

Piano_x

Aircraft Emissions and Performance

Piano X

Load: Airbus A300 600R

Adjust: Basic Design Weights

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

Save Adjustments... Load Adjustments

Output: Block Range Summary GO

☒ Design Range with Standard Payload

☐ Range (nm) with Payload (kg)

2000 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. (S.L to ICA) |
| Cruise | 3709. | 486. | 43598. (ICA to ICA) |
| Descent | 100. | 18. | 380. (ICA to S.L) |
| Trip total | 3913. | 520. | 47166. |
| Block total | ===== | 534. | 48012. |

| Emissions: taxi,t/o | climb | cruise | descent | app,taxi | total | |
|---------------------|-------|--------|---------|----------|-------|---------|
| (kg.NOx) | 8.9 | 72.7 | 529.0 | 1.4 | 2.6 | 614.6 |
| (kg.HC) | 1.09 | 0.33 | 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.

Save Output... Clear Output

Piano X

Load: Airbus A300 600R

Adjust: Basic Design Weights

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

Save Adjustments... Load Adjustments

Output: Block Range Summary GO

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☐ Range (nm) with Payload (kg)

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Save Output... Clear Output

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.

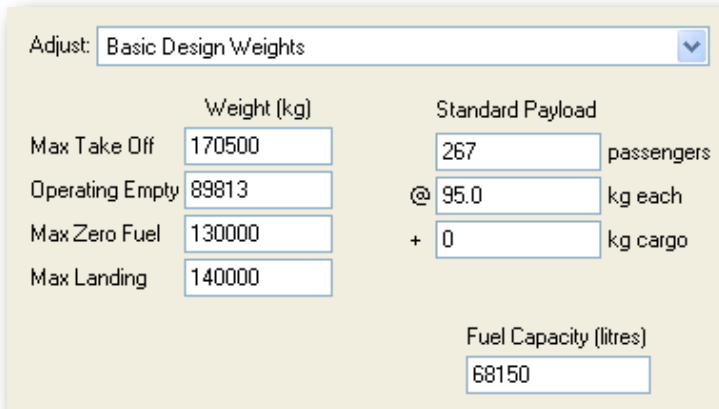
Depending on what you choose from the 'Adjust' and 'Output' menus, you will be presented with clear input options for specifying your requirements.

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. On the left, under the heading 'Weight (kg)', are four rows: 'Max Take Off' with value 170500, 'Operating Empty' with 89813, 'Max Zero Fuel' with 130000, and 'Max Landing' with 140000. On the right, under 'Standard Payload', there are three rows: '267 passengers', '@ 95.0 kg each', and '+ 0 kg cargo'. At the bottom right, there is a field for 'Fuel Capacity (litres)' with the value 68150.

| | 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_x), hydrocarbons (HC), carbon monoxide (CO) and carbon dioxide (CO₂). All except the CO₂ 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 _x | 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 CO₂. 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 initial 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 ☐ 0.780
☐ 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

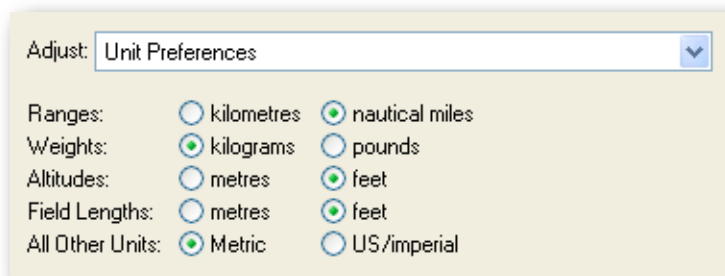
Allowances: taxi out takeoff approach taxi in miss.app.
Time (mins)

