X-Plane 10 to 11
Boeing 777-300 Extended Range
For Version 0.35.0 (Early Development)

Full Manual & Documentation

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Freeware Product – Do not redistribute*

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PLEASE READ THE INTRODUCTION (P. 5)

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KEY:
GREY chapters are documentation – **not yet implemented**.

Introduction

Thank you downloading Chai112's Boeing 777-300ER.
I, Chai112, author and developer of the product, wish not to claim the design of this product as my own. I have created this product simply for entertainment purposes; the product has been distributed freely from X-Plane.com by Chai112. If you have not downloaded the product from Chai112 or have seen another download of this product without reference to my name, please contact me at

http://forums.x-plane.org/index.php?/profile/520176-chai112/

We highly urge you to read the whole of this manual to maximize your experience with this product – we have designed this product with realism and intuitiveness in mind.

There are two section to this document
Section 1 & 2 are the manual, which describes the product
Section 3 & 4 are the documentation, which is an outline for future reference.

This manual is a combination of everything you need to know about this product.
The charts, specifications and guidelines in this manual will be explaining how you may use this product to it's full extent but is only a simplification and alteration of the real Boeing 777-300ER's guidelines to reduce confusion and complexion and ensure an intuitive gameplay mixed with a high level of realism.

This, as a product is not close to the actual Boeing 777's complexity. Though for the technical and flying characteristics, we strive for mimicking it as closely as we can.

Chapter 1.0 – Getting Started

Section 1.1 – In the Real World

In the real world, the Boeing 777-300ER is manufactured by Boeing, a large and well known aviation company.
The Boeing 777-300 Extended Range is the second longest commercial aircraft in the production to this day, just a few feet shorter than Airbus' A340-600, the longest jet ever. Ever since it's launch in June, 1995, it has been a real money maker for both airlines and Boeing. It's a wide body, twin engine aircraft (this is the GE engine variant) boasts an 8,555 nautical mile range whilst having the ability to carry 350 passengers. It's system and fly-by-wire capabilities are complicated but intuitive to ensure the safety of passengers riding on-board it.

Section 1.2 – An Exterior Tour

Many days have been dedicated to perfecting the exterior of the aircraft. All of this is made with HD, 2048x2048 textures. These details really separate the ordinary freeware aircraft from this one.

Here are some things to look at –

- All ten passenger doors and two cargo cargo doors can be opened. Even the emergency ones!
- Smooth flap deployment
- Smooth slat deployments
- Smooth spoiler deployments
- Working flight controls
- The RAT (Ram Air Turbine) can be deployed – it's a tiny fan to power the aircraft.
- The wings will flex accordingly
- Detailed gear and gear doors
- Chocks to lock the gear

  Realistic rain stains on the wings, flaps etc.

Section 1.3 – An Interior Tour

Just as much effort has been put into the interior – perhaps even more. You could take a stroll around the economy class and feel just as tightly packed as the real one! I've used Boeing's recommended seat arrangements (three-class) as they provide more room than some airline's.

Here are some things to look at –

- Detail & baked textures – looks realistic!
- Seat designs & patterns may be changed according to the airline/livery
- Some blinds are lowered to add a sprinkle of realism.
- Overhead rests (upstairs!) for the pilots and flight attendants
- Objects will be less detailed the farther the way you are, allowing models to be very details whilst doesn't lag your computer

Section 1.4 – Aircraft Services

This aircraft, unlike many freeware products, has vehicles to 'service' the aircraft while start-up & boarding. Some of these do nothing (e.g. galley service vehicles) while some do (e.g. AC unit). Timetables will be specified in section 2.4, services.

Here are some things to look at –

- Ground Power Unit (Provides ground power & air)
- Air stairs
- Fuel Truck (They actually do nothing; you should use the fuel & balance menu)
- Container Trailers
- Container Cargo Loader
- Galley Services
- Potable Lavatory Water Truck
- Cabin Cleaning
- Emergency Fire Vehicles (They extinguish both engines and deploy emergency slides)

Section 1.5 – Graphics Recommendations

Of course, this aircraft can be run using any graphics options. Here's my recommendations if you want this aircraft to look superb yet doesn't set your computer on fire.

1.5.1 For slow computers – (20-30 fps)

I would make sure the 'shadow detail' is set to overlay, especially if you're going to use the cockpit view – it just disables shadow casting on objects which means that the 3D cockpit items will not be included in the shadow mode. Of course, HDR should be off – it is very GPU intensive and the textures doesn't really matter, the textures are set so that they are *always* HD. Don't forget that if you turn traffic to off, it will significantly increase your framerate. FOV should always be set to 70˚-90˚.

1.5.2 For normal computers – (30-60 fps)

Shadow detail should be set to 3D shadows as that allows shadows to be cast on objects. It really allows for realistic shadows but takes a lot from the GPU. HDR could be turned on. FOV should always be set to 70˚-90˚.

1.5.3 For fast computers – (60+ fps)

Shadow detail could be set to global – I find that you should set it to 'medium' or higher. HDR and anti-analysing should be on. FOV should always be set to 70˚-90˚ though I would recommend using multiple monitors (if applicable).

Section 1.6 – Add-on Recommendations

With so many add-ons to choose from, here are some add-ons that would contribute to the 'realism' of flying. I cannot pre-install these add-on due to copyright issues but I have provided links to them. All of these are free so don't worry!

- X-FMC (Provides realistic FMC support – just like the real deal)
-
- HeadShake (A must have – it adds head movements which makes everything more realistic)
- X-Passenger (You could serve them food and let them complain!) - http://forums.x-plane.org/index.php?/files/file/18692-xpassenger/

1.6.1 X-FMC

This add-on will replace X-Plane's default FMS with a more realistic and powerful one. It introduces a wide range of features found in Boeing's FMS including VSPDs, fuel calculations and etc. Although it does not fully simulate a Boeing 777's FMS, it is very close to one and is a great improvement to the default FMS.

https://www.x-fmc.com

1.6.2 HeadShake

Not only is this plugin great for this aircraft, it can be used with every type of aircraft; from a GA plane to a fighter. It moves the camera around in a realistic manner when affected by G-forces, touchdowns, turbulence and many other factors.

https://www.simcoders.com/headshake/features-and-download

1.6.3 Passenger FX

With many cabin noises & announcements, it adds a whole new level of realism.

http://forums.x-plane.org/index.php?/files/file/38625-passengersfx-adding-realistic-passengers-to-your-aircraft/

Section 1.7 – Installation of Aircraft

1.7.1 Installing Aircraft

First, find your X-Plane folder. Just do a search for X-Plane and select the folder. Make sure it has the 'X-Plane' app in it with folders like Aircraft, Airfoils, etc.

