

# Piano<sub>x</sub>

## Aircraft Emissions and Performance

The screenshot displays the Piano X software interface. The left panel contains input fields for aircraft configuration: Load (Airbus A300 600R), Adjust (Basic Design Weights), Max Take Off (170500 kg), Operating Empty (89813 kg), Max Zero Fuel (130000 kg), Max Landing (140000 kg), Standard Payload (267 passengers @ 95.0 kg each), and Fuel Capacity (68150 litres). The right panel shows a RANGE REPORT for a design range of 2000 nm with a standard payload of 25365 kg. The report includes performance metrics such as range mode (fixed mach, step-up cruise), climb schedule (250. / 308.kcas/ mach 0.737 above 25072. feet), and cruise at Mach = 0.790 (FL 310 350). It also provides ICA and FCA performance data, a table of flight phases (Climb, Cruise, Descent) with distance, time, and fuelburn, and a table of emissions (kg.N0x, kg.HC, kg.CO, kg.CO2) for taxi, climb, cruise, descent, and taxi-in. Additional sections cover manoeuvre allowances (taxi-out, takeoff, approach, taxi-in) and reserves (diversion distance, holding time, contingency fuel, total reserve fuel).

**Input Parameters:**

- Load: Airbus A300 600R
- Adjust: Basic Design Weights
- Max Take Off: 170500 kg
- Operating Empty: 89813 kg
- Max Zero Fuel: 130000 kg
- Max Landing: 140000 kg
- Standard Payload: 267 passengers @ 95.0 kg each
- Fuel Capacity (litres): 68150

**Output Parameters:**

- Output: Block Range Summary
- Design Range with Standard Payload: 2000 nm with Payload (kg) 25365

**RANGE REPORT (design range & standard payload)**

{TOW 170500.kg./ OEW 89813.kg./ Fuel 55322.kg./ Payload 25365.kg.}

Range mode: fixed mach, step-up cruise

Climb schedule: 250. / 308.kcas/ mach 0.737 above 25072. feet

Cruise at Mach = 0.790 (FL 310 350)

ICA 31000. feet, 464.ktas, 293.kcas, CL=0.50, 50016.newtons/eng=MCR-13%

FCA 35000. feet, 455.ktas, 268.kcas, CL=0.45, 37661.newtons/eng=MCR-25%

	Distance (n.miles)	Time (min.)	Fuelburn (kg.)
Climb	104.	16.	3188.
Cruise	3709.	486.	43598.
Descent	100.	18.	380.
Trip total	3913.	520.	47166.
Block total	=====	534.	48012.

Emissions: taxi,t/o	climb	cruise	descent	app,taxi	total	
(kg.N0x)	8.9	72.7	529.0	1.4	2.6	614.6
(kg.HC)	1.09	0.38	11.39	3.81	1.13	17.75
(kg.CO)	5.1	2.3	102.3	17.7	5.5	132.9
(kg.CO2)	1539.	10075.	137768.	1202.	1136.	151719.

**Manoeuvre allowances:**

- taxi-out: 114. kg. (extra to t/o mass) 5.0 min.
- takeoff: 373. kg. 1.5 min.
- approach: 246. kg. 3.0 min.
- taxi-in: 114. kg. (taken from reserves) 5.0 min.

**Reserves (at landing mass 122715.kg.):**

- Diversion distance: 200. n.miles
- Diversion mach: 0.607
- Diversion altitude: 22044. feet
- Diversion fuel: 2785. kg.
- Holding time: 30. minutes
- Holding mach: 0.290
- Holding altitude: 1500. feet
- Holding fuel: 2363. kg.
- Contingency fuel: 2389. kg. (5.4 of mission fuel)
- Total Reserve fuel: 7537. kg.

## User's Guide

## Getting Started

Double-click on the compressed file you downloaded. This will create a new directory called 'Piano-X'. Inside it you will find the application itself ('Piano-X.exe'), and two directories: One called 'pianox-planes', which holds all your aircraft files, and another called 'pianox-adjustments', in which you can save any adjustments you make. The application always expects to find these two directories at the same hierarchical level as itself. That's all.

