Podcast 37 - EFATO

Hello everyone, and welcome to another episode of the 737 Talk, where we try to help with aircraft technical refreshers and operating procedures, as well as discussing together incidents involving the 737 from which we can all learn. With many years of instructing and examining between us, we also thought it would be a good idea to introduce a series of focussed Talk episodes where we concentrate of individual mandatory items that most of us still need to do to re validate our licence during the Licence/Operator proficiency Check, or LPC/OPC. We will intersperse these 'training talks' with other tech subjects and incident investigation discussions.

Today we shall concentrate on the EFATO, or engine failure after takeoff, or even referred to as the V1-Cut, back in the day that I still had hair and Ian didn't due to still being in his cot.

Our objectives today will be to discuss:
-1, how to accurately fly the aircraft using the FCTM recommended profile, and where we can we'll also suggest some techniques.
-2, to correctly diagnose the engine malfunction; and
-3, to give you the confidence that not only will you satisfy the examiner enough to sign your licence, but that should this ever happen on the line, a safe outcome will result.

We will be discussing techniques required at different parts of the profile, what to look out for, how to fly accurately, and common errors. We'll also integrate thoughts on any threats to the flown manoeuvre, and possible mitigations.

So, let's begin. Our engine failure will occur between V1 and V2 – as is currently required to be demonstrated by UK and EASA Appendix 9, Part FCL.

When the engine fails, there will be a varying amount of swing, depending on a number of factors including how severe the failure is and what sort of derate you have on the engines. The best way of correcting for this swing is to be looking at the end of the runway and keep the aircraft straight, as you should be doing on a normal take-off.

Instinctively you will know which rudder to SQUEEZE to keep straight, do it smoothly and in proportion with thrust decay and keep the aircraft from diverging further from the centreline. Unless the engine has seized, the thrust lost will not be immediate, and the swing, or centreline divergence will be gradual and will be able to be corrected by gentle application of the rudder.

Remember that at airspeeds above 135kts, Hydraulic systems A and B pressure are each reduced within the main PCU by 25% - this will limit full rudder authority in flight. It could mean that in a crosswind, or full thrust departure, to maintain correct lateral tracking a small amount of bank towards the live engine might need to be applied when approaching max weight takeoffs.

Once the divergence from the centre line is arrested and the aircraft is stable laterally, it is recommended to lock the foot with which you applied the rudder and keep it in the displaced position. The phrase 'squeeze and freeze' is a nice way of remembering it. You can expect a call from the PM to state that there is an engine malfunction but not specific to which engine as soon as they notice it.

As the failure occurs after V1, by definition, we are taking the aircraft into the air.

The rotation manoeuvre is different to that of a standard 2 engine rotation. Firstly, the aircraft is trimmed for a 2-engine rotation. Now we have effectively halved the thrust, and remember we have underslung engines which create pitching tendencies, our trim will now be wrong, and therefore a slightly greater force is required for the rotation on the control column.

The rate is also approximately 0.5 degree slower than a normal 2 engine rotation, and we are looking for about 1.5 – 2.5 degrees a second. The heavier feel to the aircraft may well assist in naturally slowing the rotation down.

The initial pitch target is towards 12-13 degrees. A good aiming point is the first smaller line above the 10 degree datum on the PFD as this is 12.5 degrees.

Once pitched to this new datum, the pilot as a technique can relieve some of the nose down force, with 3-4 seconds of the elevator nose up trim.

You will now adjust your pitch to follow the flight director which will command either V2 or Vlof, whichever is higher if the failure occurred on the ground.

If the failure occurs after lift off you will need to apply rudder and aileron to control heading and keep wings level. Inflight, correct rudder input will approximately centre the control wheel for stable lateral flight. In this situation the FD will command either V2 if at or below that speed, current speed up to V2 + 20kts or V2 +20kts if we are above that speed.

I just mentioned having to centralise the control wheel, so we'll now look at a technique of how to do it. Boeing have been quite helpful here. When the control wheel points down to the right it is pointing towards which foot you need to use to centralise it, so you need a squeeze of that right rudder. When it's pointing down to the left a squeeze of that left rudder. Now be careful here as the rudder is very sensitive so don't put in too large an input, just give it a gentle squeeze, hold it there and see if it approximately centralises the control wheel and then trim off the forces.

Once settled into the initial climb, it is important to remember to raise the gear after a positive rate of climb is shown on the altimeter for performance reasons. With the startle factor of an engine problem, the increased workload in new pitch datum, coupled with Master cautions and possibly Fire warnings, the threat is to fail to remember to raise the gear – possibly caused by distractions, and this is a common error. You will need to develop a strategy to help remember to perform this important part of the profile. It is PMs call to say "Positive rate" but remember as PF if it is not made you should call it yourself.

V2 – which we have already calculated pre-flight and is our single engine takeoff safety speed – is the minimum speed that needs to be maintained in the event of an engine failure to ensure that the minimum required climb gradient is achieved, giving adequate terrain separation, and keeping the aircraft controllable. Therefore, accurate flying is needed to ensure your speed is at or above V2.

