Podcast 21 - Engines

Hi and welcome back to another technical episode of the 737 podcast. Here we are going to discuss a very important system to us and that's our engines. We'll keep it specifically to the NG, knowing that the MAX, for instance, has different engines. We'll look at a bit of background of powerplant evolution for the 737, a bit of tech discussion which is from the Vol 1 and elsewhere, and a bit of flight crew interaction with the engines. Fresh from home schooling, here's Ian with a bit of history lesson. You don't need to listen to him on this bit if you're operating heavy machinery.

The original 737, 100/200 were fitted with the Pratt and Witney JT8Ds, a low bypass ratio turbojet engine which, after a few iterations were producing about 17,000 lbs of thrust. Since then, the 300/400/500 now known as the classic, and the 600/700/800/900s known as the NGs, use an engine manufactured by CFM, the CFM56 and various derivatives of it, which can provide over 27,000 lbs of thrust.

All 737s after the 200, up until the MAX use various CFM56s, but it is such a well designed and reliable engine that another large European aircraft manufacturer has chosen it as an option for its single-aisle jets. As a joint company between French company Safran (formally SNECMA), and the American giant GE, the engine is manufactured in both France and the US. Powering over 13,400 aircraft it is the most successful and best-selling engine in the history of aviation.

The CFM56 is what's known as a high bypass ration engine, which utilises a large fan at the front which provides a large amount of cold air (air that hasn't travelled into the compressor or hot part of the engine) and the ratio of cold air to hot air is high. Hence the name. Jet engines are measured by their propulsive efficiency, and I've chosen not to go too technical, because it gives Ian a headache, but suffice to say the efficiency with large bypass ratio turbofans increases markedly. To get such a large bypass ratio, you need a big fan, and with that comes problems due to its physical size and mounting it on the wing. The original sixties design of the 737 hasn't changed that much in terms of basic wing height above the ground, so to accommodate such a larger engine than the original PW, the engineers came up with a few ingenious ideas of mounting some of the accessories of the engine on the sides of the engine, as opposed to the bottom, and thus they were able to flatten the lower nacelle section to comply with ground clearance requirements.

Not only are higher bypass ratio engines more fuel efficient, because of their higher propulsive efficiency (you still with me there Ian???) but they are quieter, due to the large shrouding of cold air around the noisy exhaust.

Sorry, what did you say Mark? I was dreaming of hydraulic systems. Anyway, another downside of having to mount larger engines than the airframe was originally designed for, is that the engines have had to be mounted further forward. Moving them away from the centre of gravity, has made Airbus pilots to this day run a cold sweat, with the very marked pitch/power couple which we know is a feature of the 737NG.

They are mounted on pylons, via a forward and an aft mount, with 4 bolts on each, making 8 bolts attaching the 2.5 Tonne engine to the pylon. These bolts are 22mm across and made from a nickel alloy so able to fully support the vertical loads and stresses generated with even some of Mark's landings that I've witnessed. Incidentally the forward mount has 2 shear pins and the aft mount one shear pin, which transfers most of the thrust force horizontally to the wing and thus the aircraft.

The CFM56 is known as a dual rotor turbofan. This means it has 2 independent spools or rotors. The N1 rotor compromises a fan, low pressure compressor and a Low-pressure turbine, all connected on the same shaft or spool and thus rotating with the same angular velocity. The N2 rotor consists of a high-pressure compressor and high-pressure turbine and runs inside the N1 shaft. The N2 rotor drives the engine gearboxes, and the starter motor (bleed air driven) is also connected to the N2 rotor.

In the flight deck we have indications of the engine performance so we can equate that to how much power/thrust we are generating. Our primary engine indications are N1 and EGT, N1 being a percentage of the RPM of the rotor, incidentally 5382 RPM. The N2 can spin at 3 times that and can produce RPMs of around 15,200. EGT is the exhaust gas temperature, it is the temperature of the exhaust gases taken by a thermocouple in the engine exhaust. These primary indications are normally displayed on the centre forward panel upper DU.