## Concept

There are three menus: 'Load', 'Adjust', and 'Output'.

Use 'Load' first, to choose an aircraft.

If you want to change anything, select an option from 'Adjust'. You can reset the basic design weights, factor the thrust, drag, or fuel consumption, input your own emissions indices, alter the flight levels and speeds, specify reserves and allowances, or pick the units you prefer.

Finally, select the 'Output' you are interested in and click the 'GO' button. The report you asked for will be shown in the text output area on the right side.

Outputs can include: Summaries (or detailed step-by-step analyses) of any flight over arbitrary distances with given payloads, tabulations of block missions, instantaneous performance at any particular flight conditions, complete payload-range characteristics, and takeoff / landing field lengths.

Depending on what you choose from the 'Adjust' and 'Output' menus, you will be presented with clear input options for specifying your requirements.

Two buttons are available that let you save, and later reload, any adjustments you make to the aircraft. You can create and keep as many adjusted models as you want.

Output reports can be saved to a text file or cleared from the screen at any time.

## Basic Weights

Basic aircraft weights are the maximum takeoff weight (MTOW), operating empty weight (OEW), maximum zero fuel weight (MZFW) and maximum landing weight (MLW).

The screenshot shows a software window titled 'Adjust: Basic Design Weights'. It contains several input fields for aircraft specifications:

	Weight (kg)	Standard Payload
Max Take Off	170500	267 passengers
Operating Empty	89813	@ 95.0 kg each
Max Zero Fuel	130000	+ 0 kg cargo
Max Landing	140000	
		Fuel Capacity (litres)
		68150

Piano-X weights represent the best available information, and you can always adjust them to any alternative specification. Some aircraft (such as recent versions of the ubiquitous Boeing 737) are marketed in a great variety of certificated weights. Information on weight options is easy to find, though often with one significant exception: Manufacturers may be reluctant to quote a representative OEW. In fact this is the most critical weight needed in assessing performance. Specifications often provide a manufacturer's empty weight (MEW), but this does not include operational items needed by the airline, and is not usable without an indication of the extra weight for a particular operator.

The 'standard payload' is one for which the aircraft is nominally designed, with all seats filled, in a typical seating configuration. Maximum payload (equal to MZFW minus OEW) can be higher, corresponding to extra cargo or dense seating arrangements.

The maximum fuel capacity is not a weight limit, but is required because it will normally constitute a boundary in the Payload-Range capabilities of the aircraft (together with the MZFW and the MTOW).

## Thrust, Drag, and Fuel Flow

Engine performance in Piano-X is based on calibrated best estimates of typical installed powerplants. In cases where different engine options are available on the same airframe, the calibration will be as representative of the fleet as possible but may not explicitly identify any differences between engine types. Normally, these are small. You can use factors to adjust the maximum takeoff, climb, or cruise ratings of the engine, as well as its specific fuel consumption (SFC). Calculations of engine thrust and fuel flow depend on altitude, Mach number, and power setting; any factors you apply will shift all relevant characteristics up or down in direct proportion.

Aerodynamic drag is calculated in detail (as a function of lift coefficient, Mach number, and Reynolds number) and tuned with actual lift/drag data ('polars') whenever these are known. You can either factor the drag uniformly using one overall value or you can adjust certain items individually. These are the zero-lift and lift-induced drag contributions, and the nominal divergence Mach number (which will influence the high-speed compressibility

drag). If you change them, you should know that aerodynamic methodologies generally differ in their accounting of drag items, which may be grouped under various labels.

