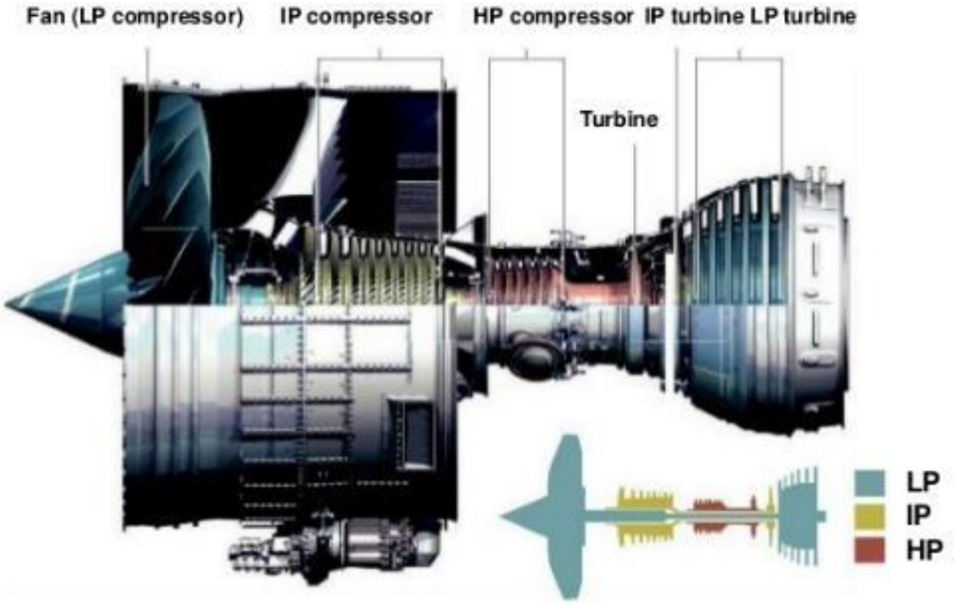
They key customer requirements and jobs-to-be-done are discussed in further detail below. For context, it is also important to note that certain characteristics of widebody aircraft engines (also referred to as the 'power-plant') drive aspects of the business models needed to operate and service them:

- **They are high-value assets**: Widebody engines typically cost over USD 20m at list price.
- **They have a long operating life**: The typical lifetime of an individual engine is 20-25 years.
- **They are mission-critical**: They need to be able to operate safely and efficiently within high temperatures and highly corrosive environments (core engine temperature can reach 1,500ºC).
- **They are high-tech and complex**: Typically composed of about 10,000 parts and several key modules.

FIGURE 6 WIDEBODY ENGINE MODULES (ROLLS-ROYCE TRENT 1000)



Source: Ojha, P. (2014)

3.2.2 Optimising maintenance costs and time-on-wing

When an airline takes delivery of a new fleet of aircraft and engines it needs to establish and implement an engine lifecycle management plan to maximise 'on-wing' time and minimise costs of maintenance and shop visits. When engines are purchased without an OEM service package such as TotalCare, it will manage and maintain its fleet of engines itself (either through own technical expertise and MRO facilities, or in partnership with third party MRO suppliers).

Engine fleet management and MRO planning and execution is a complex process that needs to take into account multiple factors and changing circumstances. These include:

- Managing and keeping engines within their performance and safety parameters (stipulated by industry regulators and OEMs)

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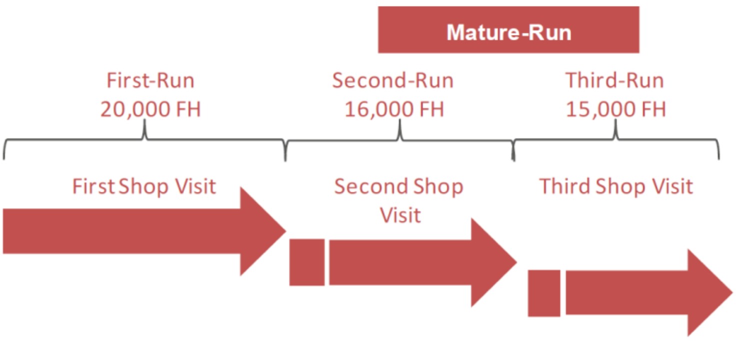
- Replacing Life Limited Parts (LLPs) based on their designated lifetimes. LLPs cannot be repaired and reused, so are effectively 'consumed' over a given number of flight cycles.
- Changes to performance and LLP consumption due to changes in aircraft operations and increased or decreased intensity of use as well as normal wear and tear.
- Own commercial considerations and policies (e.g. degree to which an airline wishes to 'sweat its assets', operational time horizon of aircraft, etc.)
- Unforeseen events requiring increased maintenance, such as Airworthiness Directives placed on engines, or unexpected engine failures.
- Changing technical and commercial needs as engines move through their lifecycle (see below).

Engine maintenance throughout an engine's lifetime is required to keep it in good operating condition to maintain and preserve its value (minimising deterioration) and to meet stringent safety requirements. The engine needs to undergo a shop visit, in which it is removed from the wing and disassembled, at key intervals over its lifetime (illustrated in Figure 7). The main elements of a shop visit are one or a combination of both:

- Performance restoration. Servicing or replacing elements of the engine to bring it back to required performance.
- Replacement of Life Limited Parts (LLPs). These are parts that have a defined lifetime (number of flight cycles) and which are consumed through use and need to be replaced once this is exhausted.

FIGURE 7 SHOP VISIT INTERVALS OVER AN ENGINE LIFECYCLE (ILLUSTRATIVE)



Source: Ackert, S. (2011)

The workscope of a shop visit (i.e. the combination of performance restoration and LLP replacement across an engine's different modules and parts) will vary over the engine's lifecycle stages. Figure 8 illustrates a typical shop visit process.

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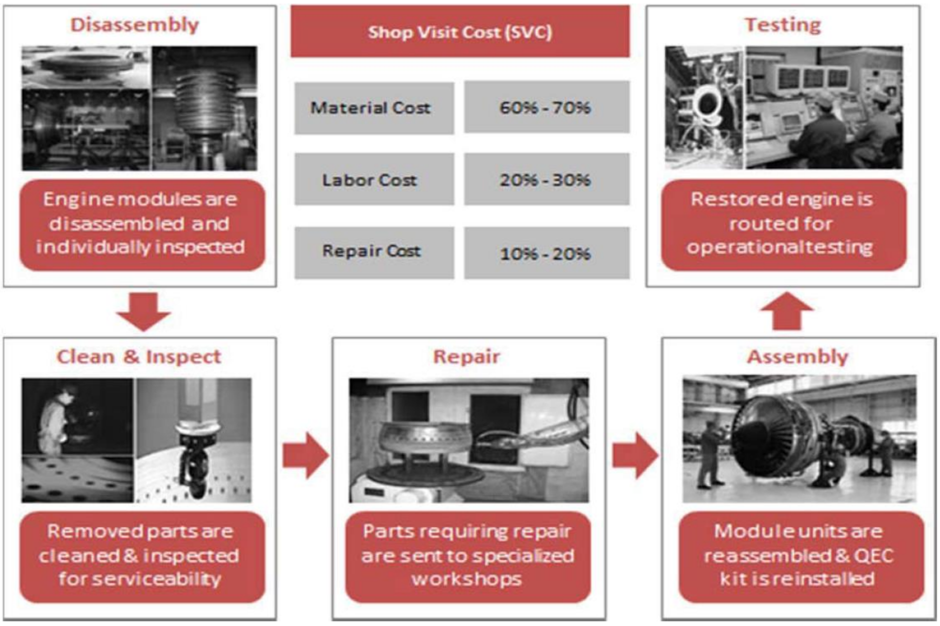
FIGURE 8 SHOP VISIT AND MAINTENANCE PROCESS (ILLUSTRATIVE)



Source: Ackert, S. (2011)

An ideal objective is to keep an engine utilised and on-wing (i.e. keeping an aircraft flying and generating revenues) for as long as possible between shop visits, and reduce the cost of shop visits. This is done through careful management of workscopes, which in turn depends on level of engine wear and tear (manifested through engine performance) and the 'hard' limiting factor of LLP lifetime.

Historically, engines were removed for shop visits at specified time intervals. However advanced engine health monitoring systems and analytics is enabling effective 'on-condition monitoring' that allows engines to fly as long as possible until they reach a hard performance constraint or LLP replacement.

Over the 20-25 year typical lifetime of an individual engine, a number of things will change:

- Maintenance costs will increase with increasing age of the engine (see Figure 9)
- The likelihood and frequency of maintenance events will vary (from relatively 'light touch' on-wing, to shop visits for performance restoration or full overhauls)

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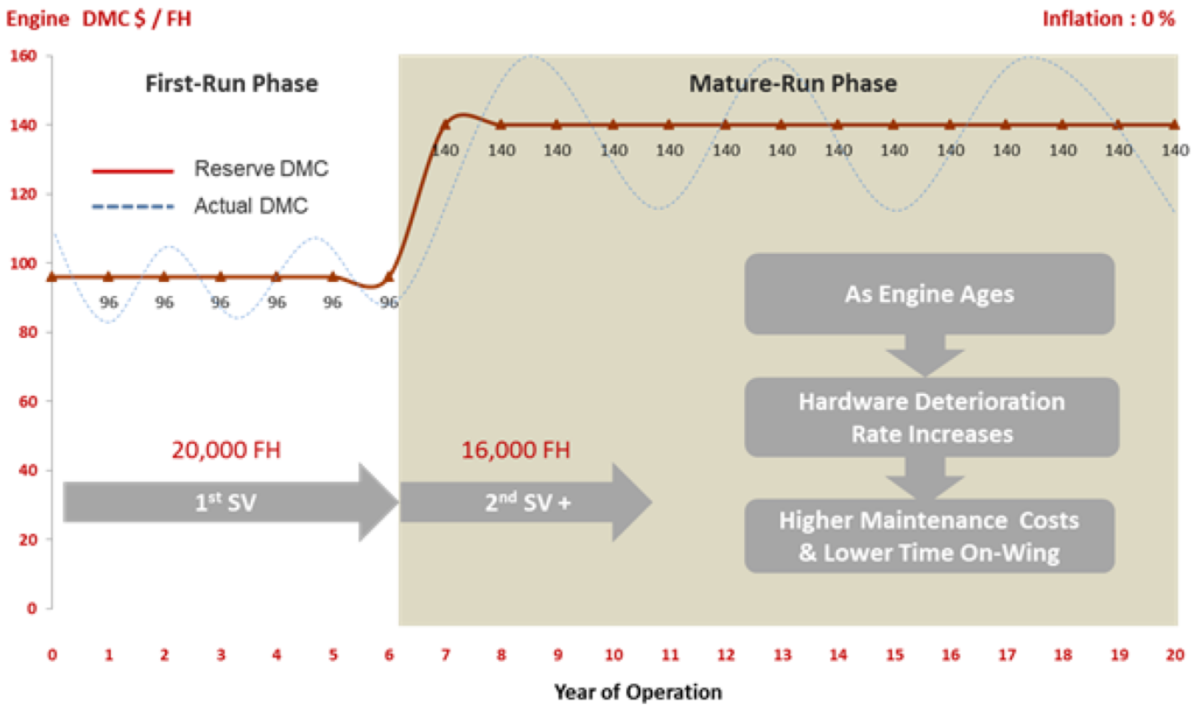
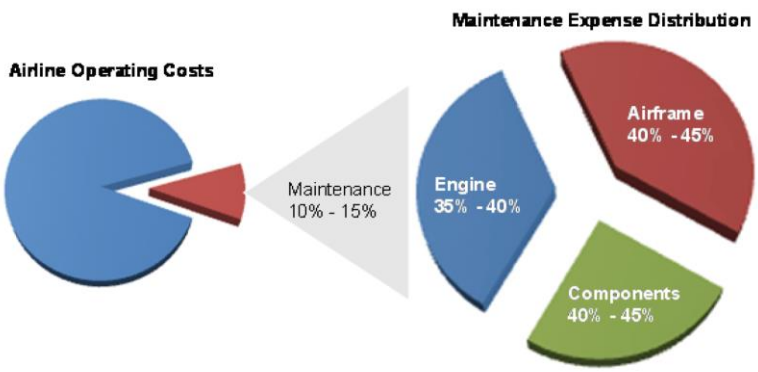
FIGURE 9 IMPACT OF ENGINE AGE ON DIRECT MAINTENANCE COSTS (ILLUSTRATIVE)



Source: Ackert, S. (2012)

Maintenance costs for an airline operator are approximately 10-15% of total aircraft operating costs, of which over a third (35%-40%) are related to engine maintenance (see Figure 10). Maintenance costs of aircraft engines therefore translate into approximately 4% of total operating cost.

FIGURE 10 ENGINE MAINTENANCE COST BREAKDOWN



Source: Ackert, S. (2011)

A number of decisions need to be made to plan maintenance interventions that optimise engine 'time on wing' between shop visits, and the cost of shop visits (see Figure 11). Key factors influencing planning are:

- Age of engine (the older the engine, the higher the rate of deterioration)
- Remaining lifetime (Flight Cycles) of Life Limited Parts in the engine

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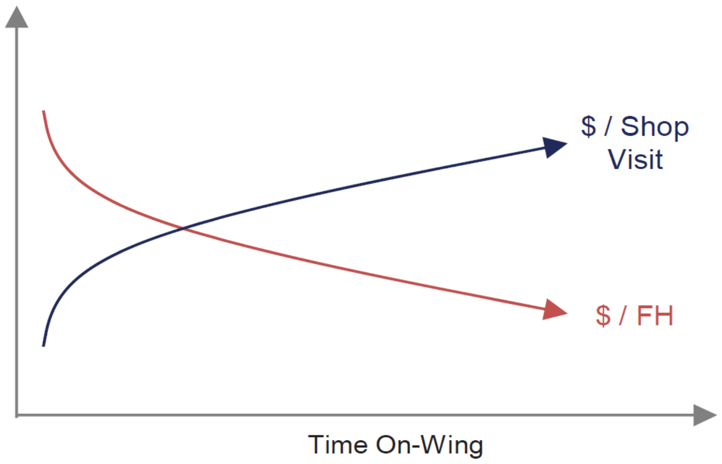
- Actual engine performance
- Operational conditions influencing rate of wear and tear, and engine performance, for example:
    - Operating environment: Flight paths over different latitudes and regions subject the engines to different rates of corrosion.
    - Operating methods: Levels of thrust applied at take-off.
    - Flight distance and profile: Shorter-haul flights result in proportionally higher flight cycles, and therefore take-offs, in which thrust required impacts wear and tear.

FIGURE 11 TRADE-OFF BETWEEN TIME ON-WING AND SHOP VISIT COST



Source: Ackert, S. (2011)

3.2.3 Maximising aircraft availability

Unexpected events causing aircraft to be grounded (so-called ‘Aircraft on Ground’ or AOG) resulting in flight delays or cancellations have a significant and direct impact on airline revenues and costs. An out of service aircraft can cost an airline thousands of dollars a day. This includes lost sales; passenger compensation; and higher cost of unscheduled maintenance.

Airlines therefore value solutions that enable their aircraft to be available to fly when needed and to avoid the financial and reputational impact of delays and cancellations.

3.2.4 Maximising operational efficiency

Flying methods that are inefficient increase fuel consumption and costs, as well as imposing unnecessary wear and tear on the engine which reduces its lifetime between shop visits. For example, depending on fuel prices, a one per cent fuel saving has been estimated to save USD 250,000 per aircraft per year.

Factors airlines need to pay attention to which influence fuel consumption include use of thrust; how much fuel to take on-board (which influences airplane weight); as well as optimal flight paths to avoid certain atmospheric conditions.

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3.2.5 Managing asset value

Aircraft engines are distinguished by the fact that their 'life' is restored through maintenance. Remaining lifetime is measured in terms of flight hours and cycles before the next shop visit, and is determined by the component part that has the shortest remaining life (each engine part and module has a defined lifetime or performance parameter).

An engine value starts at "full life" and this value reduces with engine usage based on the cost it would take to restore component parts. The remaining 'maintenance utility' is assessed by keeping track of maintenance status and when the next shop visit is due for each major engine module. Maintenance processes enable the value and useful life of engines to be restored each time (see Figure 12). The maintenance status of engine modules and lifetimes of LLPs need to be carefully monitored to ensure that these remain within stringent safety as well as performance parameters.

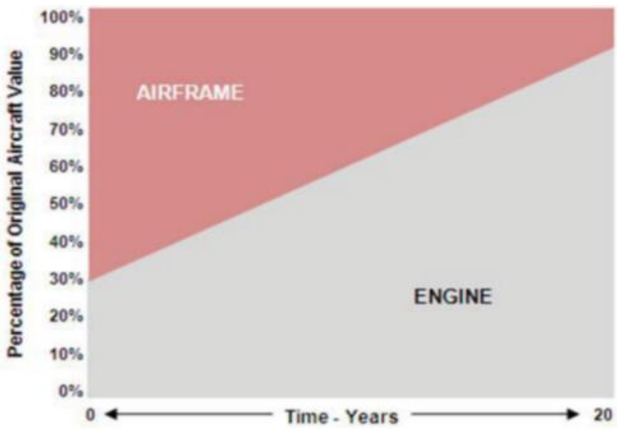
FIGURE 12 IMPACT OF SHOP VISITS ON MAINTENANCE UTILITY OF ENGINES

Source: Ackert, S. (2011)

Because of ongoing monitoring and maintenance, the economic value of engines remains relatively stable during a large part of their lifetime. Optimising the value of engine assets is therefore an important consideration for airlines as these may be sold and transferred at various points over their lifecycle.

The dynamics of engine maintenance and value optimisation means that they retain their value (depreciate less) over the lifetime of the aircraft compared to the airframe they are powering (see Figure 13). Therefore as an aircraft matures, the engines become the most valuable asset.

FIGURE 13 ASSET VALUE OVER THE AIRCRAFT LIFETIME



Source: Ackert, S. (2011)

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For mature engines approaching end of life, those that have sufficient “green time” (remaining life, expressed in terms of flight cycles) can be traded and are attractive to airlines planning to retire their aircraft. If these operators have engines requiring a shop visit, they may wish to buy a green time engine for that remaining period instead, rather than incurring the cost and disruption of an engine overhaul.

Engines that have reached the end of their flight hours (have no green time remaining) will be traded and purchased for the value of those modules and parts within the engine that still have “life” within them and can be reused to maintain engines that are still in service. Used parts that can be can be restored and reused are referred to as ‘used serviceable materials’.

3.2.6 Customer requirements over the engine lifecycle

As described above, there are a number of decisions and processes needed to ensure that engines perform as required and that as much value as possible is delivered by the asset. Factors influencing these will vary and change over the operating lifetime of the engine, and therefore so will the key priorities of the airline operator.

Table 1 and Table 2 below respectively illustrate typical characteristics of an engine lifecycle; and corresponding aircraft operator priorities and risks over those lifecycle phases.

