Boeing Training Session #2

Held at KSFO,
December 2005

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Welcome everyone to tonight's session, a further discussion of Boeing systems. As always, if you have any questions, on any Boeing operation, please feel free to ask at any time.

The APUs

One thing that I will mention, straight off the bat, is something I was asked this week, when to use external power, and when to use APU - at the gate. It is customary to run off external power until approx 10 mins before departure just before loading the FMC. The reason for this is so as there is no additional fuel burn, and also for safety, to leave the APU off for as long as possible to limit fire risk.

We put the APU on, 10 mins before departure, as the electrical supply is much cleaner from the APU - than from the ground cart, which can fluctuate. There is nothing worse than setting up your FMC and losing power from the cart. Every carrier has its own preferences, and I can only talk from our SOPs really and my training - but I think every carrier will go to APU before setting up the FMC.

There are a number of types of APU, and I will quickly mention them whilst we are the subject. Have any of you heard of an APU-PACK departure? In the tropics, some airlines will keep the APU on for departure, using the APU to power the PACKS for air conditioning, so as there is no loss of thrust. At 10,000ft the engines are then transferred back to the PACKS. This is called an APU-PACK departure, it is very often used in the 767 for example.

There is a "gotcha" on the latest version of the 747-400 in that the APU cannot be started when airborne. If the wheels up sensor is triggered, the APU is inhibited! It can be kept on up until 28000ft if started on the ground, but no air start at all!

So the use of APU in the 747 apart from gate power is limited to an APU-PACK departure. The reason is that the engines on the 747 are deemed to have a very strong windmill, so even if "dead" they are able to turn freely to generate electricity and of course there are 4 of them, so losing them all is very unlikely. So it was decided on the 747 to allow the engines to windmill for electricity, or to have one of the running engines support power.

This is very different to a 767 which allows high altitude APU starts. Many people with the PMDG 747 reported bugs that the APU wouldn't start in the air, not realizing the aircraft conforms to the new Boeing standard. Despite not being used in the air, the 747 has the most powerful APU of any aircraft.

Those of you flying the LDS767 can start the APU up to 35000ft, to replace a failed engine output. The 767 has a special edition APU, made by Garrett that is tested at high altitude and also to be fire resistant. It is said that the APU can contain a fire for up to 4 hours, long enough for an aircraft to reach an alternate airport. The standard APU on the classic 737s only gives one hour of protection.

With the NGs, many have a specialist APU, and that is one of the reasons that the aircraft could be certified for oceanic flight.

OK, what about an INOP APU. It is prohibited to fly oceanic ETOPS sectors, but domestic flights can dispatch without a working APU. Many years ago an APU failed on me and we did a gate start on external power. The Boeings can have their engines started that way without APU, but again, this is not allowed for oceanic flights and many airlines prohibit this in their SOP anyway.

For those of you with the 747 you will notice that there are 2 APU gen switches, cunningly named, APU GEN 1 and 2. The 747 APU is like two separate APUs in one unit, if one gen fails, the other is an independent system. Under normal ops, we have GEN1 power the left side of the aircraft, and GEN2 the right on the ground, but on one GEN we can power the whole aircraft from that generator, if there is a failure. As such, it is very rare for the APU system to fail a 747.

But here is what impresses me with the power of the 747 APU, unlike any other aircraft - it can power air conditioning and still start all 4 engines simultaneously. The APU actually generates more power than both engines together on a 737-300.

Again some people think it was a bug in the PMDG 744 that they could start all engines with the PACKS on at the same time, but this is indeed done by some airlines, Lufthansa starts all 4 engines at the same time as part of their SOP, and the APU doesn't even flicker the cabin lights despite that load! The downside is that the 744 APU is a gas guzzler, about the equivalent per minute of five family cars traveling on a freeway for an hour at 70mph or up to a couple of thousand pounds per hour.

This is one of the reasons we try not to start the APU too early, depending on load, so we leave the APU until we get to the electrical critical part of operations as mentioned previously.