Adjust: Thrust, Drag, Fuel Flow

	Factor		Factor
Takeoff Thrust	1.000	Zero-lift Drag	1.000
Climb Thrust	1.000	Induced Drag	1.000
Cruise Thrust	1.000	Divergence M	1.0000
All Thrusts *	1.000	All Drag *	1.000
* (applied on top of other factors)			
		Fuel Flow (SFC)	1.000

## Emission Characteristics

Aviation pollutant emissions include oxides of nitrogen (NO<sub>x</sub>), hydrocarbons (HC), carbon monoxide (CO) and carbon dioxide (CO<sub>2</sub>). All except the CO<sub>2</sub> are calculated according to standard procedures based on tested engine characteristics. The best public source for engine emissions is the 'ICAO aircraft engine emissions databank' maintained by the UK Civil Aviation Authority. This uses four sea-level conditions which are representative of idle, approach, climbout and takeoff. Values at arbitrary flight conditions are derived by a method based on fuel flow ('Boeing 2'). Inputs take the form of 'reference emissions indices', which means simply the grams of each pollutant per kilogram of fuel burn.

Adjust: Emission Indices

fuel flow	idle	approach	climbout	takeoff
kg/sec	0.1000	0.2500	0.7000	0.8500
Reference Emissions Indices (grams pollutant per kg fuel):				
NO <sub>x</sub>	4.00	9.00	17.00	20.00
HC	0.100	0.050	0.050	0.050
CO	20.00	4.00	0.60	0.60

Carbon dioxide is not part of any databank as it is directly proportional to the fuel burn: One kg of jet fuel will produce 3.16 kg of CO<sub>2</sub>. It is only shown explicitly in the summary range reports.

Piano-X models include predefined values for emissions characteristics according to either the actual engine or a nearest approximation to an actual engine. Data may not be provided for some 'early project' aircraft and for turboprops. If input boxes are left blank, no emissions will be calculated.

## Speeds and Flight Levels

You can obtain mission performance data for any speeds and Flight Levels within the capability of the aircraft (FL is standard pressure-altitude in hundreds of feet). Piano-X selects optimum FLs from those listed as available. Cruise Mach can be set to a specific value, or calculated as 'Economy' (maximum air range), 'Long Range' (99% of max air range), or nominal 'High Speed' (max cruise rating at reference cruise). The 'Max' Mach option keeps max cruise rating throughout, provided only one FL is supplied (this option is used rarely, sometimes by business jets).

Adjust: Speeds and Flight Levels

Cruise Mach

Economy  Long Range  High Speed  Max (single FL)

Available Flight Levels:

ft/100

Climb Speed \*  KCAS, up to Climb Mach \*

\* Leave empty for standard climb  
250 kts limit used below FL100

Climb speeds are calculated (or assigned) based on a constant calibrated airspeed in knots (kcas), subject to a 250 kt limit below FL 100, and up to some Mach limit at high altitude. Descent uses a similar speed schedule in reverse.

## Reserves and Allowances

Range calculations include sufficient fuel reserves to cover some combination of diverting over a fixed distance, holding for a set time, and retaining an amount for contingencies (as a percentage of fuel or time).

Adjust: Reserves and Allowances

Diversion Distance (nm)

Holding Time (mins)

Contingency Fuel Rule  % of mission fuel

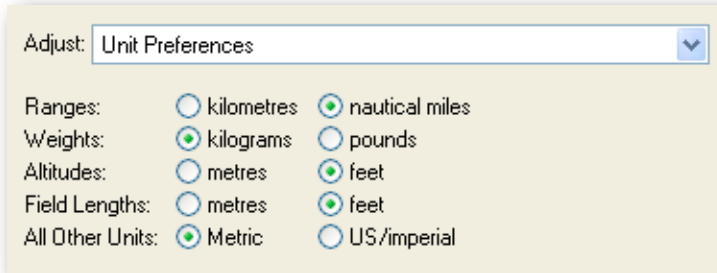
Allowances:	taxi out	takeoff	approach	taxi in	miss.app.
Time (mins)	<input type="text" value="5.0"/>	<input type="text" value="1.0"/>	<input type="text" value="3.0"/>	<input type="text" value="5.0"/>	<input type="text" value="0.0"/>

In calculating block fuel, allowances are normally made for taxi-out, takeoff, approach, and taxi-in, based on time spent at a corresponding power setting for each phase.