During this second segment climb following an engine failure, minor speed excursions below V2 are acceptable but only if you show you are correcting the pitch without delay.

When workload permits, you will have the opportunity to trim off some of that pedal force, using the rudder trim. There is no exact number to trim to, or an exact time, but in the region of 10-15 seconds is a good start and then fine tune from there. Another error seen in this area is using the wrong trim direction. Remember to turn the trim in the same direction as the foot holding the load. If your right foot is working Right Trim is required. If your left foot is working left trim is required.

A nice technique to employ is to know where the rudder trim switch is located from your seat, without having to look down. As soon as you take your eyes form the PFD, there is a risk of over or under pitching by even a few degrees, which would have consequences on the FD pitch bar as it attempts to correct the speed increase or decay. Have a feel of where the rudder trim switch is pre flight and try finding it a couple of times while looking ahead. This should help with the muscle memory required.

As previously mentioned, you are looking to have the pressure removed from your foot and the control wheel centralised for the aircraft to be in trim.

400' RA is the next cue for some action: This is normally monitored and called by the PM and is the minimum height for the next action. It can be delayed to make sure the aircraft is under control and trimmed sufficiently.

An emergency turn or an engine failure procedure will be required (as calculated from your performance software or otherwise necessitated) and you should request 'Heading Select', so that the lateral navigation can be accomplished. Remember below 400 feet, if LNAV was armed on the ground, you cannot change the roll mode, which is something we've often seen attempted in the simulator. This should give you something to consider on a departure where an emergency turn is predicated below 400ft. It can be preferable to leave LNAV selection until airborne if you do have a low level emergency turn on a particular departure but that is personal or company preference so we'll leave that for you to think about or use your company SOPs.

In the event of an emergency turn here is where you would limit the bank angle to 15°. This is to maintain your manoeuvre margin and is required until the speed reaches V2 + 15, after this bank angles of up to 30° are permitted with takeoff flaps. Here lies the threat with LNAV engaged as it will not necessarily obey these limits. If a speed is predicated for the turn radius it would also be the time to speed intervene to open that speed window.

Once in HDG mode, any swing or lateral divergence can be corrected, to ensure that the aircraft remains in swung performance cone, and thus clear of obstacles.

Having got the aircraft under control and in trim, with the gear retracted and at a safe minimum altitude now would be a good time to put the autopilot in, if on a VNAV profile, which Mark will discuss more in a second, and diagnose what type of engine malfunction you have. Noting that some engine malfunctions require memory items, and some do not – is critical.

You will have asked the PM to restate the failure using your company SOP call, he or she will check the engine instruments top to bottom and give a diagnosis for you to confirm. A gross error check for PF of live leg, live engine is always a good idea to confirm any diagnosis and help mitigate identification error threats.

If there are any memory items required, this is when they are carried out. Remember you can only engage the autopilot here if your operator SOPS and aircraft fit allow for you to use VNAV for departure, and we strongly recommend if you can, then do so. This will free up your capacity to monitor, but as always if things don't go as you would like, take control. For your LPC, the examiner does not have to see you manually fly all the any up to a clean aircraft. If the autopilot is available, and you have VNAV armed for departure, our recommendation is to use it. If your SOP is to fly without VNAV engaged, then you will have to manually fly until clean up as engaging the AP without VNAV would lead to TOGA mode disengaging.

After memory items, or just diagnosis completion if no memory items are required, it would be a good time for PM to put out a call to ATC informing them of the situation and initial intentions. Your primary focus is on safely flying the aircraft so beware of ATC distractions. If you are doing an emergency turn away from the ATC clearance they may well call you, so in this scenario getting the call in once PF is established in the turn may be in order but remember monitoring your PF is your primary task at this critical phase.

You may also disengage the autothrottle at this point if not done by the memory items. The FCTM states "ensure the auto throttle is disconnected before reaching level off altitude" and as it would be done under the memory items now would be a good time. However, if your company SOP's state differently please follow them.

How we perform these memory items can sometimes be the source of some confusion. They are applied in accordance with Areas of responsibility. These can be reviewed in your Vol 1. Whoever is performing the action announces it. This is the recommended way of doing things but if your company/operator SOP's dictate otherwise you are again to follow them.

So, let's say we have a number 1 engine fire, it would go like this… the PM would identify the failure as a number 1 engine fire which the PF would confirm and then announce:

"Engine Fire or engine severe damage or separation Memory Items."
The PF would continue by stating Autothrottle: Disengage, which he or she would then action. Next the PF would continue by saying Thrust lever number 1 confirm placing the hand on the stated lever, the PM would then confirm the correct lever is selected and the PF would say,

close, and perform the action. Next is the Engine start lever which is in PM's area of responsibility so PM will now announce Engine start lever number 1 confirm, placing the hand on the correct start lever which PF will then confirm and with that confirmation PM will action it. The same goes for the Engine Fire switch, in that it is in the PM's area of responsibility so is announced and actioned by PM with the confirmation of PF.

We now continue to smoothly fly to our predetermined SE acceleration altitude, once again Calculated by performance software or tables.

