1) **Jet engine basics**

- Which are the basic types of aircraft engines? Assign approximate speed ranges of the corresponding aircraft to the engine types.

![Diagram of propulsion engines](image_url)

**FIG. 3.2 Propulsion engines**

(Source: Gas turbine theory, 4th Ed.)
- Turboprop engine (e.g. TP400 engine for the Airbus A400M)

  ![Turboprop Engine Diagram](http://www.aircraftenginedesign.com/pictures/TP400.jpg)

  - Best propulsive efficiency for low-speed-aircraft
  - Last stage of the turbine is driving the propeller or propeller plus LP compressor stage
  - Flight velocity of an Airbus A400M approx. Mach 0.72= 880kmph at ground conditions

- Propfan, CRISP, Openrotor

  ![Propfan Diagram](http://regmedia.co.uk/2008/10/31/open_rotor.jpg)

  - a turbine is driving a propeller mounted on the outside of the housing, behind that, a counterrotating propeller is mounted
  - allows higher propulsive efficiencies than the turbofan engines
    - relatively swirl-free outflow due to the counterrotation
  - were already researched in aircraft during the 80s (f.e. with McDonnell Douglas MD81), but research was canceled due to high noise emissions and the high engineering effort
  - research topic for Rolls Royce in the Clean Sky project
- By-pass or Turbofan engine (eg. Trent XWB in the Airbus A350)

- Fluid flow separated into two parts:
  - Core flow passing compressor and turbine-section and generating a high-velocity-fluid flow
  - Bypass-flow passes fan and produces additional thrust at a lower velocity, but higher mass flow

- Low mean outlet velocity
- Latest Rolls Royce design: three shafts, allowing rotor diameter to be very high and therefore higher bypass ratios
- Different technological approach is the use of a two-shaft-design and a geared fan
- Velocity approx. Mach 0.85 (Airbus A350) = 1040 kmph at ground conditions
- **Turbojet engine (Concorde, milit. Aircraft)**

![Diagram of a Turbojet Engine](http://upload.wikimedia.org/wikipedia/commons/4/4c/Jet_engine.svg)

- High outlet velocity, little outlet mass flow
- Turbine produces just enough power to drive the compressor
- Exh. Gases are expanded to atmospheric pressure in a propelling nozzle to produce a high velocity jet
- Aircraft velocity for example Ma 2.2 (Concorde), military aircraft even higher

(Source: http://upload.wikimedia.org/wikipedia/commons/4/4c/Jet_engine.svg)
• Explain why are by-pass engine the most appropriate for civil aviation.

For subsonic speed ranges the turboprop engines provide the highest absolute propulsive efficiency. Nevertheless, their highest efficiency is reached at a relatively low operational speed respectively flight velocity. Additionally, their noise emissions are much higher compared to bypass- or turbofan engines which results in lower comfort during the flight. Considering civil aviation the benefit in efficiency does not compensate the lack in speed and in noise emissions. Concerning these influence factors, the turbofan engine is the most suitable engine type for civil aviation.

2) Rolls Royce Germany and Oberursel

• How big is Oberursel site?

Currently, there are 1300 employees working at the Oberursel factory. Additionally, the site receives support from 200 suppliers.

The number of built engines are divided into the following fractions:

53% are destined to civil uses, 11% to military uses, 9% to nautical, and 27% to energy.

• Which components are manufactured at Oberursel?

Oberursel’s factory possess latest manufactory technology for high-tech rotative components, such as the ones from the BR700 series, the Trent series, and Blade Integrated Disc (Blisks) manufacturing. Over 19 different components can be manufactured at Oberursel, some of which are mentioned in the table below:

<table>
<thead>
<tr>
<th>Part</th>
<th>Engine</th>
<th>Plane</th>
</tr>
</thead>
<tbody>
<tr>
<td>Front and rear drums</td>
<td>BR715</td>
<td>Boeing 717-200</td>
</tr>
<tr>
<td>Rear drum LPC + HPT</td>
<td>TP400</td>
<td>Airbus A400M</td>
</tr>
<tr>
<td>TP400-Blisk</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tail HPC</td>
<td>Trent XWB</td>
<td>Airbus A350</td>
</tr>
<tr>
<td>Front and rear drums</td>
<td>BR725</td>
<td></td>
</tr>
<tr>
<td>Front and rear drums</td>
<td>BR710</td>
<td></td>
</tr>
<tr>
<td>Front and rear drums</td>
<td>V2500</td>
<td></td>
</tr>
<tr>
<td>HPT2</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Compressor Pegasus</td>
<td>Harrier</td>
</tr>
</tbody>
</table>

TP400-D6 engine from Rolls-Royce
How long is the development time for a complete engine?