Note that individual aircraft models may use different assumptions, depending on their calibration and reflecting real-world discrepancies in reserve rules (typical International, US domestic, European shorthaul, etc). Each model can be adjusted as necessary.

## Unit Preferences

You can choose various combinations of metric and imperial (US) units.

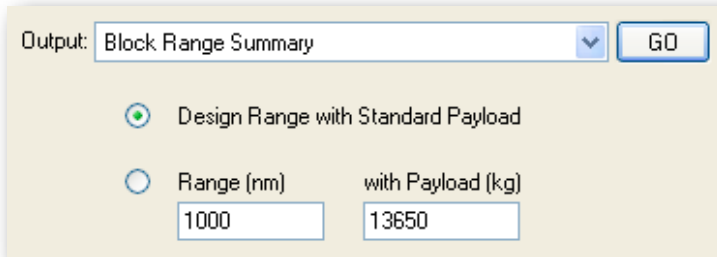


Adjust: Unit Preferences

Ranges:  kilometres  nautical miles  
Weights:  kilograms  pounds  
Altitudes:  metres  feet  
Field Lengths:  metres  feet  
All Other Units:  Metric  US/imperial

## Block Ranges and Flight Profiles

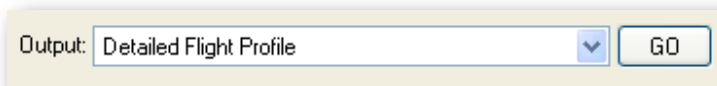
Mission performance can be calculated for any required combination of range and payload within the capability of the aircraft. The nominal design range is also shown, based on the standard payload.



Output: Block Range Summary GO

Design Range with Standard Payload

Range (nm) with Payload (kg)  
1000 13650

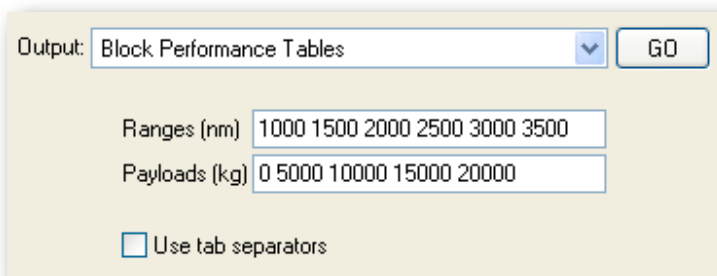


Output: Detailed Flight Profile GO

The outputs from a 'Block Range Summary' include all necessary times, distances, fuel burns and pollutant emissions. This is sufficient for most practical purposes. The alternative choice of a 'Detailed Flight Profile' uses the same inputs but generates an exhaustive step-by-step history for the entire flight. From this it is possible to derive any spatiotemporal information and a detailed in-flight distribution of pollutants.

## Block Performance Tables

This output option will generate tabulated block mission data for any specified combinations of range and payload.



Output: Block Performance Tables GO

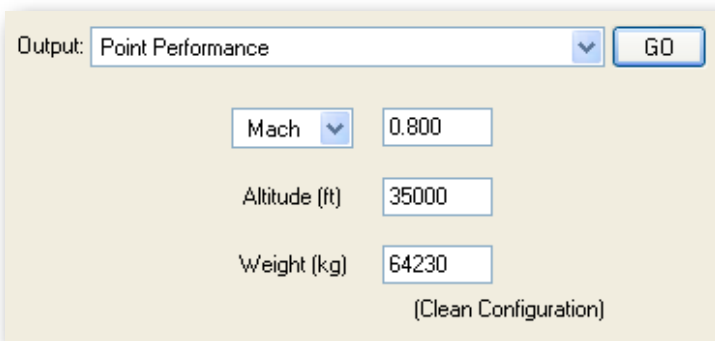
Ranges (nm) 1000 1500 2000 2500 3000 3500  
Payloads (kg) 0 5000 10000 15000 20000

Use tab separators

The resulting tables can be large and you may need to scroll to see specific portions. It is best to save such output in a file (using the 'Save Output..' button) and then examine it separately in any editor (like WordPad). If you tick the box labelled 'Use tab separators', the subsequent text can be copied/pasted into a spreadsheet document and will then align correctly in rows and columns.

