Second Level Technologies
Benchmark TCH 2-20a

Power for Flight Pt 7

Exploring the ways that a gas
turbine engine can turn
a fan to produce thrust.

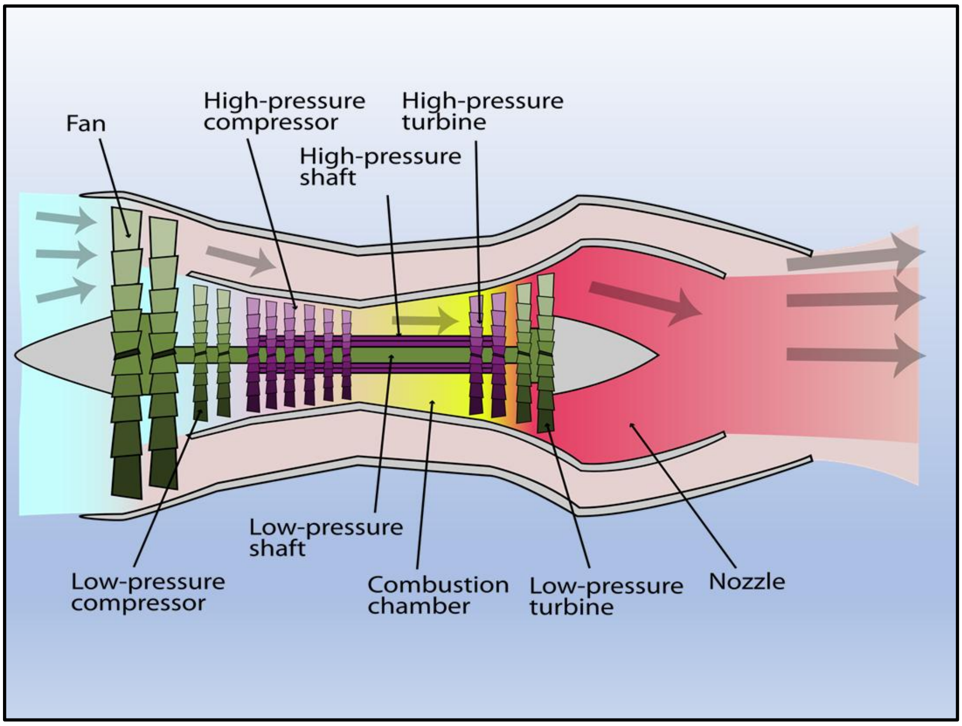
WE COULD USE SOME OF THE AIR FROM THE COMPRESSOR OF A GAS TURBINE ENGINE TO PRODUCE ADDITIONAL THRUST

The engine designers now had to face up to a problem that had been known for some time. The exhaust, that produced the thrust of the Turbo-jet engine, was actually travelling far too fast for efficient use in airliners. What was needed was an engine that had a slower exhaust gas speed, but that was not what Turbo-jet engines were good at.

The Turbo-prop engines had shown that using a turbo-jet to drive a propeller gave a very efficient way of producing thrust but the propeller limited the speed of the aircraft to about 350-400 mph or up to nearly 500mph with very special propellers.

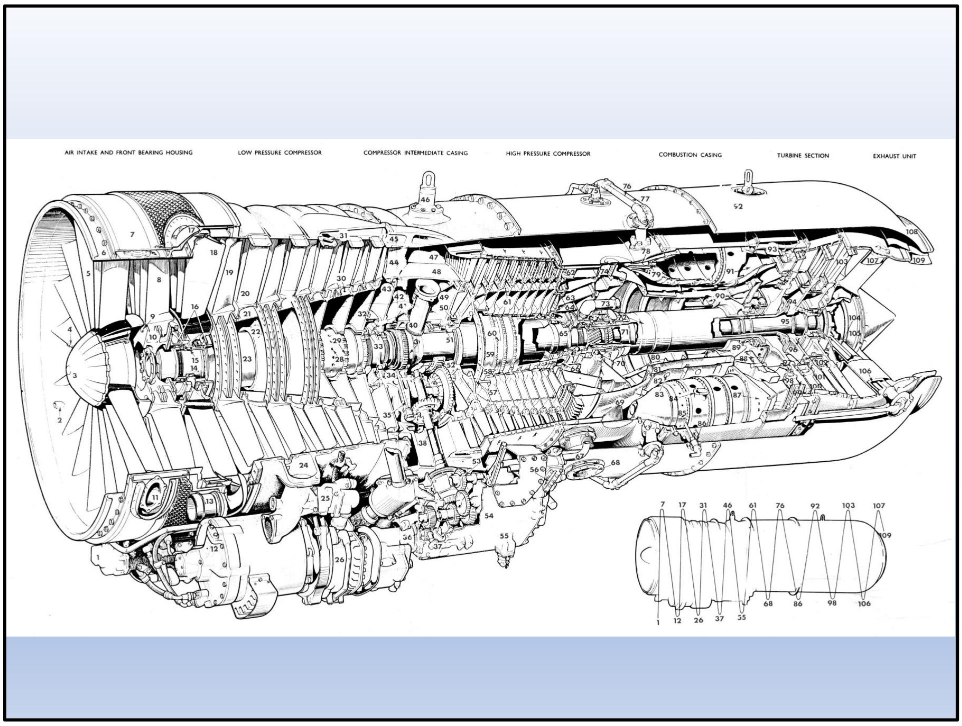
What was needed now was an engine that could produce thrust efficiently at speeds from about 400 – 600 mph.