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

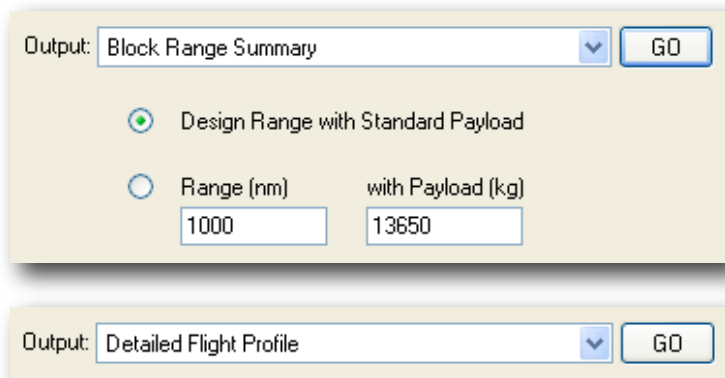
Altitudes: ☐ metres ☒ feet

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)

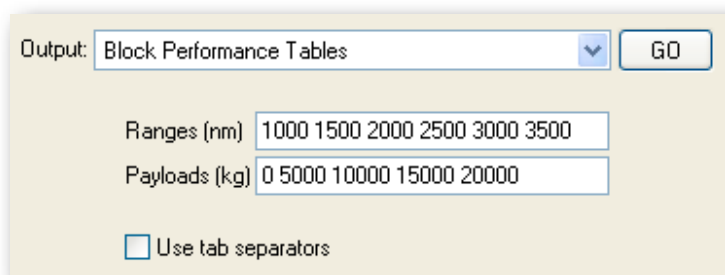
1000 13650

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

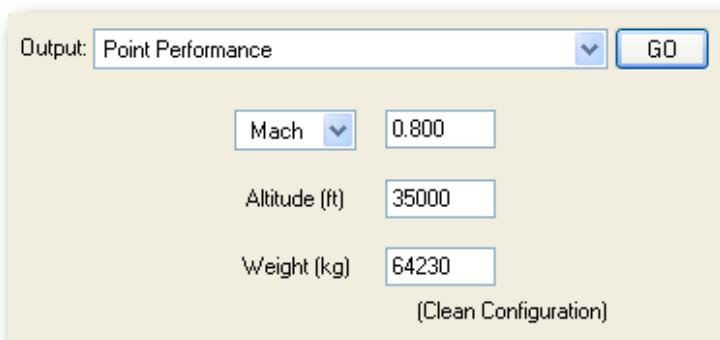
Payloads (kg) 0 5000 10000 15000 20000

☐ 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 GO

Mach 0.800

Altitude (ft) 35000

Weight (kg) 64230

(Clean Configuration)

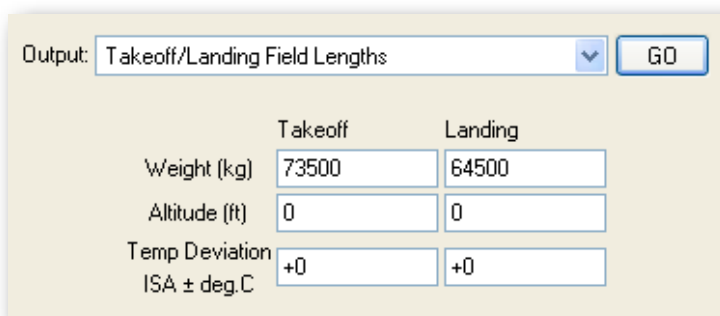
The aircraft is assumed to be in a 'clean' cruise configuration.

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 GO

| | Takeoff | Landing |
|-------------------------------|--------------------|--------------------|
| Weight (kg) | 73500 | 64500 |
| Altitude (ft) | 0 | 0 |
| Temp Deviation ISA ± deg.C | +0 | +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 when a calculation cannot be completed some specific warning will be shown. If aircraft performance is insufficient for a given mission, consider allowing more (lower) Flight Levels or changing the speed mode. For extremely short stage lengths (say 200 nm), you may need to fix a single low level such as FL 200. If you factor thrust ratings individually, the climb, cruise or takeoff may 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 run Piano-X for a considerable time and produce long reports, text output may start to scroll more slowly. You can use the 'Clear Output' button to restore full performance.

You will find much more information in the User's Guide for Piano, the complete aircraft design and performance tool, available at 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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