TABLE 1 CHARACTERISTICS OF ENGINE FLEETS OVER THEIR LIFECYCLE

	Phase 1 (“Sunrise”)	Phase 2 (“Mature”)	Phase 3 (“Sunset”)
Characteristics of engine lifecycle phase	From Entry Into Service (EIS) of the engine until production ceases – typically a period of 6-10 years depending on the model. The majority of engines have yet to have their first performance restoration through a Shop Visit. The value of young and popular engines can remain close to original market value and list price after maintenance.	When production of the engine model ceases, the programme lifecycle enters a “maturing” phase, covering the period approximately 6-20 years after EIS. By this point most engines across the aircraft fleet are characterised by: • Relative stability in engine values and an increase in the trading of engines (e.g. transfer between aircraft operators/owners). • Stable rate of performance restorations through Shop Visits. • Increasing importance of maintenance status of the engine, which determines the degree of “life” left in the engine before its next Shop Visit.	Aircraft models carrying the engine start being withdrawn from service. Key aspects of this phase are: • Increase in supply of engines after their aircraft have been retired. • The value of an engine approximates the cost of overhauling it. • Engines in aircraft fleet are traded and valued on the basis of remaining maintenance “green time”.

Source: R2Pi Project analysis

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TABLE 2 AIRLINE CUSTOMER PRIORITIES AND RISKS OVER THE ENGINE LIFECYCLE

	Phase 1 ("Sunrise")	Phase 2 ("Mature")	Phase 3 ("Sunset")
Airline operator priorities	• Maximising time on wing and return on investment before first shop visit.	• Planning timing and workscope of shop visits to optimise time on-wing and shop visit costs. • Potential sale and transfer of engine to new owner (e.g. as part of aircraft fleet renewal).	• Matching remaining operating life of the engine in line with time horizon of aircraft retirement. • Minimising/ avoiding unnecessary maintenance costs and realising maximum remaining asset value.
	• Maximum aircraft availability • Operational efficiency of flights and overall fleet		
Risks and uncertainties	• Uncertainty over maintenance costs and requirements • Uncertainty of timing of first shop visit for new models. • Teething problems of new models with new technologies may require unforeseen shop visits, costs, and disruption to rectify.	• Rates of engine wear and tear depending on operating environment conditions (e.g. geographic regions) and severity of aircraft operation (e.g. thrust rating; intensity of use; flight distances). • Inflation and volatility of maintenance costs (labour and parts)	• Leaving too much unused value (life) within the engine prior to retirement. • Increasing supply of engines in the market with remaining 'green time' (from decommissioned aircraft) influences resale value of engines. • Timing of aircraft retirement.
	• Unforeseen events resulting in AOG and requiring costly maintenance. • Aircraft is grounded requiring major repair to engine, but no capabilities exist locally to do so.		

Source: R2Pi Project analysis

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3.3 Value proposition

3.3.1 Historical perspective – before TotalCare

Up to the 1990s, Rolls-Royce traditionally generated revenues from the aftermarket (after an engine was sold to a customer) by selling spare parts and dealing with distressed repairs. A lot of the support and maintenance for aircraft was licensed out to third parties.

As discussed above, airlines undertaking their own engine maintenance activities (either through their own MRO capabilities or third party MRO service providers), need to plan regular interventions to keep engines running well and safely. Planned maintenance therefore offered one avenue for Rolls-Royce aftermarket revenues. Airlines also have to deal with unplanned maintenance events when something goes wrong or there is an unexpected decline in engine performance. Rolls-Royce would originally also support airlines in servicing unplanned maintenance events – providing a so-called 'break-fix' service. In either planned or unplanned maintenance scenarios, Rolls-Royce services were charged on a time-and-materials basis: customers paid for parts and labour costs (with price including a profit margin for Rolls-Royce).

Rolls-Royce therefore profited from each maintenance event (whether planned or unplanned). While this time-and-materials model addressed the specific and immediate maintenance needs of customers, it did not address the wider set of challenges and issues that airline customers had to deal with (explained in detail above). *In particular, it did not align incentives towards the desired customer outcome: keeping engines on-wing for as long as possible; performing as well as possible; avoiding unplanned events; and at a predictable total lifetime cost*.

This traditional model wasn't satisfactory for Rolls-Royce either. Aftermarket revenues were correspondingly unpredictable, and *neither was it delivering nor capturing the full value Rolls-Royce's technology, knowledge, and capabilities could bring to solving customer problems*.

3.3.2 Origins of TotalCare

Breakthroughs occurred in the 1990s when Rolls-Royce responded to customer needs and created a new model that aligned these incentives, becoming the basis for TotalCare. The integration of engine sale and aftermarket services into a lifecycle contract originated from Rolls-Royce's response to customers such as Cathay Pacific and American Airlines, creating the precursor for what later became TotalCare.

A key innovation underlying the TotalCare model was addressing the unpredictable timing and cost of engine overhauls and maintenance faced by airlines by integrating these into a service package that was charged at an agreed cost per engine flight hour (EFH) – referred to as '$/EHF'. Under this revenue model – also referred to as 'Power By the Hour' (PBH) – Rolls-Royce is paid a given rate for each hour which the engine is being utilised to power an aircraft. When the engine is not able to be utilised (e.g. if it isn't working or is being maintained), the airline does not pay Rolls-Royce.

This innovation effectively turned the physical engine into the equivalent of using a service. It also perfectly aligns incentives between Rolls-Royce and its customer: when the engine performs such that the airline generates revenues from a flight, Rolls-Royce gets paid. If the engine is not being utilised or cannot power the aircraft when needed, the airline doesn't incur the PBH cost and Rolls-Royce isn't paid. It is Rolls-Royce's responsibility to deliver and optimise all the MRO processes and costs enabling engines to be utilised as much as possible.

This 'servitised' or 'product-service' innovation subsequently evolved into the broader package of TotalCare services which still retain the PBH revenue model that aligns incentives. Since its introduction in the mid-1990s, the TotalCare aftermarket service model has successfully been taken

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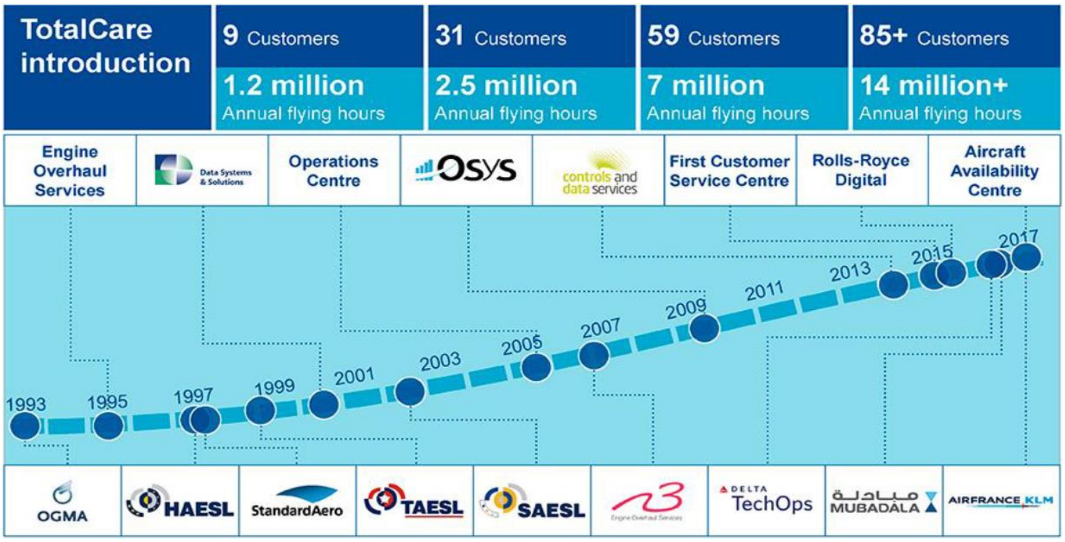
up by customers and virtually all Rolls-Royce Trent engines are now covered under this package. Figure 14 below illustrates the growth trajectory of TotalCare since its beginnings.

FIGURE 14 GROWTH OF TOTALCARE

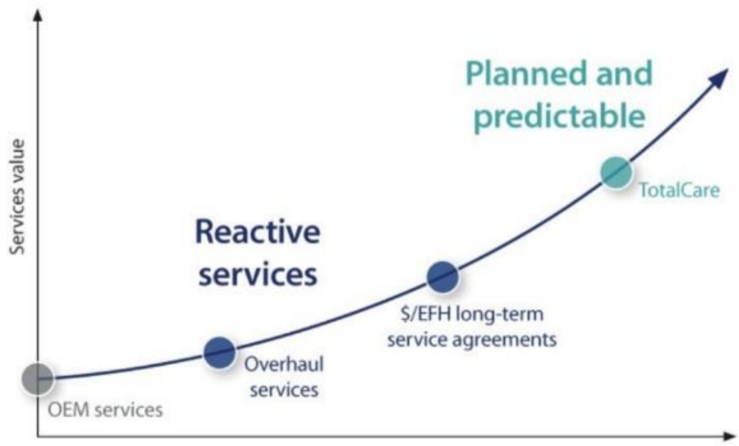


Source: Rolls-Royce plc (2017) – Rolls-Royce Services – Pioneering Care for the widebody market

The TotalCare value proposition is described in more detail in the sections below. As will be explained, TotalCare itself has innovated and evolved following changing customer needs and requirements over the course of an engine lifecycle (referred to in Section 3.2.6 above). Whereas the first iteration of TotalCare was focused on a new engine deal and the early phase of the engine lifecycle, Rolls-Royce has created variations of this value proposition that meet customer needs as the engines mature and later approach their end of life.

The historical evolution of Rolls-Royce's aftermarket services is illustrated in Figure 15 below. This shows how the company moved from being mainly focused on manufacturing (OEM-focus) and later providing services on a time-and-materials basis, to then innovating the PBH-based service and subsequently the suite of TotalCare services it now offers. Furthermore, many aspects of Rolls-Royce's business model have changed and continue to evolve to enable the TotalCare value proposition, as will be described in later sections.

FIGURE 15 EVOLUTION OF ROLLS-ROYCE SERVICES



Source: Morris, B. (2014). Rolls-Royce plc.

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3.3.3 The engine product

Before describing the specifics of the TotalCare value proposition, it is important to consider the engine product itself which lies at the centre of Rolls-Royce's value proposition.

The jet engines which are part of the TotalCare model being discussed in this case study are for widebody aircraft used in civil aviation. Examples include the Rolls-Royce models Trent 700 (used on the Airbus A330); Trent 1000 (used on the Boeing 787); the Trent XWB (for the Airbus A350). The Trent 7000 is the most recent model entering into service, powering the A330neo aircraft.

Engine characteristics are an important context for understanding the customer needs and service requirements arising around them. Widebody aircraft engines are high value, high-technology, long-life products, operating in challenging environments. The core value of jet engines to airline operators is delivering high power performance, fuel efficiency (a key operating cost for airlines), and mission-critical reliability and safety. Section 3.2 above described the customer perspective and implications this has in terms of complex MRO processes needed to keep engines performing as required.

From Rolls-Royce's perspective, the aircraft engine manufacturing business is characterised by a very long business cycle of up to forty years spanning development phase, production phase, and product lifetime. Importantly, engine development costs are very high (typically over USD 1bn) and require a reliable source of revenue to fund the development of each new generation, as well as ways of sharing risks over the lifetime of the engine programme.

TABLE 3 KEY CHARACTERISTICS OF ROLLS-ROYCE WIDEBODY ENGINES

Key characteristic	Description
High value products	
Engine price excl. TotalCare	~ USD 15-20 million [(1)] (~ 10% of aircraft cost)
Engine price incl. TotalCare	~ USD >40 million [(1)]
Complex products	
Complexity: A typical jet engine contains 10,000 parts. **Product lifecycle**: Most of the high-value parts will need to be replaced up to four times over an engine's lifetime due to wear and tear and specified limited lifetimes. **Material characteristics** – High value and rare materials and alloys are used in Rolls-Royce engines including: hafnium, rhenium, tantalum and titanium. Engines also use large quantities of high-grade steel and aluminium and, increasingly, composite materials.	
Long product business cycle	
Product development time – Typical timeframe for developing and commercialising a new engine model prior to Entry into Service (EIS)	3-5 years
Production lifetime – Typical period over which the engine is being manufactured and offered to the market	10-15 years
Product lifetime – Typical lifetime of the engine in use by airline.	20-25 years
High development cost	
Programme development (R&D) cost	~ USD 1 billion

[(1)] Figures are for the Rolls-Royce Trent 1000 engine. Estimated values have been sourced from multiple press releases of Rolls-Royce engine deals.

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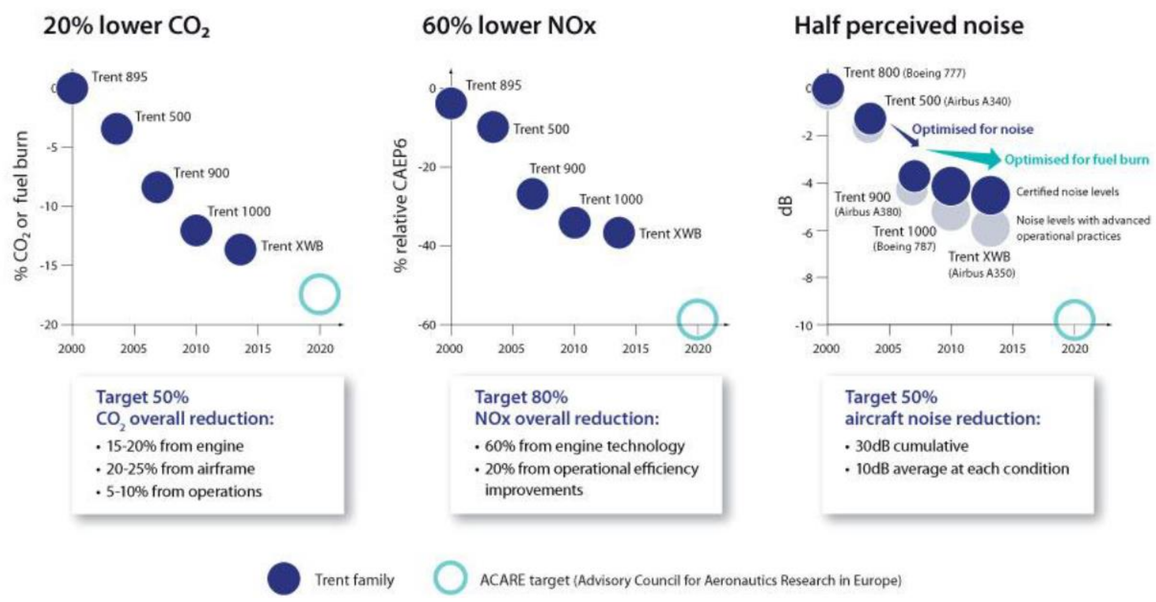
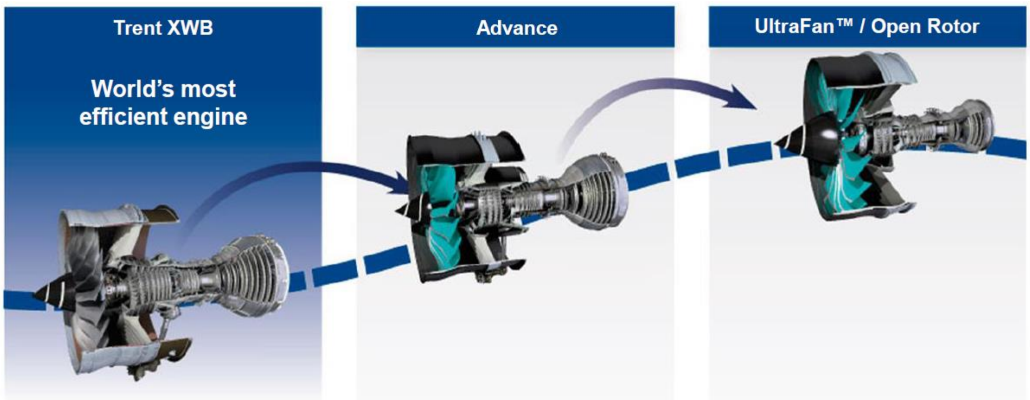
Each new generation of Rolls-Royce Trent engine pushes the boundaries of performance including areas with direct environmental benefits. They incorporate increasingly sophisticated electronic controls and health monitoring systems, as well as providing increasingly better fuel efficiency and environmental performance (noise levels; carbon emissions; and pollutant emissions such as NOx and SOx). These are particularly important considerations for airline operators who are under pressure to manage carbon emissions from both a reputational as well as regulatory perspective (e.g. via the EU ETS carbon trading scheme). Fuel efficiency can also have a significant impact on operating costs. Figure 16 and Figure 17 demonstrate past performance improvements, as well as future performance developments planned for Trent engines.

FIGURE 16 ENVIRONMENTAL PERFORMANCE IMPROVEMENT OF TRENT ENGINE GENERATIONS



Source: Koyama, D. (2016). Better power for a changing world, Rolls-Royce plc

FIGURE 17 FUTURE PRODUCT EVOLUTION



Technology EIS Readiness	2020+	2025+
Bypass Ratio	11+	15+
Overall Pressure Ratio	60+	70+
Efficiency relative to Trent 700	20%+	25%+

Source: Rolls-Royce plc (2016) – Pioneering a Better World – Integrating sustainability into design

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The high stakes and high costs of each engine development programme highlight the importance to Rolls-Royce of having a business model that can fund and support this. The growth of reliable TotalCare revenues has been critical to enabling this.

3.3.4 The TotalCare value proposition

From its origins in the 1990s (described above), Rolls-Royce's aftermarket services have evolved into a comprehensive suite of services, outlined in Figure 18 below. TotalCare has three key variants which correspond to evolving needs of airline operators over the lifetime of their engines and are explained in detail below. Rolls-Royce also offers additional services which leverage the capabilities, technology and business model underlying TotalCare (however these are not the focus for this case study).

FIGURE 18 ROLLS-ROYCE TOTALCARE AND AFTERMARKET SERVICES PORTFOLIO

TotalCare			LessorCare	SelectCare	Foundation Services
TotalCare Life Protects asset value for the life of the engine and promotes flexibility by virtue of always being fully-reserved	**TotalCare Term** Provides a lower $/EFH rate over fixed calendar term, via a non-fully reserved structure	**TotalCare Flex** Provides an adapted/flexed structure to facilitate asset value release for mature engines	A simple framework that provides access to all the services that a lessor may need throughout the lifecycle of the engine	Combining a pay at event structure with an engine flying hour rate for the ongoing services	Overhauls priced and paid for at event. Additional services may be contracted as required. Short-term agreements only.

Source: Rolls-Royce plc (2017) – Rolls-Royce Services – Pioneering Care for the widebody market

3.3.5 TotalCare Term

TotalCare Term is the original package offered by Rolls-Royce, in which the customer signs up for coverage over a fixed term, paying a fixed fee per engine flight hour ($/EFH) rate. The customer only pays for the shop visits expected to occur during the length of the agreement. This is calculated based on the number of shop visits required over the given period and other maintenance related costs, divided by the estimated number of flight hours. Dividing the cost of shop visits by engine flying hours across a set period is effectively a way of amortising the refurbishment element of the TotalCare service.

From a longer lifecycle perspective, a challenge with TotalCare Term is that later overhauls beyond the contract term are not planned into the cost and revenue model, and there is no guarantee of what condition the engine will be in at end of contract. This means that if the contract term ends midway between shop visits, the customer will not have made any contribution towards the engine life used since the last shop visit. This enables a lower $/EFH rate, but the consequence is either a higher $/EFH if the contract is extended, or that the engine re-sale value may be lower as the next owner will need to take into account additional maintenance needed.

Despite the uncertainty over engine condition and value at end of contract, some airline operators still choose this package as it offers the lowest rate per flight hour.