This problem was solved by having a compressor that not only compressed air into the engine but also sent a percentage of the cold air around the outside of the engine. This had two advantages, the exhaust gas was slower since it mixed with the cold air that had not gone through the engine and also it quietened the noise of the high speed exhaust.



This is how a Low Bypass Turbofan works.

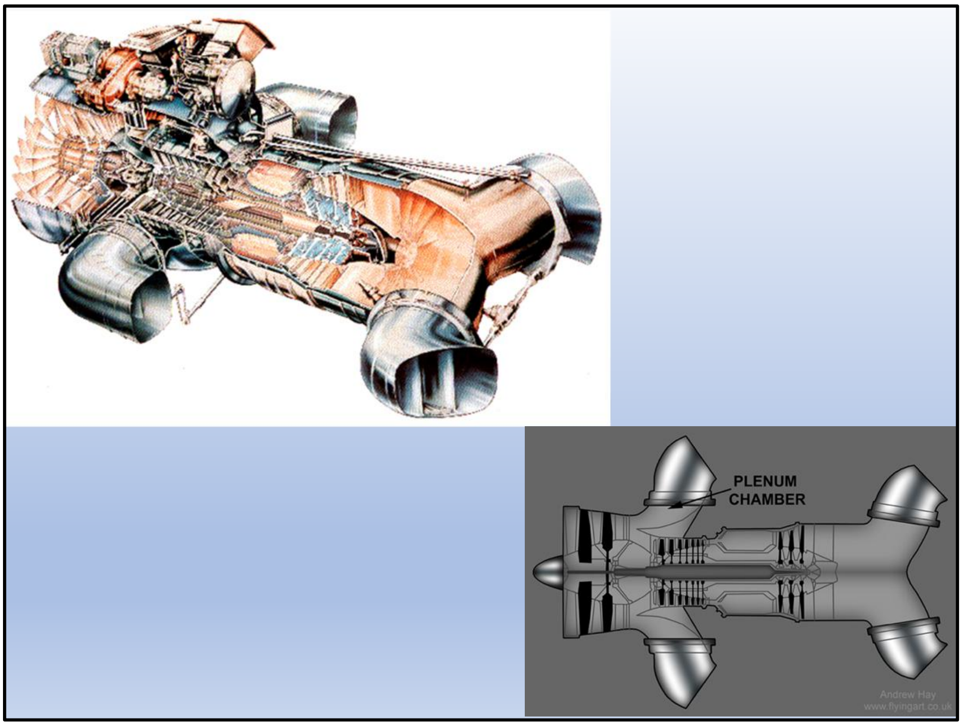
The first two stages of the compressor not only force air into the engine intake but also blow the relatively cold air back along the engine to exit along with the turbojet exhaust. The other clever thing about this engine is that it has two shafts. The high pressure compressor and turbine are on one shaft and the low pressure compressor and turbine are on the other. This makes the engine more efficient.



This engine, called the Conway, was the Rolls Royce designed version of a low by-pass turbofan engine.

This very efficient engine produced just over 17,000 lb of thrust and about 25% of the air coming into the intake was by-passed round the engine. This was the first by-pass engine to enter service anywhere in the world.

This is the beautiful Vickers VC10 and it was powered by four RR Conway engines. It set speed records for crossing the Atlantic back in the 1960’s and 70’s. The aircraft was capable of cruising at 580 mph which was getting very close to the speed of sound at its cruising altitude.



This was the most unusual of all the By-Pass Turbo-fan engines. The engine was called the Rolls Royce Pegasus but had been originally designed by the Bristol Siddeley company. Pegasus was the name of the ancient mythical flying horse.