Find The B777-300ER folder where in it you'll find folders such as Airfoils, Cockpit, etc.

Drag the B777-300ER folder into **X-Plane > Aircraft > Heavy Metal**

Turn on X-Plane (or restart it if it is on) and it should be there.

1.7.2 Installing Liveries

Go into the B777-300ER folder and drop the livery into the Livery folder.

Section 1.8 – Liveries

1.8.1 Note

As of now, there are no liveries.

Chapter 2.0 – Specifications & Limitations

Section 2.1 – Weights & Runway Lengths

2.1.1 Weights

In this section, I will describe the maximum weights & runway lengths required for a safe and routine flight. The graph below depicts the maximum weights allowed for the aircraft and the descriptions for the terms below.

	POUNDS	KILOGRAMS
MAXIMUM DESIGN TAXI WEIGHT	777,000	352,442
MAXIMUM DESIGN TAKE-OFF WEIGHT	775,000	351,535
MAXIMUM DESIGN LANDING WEIGHT	554,000	251,290
MAXIMUM DESIGN ZERO FUEL WEIGHT	524,000	237,683
OPERATING EMPTY WEIGHT	370,000	167,829
MAXIMUM STRUCTURAL PAYLOAD	154,000	69,853
MAXIMUM FUEL LOAD	320,863	145,538

http://www.boeing.com/assets/pdf/commercial/airports/acaps/777_2lr3er.pdf p15

2.1.2 Definitions

You may not know what all these terms mean, here they are listed below –

Maximum Design Taxi Weight
This is the maximum weight while taxing, this extra 2,000 pounds either must be fuel or passengers who you'll be jettisoning.

Maximum Design Take-off Weight
This is the maximum take-off weight, if you go above this weight, the aircraft could run out of runway during take-off.

Maximum Design Landing Weight
You must be below this weight during landing or else you could damage the gear during touchdown or run out of runway during braking.

Maximum Design Zero Fuel Weight

This is if you completely drained the fuel out the aircraft. Basically, it is the empty weight of the aircraft with the payload weight.

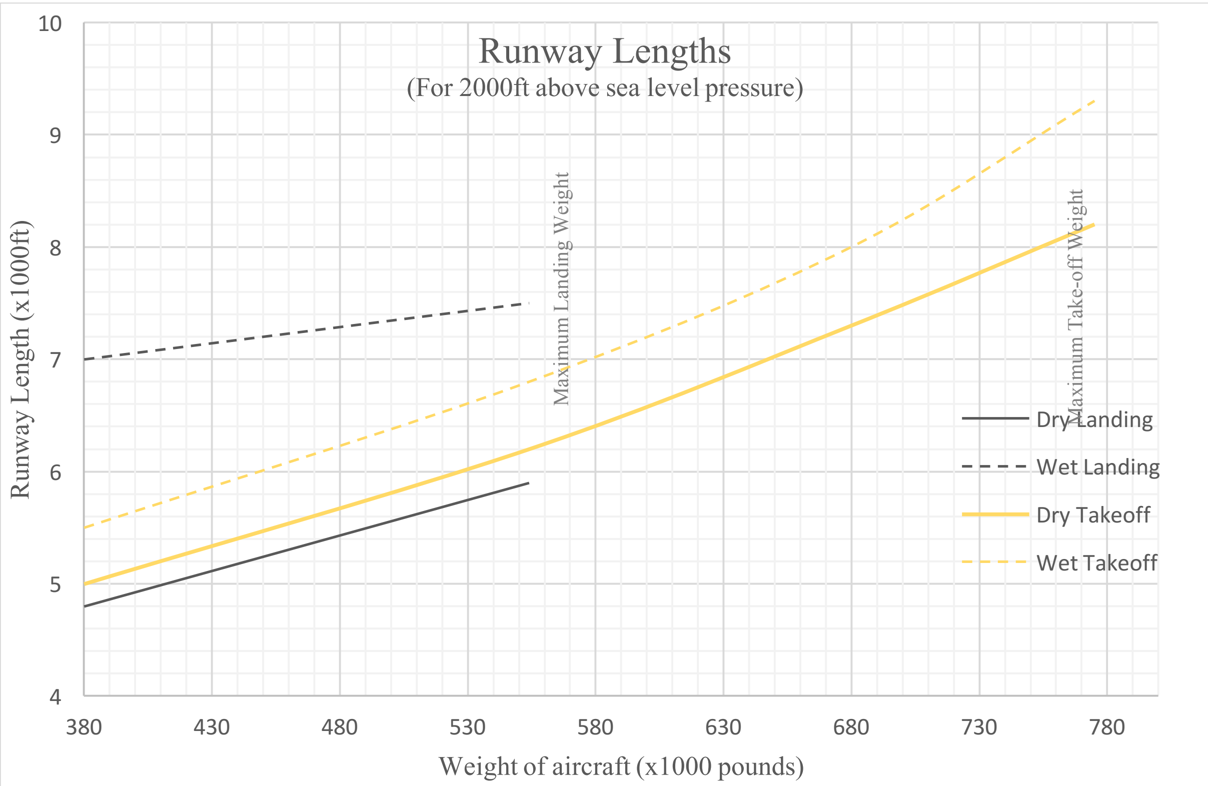
Operating Empty Weight
This is the empty weight of the aircraft without any cargo, passengers nor fuel. Nothing is in the aircraft.

Maximum Structural Payload
The maximum weight of the cargo, passengers, etc *but* excluding the fuel and empty weight.