The development time for a complete engine starting from design to mass production, takes around three years.

How do the activities of Rolls-Royce Germany differ from those of Rolls-Royce England?

There are several differences between the activities of Rolls-Royce Germany and those of Rolls-Royce England. The main difference mentioned during the factory tour is that the production process starts in Rolls-Royce England with the machining of some parts, for example turbine disks, shafts and drums, and then continues in Oberursel, where they are welded. Another difference mentioned is that most of the turbine tests are held in England.

Through further research it was found that Rolls-Royce Germany focuses on the production of two shaft turbofans, while Rolls-Royce England on the production of three shaft civil turbofans. This happened as the german sites inherited responsibility for the Tay, Spey and IAE V2500 two shaft turbofans and the Dart turboprop from the Derby site.

Which types of aircraft are equipped with the engines developed by Rolls-Royce Germany?

There are two different types of aircraft which are equipped with the engines developed by Rolls-Royce Germany:

- **Civil aircraft** (for public transportation, but also regional jet aircraft and business jets)
- **Military aircraft**: fighting jets and transport aircrafts

Rolls-Royce Germany has had for a long time a strong cooperation with german company Lufthansa. Some of the civil aircrafts powered by Rolls-Royce’s engines are: Airbus A380, Boeing 717/200, and Airbus A350.

The most important product of Rolls-Royce Germany is the BR 7xx jet engine family, which is installed in regional jet aircraft and business jets. The company is in charge of manufacturing several engines used in military aircrafts, like the TP400 engine, used in the Airbus A400M (military transport), the engine series for the Panavia Tornado aircrafts, and the engines of several helicopters, such as the SeaKing, the NH90, and the Lynx- und SeaLynx series.
3) Development trends for the future

- What are the possible drive concepts in the future?
  - **eConcept (Airbus/Rolls-Royce)**: one gas turbine engine with generators, 6 electrically driven fans, and battery to store electrical energy.
  - **Turboelectric hybrid propulsion (NASA Concept)**: separate power and thrust generation, electrically driven fans and gas turbine in wing tips generates electrical power.

- **Fuel cells** (Airbus, DLR German Aerospace Centre and Parker Aerospace): Study about usage of Multifonctionnal Fuel Cell system on aircraft to replace gas turbine-based auxiliary power units which could provide 100 kW electricity, reduce fuel consumption, noise and pollutants emissions. A fuel cell is a device that transforms chemical energy from a fuel, such as hydrogen, into electricity through an oxidation reaction.

- What are the main optimization/targets in the development of civil engines?

The main optimization and targets in the development of civil engines are:

- Reduction of noise
- Reduction of pollutants emissions (such as CO2, NOx ...)
- Reduction of fuel consumption
- Increase of efficiency

In fact, the Advisory Council for Aviation Research and Innovation in Europe (ACARE) has set technology goals to achieve by 2050:

- 75% reduction in CO2 per passenger kilometre
- 90% reduction in NOx emissions
- 65% reduction in noise
What are the advantages and disadvantages of lean-direct-injection combustion process compared to rich-quick-lean?

The Rich-Quick-Lean combustion process is designed to operate at ultralow NOx emissions. First, the fuel is burned under highly rich environment, and then, quickly quenched with cool air. Finally, it is burned very lean. This allows to have a low temperature and therefore low NOx emissions. The disadvantages of this method is that, if the mixing is not rapid enough, a lot of heat is transferred to the walls, which may cause material problem. Furthermore, a lot of soot and carbon monoxide will be emitted at the exhaust of the burner; flashback and autoignition can also happen sometimes.

On the other hand, the Lean-Direct-Injection is operating at the near premixed regime which results in very low NOx, soot and CO emissions. The method consists in mixing the air and fuel droplets and atomizing them completely. The mixing and the uniformity of the flow reduce the NOx emission but might generate undesirable flame instabilities. However, it is more reliable and safer than the RQL method.
References

- www.rolls-royce.com
- www.airbus.com