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3.3.6 TotalCare Life

In 2007, Rolls-Royce launched TotalCare Life. As with TotalCare Term, the service is designed for engines starting at the early stage of their lifecycle. As such, maintenance and shop visits are designed to maximise time on wing, producing the most efficient outcome for operators over the long term.

TotalCare Life has three important difference to the TotalCare Term offering. Firstly, there is no end date to the contract, which continues for as long as the customer wishes.

Another important difference is that the portion of the power by the hour $/EFH rate determined by maintenance visits is calculated by dividing the cost of the shop visit by the number of flying hours between shop visits – essentially calculating this on a pro-rata basis. This reflects the true cost of engine maintenance throughout the period of operation. So if a customer wishes midway between overhauls to sell their aircraft to another operator, the seller's contributions already made towards the next overhaul are transferred to the buyer (if they also choose TotalCare this will be seamlessly integrated into their contract). The next owner of the asset does not incur costs of maintenance for which it has not received the benefit of utilising the engine. This arrangement is therefore designed to be 'portable' from one asset owner or operator to the next, and the Rolls-Royce customer is able to sell the engine for a higher price.

The advantages offered by the above arrangements are matched by a $/EFH rate that is typically higher than for TotalCare Term.

3.3.7 TotalCare Flex

In 2015, Rolls-Royce launched TotalCare Flex for one of its original TotalCare customers, Cathay Pacific. At that time, Cathay's Trent-powered 777 fleet averaged about 16 years of age, including five aircraft that had been in service for more than 20 years.

TotalCare Flex is primarily designed for those engines in the mature phase of the lifecycle with up to 5 years or so of remaining life.. This can include customers who have completed their TotalCare Term contract, but who wish to continue with a service package adapted to that stage of the lifecycle. It can be suited to customers who:

- Hold engines whose remaining lives may be shorter than what a full overhaul provides (i.e. an overhaul would put too much life back into the engine);
- May be interested in offloading the engine before its newly overhauled useful life runs out;
- Are acquiring older aircraft that will stay in their fleet until the end of their useful life.

Under this package, engines are managed to the end of their operating life in a planned manner, with engine support and shop visits tailored to only provide the life on wing needed over that time horizon. TotalCare Flex uses cost-saving strategies to broaden its support options for older engines, for example:

- Repairing and restoring engine modules only to the extent needed.
- Using spare parts recovered and sourced from other engines that are disassembled and cannibalised for parts. This includes Life Limited Parts that still have sufficient flight cycles (called 'stub life') remaining in them.
- Swapping with 'green time' engines (which Rolls-Royce acquires from other customers).

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As this arrangement is within the TotalCare framework, it gives customers certainty over the quality of parts, engines and maintenance standards. It reduces the ongoing cost of maintenance and releases maximum asset value through to end of life (not leaving any "money on the table").

3.3.8 Extending the range of services and support offered

In addition to MRO services, Rolls-Royce has innovated and expanded the TotalCare offering to incorporate a range of additional options and services. These recognise that, while TotalCare's MRO services address the 4% of airline operating costs relating to maintenance, Rolls-Royce's engines have a much broader impact on value to an airline (as explained in Section 3.2.1).

Through the expanded offering, the TotalCare value proposition is targeting key customer needs, namely: ensuring the aircraft is always ready and available to fly when needed; that it is flying efficiently and routing is optimised; and that engine assets are managed effectively to maximise value.

Additional TotalCare services are typically charged within the Power by the Hour (PBH) framework, and so remain aligned with its overall philosophy of aligning incentives. One of the reasons Rolls-Royce is able to develop and deliver these services and offer them through the TotalCare model is the intimate knowledge it has of its own engines and how they perform throughout their lifetime (obtained via engine health monitoring and MRO services). Through this, Rolls-Royce is able to offer customers support and services for better operational decision-making and efficiency.

TotalCare service options available depend on the type of TotalCare package (e.g. Term, Life or Flex), and correspond to six categories of value to customers:

- Maintenance service and cost management
- Improving aircraft availability
- Improving efficiency
- Facilitating transition of engines between owners
- Engine asset management
- Customer support solutions

Figure 19 below shows the range of TotalCare services and options offered for the portfolio of value propositions under TotalCare and other packages.

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FIGURE 19 RANGE OF TOTALCARE SERVICES OFFERED

Service Solutions	Services	TotalCare			SelectCare	Foundation Services	Available on other engine brands
		Life	Term	Flex			
Maintenance	Overhaul Services	●	●	●	●		
	T&M Overhaul					○	
	Engine Logistics Management	●	●	●	●	○	
Availability	AOG Support	●	●	●	●	○	
	On-Wing Services	●	●	●	●	●	
	Intelligent Engine Lifing	●	●	●	○	○	
	Fleet Planning	●	●	●	●		
	Engine Health Monitoring	●	●	●	●	●	
	Intelligent Engine Health Management	○	○	○	○		
	Remote Site Rescue	○	○	○	○	○	
	Spare Engine Services	○	○	○	○	○	
	Materials Management	○	○	○	○	○	
Efficiency	Efficiency Insight	○	○	○	○	○	○
	Enhanced Efficiency Management	○	○	○	○	○	○
	Integrated Efficiency Optimisation	○	○	○	○	○	○
Transitions	Maintenance Value Portability	●					
	Return Condition Management	○	○				
Asset Management	Engine Records Management	○	○				
	Greentime Management			●			
	Engine & Parts Trading	○	○	○	○	○	
Customer Support	Rolls-Royce Care portal access	●	●	●	●	●	
	Technical Publications	●	●	●	●	●	
	Airline Support Team	●	●	●	○	○	
	Customer Training	○	○	○	○	○	
	Safety Management System	○	○	○	○	○	○

Key: ● Core item ○ Optional item

Source: Rolls-Royce CareStore Services – Airline (downloaded August 2018)

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3.3.9 Summary of value created by TotalCare

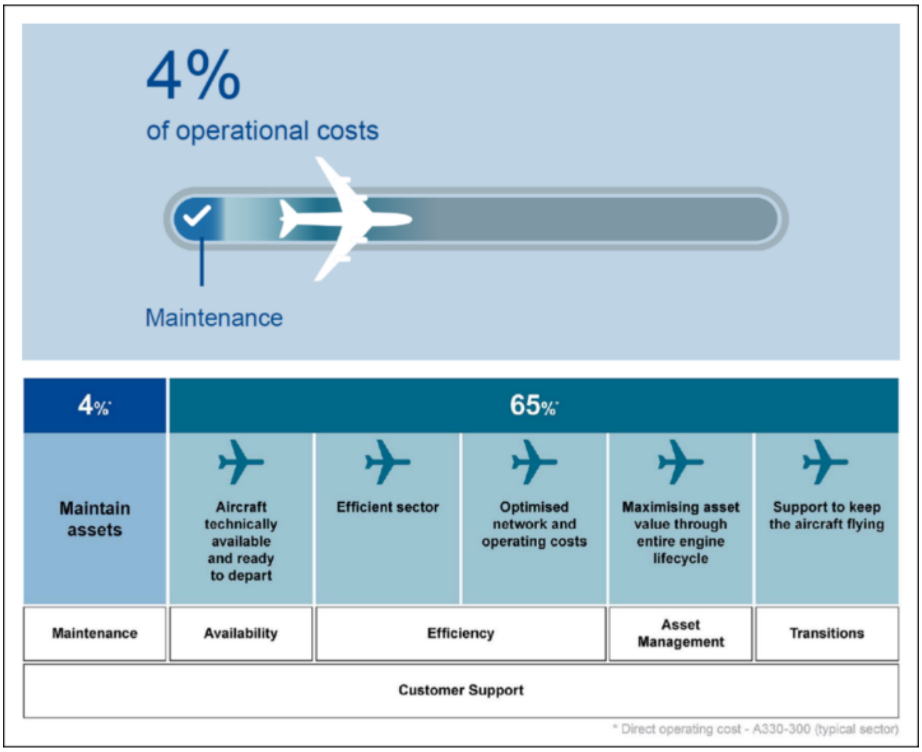
As discussed in Section 3.2 and summarised in Table 2 of that section, airlines face a number of risks and uncertainties in managing and operating their engine assets, with knock-on consequences for their operating costs and aircraft performance.

The fundamental philosophy behind TotalCare – from its origins through to today – is the value created by transferring this risk from the airlines to Rolls-Royce within a revenue model that charges per engine flight hour. The value generated for airline operators from this model are:

- Predictability of MRO-related costs over engine lifetime, through a simple and well-understood charging mechanism
- Higher operational efficiency (including fuel costs)
- Avoided disruptions, avoiding associated costs and improving quality of service
- Higher value of engine asset (facilitating sale and transitions)
- Focus of own resources on core business

Rolls-Royce is able to take on this risk due to its intimate knowledge of the engine technology and performance in-use. As will be seen in the following sections, Rolls-Royce has developed a business model that effectively manages these risks and delivers the TotalCare value proposition service in a reliable and efficient way. In return, Rolls-Royce has been able to create an attractive source of predictable, recurring revenues for delivering TotalCare and, importantly, to reinvest in new generations of better-performing engines as well as continuous service innovations.

FIGURE 20 SCOPE OF VALUE DELIVERED BY TOTALCARE AGAINST AIRLINE VALUE AT STAKE



Source: Adapted from Rolls-Royce plc (2017) – Rolls-Royce Services – Pioneering Care for the widebody market

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3.4 Channels

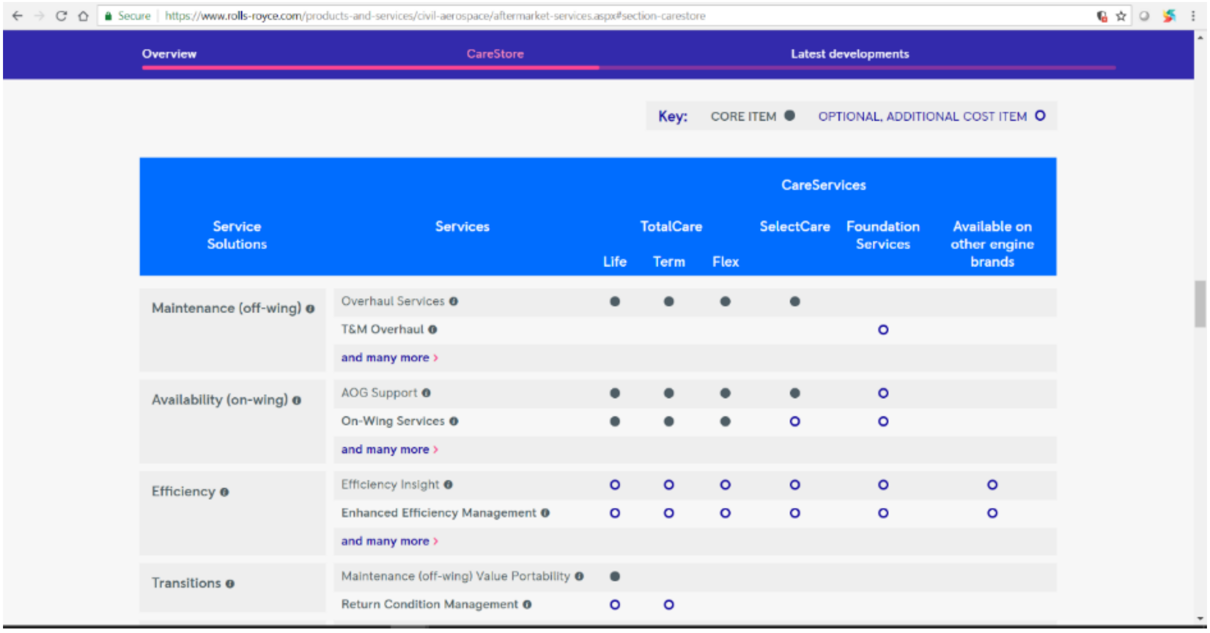
3.4.1 Direct customer sales

TotalCare is offered to customers at the point of sale when airlines (or leasing companies) are considering the purchase of engines as part of a broader aircraft procurement deal. Rolls-Royce sales teams will negotiate deals directly with the customer. Virtually all Trent engines are sold with a long-term TotalCare agreement attached.

3.4.2 CareStore

Rolls-Royce established the CareStore as a way of raising customer awareness of the wide range of services and options they can procure as part of a TotalCare package. The CareStore website (Figure 21) identifies what options are available for each of the different types of TotalCare packages (e.g. Life, Term, Flex, Select Care, Foundation Services, etc.).

FIGURE 21 CARESTORE WEB SITE



Service Solutions	Services	TotalCare Life	TotalCare Term	TotalCare Flex	SelectCare	Foundation Services	Available on other engine brands
Maintenance (off-wing)	Overhaul Services	●	●	●	●		
	T&M Overhaul					O	
	and many more ›						
Availability (on-wing)	AOG Support	●	●	●	●	O	
	On-Wing Services	●	●	●	O	O	
	and many more ›						
Efficiency	Efficiency Insight	O	O	O	O	O	O
	Enhanced Efficiency Management	O	O	O	O	O	O
	and many more ›						
Transitions	Maintenance (off-wing) Value Portability	●					
	Return Condition Management	O	O				

Source: Rolls-Royce website (accessed August 2018)

TotalCare services and options are organised based on key solutions customers may be looking for, namely:

- Maintenance service and cost management
- Improving aircraft availability
- Improving efficiency
- Facilitating transition of engines between owners
- Engine asset management
- Customer support solutions

By structuring the key elements of the TotalCare value proposition in the CareStore, this enables informed discussions between Rolls-Royce's sales and account management teams, and customers. As Rolls-Royce creates new services and options, these will be continually added and communicated to customers via the CareStore. Figure 19 above shows the current range of services offered.

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3.4.3 Airframe OEMs

Airframe manufacturers are increasingly becoming an important channel to market for Rolls-Royce with the emergence of exclusive joint development of engine programmes. For example, Airbus has an agreement with Rolls-Royce whereby the company developed the Trent 7000 engine exclusively for the A330neo.

This commercial arrangement is made to reduce overall development costs and increase speed to market through tighter integration and collaboration. Rather than multiple OEMs investing in R&D and having to recoup this through sales (because each jet engine model is designed and developed for a specific aircraft model), an exclusive arrangement reduces overall supply chain development costs and enables a more cost-effective procurement deal for the buyer.

Under this type of arrangement, the airframe manufacturer becomes an exclusive channel for Rolls-Royce engines, from which Rolls-Royce is able to up-sell TotalCare services.

3.5 Customer relationships

Rolls-Royce has deep, long-lasting relationships with airlines. The insight into customer needs and openness to co-innovate which this has created was a key factor in the original development of the TotalCare value proposition.

Under the traditional 'time-and-materials' model, prior to introduction of TotalCare, Rolls-Royce's customer relationships would have been relatively transactional. These would have focused mainly on the engine sale deal and contracts for spare parts, as well as provision of planned or reactive ('break-fix') MRO services.

TotalCare has instead established a partnership-style relationship, where the success of the airline's operational performance is a mutual interest. The power-by-the-hour (PBH) arrangement and increasing focus of TotalCare contracts on ensuring aircraft availability (i.e. the aircraft is there to take off at the required time and location) has aligned Rolls-Royce's business model with that of its customers.

In addition, the range of TotalCare services – in particular those based on the digitisation of engine performance tracking and data management – is further deepening Rolls-Royce's relationship with customers. This is enabling Rolls-Royce to, for example, offer consultative value-added services such as optimisation of in-flight operations and routing.

In terms of day-to-day service operations, Rolls-Royce has established a network of Customer Service Centres (CSC) around the world covering key regions and timezones. These are on hand to address the full range of issues which customers may encounter, such as managing urgent operational situations or drawing on other TotalCare services. The improved quality of customer service which CSCs were designed to deliver has been demonstrated by the Singapore CSC reducing response times to customers by 75% in its first year of operation.

> ***"Being based in Singapore has enabled our customer service team to react and provide solutions for customers in their own time zone. Deploying engineering support within hours when it's required and working round the clock with our team in the UK means customers are seeing up to 18 hours of continual service. It's helped us to strengthen our customer relationships and develop a greater understanding of their needs."***
>
> **Ewen McDonald, Senior Vice President – Customers – Asia-Pacific, Rolls-Royce**

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"Rolls-Royce is committed to delivering excellence in our services, really caring for our customers, understanding their needs better, and being ever more responsive. Today is the beginning of a global journey to get closer to our customers and to do more work in the regions where they operate."

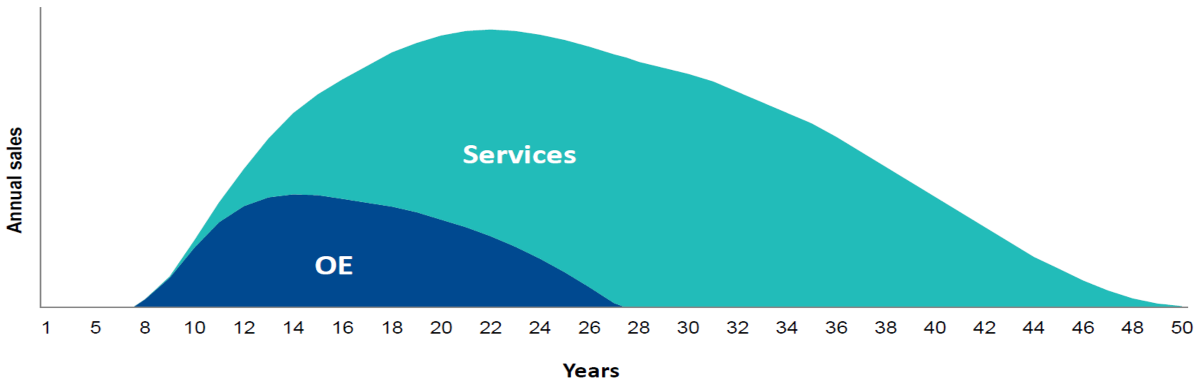
Dominic Horwood, Chief Customer Officer
Rolls-Royce Civil Aerospace

Source: Rolls-Royce press release

3.6 Revenue streams

The TotalCare model drives recurring revenues primarily by charging customers on the basis of hours flown by each engine it serves. Over the lifetime of a typical engine programme, this translates into a volume of revenues which is approximately four times as large as that of the initial engine (original equipment) sale, as shown below.

FIGURE 22 ILLUSTRATION OF ENGINE AND SERVICE REVENUES OVER A TYPICAL ENGINE PROGRAMME LIFEYCLE



Source: Wood, T. (2014) Rolls Royce plc

3.6.1 Engine sales

Engine sales are the foundation of Rolls-Royce's TotalCare aftermarket services. Rolls-Royce engine sales contracts are often at-cost when they are sold together with a TotalCare package. Factors influencing engine pricing are:

- Recovering R&D costs of the engine programme
- Covering manufacturing costs
- Factors relevant to negotiation of an overall deal incorporating TotalCare services

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3.6.2 Service revenue: Power-by-the-hour

One of the hallmarks of TotalCare is the revenue model whereby Rolls-Royce charges customers and receives predicable recurring revenues based on the utilisation of its engines, measured in terms of engine flight hours (EFH). This is scaled across the entire Rolls-Royce engine fleet operating under Power by the Hour (PBH) contracts. TotalCare revenues are therefore driven by total EFH, and the rate per hour charged:

TotalCare lifecycle revenue = [EFH] x [rate per hour]

Total hours flown across Rolls-Royce's engine fleet is itself driven by:

- Global growth in **engine fleet size under** TotalCare contract.
- **Engine utilisation and uptime**, translating into **total hours flown per engine** (on average, an engine flies approximately 4,000 hours per year).