Maximum Fuel Load
This is how much fuel you can load into the aircraft. Careful - This is the weight of the fuel; this is not it's volume!

Seating capacity –
370 people

2.1.3 Runway Lengths
This graph shows the runway lengths needed during both a wet and a dry take-off at 2000ft above sea level (pressure). The pressure only matters a little bit, but if you wish to account for that, keep in mind that for each 1000ft above sea level, the airplane requires 100ft of more runway.

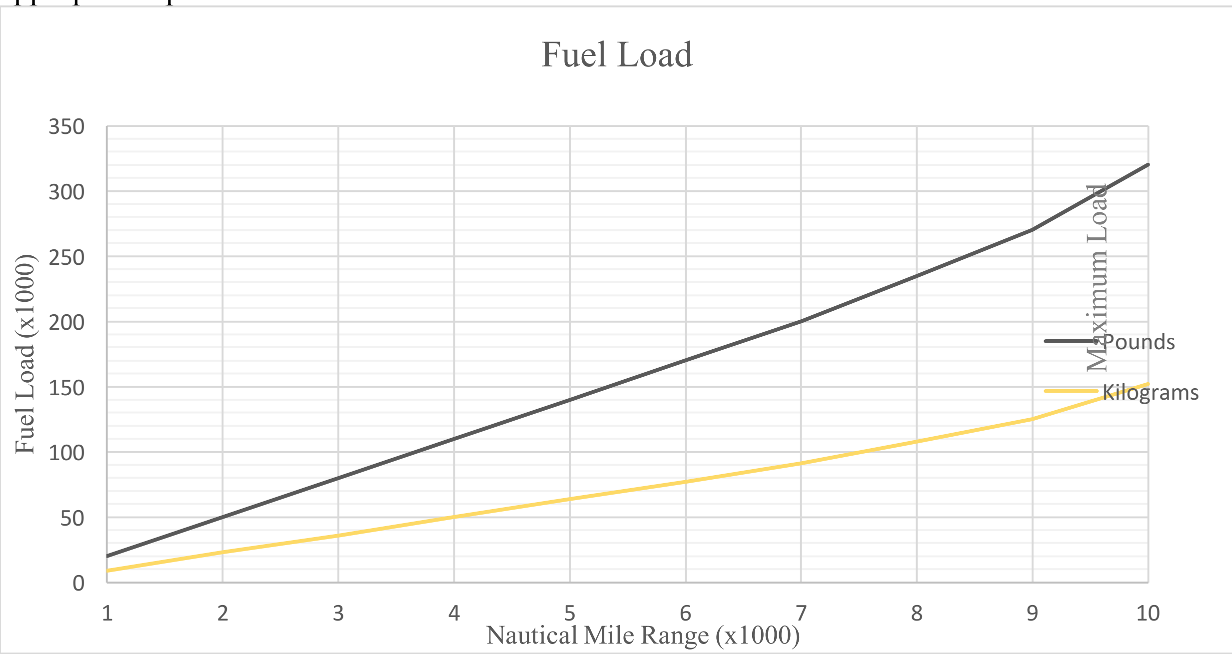


Section 2.2 – Fuel

The graph below illustrates how much fuel to load for each nautical mile. The orange line are kilograms and the blue line are pounds.

Be sure to have reserve fuel, enough for approximately one hour *plus* the amount of fuel to reach your alternate airport! If you use a fuel planning website, make sure it calculates it for you.

This graph assumes step climbs of 2,000ft and normal weather & temperature. Fly at appropriate speed and altitude.



http://www.boeing.com/assets/pdf/commercial/airports/acaps/777_2lr3er.pdf p43

Alternatively, you could find out that for approximately each NM, you will use around 30,000 pounds of fuel. This is assuming that you are at cruising altitude (FL270 – FL370) and at lower altitudes, more fuel will be required.

Section 2.3 – Aircraft Services

2.3.1 Positioning & Diagrams

There are ten services available when your aircraft has come to a complete stop. Be sensible as the program really doesn't know if you're still on the runway and you've just requested a lavatory cleaning truck to service it immediately – it's not that much of an emergency.

Here is a diagram of where the vehicles should be positioned at –

2.3.2 Times

Here's the timetable of the typical aircraft operation. Ignore the dark orange slots if you're shutting down the aircraft. If you're doing a cold & dark start-up, ignore the orange slots. A lot of these services don't really do anything so you'll just have to use your *imagination*. Of course, you may dispatch vehicles to service your aircraft for these lengths of time and dismiss them when you wish.

Minutes		3	6	9	12	15	18	21	24	27	30	33	36	39	42	45	48	51	54
Deplane & Board Passengers	24																		
Moving Passenger Bridges or Stairs	0																		
Service Cabin & Galleys	24			Clean & Sanitize					Prepare & Load										Pushback & Engine Start
Unload Cargo	21																		
Load Cargo	21																		
Unload & Load Bulk Cargo	42		Unload Bulk Cargo							Load Bulk Cargo									
Load Fuel	39																		
Service Lavatories	15					Clean & Sanitize				Prepare & L									

NOTES:

En-route operations – Only preform if aircraft will be continuing on another destination.

Unloading & servicing operations – This should always be preformed unless you are doing a cold & dark start-up

Position/Remove Equipment

BE SURE TO SHUTDOWN ALL ENGINES DURING OPERATIONS

Section 2.4 – Speeds & Limits

2.4.1 – Recommended Speeds

The speeds will vary because of air pressure and weight. The speeds below are recommended speeds while the speed limits chart illustrates the *maximum* speeds – don't go over (or under) them! Do keep in mind that these numbers are *indicated* airspeed (IAS) and not true airspeed (TAS); they could differ wildly. Be sure to use the FMC to find the V_1, V_R, and V_2 speeds as well as climb, decent and cruise speeds.

Approach Speed – 130-180 knots
Landing – 130-170 knots
Take-off (V_R) Speed – 120-160 knots
Cruise Speed – 250-330 knots

2.4.2 – Maximum Wind Speeds

Headwind – 25 knots
Tailwind – 10-15 knots
Crosswind – 25 knots

2.4.3 – Operation Limits

Runway slope – ± 2˚
Maximum Operating Altitude – 43,100 feet
Maximum Take off & Landing Altitude – 8,400 feet
Minimum

2.4.4 – Maximum Speeds

The charts below are speed limits and restriction – obey these or your aeroplane is no more.