If we expect gate delays we factor extra fuel too. Here is a good tip for those of you who sometimes find themselves at the gate a while. On all the Boeings, when running the APU for some time, you will notice that it drains the left tank. So open your crossfeeds - and the tanks will stabilize, otherwise you will find an imbalance. If that imbalances exceeds 4000lbs on a 737, the aircraft is unstable in the air.

So if you expect more than 30 mins at the gate, open the feeds and keep your tanks balanced. My final point on APUs is interesting. The fuel pumps need electricity, the APU generates that electricity with the engines off, but needs fuel itself. So how does the APU start, if it needs fuel, and there is no electricity until it is on? All Boeings have a gravity feed tank, so the APU can get fuel even without power to the fuel pumps, there is a special feed from that tank to the APU.

So even with a complete electrical failure we can start the APU, even with the fuel pumps unpowered. On many of the Boeings you can also start the engines with the fuel pumps in the off position. There is an emergency circuit that generates a system warning if you start with pumps off and diverts gravity fuel, although this is not recommended. Being gravity fuel, it comes from the bottom of the tank, and has the risk of being sludgy.

The normal feeds higher in the tank have filters, but this is why you can start aircraft such as the PMDG 737 with the pumps off! Ok that's it for APU.

The PACKS

Those of you with the 747 tonight will notice that you have 3 PACKS aboard, and to answer the common question, PACK means pressurization and air conditioning kit. All the Boeings have either 2 or 3 packs.

Each PACK pressurizes the aircraft, maintains the airflow through the cabin and sets the temperature. On all of the Boeings each pack is separate, so if one fails, the other should be unaffected. The 747 is particularly safe with 3.

The aircraft can manage an entire flight on 1 pack quite safely, even a long haul 14 hour trip, so each Boeing has double or triple redundancy. For those of you with the 747 overhead tonight you will see the PACKS are normally in the NORM position.

At 12 o'clock, to the right of that position is A and B positions. This is further redundancy, the pack has two controllers. So if a PACK fails it can switch to either controller A or controller B, and very often function on the other controller.

This in effect gives almost 6 packs to the 747, and 4 to the other Boeings. Each aircraft can fly on one, so if one fails, we try position A and B to see if we can function on the backup controller. There is special internal logic, this internal logic automatically swaps the controller after each touchdown and cycles between A and B to give equal wear and tear. You can see this on the 747 lower EICAS where it will signal A or B, so you can see the active controller. In many hundreds of oceanic flights I have only ever lost a pack once, the number 3 pack coming home near Iceland. 1 and 2 continued to function normally, and passengers and FAs were not aware. Of course were all packs to fail, we would depressurize rapidly requiring a rapid descent to 10,000ft or below.

There is system logic on the 744 and 767 that if the software detects loss of all packs, oxygen masks deploy and flow without pilot request.

When we plot our 3 hour diversion from airports, to meet ETOPS requirements, this is the greatest thing we have to consider. Many people think loss of an engine is the biggest problem, but actually it is the loss of pressure. Because of having to fly so low our fuel requirement increases dramatically - and taking the 767 for an example, we burn more fuel with 2 engines at low altitude, than with 1 engine at high altitude - we can happily make a diversion on one engine.bBut we have to really nurse the plane to make a diversion with pressure loss even with both engines running normally. This is something I have only done on the simulator and it is quite challenging

The PACK has two independent circuits that drive each PACK, although with only one air feed to each pack. If the pneumatics are intact, a change of controller will often rectify a failed pack. Obviously if the airflow is lost to the PACK, this will not help, but if the pneumatics are fine then the other controller essentially is a whole new pack. On my flight, the PACK I lost was due to a failed pneumatic feed to that pack, as a seal broke, thats why I was unable to use A or B and lost the use of the PACK as the air was not getting there. But in over 80 percent of pack failures, it is electronic - so it is rectifiable with a controller change.

