FLEET MANAGEMENT

Proposed by https://www.appsintellect.org/

28th September 2024

User Manual Version 6.2

Demo tool -> appsintellect.org (airlineservices.eu.pythonanywhere.com)

GOALS

* Firefox is recommended

Using one unique web based / database tool, accessible from any browser *, Airlines can:

- Configure their fleet, aircraft types, number of seats, hourly operational costs, crew costs, turn around times
- Plan graphically their routes / flight legs using a 3 Dimensions map,
- Exploit results from a 4 Dimensions trajectory such as trip duration, distance flown, fuel consumptions, etc.
- Choose the best aircraft – flight leg combination
  - to minimize Costs such Fuel , Crew, etc.
  - to minimize Costs per Available Seat Miles,
  - to maximize Seat Miles
- Choose the Reduced Climb Power Coefficient to maximize fuel savings
- Support flight leg planning through fuel capacity estimation

Benefits of a full-fledged interactive 3D Globe with street maps hence runways & terrain elevation data

BROWSER RECOMMENDATION

AVOID BROWSER ERROR RAISED WHEN TRYING TO ACCESS OPEN STREET MAP TILES

Context : open street map is one of the "tile" providers to support displaying geo referenced map over the globe

Problem manifestation : no underlying map appears when the open globus map is displayed

Verification : you are using one the following browser : edge, chrome, others but not using firefox

Confirmation: open the browser web tools and select the console tool

Access to fetch at 'https://c.tile.openstreetmap.org/6/10/23.png' from origin 'https://airlineservices.eu.pythonanywhere.com' has been blocked by CORS policy:

No 'Access-Control-Allow-Origin' header is present on the requested resource.

If an opaque response serves your needs, set the request's mode to 'no-cors' to fetch the resource with CORS disabled.c.tile.openstreetmap.org/6/10/23.png:1

Failed to load resource: net::ERR_FAILED

To ensure displaying globe with underlying street map , recommendation is to use FireFox

HISTORY OF CHANGES (1/2)

Date	What	Where
25th June 2023	On an airport right click contextual menu show both departing and arriving flight legs	Airport contextual right-click menu
1st July 2023	Display default reference mass in Profile compute menu (instead of Max Takeoff mass)	In Flight Profile menu
8th July 2023	Cleaning of Open Globus layers	Additional window to allow for clearing an existing flight leg ray layer (experimental feature)
16th July 2023	Departure Runway overshoot aborts the computation	Computation of departure ground run leg
22nd July 2023	Add browser recommendation to use FireFox	In the pdf presentation file (to download)
30th July 2023	Reduced Climb Power Percentage	Input added in Profile computation menu
6th July 2023	Latitude and longitude shown on the map as degrees & minutes (instead of decimal degrees)	See earth coordinates area in the bottom right of the map
10th August 2023	Reduce size of KML file, record only every 10th point in the trajectory	In the Flight Profile menu when launching KML computation
15th August 2023	In the Profile menu, add checkboxes to select the Best Runway	In the Flight Profile Menu
10th September 2023	In the EXCEL State Vector, second column contains either characteristic point or flight phase	In the EXCEL state vector output (vertical profile)
30th September 2023	Query the US aviation weather site to retrieve the airport meteo station METAR	Main menu on the upper right
3rd October 2023	Progressive deployment of Sortable tables	Click on a table header to sort the table according to the clicked column
11th November 2023	Descent Glide Slope Ramp starts at 10 Nautical Miles (instead of 5 NM)	Vertical profile
14th November 2023	Apply Speed Restriction below 10.000 feet Mean Sea Level	Vertical profile

HISTORY OF CHANGES (2/2)

Date	What	Where
24th December 2023	Add Fuel Efficiency computations (airline/airlineFuelEfficiency/xxxWings)	Only available as a URL query
3rd January 2024	Add Fuel Efficiency in a submenu Fuel beside Fuel Planner	Main menu
23rd January 2024	Costs are computed for each integer value of the Reduced Climb Power coefficient in a range from 0 to 15	Offline costs computation
24th January 2024	Add slides on the vertical profile defined by stall speeds	This file
25th January 2024	Add a features slide	This file
6th April 2024	In the Flight Profile menu, add checkbox to fly direct route, add "direct" column in flight leg costs	Flight profile menu with direct route checkbox
7th July 2024	Rewrite the features page	In this slideware
23rd August 204	Add a button to download an EXCEL with Wind Temperature data	Main menu – Meteo sub menu
16th September 2024	EXCEL vertical profile with nearest NOAA weather station	Flight Profile EXCEL vertical profile with weather station
28th September 2024	EXCEL vertical profile with nearest NOAA weather station and interpolated forecasts temperature at the flight level	Flight Profile EXCEL vertical profile

FEATURES

FEATURES

Configuration of
- airport's locations, waypoints, runways, SID, STAR independently of any airline
- aircraft performance with stall speeds for each aircraft configuration, mass, fuel capacity, flight envelope
- airline data with aircrafts seats, hourly operational costs, airline routes

4D Trajectory computations
- based upon aircraft takeoff mass and performance database
- generating both vertical and longitudinal trajectories displayed on an interactive 3D map
- producing a Google Earth KML file
- producing a state vector EXCEL file with thrust, lift, drag values, including speeds and altitude
- Resulting in flight leg durations, fuel consumption, to further estimate the operational costs

Optimizations allowing to
- to select the best aircraft type and flight leg pair to minimize costs including costs per Available Seat Miles
- to select the best aircraft type and flight leg pair to maximize Seat Miles in the daily rotations
- Compute optimal Reduced Climb Power Coefficient to maximize fuel savings

Miscellaneous features
- Use a fuel planner to identify optimal fuel capacity to fly the leg with one hour Fuel Reserve constraint
- Monitor ground run length to detect runway overshot
- Monitor fuel exhaustion
- Query airport METAR data to estimate the influence of wind on the ground run (both departure and arrival)

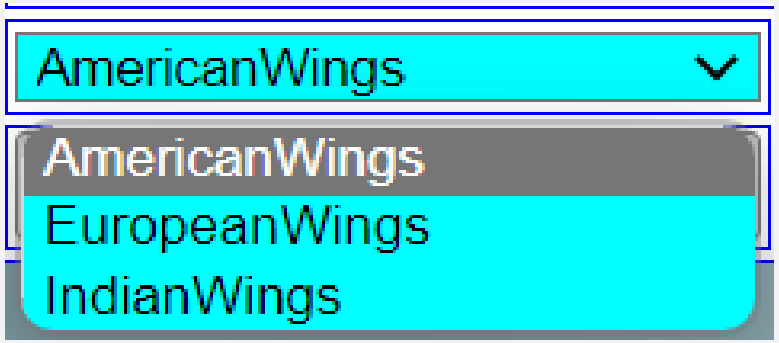
CONFIGURATION

Configuration data is made available in EXCEL data files and loaded into the SQL database

TOOL MAIN CONFIGURATION

3 different airlines have been configured with different parameters – for demonstration purpose

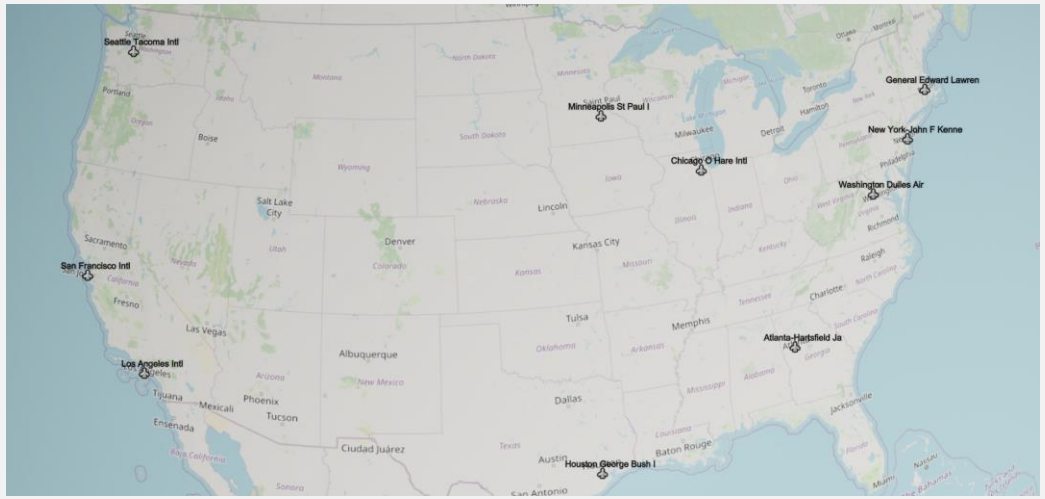
Airline Configuration data is stored in a SQL database



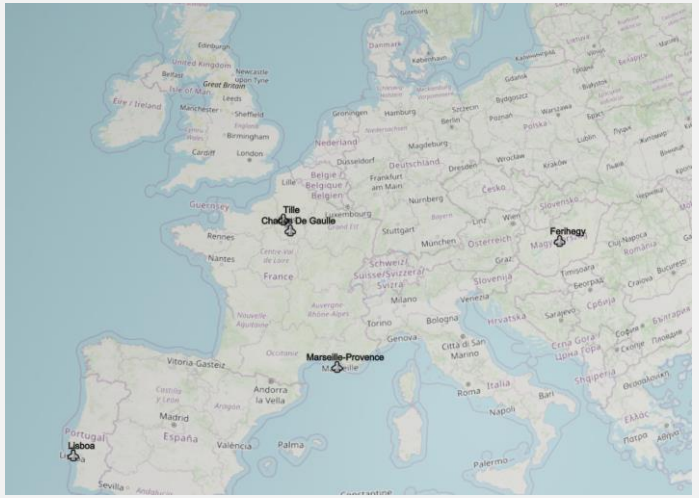
Each airline has its own map initial limits

Future: changing the airline will zoom again to see all the airports of the selected airline

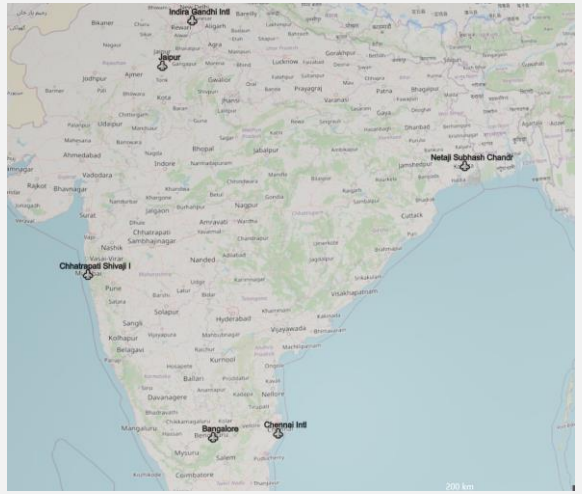
AmericanWings



EuropeanWings

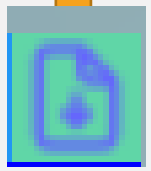


IndianWings



(ONLINE) HELP & CONFIGURATION

Click here to move -> Main navigation bar ---> click to download a User Manual -->

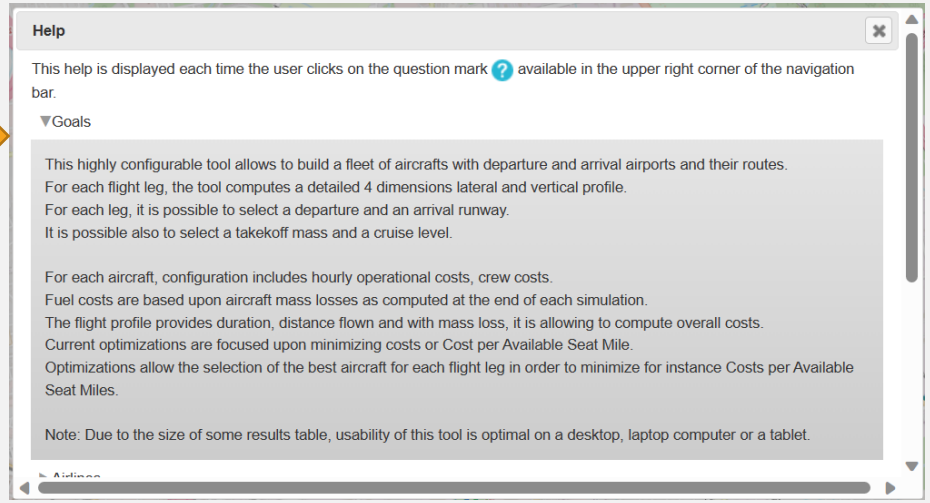


Click to get this presentation in pdf format

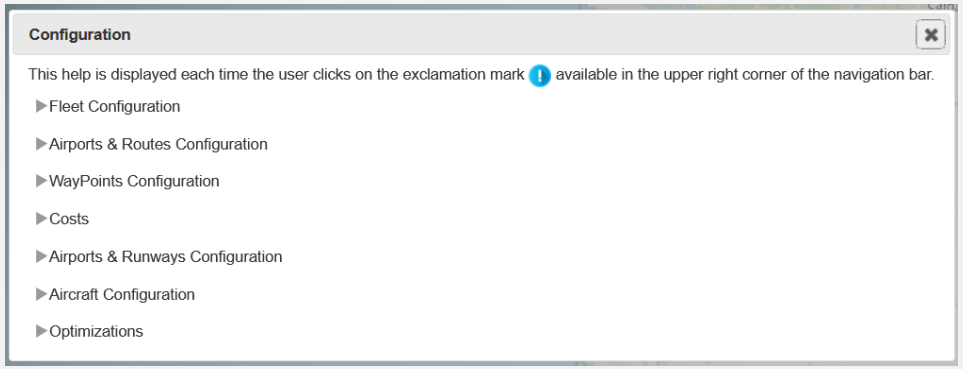
Right end of main menu bar

help

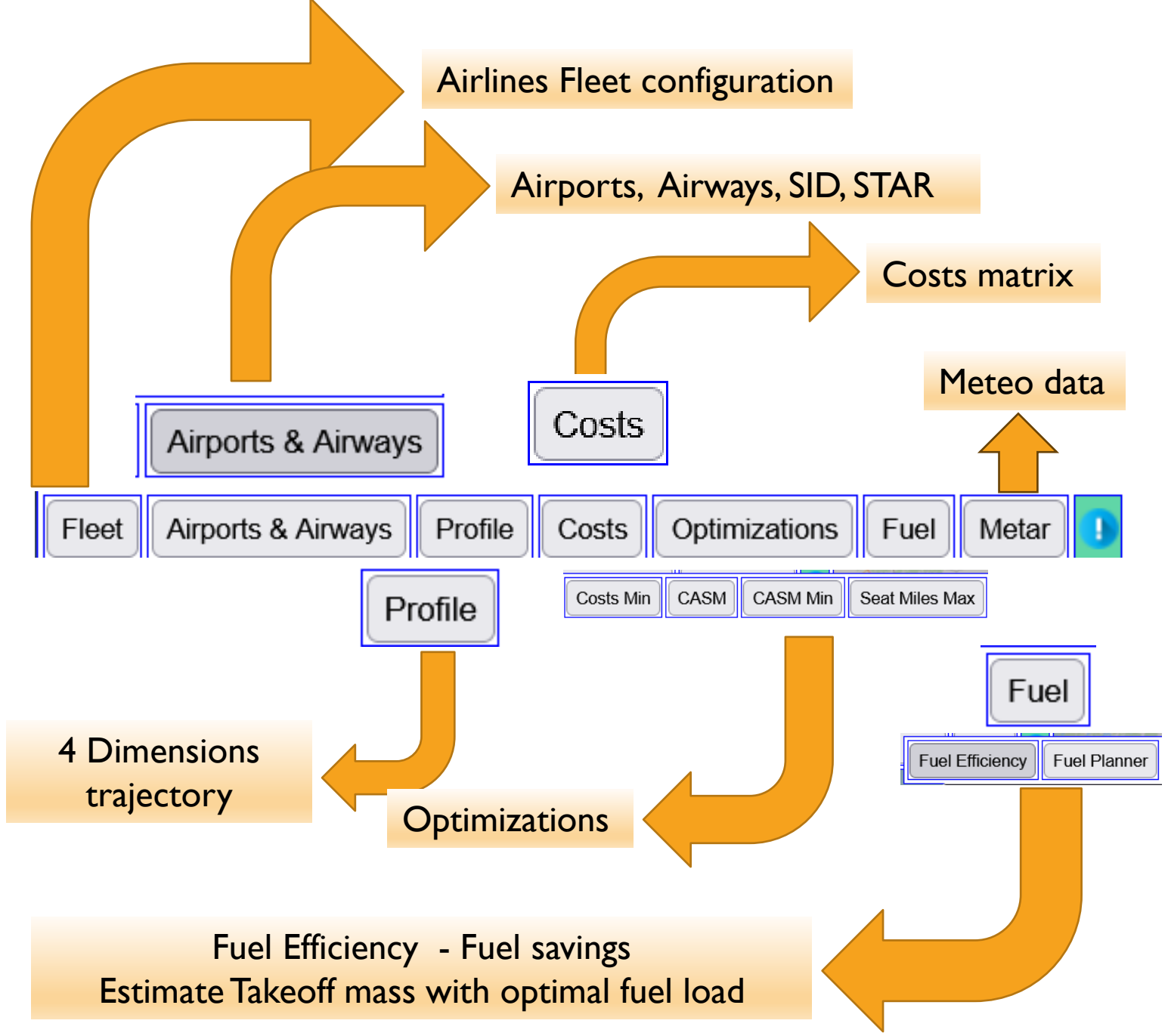
Help Informations



Configuration Informations



MAIN MENU BAR



AIRLINE FLEET CONFIGURATION

Aircraft ICAO code

Aircraft ICAO code is used to access aircraft performance data

Values are loaded into a database

Values are specific to each airline

Click here to move -> Airline Fleet Configuration

Click to hide

Airline	Aircraft ICAO Code	Aircraft Full Name	Number Of Aircrafts	Number Of Seats	Flying Costs Per Hour (US$)	Crew Costs Per Hour (US$)	Minimum Take Off Mass (Kg)	Reference Mass (Kg)	Maximum Take Off Mass (Kg)	Aircraft Turn Around Time (Min)
AmericanWings	A320	Airbus A320	5	157	2840	1657	39000	64000	77000	25
AmericanWings	A332	Airbus A330-200	5	234	3300	1857	120600	190000	230000	35
AmericanWings	B738	Boeing 737-800	5	160	3010	1557	41150	65300	78300	25