Don’t forget that legally, you’re not allowed to go faster than 250 knots while under 10,000 feet unless advised; not like crashing into another aircraft isn’t fatal at those speeds.

Vmca	150 knots	Minimum speed with one engine out.
Vso	130 knots	The speed at which the aircraft will stall with full flaps.
Vs	170 knots	The speed at which the aircraft will stall with no flaps.
Vyse	160 knots	The speed suitable for climb with one engine out.
Vfe-m	180 knots	Maximum speed with flaps fully deployed.
Vfe-1	250 knots	Maximum speed with first-notch flaps.
Vle	190 knots	Maximum speed with gears deployed.
Vno	250 knots	Maximum speed in bad weather.
Vne	350 knots	Maximum speed without flaps. The wings could literally break beyond this speed.
Positive G Limit	10Gs	The maximum amount of Gs you can pull.
Negative G Limit	-5Gs	The minimum amount of Gs you can pull.

Section 2.5 – Gear

2.5.1 Operation

This aeroplane has a nose gear and two main gear. The gear cannot be retracted on the ground but lifting the gear lever to ‘retract’ will unlock them and when the aircraft gets lifted up, the gear immediately gets retracted. Remember that only the rear gears brake, the nose gear only acts for support and steering.

2.5.2 Steering capabilities

Low speed steering (1-30knts) – up to 70˚
High speed steering (30+knts) – up to 30˚

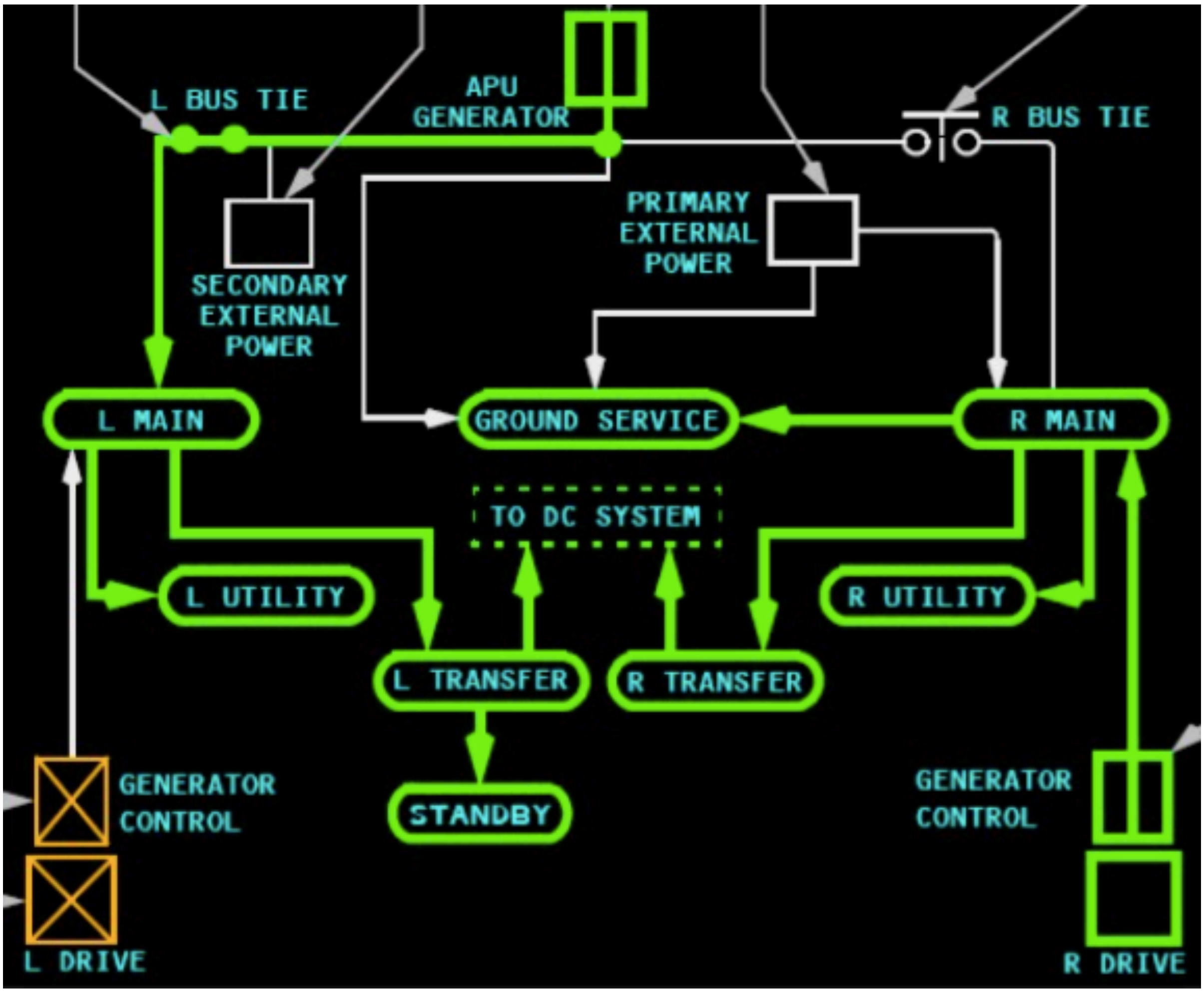
2.5.3 Wheel retract time

Nose gear – 11.3 seconds
Left main gear – 18.3 seconds
Right main gear – 18.1 seconds

Chapter 3.0 – Systems

Section 3.1 – Electrical[2][6][8]

3.1.1 Introduction



Altered Boeing 777 screen – electrical page

The electrical system of the Boeing 777 is complicated and massive. However, if we are to simplify it (as I have done), we would find that it does not differ greatly from a commercial airliner's or any other jet of it's kind. There are some additional features which were added to X-Plane's already intricate electric systems – not a great deal but rather a few minor buttons here and there.

