

FLIGHT-X Software

Aircraft Performance Software: Selected Features & Operations

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This is a summary of tips and how-to for special operations to be carried out with the computer code FLIGHT-X. This report is normally updated when there are updates to the software. For information, please contact the author.

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FLIGHT User-Inputs

LOAD AIRPLANE MODEL

- **Turbofan [24 families]**
 - Airbus A300-600 (GE CF6 engines)
 - Airbus A319-100 (CFM56 engines)
 - Airbus A320-Series
 - CFM56 engines
 - IAE V2527 engines
 - NEO (GE Leap 1A engines)
 - Airbus A321-200 (CFM56 engines)
 - Airbus A330 Series
 - -200 (CF6 engines)
 - -240 (Rolls-Royce Trent 772 engines)
 - -300 (CF6 engines)
 - -340 (Rolls-Royce Trent 768 engines)
 - -900 (neo, Rolls-Royce Trent 7000-72 engines)
 - -743 (XL, Beluga, Rolls-Royce Trent 772 engines) → also Cargo/Freighter
 - Airbus A340 Series
 - -200 (CFM56 engines)
 - -300 (CFM56 engines)
 - -500 (Rolls-Royce Trent 553 engines)
 - -600 (Rolls-Royce Trent 553 engines)
 - Airbus A350 Series
 - -900 (Trent XWB_075 engines)
 - -1000 (Trent XWB_084 engines)
 - Airbus A380 Series
 - -861 (GP 7270 engines)
 - -841 (Rolls-Royce Trent 970 engines)
 - Boeing B737 Series
 - -700
 - -700W
 - -800
 - -800W
 - -900W
 - -MAX8 (LEAP-1B25 engines)
 - Boeing B757-200 (PW engines)
 - Boeing B767 Series
 - -300 (CF6 engines)
 - -300ER (CF6 engines)
 - -300ERF (CF6 engines) → also cargo/freighter
 - Boeing B777 Series
 - -200 (GE engines)
 - -300 (GE engines)
 - -300ER (GE engines)
 - -200IGW (GE engines)
 - Boeing B747 (all)
 - -400 (CF6 engines)
 - -400F (CF6 engines) → also cargo/freighter
 - -800 (GENx engines)
 - -100-SCA (with Space Shuttle Orbiter, coupled/decoupled)

- Boeing B787 Series
 - -800 (Trent 1000 engines)
 - -900 (GEnx-1B engines)
- Bombardier CS series
 - CS300
- Bombardier Regional Jet
 - CRJ900 (CF34-8C5A1 engines)
 - CRJ700 (CF34-8CAB1 engines)
- Cessna Citation Latitude (PW306 engines)
- Embraer ERJ Series
 - -170 (CF34 engines)
 - -175 (CF34 engines)
 - -190 (CF34 engines)
 - -195 (CF34 engines)
 - -145 (AE3007 engines)
 - -145XR (AE3007 engines)
- Gulfstream G550 (BR7 engines)
- Dassault Falcon 2000
 - (no winglets)
 - -S/LX (PW308C engines)
- BAe Systems (Avro) 146
 - Series 200, RJ85 (Lycoming LF507-1F engines)
 - Series 300, RJ100 (Lycoming LF507-1F engines)
- Ilyushin Il-76TD (D-30KP engines)
- Lockheed U-2S (F118-GE-101 engines)
- **Turboprop [11 families]**
 - Bombardier Dash8-Q400 (PW150 engines)
 - ATR72-500 & -600 (PW127 engines)
 - ATR42-500 (PW127 engines)
 - Airbus A400M (TP400 engines) → also cargo/freighter
 - Airbus/CASA CN295 (PW127 engines)
 - Lockheed Hercules C130J → also cargo/freighter
 - Conventional
 - With external fuel tanks
 - Beechcraft B350i (*King Air*)
 - General Atomic MQ-9, *Reaper*, (TPE-331 engines)
 - Pilatus PC-12
 - SAAB 340B (CT7-9 engines)
 - (cargo version) → see cargo/freighter
 - Cessna C208 Series
 - -B Standard
 - Floatplane
 - Super Cargo Master (→ see cargo/freighter)
- **Cargo/Freighter [19]**
 - Airbus A300-600F (CF6 engines)
 - Airbus A330-200F (RR Trent 768 engines)
 - Airbus A330-743 (XL, *Beluga*, Trent 772 engines)
 - Boeing B757-200PF (PW engines)
 - Boeing B767-300ERF (CF6 engines)
 - Boeing B777-F (GE engines)
 - Boeing B747-400F (CF6 engines)
 - Boeing B747-800F (GE engines)

- ATR72-600F (PW engines)
- Airbus A400M → also turboprops
- Lockheed C130J → also turboprops
- MD-Boeing C17 “Cargomaster” (PW engines)
- Antonov An-124 (Lotarev D-18T engines)
- Antonov An-22a (Soloviev NK-12 engines/open propellers)
- Antonov An-225 (Lotarev D-18 engines)
- Antonov An-72 (Lotarev D-36 engines)
- Ilyushin Il-76TD (D-30KP engines)
- SAAB 340 Cargo (CT7 engines) → also turboprops
- Cessna Super Cargo Master
- **Business Jets [3]**
 - Gulfstream G550
 - Dassault Falcon 2000
 - Cessna Citation Latitude
- **Military Aircraft (not disclosed)**