The rate per flying hour can vary based on TotalCare service type and customer service level (e.g. TotalCare Life / Term / Flex). The range of add-on services available through the CareStore are generally incorporated into PBH arrangements.

3.7 Key resources

3.7.1 Engine fleet

Rolls-Royce's fleet of engines in service are the key asset that drive TotalCare service revenues.

Well-functioning engines provide recurring revenue through Rolls-Royce's power-by-the-hour (PBH) revenue model, with additional revenue from value added services that may be purchased by airline operators.

Rolls-Royce has multiple generations of engine currently in service, being used by airlines across the world. Viewed in aggregate, each generation (or engine programme) has a particular spread of age across engines in service – from those that first entered into service with initial customers, to those that are being manufactured and sold today. Even after production has ceased, as long as engines are under TotalCare contract, Rolls-Royce will be responsible for servicing them and they will generate service revenues for the company. The profile of Rolls-Royce Trent model engine generations since Entry Into Service are shown in Figure 23.

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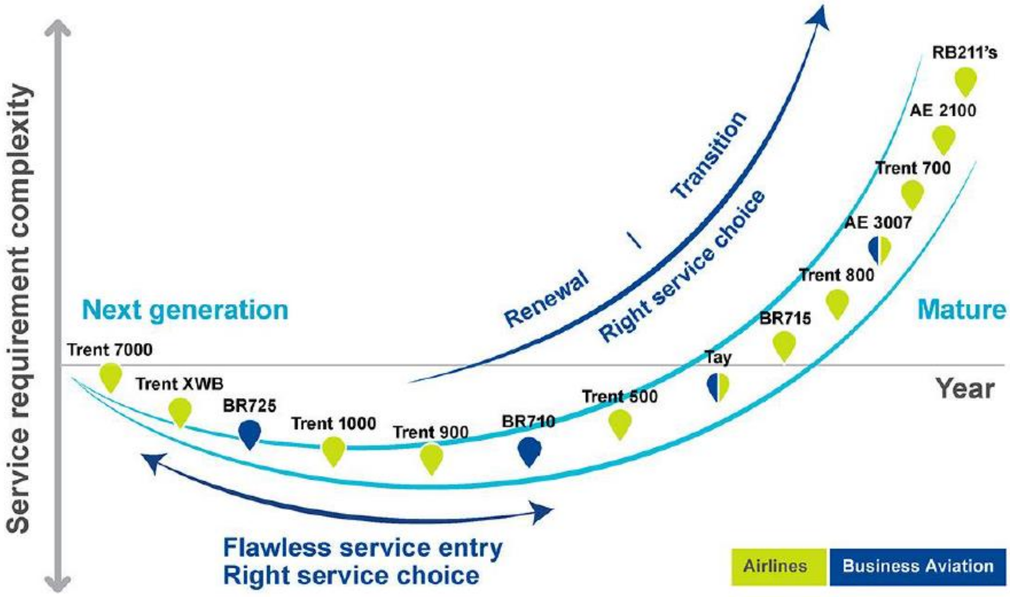
FIGURE 23 ROLLS-ROYCE ENGINES AND STAGE OF LIFECYCLE

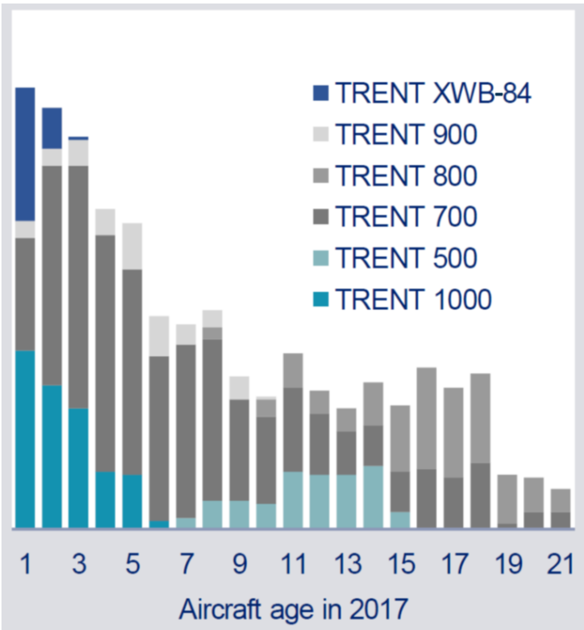


Source: Rolls-Royce plc (2017) – Rolls-Royce Services – Pioneering Care for the widebody market

Furthermore, as TotalCare enables Rolls-Royce to have thorough knowledge of and access to its engines throughout their lifetime, engine assets at end-of-life can be a source of value for Rolls-Royce through buy-back and re-use of 'green time' engines or their component parts (as used serviceable materials for other engines). This is explained in further detail below.

Figure 24 shows the relative volume of Trent engines in service based on age of aircraft using them. This shows some engine programmes spanning long periods of time, such as the Trent 700 programme which is powering newly manufactured aircraft as well as airplanes that are over 15 years old. Overall, the balance of Rolls-Royce's engine fleet age is relatively young, but increasingly maturing.

FIGURE 24 AGE OF AIRCRAFT IN OPERATION UTILISING DIFFERENT ROLLS-ROYCE ENGINES



Source: Rolls-Royce plc Annual Report 2017 Fact Sheet

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The implications for Rolls-Royce with regards their engine fleet volume and age profile are that:

- The volume of relatively young engines will be a strong driver of revenue growth and profit (as they generally require little maintenance in their early lifetime).
- Airlines coming to the end of a TotalCare Term contract may be looking to extend it, which will require a review of expected service requirements and pricing (such as extending to another fixed term, or moving to a TotalCare Flex package).
- Airlines with mature aircraft and engines may seek to sell these on to a new owner (or, if leased, they may transition to a new operator), which will require managing the transition of asset value between owners or operators, based on the maintenance status and remaining 'life' of the engine and its components.

BOX 1 END-OF-LIFE MANAGEMENT OF ENGINE ASSETS, PARTS AND MATERIALS

Mature engines that are approaching the end of their operational life but still have sufficient flight hours remaining (called "green time") can be traded and transferred to airlines who need to continue powering older aircraft but don't wish to incur the cost and disruption of overhauling existing engines. Rolls-Royce is able to purchase these green time engines from the market and re-deploy them as a cost-effective option under TotalCare Flex contracts. It is especially advantageous if those engines were already under a TotalCare contract as Rolls-Royce will have the full set of information on their maintenance status and history, which minimises risk and optimises value.

When a mature engine has used up its operating life as an asset (and there is no desire to overhaul it), parts and materials can be used by Rolls-Royce. Once again, if those engines were under TotalCare contract, Rolls-Royce has the advantage of fully understand their maintenance history so that maximum value can be extracted: re-using parts considered to be Serviceable Used Material (SUM). These will be serviced and re-deployed through parts supply across the CareNetwork of maintenance shops.

TotalCare also enables assurance of 'chain of custody' so that materials can be recovered and recycled back into manufacturing. This is important because such materials are 'aerospace-grade' and segregating them from other sources of scrap enables them to be re-used – otherwise they would effectively be 'downcycled'. Such materials will be re-used in Rolls-Royce's supply chain through its Revert programme (see below for details).

Almost 95% of a used aero engine can now be recycled and around half of the recovered material is of such high quality it can be safely used again to make a new engine. Reasons for materials not being recycled include when these utilise composites (such as new fan blades) and recycling processes have not yet been developed. This is an area for improvement that Rolls-Royce is actively investigating.

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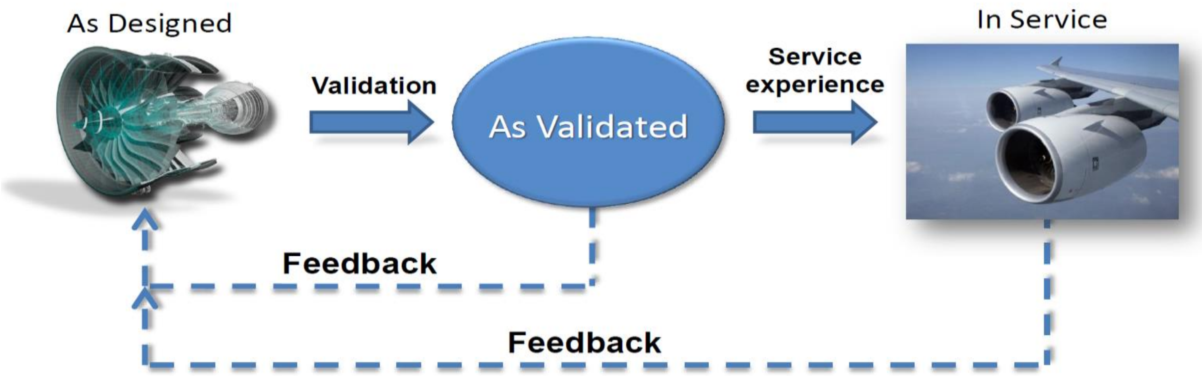
3.7.2 Engine performance data

The monitoring of engine performance data has been an important element of Rolls-Royce's TotalCare model for many years through Engine Health Monitoring (EHM). Each new generation of engine includes new and more sophisticated sensors and monitoring capabilities. What used to previously be several gigabytes of data per engine flight hour is now orders of magnitude greater: each flight hour typically generates several terabytes of data which can be uploaded to Rolls-Royce systems (either remotely while the aircraft is flying or after landing). Rolls-Royce has access to this data subject to contractual arrangements with the airline customer.

Engine flight data is used by Rolls-Royce to provide value added services to customers, such as in-flight diagnostics and issue resolution, as well as broader advice on optimisation of flight operations and routing.

But in addition to this, data generated across Rolls-Royce's entire fleet of engines is a unique asset which enables Rolls-Royce to continuously manage and improve the efficiency and quality of its TotalCare service operations, and also feeds back into the design of new generations of engines (this is illustrated in Figure 25 below).

FIGURE 25 DATA ENABLES POSITIVE FEEDBACK LOOP BACK TO ENGINE AND SERVICE DESIGN



Source: Wood, T. (2014) Rolls Royce plc

Data from engine health monitoring, but also data and knowledge collected from its TotalCare service operations provides Rolls-Royce with a unique advantage in ensuring that the TotalCare value proposition remains relevant and competitive. The value drivers of data to Rolls-Royce and its customers are outlined below.

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TABLE 4 VALUE DRIVERS OF DATA

Value driver of data	Description
Operational efficiency and cost management	• Maximising the time on-wing of engines between shop visits, thereby keep them flying (and generating revenues for Rolls-Royce and its customer) as long as possible • Optimising the workscope of shop visits to avoid unnecessary costs • Optimising Rolls-Royce's overall MRO network operations through forecasting and planning of maintenance events and labour and materials/parts.
Optimising and maximising the value of the engine asset	Engines under TotalCare have a higher residual value.
Improving engine designs and technology	• Keeping them at the cutting edge of performance requirements valued by customers (including fuel efficiency and environmental performance) • Building in further digital capabilities that can driver additional value-added services as well as efficiencies for maintenance.

3.7.3 Global CareNetwork

When an engine needs to go off-wing for servicing, it will go to a maintenance shop specified in the customer's TotalCare contract. Rolls-Royce's aftermarket services network comprises a mix of wholly-owned, joint venture, and customer-owned or independent MRO shops, now standing at about 20 centres around the world, as shown in Figure 26 below. Any TotalCare work required will generally be directed to the appropriate centre within this network. Third party centres in the CareNetwork are not necessarily exclusively dedicated to serving Rolls-Royce engines, and may also provide MRO services to competitor engines.

FIGURE 26 ROLLS-ROYCE GLOBAL CARENETWORK

Source: Rolls-Royce plc (2017) – Rolls-Royce Services – Pioneering Care for the widebody market

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Within the CareNetwork, there are centres that specialise in certain complex types of repair, or in rarer types of repair interventions where it makes sense to achieve scale economies by centralising expertise and capabilities.

3.7.4 Customer Service and Relationship Network

Regional Customer Service Centres

Rolls-Royce has established a network of Customer Service Centres (CSC) around the world covering key regions and timezones. These are on hand to address the full range of issues which customers may encounter, such as managing urgent operational situations or drawing on other TotalCare services. Customer Service Centres coordinate operational planning and have engineering capabilities to be able to deliver services to customers, including data services. The centres have local decision-making authority and are connected to the **Rolls-Royce Airline Aircraft Availability Centre** (see below) in Derby, which tracks engine data and provides engineering expertise worldwide. The regional Customer Service Centres also act as hubs for the Rolls-Royce Airline Support Teams which are based in major airport locations across regions.

Originally, customer service activities were centralised in Rolls-Royce's UK Derby centre. However with the growing number of Rolls-Royce engines flying around the world and within regions, the company decided that it needed to be closer to its customers. The first CSC was opened in Singapore in 2015, serving customers in Asia. This was followed by CSCs serving the Americas, Greater China, and the Middle East and Africa regions.

In addition to regional and local service delivery functions, Customer Support Centres also support sales campaigns and lead customer account management. This includes supporting Rolls-Royce's five Customer Regional Teams serving Asia Pacific, Americas, Europe, Greater China, and Middle East and Africa.

Airline Aircraft Availability Centre

In 2017 Rolls-Royce established the Airline Aircraft Availability Centre, in Derby (UK). This is the central global planning function for Rolls-Royce engine operations and maintenance, ensuring aircraft under TotalCare are available for service 24/7, with the right parts and expertise available. Preceding the Aircraft Availability Centre, Rolls-Royce had established in 2004 the Operations Centre in Derby which provided central coordination of TotalCare.

The Airline Aircraft Availability Centre is effectively the 'nerve centre' of TotalCare operations globally: receiving, monitoring, and making decisions based on the data received from engine health monitoring. It complements and provides expertise to Rolls-Royce's global network of Customer Service Centres who work locally with customers.

In addition, the Aircraft Availability Centre is at the forefront of Rolls-Royce's digital strategy for value-added engine services:

- Data analysis and decision support (Rolls-Royce's so-called "IntelligentEngine" concept), combining analysis of data from Rolls-Royce engines with data from customers and partners to enable improvements in aircraft availability and fuel efficiency – thus improving airline economics.
- Acting as a hub for the introduction of new technologies. For example, a new real-time collaboration system lets engineers working on engines around the world share live pictures from inside an engine with the team at the Centre, and receive their advice on the next steps

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to take. It is envisaged that, in the future, "remote surgery" techniques will let experts at the Centre carry out complex engineering tasks on the engine by remote control.

> ***"We are entering a new era of digital connectivity and new services technology which allows us to greatly expand the type of services we can offer, with aircraft availability a key objective. As the industry services innovator, our Airline Aircraft Availability Centre incorporates the advances of today and tomorrow to support our vision of every Rolls-Royce powered aircraft taking off and landing on time, every time."***
>
> **Tom Palmer, Senior Vice President – Services,**
>
> **Rolls-Royce Civil Aerospace**
>
> Source: Rolls-Royce press release

3.8 Key activities

3.8.1 MRO services

MRO services are a key activity of the TotalCare business model – these are the aftermarket services Rolls-Royce provides through its value proposition and power-by-the-hour revenue model. These are provided through Rolls-Royce's CareNetwork, described above.

As described in Section 3.2, MRO processes require sophisticated planning and decision-making to ensure that maintenance interventions optimise safety, performance, and financial considerations.

3.8.2 Digital analytics and value-added service

Planning and decision-making based on engine health monitoring has been an important part of TotalCare for many years. About 15 years ago, engines had relatively few sensors. However today engines have many sensors generating thousands of signals. It is estimated that Rolls-Royce will soon receive more than 70 trillion data points from its in-service fleet each year. Large aircraft fleets generate terabytes of data, with gigabytes generated per hour. Data management and analysis is therefore a key activity for delivering effective and efficient TotalCare services.

> ***"There's no lack of data in our market today. We and our customers are drowning in data, and many existing systems struggle to filter the signal from the noise and offer the means to analyse things in a consistent way. Our heritage and focus have been intelligent systems linked to engineering knowledge and designed to provide high-quality information and insight. Digital technology and analytical insight deliver a real, sustainable advantage in the services we provide,"***
>
> **Nick Farrant, Senior Vice President**
>
> **Rolls-Royce**
>
> Source: Rolls-Royce press release

As illustrated in Figure 27, engine data is used to inform engine maintenance requirements, and to provide advice to pilots in flight as well as to airline fleet planners.

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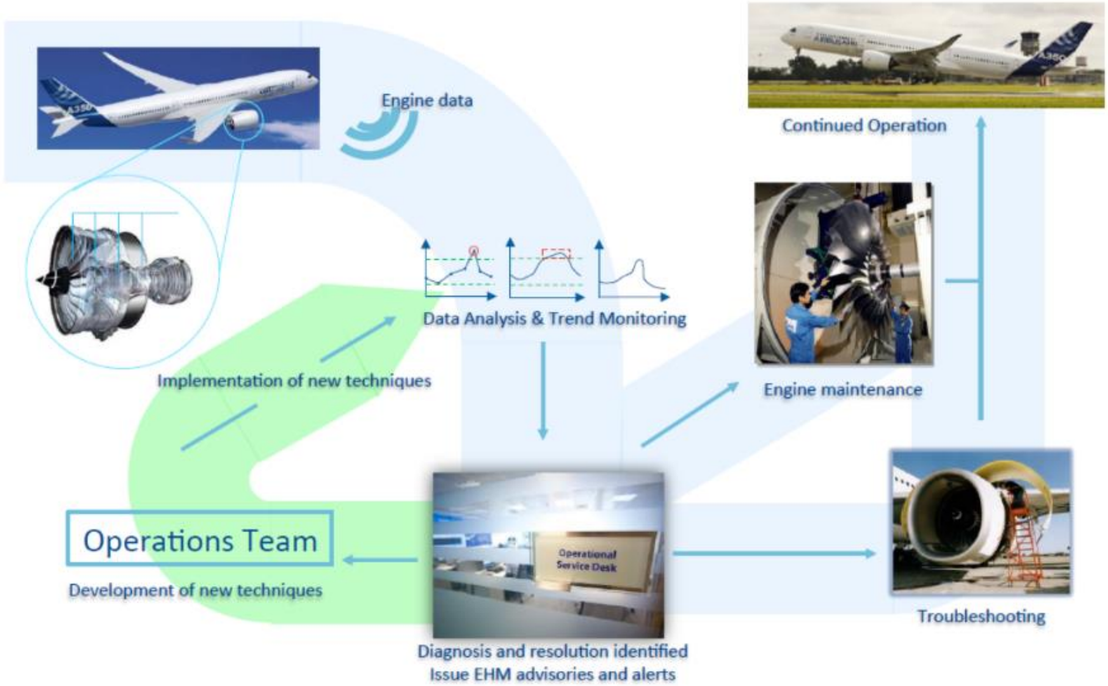
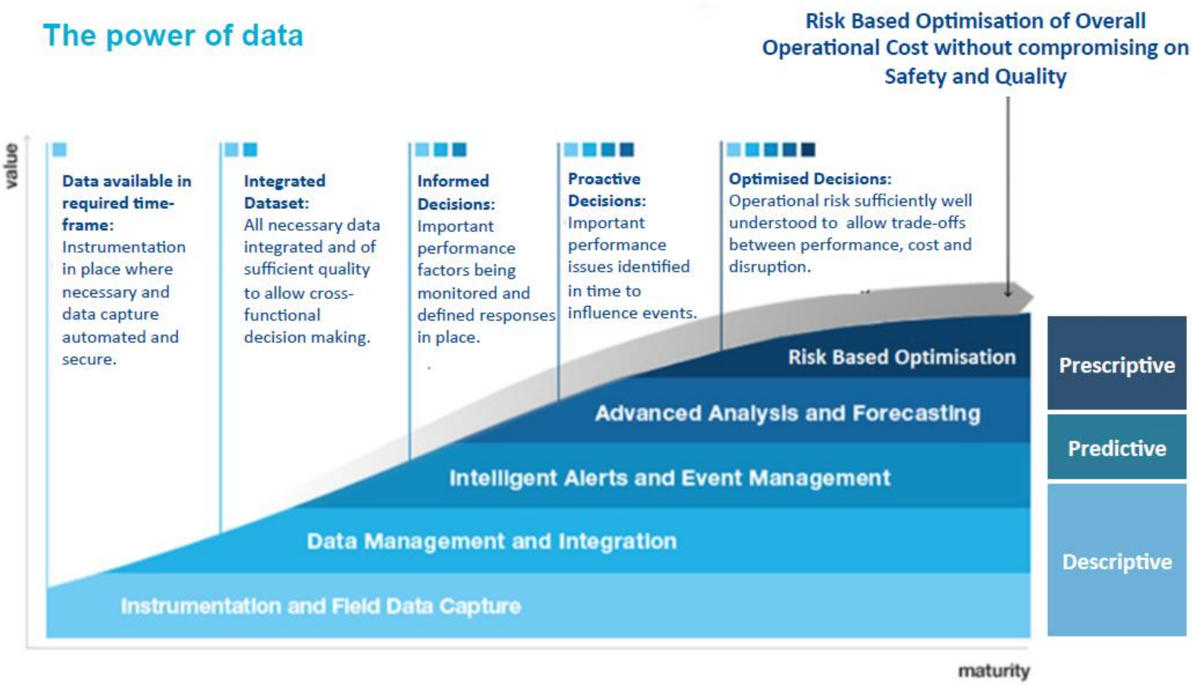
FIGURE 27 ENGINE HEALTH MONITORING



Source: Palmer, T. (2015), Rolls-Royce plc

Over the years, Rolls-Royce has been developing and evolving the use of analytics from engine data aggregated across the fleet to provide better planning of MRO services and interventions. As illustrated in Figure 28, the trend has been to move towards optimisation of financial outcomes for the airline based on sophisticated data analysis, while maintaining safety and quality.

