Podcast 011 - UPRT

Hello everyone and welcome back to episode 11 of the Boeing 737 Talk. We are going to stick with a training theme this week before we return to another technical subject. There has been a real drive in the industry over the last few years about the recognition and recovery from aircraft upsets with cross carrier and manufacturer collaboration to improve safety in this area. The impact is such that as of December 2019 advanced UPRT is now mandatory for all ATPL's, MPL's and some CPL's for certain class and type ratings. As well as for new entrants, those of us already in the system are included, with commercial airlines required to include UPRT in the normal 3-yearly Simulator programmes.

The reason behind this is because loss of control in flight is the single largest cause of commercial aircraft accidents and fatalities.

As I'm sure a lot of you are aware by now, we have a new definition of an aircraft upset. I'm not going to mention the old parameters as I think that just confuses things so let's concentrate on the new. An upset now exists anytime an airplane is diverging from what the pilots are intending it to do, this divergence will become larger until action is taken. Prior training practises missed the primary objective for intervention as soon as an undesired state starts occurring by placing us in an already highly undesirable state, usually achieved by having our eyes closed while the TRI or sim partner puts us into a rather alarming attitude.

More emphasis is now put on the criticality of recognition and prevention. Training programmes leading up to checks are usually focussed on the areas to be tested, perhaps missing out on the pilots having the exposure to be trained on the entire operational flight envelope. With a large proportional of that flight envelope managed through autopilots and auto throttles it is realistically impossible for pilots to recognise and respond correctly to an undesired state without having practical knowledge of performance and handling characteristics available to them.

Here is where the new UPRT guidance comes in aiming to give pilots a look at the aircraft across its entire operational flight envelope developing both awareness and handling skills in manual and automatic flight. Original Equipment Manufacturers or OEM's, Boeing in our case came up with recommended training sequences. Recommended crew actions for both Stall Recovery Procedures and Upset Recovery Techniques have unanimous agreement across OEM's and we'll look at outlining them here for you.

Firstly, because there are an infinite number of variables that comprise an upset it is not appropriate to attempt to define testing or checking criteria. The goal here is to either avoid the upset completely, intervene if one is developing, or to regain control if one occurs. Training to proficiency is what we're aiming for.

The objectives of the AUPRTA, or the Airplane Upset Prevention and Recovery Training Aid are four-fold.

1. To Aquire the knowledge to recognise and avoid upset situations
2. To learn to take appropriate and timely measures to prevent further divergence.
3. To understand basic aeroplane aerodynamics and
4. Learn airplane manoeuvring techniques throughout the airplane operational flight envelope to perform recoveries from upsets.

Another critical factor in prevention is monitoring and we mean as both PF and PM monitoring the aircraft state. Here comes another aviation buzz phrase of the moment for you, active monitoring. Ok, so we hear that a lot but what does it mean? It is defined as a proactive knowledge-driven process of encountering and keeping track of how things are in relation to the perceiver and his expectations to enable the perceiver to take meaningful action. It involves proactively seeking relevant information, making important information available, filtering information that is meaningless, creating new information, and off-loading cognitive processing onto the interface or adapting the interface to support monitoring.

Let's make sense of that in relation to Airplane Upsets. Firstly, sharing our mental model with our colleague allows them to effectively monitor us. Saying I'm going to fly an ILS to runway 26L doesn't really cut it. Your PM should have an idea about how you are going to fly this approach, what are your gates in regard to speed and config etc and where do you see the potential threats coming from. That way if they see you deviating from this plan they can probe as to why and pick up any potential errors early before an undesired state gets a chance to develop. Put basically, a good sharing of mental models.

Active monitoring in regard to upsets involves keeping track of the operating environment, energy state and flight path trajectory creating expectations about future aircraft states. In other words, keeping ahead of the aircraft as both PF and PM.

The causes of upsets can be broken down into 3 areas. Environmentally induced, systems-induced and Pilot-induced.

Environmental conditions tend to be either air mass related or from wake turbulence. Air mass refers to Turbulence through CAT, Mountain waves or windshear as well as Thunderstorms with their associate microbursts and Icing.

Something to remember about mountain waves is that although we tend to associate the turbulence from them with the visible lenticular clouds, they may also be present in air too dry for cloud formation.

Another little bit of trivia for you is that approximately 5% of all Thunderstorms produce a microburst. While this may seem a relatively small number it is also very important to remember that if encountered, some microbursts cannot be successfully recovered from using any known techniques.