MAIN MENU OPTIONS

- **Performance Charts**
 - Aerodynamics
 - Specific Air Range
 - All Engines operating
 - **Enter: [Atmospheric temperature, winds, weight intervals]**
 - One Engine inoperative
 - **Enter: [Atmospheric temperature, winds, weight intervals]**
 - Centre of gravity effect
 - Engine Envelopes
 - **Enter: [Mach number]**
 - Flight Envelopes
 - Propeller
 - WAT (take-off)
 - **Enter: [wind speed]**
 - Change other default parameters:
 - [Runway condition, tyre slip ratio, runway gradient, flap, CG position]
 - Balanced Field Length
 - Single-point Balanced Field Length
 - Option to change the following:
 - [GTOW, runway conditions, tyre slip ratio, airfield altitude, winds, air temperature, runway gradient, flap setting, CG position]
 - Balanced Field Length charts
 - Payload-range
 - **Enter: [cruise winds]**
 - Economic Mach number
 - CG effects
 - Buffet Boundaries
 - Specific Excess Power
 - Go-Around Charts
 - **Enter: [AUW, altitude AGL, flight path angle, wind, temperature, OEW]**
 - Atmosphere-Speed Charts
 - Pressure-altitude versus geo-potential altitude
 - Altitude-TAS-CAS-Mach
 - Holding Charts
 - **Enter: [Altitude, time, air temperature, GPS coordinates]**
 - **Enter: Flight into dust cloud or volcanic ash [Y/N]**
 - Maximum Descent Rates
 - V-n Diagram
 - Climb Polar
 - Longitudinal Trim
 - Gust Response
 - Aircraft Volumes
- **Mission Analysis**
 - Fuel Planning
 - Required range
 - **Enter: [Origin/destination GPS coordinates; Required stage length]**
 - Required bulk payload
 - Required passenger load
 - Atmospheric winds

- Cruise winds
 - Take-off & climb-out winds
 - Approach & landing winds
 - Change ATM Wind-speed profiles
 - Air temperature
 - Standard day, uniform deviation, arctic temperature model
 - Relative humidity
 - Aerodynamic deterioration
 - Engine deterioration
 - Other flight parameters (options)
 - Continuous descent approach
 - Perfect flight trajectory
 - Taxi-in time
 - Taxi-out time
 - Engine derating
 - Time delay for flap deployment
 - Final approach glide slope
 - Runway state (both take-off/landing)
 - Airfield altitude
 - Turn in climb-out
 - Flight level separation
 - Noise arrays extension
 - Aircraft Range
 - Passenger load (*not available for cargo and drone-type aircraft*)
 - Bulk load
 - Fuel load
 - Endurance
 - Passenger load (*not available for cargo and drone-type aircraft*)
 - Bulk load
 - Fuel load
 - Matrix Fuel-Plan
 - Equal-Time Point
 - → Same Options as Fuel Planning
 - Fly generic trajectory
 - Fly generic cruise trajectory
 - Fly into dust cloud/atmosphere
 - **Parse DUST cloud file (see separate documentation)**
 - **ADS-B trajectory (see separate documentation)**
 - Modify airplane configuration
- **Aircraft Noise**
 - Take-off & Departure
 - Arrival & Landing
 - Arbitrary trajectory
 - **Enter filename with trajectory data**
 - Noise footprints
 - Take-off/departure
 - Select grid
 - Self-generated
 - **Enter: [x-dimension; y-dimension; mesh resolution]**
 - Ignore atmospheric winds: Yes/No

- Externally generated
 - **Enter:**
 - Trajectory file name
 - Ignore atmospheric winds: Yes/No
 - Ignore MIK outside build-up area: Yes/No
 - Restart footprint (if available): Yes/No
 - Arrival/landing
 - Select grid
 - Self-generated
 - **Enter: [x-dimension; y-dimension; mesh resolution]**
 - Ignore atmospheric winds: Yes/No
 - Externally generated
 - **Enter**
 - Trajectory file name
 - Ignore atmospheric winds: Yes/No
 - Ignore MIK outside build-up area: Yes/No
 - Departure + Landing
 - Ground properties
 - **Enter option: [Snow, grass, Sand, Water, Tarmac/concrete]**
 - Atmospheric turbulence properties
 - **Enter Option: [Still air, moderately still, moderate, turbulent]**
 - **Post-Processing Operations**
 - Difference between Noise Footprints
 - Translate Noise Footprint
 - **Enter Longitudinal shift**
 - Remove isolated points of “silence”
- Stacking patterns
 - Footprint: Single take-off and landing
 - Footprint: Multiple take-offs and landings
 - **Enter: [time separation between landings; 3D trajectories]**
 - Output option: raw SPL [dB], OASPL [dBA]
 - Trajectory: Multiple flights
 - **Enter: configuration filename**
- Directivity analysis
 - **Enter: filename with case data**
- Options, Utilities and Defaults
 - Options include the following:
 - Parameter sensitivity analysis
 - **Single-parameter perturbation**
 - **Multiple-parameter perturbation**
 - Change ground-turbulence properties
 - Change Noise Propagation Model
 - Change sub-component noise models
 - **Slats noise**
 - **Flaps noise**
 - **Jet noise**
 - **Wing/fuselage scattering (toggle)**
 - Switch background noise
 - **Single-value background dBA**
 - **Use default noise spectrum**
 - **Read noise spectrum from data file**