FIGURE 28 EVOLUTION OF PREDICTIVE ANALYTICS



Source: Palmer, T. (2015), Rolls-Royce plc

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Rolls-Royce is now entering an era **where data enables the merging of hardware and services**, powered by 'big data' analytics, data connectivity, and machine learning. This is encapsulated in Rolls-Royce's 'IntelligentEngine' vision (see below).

Along this journey, Rolls-Royce is ramping up the sophistication of its digital capabilities, enabling a number of improvement such as:

- Better maintenance decisions resulting in cost reduction and performance improvement for itself and customers.
- Better understanding of how to structure TotalCare support contracts
- Better risk management
- Informing new product design and development

In 2017, the £1 billion-plus invested by Rolls-Royce in R&D included installation of digital engineering tools, producing the company's first all-digital engine design.

BOX 2 ROLLS-ROYCE INTELLIGENTENGINE VISION

In addition to digitally designing, testing, and maintaining engines, the IntelligentEngine vision sets out a future where an engine will be:

- Connected – with other engines, its support ecosystem, and with its customer, allowing for regular, two-way flow of information between many parties
- Contextually aware – of its operating context, constraints and the needs of the customer, allowing it to respond to the environment around it without human intervention
- Comprehending – learning from its own experiences and from its network of peers to adjust its behaviour and achieve best performance

Rolls-Royce's R^2 Data Labs, an acceleration hub for data innovation launched in December 2017, will play a key role in achieving the aims of the IntelligentEngine. Using advanced data analytics, industrial Artificial Intelligence and machine learning techniques, R^2 Data Labs develops data applications that unlock design, manufacturing and operational efficiencies within Rolls-Royce, and creates new service propositions for customers.

At the heart of R^2 Data Labs are Data Innovation Cells; mixed discipline teams of data experts who work in collaboration with teams from across Rolls-Royce's operations. These cells apply cutting edge principles to rapidly explore data, unlock and test new ideas, and turn those ideas into new innovation and services. R^2 Data Labs has data innovation capability hubs in the United Kingdom, United States, Germany, Singapore, India and New Zealand.

The passage below provides Rolls-Royce's own perspective on the importance of IntelligentEngine:

> *The IntelligentEngine is Rolls-Royce Civil Aerospace's vision for the future, the vision is one where we see the world of the product and the service becoming almost inseparable and supercharged by digital technology. We launched this vision at the Singapore Air Show earlier this year (2018). Our airline customers operate in a highly competitive market with a travelling public that expects to fly on time, every time, as*

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efficiently as possible – so aircraft availability is vitally important to an airlines performance and reputation.

We are in a great position to respond to that with the IntelligentEngine because we were the first to see the linkage between the product, service and digital with the introduction of our TotalCare services in the 1990s. This involved proactively monitoring the health of engines, enabling us to predict when they would require servicing, and thereby keeping them in service for longer. Now digital allows us to take that service much further – working closely with our customers to get even greater insight into how they operate their engines. We support this digital revolution with our relentless investment in research and technology – £1.4bn last year across the group.

With the digital revolution blurring the boundaries between our physical products and the services we provide, we see a future where our engines are:

1. Connected – connected to other engines and its ecosystem;

2. Contextually aware – aware of its operating environment;

3. Comprehending – able to learn from its experiences and the experiences of other engines in the fleet.

We see a not too distant future where we design and test engines digitally, service them remotely, and manage them through their digital twin. A future where, once again, we are pioneering the power that matters, just like we have throughout our history.

Source: Rolls-Royce (2018b); data provided by Roll-Royce.

3.8.3 Revert Programme

The Revert programme is a collaborative recycling programme between Rolls-Royce and its material suppliers. As part of this programme, metal removed form unserviceable engine parts is collected, segregated by specific type of alloy, cleaned of coating and contaminants, and returned to the material supplier for recycling.

When an engine is under TotalCare contract, this enables a continuous chain of custody assurance so that these aerospace-grade materials and specialist alloys can be confidently re-used by meeting stringent quality and safety requirements. TotalCare therefore provides a high level of material stewardship across the lifetime of an asset as well as at end-of-life, thus enabling a closed loop material system.

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3.9 Key Partners

"We are putting increased emphasis on strategic partnerships and collaborations. These collaborations range across electronics, composite materials, gearbox technology, digital technologies and services. We are determined to be at the forefront of the 'next technology revolution' built around artificial intelligence, data analytics, machine learning and digital."

Ian Davis, Chairman, Roll-Royce

Source: Rolls-Royce Annual Report 2017

3.9.1 MRO service partners

As discussed above, Rolls-Royce's network of MRO service centres – the CareNetwork – is a key asset in delivering TotalCare globally. Rolls-Royce's CareNetwork has expanded in line with growth of its engine fleet. While one centre is wholly-owned, three are joint ventures; and the rest are partnerships with airlines or independent MRO providers. Some partnerships originated from engine procurement deals where a customer already had their own in-house MRO capabilities which they wished to deploy (e.g. Air France KLM).

Rolls-Royce's partner strategy shifted significantly a few years ago. Originally, Rolls-Royce would take an equity stake and limited the shares of joint enterprises. It would also give partner shops territorial rights to serve certain regions. Now Rolls-Royce is growing the CareNetwork with members in which Rolls-Royce has no equity stake. MRO business is now also shared intra-regionally among CareNetwork members.

This partnership strategy is enabling Rolls-Royce to flexibly scale globally and at lower cost while sharing risks as well as revenues with its partners.

TABLE 5 SELECTED ROLLS-ROYCE PARTNERSHIPS

Rolls-Royce joint ventures	Example non-equity partnerships
• **Hong Kong Aero Engine Services Limited (HAESL)**: Joint venture with Hong Kong Aircraft Engineering Company. • **Singapore Aero Engine Services (SAESL)**: Joint venture with SIA Engineering Company Limited. • **N3 Engine Overhaul Services (N3EOS)**: Joint Venture between with Lufthansa Technik AG (LHT) providing MRO services over the past ten years for the Trent 500, 700, 900, and more lately the XWB.	• AFI KLM E&M • ANA Engine Technics Co. • Delta Tech Ops. • EgyptAir Maintenance & Engineering. • Emirates Engineering • Mubadala Abu Dhabi • Turbine Services & Solutions • THAI Technical

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3.9.2 Digital partners

As described above, digitisation and use of data is now core to TotalCare delivery and to Rolls-Royce's 'IntelligentEngine' vision.

Since 2016 Rolls-Royce partnered with Microsoft to use a suite of applications based on the Microsoft Azure platform to support Big Data aggregation and analysis from multiple distributed data sources at scale (such as engine performance, technical logs, flight plans, weather data, etc.).

Rolls-Royce is now in the process of expanding the ecosystem of partners it works with in this area. The newly-established 'R^2 Data Labs' within Rolls-Royce works with a variety of partners to provide IT infrastructure and to power its analytics capabilities. This includes established players such as Tata Consultancy Services (TCS) and Microsoft, as well as start-ups and academia.

3.9.3 Suppliers and Risk and Revenue Sharing Partners

In a similar way to which Rolls-Royce created the business model around TotalCare to enable risk-transfer from customers in exchange for recurring revenues from aftermarket services, it also innovated a partnership model with its suppliers.

The high cost and long development time of new engine programmes (several billion dollars over periods of up to 5 years) represents a significant risk to Rolls-Royce. This includes the ability to deliver new generations of engine in time and within budget, meeting engine sales targets, and having the right capabilities to repair and service engines with specialist parts in the aftermarket. Furthermore, as with many high-tech manufacturing OEMs, companies such as Rolls-Royce typically do not manufacture all components and sub-systems in-house, focusing instead on key areas of competence and strategic value, and outsourcing other areas. In the case of Rolls-Royce, the majority of the engine (over 70%) is manufactured by external suppliers.

In order to manage the above risks, Rolls-Royce has established Risk and Revenue Sharing Partnerships (RRSPs) with key suppliers. This approach began as early as the Trent 500 engine programme.

Traditionally, suppliers were contracted by Rolls-Royce to build parts according to Rolls-Royce specifications and were paid on delivery. In contrast, the RRSP model is an integrated and strategic approach to outsourcing based on Rolls-Royce and suppliers working in partnership and sharing in the costs, risks and benefits of new engine development based on how well it sells and performs over its lifetime. Instead of being paid for producing parts, RRSP suppliers jointly invest in an engine development programme and receive a proportional share of engine and aftermarket TotalCare sales revenues.

Rolls-Royce RRSP suppliers include major global players in the aerospace industry such as:

- GKN – United Kingdom
- Mitsubishi Heavy Industries (MHI) – Japan
- Kawasaki Heavy Industries (KHI) – Japan
- Industria de Turbopropulsoras – Spain
- Hamilton Sundstrand – USA

Figure 29 below illustrates key Rolls-Royce suppliers contributing the development of modules and components for the Trent XWB engine.

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FIGURE 29 RISK AND REVENUE SHARING PARTNERS FOR THE ROLLS-ROYCE TRENT XWB ENGINE

Source: A350 XWB News (2013)

3.10 Cost structure

3.10.1 MRO service delivery

TotalCare costs are driven by the frequency and cost of shop visits for maintenance, repair and overhaul:

TotalCare lifecycle costs = [number of shop visits] x [cost per shop visit]

The number and frequency of shop visits will be driven by:

- The engine lifetime (time on wing) and engine age
- Intensity and pattern of usage (hours flown and the way in which the engine has been used)

The cost per shop visit is influenced by:

- Scope of work needed for visits (complex or lengthy workscopes and procedures increase costs)
- Degree to which parts are re-used, repaired, or replaced (re-use and repair generally lowers costs compared to using a new part)
- Labour costs

3.10.2 Engine development and production costs

While not directly part of the aftermarket services model provided under TotalCare, engine development and manufacturing costs need to be recouped and financed through the revenues provided by TotalCare.

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While engines may be sold 'at cost' as part of a TotalCare package (recovering the production costs), engine sales alone are not sufficient to cover the investment required for development of the next generation of engines. An engine programme requires about USD 1 billion of investment with a development cycle for a new engine generation of approximately 3-5 years.

The revenue generated by TotalCare is therefore essential for investing in each new cycle of engine development.

As discussed above, Rolls-Royce has innovated a new model with suppliers – Risk and Revenue Sharing Partnerships – as a way to manage and share the risk and rewards of engine development. TotalCare revenues are linked to this model as suppliers get paid through aftermarket sales for their share of investment and are rewarded based on the success of an engine programme.

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3.11 The Value Network

Rolls-Royce's value network is composed of two interrelated aspects: one is around new engine manufacturing; and the other is around aftermarket services once the engine has been sold and is in operation.

The manufacturing network is composed of Rolls-Royce's own manufacturing operations and the multiple suppliers it works with including direct suppliers and higher-tier upstream suppliers. Direct suppliers include the Risk and Revenue Sharing Partners (RRSPs) discussed above.

The aftermarket services network is principally the operations and partners Rolls-Royce works with to deliver TotalCare. This includes MRO operations (repair and overhaul shops, etc.) – either owned, JV, or partnerships with third party organisations – making up the CareNetwork discussed above. This network also includes other partners fundamental to delivering today's cutting-edge TotalCare services including software and ICT partners.

Figure 30 below illustrates the flow of materials through this network. As can be seen, product and material re-use and cycling occurs in the following ways:

- **Maintaining assets at their highest utility and maximising their lifetime**: TotalCare MRO services provide regular maintenance and overhaul of engines which 'restore life' (in terms of remaining flight cycles until the next shop visit). Other services enabled by engine health monitoring also ensure that engines are functioning as efficiently as possible and avoiding unnecessary wear and tear.
- **Engine transfers to new owners/operators**: TotalCare enables engine value to be preserved and facilitates that transfer of engine assets mid-way through their lifecycle.
- **Cycling of parts**: In the mature phase of the engine lifecycle, MRO services increasingly incorporate the re-use of parts re-claimed from other engines that have been retired as 'used serviceable materials'. This substitutes the use of new manufactured parts, and also extracts the maximum life from parts that have defined lifetimes (Life Limited Parts).
- **Cycling of engines**: Where aircraft have been retired but engines still have remaining life ('green time'), Rolls-Royce reclaims and re-deploys them in other aircraft as an alternative to repair – thus extracting the maximum value from the given engine.
- **Cycling of materials**: Rolls-Royce's Revert programme enables materials from parts that are no longer re-used to be reclaimed and incorporated back into the supply chain manufacturing of new components, thus substituting the use of virgin materials (including rare metals and exotic alloys). The Revert programme also includes the cycling of off-cuts from Roll-Royce manufacturing, or upstream manufacturing of components and systems, back into the supply chain.

Figure 31 overlays onto the previous illustration key areas of financial value creation and transfer. These include:

- Service revenues principally via the TotalCare power-by-the-hour ($/EFH) charging model. These are in turn shared with RRSPs in the supply chain (as explained above) and CareNetwork MRO partners.
- Cost savings generated by re-use of parts and engines
- Cost savings passed on by suppliers receiving material recovered via the Revert programme.

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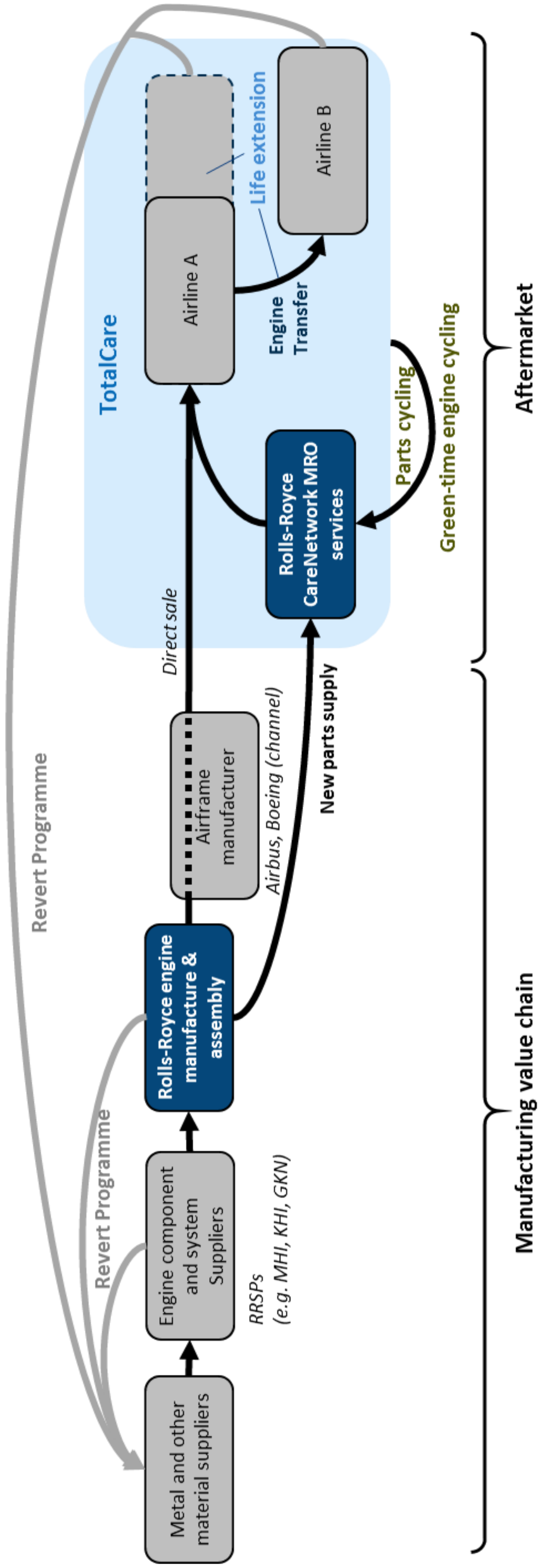
FIGURE 30 MATERIAL FLOW