Icing will lead to a large degradation in airplane performance if allowed to build-up on airplane surfaces. Ice tends to accumulate over time but in areas of severe icing it can be very quick indeed. Unexpected handling characteristics can be expected with ice build-up hence the phrase clean surfaces being very familiar and of utmost importance to us as the operating crew. Flights in freezing rain, freezing drizzle or certain mixed icing conditions may encounter water droplets larger than those defined in certification criteria and are referred to as super-cooled large water droplets or SLD. An SLD encounter may rapidly exceed the capability of ice protection systems seriously degrading the performance and controllability of the airplane.

To the final environmental factor and a very important one. Wake turbulence is involved in the largest number of documented upset events. An encounter usually results in a rapid but short rolling or pitch moment and quite often it is a crew over reaction to this that then causes the resulting upset condition. Environmental wind is your friend when it comes to vortex dissipation here so be particularly mindful of this under calm conditions and never feel rushed into a take-off clearance or too keen on a short cut if you think separation may be compromised.

As a reminder the 737 is a medium category aircraft so on departure from the same position we need 2 minutes from a heavy or 3 minutes from a super heavy. Remember these times differ for intersections so please refer to your manual in that case. For arrival without a displaced threshold, we are looking at 3 miles behind another medium, 5 behind a Heavy and 7 miles behind the Super. Some states apply a higher category for the 757 so please be sure to know your rules!

Thanks Mark, a good little reminder for all of us. The second area Mark mentioned was System induced upsets. These can be from flight instruments, Autoflight systems and flight control and other anomalies. In our training we're taught how to overcome or mitigate against the impact of single or multiple system failures. We should remember that Airplanes are designed to make sure we have at least the minimum information needed to safely control the aircraft. It still stands though that past accident reports point out that pilots are not always prepared to correctly analyse the situation and an upset can develop. Here is where active monitoring is of upmost importance.

The automatics may mask an upset situation developing as they try to control the airplane within their limits. Once those limits are reached the AP could well throw the airplane back to you out of trim and in an attitude you weren't expecting if the system wasn't being monitored.

Complacency with autoflight systems and their reliability can lead to upsets with a typical example being an unnoticed autothrottle failure leading to low-speed upsets and sometimes accidents such as the Turkish 737 at Schiphol in 2009. Perhaps a podcast for another day.

Flight control anomalies such as flap asymmetry can quickly lead to a divergence and, unlike most system faults could require immediate pilot action.

Pilot induced upsets could result from a misinterpretation of the instruments perhaps from lack of instrument cross check, or from a lack of understanding of what the outcome will be of a particular input especially if it's reactionary, unplanned or excessive.

Inattention and complacency could be a factor as well as distractions or pilot incapacitation, especially if it's subtle. Failure of a crewmember to respond to a second request or a checklist response is cause for intervention.

Vertigo or Spatial disorientation can also cause pilot induced upsets and a knowledge of when these effects are more likely to occur can help to mitigate the threat, but we can't eliminate this one. Again, active monitoring is our best defence, and the communication of our mental models is vital. The old adage of Aviate, Navigate, Communicate is a great back up at all times and applies here too. Fly the Aircraft using instruments, point it somewhere you want to go, and talk to your colleague to see if they share what you see.

Other things that can come from us as pilots is the misuse of automation, perhaps due to a system knowledge issue and that overcontrolling we can sometimes be susceptible too that leads to Pilot Induced Oscillations. We can cause this in an upset recovery if we react with large rapid inputs before determining what's actually happening.

Now we'll take a look at flight fundamentals for pilots. This is a recap of our knowledge to help us understand the aircraft and the environment we operate in. I hope it's not like teaching you to suck eggs, but I know that I personally need reminding of these things from time to time and it's usually from a frowning TRE!

We have three sources of energy available to us to manage or manipulate the flight path. Those who understand the airplane energy state will be in a position to know instantly what options they may have to manoeuvre and therefore manage the trajectory.

Our three sources are Kinetic – which increases with increasing speed, Potential – which is proportional to altitude and Chemical which is from the fuel in the tanks and can be converted to thrust.

We can trade these energies around. Airspeed can be traded for altitude, kinetic to potential or vice versa, and Thrust can be traded into airspeed and or altitude, chemical to either kinetic or potential.

Our Kinetic energy is always in need of replenishment as it is continuously expended in the process of generating the aerodynamic forces acting on the airplane which result in controlled flight i.e., lift and drag.