Each engine bleed also has its own pneumatic duct, so even if you are down to one engine you will get air. On the 767 you can also use the APU to provide the air at high altitude, and as mentioned before, the 747 will windmill so there are many sources of air into the system which is shared amongst the packs. Thus, the chances of losing all air, and all packs is virtually zero. The problem with the 737 recently in Greece where they lost cabin air is believed to have been a maintenance issue - where the packs were not refitted properly after a service.

For the 747 we keep all the air valves open at all times - but what we do is just press two packs to OFF for engine start. As mentioned before, we could actually start with all packs but this saves some stress on the APU. So all bleeds are always left open. The 744 has much cleverer systems logic which allows all air to be open, and its cleverer than me.

We also use an APU bleed air switch which drives air from the APU for engine start. On the 744 we also leave this switch permanently on, even if the APU is off. On other Boeings, using APU bleed air and engine bleed air gives a "dual bleed" error. The 744 however, detects which air supplies are currently connected, and even if it is all 4 engines and APU, will work out which is best to use and use the appropriate one. So the pilot need never touch air switches and valves unless a failure occurs.

The mentality of the 744 is "quick scan" - leave everything on and only worry if something is off or amber.

Starting first with the 767 as a comparison, the duct pressure is fixed, and drops at engine start, when there is required air. On the 744 there is a special controller, and the controller senses that there is no engine start and just gives the pressure it thinks it needs for PACKS. Then when engine start is sensed, the system uprates the pneumatic output. So you can see a rise in pressure, depending on the load. This can vary, the controller matches the load requirement, but in real terms it takes about 1/5 seconds for the load sensor to make the change.

If there is insufficient duct pressure for all the engines and packs, the system will close down all but one engine, and then use all air to start it. This is fully automatic, and only happens if there is a low pressure failure. The autostart system will make three attempts to start the engine with various pneumatic configs before calling it a day and giving up.

So the minimum air, is actually dependent on load requirements on the day, and we can sometimes start an engine with 22PSI or so, but usually this is in the 40's. The 744 has a full autostart system with an autostart switch on the overhead.

The Hydraulics

The 747-100 has air driven pumps to operate leading edge flaps, the question was does the 744 still have this?

Well, it is cleverer than that. If you are sitting in a 744, go to the EICAS hydraulic page.

Shutdown engine #1 and you still get hydraulics. You will see there EDP - engine driven pumps - which are driven as the name suggests by the engine . But you will also see a secondary line to each system they are demand pumps. Those demand pumps are electrically driven and kick in if the engine air driven pumps are off.

This is fully automatic, you can also have one engine power all 4 EDPs. So that means flap transit can be commanded by any engine, or the electrical demand pump. The demand pump will also kick in automatically if there is a high hydraulic demand to save wear and tear on the EDP.

So if you are in the air on the PMDG, and drop flaps and gear at the same time, you will see both the EDP and demand pump lines go green temporarily. The electrical demand can get its electricity from any engine, from the APU, or even the ships battery.

And if all that fails, there is standby hydraulic sourcing with the alternate flaps systems. I think you will agree, the smartest aircraft in the business. The 777 or even the new 380 doesn't have that as they kept the costs down on equipment. You can even drop gear using gravity latches. The PMDG models all these systems fully.

Whilst on the 744 hydraulics you will see on the far right of that eicas page on system four, the aux line. Before pushback we put hydraulic 4 into AUX using the overhead rotate switch. This is the only line that has an aux and what happens is that it releases pressure on the nosewheel for pushback control. So the aircraft must have 4 on aux for pushback and then back to norm after engine start.

Aux 4 will be fed by a number of systems, picking what is the best available at pushback.

As an aside to the flaps - you will also spot, if you look in the fuel EICAS that as flaps go to 10 or above, the fuel pumps reconfigure automatically, to give each engine its own tank to give maximum fuel safety at takeoff. As flaps come back from 10, then the fuel tanks readjust themselves back to the previous setting.