There are also secondary engine indications, being N2, fuel flow, oil temperature, pressure and quantity and also engine vibration readouts. Because these are secondary and are not of primary importance, they are mostly manually selected to either the Captains or First Officers inboard DU or indeed the lower DU. Fuel flow is shown on the upper DU. There are many different iterations on how these indications are displayed to you, the pilot, depending on optional fit and pin programme, whether they be in numerical or analogue format with a dial. As we know the lower DU, and consequently the secondary engine instruments, are blanked for the majority of the flight but they will automatically appear when:

--The displays initially receive electrical power
--In flight when an engine start lever is moved to cut-off
--In flight when an engine N2 RPM is below idle (engine failure scenario)
--Or when a secondary engine parameter is exceeded.

Each engine has its own independent EEC (we were doing so well with the acronyms…), or Electronic engine Control. Each EEC has 2 channels, which are automatically cycled on each engine start. If one channel fails, the other will automatically take over.

The EEC monitors auto throttle and flight crew inputs to automatically set the engine thrust. They provide full authority digital engine control when operating in their normal mode, and completely control how the engine runs taking into account many inputs, e.g. ambient temperature, pressure and thrust demand.

Here is a shorted list of what the EECs provide:
-During start, controls the ignition and provides start protections:

-During engine operation, protects the engine from stalls and surges by varying the angles of the variable stator vanes.
-Selects and controls minimum idle operation of the engine, be it flight idle or approach idle.
-Keeps blade tip clearances to a minimum. This is done to improve efficiency of the blades and the EECs actively control the temperature, and thus expansion/contraction of the case to provide this minimum tip clearance.

The EECs operate in a normal or Alternate mode. Most of the time it will be in a Normal mode of operation, and there are 2 white ON lights on the upper overhead panel to indicate this.

If the EECs lose some inputs, they will switch to ALTN mode, either SOFT Alternate or Hard alternate. This switch is done automatically if the EECs lose the total air pressure as an input, and after 15seconds, will display an amber ALTN on the overhead, coupled with an Engine indication of the annunciator.

When in Soft Alternate mode, exceedances or shortfalls in thrust may occur, and it is possible to over-boost the engines.
Hard Alternate is pilot selectable, by certain failures and is directed by the QRH and is actioned by a button press on the overhead.

The engines are also used to provide air or pneumatics to other aircraft systems, eg the packs or anti ice systems. Air is bleed air taken from the 5th or 9th stage of the N2 compressor. The 9th stage air will be hotter and under more pressure than the 5th stage air, and during low power settings any required air is bleed from the 9th stage of the compressor. The pneumatic system fully regulates depending on demand.

Much to the airline executive's annoyance, engines still require fuel, and whilst the fuel system is another one of our riveting podcasts, we'll make a brief mention of it here. The engine requires fuel under pressure which makes its journey from the fuel tank to the engine via a fuel spar shutoff valve, located at the engine mounting wing stations. On its journey to the combustion chamber the fuel also passes through 2 fuel/oil heat exchangers. This raises the temperature of the fuel and also lowers the temperature of the engine and IDG oil. It is desirable to have less viscous fuel for more efficiency, and it's all to do with the fuel temperature affecting the modulus of elasticity and density. We don't need to go into it further for Ian's sake, as I can already see he's getting confused.

The fuel then passes through a filter, which removes any contaminants, but if the filter gets clogged or saturated, then it will automatically bypass the filter on its way to the engine. In this scenario we get the, you guessed it: FILTER BYPASS alert on the fuel control panel and this will require maintenance action.

Having been filtered the fuel then is further pressurised, via another pump, and then passes to the HMU – it's been a few minutes, so I had to get in another acronym. HMU is the Hydro mechanical unit. The EEC (doesn't count as we've already talked about it) sends signals to the HMU to give the engine the required amount of fuel it needs. We've mentioned the Spar shut off valve, located in the errr Spar, but the HMU also has another shut off valve – the Engine Fuel shut off valve. Both valves have an indication on the overhead panel.

The fuel system and oil system are intrinsically linked, via these heat exchangers. Our engine needs oil to lubricate the engine bearings and accessory gearbox. This oil flows around the engine parts under pressure, pressurized by an engine driven oil pump. The oil is fed into the top of the engine, lubricates the parts it needs to and then drips down into one of 2 sumps, forward and rear, and is then fed back to the oil tank via scavenge pumps.

Similarly to the fuel, the oil is fed through a scavenge filter, and again if this gets clogged, it will automatically bypass it with an OIL FILTER BYPASS alert on the upper DU. After the filter on its way back to the oil tank, it passes though the main engine oil cooler, which as discussed above, cools the oil, and warms the fuel.