Not yet used

Used to compute CASM

CASM : Cost per Available Seat Miles

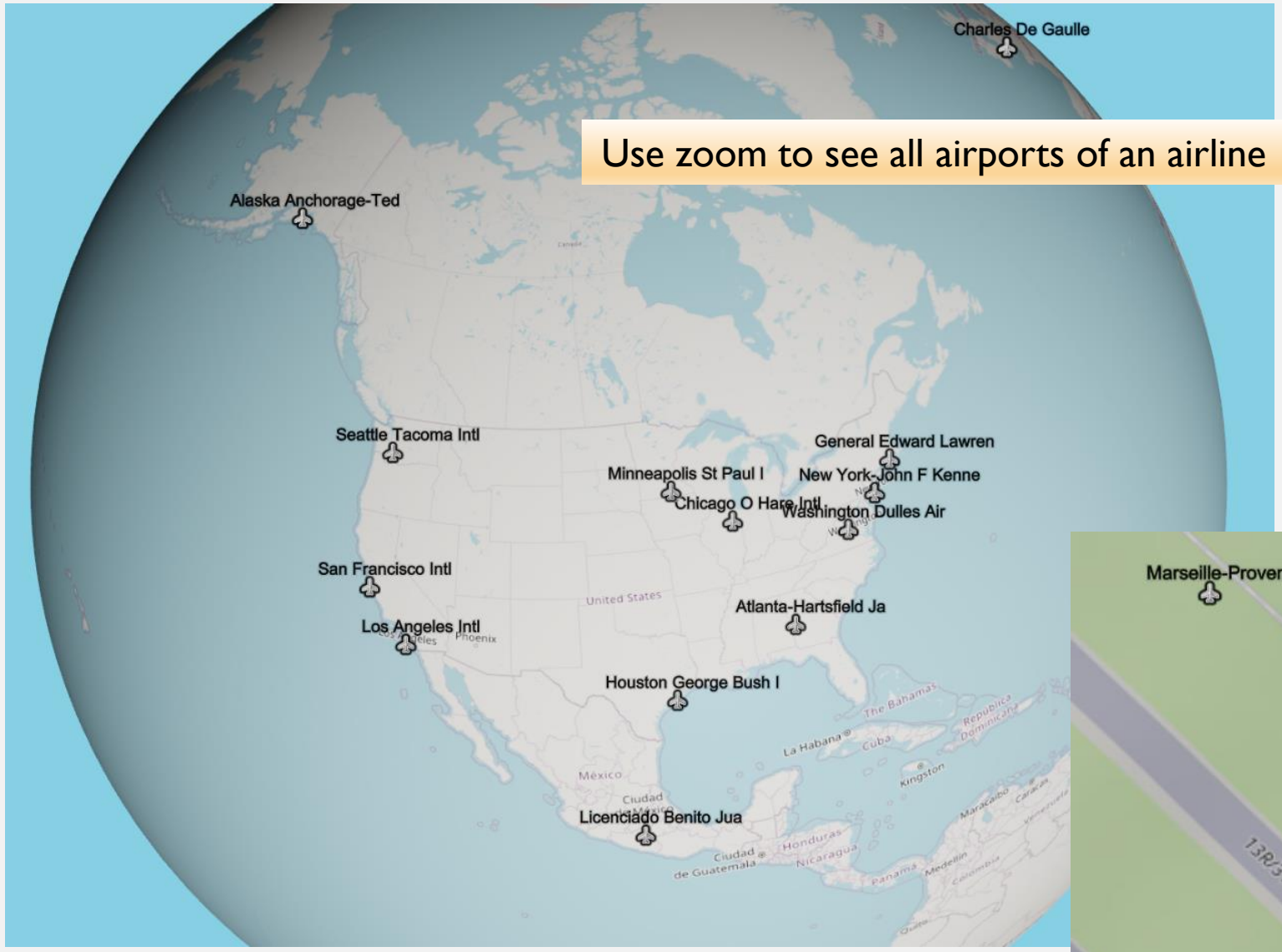
Used to compute costs

Used to compute profiles

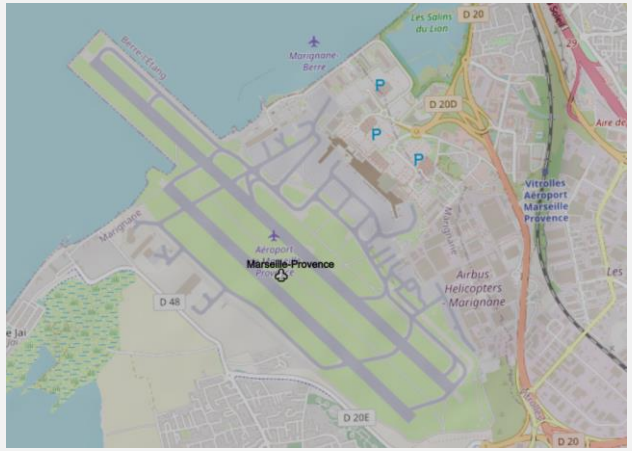
Used to compute airport turn around times -> used to compute Seat Miles

Since version 4.0 -> table has clickable headers allowing to sort according to the content of one table column

AIRLINE AIRPORTS – MAIN VIEWPORT CONFIGURATION



Street map appears only when « sufficient » zoom is set & street map tile is available



-> Runways identifiers are visible

AIRLINES ROUTES

Defines the departure and arrival airports for each airline flight leg / route

Example of database extract for Routes

	id [PK] integer	DepartureAirport character varying	DepartureAirportICAOCode character varying	ArrivalAirport character varying	ArrivalAirportICAOCode character varying	airline_id integer
1	23	Atlanta-Hartsfield Jackson Intl	KATL	Los Angeles Intl	KLAX	4
2	24	New York-John F Kennedy Intl	KJFK	Seattle Tacoma Intl	KSEA	4
3	25	Aeropuerto México Ciudad Intl	MMMX	Seattle Tacoma Intl	KSEA	4
4	26	General Edward Lawrence Logan Intl	KBOS	Atlanta-Hartsfield Jackson Intl	KATL	4
5	27	Houston George Bush Intl	KIAH	Chicago O'Hare Intl	KORD	4
6	28	Washington Dulles Airport Intl	KIAD	San Francisco Intl	KSFO	4

record id *

* Primary key

Airport ICAO code

* Foreign key

Airport ICAO code

* Foreign key

Airline id *

* Foreign key

HOW TO ACCESS A ROUTE FROM THE MAIN MENU

Airports & Airways

click

Airports | Airways

click

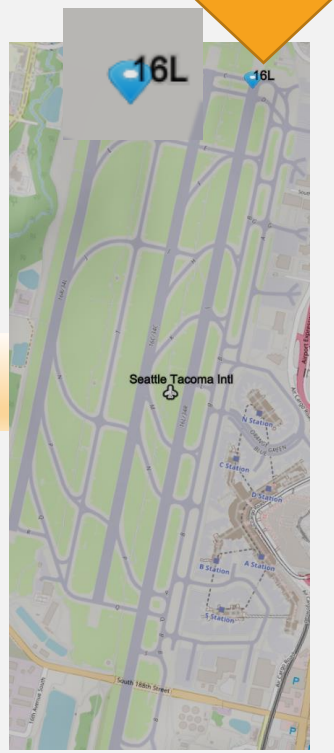
Since version 4.0 -> table has clickable headers allowing to sort according to the content of one table column

Click here to move Airline Routes Configuration — Click to hide

Airline	Departure Airport	ICAO	SID	Best Rwy	Destination Airport	ICAO	STAR	Best Rwy	Action
AmericanWings	Atlanta-Hartsfield Jackson Intl	KATL		27R	Los Angeles Intl	KLAX		07L	Show

Best runway computation based upon distance from runway end to first / last waypoint of the route

Best runway also displayed on the map



Click to show / hide the way points on the map

SQL Database table view

degrees — degrees

	WayPointName [PK] character varying	Type character varying	Latitude double precision	Longitude double precision	Continent character varying
343	VLN	WayPoint	50.667005555555555	-104.88971111111111	North America
344	VORIN	WayPoint	41.548002777777775	-89.336375	North America
345	VUZ	WayPoint	33.67013055555555	-86.89983611111111	North America

VUZ latitude & longitude & elevation as seen when hovering on the map

SID STAR -> CLICK TO SEE AIRPORT PROCEDURES

Since version 4.0 -> table has clickable headers allowing to sort according to the content of one table column

Click here to move Airline Routes Configuration — Click to hide

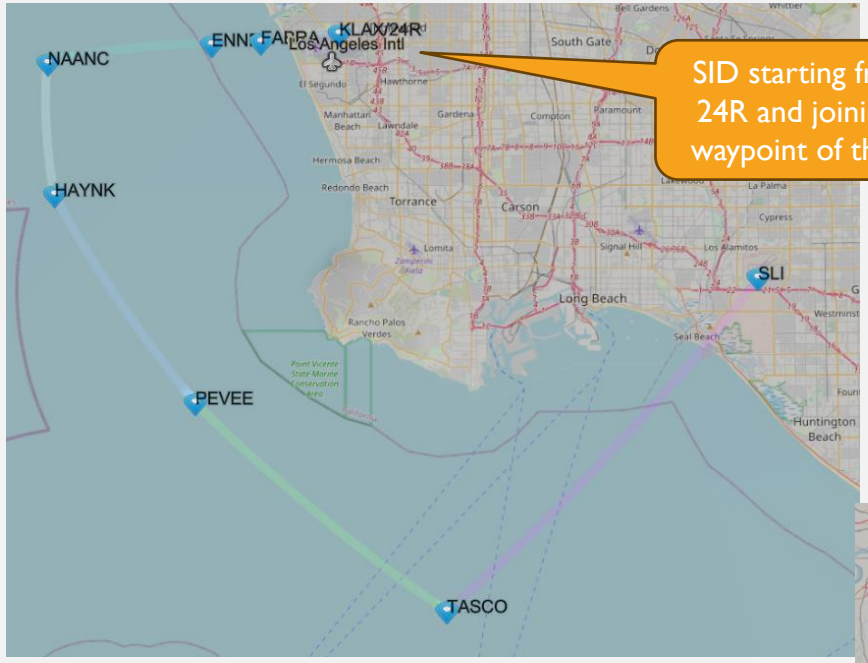
Airline	Departure Airport	ICAO	SID	Best Rwy	Destination Airport	ICAO	STAR	Best Rwy	Action
AmericanWings	Los Angeles Intl	KLAX	KLAX/24R/SLI	07L	Atlanta-Hartsfield Jackson Intl	KATL	KATL/26L/MEM	27R	Show

SID

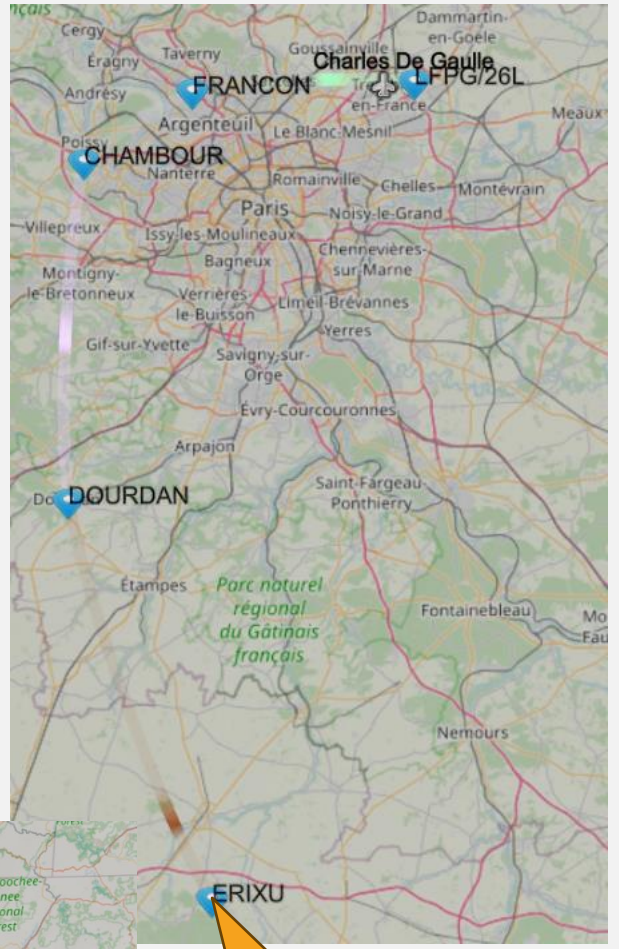
Click to see the SID on the map

STAR

Click to see the STAR on the map



SID starting from KLAX 24R and joining SLI first waypoint of the flight leg



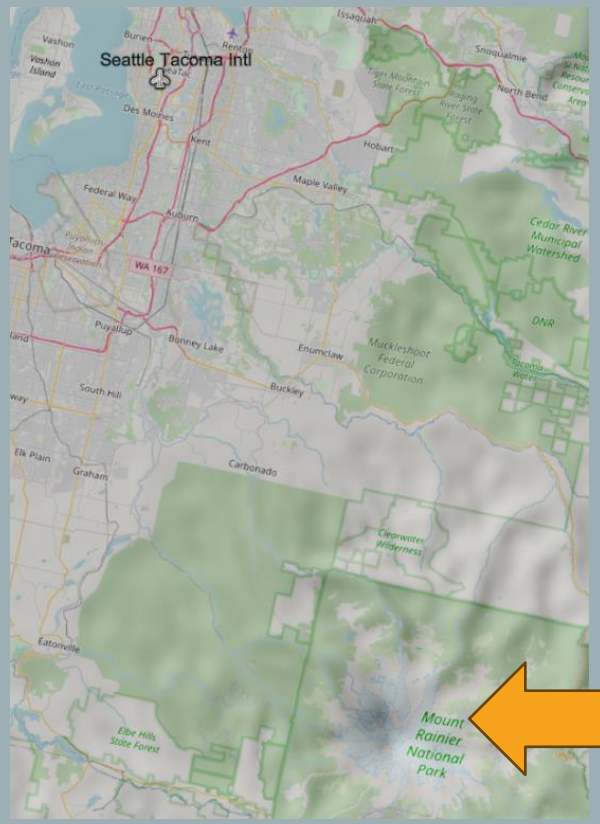
STAR starting from MEM last waypoint of the flight leg and joining KATL 26L

STAR starting from LFPG 26L and joining ERIXU first waypoint of the flight leg

SID & STAR PURPOSE

Purpose : avoid obstacle or noise or air pollution over crowed city suburbs, during climb & approach phase,

Example : taking off from Los Angeles with sea head wind, the aircraft is following a SID that is climbing with reduced speed hence reduced noise pollution over the sea before turning back to the land to join the flight leg first way point



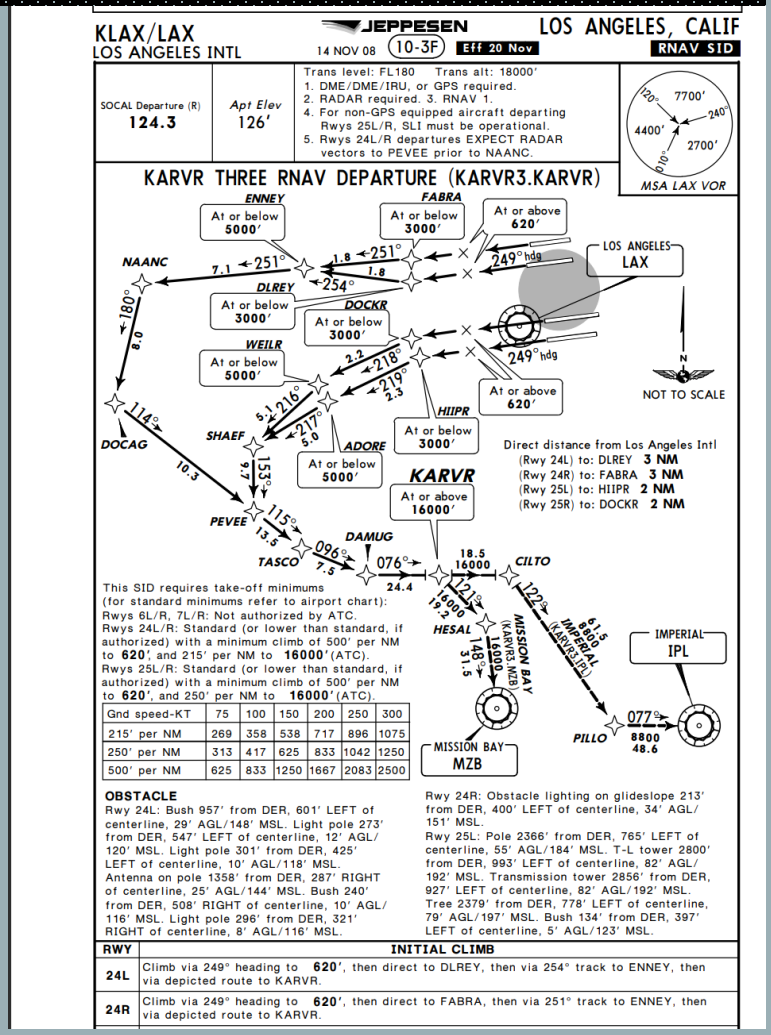
Example : Mount Rainer obstacle avoidance during approach to Seattle from Southeast