- Switch APU noise
- Switch Fan Liner Boundary Layer
- Switch Noise Topography Effects
- Switch Wing-Fuselage Noise Shielding
- Switch Fan Temperature Control
- Convert noise trajectory to 2D
- Refine noise carpet/footprint
- Reset Atmospheric Winds
- Generate fly-over trajectory
- Debug jet noise
- **Exhaust Emissions**
 - Exhaust emissions versus range
 - **Enter: [pax load, cruise winds, air temperature, bulk payload]**
 - Emissions sensitivity analysis
 - **Enter: [Required range, pax load, cruise winds, cruise temp, bulk load]**
 - **Options: ICAO Databank, Surrogate model, Own model**
 - Taxi/ground roll emissions
 - Contrail analysis
- **Flight Optimisation**
 - Minimum climb-fuel¹
 - **Enter: [En route flight distance; Flight level at terminal point]**
 - Optimum climb between flight levels
 - **Select weight intervals: [kilograms; pound-force]**
 - Fuel tankering analysis
 - **Enter: [same data as Fuel Planning; fuel price differential]**
- **Manoeuvre Analysis**
 - Landing in a downburst
 - **Enter: [height of cloud base, downburst diameter, vertical speed]**
 - Wind model output
 - Downburst flight path
- **Trim Analysis**
 - Minimum control speed on the ground, VMCG
 - Minimum control speed in the air, VMCA²
- **Direct Operating Costs³**
- **Utilities**
 - Generate Unix “makefile” (*Owner only*)
 - Calculate distance between two GPS points (*great circle distance*)
 - **Enter two points separated by blank space**

¹ Solution may be impossible, depending on input data.

² Solution may be impossible; sensitive to aerodynamic derivatives.

³ Uses default DOC database, which can be edited by user.

How to Calculate Taxi Emissions

Calculation of engine emissions during taxi-out and –in, requires setting up a sequence of events, which include various combinations of acceleration, roll, braking, stopping/idle and turning. This is done with a configuration file shown below.

```
# All lines starting with # are comment lines and are ignored on input
# Taxi-schedule
# This is a sequence of steps, with a category and a number which qualifies the step, as described

accelerate  5.0           ! accelerate to a final speed [m/s]
roll        0.5           ! roll at the specified speed for given distance [km]
idle        2.5           ! halt/stop for specified time [minutes]
accelerate  5.0           ! accelerate to a final speed [m/s]
roll        1.0           ! roll at the specified speed for given distance [km]
idle        1.0           ! halt/stop for specified time [minutes]
turn        180           ! total turn during taxi (no difference between left/right)
```

The configuration file resides in the **./Data** sub-folder. The procedure is as follows:

Select: Airplane → Exhaust Emissions → Taxi/Ground Emissions

Calculations are done automatically; the results are found in the file **report_taxi_emissions.out**.

A typical report shows the data as in the table below.

TAXI EMISSIONS REPORT							

	Segment	fuel[kg]	CO2[kg]	CO[g]	NOx[g]	HC[g]	soot[mg]
1	accelerate	4.1	13.1	0.00	0.00	0.00	0.04
2	roll	15.9	50.1	7.83	1.07	0.57	0.16
3	idle	41.4	130.7	0.47	0.06	0.03	0.41
4	accelerate	4.1	13.1	0.47	0.06	0.03	0.04
5	roll	31.7	100.2	15.66	2.15	1.14	0.32
6	idle	16.6	52.3	0.19	0.03	0.01	0.17
7	turn	16.8	53.1	0.10	0.09	0.00	0.17

	TOTAL	130.7	412.5	24.71	3.47	1.80	1.31

How to Calculate Direct Operating Costs (DOC)

Calculation of direct operating costs relies on a large number of assumptions about present and future costs, often in an uncertain environment that requires long-term forecasting. Inevitably, the results depend on how good these assumptions on future costs are.

FLIGHT can handle several assumptions, which are found in a configuration file that resides in the ./Airplanes/airplane_name sub-folder.