The structure of the aircraft's electrical system is fairly simple. There are two main busses to provide power to the components of many of the aircraft's system. Two IDGs (refer below) generate power from each engine into their respective bus (either on the left or right side). These busses may be joined by bus ties and may be powered by either the APU generator (again, refer below) and external power sources.

3.1.2 Electrical Busses & Sources

The Boeing 777 has equipment which runs on either Alternating Current (AC) or Direct Current (DC). AC power runs components of systems such as the air conditioning system, fuel pumps, electrical hydraulic pumps, anti-ice systems and other main systems of the aircraft whilst the DC current powers flight instruments, PFCs, autopilot and etc. The power sources such as the IDGs and external sources provide only AC power. This AC power is sent to the Main Busses and then sent to either the Utility Busses or the Transfer Busses.

The Utility Busses power the components in the systems listed above. The Transfer Busses are linked to the Transformer Rectifier Units (TRUs) which convert AC to DC power for the DC Main Bus to use.

The Right Main Bus, Primary External Power and APU Generator all supply power to the Ground Service Bus which powers the main battery recharger and APU battery recharger.

The Standby Electrical System is used in emergencies where all main power sources have failed. The main battery and Ram Air Turbine (RAT) generator powers the bus which the standby inverter converts AC to DC. The Standby Electrical System can only power essential systems of the aircraft and will not be sufficient to power the aircraft normally.

AC busses can be linked by turning both ‘bus tie’ switches to ‘auto’, this will connect the left and the right bus together and is usually done if one bus has lower/higher amps than the other due to a failure or the absence of a load.

3.1.3 Electrical Load Management System (ELMS)

The ELMS is a system to manage electrical load by shedding electric outputs and inputs. If the electrical load is too great for the electrical sources, it will firstly, close the in-flight entertainment and galleys to reduce load. If the load is too high, it will then close the utility bus, then the equipment and monitors powered by the main AC busses (which is not good!). If power is restored, the ELMS will return power to those systems.

3.1.4 Integrated Drive Generators (IDGs) & APU Generator

There are two IDGs in the Boeing 777, each at their respective engine. The IDG is a generator which generates AC power from the spinning of the engine and acts as the main source of AC power whilst in mid-flight. IDGs will automatically reduce their input power to match the required power in their respective bus. If the engine which the IDG is on is not spinning sufficiently fast enough, the IDG will stop providing power and will turn off. If an IDG is disconnected, it can only be reconnected by ground crew and not in flight.

The APU generator provides power exactly as how an IDG will. The APU generator will use the Auxiliary Power Unit (APU) as a power source and will only work if the APU is on. The APU generator will automatically connect to the bus which is not powered by any source, if all busses are powered or not powered, it will connect to all busses. When in-flight and both of the main busses are unpowered, the APU will start automatically regardless of the APU selector.

3.1.5 External Power & Ram Air Turbine (RAT) Generator

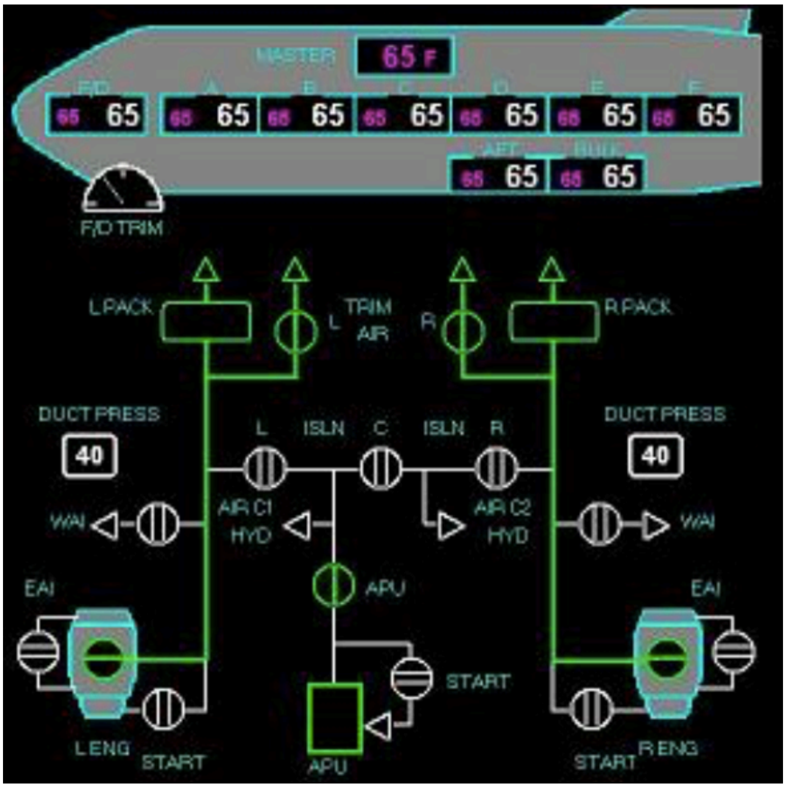
In the Boeing 777, there are two external power sources, the Primary and Secondary sources. Once on ground, the airline may request a Ground Power Unit (GPU) to wire up to the aircraft to power it. The Primary External Power or Secondary External Power will power both busses if no other power source is available and the battery switch is on. The Primary

External Power will connect to both busses if no other sources exist. If one IDG or APU generator is powering both busses, the Primary External Power will remove the IDG or APU generator and power both busses. If both busses are being powered by a/multiple sources, the Primary External Power will remove the source from the right bus and power it instead. Secondary External Power will replace the left side instead of the right side as done by the Primary External Power and will still replace a single power source with itself, turning the single source off.