This energy management as we like to call it must be accomplished with a view toward the final desired state which always involves keeping the aircraft within operating limits.

When we are in an upset, we must recognise that the process of controlling the forces to produce a new energy state takes time with the amount of time a function of the mass of the airplane and the magnitude of the applied forces.

When we know our aircrafts flight envelope we know where we should be operating it. OEM and test pilots have evaluated the characteristics of our aircraft including inadvertent exceedances to demonstrate that the aircraft can be returned safely back to these envelopes. So, let's talk about some of these exceedances starting with Angle of Attack and Stall.

Going back to ATPL theory days the lift we produce is a function of speed, density, wing area and Angle of Attack. Angle of attack is of course the difference between the chord line of the Airfoil and the relative airflow. As angle of attack is increased, lift increases proportionately and generally linearly up to a point. Swept wings like ours stall at higher angle of attacks with a flatter coefficient of lift curve compared to the straight wing. Remember that curve? If not google it when you get the chance!

The critical angle of attack is the angle of attack at which the stall occurs, and we need to remember that this can occur at any aircraft altitude, attitude or speed on our PFD as we don't necessarily know the relative airflow.

We can recognise a stall by the following. Buffeting which could be heavy, a lack of pitch authority, a lack of roll control and the inability to arrest decent rate. We of course have aural and tactile warnings in the 737 but these are generally an approach to stall warning rather than the stall itself.

Should any of the above occur then it is vital we perform the stall recovery memory items from the QRH which we will leave you to read at your leisure but of course involve reducing that angle of attack.

Back to Upset prevention and recovery now. All transport aircraft, including the 737, demonstrate positive static stability. In other words, they have a tendency to return to an undisturbed state after a disturbance. This is why we as pilots must not arbitrarily react before analysing a situation and also why you see the very important first line in the QRH before recovery actions for each upset situation is "Recognise and confirm the developing situation".

I'm not going to go into what flight controls we have to control pitch, roll and yaw as I think we're all up to speed on that, but I think something about the rudder is worth mentioning here. Airplanes are certified to withstand a full-scale rudder deflection from neutral, in one direction. However, reversing the rudder from one direction to the other is not considered and can result in excessive structural loads, even at slow speeds. Rudder limiters do not protect against structural loads or excessive sideslip angles that can be generated from reversals.

We must be aware that rudder on Transport aircraft is not intended to be used as a primary roll control. There is the caveat here that when all normal means of roll control have been unsuccessful very careful rudder input in the direction of desired roll should be considered. Again, remember how powerful the rudder is on the 737 and it should never be used as an initial response for events such as wake turbulence, windshear or to reduce bank angle during any upset including a stall event.

An understanding of load factor is critical to properly understand the mechanics and performance of manoeuvring flight. Load factor is a measure of loads on the airplane structure and is referred to in terms of acceleration of gravity, or "g" value.

When the wing is producing lift equal to airplane weight, we refer to this as 1g. When we manoeuvre load factor will be greater of less than this. In a pull up lift produced is greater than airplane weight so load factor is greater than 1.

In a turn we reduce the vertical lift vector so would be producing less lift than the aircraft weight leading to a decent unless we increase that vertical vector by increasing overall lift. This means we are producing more lift overall than airplane weight so we have a load factor greater than 1. On the 737 at bank angles greater than 67 degrees it is not possible to maintain level flight within the AFM load factor limits.

Load factor itself has an effect on stall speed. It will cause the stall speed to increase by a factor equal to the square root of the load factor. For example a load factor of 2 increases the stall speed by about 40%.

As we spend most of our time operating at high altitudes, we'll take a look at aerodynamic principles up there. Aerodynamic principles become particularly significant in respect to upsets above FL250.

At high altitudes high mach numbers exist at relatively low calibrated airspeeds. At a constant airspeed elevator deflection at 35,000ft will result in a higher pitch rate than the same deflection at 5,000ft because there is less aerodynamic damping due to the decreased density aloft. For a given pitch attitude, the change of rate of climb or decent is proportional to the true airspeed. So, for example at 290kts at sea level a pitch attitude that gives 500fpm will generate about 900fpm at 35,000ft where 290kts will give you an approximate TAS of 490kts.

This is why smooth and small control inputs are required at high altitude, particularly when disconnecting the AP.