Avoid Mount Rainer

N 46°51'5" W 121°45'41" 4355 m

Altitude above Ground

Example : Departure from Los Angeles -> climb over the sea to avoid noise and pollution before flying over residential area



STANDARD INSTRUMENT DEPARTURE (SID)
EXAMPLE : LOS ANGELES KLAX/24R TO SLI

Warning : outdated Jeppesen departure chart for demonstration purpose only

KLAX/LAX
LOS ANGELES INTL

JEPPESEN
14 NOV 08 (10-3F) Eff 20 Nov

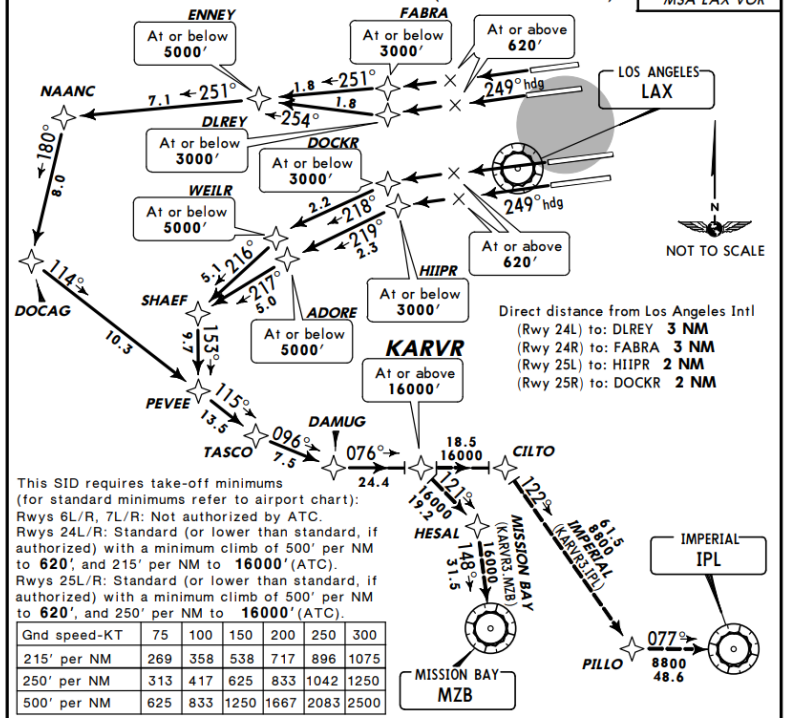
LOS ANGELES, CALIF
RNAV SID

SOCAL Departure (R)	Apt Elev
124.3	126′

Trans level: FL180 Trans alt: 18000′
1. DME/DME/IRU, or GPS required.
2. RADAR required. 3. RNAV 1.
4. For non-GPS equipped aircraft departing Rwys 25L/R, SLI must be operational.
5. Rwys 24L/R departures EXPECT RADAR vectors to PEVEE prior to NAANC.

MSA LAX VOR
120° 7700′ 240° 4400′ 2700′ 010°

KARVR THREE RNAV DEPARTURE (KARVR3.KARVR)



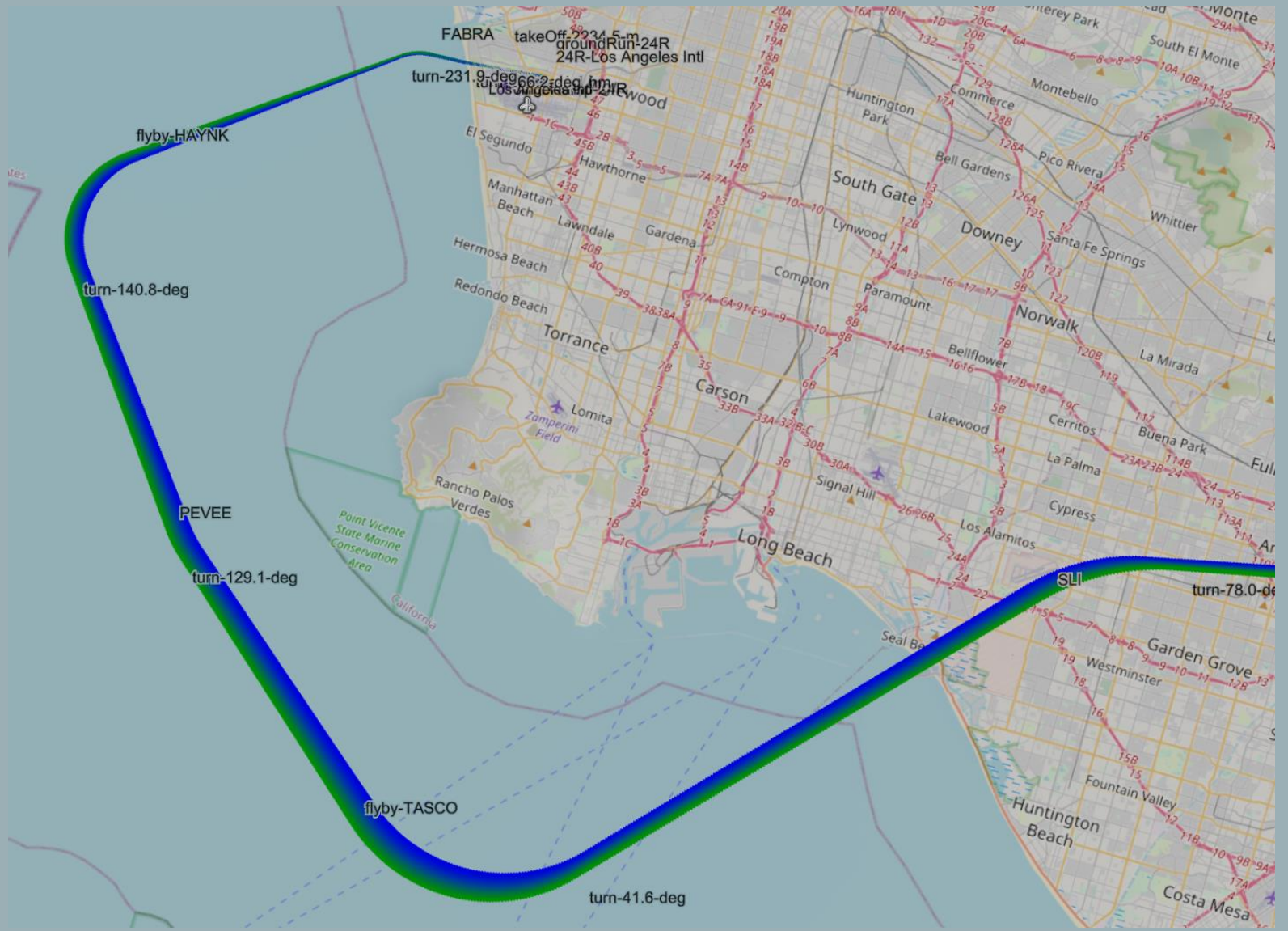
This SID requires take-off minimums (for standard minimums refer to airport chart):
Rwys 6L/R, 7L/R: Not authorized by ATC.
Rwys 24L/R: Standard (or lower than standard, if authorized) with a minimum climb of 500′ per NM to **620′**, and 215′ per NM to **16000′** (ATC).
Rwys 25L/R: Standard (or lower than standard, if authorized) with a minimum climb of 500′ per NM to **620′**, and 250′ per NM to **16000′** (ATC).

Gnd speed-KT	75	100	150	200	250	300
215′ per NM	269	358	538	717	896	1075
250′ per NM	313	417	625	833	1042	1250
500′ per NM	625	833	1250	1667	2083	2500

OBSTACLE
Rwy 24L: Bush 957′ from DER, 601′ LEFT of centerline, 29′ AGL/148′ MSL. Light pole 273′ from DER, 547′ LEFT of centerline, 12′ AGL/120′ MSL. Light pole 301′ from DER, 425′ LEFT of centerline, 10′ AGL/118′ MSL. Antenna on pole 1358′ from DER, 287′ RIGHT of centerline, 25′ AGL/144′ MSL. Bush 240′ from DER, 508′ RIGHT of centerline, 10′ AGL/116′ MSL. Light pole 296′ from DER, 321′ RIGHT of centerline, 8′ AGL/116′ MSL.

Rwy 24R: Obstacle lighting on glideslope 213′ from DER, 400′ LEFT of centerline, 34′ AGL/151′ MSL.
Rwy 25L: Pole 2366′ from DER, 765′ LEFT of centerline, 55′ AGL/184′ MSL. T-L tower 2800′ from DER, 993′ LEFT of centerline, 82′ AGL/192′ MSL. Transmission tower 2856′ from DER, 927′ LEFT of centerline, 82′ AGL/192′ MSL. Tree 2379′ from DER, 778′ LEFT of centerline, 79′ AGL/197′ MSL. Bush 134′ from DER, 397′ LEFT of centerline, 5′ AGL/123′ MSL.

RWY	INITIAL CLIMB
24L	Climb via 249° heading to **620′**, then direct to DLREY, then via 254° track to ENNEY, then via depicted route to KARVR.
24R	Climb via 249° heading to **620′**, then direct to FABRA, then via 251° track to ENNEY, then via depicted route to KARVR.



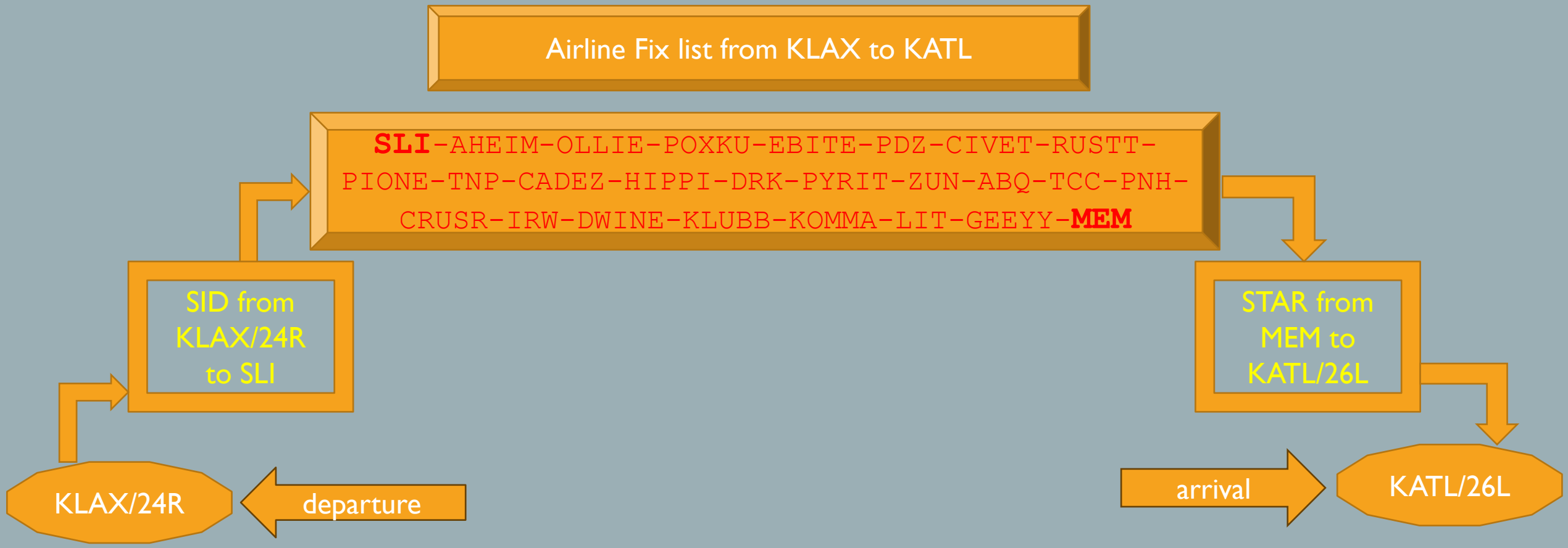
SID & STAR

SID waypoints are inserted in the fix list as soon as :

1) Departure airport is matching SID airport
2) Departure runway is matching SID runway
3) First fix of the route is matching last waypoint of the SID

STAR waypoints are inserted in the fix list as soon as :

1) Arrival airport is matching STAR airport
2) Arrival runway is matching STAR runway
3) Last fix of the route is matching first waypoint of the STAR



SID & STAR DATA

SID & STAR are generic, not related to any airline route

SID STAR id is a primary key

	id [PK] integer	isSID boolean	DepartureArrivalAirport_id character varying	DepartureArrivalRunWay_id integer	FirstLastRouteWayPoint_id character varying
1	19	true	KLAX	1168	SLI
2	20	false	KATL	1122	MEM

airport id is a foreign key

runway id is a foreign key

Waypoint id is a foreign key

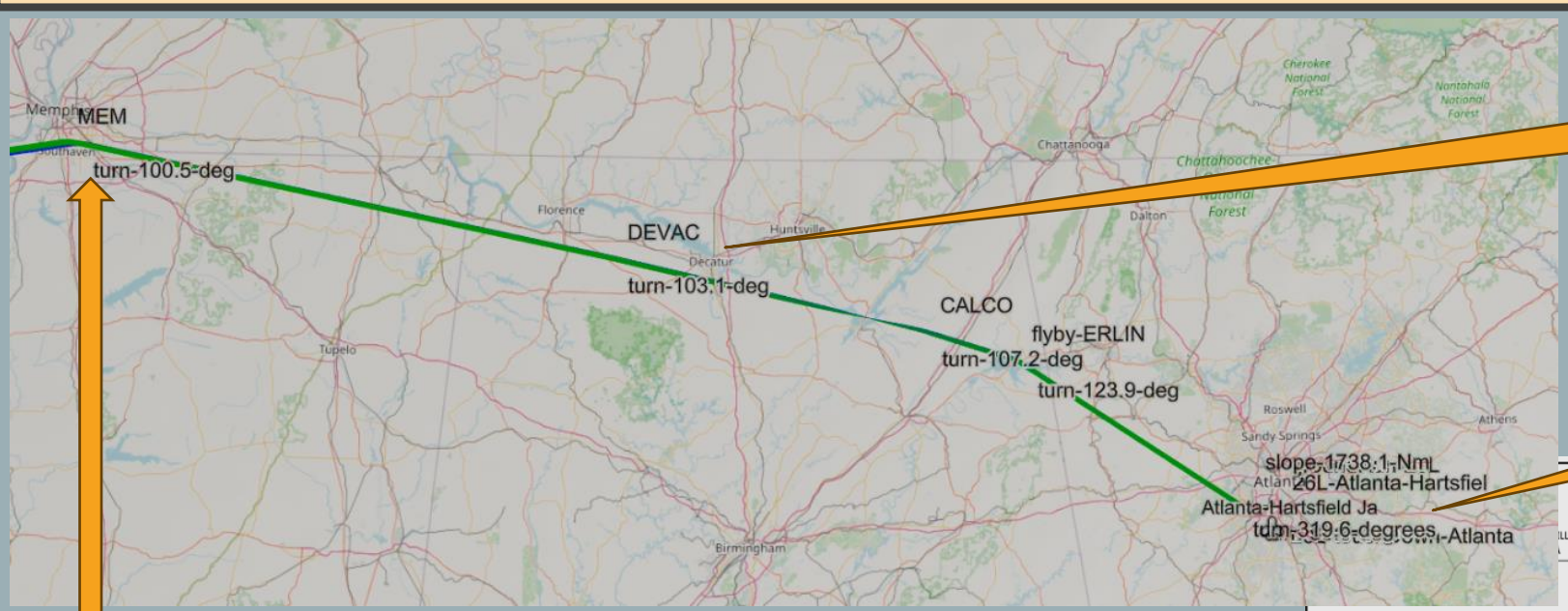
SID & STAR waypoints are inserted automatically in the fix list when the adequate runway is selected

Route id

Route id is a foreign key

	id [PK] integer	Order integer	WayPointName character varying	LatitudeDegrees double precision	LongitudeDegrees double precision	Route_id integer
1	25	0	KLAX/24R	33.95209884643555	-118.4020004272461	19
2	26	1	FABRA	33.94638888888888	-118.46708333333333	19
3	27	2	ENNEY	33.94461111111111	-118.5078888888889	19
4	28	3	NAANC	33.931666666666665	-118.6438888888889	19
5	29	4	HAYNK	33.84075000000001	-118.63791666666668	19
6	30	5	PEVEE	33.697222222222216	-118.52083333333333	19
7	31	6	TASCO	33.55361111111111	-118.31277777777777	19
8	32	7	SLI	33.783297222222224	-118.05475555555556	19
9	33	1	MEM	35.015116666666664	-89.98320833333332	20
10	34	2	DEVAC	34.61830555555556	-87.43516666666667	20
11	35	3	CALCO	34.34525277777777	-86.01936666666667	20
12	36	4	HERKO	33.069075000000005	-86.84538055555555	20
13	37	5	KATL/26L	33.64680099487305	-84.40550231933594	20

STANDARD TERMINAL ARRIVAL (STAR MEMPHIS -> ATLANTA KATL/26L)