The Ram Air Turbine (RAT) generator can generate power by deploying a fan which spins in the wind. The RAT can be used at all altitudes and airspeeds. It is used only in emergencies and will supply power to the standby bus which may be transferred to the main AC and DC busses. The amount of electricity it produces is not enough to fully power the aircraft and will only be able to provide functions to only the left, captain monitor and few components such as the radios and navigation. If both AC busses loose power during flight, the RAT will automatically deploy.
Section 3.2 – Fuel

<u>Section 3.3 – Pressurisation & Air Conditioning</u>

3.3.1 Introduction



3.3. Packs & Trim Air
There are two packs, one for each side. Bleed air from either the engine, APU or ground pneumatic source goes into a precooler which uses air from the turbine stage to lower the temperature to around 150˚C. Packs then take the pre-cooled air and further cool it with ram air then transferred into a mixing manifold. Controlled, Trim air (warm, precooled air) is not processed through the packs and is also sent to the manifold where trim air and packs are mixed to produced the requested temperature. A pack will be automatically set to a higher

output rate if there is a fault with either a recirculation fan or another pack. A pack will also be limited for high use of bleed-air (say gear retraction). Packs may also be set to a standby cooling mode if normal mode should fail. PACK MODE L/R will be displayed STBY COOLING will be displayed. Packs with standby cooling will automatically shut off in lower altitudes where warmer air is present and restart automatically when in cool air. If both air in standby cooling mode, they will continue to function in warmer air.

3.3. Air Distributing

The air from the can is redistributed through filters and recirculation fans. The air in the flight deck is taken from the left pack but is not redistributed and is kept at a higher pressure to prevent smoke from entering the cabin from the engine and cabin fires. The air from the cabin (which has been exhausted) is transferred to recirculation ducts where new air (from the mixing manifold) gets sent into the cargo holds or is sent to the outflow valves. Outflow valves are regulated automatically, the aft normally shut and forward dynamically changing.

3.3.3 Pressurization

Pressurization on the aircraft is fully automated. The landing altitude are set according to the FMC destination airport. The landing altitude may be set from 1000ft below sea level and 14000ft above sea level. The system will maintain the cabin pressure so that it does not go above 10000ft. An alert will sound if the cabin altitude goes above 10000ft and effects of hypoxia may arise; oxygen masks will automatically deploy.

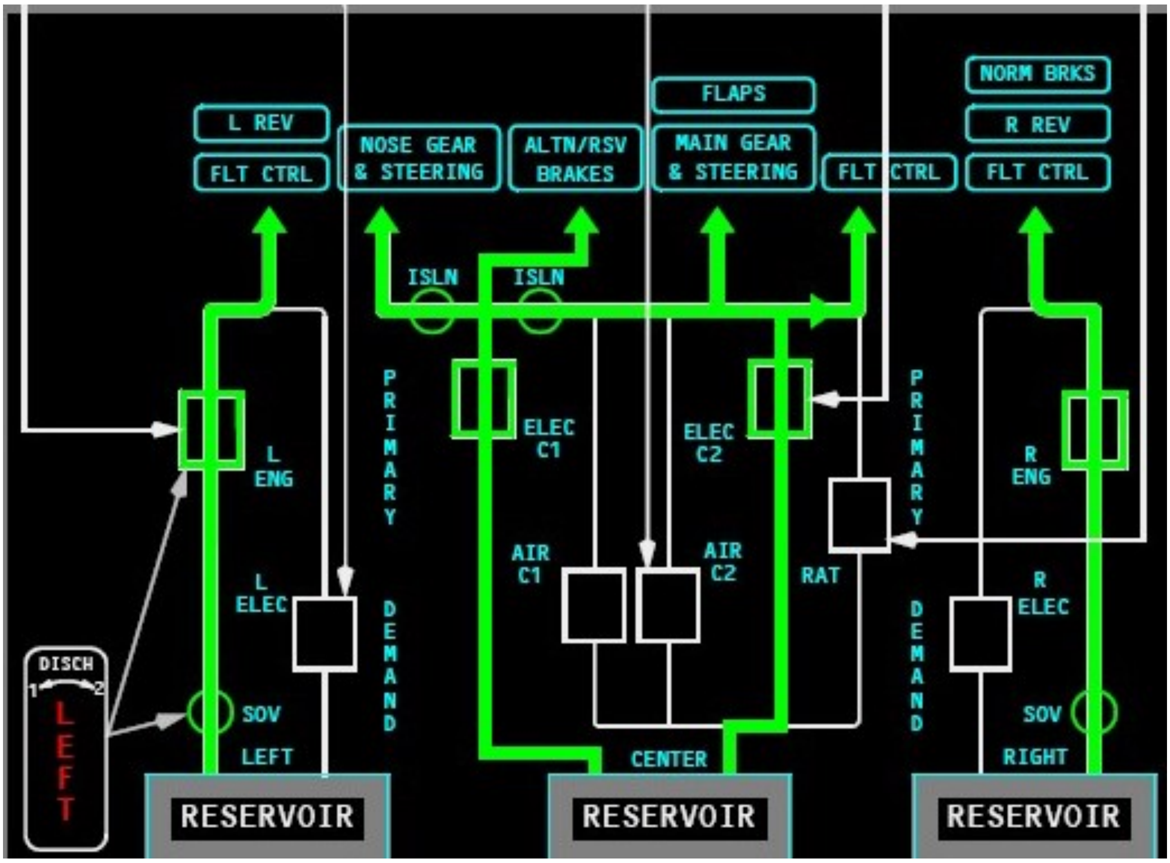
3.3. Air Sources & Ducts

Bleed air is high-pressurised, hot air which may be used for pressurisation, air conditioning, pneumatic, and hydraulic use. Air may be provided using the engines, APU, or a ground pneumatic source. If we are to refer to the schematic, we can see that there are two valves connecting to the engine and APU. One is a source supplying air to the system and another is opened automatically only when starting the source. The two valves are independent of each other which means that if the bleed air valve is closed, the engine's starter valve may still open. The Boeing 777's engines are started first with air, supplied by the APU or external source. There are three isolation valves connecting the two left and right system which are normally open and allow for the pilot to select the connection of the APU and of the hydraulic air pumps. The ducts from the engine connects to the cabin air conditioning system and pressurisation system.

Wings & Engines use bleed air for anti-icing as it is hot and can prevent ice from accumulating. Hydraulic air demand pumps (for the central hydraulic system) uses bleed air to run. Hydraulic reservoirs and water tanks are also kept pressurised with bleed air.