## Point Performance

The 'point performance' option generates details of instantaneous aircraft performance at a specific speed, altitude, and weight. Speed can be given in terms of Mach or kcas, ktas and keas (calibrated, true, equivalent). Outputs include various drag coefficients, lift/drag ratio, engine thrust, fuel flow and SFC, specific air range (nm/lb or km/kg) and residual performance capability as an available rate of climb.



Output: Point Performance

Mach

Altitude (ft)

Weight (kg)

(Clean Configuration)

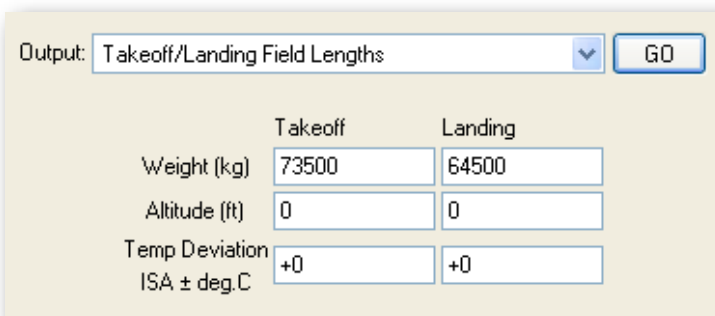
The aircraft is assumed to be in a 'clean' cruise configuration.

## Payload-Range Boundary

The boundary of the Payload-Range chart is shown at the standard corner points (which correspond to MTOW with max payload, MTOW with max fuel, and zero payload cases), together with an additional list of intermediate points.

## Takeoff and Landing Field Lengths

Takeoff and Landing field lengths are calculated according to FAR/JAR-25 rules at arbitrary combinations of weight, pressure-altitude, and temperature deviation from the International Standard Atmosphere (delta ISA).



Output: Takeoff/Landing Field Lengths

	Takeoff	Landing
Weight (kg)	<input type="text" value="73500"/>	<input type="text" value="64500"/>
Altitude (ft)	<input type="text" value="0"/>	<input type="text" value="0"/>
Temp Deviation ISA ± deg.C	<input type="text" value="+0"/>	<input type="text" value="+0"/>

Note that (in contrast to in-flight performance predictions) takeoffs and landings are subject to variation from uncertainties regarding retardation systems, high-lift devices, differences in flying techniques, rating structures, etc. Takeoff and Landing performance should therefore be regarded as indicative only.

## Using Piano-X

Piano-X is extremely simple to run. Nonetheless, the underlying methods are complex and various warnings may be shown if a calculation doesn't complete. If you can't obtain performance for a mission that you think is achievable, consider allowing lower and higher Flight Levels or changing the speed mode. For ultra-short stage lengths (say 200 nm), you may need to fix a single low level (such as FL 200). If you factor individual thrust ratings, the climb, cruise or takeoff can become impossible under different flight conditions.

There may be small differences between numbers given by the 'Block Range Summary' and 'Detailed Flight Profile' outputs. The latter, more detailed method calculates portions of fuel allowances instead of using fixed time assumptions. Results will be essentially the same for typical allowances.

If you produce very long reports, you may want to use the 'Clear Output' button at various times (preceded by 'Save Output, if required) to flush all previous screen output.

There is much more information in the User's Guide for Piano, the complete aircraft design and performance tool, available at [www.piano.aero](http://www.piano.aero). This online guide includes a list of terms and abbreviations applicable to all output reports produced by either Piano or Piano-X. There are also descriptions of the basic concepts and methodologies, which are common to both programs.