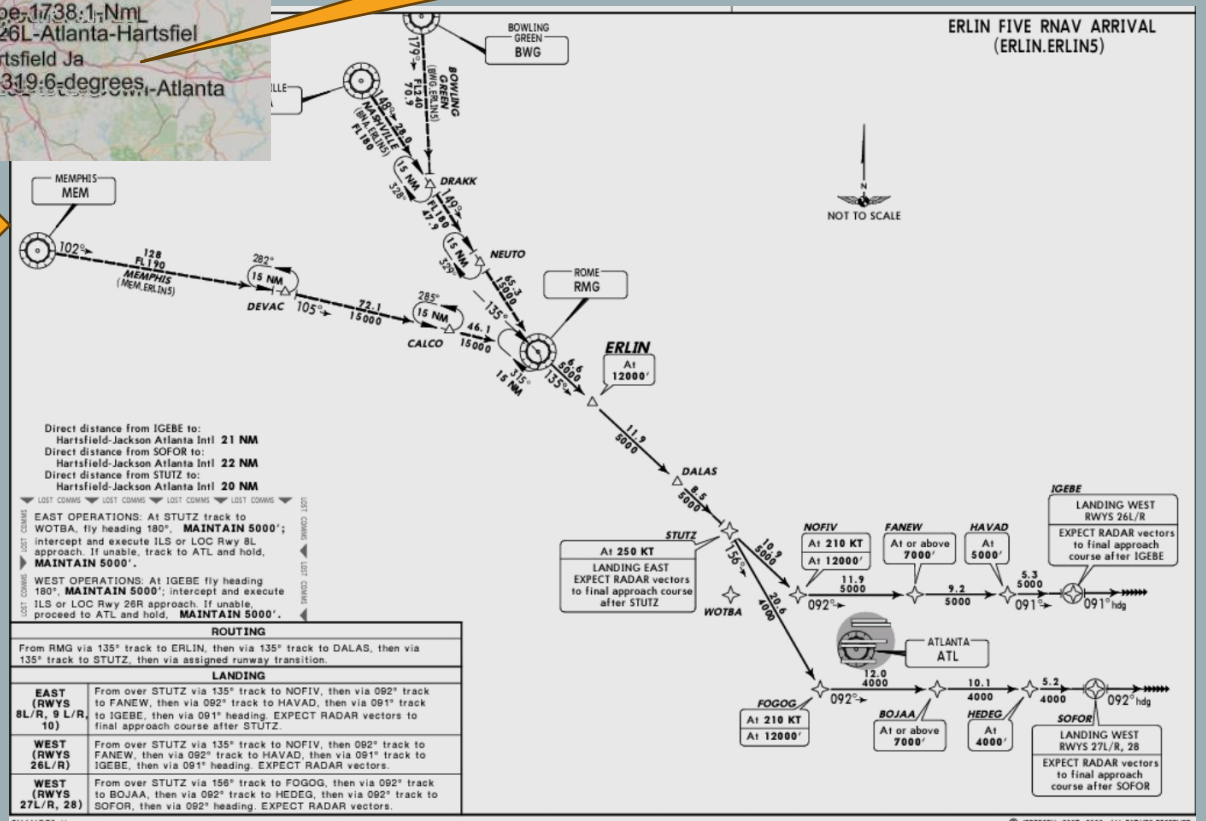


STAR waypoint

Arrival runway = 26L
~ 270 degrees true heading

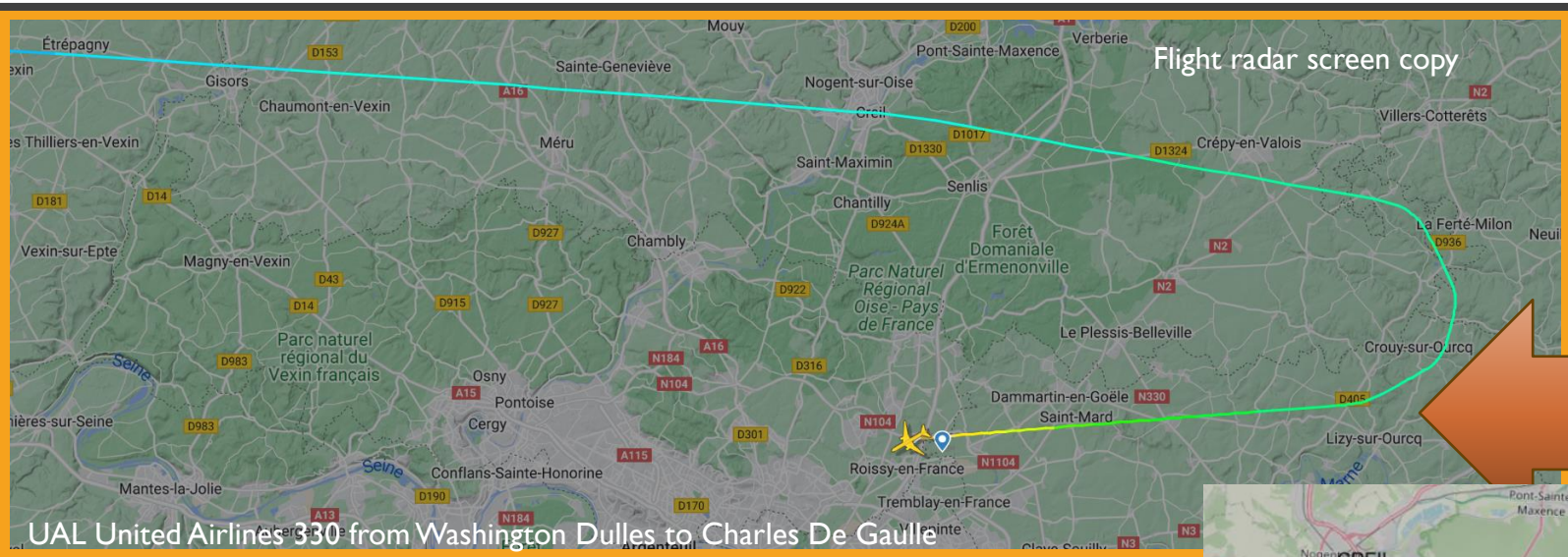
MEM

MEM – Memphis is the last waypoint of the flight leg



Warning : outdated Jeppesen arrival chart

STAR - ALIGNMENT ON THE ARRIVAL RUNWAY



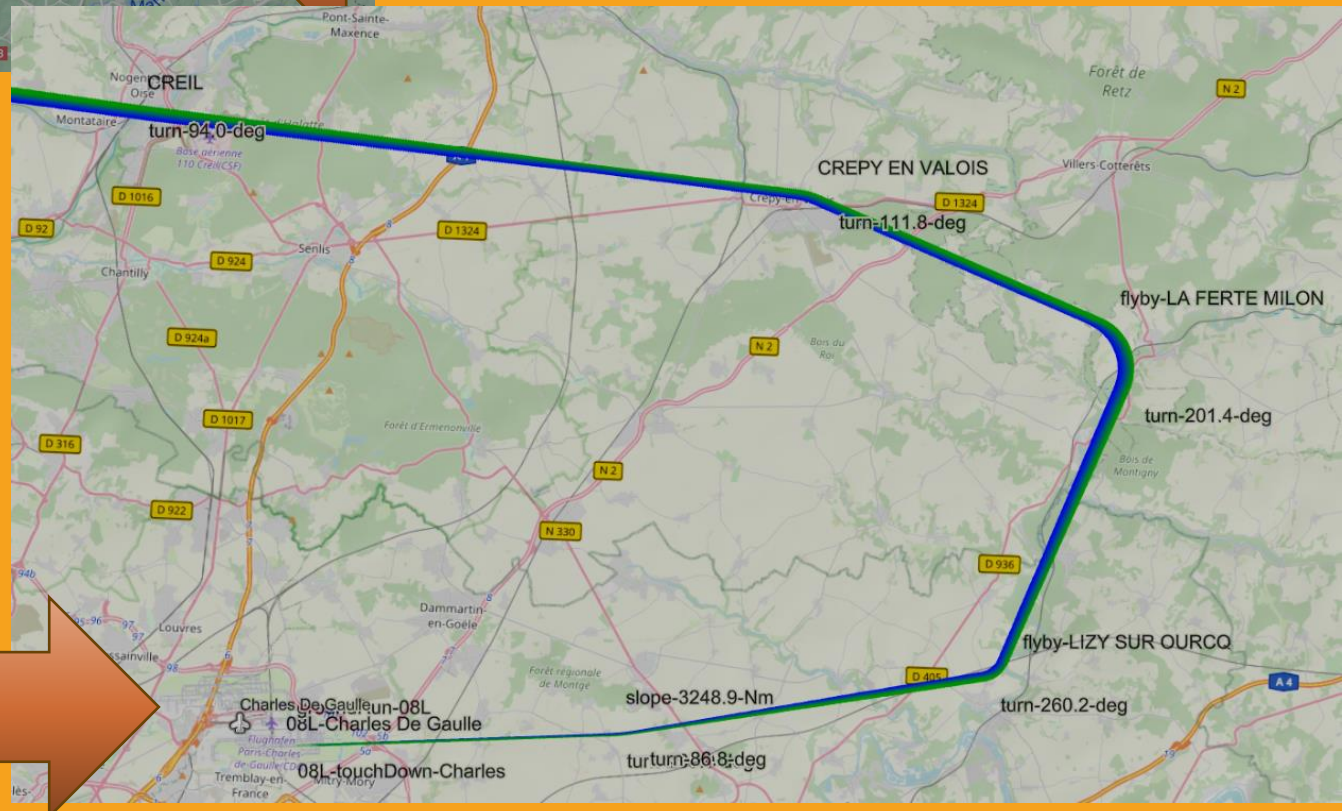
UAL United Airlines 330 from Washington Dulles to Charles De Gaulle

Runways are selected in accordance with head winds -> aircraft must land with head wind , nose pointing to the wind

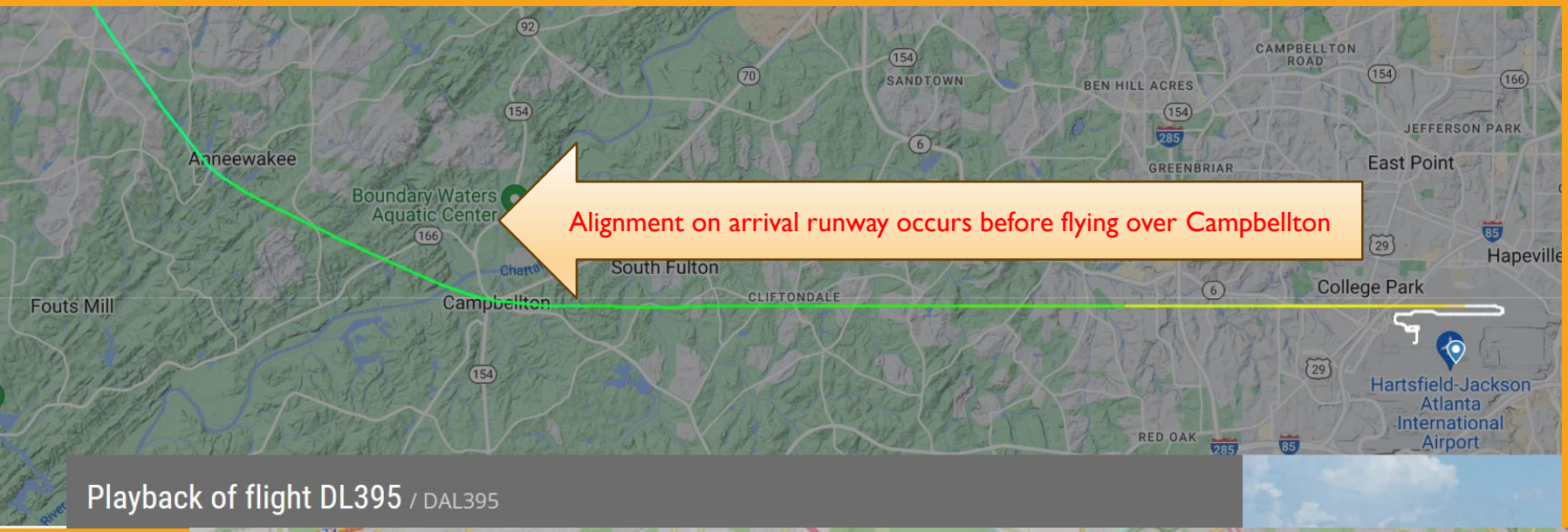
Comparison of alignment on the arrival runway

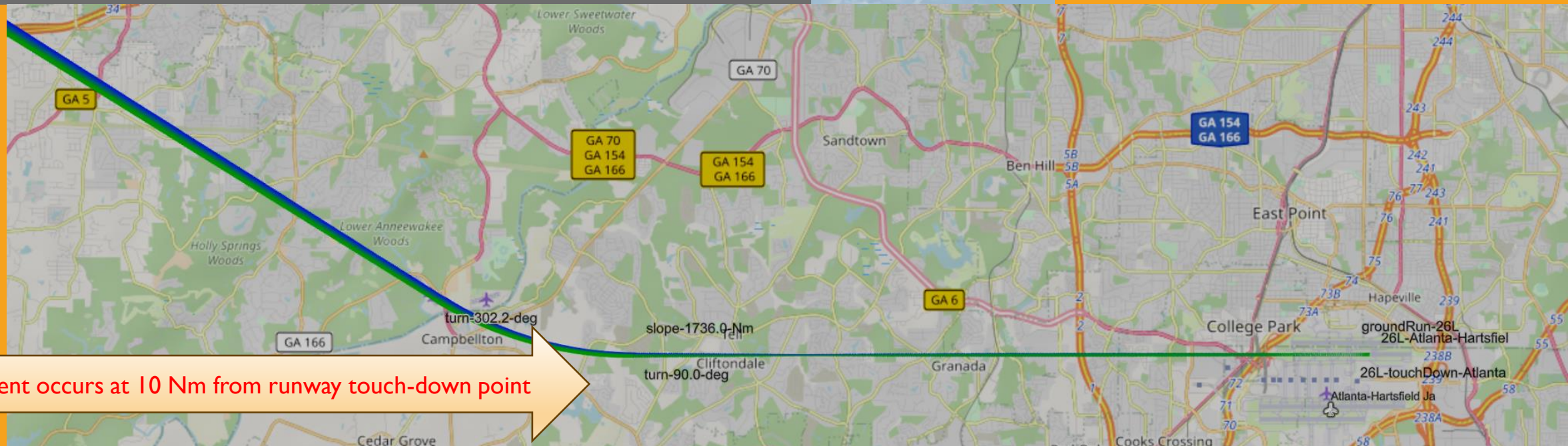
A330 – KJFK – LFPG -> 08L

Alignment on the arrival runway at 10Nm from runway touch-down



STAR - ALIGNMENT ON THE ARRIVAL RUNWAY





ALIGNMENT ON ARRIVAL RUNWAY ATLANTA 26L

10 Nm from runway touch-down point

STAR – PURPOSE IS ALSO OBSTACLE AVOIDANCE

Mexico MMX to Seattle
Arrival using runway Seattle KSEA/16L
180 degrees True Heading

Without a STAR, aircraft would « crash » into the mountain

Google Earth view using the KML generated file

Aircraft altitude above Mean Sea Level (meters)

The Google Elevation API provides elevation in meters relative to the local mean sea level (LMSL)

Obstacle is Mount RAINER

HOW TO ACCESS A ROUTE FROM THE MAP (USING A CONTEXTUAL RIGHT CLICK ON AN AIRPORT)

Note: currently route and airway are designating the same "concept" of a departure airport and the waypoints to reach the destination airport

Hover over the airport until mouse pointer changes to "hand", then right click to access a contextual menu

Right click on an airport
to see routes starting / ending at this airport

Airline	direction	action	Departure Airport	ICAO	Arrival Airport	ICAO
AmericanWings	←	show / hide route	New York-John F Kennedy Intl	KJFK	Seattle Tacoma Intl	KSEA
AmericanWings	→	show / hide route	Seattle Tacoma Intl	KSEA	New York-John F Kennedy Intl	KJFK
AmericanWings	←	show / hide route	Aeropuerto México Ciudad Intl	MMMX	Seattle Tacoma Intl	KSEA

Note: a route is mono directional

Note: the table disappears as soon as the mouse posiion leaves the table area

Click on the link to see / hide the location of the waypoints on the map

AIRPORTS CONFIGURATION DATA

Example of database content for Airports

degrees

degrees

meters

* PK = Primary key

	AirportICAOcode [PK] character varying	AirportName character varying	Latitude double precision	Longitude double precision	FieldElevationAboveSeaLevelMeters double precision	Continent character varying
1	KATL	Atlanta-Hartsfield Jackson Atlanta Intl	33.636719	-84.428067	312.7248	United States
2	KBOS	General Edward Lawrence Logan Intl	42.364347	-71.005181	5.7912	United States
3	KIAD	Washington Dulles Airport Intl	38.944533	-77.455811	95.4024	United States
4	KIAH	Houston George Bush Intl	29.984433	-95.341442	29.5656	United States
5	KJFK	New York-John F Kennedy Intl	40.639751	-73.778925	3.9624	United States
6	KLAX	Los Angeles Intl	33.942536	-118.408075	38.4048	United States
7	KMSP	Minneapolis St Paul Intl	44.881956	-93.221767	256.33680000000004	United States
8	KORD	Chicago O'Hare Intl	41.978603	-87.904842	203.6064	United States
9	KSEA	Seattle Tacoma Intl	47.449	-122.309306	131.9784	United States
10	KSFO	San Francisco Intl	37.618972	-122.374889	3.9624	United States