If you have VNAV for departure, this mode will then guide you to accelerate the aircraft and you will retract flaps on schedule. This guidance comes from your EOAA input into the FMC pre-flight. If VNAV is not armed, you will need to accelerate the aircraft manually, by setting Up speed actioned using your company SOP call. Either way, The AFDS will then command a near level-climb acceleration or a very shallow climb of up to 200fpm.

Dependant on takeoff flap setting, the flaps are then retracted on schedule, as per a normal flap retraction profile, noting that the acceleration will be slower due to the reduced net thrust. A risk to the flight here is when cleaning up, a sink or slight descent can occur, potentially dipping below SE acceleration altitude, and thus reducing terrain clearance. Precise manual flying or Autopilot monitoring is required, knowing the potential risk of a sink and being prepared to manually intervene if necessary. We know that when we retract the flaps we cause a loss of lift so just anticipate that some gentle back pressure will be needed to arrest this sink.

Anticipate trim changes as more airflow starts to occur over the rudder. A technique here is to use your feet to maintain that centralised control column but wait to trim the force off until you are clean and established in your climb with MCT set.

You must also be aware of your particular aircraft thrust limit, be it 5 minutes or 10 and Max Continuous has to be selected if that limit time is reached.

When the aircraft is clean and 'up' speed is achieved, we then need to climb away to a safe altitude.

If VNAV is being used, This is achieved by the AFDS guidance using pitch to maintain flaps up manoeuvre speed.

If not on a VNAV departure, the PF will call for 'Level Change', and it is also this point where the AP can be engaged.

Next, we usually call for Maximum Continuous Thrust, if we haven't already exceeded our take off thrust limits before now.

The PF can either call for PM to set CON and move the thrust levers or call for the selection of CON and move the levers themselves, company SOP'S hold precedence hear. The PM selects 'continuous' from the N1 limit page which will give the CON chevron on the N1 dial. Communication is key here if PM is moving the levers, as there may be a significant change of

thrust, with associated manual trim changes in the lateral required. If you have the AP in the nose trim will be taken care of but you will have to work the rudder still. Always anticipate this as PF and stay ahead of what you are required to do flight control wise. Once settled in the climb Trim out any forces you are holding.

A point to be wary of here is that if you are using a derate, which is quite likely, the setting of continuous thrust may well result in an increase in thrust. Just something to think about for your trim anticipation.

Climbing away to a predetermined safe altitude, eg MSA, the aircraft will capture what you have selected in the ALT window. If you are in a long climb this would be the point to do the NNC related to your malfunction. If you are close to level off already then delaying this to monitor the level off would be preferable.

During level off a large change of thrust is required to maintain the speed, and with such a large change of thrust, comes a large rudder trim change. This needs to be anticipated as we get the classic 737 wobble. Remember your single engine datums here.

Having completed the agreed upon non-normal checklist you can now do the After-take-off checks. It is here now, with the aircraft engine secured, checklists completed and navigating safely, that a plan of what to do next and where to go can be formulated using your company approved decision making tool.

To summarise.

The EFATO manoeuvre requires smooth accurate flying, from rudder sufficient to control direction on the ground, or perhaps aileron for directional control with a progressive squeeze of the rudder if the failure occurs in the initial airborne segment, to accurately following or monitoring the FDs on the acceleration.

A sound knowledge of the profile is required, for example when will acceleration be commanded, or where and how to navigate using appropriate AFDS selections. This will come with training and practice, and of course a relevant, engaging, and thorough pre-departure brief.

Manoeuvres such as these can always be thought about away from the aircraft, in a technique known as ‘armchair flying’. This will work for some people but not others, but anything allowing you to gain familiarity of the profile and procedure will help and give you extra capacity to fly more accurately.

Diagnosing the engine malfunction together using good CRM is critical. Remember to read those dials top to bottom gathering the information on offer and thinking about whether any bangs or heavy vibrations were heard or felt at that point of failure or even subsequently. This should allow you to diagnose that severe damage scenario and If required the memory items should be easily drawn upon and accurately and readily applied.

Lastly, because of the pitch-power trim couple which we know is marked on the 737NG, once we introduce another axis in which trimming is required, i.e., the yaw axis, any change in thrust will require a trim change to the THS and rudder. Therefore, thrust changes need to be anticipated. Think about aircraft dynamics away from the jet and they will become second nature when you're under duress.

So, there it is, the first in our series of LPC mandatory items, with training inputs and suggested techniques to fly the manoeuvre to the required standard. We discuss this, and the other mandatory items in more detail, on our subscription-based service b737training.org, where you can watch interactive presentations and full flight sim manoeuvre demonstrations, together with TEM briefs and de-briefs.

If you'd like to keep the talk going please head over to our various social media pages including Instagram, Facebook and twitter @b737Talk. We also have our website www.B737Talk.com where you can sign up for our newsletter giving you information on the podcast ahead of anyone else. Let us know if there are any burning topics you would like covering, and we'll take on board all feedback. Until next time, fly well and be safe.