Source: R2Pi Project analysis; company interviews

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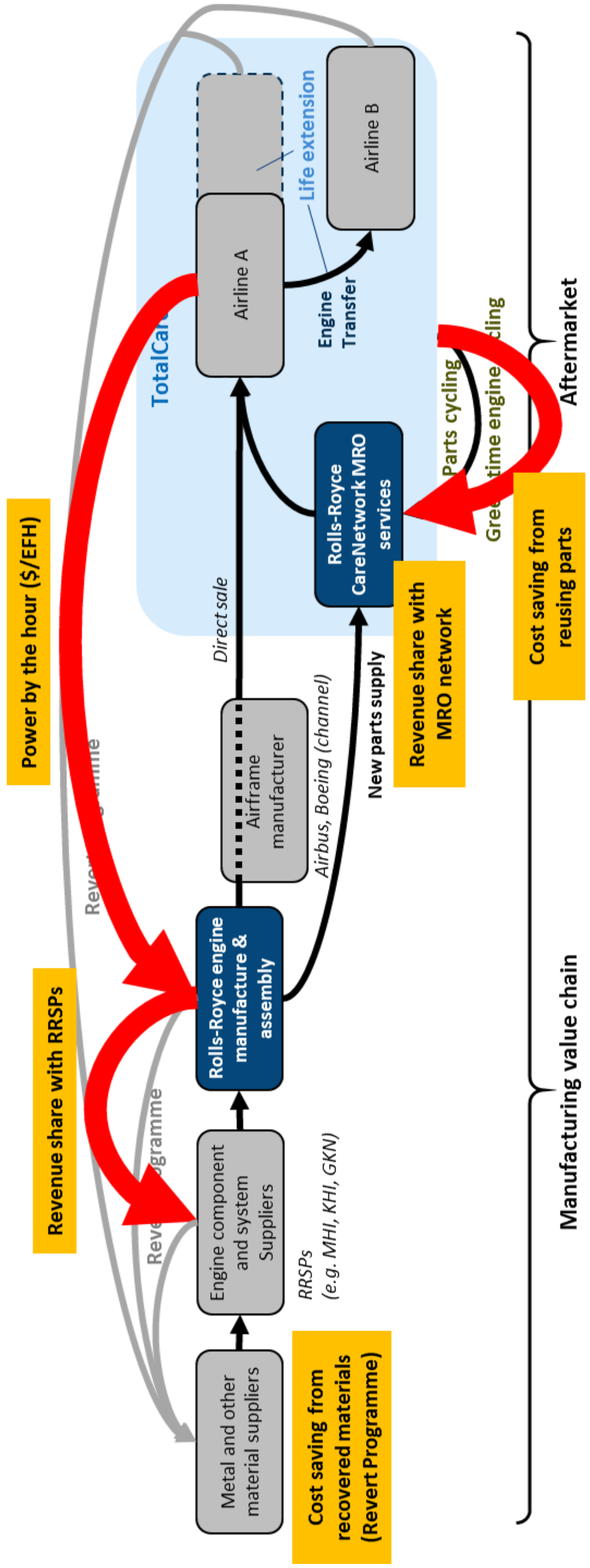
FIGURE 31 KEY AREAS OF VALUE FLOW AND CREATION



Source: R2Pi Project analysis; company interviews

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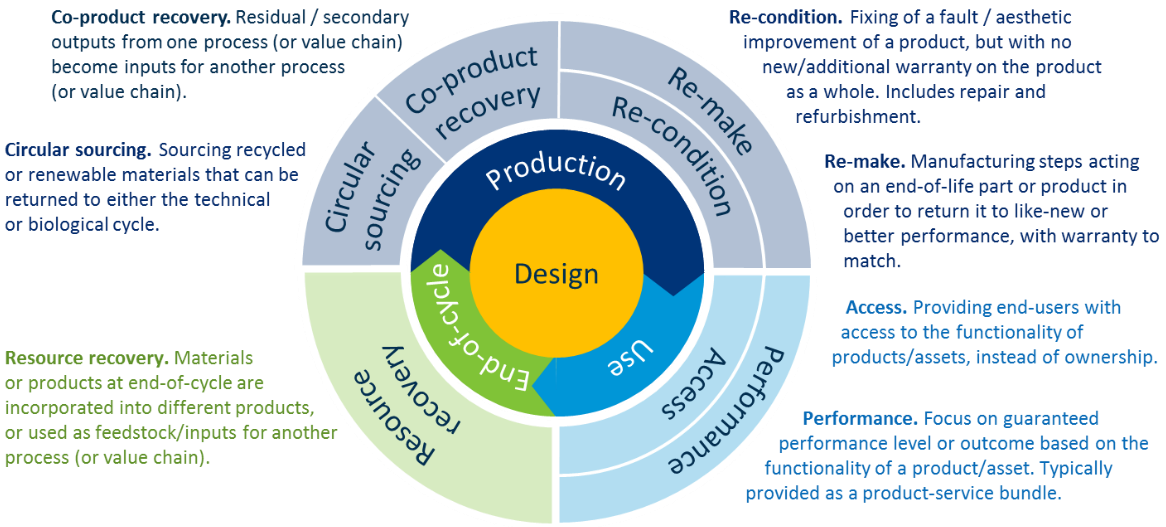
3.12 Business model circularity assessment

The R2Pi project has established seven key patterns of circular business model, described in Figure 32 below.

FIGURE 32 THE SEVEN CIRCULAR BUSINESS MODEL PATTERNS



Source: R2Pi Project

Rolls-Royce's TotalCare business model incorporates several of the above patterns:

- **Performance**. The TotalCare value proposition combines service with product as a 'servitised' offering. It incorporates delivering a level of performance linked to the engine asset over its lifetime. TotalCare is now focused on ensuring maximum availability of aircraft powered by Rolls-Royce engines so that they can fly 'on time, every time'.
- **Re-condition**. TotalCare includes the ongoing maintenance of engines and component parts over the asset lifetime, restoring 'life' into the asset at intervals and as required. Regular maintenance, repairs and overhauls (MRO) are a normal requirement of the aero engine sector, however through TotalCare Rolls-Royce has been able to achieve a better optimisation of the planning and process, enabling longer times on-wing (see below).
- **Resource recovery**. The TotalCare model has further enabled Rolls-Royce's Revert programme for materials recovery. TotalCare provides Rolls-Royce with access to the engine over its lifetime while it is under its aftermarket services contract, including at the end-of-life when airline customers begin to retire aircraft. This allows Rolls-Royce the option to buy-back and reclaim end-of-life engines so that materials can be re-cycled back into its manufacturing supply chain. The Revert programme also operates at the engine manufacturing stage, recycling any waste materials.

The TotalCare 'servitised' product-service offering is therefore part of an integrated model which enables and enhances other circular business model patterns, as illustrated in Figure 33 below.

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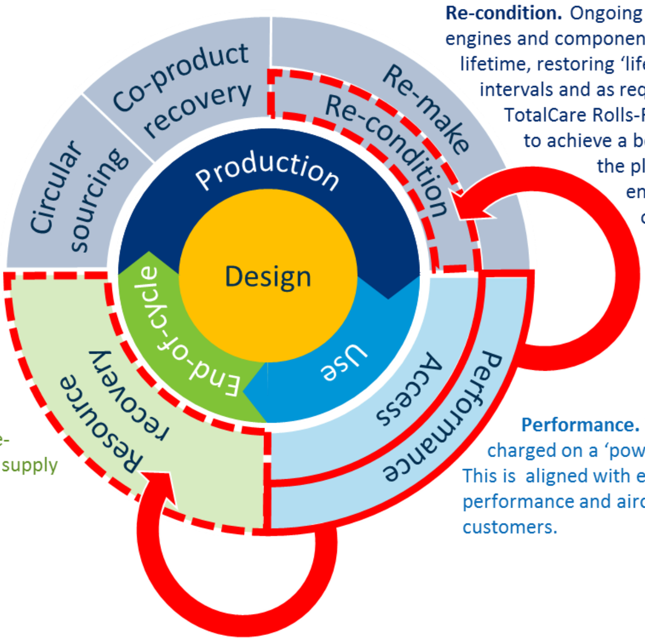
FIGURE 33 CIRCLAR BUSINESS MODEL PATTERNS APPLICABLE TO ROLLS-ROYCE



Source: R2Pi Project analysis

3.13 Financial outcomes assessment

3.13.1 Commercial success

The TotalCare proposition has been key to transforming Rolls-Royce's market share and reputation, as well as its ability to invest in new generations of powerplant and technology.

Rolls-Royce's financial model is based on selling engines (Original Equipment, or 'OE') at or below cost, recouping the manufacturing cost and generating the bulk of profits from sales of the TotalCare aftermarket solution. Indeed, profits from aftermarket services not only need to recover manufacturing and overhead costs of the engines they respectively serve, but also – cumulatively over the engine lifetime and across multiple engine programmes – are essential to funding the high R&D cost of Rolls-Royce's next generation of engines and technologies. Cashflow from TotalCare is essential for reinvesting into future product development.

Figure 34 below shows an illustrative net cashflow of an engine programme over its lifecycle. The diagram shows the relative cash generation (or consumption) of particular Trent engine programmes – both today and expectations in ten years' time.

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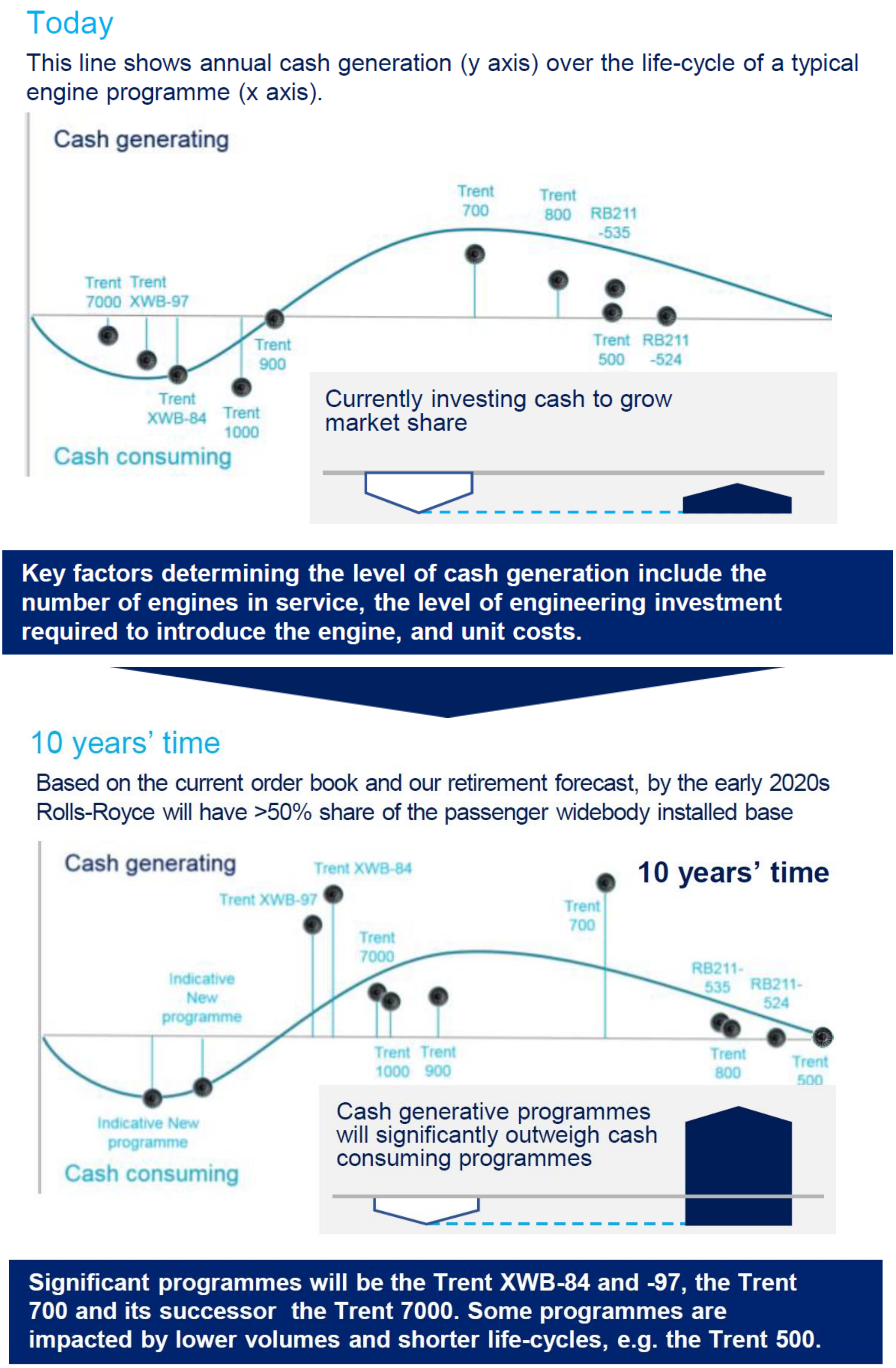
FIGURE 34 LIFECYCLE CASH FLOW PROFILE FOR A TYPICAL ENGINE PROGRAMME



Source: Rolls-Royce plc Annual Report 2017 Fact Sheet

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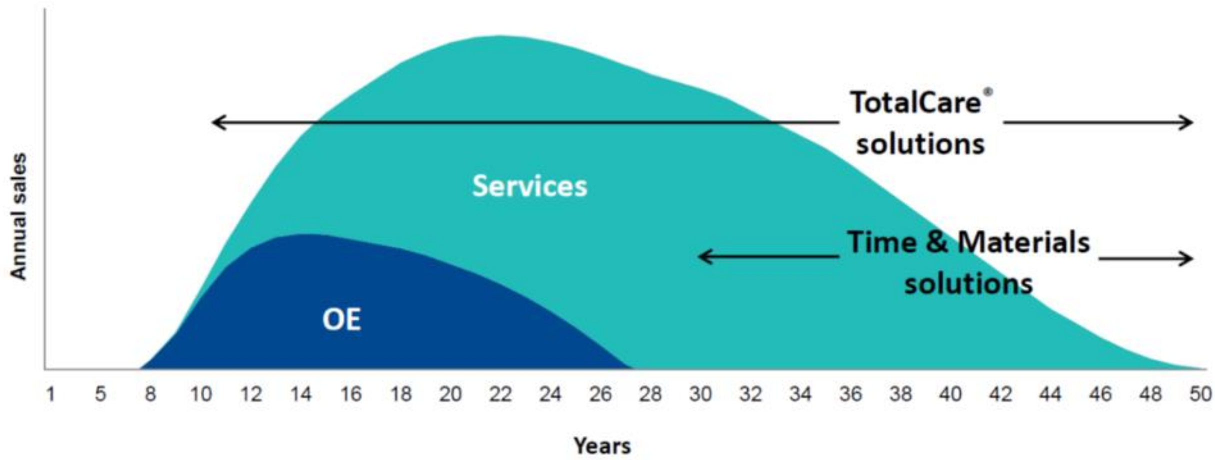
Service revenues for a particular engine programme are typically four times that of OE sales over the lifetime of that programme (from first entry into service through to final decommissioning). The majority of aftermarket sales are generated by TotalCare, although some are still based on time-and-materials for customers choosing this option as engines approach end-of-life (via Rolls-Royce's 'Foundation Services'). This is illustrated in Figure 35 below.

FIGURE 35 TYPICAL REVENUE PROFILE OF ENGINE AND AFTERMARKET SERVICE SALES



Source: Wood, T. (2014) Rolls Royce plc

To maximise profitability under this model, it is essential for Rolls-Royce to:

- Ensure engines are always available to fly when needed
- Minimise the frequency of planned shop visits (increasing the time between shop visits)
- Reduce shop visit costs through operational and material efficiency
- Eliminate or minimise unplanned shop visits

The outcome of the TotalCare model has been that both Rolls-Royce and its airline customers have benefited by avoiding and reducing MRO-related costs and maximising engine availability. Further benefits generated by the model come from the technology and software platforms such as engine health monitoring and data analytics that provide additional value to customers by improving in-flight operational efficiency. This has enabled Rolls-Royce to offer further services – and incremental revenues – through its CareStore.

Figure 36 below illustrates the profit recognised by Rolls-Royce for OE (engine) and aftermarket sales for a particular engine programme. While profit recognition is influenced by accounting methods, it demonstrates how TotalCare has enabled profits to be smoothed over the lifetime of an engine programme. Figure 37 super-imposes the net cash flow position onto this diagram, showing how TotalCare enables Rolls-Royce to continue generating cash well beyond the end of engine manufacturing and over a period of 20-plus years.

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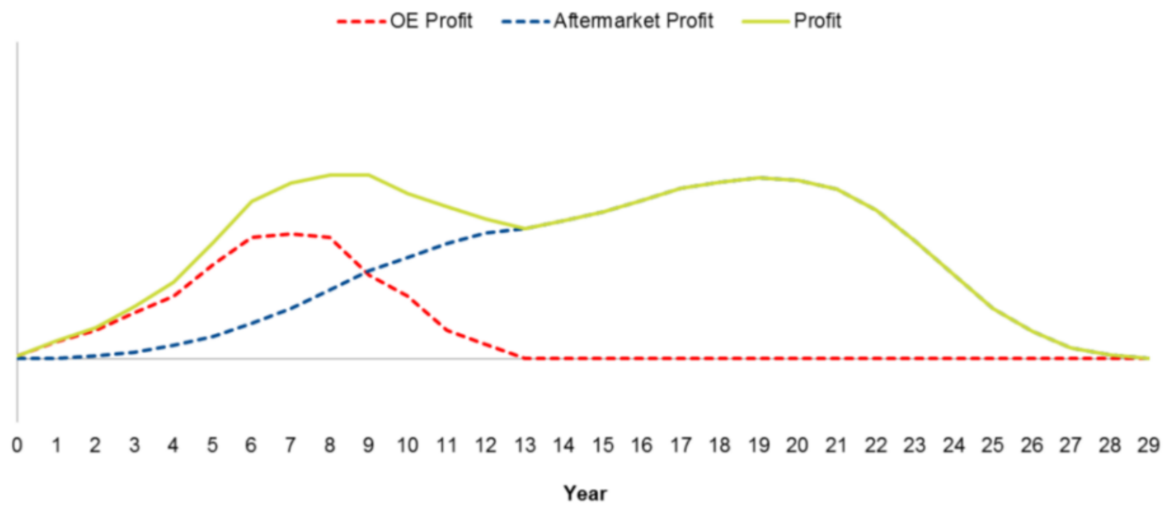
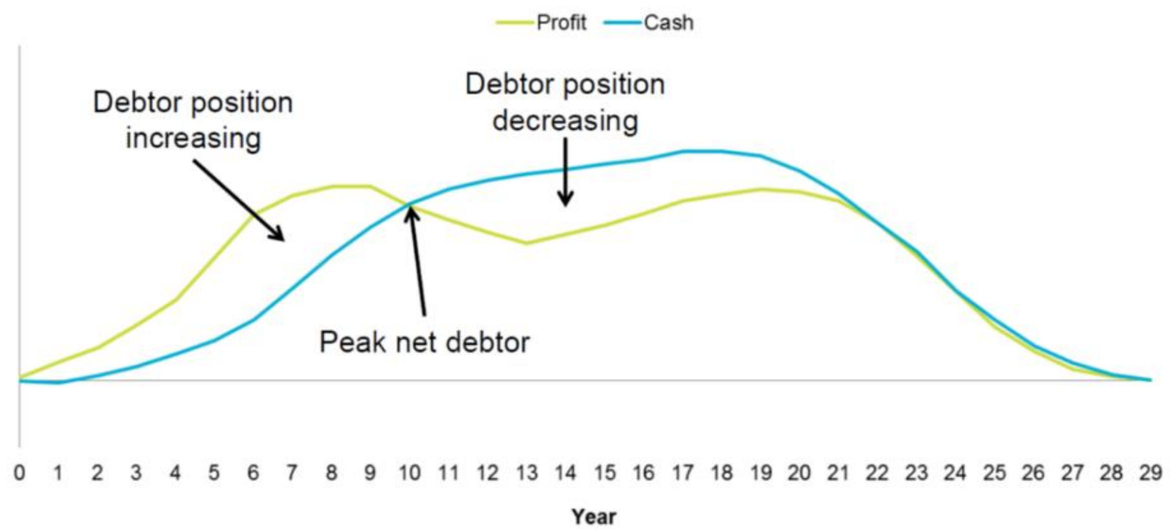
FIGURE 36 LIFECYCLE PROFILE OF RECOGNISED PROFIT FOR TOTALCARE (LINKED TOTALCARE PROGRAMME)



Source: Morris, M. (2014), Rolls-Royce plc

FIGURE 37 LIFECYCLE PROFILE OF RECOGNISED PROFIT FOR TOTALCARE (LINKED TOTALCARE PROGRAMME) – INCLUDING NET CASH FLOW



Source: Morris, M. (2014), Rolls-Royce plc

The above financial dynamics underline how today Rolls-Royce's civil aerospace business makes more revenue from services (52%) than it does from engine sales (as shown in Figure 38).