*

Name displayed on the map

Each airport is defined by a unique 4 letters ICAO code

RUNWAY'S CONFIGURATION DATA

Example of database content for KATL – Atlanta runways

degrees

True heading is the angle computed from the magnetic north to the orientation of the runway

	id [PK] integer	Name character varying	LengthFeet double precision	TrueHeadingDegrees double precision	LatitudeDegrees double precision	LongitudeDegrees double precision	Airport_id character varying
1	1	08L	9000	90	33.64950180053711	-84.43900299072266	KATL
2	2	26R	9000	270	33.64950180053711	-84.40950012207031	KATL
3	3	08R	10000	90	33.64680099487305	-84.43840026855469	KATL
4	4	26L	10000	270	33.64680099487305	-84.40550231933594	KATL
5	5	09L	11890	90	33.634700775146484	-84.447998046875	KATL
6	6	27R	11890	270	33.634700775146484	-84.40889739990234	KATL
7	7	09R	9001	90	33.63180160522461	-84.447998046875	KATL
8	8	27L	9001	270	33.63180160522461	-84.41840362548828	KATL
9	9	10	9000	90	33.62030029296875	-84.4478988647461	KATL
10	10	28	9000	270	33.62030029296875	-84.41829681396484	KATL

For one airport, number of Runways contributes to compute the airport turn around time specific part

Future : number of runways per airport will be used to compute Block Hour from trip duration

WAYPOINTS CONFIGURATION DATA

Example of database content for waypoints (one unique data table for all airlines)

Waypoints configuration are common for all airlines routes

degrees degrees

	WayPointName [PK] character varying	Type character varying	Latitude double precision	Longitude double precision	Continent character varying
1	47N050W	WayPoint	47.5	-50	Europe
2	49N040W	WayPoint	49.5	-40	Europe
3	51N030W	WayPoint	51.5	-30	Europe
4	52N020W	WayPoint	52.5	-20	Europe
5	ABQ	WayPoint	35.043794444444444	-106.81631111111112	North America
6	ABR	WayPoint	45.41735277777778	-98.36871944444444	North America
7	ADUKE	WayPoint	31.882430555555555	-94.21646666666666	North America
8	AGROM	WayPoint	22.529163888888885	84.83333055555555	India
9	AHEIM	WayPoint	33.82031388888889	-117.91197222222222	North America
10	ALBED	WayPoint	18.117219444444444	78.6566638888889	India
11	ALEPO	WayPoint	42.343608333333336	-1.9633333333333334	Europe
12	AMDID	WayPoint	48.09721944444445	12.396944444444443	Europe
13	ANDAV	WayPoint	17.471666666666664	78.81361111111111	India

Warning: waypoint name (as a primary key) must be unique for all routes / all flight legs

4 DIMENSIONS TRAJECTORY COMPUTATION

Dimensions are

1) *Latitude (degrees)*
2) *Longitude (degrees)*
3) *altitude above mean sea level MSL (meters)*
4) *a relative time stamp (seconds) for each previous 3D point with the reference defined when the aircraft release breaks release and put full throttle on the departure runway*
    1) *Hence timestamp defines an ordered sequence of 3D positions*

PHASES OF FLIGHT
EXTRACT FROM EUROCONTROL SKY LIBRARY

Choice is made to start phases when aircraft is on the runway, and pilot receives clearance to take off from Air Traffic controllers

First phase called « ground run » starts when engine power is applied and until aircraft achieves rotation speed -> aircraft nose rises above the runway

Second phase called « take off » when aircraft leaves the ground run until it reaches an altitude of 35 feet above the runway (obstacle clearance) or until landing gear is retracted (whatever comes first)

Third phase called « climb ramp » where aircraft climbs along a 6-8 degrees ramp until its distance from runway is greater than 5 nautical miles or Standard Instrument Departure comes into play

Next phase called « SID » follows Standard Instrument Departure waypoints until first flight leg waypoint is reached

… loop through great circles followed by turn legs

After last leg waypoint, follow a STAR if defined, to align with the arrival runway heading.

At 10 Nautical miles from arrival runway, aircraft route aligns with the arrival runway heading and resume the descending glide slope until touch-down

Ground run until speed reaches taxi-speed and aircraft is ready to leave the runway

Future: *extend flight duration from un-docking to taxi towards departure runway to compute Block Hour instead of only trip duration*

VERTICAL PROFILE DEFINED BY STALL SPEEDS

```
Aircraft ==================================
Aircraft entering take-off configuration - flown 1464.19 meters - distance flown 0.79 Nm
Aircraft alt= 312.72 meters alt= 1026.00 feet
Aircraft TAS= 70.03 m/s - TAS= 136.13 knots - CAS= 69.06 m/s - CAS= 134.24 knots - Mach= 0.21
Aircraft ==================================
Aircraft entering initial-climb configuration - flown 1967.50 meters - distance flown 1.06 Nm
Aircraft alt= 360.94 meters alt= 1184.17 feet
Aircraft TAS= 72.80 m/s - TAS= 141.51 knots - CAS= 71.63 m/s - CAS= 139.24 knots - Mach= 0.21
Aircraft ==================================
Aircraft entering climb configuration - flown 27625.98 meters - distance flown 14.92 Nm
Aircraft alt= 3037.70 meters alt= 9966.21 feet
Aircraft TAS= 128.61 m/s - TAS= 250.00 knots - CAS= 111.31 m/s - CAS= 216.36 knots - Mach= 0.39
Aircraft ==================================
Aircraft entering cruise configuration - flown 506001.78 meters - distance flown 273.22 Nm
Aircraft alt= 11787.13 meters alt= 38671.68 feet
Aircraft TAS= 242.08 m/s - TAS= 470.57 knots - CAS= 132.18 m/s - CAS= 256.93 knots - Mach= 0.82
Aircraft ==================================
Aircraft entering descent configuration - flown 2924335.32 meters - distance flown 1579.01 Nm
Aircraft alt= 11787.32 meters alt= 38672.30 feet
Aircraft TAS= 242.12 m/s - TAS= 470.65 knots - CAS= 132.20 m/s - CAS= 256.98 knots - Mach= 0.82
Aircraft ==================================
Aircraft entering approach configuration - flown 3106177.20 meters - distance flown 1677.20 Nm
Aircraft alt= 1957.88 meters alt= 6423.48 feet
Aircraft TAS= 56.20 m/s - TAS= 109.23 knots - CAS= 51.08 m/s - CAS= 99.29 knots - Mach= 0.17
Aircraft ==================================
Aircraft entering landing configuration - flown 3113195.96 meters - distance flown 1680.99 Nm
Aircraft alt= 1581.87 meters alt= 5189.88 feet
Aircraft TAS= 51.98 m/s - TAS= 101.03 knots - CAS= 48.18 m/s - CAS= 93.66 knots - Mach= 0.16
Aircraft ==================================
Aircraft entering arrival-ground-run configuration - flown 3142744.21 meters - distance flown 1696.95 Nm
Aircraft alt= 38.80 meters alt= 127.31 feet
Aircraft TAS= 41.15 m/s - TAS= 79.98 knots - CAS= 41.08 m/s - CAS= 79.85 knots - Mach= 0.12
Aircraft ==================================
Aircraft - taxi speed reached => end of simulation
```

Stall Speed - rotate

Stall Speed – retract landing gear

Stall Speed - flaps

Stall Speed - clean

Stall Speed – idle thrust

Stall Speed - flaps

Stall Speed – landing gear out

taxi Speed

REDUCED CLIMB POWER COEFFICIENT

Experimental feature

Click here to move -> Flight Profile Computation — Click to hide

Select the aircraft -> Airbus A320

Enter Reduced Climb Power % -> 15

Reduced Climb Power coefficient expressed as a percentage

min -> 39000 TakeOff Mass (kg) -> 64000 max -> 77000

Requested Flight Level (feet) -> 39000 max -> 39000

KATL Route Selector -> Atlanta-Hartsfield Jackson Intl -> Los Angeles Intl KLAX

Departure RunWay -> 08L -> 90 degrees True Heading

Arrival RunWay -> 06L -> 83 degrees True Heading

Compute Flight Profile | Compute Costs | Download Vertical Profile | Download KML

Reduced Climb Power coefficient

click

Reduced climb power

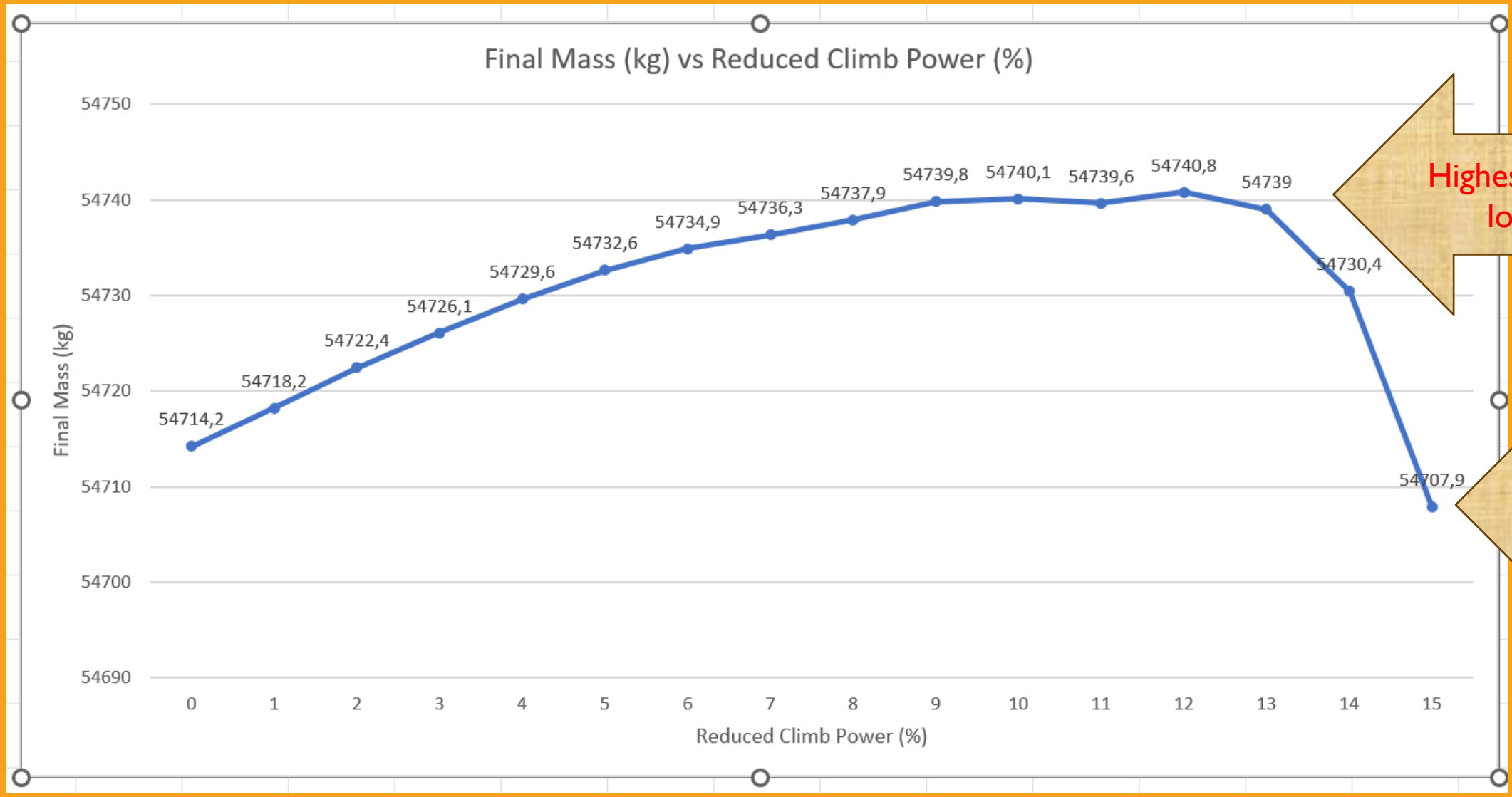
Click here to move -> Flight Leg Costs Computation — Click to hide

Airline	Aircraft	Seats	Adep	RunWay	Ades	RunWay	Is Aborted	TakeOff Mass Kg	Cruise Level Ft	Climb Power %	Final Mass Kg	Lost Mass Kg	Fuel Costs US$	Flight Duration Hours	Flying Costs US$	Crew Costs US	Costs US$
AmericanWings	A320	157	KATL	08L	KLAX	06L	false	64000	39000	15	54707.9	9292.1	9966	4.0675	11552	6740	7
AmericanWings	A320	157	KATL	08L	KLAX	06L	false	64000	39000	14	54730.4	9269.6	9942	4.0959	11632	6787	1
AmericanWings	A320	157	KATL	08L	KLAX	06L	false	64000	39000	13	54739	9261	9932	4.1078	11666	6807	
AmericanWings	A320	157	KATL	08L	KLAX	06L	false	64000	39000	12	54740.8	9259.2	9931	4.1095	11671	6	
AmericanWings	A320	157	KATL	08L	KLAX	06L	false	64000	39000	11	54739.6	9260.4	9932	4.1128	11680		
AmericanWings	A320	157	KATL	08L	KLAX	06L	false	64000	39000	10	54740.1	9259.9	9931	4.1161	11690		
AmericanWings	A320	157	KATL	08L	KLAX	06L	false	64000	39000	9	54739.8	9260.2	9932	4.1186	11697		
AmericanWings	A320	157	KATL	08L	KLAX	06L	false	64000	39000	8	54737.9	9262.1	9934	4.122	11706		
AmericanWings	A320	157	KATL	08L	KLAX	06L	false	64000	39000	7	54736.3	9263.7	9935	4.1253	11716		
AmericanWings	A320	157	KATL	08L	KLAX	06L	false	64000	39000	6	54734.9	9265.1	9937	4.1281	11724		
AmericanWings	A320	157	KATL	08L	KLAX	06L	false	64000	39000	5	54732.6	9267.4	9939	4.1311	11732		
AmericanWings	A320	157	KATL	08L	KLAX	06L	false	64000	39000	4	54729.6	9270.4	9943	4.1339	11740	68	
AmericanWings	A320	157	KATL	08L	KLAX	06L	false	64000	39000	3	54726.1	9273.9	9946	4.1375	11751	6856	
AmericanWings	A320	157	KATL	08L	KLAX	06L	false	64000	39000	2	54722.4	9277.6	9950	4.1409	11760	6861	2
AmericanWings	A320	157	KATL	08L	KLAX	06L	false	64000	39000	1	54718.2	9281.8	9955	4.1439	11769	6866	0
AmericanWings	A320	157	KATL	08L	KLAX	06L	false	64000	39000	0	54714.2	9285.8	9959	4.1473	11778	6872	9

Impact analysis of Reduced Climb Power coefficient from 0% (full power) to 15% of reduced climb power