In this engine, the cold by-pass air from the front of the compressor was exhausted through two swivelling ducts and the hot exhaust gas from the rear of the engine was split to exit through another two swivelling ducts. This allowed four jets of air to be directed backwards or downwards.

The engine was fitted to an equally unusual aircraft that could fly quickly forward but was also able to stop in flight and hover above the ground.

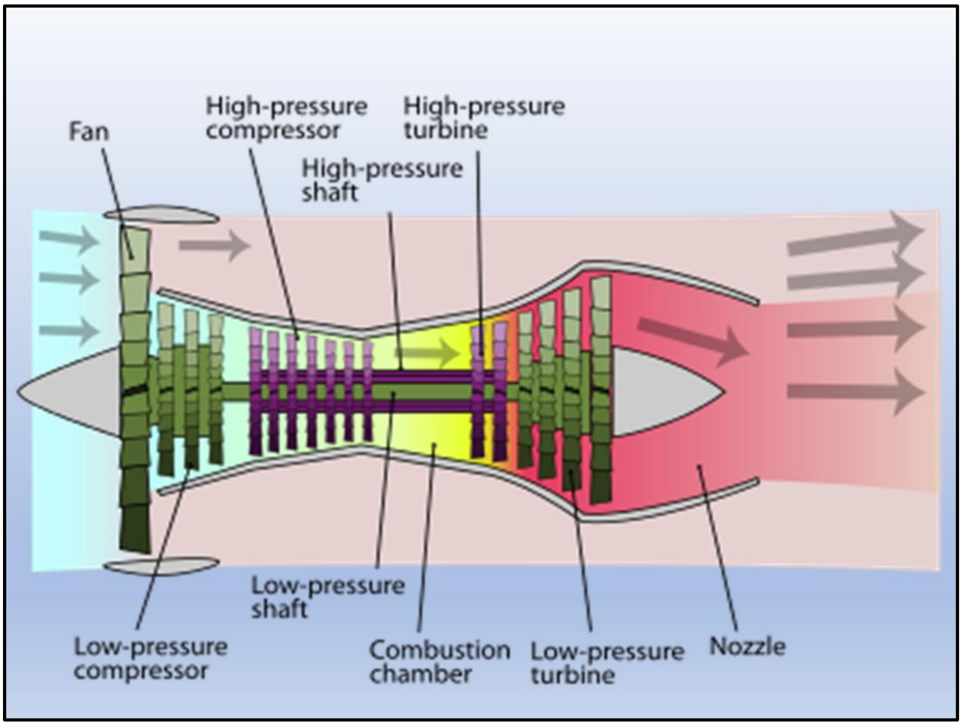
This is the remarkable Harrier aircraft, sometimes called the “Jump Jet” because of its ability to take-off vertically when it was lightly loaded.

WE COULD USE A GAS TURBINE ENGINE TO TURN A MULTI-BLADED FAN TO PRODUCE THRUST

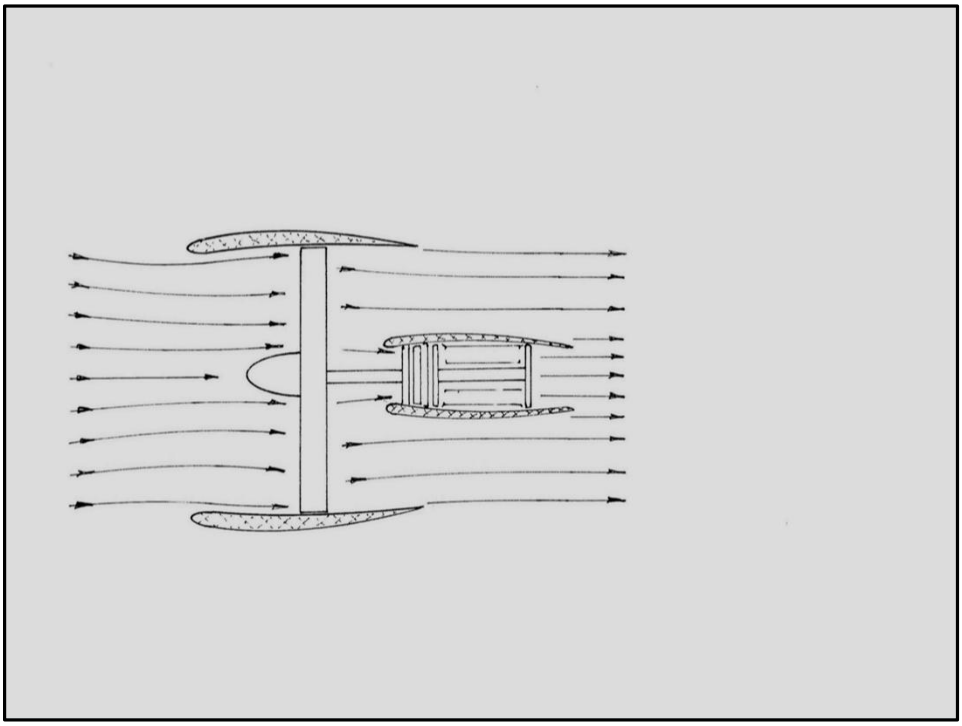
The success of the Low By-pass Turbofan engine led the engine designers down the route of investigating if engines could be even more efficient if more of the intake air could by-pass the engine. The result was the High By-pass engine that became known simply as the Turbofan.