## Contact

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## Piano-X Aircraft List\*

\*Sample as of March '08. The list of available models is subject to change.

Aerospatiale AS100	B737-800 (NG basic)	Bombardier C(v05) 130ER	Fokker F50 Srs 100
Aerospatiale AS100ER	B737-800 (NG basic)wnglt	Bombardier C(v05) 130STD	Fokker F70 basic
Aerospatiale AS125	B737-800 (NG option)	Bombardier Challenger 300	Fokker F70 option
Aerospatiale AS125ER	B737-900 (NG option)	Bombardier Continental(v02)	Fokker F100 basic
Al(R) 58	B737-900ER(wnglt)	Canadair Challenger 601-3A	Fokker F100 option
Al(R) 70	B737-BBJ1	Canadair Challenger 604	Fokker F130 basic
Airbus A3XX-50R	B737-BBJ2	Canadair CRJ 200ER	Fokker F130 option
Airbus A3XX-100	B747-8 Intercontl (v06)	Canadair CRJ 200LR	Fokker-F28 Mk4000
Airbus A3XX-100R	B747-8 Intercontl (v08)	Canadair CRJ 700	Global 5000
Airbus A3XX-200	B747-100	Canadair CRJ 700ER	Global Express (v02)
Airbus A300 600 light	B747-200B	Canadair CRJ 900	Global Express (v99)
Airbus A300 600R	B747-400 mfrspec	Canadair CRJ 900ER	Global Express XRS (v08)
Airbus A300 B2-200	B747-400 stretch (v91)	Canadair CRJ 900LR	Gulfstream G IV
Airbus A310-200	B747-400ER	Canadair RJ 100	Gulfstream G IV-SP
Airbus A310-300	B747-500X (dec96)	Canadair RJ 100ER	Gulfstream G V (v99)
Airbus A318 basic	B747-600X (dec96)	Cessna Citation III	Gulfstream G V-SP
Airbus A319 basic	B747-SP	Cessna Citation V	Gulfstream G550
Airbus A319 option	B747X (v01)	Cessna CitationJet1	Gulfstream G650
Airbus A320-200 basic	B747X stretch (v01)	Cessna CitationJet2	Honda HondaJet
Airbus A320-200 option	B757-200 basic	Cessna Sovereign	IAI 1125 Astra
Airbus A321-100	B757-200 option1	Cessna X	IAI Galaxy G200
Airbus A330-200 230t	B757-200 option2	Dash 8 Series 100	Ilyushin IL-62M
Airbus A330-300 230t	B757-300	Dash 8 Series Q200	Ilyushin IL-96-300
Airbus A340-200 275t	B767-200 basic	Dash 8 Series Q300	Ilyushin IL-96M
Airbus A340-300 271t	B767-200ER	Dash 8 Series Q400 HGW	JADC YSX75
Airbus A340-500 (v03)	B767-300	Dassault Falcon 7X	KARI-100seater
Airbus A340-500 (v05)	B767-300ER	Dassault Falcon 900 C	Learjet 31A
Airbus A340-600 (v03)	B767-300ER option	Dassault Falcon 900 EX	Learjet 31A ER
Airbus A340-600 (v05)	B767-400ER(X)	Dassault Falcon 2000	Learjet 45
Airbus A350 XWB-800	B777-200 A (506)	Dassault Falcon 2000EX	Learjet 55C
Airbus A350 XWB-900	B777-200 A (515)	Dassault Falcon 9000 (v92)	Learjet 60
Airbus A350 XWB-1000	B777-200 A (535)	Dornier 328	Lockheed L-1011-200
Airbus A350-800 (v05)	B777-200 B (580)	Dornier 328JET	Lockheed L-1011-500