REDUCED CLIMB POWER COEFFICIENT -> CONSEQUENCES ON FUEL BURN

Experimental feature

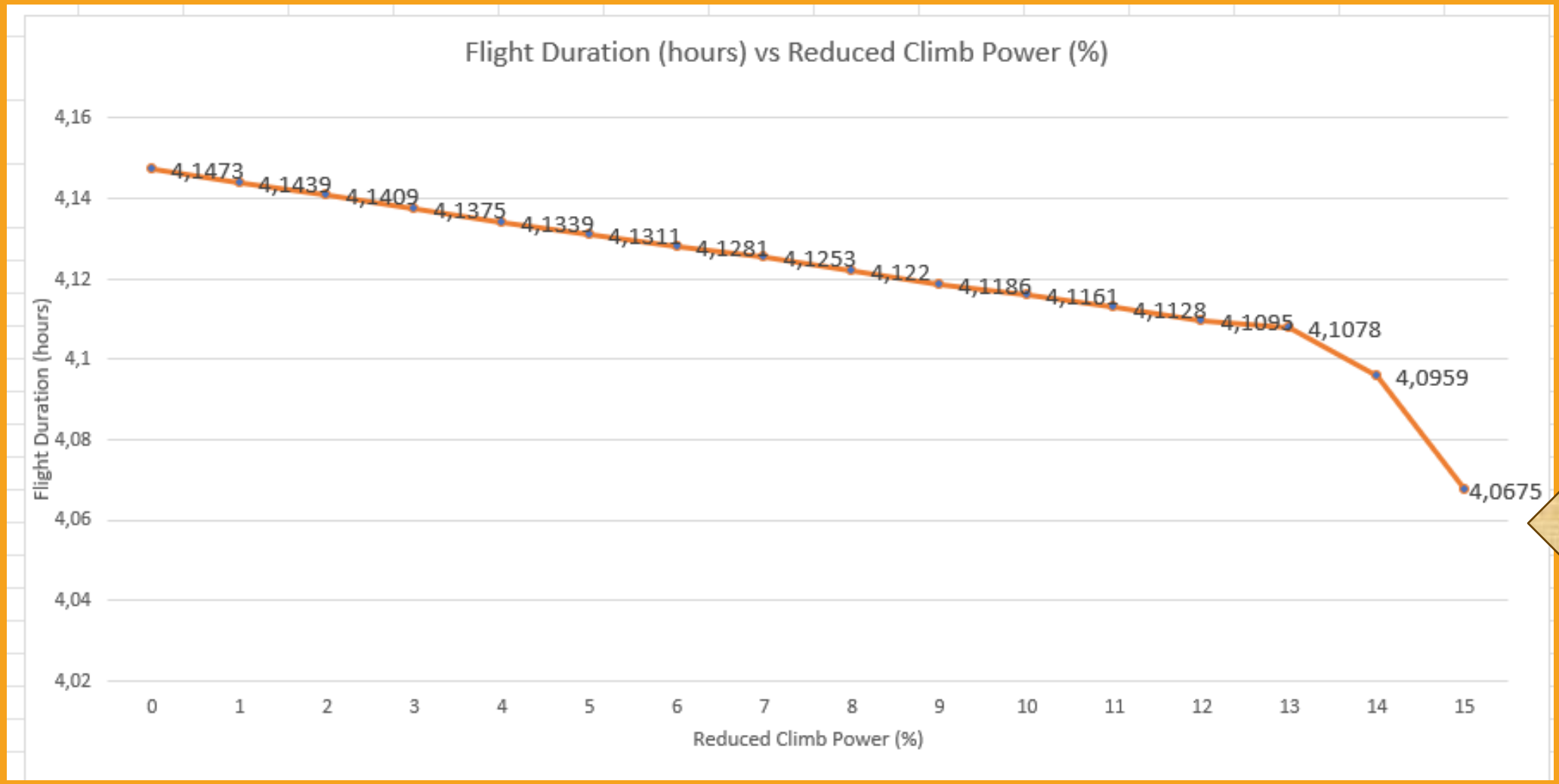


Highest final mass means lowest fuel burn

Lowest final mass means highest fuel burn

REDUCED CLIMB POWER COEFFICIENT -> CONSEQUENCES ON FLIGHT LEG DURATION

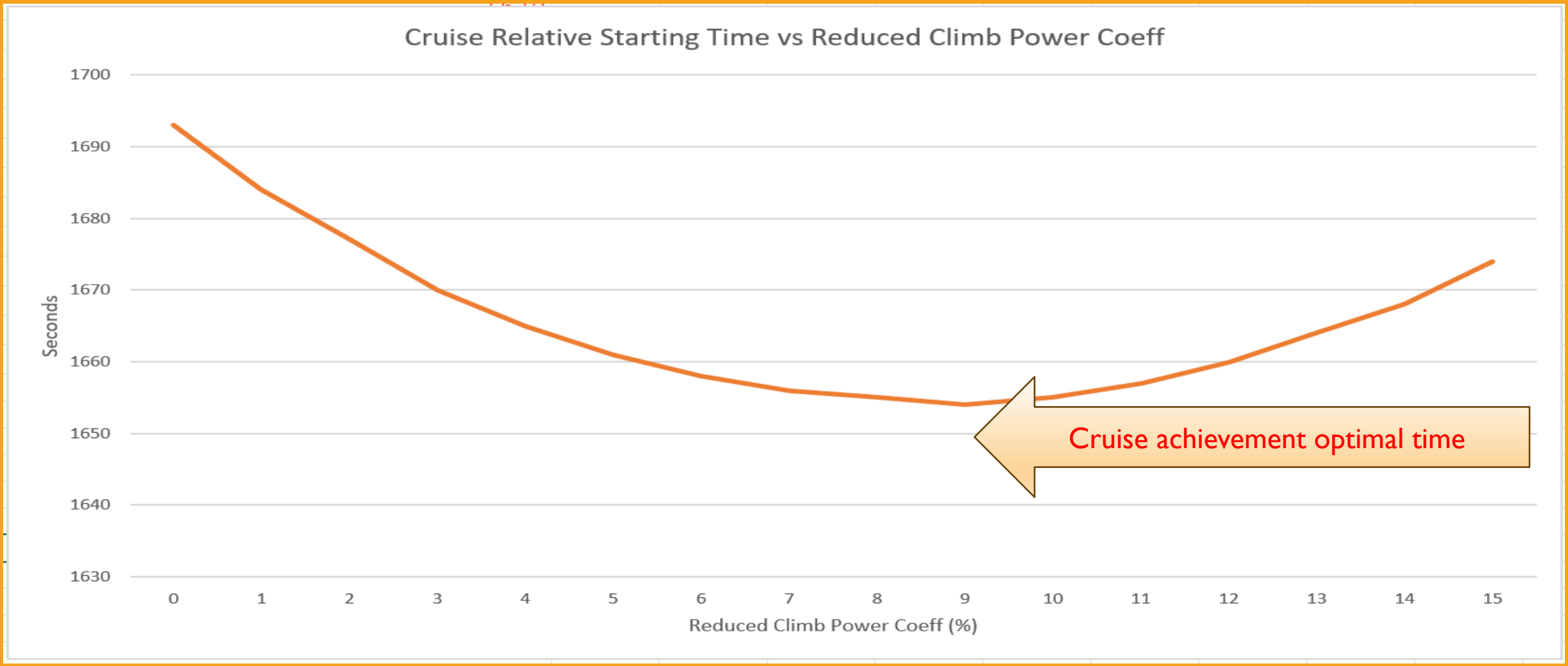
Experimental feature



Lowest flight leg duration

REDUCED CLIMB POWER COEFFICIENT CONSEQUENCES ON START OF CRUISE (TOP OF CLIMB)

Y axis represents the relative time from applying full thrust on the departure runway until reaching Cruise conditions



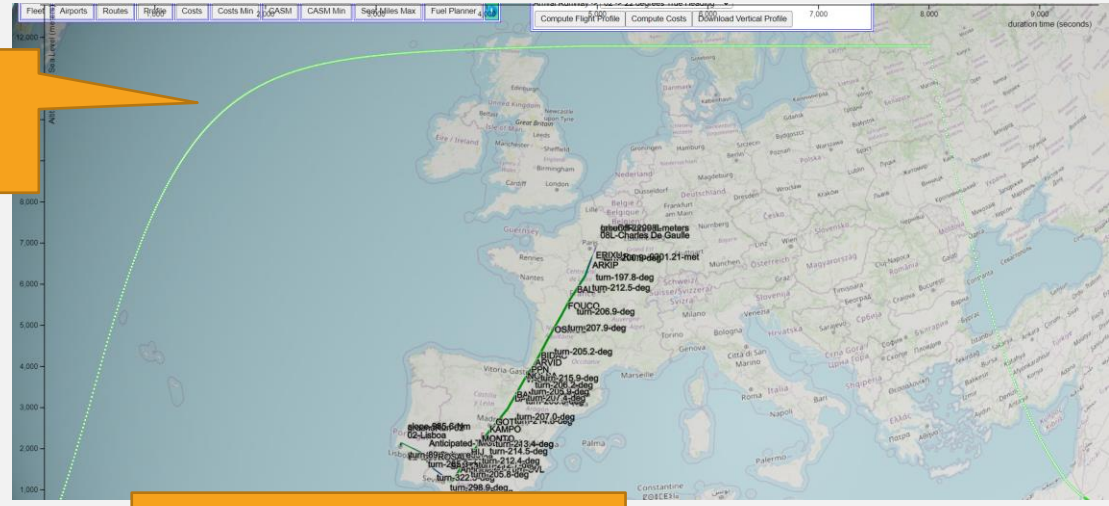
4 DIMENSIONS TRAJECTORY (CORE FEATURE)

Click here to move -> Flight Profile Computation — Click to hide

Select the aircraft -> Airbus A320	Enter Reduced Climb Power % -> 0
min -> 39000 TakeOff Mass (kg) -> 64000 max -> 77000	Requested Flight Level (feet) -> 39000 max -> 39000
KATL Route Selector -> Atlanta-Hartsfield Jackson Intl -> Los Angeles Intl	KLAX
Departure RunWay -> 08L -> 90 degrees True Heading	Arrival RunWay -> 06L -> 83 degrees True Heading
Compute Flight Profile / Compute Costs	Download Vertical Profile / Download KML

click

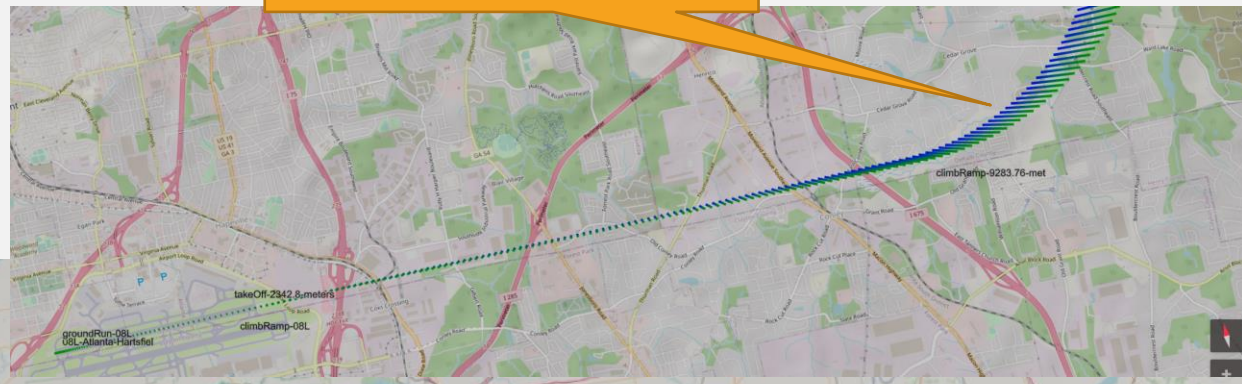
Vertical Profile



Time Reference

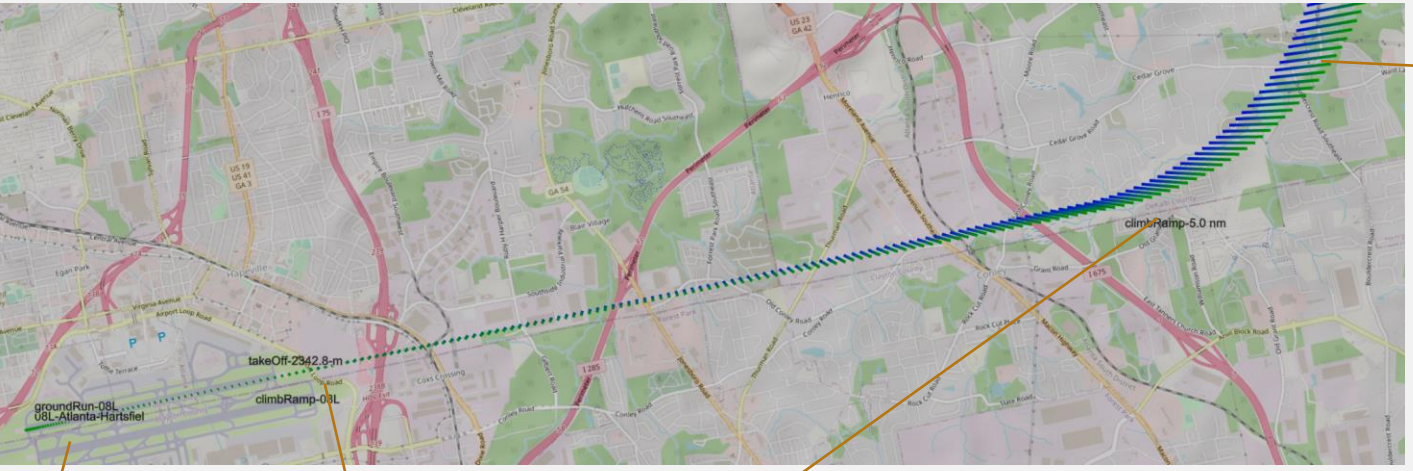
elapsed-time-seconds	altitude-MSL-meters	altitude-MSL-feet
57	125,9735776	413,2991396
58	132,4804677	434,6472044
59	139,0022023	456,0439714
60	145,5387129	477,4892162
61	152,0899309	498,9827137
62	158,6557876	520,5242384
63	165,2362141	542,1135641
64	171,8311411	563,7504639
65	178,2942447	584,954872
66	184,7753603	606,2183745
67	191,2744371	627,540805
68	197,791424	648,9219957
69	204,3262696	670,3617778

Ground Track



Lateral Route

4 DIMENSIONS TRAJECTORY (CORE FEATURE)

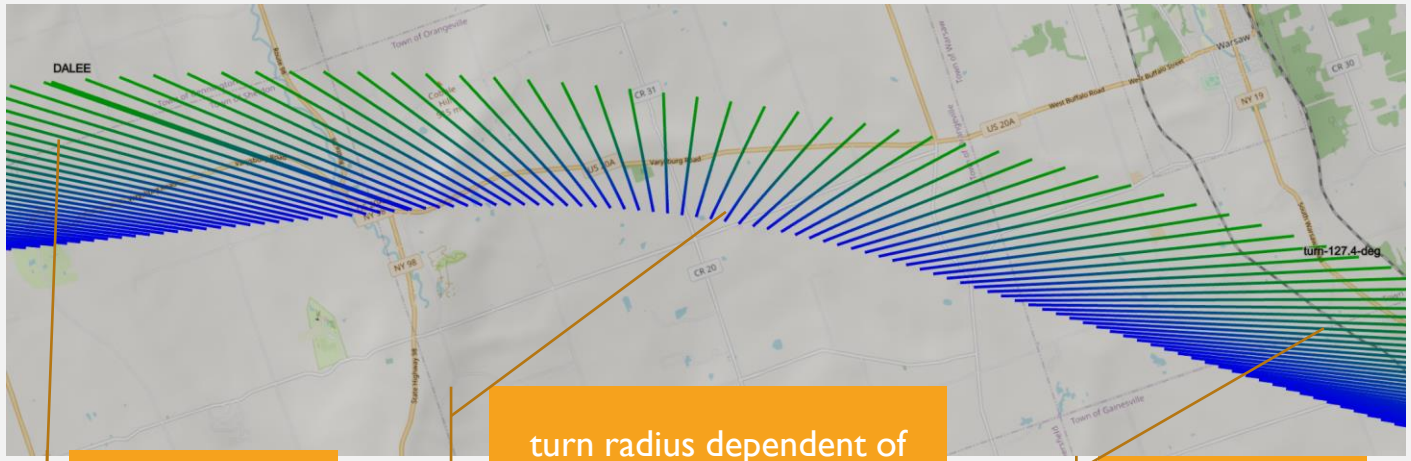


First turn – radius dependent upon speed

Ground run

Takeoff

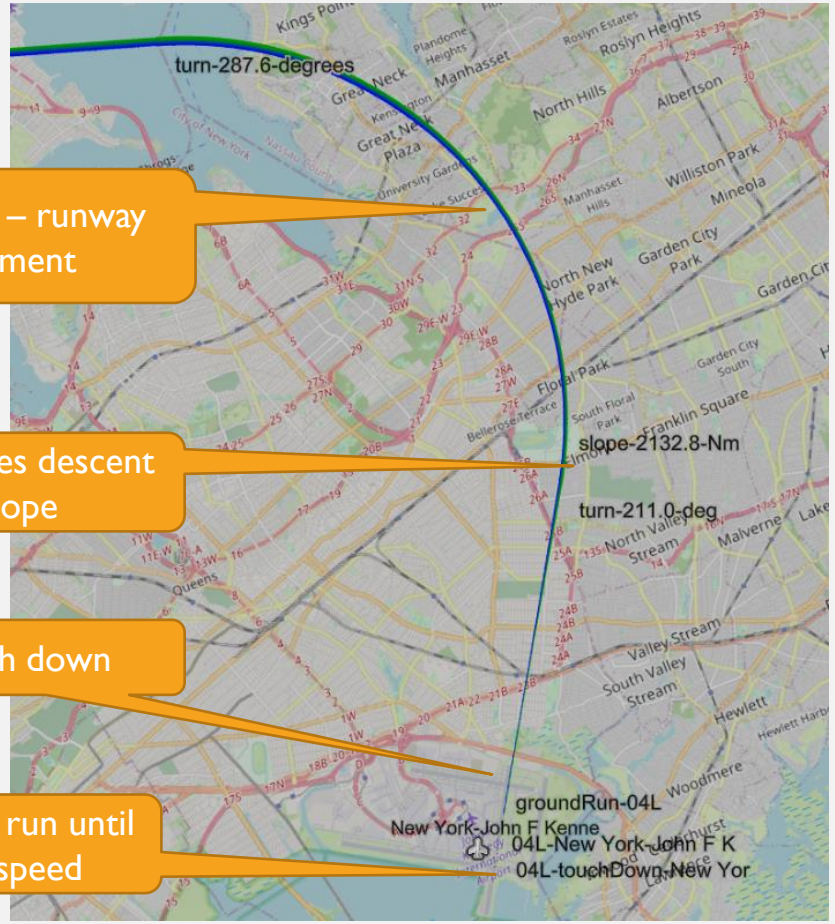
Approx 8 degrees Climb Ramp on an approx. distance of 5 nautics



Great circle

turn radius dependent of true speed and bank angle

Great circle



Last turn – runway alignment

3 degrees descent slope

Touch down

Ground run until taxi speed

4 DIMENSIONS TRAJECTORY (GROUND RUN)

Airbus A330-200 - Take-off Mass = 190 tons

Mexico – Mean Sea Level = 2230 meters

Ground Run = 2661,8 meters

Take-off Speed CAS = 117 knots

Take-off True Air Speed = 81.21 m/s

Explanation: Air density is lower at Mexico airport = 2230 meters MSL -> true speed must be higher before take-off
Note : only ISA temperature is used

