Podcast 27 – Flight Controls, Part 1

Hello and welcome back to another episode of the 737 Talk where today Ian and I will discuss the 737NG flight control system. We will again be splitting this subject into two digestible podcasts as there's a lot to take onboard and Ian may get a sore throat or feel faint if he has to do too much work. On the 737 the primary flight controls use conventional control wheel, column and pedals linked mechanically to hydraulic power control units which command our primary flight control surfaces, ailerons, elevators and rudder.

Flight controls are powered through system A and B with either system being able operate all primary controls alone. You also have mechanical manual reversion for the ailerons and elevators which is a akin to losing power steering in your 75Tonne car, and a backup of the standby hydraulic system for the rudder should both system A and B be unavailable.

The secondary flight controls, high lift devices are powered by system B. The TE flaps have an electrical alternate system while under certain conditions the PTU will power the LE devices. Take a listen back to the podcast 7, Hydraulics, if you need reminding of those. The LE can also be extended only using standby hydraulic pressure in the event of B system loss.

We also have the horizontal stabiliser which is controlled via an electric motor or manually using the manual trim wheel and 8 flight spoilers which are too operated through Hydraulic system A and B.

Let's talk about roll control first. Here we use our two ailerons and eight flight spoilers controlled by rotating either control wheel. The A and B FLT CONTROL switches control flight control shut off valves which will isolate the respective system hydraulics from the ailerons, elevators and rudder.

The way the control wheels are linked to their respective PCUs and each other provides redundancy in case of a jam situation as well as the aforementioned manual reversion in case of total hydraulic system loss.

To clarify that, the captains control wheel is connected to the aileron PCUs through the aileron feel and centring unit with the FO's control wheel connected to the spoiler PCUs through the spoiler mixer. The whole system is then brought together by a cable drive system allowing the actuation of both spoilers and ailerons by either control wheel. That's almost like a Boeing version of the song Dem bones though I'm not sure it'll catch on so well. The control wheels connected to the PCU, the PCUs connected to the…

I think he's finally lost it. Anyway, before Mark started singing, he mentioned how the system protects against jams. This is through the Aileron Transfer Mechanism which consists of that cabling, a torsion spring and a lost motion device. So, if the ailerons are jammed force applied on the First Officers side to overcome the torsion spring will provide roll control via the spoilers. There is however a 12° dead band in roll in this case for the engagement of that lost motion device and the captains control wheel is now inop. During normal operations the lost motion device ensures spoiler control inputs are sequenced through the aileron system. If the spoilers are jammed then the captains control wheel can overcome the torsion spring and control roll through the ailerons, in this case the FO's control wheel is inop.

We also have the ability to trim the ailerons through the dual aileron trim switches located on the aft electronic panel. The switches must be pushed simultaneously to command trim changes. This is an electric trim which repositions the aileron feel and centring unit causing the control wheel to rotate, and it redefines the aileron neutral position. The amount of aileron trim is indicated on the top of each control column.

A warning here is that if you use this trim with the autopilot engaged the trim won't be reflected in the control wheel position as the autopilot will compensate and overpower the trim input. If you have put aileron trim in with the AP engaged, when you return to manual flight you are at risk of an abrupt and perhaps unexpected roll movement. That is why the limitation exists prohibiting the use of aileron trim with the AP engaged. Now back to Frank Sinatra's tone-deaf cousin for a review on flight spoilers.

I thought you'd appreciate that being from the land of song! On the 737 we have 4 flight spoilers per wing with hydraulic systems A and B dedicated to a different set of spoiler pairs to provide redundancy and maintain symmetric operation in the event of either hydraulic system loss. Hydraulic pressure shut off valves are controlled by the two flight spoiler switches on the overhead panel.

Our spoilers can be used as speedbrakes, both in flight and on the ground, as well as supplementing roll control. As previously mentioned, the spoiler mixer then controls the hydraulic PCUs on each spoiler panel to provide spoiler movement proportional to aileron movement.

The flight spoilers will rise on the wing with up aileron i.e., the wing of the turn direction and stay faired on the opposite side. A control wheel displacement of approximately 1.5 units on the trim scale will give you the 10° required to initiate spoiler deflection.