The difference with these engines was that the first stage of the compressor became much larger, now called the “fan”, and the air that it forced backwards now went aft entirely outside the turbojet engine that powered the fan. Like the turboprop engine, the fan now used almost all of the power of the turbojet engine and produced almost all of the thrust.

The big advantage of the Fan over the Propeller was that the fan lived inside its own cowling and the shape of the cowling allowed the intake air to be slowed down before it approached the face of the fan. So now the fan could work at an efficient maximum airspeed equivalent to about Mach 0.5 when the aircraft was flying at about Mach 0.8.



This is what a typical Turbofan engine looks like. Note that the Fan is in its own cowling and that the air that is forced backwards by the fan travels aft outside the engine casing. Also note that the low-pressure turbine is getting bigger to develop more power to drive the fan.



This diagram of a “Turbofan” engine shows how air is sucked into the fan casing from ahead of the fan and then accelerated by the fan blades to flow quickly aft out of the back of the fan casing. Note that some of the air travelling back from the fan goes into the intake of the gas turbine engine that is driving the fan. Almost all of the power of the turbine engine is used to drive the fan which is supplying most of the thrust.

There are advantages in using a fan instead of a propeller. The fan has more blades so it can develop more thrust. The blades tips fit closely to the fan casing so there are almost no losses round the tips. The air coming into the fan casing can be slowed down so that the fan can still deliver thrust even when the aircraft is flying at near to the speed of sound.

This is the General Electric CF6-50 engine, one of the most common of the big turbofan engines. In this photo the cowlings have been opened up to allow the engine to be inspected. We can see the size of the fan and the number of blades.
The odd white shape on the spinner is to make the engine face more visible to let birds see it coming and hopefully avoid the engine.

As aircraft became bigger, heavier and faster there was a need for even more thrust. The impellers became much bigger and were now commonly called fans. You can see the fan inside the cowlings of this Airbus A350 airliner.

This is the General Electric GEnx engine. Note how big the fan is compared to the turbojet engine in the centre that produces the power to turn the fan.

This is the latest in the long line of types of the Boeing 747 aircraft. The aircraft familiarly known as the Jumbo Jet. This is the Series 800 and is powered by four of the General Electric GEnx engines that can produce up to 76,000 lb of thrust.

This aircraft, the Boeing 787 Dreamliner is also powered by two of the General Electric GEnx engines. The Rolls Royce Trent 1000 engine can also be fitted to this aircraft. Note that this aircraft, like many new airliners, only has two engines. This gives a large saving in the cost of engines but, as we will see, brings other problems in designing these aircraft.

A word about safety.