Section 3.4 – Hydraulics[2][7][10]

3.4.1 Introduction



Altered Boeing 777 screen - hydraulic page

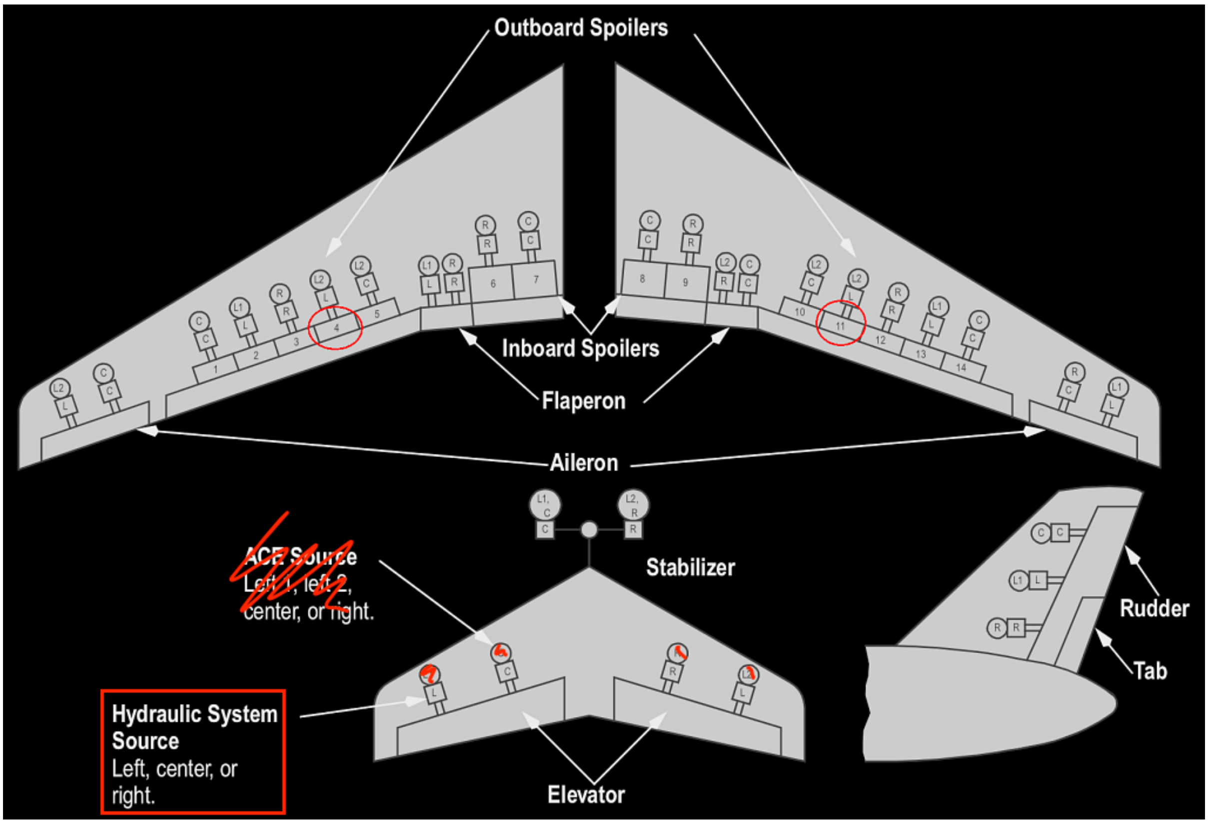
The Hydraulic Schematic (shown above) details the hydraulic system – it concludes it well if you know what you're looking at. Different systems are powered by the hydraulic system, a pressurised fluid system. Ignore the arrows pointing from the top.

3.4.2 System & Sources

The Aircraft has three hydraulic systems, each powering vital equipment; the central line has two lines (C1 and C2) but acts as one. Each are independent of each other and a failure of one will not affect each other. The middle two are combined with each other and are the most important. These lines are filled with hydraulic fluid which are pressurised by pumps. On the left and right systems are primary pumps operated by the engine; if the engine is discharged, there is a shutoff valve (SOV) which will disable the pump. Isolation valves positioned on the central hydraulic system cannot be controlled by the cockpit and only used for maintenance.
Four AC electric-driven pumps can be found in all three systems, two demand and two primary (explained below). Two pumps, driven by bleed-air from the engines provides demand hydraulic pressure to the central system; if their respective engine is off, APU bleed can be substituted in. On the central system is an emergency hydraulic pump which is normally off and powered by the Ram Air Turbine which should not be deployed in normal conditions. The emergency pump is as powerful as the other pumps. There are nine pumps mainly for redundancy and safety. The fluid in all systems are kept pressurised at 3000psi and the reservoir is pressurised with bleed air.

On the left system, there is an engine-driven pump and and an electric pump. If we were to refer to the schematic, we can see that the bottom one, the electric pump (L ELEC) is lower than the engine-driven pump (L ENG). The top one is a primary pump(s) which serves to pressurise the system whilst a bottom, demand pump(s) is used for extreme use of the system or a failure. The demand pumps will automatically turn itself on or off (if set to auto) to accommodate for a dip in pressure. All pumps are capable of the required 3000psi expect for the emergency one which goes to 3000psi. The central system will operate at 3000psi but could draw more pressure if many functions are used, thus two primary pumps.

3.4.3 Dependant Systems



http://www.davi.ws/avionics/TheAvionicsHandbook_Cap_11.pdf

Many systems depend on the hydraulic system. The diagram above shows the flight controls which may be affected by the loss of a hydraulic system in the square (NOT CIRCLE), All surfaces (expect for the spoilers) have more than one actuator, note that the actuators are not from the same hydraulic line (in square). Flaperons work as ailerons- not flaps. Flaps are powered by the central system.

The left and right system enables various flight controls and the respective engine reverser. However, a failure does not mean that the reverser will be unlocked as there are electric locks on the reverser but the reverser will not be able to deploy/retract once on ground. The parking brake also requires hydraulic power; once engaged, will put full power to the brakes. Hydraulic power, once removed will mean that there are no brakes and a rolling multi-million-dollar aircraft. Therefore, the aircraft must be placed in the chocks when parked to avoid this from happening.