Now to look at pitch control which is provided by two hydraulically powered elevators and an electrically powered moveable horizontal stabiliser.

We position the elevators through control column movement where cables connect to the elevator PCUs who are powered through Hydraulic system A and B. The elevators are interconnected by a torque tube. Those A and B FLT CONTROL switches will, as previously mentioned, isolate the elevators from the respective system. We again have the back up of manual reversion should both hydraulic systems be lost.

In the event of a control column Jam we have an override mechanism installed on the torque tube which allows the columns to be physically separated. Necessary column forces exceed those of manual reversion, about 45kg of force will move the elevator by 4°, so you can imagine this would be a very fatiguing and challenging way to fly the Jet. You will have sufficient elevator authority to flare for landing and the stabiliser trim is available to counteract any sustained control column force. That said you're still going to feel this one in the arms the next day should it ever happen to you.

Talking of feel we also have an elevator feel system where a feel computer provides us with simulated aerodynamic forces by using airspeed from the elevator pitot system and stabiliser position. Feel is then transmitted to the control column by the elevator feel and centring unit. The system uses the higher of Hydraulic A or B pressure for operation and if one of the hydraulic systems loses pressure excessive pressure differential is sensed and the FEEL DIFF PRESS light illuminates. This light will also illuminate for a failure of the elevator system pitot probe.

Here we'll also take a quick look at the Mach trim system as this uses the elevators. The system is active above Mach .615 and provides speed stability at higher Mach numbers. It is an automatic function achieved by adjusting the elevators with respect to the stabiliser as speed increases. The FCCs are provided with information from the ADIRUs to compute Mach trim actuator position allowing the Mach trim actuator to then reposition the elevator feel and centring unit which in turn adjusts the control column neutral position. In essence the system is preventing Mach tuck through automatic elevator adjustment.

That's the elevators covered now to the stabiliser. We normally trim the stabiliser through the electric trim actuator, which is controlled by either the stab trim control wheel switches or the AP trim. There is also the manual trim wheel option should we lose the electric system which is incidentally powered by Transfer Bus 2 as you may remember from our recent Ryanair podcast.

The main electric and autopilot trim have two speed modes, high speed with flaps extended and low speed with flaps retracted. For those technically minded the high-speed rate is between 0.27-0.4 units per second with the low speed 0.09-0.2 units a second. Whenever you or the autopilot is trimming you will get feedback through the movement of that manual wheel. If you were to actuate the main electric trim when the AP was engaged, you would cause the AP to disengage.

A little more knowledge than perhaps is needed here but we know some like the numbers so for your information 1 unit of stab trim equates to around one degree of stabiliser movement and takes around 15 rotations of the trim wheel to achieve.

On the NG we have two cutout switches, one for the main electric trim and one for the autopilot trim. They allow any inputs from either of these sources to be disconnected from the stabiliser trim motor and no doubt you have become quite familiar with these since the Max accidents.

We also have switches on the control column which will stop inputs from both the main electric trim and the autopilot trim when control column movement opposes trim direction.

The other switch of note in this system is the stab trim override switch which allows the use of electric trim regardless of control column position i.e., you could push forward and trim ANU at the same time, particularly useful for safety when flying one of those 737 low level missions.

Manual trim is accomplished through cables connected to the stabiliser trim wheels. These wheels are offset by 90° to ensure at least one pilot has leverage if a two-crew effort is required due to high air loads. In the event of a runaway, we will see the trim wheels spinning and have the ability to stop them physically should all other efforts fail.

When not trimming, the stabiliser is held in place by two independent brake systems giving a good level of redundancy to protect against aerodynamic runaway.

With manual trim there is a slightly larger range of trim available in the nose up and nose down direction. If you have used manual trim to position the stabiliser beyond the electrical trim limits, this would be highly unlikely in commercial operation, then you can still use the trim switches to get the trim back within those electrical trim limits.

Our stabiliser trim position is displayed next to the trim wheel on the STAB TRIM indicators which also have that familiar green band which shows the takeoff trim range. You will get the takeoff warning horn should you attempt to commence the takeoff with the trim set outside this range.