Airbus A330-200 - TakeOff Mass = 190 tons

JF Kennedy – Mean Sea Level = 4 meters

Ground Run = 1779,3 meters

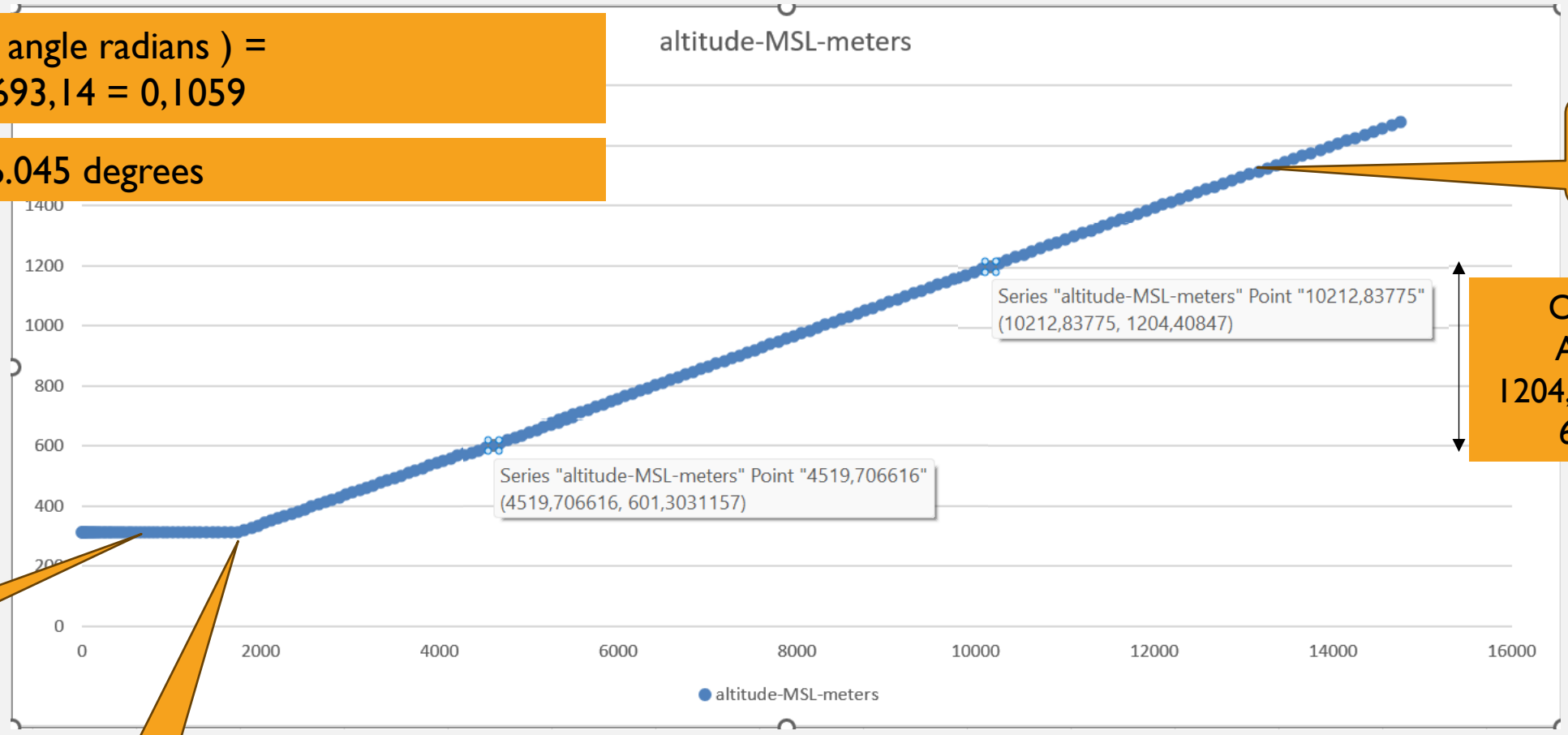
Take-off Speed CAS = 117 knots

Take-off True Air Speed = 72,67 m/s

CLIMB RAMP (~6..8 DEGREES – 5 NAUTICAL MILES LENGTH)

Tangent (angle radians) =
603,1 / 5693,14 = 0,1059

Angle = 6.045 degrees



Climb ramp

Opposite side
Altitude MSL
1204,4 m – 601,3 m =
603,1 meters

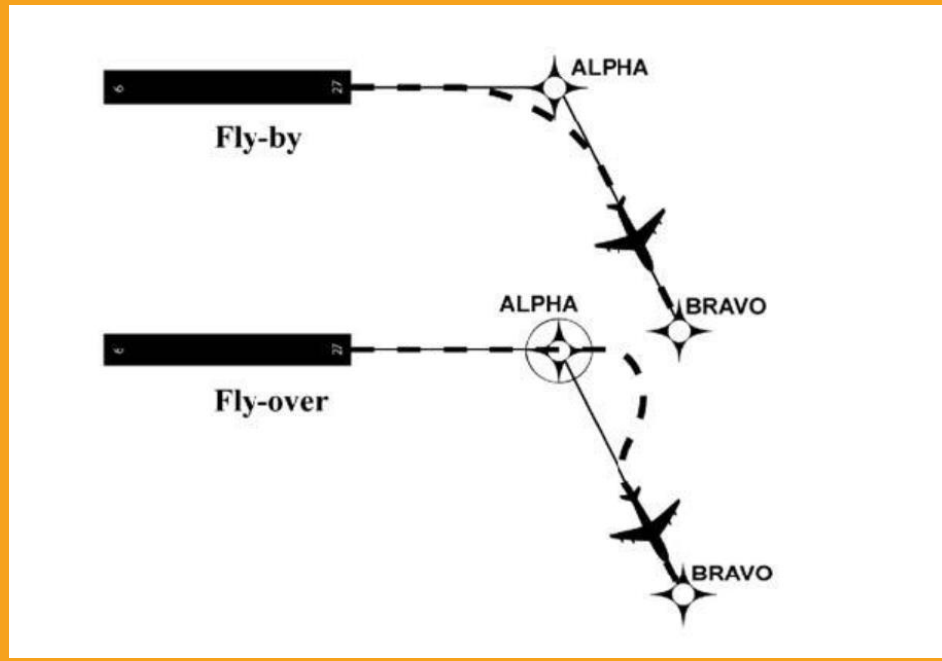
Ground run

takeoff

Adjacent side – distance flown
10212,84 m – 4519,7 m = 5693,14 meters

TURN LEG

Fly-by waypoints. Fly-by waypoints are used when an aircraft should begin a turn to the next course prior to reaching the waypoint separating the two route segments. This is known as turn anticipation.



TURN LEG

Turn leg radius is a function of True Air Speed (TAS) and bank angle.

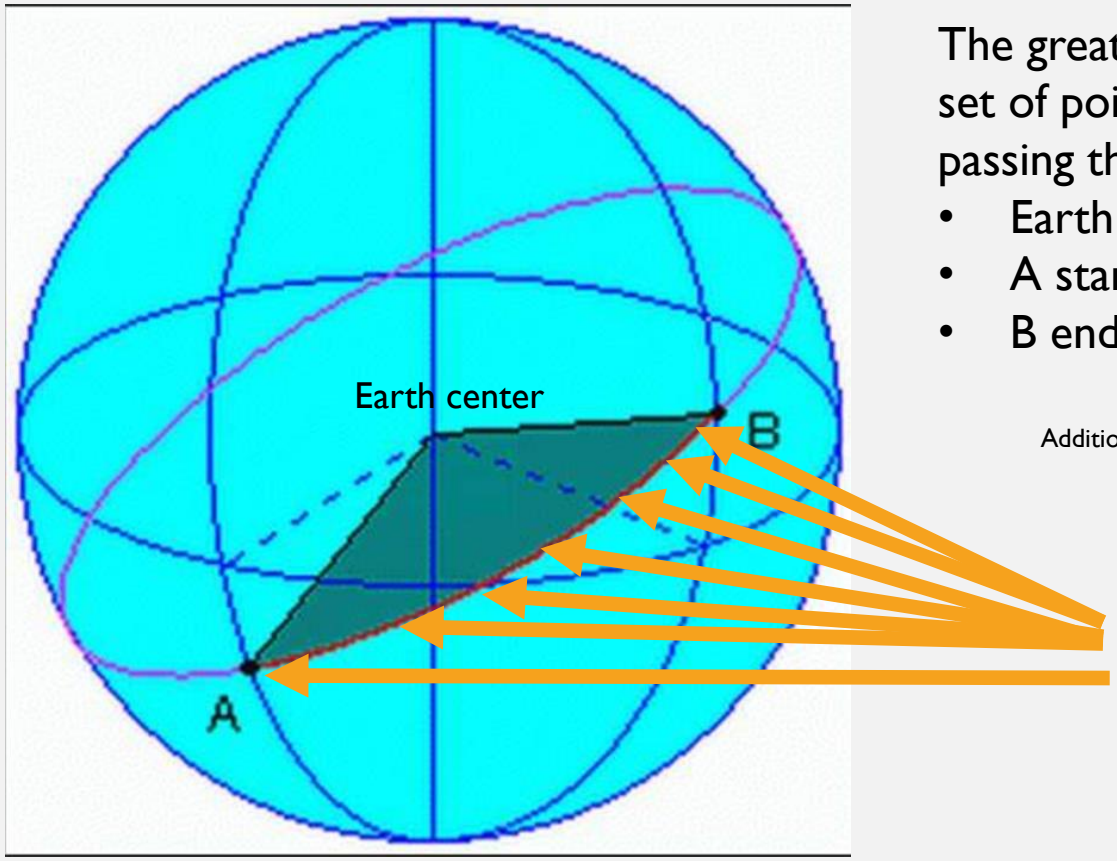
Aerospaceweb.org | Ask Us - Bank Angle and G's

TAS [knots]	Radius in Nautical Miles for a bank angle of 15 degrees	Radius in Nautical Miles for a bank angle of 25 degrees
150	1.2	0.7
180	1.8	1.0
210	2.4	1.4
250	3.4	2.0
300	4.9	2.8
480	12.5	7.2

GREAT CIRCLE (DEFINITION)

Also called orthodromic route

Shortest path between two points on the globe



The great circle (or orthodromic route) between A and B is defined as the set of points at the surface of the globe intersecting a « geometric plan » passing through

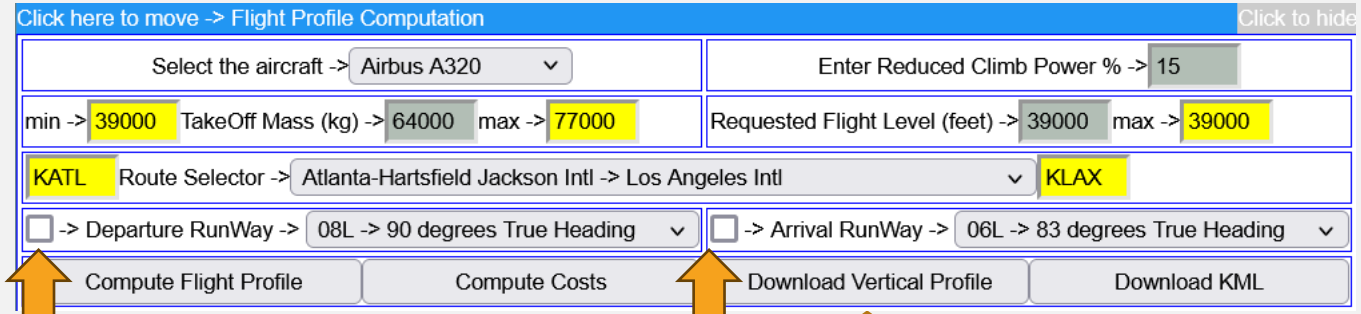
- Earth center
- A starting point of the route
- B ending point of the route

Additional condition : the set of points are defining the shortest path (from A to B)

Great circle route points along the surface of the globe

Use Haversine formulae to compute the shortest distance between A and B

DOWNLOAD VERTICAL PROFILE (EXCEL FORMAT)



Future: max fuel load as a constraint

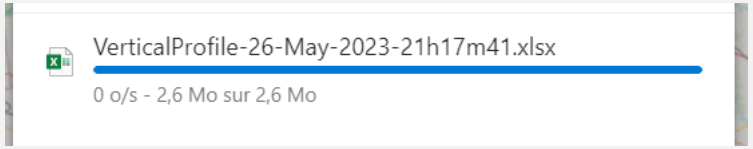
Inputs in gray input cells are checked against acceptable ranges

Check-box to select best runway

Check-box to select best runway

click

Results available in an EXCEL file to download



a full trajectory computation is launched to obtain the results

State vector

	elapsed-time-seconds	characteristic-point	altitude-MSL-meters	altitude-MSL-feet	true-air-speed-meters-second	true-air-speed-knots	calibrated-air-speed-knots	mach	rate-of-climb-descent-feet-minute	distance-flown-nautical-miles	distance-to-fly-nautical-miles	aircraft-mass-kilograms	flight-path-angle-degrees	thrust-newtons	drag-newtons	lift-newtons	load-factor-g	end of simulation
0		Atlanta-Hartsfield Jackson Atlanta Intl/08L	312,7248	1026	0,1	0,19438445	0,19164697	0,00029492	0	0	0	64000	0	0	0	0	0	False
1		departure-ground-run	312,7248	1026	1,91472755	3,72193261	3,6695179	0,00564683	0	0,00103387	1694,94489	63998,5361	0	138091,435	0,02909332	0,0732903	1,1452E-06	False
2		departure-ground-run	312,7248	1026	3,72935291	7,24928211	7,14719563	0,01099843	0	0,00304756	1694,94385	63997,0663	0	138091,435	10,6661381	26,8695538	0,00041986	False
3		departure-ground-run	312,7248	1026	5,54360327	10,7759027	10,6241599	0,01634894	0	0,00604087	1694,94184	63995,5904	0	138091,435	40,4631969	101,932681	0,00159281	False

DOWNLOAD KML FILE

KML : Keyhole Markup Language

Click here to move -> Flight Profile Computation | Click to hide

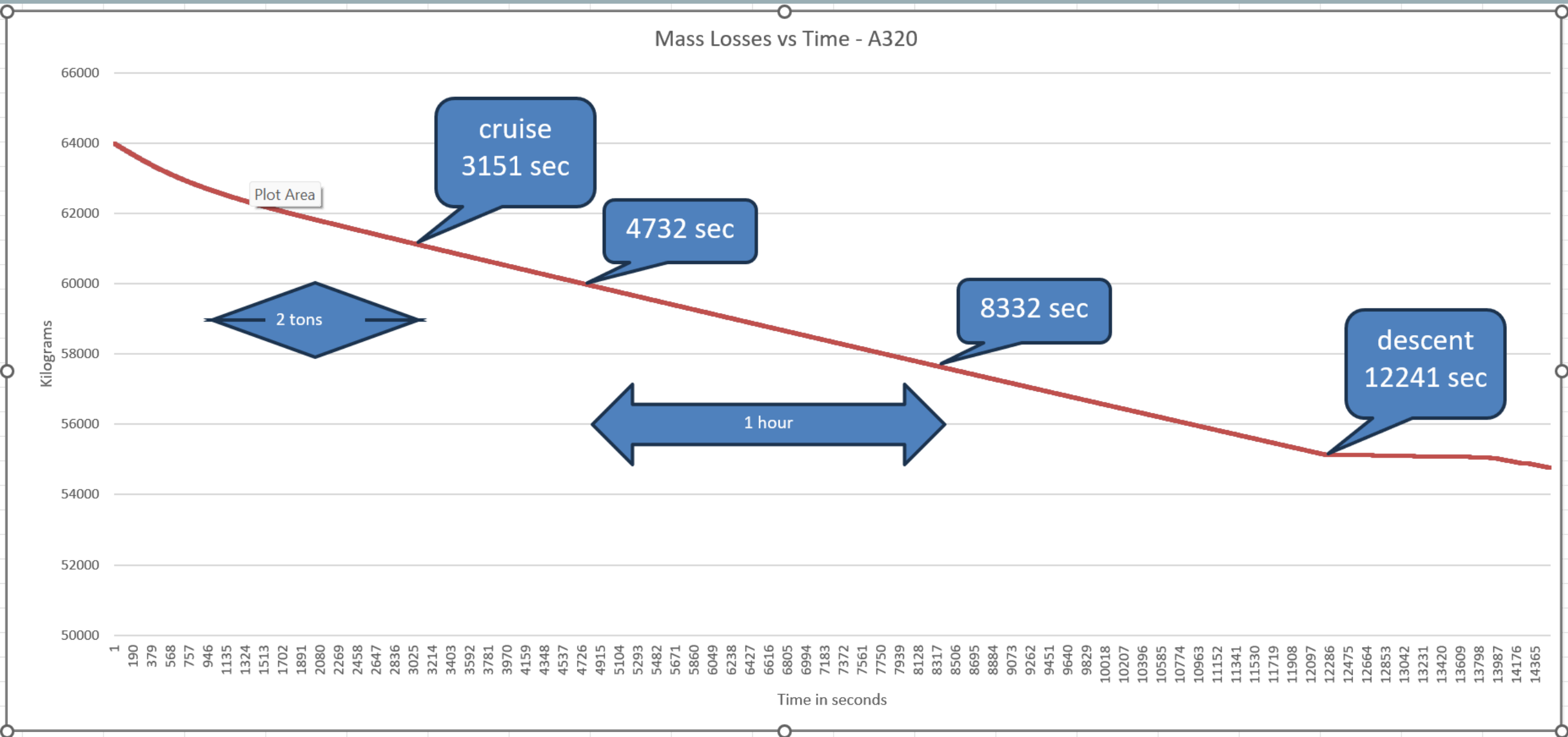
Select the aircraft -> Airbus A320	Enter Reduced Climb Power % -> 15
min -> 39000 TakeOff Mass (kg) -> 64000 max -> 77000	Requested Flight Level (feet) -> 39000 max -> 39000
KATL Route Selector -> Atlanta-Hartsfield Jackson Intl -> Los Angeles Intl	KLAX
☐ -> Departure RunWay -> 08L -> 90 degrees True Heading	☐ -> Arrival RunWay -> 06L -> 83 degrees True Heading
Compute Flight Profile / Compute Costs	Download Vertical Profile / Download KML

click

If Google Earth is installed on the PC downloading will open Google Earth

Hint:Vertical profile on the web OpenGlobus map overlay is shown with x-axis being the time while in Google Earth x-axis shows the ground distance

MASS LOSSES – FUEL CONSUMPTION



DIRECT ROUTE

DIRECT ROUTE

Click here to move -> Flight Profile Computation — Click to hide

Select the aircraft -> Airbus A320	Enter Reduced Climb Power % -> 15
min -> 39000 TakeOff Mass (kg) -> 64000 max -> 77000	Requested Flight Level (feet) -> 39000 max -> 39000
MMMX Route Selector -> Aeropuerto México Ciudad Intl -> Seattle Tacoma Intl KSEA Fly Direct Route -> ☐	
☑ -> Departure RunWay -> 05L	☑ -> Arrival RunWay -> 16L
Compute Flight Profile / Compute Costs	Download Vertical Profile / Download KML