The central system enables flight controls, nose-wheel deployment and steering, alternate brake (they replace brakes if they are to fail), flaps, and main gear deployment. A failure of the central hydraulic system is very rare but does not pose quite a risk. In-fact, a failure of a single system poses no life-threating issue on it's own. The gear can be manually deployed (by gravity) if the deployment should fail. Belly-up landings and no flaps landings can be attempted with successful results.

Section 3.5 – Fly-by-wire[1][2][4][5]

3.5.1 Functions & Operation

The fly-by-wire system (FBW) of the Boeing 777 is a system made to improve handling and safety of the aircraft. There are seven major functions which were implemented into this product;

- Protections
- Configuration change compensation
- Thrust Asymmetry Compensation (TAC)
- Trim Reference airSpeed (TRS)

- Turn compensation
- Yaw dampening

3.5.2 Laws

The aircraft operates on three laws; normal law, secondary law and direct law. Normal law is when the PFC is fully capable of commanding the aircraft and everything is going fine. The FBW system is fully operational. Secondary law is when some parts of the PFC has failed, this will result in the autopilot disconnecting and protections disabled. Direct law is when the PFCs had completely failed and you have full control of the aircraft. This is when the multi-million pound Boeing 777's Fly-By-Wire is now as useful as a paper aeroplane's.

The FBW Artificial Stability system is a system already implemented into X-Plane. To save time, it is used as the system for the FBW. The system changes the pilot's initial pitch, roll and yaw input in-order to achieve a smoother flight for the passengers and keeps the plane fairly aligned whilst the pilot is not moving the control.

Deflections by the pilot will be added with the Artificial Stability's inputs which are all trying to stabilize the aeroplane at a specific AOA, bank angle & sideslip. For example, if your aircraft is climbing and you leave the control column alone, without the Art Stab system, your aircraft may nose up until it stalls. However, with the Art Stab system, it will command the aircraft to lower the nose and (with enough time) the aircraft will stay at a constant AOA and will not stall.

3.5.3 Protections

Boeing's philosophy dictates that the pilot should have the final say in everything. This lead to the FBW protections – a set of rules which if exceeded, the aircraft will attempt to resist. Unlike Airbus's aircraft, the FBW will not actually *limit* your controls, just make it harder. There are four protections in this product's FBW – bank angle, pitch, over-speed & stalls. The bank angle protection will stop you from exceeding 33˚ of roll, if the roll is more than this, the FBW will 'jerk' the controls back to less than 33˚. If you put full roll, the system will still try to jerk the controls back (indicating the bank angle) but will not be enough to stop you from rolling further. The pitch protection will do exactly the same, except with 30˚ of upwards or downwards pitch and on the vertical axis. The over-speed protection is a bit different; if your aircraft happens to over-speed, it will firstly turn on the auto throttle (if armed) and bring the throttles to idle. If the speed goes higher, it will pitch up, attempting to slow the aircraft down whilst increasing the altitude.

3.5.4 Configuration Change Compensation

This function is used when the flaps or gears are changed; it will attempt to stabilize the altitude and speed of the aircraft in level flight. If the aircraft is descending/ascending more than 500 fpm, the system will not engage. When you lower the flaps, it will create lift which will increase the altitude of the aircraft and drag which will slow the aircraft down. The FBW will remember the vertical speed before the flaps were introduced and adjust the elevator trims so that the aircraft will remain at that vertical speed. If the pilot moves the control column, the system will automatically disconnect so that the pilot can change the rate of climb/descent. If the airspeed of the aircraft is not equal to the TRS, the FBW will override this function and will adjust the speed as required so do be sure to engage the auto throttle to prevent this from happening.

3.5.5 Trim Reference Airspeed (TRS)

Notice that the trim tabs of the Boeing 777 (on the control column & controlled by X-Plane's normal pitch trim commands) does not trim the horizontal stabilizers but instead, moves a bug on the airspeed tape. The bug is a light blue marker labeled 'FBW' and it moves when you move the trim. If you're on the ground or autopilot is on, the marker will not be there but once you disconnect autopilot and up in the air; it should be there. The FBW will adjust the elevator trims so that the aircraft will pitch so that it's speed remains constant with the bug. For example, you are flying at 260 knots and your bug is at 250 knots; the aircraft will *ever so slowly* pitch up so that the speed goes down. The aircraft (like the real 777) will undershoot the speed (goes to, say 245 knots) and then *ever so slowly* pitch down so that it's speed goes up. It will repeat this process until it has found a perfect AOA so that the speed is constant and the attitude is constant. The TRS does not really mind about the altitude – if you want the altitude to matter, you must either manipulate the throttles yourself or engage auto throttle. Apply more throttle so that it must go into a 'nose up' position to maintain the speed or vice versa; it's basically FLCH but much more slow.

3.5.6 Turn Compensation, Thrust Asymmetry Compensation (TAC) & Yaw dampening

Since these are all concerning rudder movements, I have decided to put them into once section. Whilst preforming turns in level flight (±500 fpm), the FBW uses rudder trim to stabilise the altitude of the aircraft – this is turn compensation. If the airspeed is not equal to the TRS, the FBW will adjust the pitch based on the TRS instead. The TAC system is a bit more different, when an engine fails or looses thrust, the TAC will trim the rudder in the opposite direct to compensate for any yawing motion. This brings me onto 'yaw dampening', an alternative to the classic 'Dutch roll', the tendency of an aircraft to yaw it's tail back and forth – usually quite inefficient for the flight and quite nauseating for the passengers. The yaw dampener also coordinates turns – eliminating sideslips from a roll or crosswind to make a flight more efficient.

Section 3.6 – Notes to keep in mind

Notes:

Outboard ailerons will not function in high speeds to avoid twists.
Turbines have 22 blades
EGT ˚C of the engines goes from 500˚C to 1000˚C.
The APU tailpipe is only visible on the left side.
The rudder has a trim tab.
There is a simulated auto-trim already.
The speedbrake deployment is realistically simulated.
The engine N1 prediction is simulated using a plugin.
It took five full days to program the EICAS. It's painful to do.

Chapter 4.0 – Bibliography

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