The oil indications, quantity, temperature and pressure, are located on the upper and/lower DU, depending on fit. The maximum oil tank capacity is around 20 litres, with a low oil quantity indication appearing in reverse video, as LO, on the secondary instruments display.

To start the engine, the engine requires pressurized air, and electrical power. The air is bleed air from any one of a number of sources (APU, external ground cart, or the other engine) and is fed to the N2 rotor via a starter motor. Once at the recommended rotation, 25% N2, the pilot will then move the start lever to IDLE and this opens those 2 fuel valves, and also powers the EEC to supply fuel via the HMU to the combustion chamber.

Simultaneously this action also powers the igniters which will ignite the fuel being forced into the combustion chamber. As the burning fuel starts to turn the turbines more, at about 56%, the solenoid holding the start switch is deenergised, and the start valve closes as the engine has reached self-sustaining speed.

During start the EEC will provide a degree of start protection, and will monitor and display on the DUs impending engine malfunctions: Those being hot starts, engine stalls, EGT start limit exceedances and wet starts (i.e. no ignition). The pilot then has memory actions to perform, or the newer EEC software will perform some of the actions automatically.
If an impending hot start is detected by a rapidly rising EGT, or a compressor stall, the white box surrounding the EGT digital readout flashes white. Newer EECs will automatically shut off the fuel and ignition for the impending hot start.

Again, if no ignition is sensed by the EEC during the start process, the EEC will turn off the ignition and fuel after 15 seconds of the start lever being moved to idle.

Each engine has 2 igniters, armed by the EEC. The Left igniter plug on each engine gets it power from its respective AC transfer bus. The right igniter from the AC Standby bus. As you can see, high levels of redundancy are provided if an inflight start is ever needed.

Speaking of which, the CFM 56 has an auto in flight restart function, whereby the EEC will detect a flameout by a rapid decrease in N2 or if N2 drops below idle. The EEC will then activate both igniters on that particular engine.

If an inflight restart is needed, then you can either cross bleed, to get the air needed to start the engine, or windmill – which means you use the airflow generated by your forward movement to provide the rotation required. Guidance is provided in the QRH on in flight restarts and depends on your speed and altitude.

We can't finish up without a brief (and we'll keep it brief because of Mark's toddler attention span) mention of the thrust reverse system. Older CFM56s used pivoting doors, but the dash 7, for the NG, utilises sleeves and blocker doors. Each engine has a hydraulically operated thrust reverser, used to vector the bypassed cold air forward to provide retardation.

There are two translating sleeves on each engine, which when activated, also cause 10 blocker doors to deflect fan air forward through fixed cascade vanes.
As mentioned, they are operated hydraulically, using the Left and Right hydraulic systems respectively, with the standby hydraulic system as a backup – but providing a slower rate of movement.

Thrust reversers can be deployed when either radio altimeter senses less than 10 feet altitude, or when the air/ground safety sensor is in the ground mode. Movement of the reverse thrust levers is mechanically restricted until the forward thrust levers are in the idle position.

When reverse thrust is selected, an electro–mechanical lock releases, the isolation valve opens and the thrust reverser control valve moves to the deploy position, allowing hydraulic pressure to unlock and deploy the reverser system. When either reverser sleeve moves from the stowed position, the amber REV indication, located on the upper display unit, illuminates.

As the thrust reverser reaches the deployed position, the REV indication illuminates green. Past the interlock position on the thrust levers, there are two detents. Detent one will give you idle reverse, and Detent 2 gives you enough reverse for normal operations. If required, you can go past detent 2 to a further position which will give you maximum reverse thrust.

Downward motion of the reverse thrust lever past detent No. 1 (reverse idle thrust) initiates the command to stow the reverser. The REVERSER light, located on the aft overhead panel, illuminates when the thrust reverser is commanded to stow and extinguishes 10 seconds later when the isolation valve closes. Any time the REVERSER light illuminates for more than approximately 12 seconds, a malfunction has occurred, and the MASTER CAUTION and ENG system annunciator lights illuminate.

I think we've lost Mark now, so I'll hand back to him to wrap things up.

So, that's it for this week and thanks for joining us again and we'll look forward to seeing you in a couple of weeks to share more 737 information with you. Please do join us over on social media and sign up for our newsletter over on B737talk.com for more information on what we’re up too. Until next time though, fly well, and be safe.