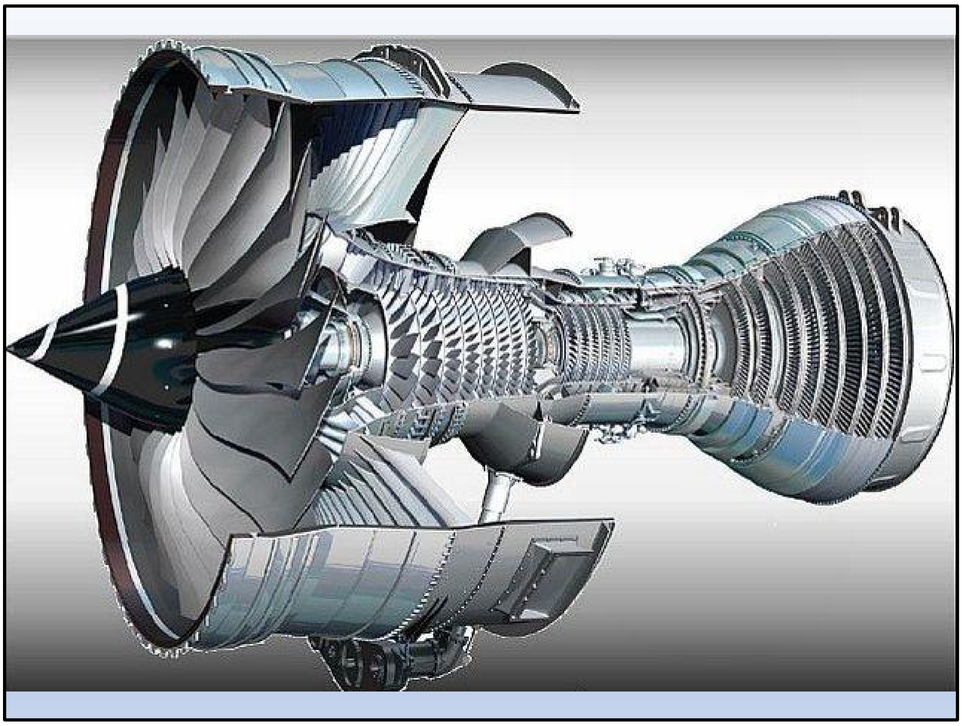
All airliners have to meet a strict rule that they have to be able to take-off safely if an engine fails at the critical speed, known by the pilots as V1, during the take-off run. The pilots calculate this speed before take-off since it will be different at each airport depending on various factors and the length of the runway.

If an engine fails before the aircraft reaches the critical speed, the remaining engine power will be reduced or reversed, the brakes applied, and the aircraft will stop safely on the runway. If however an engine fails after the aircraft has reached the critical speed then there is no option but to continue with the take-off.

Now you can see how difficult it is to design a twin engine aircraft. The aircraft has to be able to continue to accelerate to a safe speed and climb away from the runway on only one engine.

So a twin engine aircraft, full of passengers, depends on the thrust from one engine and that is why the engines have to be so powerful. The next time you fly in a twin engine airliner you may be comforted by the fact that the aircraft normally has twice the power that it really needs during the take-off.

This is the latest large airliner from Airbus, the A350XWB. This is also a twin engine aircraft and again the engines have to very powerful to allow it to continue to take-off safely after an engine failure.



This is the engine that powers the Airbus A350 XWB. It is the Rolls Royce Trent XWB and it can produce a thrust of between 84,000 lb and 97,000 lb. [44 tonnes]

This is the Airbus A380, the largest airliner in the world. It needs the power of four engines to be able to safely complete a flight if an engine should fail.

It should be noted that modern engines are so reliable that the chances of an engine failure are very remote. An airline pilot may never experience an actual failure in the whole of his career.

This is one of the engine types that the customer can choose to power the Airbus A380. This is the Engine Alliance GP 7200, the other possible engine is the Rolls Royce Trent 900. Both of these engine types can produce up to 70,000 lb of thrust.

This big modern airliner, the Boeing 777-300ER, needed a really powerful engine. So the challenge for the engine designers was to design an engine that could produce more than 100,000lb of thrust.

This is the General Electric GE90-115B, the most powerful Turbofan in the world. It could lift three loaded London buses straight up into the air vertically.

This is the GE90-115B being flight tested on GE's test aircraft. It is mounted on the left-hand inboard engine pylon and you can see how large it is compared to the existing engines.

The engine normally produces about 115,300lb of thrust but, under test conditions, it produced a world beating 127,900lb of thrust. This test aircraft was able to fly on the power of this one engine alone.

This is what the GE90-115B engine looks like when mounted on a Boeing 777 airliner. This airliner can carry 400-500 passengers and can, if required, safely complete a flight on one engine.

We have now covered over
100 years of engine development.

The design of aircraft engines has improved to the point where we now can depend on extremely powerful and reliable engines.

Will that be the end of the story?

I doubt it.

One last thought on aircraft engines :- - - - - -

During the Second World War when the turbojet engine was being developed the work was top secret.

But the public started to see aircraft without propellers flying overhead so the secret was out. The newspapers of the day ran the story about the new engine but, as newspaper editors do, the name Turbojet was shortened to the snappier name “Jet”. So the name Jet passed into common language and is still used today.

When airliners first appeared powered by turbojet engines, other words crept into our language. Rich people who could afford to fly away on holiday at any time became “jet-setters” and of course they suffered from “jet-lag”.

Modern travellers still think that they have flown on a jet airliner even though the last one went out of service many years ago. The very last one to fly was the Concorde.

All modern airliners are powered by turbofan engines but “fanning” off on holiday does not quite have the same kudos.