The autoflight system will also configure itself, to current hydraulic status etc, and will offer a type of autoflight appropriate to equipment. So with certain hydraulic failures etc, the system can block autolands.

The idea being with a major system failure, they want us to fly the plane ourselves for maximum safety and control even if the system does not always directly affect the autopilot.

Ice

Back to the overhead, I was asked about icing recently. The rules for any Boeing are this: if the temperature is 10 degrees C or below, AND there is precipitation (ie clouds or rain) then anti icing must be used. Engine anti-ice stays on, wing anti ice is prohibited on the ground.

In some versions of the 747 the switch will not function groundside, the ground sensor on the gear blocks the function. The reason for the disable, is that air is diverted from thrust over the wings so thrust can be lost on takeoff. Some aircraft such as the 767 are slightly different - there are 767 versions where wing anti ice can be used during taxi, but again, must be off for takeoff. Ditto for the 737. Think of engine anti-ice as always on in these conditions. The wing anti-ice being used in short bursts as needed and not in the takeoff phase.

IRS

OK, I was going to finish with the IRS, the inertial reference systems. These are becoming less and less important in the days of GPS. The 747 has three IRS systems, 3 GPS systems, and 3 radio tuners and mixes

these to find the current location. When I say 3 radio tuners, these are separate to the ones you tune for your VORs. They are invisible to the pilot, but are used only by the FMC for position. Over the water, we cannot obviously tune VOR stations so the aircraft relies on GPS. But, the law states that we cannot assume that GPS will always be available so it is mandatory to use IRS on all oceanic flights regardless of GPS reception. In the modern Boeings, the IRS operates using a series of laser gyros. The laser signals are reflected around the aircraft, and the motion of the aircraft in any axis is detected by the laser signal being deflected at a slightly different path. So this means that IRS is completely independent of any external source.

The theory being that if you have IRS, you can always find your way home. We align the IRS at the gate, what this does is synchronize all the lasers to a "home" position. The system can detect true and magnetic north and synchronizes. We give our current gate position to the IRS receivers once synchronized, this is then used as a start position . Whilst synchronizing we cannot move the aircraft as this knocks the lasers from their base position. This normally is a ten minute process. If you move the PMDG 744 for example, you will get a warning of IRS MOTION and you have to restart the process if incomplete.

This is especially annoying if a little nudge happens when they connect the ground truck. We try and tell them not to hook up whilst we align.

Further, engines must be off, officially, vibration can throw the synchronization out . On the 747 we have 3 IRS receivers which we prime from the FMC pages. Again, triple redundancy, we can happily fly with just one. In fact in most cases the IRS is ignored by the system and the GPS is master. You will see on the PMDG 747 for example, GPS and then IRS written underneath it. This order is important, it means the GPS is master. We can run the other way around, with IRS shown above and then IRS is in charge of the navigation. You will find pages in the FMC, in the PMDG as well as the real plane, to switch off the GPS as master. This is rarely used.

The IRS also drifts over time as the motion sensing is not completely accurate. So on a transatlantic flight we can lose 5 or 6 miles. With aircraft such as the 767 that doesn't have GPS, this can be an issue. We then have to confirm when we get a VOR in range of land. Luckily for 747 pilots, the system software detects the drift and uses the GPS to readjust the IRS coordinates in flight. This is called GPS updating.

So on a long haul you will land with IRS accurate, and again, even on the PMDG you can see the update happening on the FMC pages if a drift occurs. The 747 has the best of everything.

This is the only aircraft that has 3 IRS and 3 GPS as standard . Yes, the GPS automatically fixes IRS issues, and the GPS auto primes itself on power up of the aircraft. We never have to give the GPS a position or touch it at all, in fact it is not directly accessible to the pilot. We can only see the GPS pos through the FMC pages.

An IRS unit can only be realigned on the ground. If it fails in flight, or is switched off, it cannot be reset in the air. It can be put into ATT mode only which gives basic heading information.