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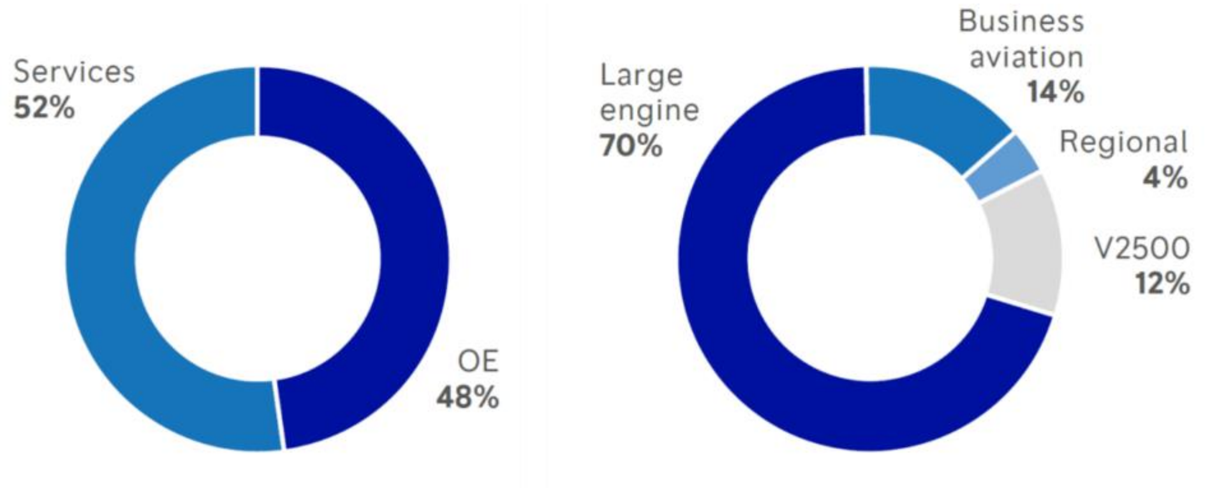
FIGURE 38 ROLLS-ROYCE CIVIL AEROSPACE BUSINESS REVENUE MIX



Source: Rolls-Royce plc Annual Report 2017

In terms of market share, Rolls-Royce commands a 35% share of engines installed in the passenger fleet for widebody aircraft. Based on order books and trends, Rolls-Royce predicts that its market share will reach 50% by the early 2020s.

The commercial success of TotalCare hinges on the value that it creates for customers over the lifetime of an engine. TotalCare has enabled Rolls-Royce to capture this value from aftermarket services. As these are long lifecycles of 20-plus years, TotalCare has created long-term recurring revenues for the company and its key partners. It also highlights the strategic importance of growing the installed base of flying engines as each contributes to revenue generation.

3.13.2 Commercial risks

Recent problems with the Trent 1000 and Trent 900 engines highlight the importance of ensuring that the engine hardware works as intended, and the financial exposure created by the risk-transfer model of TotalCare. Problems in these engine models have required Rolls-Royce to carry out costly inspections and repairs, as well as to redesign some parts. Several aircraft have been grounded, leading to flight cancellations and forcing airlines to lease other planes. These challenges have therefore not only reduced some of the TotalCare revenues that would have been generated, but also increased costs. It has led to a significant financial impact, with Rolls-Royce taking an exceptional charge of £554m in the first half of 2018, and remedial measures are estimated to cost around £1.3bn.

Nevertheless, while this has impacted Rolls-Royce and some of its customers in the short term, it also demonstrates the value of TotalCare risk-transfer working for airline customers under extreme conditions. At time of writing, the overall strength of Rolls-Royce's financial position is expected to carry the company through this challenge and service revenues from the civil aviation business continues to steadily grow.

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3.14 Non-financial outcomes assessment

The success of TotalCare hinges on the value delivered to customers in terms of risk transfer, cost predictability, increase engine availability, improved flying efficiency, and better management of high-value engine assets.

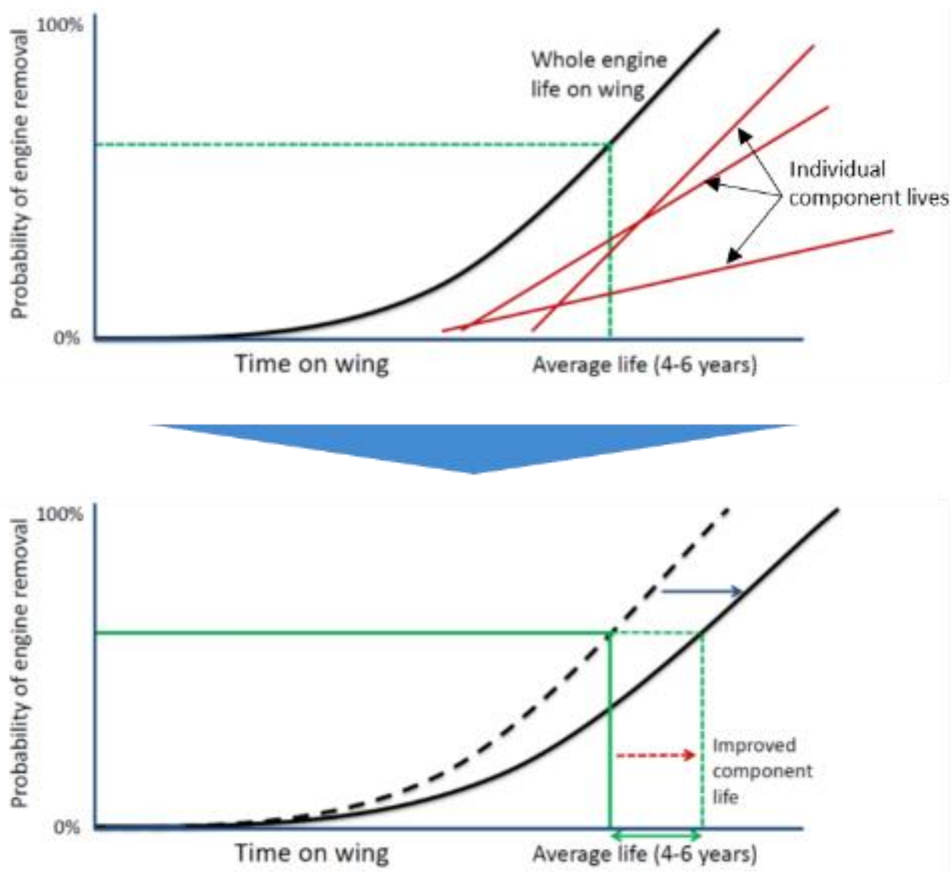
One of the consequence of the TotalCare model is improved efficiency in the use of materials by keeping engines at their highest utility, reusing parts, material recycling, and avoiding waste and unnecessary use of virgin materials. These are discussed below.

3.14.1 Material efficiency through extending lifetime and utility

TotalCare has enabled Rolls-Royce to extend the service intervals between engine overhauls by around 25%. By keeping engines flying for longer there is less demand for new products and components that require complex materials that are expensive and resource-intensive to manufacture (as well as avoiding wastage that occurs during manufacturing).

Figure 39illustrates how design improvements and optimised maintenance of engine components enable an increase in the average life of engines and time on wing.

FIGURE 39 DESIGN KNOWLEDGE OPTIMISING ENGINE LIFE



Source: Adapted from Wood, T. (2014) Rolls Royce plc

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The positive impact of TotalCare on maintaining engine product utility over its lifetime is demonstrated by that fact that, when an engine is under TotalCare contract, it commands a higher residual value. This benefits the aircraft owner when it wishes to sell and transfer assets, and demonstrates the way TotalCare enhances the value of engines under management.

3.14.2 Material efficiency through better parts management and reuse

The TotalCare model enables effective deployment and reuse of parts based on intelligent tracking and management of parts. To ensure quality of service Rolls-Royce forecasts, plans, and monitors what servicing is needed at the required time and location; how many spares need to be manufactured; and where they are stocked. The knowledge and transparency which TotalCare data systems bring to this process means that it can be done in the most efficient manner possible, reducing over-stocking and waste across the system (illustrated in Figure 40).

Furthermore, as described above, Rolls-Royce utilised Used Serviceable Materials for engines where it is able to do so (usually for mature engines). Such parts are removed during MRO procedures, cycled back to Rolls-Royce or partner repair/remanufacturing sites, and cycled back for further use in engine maintenance.

FIGURE 40 EFFICIENT DEPLOYMENT AND REUSE OF PARTS

Source: Rolls-Royce plc

3.14.3 Material efficiency through recycling (Revert programme)

Rolls-Royce uses over 20,000 tonnes of exotic aerospace alloys from rare metals every year in its manufacturing processes, including hafnium, rhenium, tantalum and titanium.

Through the Revert programme over the past decade, Rolls-Royce has developed processes to remove coatings, separate alloys and clean the waste metal from unserviceable engine parts. For example: Rhenium alloys from used turbine blades are re-melted.

When an engine is under TotalCare contract, this enables a continuous chain of custody assurance so that aerospace-grade materials and specialist alloys can be confidently re-used while meeting stringent quality and safety requirements. TotalCare provides a high level of material stewardship

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across the lifetime of an asset as well as at end-of-life, thus enabling a closed loop material system. This retains the value of material that would otherwise be deemed waste or be downcycled with lower quality grades of metal.

Almost 95% of a used aero engine can now be recycled and around half of the recovered material is of such high quality it can be safely used again to make a new engine. This reduces the need for virgin materials, the extraction of which is expensive and has a significant environmental impact. Rolls-Royce estimates that through Revert 300,000 Megawatt hours of energy are saved each year, and 80,000 tonnes of carbon dioxide are saved compared to using virgin materials. Revert also helps safeguard the supply of critical raw materials by keeping them at the high grades needed within Rolls-Royce's supply chain.

As part of implementing the Revert programme, Rolls-Royce partnered with waste-metal processing specialist SOS Metals, which established itself close to Rolls-Royce's manufacturing plants near Derby in the United Kingdom, creating new jobs and further growth opportunities

3.14.4 Material efficiency through better repair processes

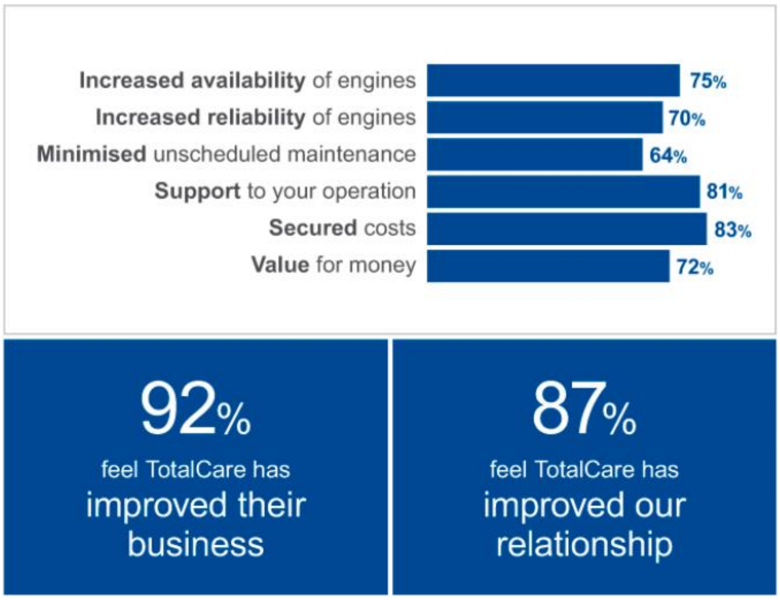
Through TotalCare, Rolls-Royce is continuously increasing its ability to repair individual engine components as well as conducting repair of parts without taking the engine off the wing. This reduces the need to manufacture new and spare parts, as well as speeding up the engine repair time. This reduces the impact of maintenance on customers, helps to optimise engine availability, and improves material resource efficiency.

TotalCare enables this through reinvestment of revenues and integration between design; data; and engineering processes.

3.14.5 Customer satisfaction and deepening relationships

High customer satisfaction underlies the continued commercial success of TotalCare and associated circularity benefits. Figure 41 below shows high customer satisfaction metrics for TotalCare: A large majority of customers (70% or over) agree that TotalCare delivers the performance outcomes they expect. Importantly, 92% of customers believe that TotalCare has helped them improve their business.

FIGURE 41 CUSTOMER FEEDBACK ON TOTALCARE



Source: Palmer, T. (2015), Rolls-Royce plc

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Customer feedback also shows that TotalCare has helped Rolls-Royce improve its relationships with customers. This underpins continuous improvement and innovation by understanding and uncovering new customer needs and requirement where TotalCare can add value.

Furthermore, TotalCare creates closer working relationships with customers, enabling Rolls-Royce to offer more and better suited services.

3.15 Role of ICT and technology in improving profitability and material efficiency

As discussed in depth in the sections above, ICT and technology has played a critical role within TotalCare to improving profitability and material efficiency. Key areas include:

- **Engine health monitoring and associated technology and data insights**. The data and insights provided from engine health monitoring are fundamental to providing TotalCare. This enables efficiency and effectiveness of MRO services; it feeds back into product design; and enables a suite of value added services provided to customers helping them improve their operations.
- **Parts and materials management**. Data and IT enables Rolls-Royce to avoid over-production of parts and ensure they are efficiently deployed around the world.
- **Repair innovations**. New technologies (such as ‘snake probes’ and 3D/additive manufacturing techniques) are enabling higher material efficiency and eliminating waste in repair operations.

Data and ICT will become increasingly important to Rolls-Royce and TotalCare as it develops the ‘IntelligentEngine’ vision. Rolls-Royce has already completed its first digital engine design, and is in the process of innovating around machine learning, AI, big data, and Internet of Things, to create further value to customers.

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3.16SWOT analysis

This section contains an analysis of the Strengths, Weaknesses, Opportunities and Threats (SWOT) associated with the circular business model. It is important to note that this is primarily an assessment of the attributes of the business model itself and only secondarily of the specific attributes of the individual company. As is customary in SWOT analyses, the Strengths and Weaknesses are internal to the case organisation's business model. Whereas the Opportunities and Threats are external to the case organisation's business model, coming from the context in which they operate (illustrated in Figure 42).

The strengths, weaknesses, opportunities and threats covered in this section have been discussed in detail within the business model assessment sections above. The purpose is to distil and highlight those key areas that result in enablers or barriers for the development of circular business models. Chapter 4 discusses these barriers and enablers, drawing lessons and conclusions.

FIGURE 42 SWOT ANALYSIS FRAMEWORK

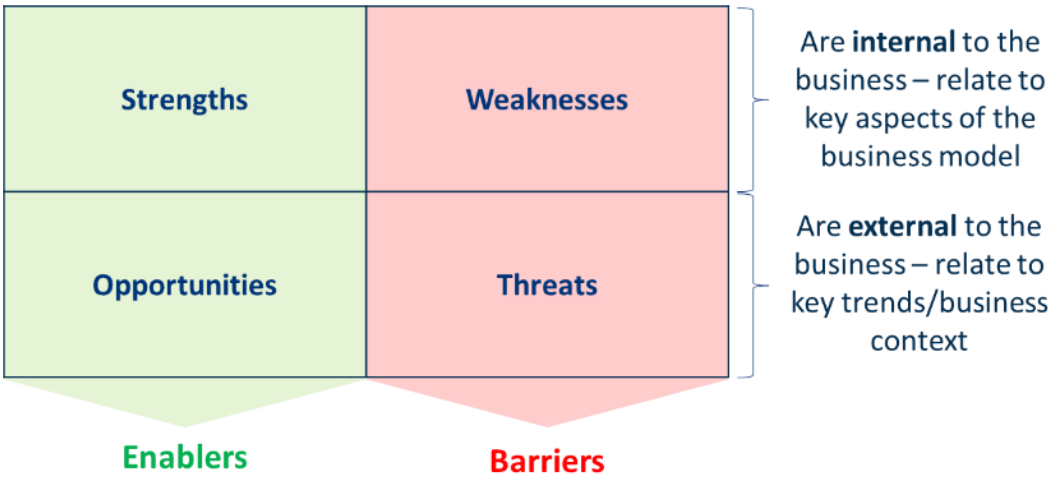

Figure 43 below summarises the key SWOT areas assessed for TotalCare, which are discussed below.

FIGURE 43 SWOT ANALYSIS

Strengths	Weaknesses
• Strong value proposition • Installed base of engines • Data and digital capabilities • Partnerships that enhance and de-risk the business model	• Technical challenges of new engine models
Opportunities	**Threats**
• Growth in air travel • Digitisation of airline industry	• Changing customer expectations • Technological discontinuities • Regulatory pressure • Cost and security of supply for key materials

Source: R2Pi Project analysis

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3.16.1 Strengths

An overarching strength of the TotalCare business model is that the various building blocks work together in a coherent and integrated manner. We highlight here some specific strengths that are 'linchpins' for the business model.

Key strengths of Rolls-Royce's TotalCare model are:

- A compelling **value proposition** for customers that addresses their key needs and requirements
- Large and growing **installed base of engines** which drive revenue when utilised
- Effective use of **data and digital capabilities** to enhance the value proposition
- **Partnerships that enhance and de-risk** the business model

Strong value proposition

The TotalCare value proposition provides compelling value to customers in a clear and transparent way:

- It focuses on significant and measurable improvements to areas that are critical to customers' own performance and success: transferring key risks and uncertainties (cost and timing of MRO events) to Rolls-Royce.
- Rolls-Royce charges customers for this value and risk transfer in a clear and transparent manner based on a rate per engine flight hour ($/EFH), so-called 'power-by-the-hour'.
- Power-by-the-hour charging ensures full alignment of incentives and interests as the customer only pays Rolls-Royce when its engine are powering aircraft.

The core value proposition is broadened with a range of standard as well as optional value added services which address further areas of customer need. These are integrated into the $/EFH charging structure which ensures simplicity and further alignment of incentives and interests.

A further strength is the evolution and adaptation of the TotalCare value proposition to changing customer needs and priorities along the lifecycle of their engine assets (TotalCare Life, Term and Flex).

Installed base of engines

Given that TotalCare revenues are driven by engine flight hours, Rolls-Royce's large and growing installed base of engines is a key strength of the business model.

While the bulk of the installed base has been relatively young, it is maturing and advancing along the lifecycle. As indicated above, Rolls-Royce successfully evolved the TotalCare value proposition to address changing customer needs and priorities. At the same time, a mature base of engines enters a more predictable pattern of operation and opens up additional opportunities for efficiency and circular economy enablers (discussed below).