"Prepared by A. Filippone, on 8 June 2014; Project = A321-200 DOC		! don't forget title
"A321"	airplane name	
"Dollars"	currency	(data below are in Dollars)
44d6	aircraft_price	(in above currency)
0.67	fuel_price_now (fuel price TODAY)	(per kg)
2.0	fuel_price_inflation	(% per year, AVERAGE)
25.0	fuel_price_hike on specified year *OIL SHOCK*	(%)
2	year at which OIL SHOCK is expected	
1.2	insurance, based on aircraft actual value	(% per year)
100.	spares_price1 (airframe, landing gear, tyres)	(per flight hour, year 1)
200.	spares_price2 (engine, APU, lubricants):	(per flight hour, year 1)
70.	spares_price3 (avionics/systems/pax_services)	(per flight hour)
25.	life_time	
85.	depreciation over life-time	(% of initial cost)
70.	financing	(% of initial cost)
4.5	interest rate	(%)
15	years of mortgage (integer number)	
58000.	crew_price1, pilots	(full time/pilot/year)
27000.	crew_price2, flight attendants	(full time/staff/year)
2.	crew_price_inflation	(%); set 0 if prices are not updated
80.	off_station_price (hotels, etc)	(per person/night)
60.	labour_rate1, power plant	(man-hour)
35.	labour_rate2, in-house maintainance	(man-hour)
50.	labour_rate3, contracted out	(man-hour)
0.5	man_hour1, powerplant	(per flight hour)
0.5	man_hour2, in-house	(per flight hour)
0.5	man_hour3, contracted out	(per flight hour)
1000.	landing_charges, airport fees	(per movement)
200.	ground handling costs	(per movement)
1d4	recurrent training_costs	(per pilot/year)
12.	flight service costs: catering, marketing	(per pax per movement, on YEAR 1)
0.	ground service costs: hangars and others	(per year) SEE NOTE [k] below
1200	cycles	(number of cycles/year; even number)
"international"	service_type	ALTERNATIVES: SEE NOTE [h] below
.true.	overrides "cycles" if true; keep above value if .false.	
1200.	stage length, n-miles	(average)
87.	average load_factor (pax/seats)	
12000.	fuel burn in full mission	(kg) ** PREVIOUSLY CALCULATED **
170.	block time	(min) ** PREVIOUSLY CALCULATED **
1000.	cargo/freight	(kg/flight) , SEE NOTE [j] below
5.25	cargo_price	(currency/kg)
1.0	other_cost (any other costs not included above)	(per flight)

1. TECHNICAL NOTES

#-----

Requires about 40 entries.

2. ASSUMPTIONS

#-----

- a. man_hour inflation is the same as "crew_price_inflation"
- b. labour_rate inflation is the same as "crew_price_inflation"
- c. all other costs (spare parts, etc.) are inflated by the same amount
- d. if no OIL SHOCK is expected, assume 1.0; the year (next record) will be ignored
- e. number of cycles is tentative; FLIGHT will make a better estimate; may override data above
- f. if you change the stage length and/or the bulk cargo, you must repeat mission calculation, because fuel burn and block time will be different
- g. the override parameter must be .true. or .false. Error is encountered otherwise.; this parameter is overridden if the number of cycles is not achievable.
- h: commuter service (X < 250 nmiles); international (250 < X < 2500); intercontinental (X > 2500)
- k: ground handling costs may include hangar rental, deicing services.
- j: if airplane operates cargo, it is likely that you need to increase ground handling charges
- i: any other costs not previously included, inc. navigation costs, damage repairs, etc.

3. WARNINGS

#-----

Program does not verify these numerical data, except the number of cycles required for stage length, block time and any negative entry; all data must be consistent and reasonable.

DO NOT swap lines: The program will not understand it.

If something is wrong on input, the program will report the line number relative to the last record read successfully. For example if last_record = currency, there must be something wrong in the "aircraft_price" data (one line below).

The program cannot be responsible for silly entries.

There are two lines denoted with **** PREVIOUSLY CALCULATED ****. This means that a mission analysis must be run on the average mission scenario, to produce two data: mission fuel burn and block time. Without these figures, the operation cannot be completed. See the note on how to set-up a Mission Analysis.

Once the configuration file is prepared, select Airplane → Direct Operating Costs.

How to Create a Sub-zone for Noise Mapping

- Parse original map with Map-Tool and visualise output file “map_raw.out” with Tecplot.
- Within Tecplot select “**Tool to Probe Data**”: probe corners of quadrilateral shape.⁴
 - Keep note of the indices (*I, J*) in the Zone/Cell Info box
- Within Tecplot select: **Data → Extract → Sub-zone** and create Sub-zone.
 - Visualise Sub-zone until content (various sub-zones may have to be generated).
- When content, within Tecplot select: **File → Write Data File**
 - Write sub-zone file with: **Format = ASCII, Zone Format = Point, Precision = 4**
 - **This sub-zone must have 5 variables: x, y, z, at, RGB**
 - Convert this file to readable Tecplot file by updating the default headers⁵.
- Exit Tecplot and run Map-Tool after preparing the maptool.cfg file as described below.

```

“LCY_subzone.dat”      ! sub-zone file name
.true.                ! write Tecplot file for visualisation (output cannot be used for noise)
.true.                ! synchronise map to trajectory
.true.                ! swap travel direction (for example East -> West becomes West -> East)
"iface_noise_landing_E195.out"! trajectory file, which must be placed in the ./Trajectories sub-folder
28.0                  ! estimated CPU time required to calculate this noise trajectory [s]
8712.  0.             ! touch-down or brake-release point on TRAJECTORY [m]
14970. 2570.         ! touch-down or brake-release point on MAP [m]
1 1                  ! grid level/resolution in x,y (1 = as it is; 2 = half resolution)
10 10                ! grid resolution [m]: IGNORED when dx < 30 m, dy < 30 m
    
```