We'll finish this first part with a look at the speed trim system, STS, and stall identification. The speed trim system seems to be one that causes a bit of confusion so let's try to clarify it in terms that maybe even Mark may understand.

This automatic system is designed to improve manual flight characteristics, and I stress the word manual, at low speed and high thrust settings, especially when at low gross weights and with an aft centre of gravity. This means the system usually operates during takeoffs, climb and go-arounds.

The aim of the STS is to return the airplane to a trimmed speed by commanding the stabiliser in an opposite direction to the speed change. In other words, if you have a speed increase away from the trimmed speed the STS will command nose up trim and vice versa. Applying manual trim will stop the STS but the STS will start again 5 seconds after manual trim release if it still senses the trim requirement. This is where you could confuse it with a trim runaway so it's worth bearing in mind.

The speed trim system achieves its aim as function of the FCCs by monitoring stabiliser position, thrust lever position, airspeed and vertical speed and then trims the stabiliser through the AP stabiliser trim input. It is normally FCC A that supplies the signal to the speed trim system, but both have capability which is why if you get a SPEED TRIM FAIL light on recall it will indicate a single FCC failure.

As the aircraft then returns to the trimmed speed the STS will reverse its inputs.

Conditions for system operation are:

- Speed between 100kts and M0.60 with a fadeout to zero by M0.68
- 10 seconds after takeoff
- 5 seconds following the release of trim switches

- Autopilot not engaged
- Sensing of trim requirement

On to a quick talk about stall identification before we can all give our brains a little rest. On the 737, stall identification and control are enhanced by the yaw damper, the Elevator Feel Shift (EFS) module and the speed trim system. The three systems work together to help the pilot identify and prevent further movement into a stalled condition.

During high angle of attack operations, the Stall Management Yaw Damper (SMYD) computers reduce yaw damper commanded rudder movement.

The EFS increases HYD A pressure to the Elevator Centring Unit during a stall which will approximately double control column forces so that the pilot cannot easily override it. EFS is inhibited on the ground, when radio altitude is less than 100ft and when the AP is engaged. However, if the EFS was active prior to going below 100ft RA it will remain active until AOA is reduced below approximately stickshaker threshold. We have no indications on the flight deck that the system is properly armed or activated.

As airspeed decreases towards the stall the STS trims the stabiliser nose down. As the pilot in this situation, we would have to pull more aft force on the control column to go on to stall the aircraft.

The other thing that may help us, stall margin wise, in this situation is the autoslats. We'll leave this on a cliff hanger though and go through the conditions for those to be available to us in the next episode. No spoilers on social media please...

If you really can't wait until the next episode, I hear the vol 2 is a good place to start but with a bit of patience we'll do the work for you. Speaking of unanswered questions

Intro to Talk Tech Ten

Q1: What does the illumination of the SPEED TRIM FAIL light without using recall indicate?

Q2: What happens to the leading edge devices on momentary selection of the alternate flap switch to DOWN?

Q3: What happenes to the control column actuated stabiliser trim cutout switches when you put the stabiliser trim override switch to OVERRIDE?

Q4: When will the SPD BRK EXTENDED light illuminate?

Q5: What is the maximum speed for lowering the flaps using the alternate system?

Q6: How many flight spoilers are on each wing and how many ground spoilers?

Q7: Above what Mach number does the mach trim system provide speed stability?

Q8: In regard to main electrical trim, in what configuration do you get a high trim rate?

Q9: For certification purposes what is the maximum time required to evacuate the 737 and are there any other stipulations to this?

Q10: Here's one for the Caribbean pilots. How long should you wait before flying if diving to depths greater than 30ft?

Remember the answers are over at b737talk.com. We hope you enjoyed that first part of the flight controls refresher and we'll look forward to continuing the talk with you soon. If you'd like to check us out on social media we are @b737talk on fb, Instagram and twitter and we also have more information including links to any reports we refer to and the all-important Tech answers over on b737talk.com where you'll also find model like pictures of Mark and I and even the ability to come join us in the simulators should you so wish. For now though from the both of us fly well and be safe.