I'll take you back to another graph from days gone by now and that's the L/Dmax graph. If you don't remember it it's the U shaped one with the diagonally decreasing thrust line through the middle that we don't want to be on the backside of at altitude. Basically, if we get a disturbance when on the backside of the curve that reduces speed, that speed will continue to reduce unless we add Thrust. At high altitude we can be very thrust limited so our only option to get on the right side of the curve again could be to use that potential energy and descend. This disturbance could be from changing winds, increased temperatures, turbulence, icing or auto throttle malfunctions to name a few or we could have got ourselves there through perhaps inappropriate use of high v/s values at altitude.

Now that we have refreshed the knowledge on how airplane upsets are caused and the aerodynamic principles behind them, we are armed with the knowledge for intervention. There is an infinite number of situations that we can experience when flying so techniques were presented that are applicable for most thought of situations.
Firstly, as we've already mentioned we must become situationally aware of the upset. What altitude are we, what attitude? Communication between crew members is vital, both pilots should announce what is being observed using primary flight instruments.

For a nose high upset we would normally see airspeed decreasing, altitude increasing and the VSI showing a climb. For a nose low we'd expect the opposite. The different colours for sky and ground are a useful check too and a cross check of the standby Attitude indicator and PM's instruments would be prudent to confirm the situation.

The situation analysis process is to Assess the energy, Confirm the airplane attitude and communicate with the other crew member which is what the first line of the QRH refers too.

Upset training in the simulator has its recognized limitations with the ability to replicate startle factor, g loads and environmental conditions challenging. However, as long as simulator training envelope limits are not exceeded the control loading responses and instrument indications should accurately replicate airplane responses.

During recovery use of full flight control inputs may be required but it is critical to guard against control reversals as there is NO situation that will require rapid full-scale control deflections from one side to the other.

We must also be prepared for perhaps counter intuitive factors such as pushing the nose down to unstall the airplane when it's already in a nose low attitude.

Other threats to us in an upset situation could be a reversion to previous type training and the possibility of a secondary upset if we don't make sure we return our aircraft back to its desired state before we start any form of diagnosis.

Recovery techniques for the 737 are based on Nose high and nose low upsets. If the airplane is also stalled it is necessary that we must first recover from the stall by applying and maintaining nose down elevator until stall recovery is complete and stick shaker stops.

For Nose High recovery the Manoeuvre section states that both pilots need to "Recognise and confirm the developing situation" and then PF will disengage the autopilot and autothrottle and then recover. The recovery states Apply nose down elevator. Apply as much elevator as needed to obtain a nose down pitch rate. Apply appropriate nose down stabiliser trim, with a note that excessive use of pitch trim or rudder can aggravate an upset, result in loss of control, or result in high structural loads. Next bullet point is Reduce thrust followed by the next being Roll (adjust bank angle) to obtain a nose down pitch rate with the same note as before attached. These actions are to induce that nose down pitch rate and use of elevator may be enough by itself or you may need to continue down that list dependant on the situation.

PF's actions continue with the section, Complete the recovery. Here PF is to, when approaching the horizon, roll to wings level. Next, check airspeed and adjust thrust and finally Establish pitch attitude.

During this PM is to Call out attitude, airspeed and altitude throughout and verify all the needed actions are done and call out any continued deviation.

For Nose Low Recovery, again both pilots are to Recognise and confirm the developing situation.

PF will the again disengage the AP and AT. Recover involves. Recover from the stall if needed. Roll in the shortest direction to wings level. If bank angle is more than 90 degrees, unload and roll with the same note attached as Mark just mentioned. Next comes the complete the recovery section. Here it states Apply nose up elevator, apply nose up trim if needed, same note again and adjust thrust and drag, if needed.

PM's actions are the same as for Nose High.

I'll try and summarise some of the key points I took onboard here. A pilot who is aware of the energy and flight path is less likely to be startled and therefore more likely to deal with the situation with controlled inputs. We must be aware of where we are in the flight envelope for us to use appropriate control inputs. If we exceed critical angle of attack the surface will stall regardless of speed or attitude. At any speed large aggressive control deflection reversals can exceed structural design limits. If we get into an upset, we must recognise and confirm the situation before initiating recovery. Altitude cannot be maintained and should be of secondary importance. In regard to training, emphasis should be put on avoidance and the importance of active monitoring. We should always recover from the stall first and excessive use of pitch trim or rudder may aggravate the upset and result in high structural loads.

I hope you all enjoyed this and there is a really good app available called AUPRTA with even more information available about the extensive research done in this area. We'll be back again soon with another episode but in the meantime head over to our social media pages and keep the talk going.