How to Create/Update maptool.cfg File

1. Sub-zone file name: must be meaningful; use the IATA airport code, in this case London City.
2. Write Tecplot file to visualise both sub-zone and trajectory position.
3. Synchronise sub-zone map to trajectory.
4. Swap travel direction. *This is tricky and must be fully tested - not fool-proof.*
5. Choose trajectory file name in ./Trajectories sub-folder.
6. Estimate CPU time to run noise analysis for single microphone (strictly not necessary here).
7. Calculate coordinates of touch-down or brake-release point from noise trajectory.
8. Calculate/estimate coordinates of touch-down or brake-release point on the raw map: this is the same point on the sub-zone!
9. Set grid level resolution to 1 1 (integer numbers separated by a blank space).
10. Set cell resolution to very low number, so this command will be ignored (see comment above).

- After running Map-Tool, proceed to Tecplot visualisation of new map and trajectory. These files are called **map_parsed.out** and **trajectory.dat**
- If satisfied with the map, run the Map-Tool again with the Tecplot-flag = false, to generate the output files needed by the FLIGHT code.
- Map-Tool generates a number of partitions of this sub-zone.

An example of sub-zoning is shown in Figure 1 for London City airport. The case refers to an Embraer E195 landing on runway 27 (e.g. westbound), and the sub-zone is North of the airfield, roughly located between Royal Albert Way to the South and the A13 to the North (the area is known as Beckton), for about 4 km alongside the runway. Each colour on the map denotes a specific value of the ground impedance.

⁴ In the future it is expected to be able to generate sub-zones of more general shapes.

⁵ The file printed out has Tecplot headers that cannot be parsed by Map-Tool.

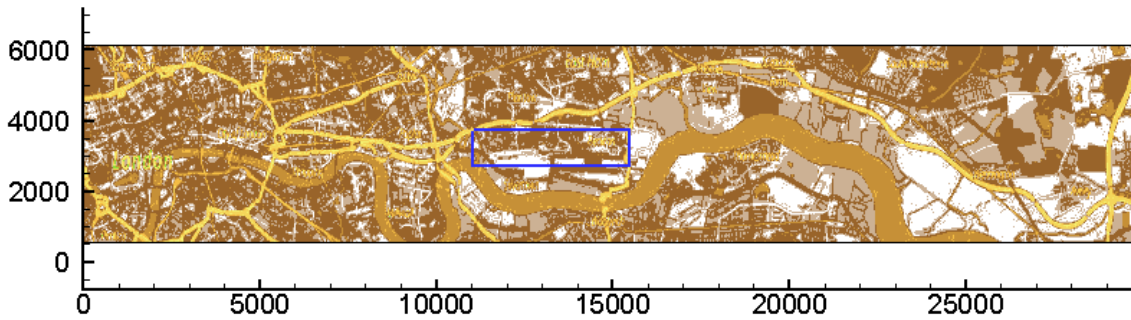


Figure 1: Sub-zone (in blue) selected for noise footprint analysis, at London City (IATA: LCY).

Use of the Topography Noise Corrections

A reasonable airfield map will have cells with dimensions 30m x 30m, approximate. A lower resolution is not currently achievable. Most likely, the resolution will be around 40m x 50m. Within each cell, it is not possible to discern differences in elevation, topographical details, etc. Therefore, each grid cell is associated to a fixed identity and ground impedance. Some topographical corrections to noise propagation are possible in a few instances, for example shielding offered by trees, forested areas, dense foliage, tall grass and (virtually) infinite barriers. This can be done by toggling the noise-topography option in the Noise Sub-Menu.

In Figure 2 we show an impedance model of the airfield. Each cell is flooded with a constant-value impedance; B denotes the reflection point of an acoustic wave eventually reaching a receiver R. The path B-C, traced on the ground, crosses through cells of fixed identity. If, for example, there are tall trees denoted by the darkest shade, the line of sight of the acoustic wave is impeded when travelling through the segments *a*, *b*, and *c*. These segments are calculated and correction to ground noise propagation, depending on frequency, is added to the signal reaching the receiver R. Likewise for other segments that cross through different ground properties. In practice the reflection point is close to the receiver, possibly within one grid cell, unless the airplane is very close to the ground.