A further advantage of a large installed base is the wealth of operational data generated through engine health monitoring (see below).

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Data and digital capabilities

Engine health monitoring has been a core part of the TotalCare business model from the beginning, providing core performance information and enabling the $/EFH charging structure.

In recent years, growing technology capabilities in terms of sensors and data analysis have enabled Rolls-Royce to add entirely new dimensions to its value proposition.

Initially, engine health monitoring data was used to better plan MRO interventions to optimise engine time on-wing and maintenance costs. Better data insights and intelligence is now enabling Rolls-Royce to expand its value proposition including:

- Ensuring 'aircraft availability' such that Rolls-Royce engines are always ready to power aircraft when needed to avoid costly delays and cancellations.
- Operational efficiency of airplanes in-flight and route optimisation.

Data and digitisation is therefore a key strength for TotalCare today, ensuring it remains relevant and innovative in the future.

Partnerships that enhance and de-risk the business model

The risk-transfer from airlines to Rolls-Royce in turn requires Rolls-Royce to manage this risk and the associated responsibilities toward customers. Rolls-Royce has the unique advantage of having an intimate understanding of its engines through design experience as well as performance in operation via engine health monitoring.

Nevertheless the success and global expansion of TotalCare, as well as its evolution beyond MRO into delivering aircraft availability and value added services, requires Rolls-Royce to have strong and integrated partnerships. These are needed to ensure that the system as a whole functions seamlessly, especially the quality of MRO service, reliability of engines, and digitisation. Strong partnerships are a key strength of the TotalCare business model in the following areas:

- **CareNetwork**: Partnerships with third party MRO service providers enabling Rolls-Royce's network of MRO services to scale globally avoid the risk and cost of large fixed costs, in exchange for revenue share.
- **Supply chain**: Risk and revenue sharing partnerships with suppliers that de-risk substantial R&D investment in each new Trent engine programme, while aligning incentives to produce high-quality engines that will generate a revenue share in use through power-by-the-hour.
- **Digitisation**: New partnerships are enabling Rolls-Royce to harness the wealth of data from engines and create new value added services for customers.

3.16.2 Weaknesses

Technical challenges of new engine models

Recent challenges Rolls-Royce has faced with technical issues on the Trent 1000 and Trent 900 engines is testing aspects of the TotalCare business model. One question is whether changes in engine technology may be introducing additional product-related risk which the current business model may find hard to manage.

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3.16.3 Opportunities

Two key opportunities for the development of TotalCare are the growth in air travel – and thereby growing business for airline customers – and the digitisation of the airline industry.

Growth in air travel and target customer segments

Forecast growth in air travel will lead to further demand from airline customers for aircraft and the engines powering them. Rolls-Royce's installed base of engines are the basis for TotalCare revenues, therefore there is an opportunity to significantly grow the TotalCare business over the coming years.

Digitisation of the airline industry

Key trends in digitisation of the airline industry will be favourable to the development of TotalCare, and Rolls-Royce is actively pursuing this with its 'IntelligentEngine' vision. Areas that will be important for Rolls-Royce include:

- **Digital design**. Using digital technology to design new generations of engine. This includes learning from analysing engine data to generate performance improvements.
- **Connectivity**. This includes connectivity between Rolls-Royce engines in flight (e.g. a 'network of engines'), as well as integration of data from airline operations, weather, etc. to provide enhanced operational advice and services, as well as further data fed back into design.
- **Big data analytics**. Analysis of data sets from multiple sources to create insights used for engine design and service delivery.
- **Artificial intelligence and machine learning**. Software assisting engineers and service operations to make use of the increasing volume and variety of data generated by Rolls-Royce and its partners.

3.16.4 Threats and uncertainties

The factors described below may be threats or potentially opportunities for Rolls-Royce and the TotalCare model depending on how they develop and how Rolls-Royce responds.

Changing airline expectations may require changes to the TotalCare and power-by-the-hour charging model. However there will be an opportunity for Rolls-Royce if it effectively responds adapts its value proposition.

Technological discontinuities such as electrification of engines (initially via hybrid-electric engines) could lead to a shift in service requirements which may have implications for TotalCare service operations.

Regulatory pressure and material resource risks have an indirect effect on TotalCare as they impact the engine manufacturing stage. Hence potential changes to engine design will be important. These pressures may nevertheless drive further circularity in managing materials (this will be addressed in the following chapter), and therefore how TotalCare operates.

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Changing airline customer expectations

Customers expect each new generation of engine to provide improved technical performance. However they also expect improvements in the TotalCare service to provide additional value to their own operations and performance.

When Rolls-Royce initiated TotalCare in the 1990s the focus was on risk-transfer related to MRO services – specifically around cost and timing of interventions. Today the focus of customer requirements is shifting towards ensuring aircraft availability within certain performance parameters (for example guaranteeing aircraft are able to depart from the gate and arrive on time 90% of the time).

This shift from cost management risks to aircraft availability may require the TotalCare model and charging structure to change (for example making service revenues subject to achieving certain performance parameters, similar to a Service Level Agreement).

Technological discontinuities

Rolls-Royce has highlighted that electrification of propulsion will be an important trend and area of attention. This is being driven by global requirements for emission reduction as well as advances in technology. In the first instance, aero engine manufacturers will look at developing hybrid-electric solutions. While this isn't an imminent change to the business, it may require changes to the TotalCare model if engine electrification results in substantially different servicing requirements, engine lifetimes, etc.

Regulatory pressure

Regulatory pressure on carbon emissions is likely to continue and may accelerate some of the technological discontinuities mentioned above. Nevertheless, this will impact the industry as a whole as well as Rolls-Royce's competitors, and the company is continually working to develop more fuel efficient and lower-emission engines. Where such regulation leads to early retirement of older engines, this may impact TotalCare revenues as Rolls-Royce will need to compete for new engine contracts with customers.

Regulations such as REACH that control the use of certain chemicals in aero engines may pose a greater challenge to the TotalCare business model given that engine lifetimes are very long (20-25 years). There is therefore a risk that mature engines and parts coming back into Rolls-Royce's repair and remanufacturing operations at the latter stages of their lifecycle run afoul of changing restrictions and authorisations.

Cost and security of supply for key materials

New engine models and technologies require ever more advanced materials for the engine's 'hot section' (those parts exposed to the highest temperatures). Many of these are exotic and rare, with constrained supply. Past experience has shown that such metals may sometimes be subject to protectionism from originating countries (impacting security of supply), and supply-demand dynamics can have a significant impact on costs.

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4 Discussion & Conclusions

Rolls-Royce's TotalCare business model is an example of 'servitisation' (also known as a product-service system), working over the whole lifecycle of a product. This is one of the key patterns enabling a circular economy business model.

Although Rolls-Royce engines are sold to the aircraft owner, the TotalCare service package means Rolls-Royce retains responsibility for ensuring the product performs to customer requirements. The power-by-the-hour charging mechanism ($/EFH) keeps incentives aligned by rewarding Rolls-Royce when the product is working as needed, and penalising it when it isn't. This mechanism and alignment between the OEM and its customers encourages continuous improvement and collaboration. Due to the nature of the business, this leads to a drive to extend the asset lifetime and reduce repair and maintenance costs – all of which reduces waste, increases resource efficiency, and enhance the asset's value over its lifetime.

Furthermore, the product-service offering enables continuous innovation around the service aspect as TotalCare provides opportunities for constant insight and learning around customer requirements (through data as well as contact with account teams). This produces ongoing improvements and evolution of the value proposition itself (e.g. developing initially into TotalCare 'Term', then 'Life', and subsequently 'Flex') as well as expansion of value added services. This means that the customer is no longer buying 'just' an engine, but gaining expanded value addressing a suite of needs and requirements. This provides greater flexibility for Rolls-Royce to manage the underlying engine asset within the TotalCare contract, focusing on outcomes for the customer, rather than the product itself.

As the OEM, Rolls-Royce is able to deploy its expertise and product knowledge to ensure engines under TotalCare stay on-wing for longer and deliver an attractive proposition for customers. Recent challenges with the quality of Trent 1000 and 900 engines are a reminder that the product is always core to the business model and that engineering excellence underlies the proper working of the TotalCare cost structure and business model.

It is important to recognise that it is the distinctive benefits that TotalCare provides to customers through alignment of incentives and business models that makes it work. The resultant benefits of increased resource efficiency and reduced waste are not enough on their own to make it successful.

4.1 Key enablers – historical perspective

TotalCare has evolved over the past 15-20 years, and a such is a relatively mature business model. This section summarises the key enablers that got it to where it is now. The following section picks up on the areas discussed in Section 3.16 (SWOT analysis) to discuss future enablers and potential barriers to further circularity within the TotalCare business model.

As evidenced above, the key strengths internal to Rolls-Royce's TotalCare business model that have underpinned its success to date, as well as circular economy outcomes, are:

- A compelling **value proposition** for customers that addressed their key needs and requirements, and fully aligned incentives and business models. This in itself underlines the importance of **gaining deep customer insights** through the business relationship.

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- A high-performance engine product that is connected to the TotalCare service proposition through **sensor technology and software applications**, namely: advanced sensor technology and data analytics. These provided the intelligence for Rolls-Royce to effectively plan MRO interventions.
- **Deep knowledge of service operations and the engine technology** acquired through own design insights, engine health monitoring data, and experience from MRO activities. This further enabled planning and optimisation of services as well as effective costing and financial management to propose an attractive power-by-the-hour service charge.

The key external ingredient that enabled the TotalCare value proposition to emerge and grow was the willingness of customers to collaborate and adopt it. Cathay Pacific and American Airlines were some of the early adopters of the model, providing a proof point and reference which Rolls-Royce was able to then use to attract other customers. As original customers such as Cathay's engine fleet matured, they again pioneered further variations of the TotalCare model such as TotalCare Flex.

Rolls-Royce is now evolving to a next stage, going beyond efficient MRO planning to new areas of value such as delivering certain levels of aircraft availability.

This underlines the importance of working closely with customers, understand their needs, and using this to innovate the value proposition and wider business model.

The Revert programme for cycling materials from decommissioned engines and parts is not necessarily core to the TotalCare model (TotalCare could still likely function without it). However it is very much enhanced and further enabled by the fact that TotalCare provides Rolls-Royce with access to the engine (even if it is owned by the customer) throughout its lifetime, and therefore access to the materials for cycling back into its supply chain.

4.2 Future enablers, barriers and challenges

Building on the strengths of the TotalCare business model and key external opportunities highlighted in Section 3.16 (SWOT analysis), the following are potential enablers for further circularity:

- **Expansion of digital capabilities** will enable even better tracking of engine assets and the maintenance status and physical location of their component parts. Combined with the increasing maturity of a large tranche of Rolls-Royce installed base, this may provide additional opportunities for **intelligent re-deployment of parts and materials**. Overall, Rolls-Royce's capabilities for tracking materials and components across its network, and making parts deployment even more efficient will be enhanced through technology.
- **Developments in digital technology** will broaden the scope of customer support and **value-added services** provided to customers, including route optimisation and end-of-life management. This can contribute to further circularity if Rolls-Royce is given more discretion to optimise management of engine assets if it delivers further value-adding outcomes to customers.
- **Growth in the airline industry** will be a key driver for TotalCare. This will especially be the case with **new or start-up airlines** who do not have the in-house knowledge of MRO operations that established airlines have. They may therefore be more willing to outsource MRO operations and seek the types of valued-added services offered by Rolls-Royce under TotalCare.

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- Continued growth of Rolls-Royce's installed base of engines, combined with growing digital and 'IntelligentEngine' capabilities will provide Rolls-Royce with even further insights and data as a key resource to improve and expand the TotalCare value position and business model.

Based on the SWOT analysis, Rolls-Royce may have to deal with some uncertainties and challenges that could impact the 'circular' aspects of its business model, but also present new opportunities.

Regulatory scrutiny and perceived anti-competitive practices

Past regulatory scrutiny of perceived anti-competitive practices in the aftermarket may re-surface. The original inquiries by the European Commission arose from airlines and their trade body IATA complaining about being locked into expensive service contracts. Similarly, independent MRO providers have also expressed concerns about being locked out of business with airline customers by these types of contracts.

Aftermarket service contracts are now offered not only by other aero engine OEMs such as GE, but are also being adopted by airframe manufacturers and OEMs of aircraft systems. It will therefore be important for OEMs such as Rolls-Royce to ensure that they continue to provide value-for- money. There is a risk that poor outcomes by other players may reflect badly on those that do provide competitive value. Rolls-Royce should therefore not take for granted that customers won't question and re-evaluate the value they get from end-to-end lifecycle contracts such as TotalCare.

Rolls-Royce currently does offer a 'Foundation Services' proposition to customers who wish to conduct their own MRO planning and pay based on the traditional time-and-materials model. The fact that virtually all customers still choose a form of TotalCare is an indication that it remains a strong and relevant proposition today.

Further efficiencies in the deployment of used parts

The re-deployment of used serviceable materials typically becomes more prevalent when engines are approaching their end-of-life and airlines are trying to minimise investment and extract as much value as possible from the remaining engine lifetime. This practice is used less for younger engines, and there may be an opportunity to extend this. In order to expand deployment of used parts to newer engines, Rolls-Royce may have to address two challenges:

- Customer perceptions that 'new is better' and acceptance of utilising used parts in new engine repair.
- Customer acceptance of Rolls-Royce managing a 'pool' of used spare parts across various customers rather than having dedicated stocks of parts.

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4.3 Replicability in other sectors

In Section 3.2 we described the value-at-stake for airline customers and how managing the engine asset impacts them operationally and financially. Section 3.3.3 described the engine asset itself, focusing on the Rolls-Royce Trent models. These highlight some key characteristics of widebody aero engines around which TotalCare's value proposition and business model has been designed:

- **The mission-critical nature of engines**. Taking safety as a given (engine design and maintenance parameters being strictly regulated), if the engine doesn't work properly, the aircraft can't fly as planned. This has significant and direct impacts on airline customers' finances and operations. A solution that reduces this risk and maximises performance for customers will gain attention and willingness to pay.
- **Engines are high cost / high value assets that are required to function over a long lifecycle**. Widebody aircraft engines are assets worth maintaining for as long as possible as they are very expensive, and are attached to aircraft that remain in service for over 20 years. They have defined lifetimes within which certain parts must be replaced or repaired, but this can be done multiple times with 'life' being put back into the asset as required. In fact the asset value of engines becomes more important than that of the airframe over the lifecycle as their value can be maintained for longer through regular maintenance and repair. Engines are not subject to replacement unless the aircraft itself is retired (as each engine model is designed for a specific airframe).
- **Cost and complexity of servicing and maintaining engines**. Widebody aircraft engine maintenance requires significant know-how and technical capabilities to ensure it optimises time on wing, asset value, and cost. This represents significant risk to airlines, and a service that enables them to transfer that risk will provide significant value they are willing to pay for.

The key success factors that the Rolls-Royce TotalCost model teaches us, which could be relevant to other sectors, are:

- A value proposition that enables a risk transfer and aligns incentives between the OEM and the customer based on a simple and transparent charging mechanism (power by the hour).
- A value proposition that stays relevant to changing customer requirements over the lifetime of the asset (evolution from TotalCare 'Term' to TotalCare 'Life' and 'Flex').
- The ability of the OEM to use its own deep design knowledge and usage/performance data to effectively accept a risk transfer and manage the asset 'end to end' (from product design through to service delivery across the lifecycle).
- Strong partnerships to support the risk transfer (e.g. Risk and Revenue Sharing Partners) as well as providing the scale and capabilities to serve customers in an integrated way (e.g. CareNetwork partners).
- Use of data and digitisation to develop additional value-added services that enhance the core proposition.

Other sectors in which capital assets represent a significant value at stake for customers and there is an opportunity to transfer risk onto the OEM, paid for through a performance contract, could be candidates for a TotalCare-type model. While TotalCare needs to be very sophisticated given the complexity of engine assets and operations, the general principles and success factors could hold for other types of assets.

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4.4 Insights for business guidelines

The core focus of this case study is on Rolls-Royce's TotalCare business model – an example of 'servitisation' (also known as a product-service system), working over the whole lifecycle of a product. The business model assessment and SWOT analysis in Chapter 3, and the assessment above of key enablers and barriers for the circular business model, provide a real-world example that organisations in similar sectors or in a similar context can draw insights and lessons from.

In particular, the following key insights are important to note:

- **Revenue mechanisms that align interests between a company and its customers can create powerful circular business models**. Although Rolls-Royce engines are sold to the aircraft owner, the TotalCare service package means Rolls-Royce retains responsibility for ensuring the product performs to customer requirements. The power-by-the-hour charging mechanism ($/EFH) keeps incentives aligned by rewarding Rolls-Royce when the product is working as needed, and penalising it when it isn't. This mechanism and alignment between the OEM and its customers encourages continuous improvement and collaboration. This also drives the extension of asset lifetime while optimising/reducing repair and maintenance costs. This results in reduced waste, increased resource efficiency, and enhances the asset's value over its lifetime.

- **Service-focused offerings that enable manufacturers to gain insight and intelligence on the use and performance of their products can lead to better customer service, improved product/service design, and resource efficiency**. TotalCare provides opportunities for constant insight and learning around customer requirements. This insight is enabled by the collection of engine usage and performance data, as well as through deep customer relationships. This produces ongoing improvements and evolution of the value proposition itself as well as expansion of value added services. This means that the customer is no longer buying 'just' a product, but gaining expanded value addressing a suite of needs and requirements. This provides greater flexibility for manufacturers to manage the underlying asset within a service contract, focusing on outcomes for the customer.

- **Servitised performance-based models can be important enablers for 'Resource Recovery' as well as 'Re-condition' / 'Re-make' circular business model patterns**. In the example of TotalCare, Rolls-Royce's service contract includes the provision of maintenance services which it has the responsibility and flexibility to deliver in an optimal way. This ensures that the 'life' and utility of the engine product is kept at the right level over its lifetime. Furthermore, the service contract gives the manufacturer visibility of the product throughout its lifecycle. This is especially relevant at the end-of-cycle where it creates an opportunity for product take-back and recovery of high value materials through close-loop recycling.

- **When transitioning from a product-focused to a service-focused business model, the installed base becomes a key asset and driver of revenue and profitability**. In product-focused business models, revenue is driven by the product sales price, and potentially some recurring revenue from maintenance services and sale of consumables and add-ons. In a service-focused business model, the installed base of products in use can become the driver of recurring revenue over the product's lifecycle. This aligns financial performance for the manufacturer (revenue and profits) with ensuring that products in use are kept at optimal

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performance for as long as possible. This in turn is a key enabler for resource efficiency and waste elimination.

4.5 Insights for policy recommendations

In this case study, issues related to policy primarily focus on the potential of product-service offerings being perceived as anti-competitive.

In order for many product-service or servitised business models to work, tight integration is required between the delivery of the product, the provision of services around the product, and the overall revenue model for charging the customer. In effect, products and services get tightly bundled and cannot be differentiated from the customer's perspective. As illustrated by the TotalCare case study, this can also require tight integration of an 'ecosystem' of partnerships and infrastructure (for example suppliers and providers of maintenance services). This integration is needed to align business models between partners, as well as processes and technology, in order to maximise efficiency and minimise risks.

This degree of 'lock-in' can create a perception of reduced choice and competition in the market. Competition policy may therefore need to adapt to account for new servitised approaches, and to ensure that unfair practices are properly distinguished from innovative and value-adding business models.

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