Airbus A350-900 (v05)	B777-200 B (590)	Dornier 428JET	MD-11 basic
Airbus A380-800 (v02)	B777-200 ER (IGW)	Douglas DC 9-14	MD-11 option
Airbus A380-800 (v03)	B777-200 ER (max)	Douglas DC 9-34	MD-12 HC
Airbus Corporate Jetliner	B777-200 LR (v04)	Douglas DC 10-10	MD-12X
Airbus Mil A400M	B777-300 (632)	Douglas DC 10-30	MD-17 Globemaster
Antonov An-70T	B777-300 (660)	Douglas MD-81	MD-XX (v91)
Antonov An-124 Ruslan	B777-300 ER (v04)	Douglas MD-82-88	NLA sample
Antonov An-124-210	B787-3 (shrink v05)	Douglas MD-83 auxCap	NSA (G1)
Antonov An-148-100	B787-3 (shrink v08)	Douglas MD-87	NSA (G2)
Antonov An-148-200	B787-8 (baseline v05)	Douglas MD-90-30	NSA (G3)
ARJ-21 (AVIC1 v05)	B787-8 (baseline v06)	Douglas MD-90-50	NSA (G4)
ATR 42	B787-8 (baseline v08)	Douglas MD-95 Tay	Raytheon Beechjet 400A
ATR 72	B787-9 (stretch v05)	Eclipse (v00)	Raytheon Hawker Horizon
Avro RJ 85 basic	B787-9 (stretch v08)	Eclipse 500 (v04)	Raytheon Premier 1
Avro RJ 85 option	BAe 125-700	Embraer 170 basic	Regioliner R92
Avro RJ-70	BAe 125-800	Embraer 170 LR	Rombac 1-11 ReEng
Avro RJ-100	BAe 1000	Embraer 175 basic	Saab 340B
Avro RJ-115	BAe ATP	Embraer 175 LR	Saab 2000
B707-320C	BAe Jetstream 41	Embraer 190 basic	Shorts FJX
B717-200 (v00)	BAe NRA	Embraer 190 LR	Sino Swearingen SJ30-2
B717-200 BGW (v99)	Beech King Air 200	Embraer 195 basic	Sukhoi-IL RRJ 60B
B717-200 HGW (v99)	Beechjet 400A	Embraer 195 LR	Sukhoi-IL RRJ 60LR
B727-200A	Boeing 7E7 (v04) baseline	Embraer EMB-120	Sukhoi-IL RRJ 75B
B737-200	Boeing 7E7 (v04) stretch	Embraer EMB-135	Sukhoi-IL RRJ 75LR
B737-300 (basic)	Boeing Business Jet (v97)	Embraer EMB-145	Sukhoi-IL RRJ 95B
B737-300 (option)	Boeing model 763-246C	Euroflag FLA turbofan	Sukhoi-IL RRJ 95LR
B737-400 (basic)	Boeing model 763-246CER	FA-X-100	Superjet 100-75B
B737-400 (option)	Boeing model 763-246CS	FA-X-100ER	Superjet 100-75LR
B737-500 (basic)	Bombardier BRJ-X-90	FA-X-200	Swearingen SJ30 original
B737-500 (option)	Bombardier BRJ-X-110	FA-X-200ER	Tupolev Tu-154M
B737-600 (NG basic)	Bombardier C(v04) 110ER	FA-X-300	Tupolev Tu-204-220
B737-600 (NG option)	Bombardier C(v04) 110ST	FA-X-300ER	Tupolev Tu-334-100
B737-700 (NG basic)	Bombardier C(v04) 135ER	FAAB-Mriya	Tupolev Tu-334-200
B737-700 (NG basic)wnglt	Bombardier C(v04) 135ST	Fairchild Dornier 528JET	Tupolev Tu-334-200Str
B737-700 (NG option)	Bombardier C(v05) 110ER	Fairchild Dornier 728JET	Yakovlev Yak-42M (v93)
B737-700ER(w)	Bombardier C(v05) 110STD	Fairchild Dornier 928JET	Yakovlev Yak-46PF (v93)

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