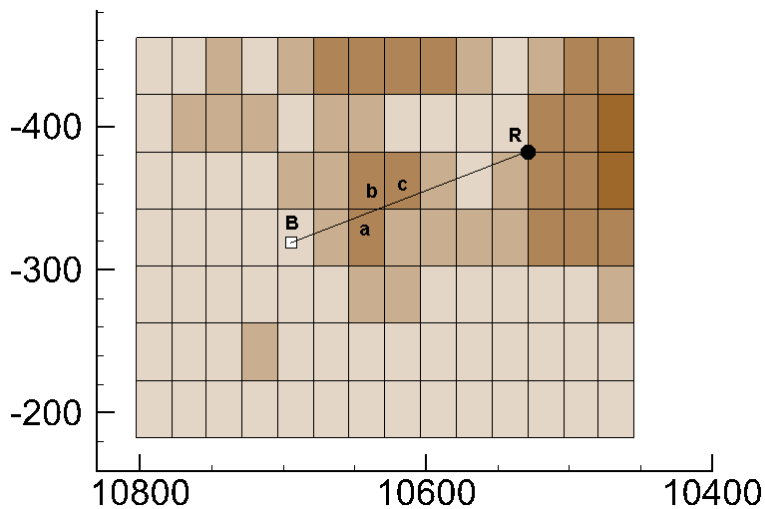


Figure 2: Detail of an airfield model, coloured by ground type, or impedance value.

How to Restart a Footprint Analysis

Noise footprint calculations are computationally very demanding. As a rule of thumb, we have:

- Twin-engine turbofan airplane: 25-30 s/grid point, depending on hardware platform
- Four-engine turbofan airplane: 30-35 s/grid point, depending on hardware platform
- Turboprop airplane, 2-3 minutes/grid point

The turboprop airplane case has not been numerically optimised, something that will be done in the future, with the goal of reducing the computing time to a similar value to that of the turbofan airplane.

The data indicated refer to absence of winds. The presence of strong winds, especially if sideways, increases enormously these computing times, and general guidance cannot be given in this instance.

Restart Procedure

If the job has been killed before completion, it can be restarted following the same steps. The program is able to identify the existence of a footprint output in the working folder and asks the user whether to restart or not. In the affirmative, the data are appended to the existing file and restarting is done from the last grid point, identified automatically. In the other case, the existing footprint output file is overwritten and computations start afresh.

The user can see where the computations have been restarted, since at each restart the code prints out a comment line such as this:

```
#----- Restarting from grid point 159 on 11 August 2015; time 9:15
```

Note: the restart file must be in the working folder! – No checks are made to verify that the existing file is consistent with the new inputs and requirements.

Noise Footprint Output File

The output file contains data that depend on many parameters. Unless all the metadata are specified, it is impossible to replicate the results or even understand under which conditions the results have been obtained. For this purpose, the top of the noise footprint file contains several metadata, as shown below.

```
title = "Embraer_E195-ST; Engine CF34-10E7 ; generated by FLIGHT V. 7.8.3 ; Database V. 21.3.0"
# METADATA: Mass[kg] = 42371; Vw[kt] = 0 (ignored); RH[%] = 70; dTemp [K] = 0; Noise propag. = Rasmussen
# METADATA: Background noise = false; Wing-Fuse shield = false; Fan-Liner B.L. = false; APU = on
# METADATA: Ground = Mixed impedance; Airfield topography effects = true
# METADATA: Flight procedure = Unspecified
# METADATA: Airport (Trajectory) = LCY
# METADATA: Airfield area = 34.207 [km^2]
# METADATA: All noise in [dB], except PNL[dBA], LA[dBA]
# METADATA: Job started on 11 August 2015; 9:56
# METADATA: Computer platform is Windows
```

CAUTION

RESTART must be used with extreme caution when the grid is self-generated. For example, at the first restart the existing grid characteristics are not checked; it is possible that the new grid is different, in which case the restarted calculations are unlikely to make any sense.

How to Run a Noise Sensitivity Analysis

Calculation of the aircraft noise along a specified trajectory depends on a large number of parameters whose exact value is unknown. More precisely, there are known and unknown parameters which may or may not affect the noise prediction at the reference microphone position. These parameters are classified according to their origin, as follows:

- Engine aero-thermodynamic parameters
- Airframe parameters (geometry/configuration)
- Propeller geometrical parameters and operation point
- Airplane position with respect to the reference microphone
- Atmospheric conditions
- Ground properties
- Program/software options

FLIGHT calculates the noise sensitivities in three ways:

1. By adding 2dB to all noise components; this is reflected in the final noise metrics, and appears in the output file "**report_noise*.out**".
2. By adding a single perturbation at a time to a number of parameters specified by a configuration file (described separately). Perturbations are assigned in the noise sensitivity configuration file.
3. By adding multiple random perturbations at a time to a number of hard-coded system parameters, in the categories listed above (described separately). *The noise sensitivity configuration file is ignored in this case.*

In the latter two cases, **FLIGHT** produces an output file (**noise_sensitivity_matrix.out**) that contains the noise metrics corresponding to each perturbation, the overall statistics and in the latter case also the list of perturbed parameters. The first option is only indicative of how much the final EPNL changes due to an uncertainty on each single noise component; this perturbation is not associated to any specific element on the airplane, or external to the airplane.

Single-Perturbation Analysis

One parameter at a time is subject to a random perturbation specified by a maximum amplitude found in the sensitivity configuration file (**./Airplanes/airplane_name/..**), an example of which is shown in Table 1 at the end of this document.