The earlier 747s that use INS are less reliable. INS is different from IRS, INS uses mechanical gyroscopes not lasers. Each will drift, both laser and mechanical, laser is obviously more accurate. You can lose 30 miles on the old 747s on a long haul. But in terms of drift rate, each unit drifts of its own accord, and not always to the same rate, it just depends on the build quality of the unit. But with IRS with GPS support the GPS always sees this and fixes it, it can adjust back by 1.5 miles per minute. So if we dispatch say with an error in position because we enter the wrong base location, the aircraft will finally fix it. This has a very handy use. At most airfields we prime our location with the gate position which we get from a reference book, but some third world airfields

don't publish this to such detail for each gate, and just publish a single position for the airport Which is dead center of the airfield. But we can align with this, and know the GPS will bring it back to accurate as we get underway. This is why in the FMC pages you will see an entry for airport, this brings up that generic airport position. You can enter this in the PMDG too, and watch the GPS fix the accuracy - we always have this base position in our FMC for all the airfields we visit, so even if we cannot get a gate reference book we can align and easier still, we just copy the GPS position straight into the IRS.

The IRS knobs have 3 positions. Flick them to NAV, then enter in the FMC page, you must do this within the 10 minutes, or you have to restart. You can enter it first, but this slows alignment with an extra integrity check. Don't put your IRS into the align position! Most people think that is where it should go, instead pass through align, from off, leaving it at NAV.

The aircraft aligns fully in the NAV position. The align position is used for a quick realignment, which is sometimes used as a quick and dirty align. To use quick align there must already be a position aligned previously and you must already be in NAV.

We flick from NAV to align for 2 mins and back to NAV again, just as a temporary realignment if a problem occurs. But for full alignment always in NAV. Above 72 degrees north the alignment takes up to 20 mins rather than 10, as alignment is slower due to the earth's rotation being slower. The software detects this and adjusts accordingly, the PMDG mirrors this also.

One other issue, you will find that you need to enter the GPS position twice. It's a backup check if the aircraft has been moved since powerdown. If the last pos is still thought of as valid, you get asked once only, entering it twice the aircraft compares the two entries as a safety entry check.

On IRS drift. If the IRS wanders from position, and the FMC uses this to draw its flightplan, and the magenta line the aircraft follows drifts by the same rate of drift, then your line of flight is inaccurate. We check this in 2 ways.

First, in a GPS equipped aircraft, such as the 744 you will see a POS button on the glareshield. Pressing this button will give you a graphic of the current IRS position and GPS position. You see a dumbbell type shape for the IRS position and three stars for the GPS. If these are all in the same place, you are good to go. If the IRS dumbbell is not on the nose of the aircraft, it means that there is a problem and that there is a mapshift error from the IRS. Those of you with the PMDG can press this button and see this display. That is the first check for map integrity.

Second, what we can do with or without GPS is to use VOR receivers to check where we are. We put a VOR in the fix page, and that is drawn on the map on your navigation screen. Then use your nav radio to tune the VOR. The VOR in the fix page is calculated by the FMC not tuned, so it is drawn based on where it thinks it is based on current position. The tuned one is real raw data and you know you have a map shift if the FIX VOR and the tuned VOR don't draw in exactly the same place.

The 744 also has an extra test built in. It is able to autotune a VOR radio for its own purposes. And it tries, if it can, to tune the next two VORs in the current flightplan and it puts a VOR symbol on the screen. So if you have a flightplan waypoint that is a VOR, and it tunes the VOR, you again should see them both in the same place. The tuned VOR sat above your waypoint on the display, one drawn from raw data, one drawn from the leg in the legs page - so again we see if the two positions do not match

So this technique with the POS and the VORs allow us to check map integrity. We do these before flight as a checklist item. In flight, we check once an hour on the POS button, which gives us the IRS and GPS position.

Thanks everyone, that is a wrap!