Multiple-Perturbations Analysis

Several parameters at a time are subject to a random perturbation specified with the program – there is no opportunity to change data here. The perturbation module constructs a vector $\mathbf{V} = (dx \dots)$ of parameters, which at the end of the noise computations is restored to its initial (default) value; then, another iteration is carried out. An example of output is shown in Table 2. The moments of the distribution are: average, mean value, standard deviation and curtosis.

Table 1: Configuration file for noise sensitivity analysis, with single-perturbation strategy

```

# Flight V.6.3.3: noise sensitivity database

"Engine"      3                ! category; number of active components to read
  "FAN"       5                ! component; number of sub-components to read
  "nb_fan_vanes" 0.0          ! change in fan vanes number, % uncertainty; * NO EFFECT FOUND *
  "TT2_2"     2.5              ! discharge side fan temperature, % uncertainty
  "W1"        5.0              ! mass flow rate, uncertainty, % uncertainty
  "N1"        5.0              ! fan rpm, uncertainty, % uncertainty
  "xduct"     12.0             ! length of acoustic liners duct (inlet/discharge), % uncertainty

"JET"         6                ! component
  "core_nozzle_area" 10.0      !
  "bypass_nozzle_area" 10.0    !
  "core_plug_length" 10.0     !
  "bypass_plug_length" 10.0   !
  "TS9"       3.0              ! relative change in exit/nozzle temperature, percent
  "Mach9"     5.0              ! change in exit/nozzle Mach number, percent

"COMB"        2                ! component
  "Wf6"       3.0              !
  "TT4"       3.0              !

"TURBINE"     1                !
  "nb_TRB_LP" 0.0              ! number of turbine blades, % uncertainty; ** NO EFFECT **

"Airframe"    4                ! category, and number of components
  "MLG"       2                ! component with two sub-components; records to read
  "main_strut_width_avg" 12.0   ! change in total strut width, percent
  "main_strut_length_all" 12.0  ! change in average strut length, percent
  "NLG"       2                ! component with 2 sub-components; records to read
  "nose_strut_length_all" 12.0  !
  "nose_strut_width_avg" 12.0  !
  "FLAP"      2                ! component
  "flap_area_in" 12.0          ! change in inboard flap area, percent
  "flap_area_out" 12.0         ! change in outboard flap area, percent
  "SLAT"      2                ! component
  "slat_area_in" 0.0           ! uncertainty, inboard flap area
  "slat_area_out" 0.0          ! uncertainty, outboard flap area

"Ground"      1                ! category, including ground properties
  "REFLECTION" 4
  "sigmae"     50.0            ! flow resistivity
  "alpha_gr"   0.0             ! effective depth (not very effective parameter)
  "mu2"        100.0           ! fluctuating index of refraction
  "backg"      0.0             ! account for standard background noise; value is ignored

"Atmosphere"  1                ! category
  "PROPAGATION" 4
  "dTemp"      10.0            ! change in temperature
  "RH"         5.0             ! change in relative humidity, percent
  "dWind"      2.0             ! change in wind speed, absolute value, direction: 0 degrees
  "dWindDir"   0.0             ! change in wind direction, absolute value (degrees)

"Trajectory"  3                ! category
  "SHIFT"      3
  "dx"         25.0            ! absolute distance in [metres]
  "dy"         8.5             ! absolute distance in [metres], 1/4 wing span
  "dz"         2.0             ! flight altitude in [metres]

```

Table 2: Result of multiple-perturbations noise sensitivity

variables = "id"	"EPNL"	"SEL"	"PNLTM"	"LAeqT"	"LAmaz"	"SPLmax"
1	98.677	93.718	105.958	74.876	91.104	92.911
2	99.739	95.165	106.444	76.128	91.792	93.687
3	101.471	96.070	109.105	76.995	93.828	95.450
4	98.255	94.597	104.834	75.628	90.957	92.899
5	96.895	90.975	103.187	71.952	87.038	89.441
6	99.609	94.209	106.831	75.158	91.417	93.224
7	95.211	90.536	100.904	71.456	85.756	88.237
8	98.225	93.799	105.037	74.815	90.831	92.802
9	98.985	94.004	105.688	75.103	90.571	92.437
10	96.419	91.305	101.958	72.186	86.871	89.358

Statistics over 10 sample points, One Microphone

Mic	Metrics	ave	adev	sdev	var
1	EPNL	98.349	1.3475	1.8100	3.2762
1	SEL	93.438	1.4994	1.8682	3.4901
1	LAeqT	74.430	1.5391	1.8930	3.5833
1	PNLTM	104.995	1.8189	2.4271	5.8909
1	LAmaz	90.016	2.0770	2.5734	6.6225
1	SPLmax	92.045	1.8195	2.2702	5.1538

List of Perturbed System Parameters

- 1 Engine: W1 (mass flow)
- 2 Engine: Wf6 (fuel flow)
- 3 Engine: N1% (speed)
- 4 Engine: TS9 (static nozzle T)
- 5 Engine: TT2_2 (fan exit total temp)
- 6 Airframe: MLG strut length (all)
- 7 Airframe: MLG strut with (avg)
- 8 Airframe: NLG strut length (all)
- 9 Airframe: NLG strut width (avg)
- 10 Airframe: core nozzle area
- 11 Airframe: outboard flap area
- 12 Airframe: inboard flap area
- 13 Position: change x-coordinate
- 14 Position: change y-coordinate
- 15 Position: change z-microphone
- 16 Atmosphere: relative humidity
- 17 Atmosphere: air temperature
- 18 Ground: flow resistivity
- 19 Code options: Fan liner boundary Layer

How to Create to Operate on Different Noise Footprints

Occasionally, it is useful to carry out operations with noise footprints, as previously calculated, to understand the effects of some operational parameters and/or numerical models. For this purpose, it is necessary to have two files having the same grid dimensions (nx,ny), otherwise the comparison becomes more complicated. There are two ways to proceed.

The first is to use a tool within FLIGHT that calculates differences and averages between noise metrics, as well as shifts of the noise metrics along the flight direction.

- Select: Aircraft Noise → Noise Footprints → Noise Operations
- For Differences/Averages between noise footprints, select the appropriate option
- FLIGHT produces two output files: "footprint_average.out", "footprint_difference.out"

Note that the user is required to type two file names. *The differences are calculated between the second file and the first file.*

The code attempts to make some preliminary checks on the input files, such as grid size (nx,ny), grid dimensions (dx, dy), location of minimum points (xmin, ymin), number of variables available in the input files (nvarf). If in any of these instances there is a mismatch, the program will stop. Differences and averages are calculated for each noise metric. Differences > 99 are automatically set to zero.

The code will stop if a "restart" command line is found. Such line must be removed.

Another way of analysing different noise footprints is within Tecplot

- Within Tecplot, load Multiple Files (which must be consistent as described above).
- Within Tecplot select: **Data → Alter → Specify Equations.**
- Define a new variable: if the data files have n variables, you need to define variable $n+1$. If a difference between variables V_i is required, then the equation is
 - $V(n+1) = V_i[2] - V_i[1]$
 - *Note: $V(n+1)$ is difference of variable V_i on 2nd file and V_i on 1st file loaded*
- Now plot contours with $V(n+1)$ as field variable, Figure 1.
- The new variable can be renamed in dialog box: **Data → Data Set Info → Zone/Variable Info**

How to Calculate Multiple Noise Trajectories

Multiple aircraft operations at an airfield can be calculated with a specific option. Select

Aircraft Noise → Noise Stacks → Trajectory: Multiple Operations

This operation requires a configuration file, which contains the following data:

```
"Flight_trajectory_file_name"    "operation"    time_delay
```

The trajectory files must be in the working folder.

Compliance

The operation data is either "landing" or "takeoff". The time delay is a numerical value, in seconds, specifying the time sequence of the various flights. It is not advisable to mix arrival and departures, since

This configuration file is to execute aircraft noise calculations for multiple operations for the SAME AIRPLANE.

The code will simulate aircraft noise at microphones specified in each trajectory. If microphones have different positions, or if the number of microphones is different, then the results are unpredictable. ALL files must have the same microphones. In summary, we must comply with the following conditions:

- Only one airplane type is possible.
- Trajectories must be calculated with respect to a common reference system on the ground.
- The microphone positions must be the same for all trajectories.
- The time gap between trajectories must be reasonable (60 to 180 seconds).

Outputs

The results are printed into two different files:

1. "cost_function.dat" which contains two parts: 1.) noise metrics; 2.) exhaust emissions.
2. "noise_multi_flight.out" which contains the time-dependent noise metrics OASPL (overall sound pressure level), OASPLf (airframe noise), OASPLp (propulsion noise), OASPLc (engine core noise), PNL (perceived noise level), PNLT (perceived noise level, tone-corrected), LAdbA (A-weighted overall sound pressure level).

Caveats

It is unlikely that the integral noise metrics (EPNL, SEL, LAeqT) are reliable, because if the time separation between flights is sufficiently large, then there will be separate noise peaks, which have their own integral characteristics.

The instantaneous noise metrics may have wild oscillations within the overlapping flight time.

How to Use GPS coordinates in Flight Planning

In the fuel mission analysis, the required range can be entered as a distance (in km) or as a double pair of GPS coordinates (latitude, longitude). In the latter case, the code calculates the distance between the two GPS coordinates, along a great circle, and performs a calculation of fuel planning along this trajectory. Note that occasionally, *the actual distance travelled is longer than the great-circle distance*.

Example: A flight from London Heathrow (**LHR** = 51.4775, -0.4610) to Doha (**DOH** = 25.2729, 50.6084) yields a great circle distance of about 2,810 nautical miles. On final approach, it is possible that the GPS coordinates are not updated, because of the larger distance travelled.

Go to: Mission Analysis → Fuel Planning → Required Range → Origin/Destination GPS Coordinates

END OF DOCUMENT