Direct route checkbox

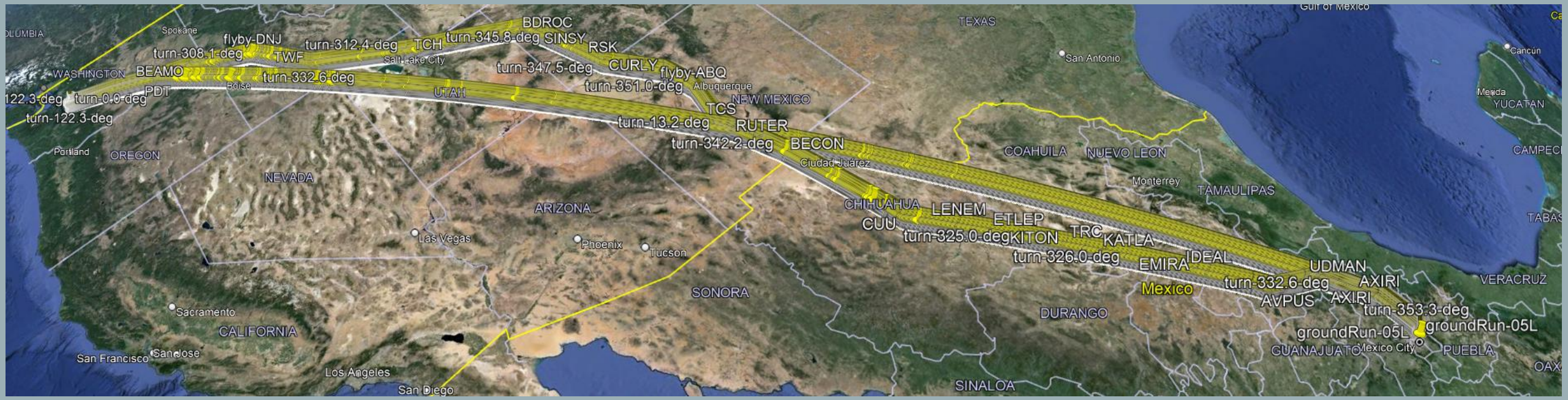
Direct Route -> consequences on costs

Click here to move -> Flight Leg Costs Computation — Click to hide

Airline	Aircraft	Seats	Adep	RunWay	Ades	RunWay	Is Aborted	Direct	TakeOff Mass Kg	Cruise Level Ft	Climb Power %	Final Mass Kg	Lost Mass Kg	Fuel Costs US$	Flight Duration Hours	Flying Costs US$	Crew Costs US$	Total Costs US$
AmericanWings	A320	157	MMMX	05L	KSEA	16L	false	false	64000	39000	15	52577.8	11422.2	12250	5.0215	14261	8321	34832
AmericanWings	A320	157	MMMX	05L	KSEA	16L	false	true	64000	39000	15	53019.4	10980.6	11777	4.8452	13760	8028	33566

Direct flag

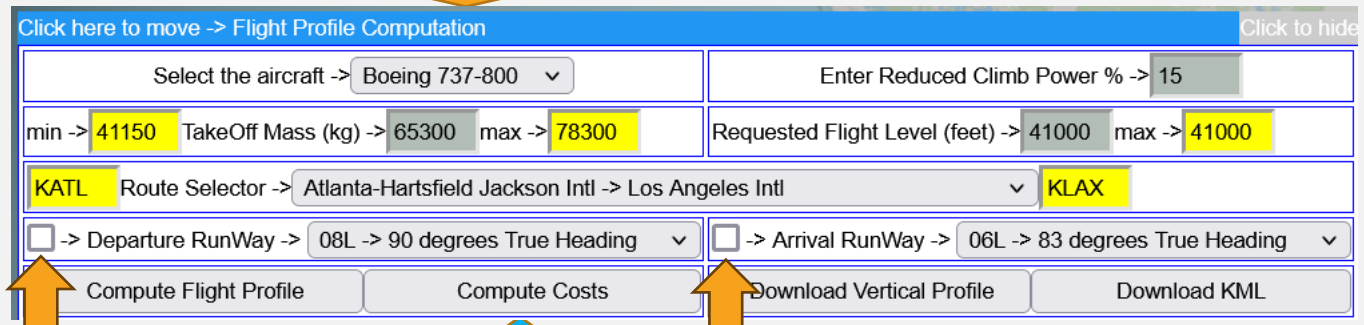
Direct Route -> lateral trajectory follows a great circle



COSTS & OPTIMIZATIONS

COMPUTE COSTS FOR ONE LEG

Select the arcraft



Inputs are checked against acceptable ranges

Take Off Mass and Flight Level can be modified

Use checkboxes to select the best runways

Best Runway checkbox

click

Best Runway checkbox

Get the results

Click here to move -> Flight Leg Costs Computation — Click to hide

Airline	Aircraft	Seats	Adep	RunWay	Ades	RunWay	Is Aborted	TakeOff Mass Kg	Cruise Level Ft	Climb Power %	Final Mass Kg	Lost Mass Kg	Fuel Costs US$	Flight Duration Hours	Flying Costs US$	Crew Costs US$	Total Costs US$
AmericanWings	A320	157	KATL	08L	KLAX	06L	false	64000	39000	15	54707.9	9292.1	9966	4.0675	11552	6740	28257
AmericanWings	B738	160	KATL	08L	KLAX	06L	false	65300	41000	15	55644.9	9655.1	10355	3.9669	11940	6176	28472
AmericanWings	A332	234	KATL	08L	KLAX	06L	false	190000	41000	15	168790.7	21209.3	22747	3.9535	13047	7342	43135

Costs are computed for one aircraft type, one leg, selected runways, a take-off mass and a flight level

In order to obtain these results a full trajectory computation is launched

Fuel Costs US dollars = mass loss kg * kerosene kg to US gallons * US gallon to US dollars

MINIMIZATIONS (COSTS)

All Optimizations are based upon computing costs computed offline

Costs are computed once for all defined routes and results are stored in the database

For each aircraft type, each flight leg a trajectory is computed, and a cost matrix is created and stored in the database

Costs minimizations compute the minimal SUM of costs for all the defined flight legs

Assumption : have an adequate fleet to assign one aircraft type to only one flight leg

Only one aircraft type assigned to one leg

Leg = oriented pair of departure and arrival airports

airline	Solver Status	aircraft	departureAirport	adepRunway	arrivalAirport	adesRunway	totalCostsUSdollars
AmericanWings	Optimal	A320	PANC	07L	KATL	26R	47673,87
AmericanWings	Optimal	A320	KJFK	13R	LFPG	27L	50639,98
AmericanWings	Optimal	A320	KSFO	01R	KIAD	30	34578,88
AmericanWings	Optimal	A320	KSEA	16L	KJFK	31L	34848,51
AmericanWings	Optimal	A320	KATL	26R	PANC	07L	47763,19
AmericanWings	Optimal	A332	KATL	08L	KBOS	27	24421,15
AmericanWings	Optimal	A332	KMSP	12R	KATL	26R	24450,89
AmericanWings	Optimal	A332	KIAH	08L	KORD	22L	23984,36
AmericanWings	Optimal	A332	KBOS	27	KATL	08L	24860,18
AmericanWings	Optimal	A332	KORD	22L	KIAH	08L	24507,91
AmericanWings	Optimal	B738	KATL	27R	KLAX	07L	29041,6
AmericanWings	Optimal	B738	KLAX	07L	KATL	27R	29218,63
AmericanWings	Optimal	B738	MMMX	05L	KSEA	16L	35732,77
AmericanWings	Optimal	B738	KIAD	30	KSFO	10L	35450,86
AmericanWings	Optimal	B738	KJFK	31L	KSEA	34R	35833,25

Computation are using the PULP optimization library -> pulp — PuLP 2.7.0 documentation (coin-or.github.io)

sum

Objective function - Minimize Sum of Costs - 503006 US$

MINIMIZATIONS (COSTS PER AVAILABLE SEAT MILES)

All Optimizations are based upon computing costs beforehand

For each aircraft type, each flight leg a trajectory is computed, and a cost matrix is created

CASM minimizations compute the minimal SUM of CASM for all the defined flight legs

Assumption : have an adequate fleet to assign one aircraft type to only one flight leg -> future usage of fleet configuration related to number of instance of one aircraft type

Table sorting

Only one aircraft type assigned to one leg

Click here to move - Costs per Available Seat Miles — Click to hide

Airline	Solver Status	Aircraft	Assigned	Departure	Arrival	Seats	Distance (Nm)	Costs US$	CASM US$
AmericanWings	Optimal	A332	yes	New York-John F Kennedy Intl	Paris Charles-De-Gaulle France Intl	234	3210.82	75991.56	0.1011
AmericanWings	Optimal	A332	yes	Atlanta-Hartsfield Jackson Intl	Alaska Anchorage-Ted Stevens Intl	234	3007.37	71692.8	0.1019
AmericanWings	Optimal	A332	yes	Alaska Anchorage-Ted Stevens Intl	Atlanta-Hartsfield Jackson Intl	234	2996.22	71604.96	0.1021
AmericanWings	Optimal	A332	yes	Aeropuerto México Ciudad Intl	Seattle Tacoma Intl	234	2136.58	52906.84	0.1058
AmericanWings	Optimal	B738	yes	New York-John F Kennedy Intl	Seattle Tacoma Intl	160	2128.2	35635.68	0.1047
AmericanWings	Optimal	A332	yes	Seattle Tacoma Intl	New York-John F Kennedy Intl	234	2127.48	52633.73	0.1057
AmericanWings	Optimal	B738	yes	Washington Dulles Airport Intl	San Francisco Intl	160	2114.24	35308.09	0.1044
AmericanWings	Optimal	B738	yes	San Francisco Intl	Washington Dulles Airport Intl	160	2112.12	35118.14	0.1039
AmericanWings	Optimal	B738	yes	Los Angeles Intl	Atlanta-Hartsfield Jackson Intl	160	1708.46	29098.75	0.1065
AmericanWings	Optimal	B738	yes	Atlanta-Hartsfield Jackson Intl	Los Angeles Intl	160	1695.84	28922.58	0.1066
AmericanWings	Optimal	A320	yes	General Edward Lawrence Logan Intl	Atlanta-Hartsfield Jackson Intl	157	832.42	15630.02	0.1196
AmericanWings	Optimal	A320	yes	Atlanta-Hartsfield Jackson Intl	General Edward Lawrence Logan Intl	157	829.09	15503.03	0.1191
AmericanWings	Optimal	A320	yes	Minneapolis	Atlanta-Hartsfield Jackson Intl	157	818.16	15423.51	0.1201
AmericanWings	Optimal	A320	yes	Chicago O'Hare Intl	Houston George Bush Intl	157	815.21	15439.79	0.1206
AmericanWings	Optimal	A320	yes	Houston George Bush Intl	Chicago O'Hare Intl	157	814.38	15190.44	0.1188

Min of sum

Since version 4.0 -> table has clickable headers allowing to sort according to the content of one table column

MAXIMIZATIONS (SEAT MILES)

All Optimizations are based upon computing costs beforehand

For each aircraft type, each flight leg a trajectory is computed and a cost matrix is created

Seat Miles maximizations compute the Maximal SUM of Seat Miles for all the defined flight legs

Assumption : have an adequate fleet in order to assign one aircraft type to only one flight leg

Only one aircraft type assigned to one leg

Airline	Aircraft	Solver Status	Assigned	Departure	Arrival	nb Seats	Aircraft Turn Around Times Seconds	Leg Duration Seconds	Leg Distance (miles)	Nb Rotations in 20 hours	Seat Miles Flown 20 hours (miles)
AmericanWings	A320	Optimal	yes	KATL	KMSP	157	1500	8288,8	854,8156123	3	805236,3068
AmericanWings	A320	Optimal	yes	KMSP	KATL	157	1500	7396,1	819,9907771	3	772431,312
AmericanWings	A320	Optimal	yes	KATL	KBOS	157	1500	7502,7	829,1098923	3	781021,5186
AmericanWings	A320	Optimal	yes	KIAH	KORD	157	1500	7213	814,4242528	3	767187,6462
AmericanWings	A320	Optimal	yes	KORD	KIAH	157	1500	7362,8	815,2396302	3	767955,7316
AmericanWings	A332	Optimal	yes	PANC	KATL	234	2100	21963,6	2996,40901	1	1402319,417
AmericanWings	A332	Optimal	yes	KJFK	LFPG	234	2100	23340,9	3214,073888	1	1504186,579
AmericanWings	A332	Optimal	yes	KATL	PANC	234	2100	22621,5	3007,623939	1	1407568,004
AmericanWings	A332	Optimal	yes	KATL	KLAX	234	2100	13452,4	1695,882484	2	1587346,005
AmericanWings	A332	Optimal	yes	KLAX	KATL	234	2100	13208,8	1707,433335	2	1598157,602
AmericanWings	B738	Optimal	yes	KJFK	KSEA	160	1500	15892,4	2128,22742	2	1362065,549
AmericanWings	B738	Optimal	yes	KBOS	KATL	160	1500	7096,5	832,4002601	3	799104,2497
AmericanWings	B738	Optimal	yes	KSEA	KJFK	160	1500	15893,3	2127,289211	2	1361465,095
AmericanWings	B738	Optimal	yes	KIAD	KSFO	160	1500	15819,8	2114,261328	2	1353127,25
AmericanWings	B738	Optimal	yes	KSFO	KIAD	160	1500	15688,3	2112,111338	2	1351751,256
											17620923,52

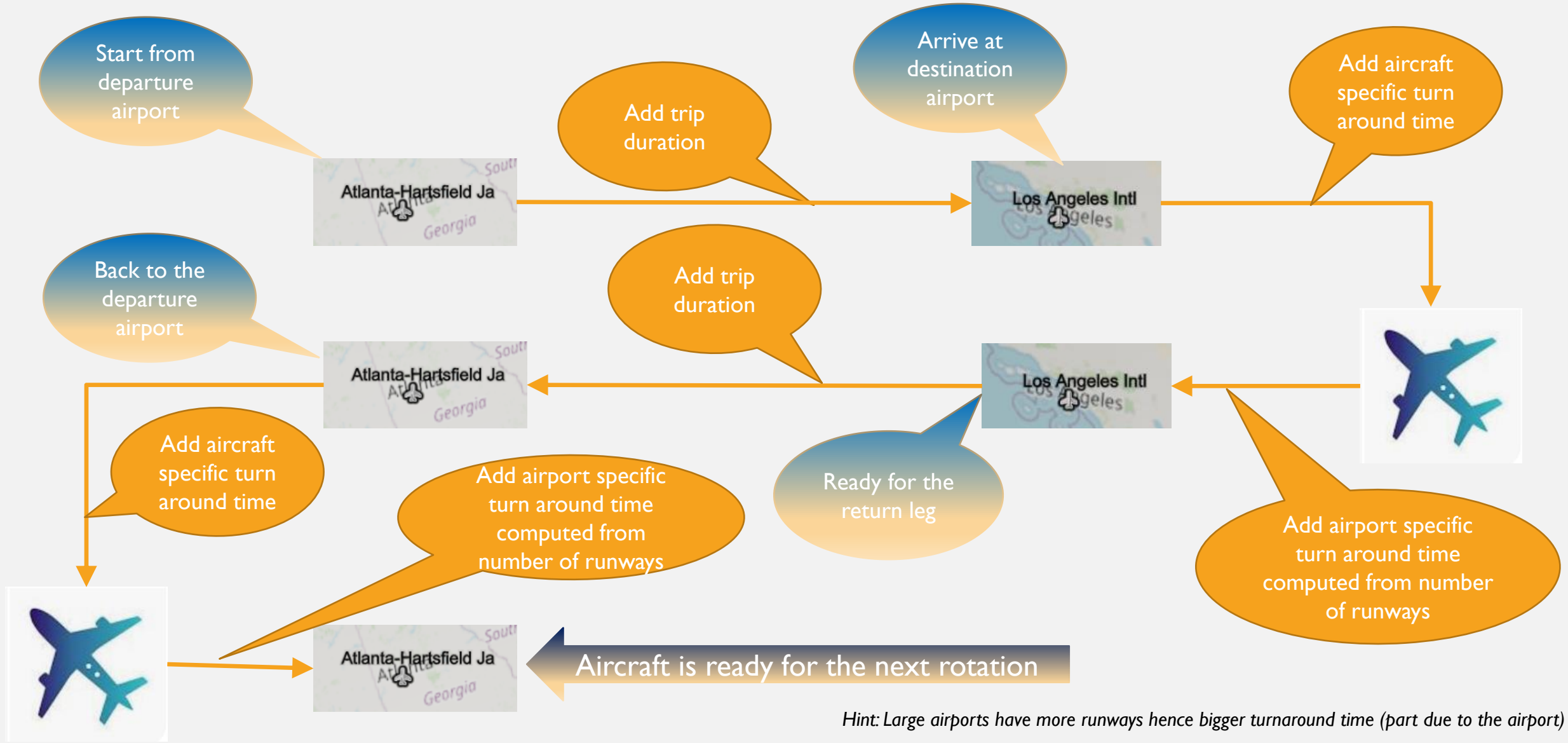
Max sum

Hint: compute number of rotations in a day, based upon trip duration, plus turnaround time

Objective function - max Sum Seat Miles 17620923,52

MAXIMIZATIONS (SEAT MILES)

How to compute a rotation – example for a KATL -> KLAX leg



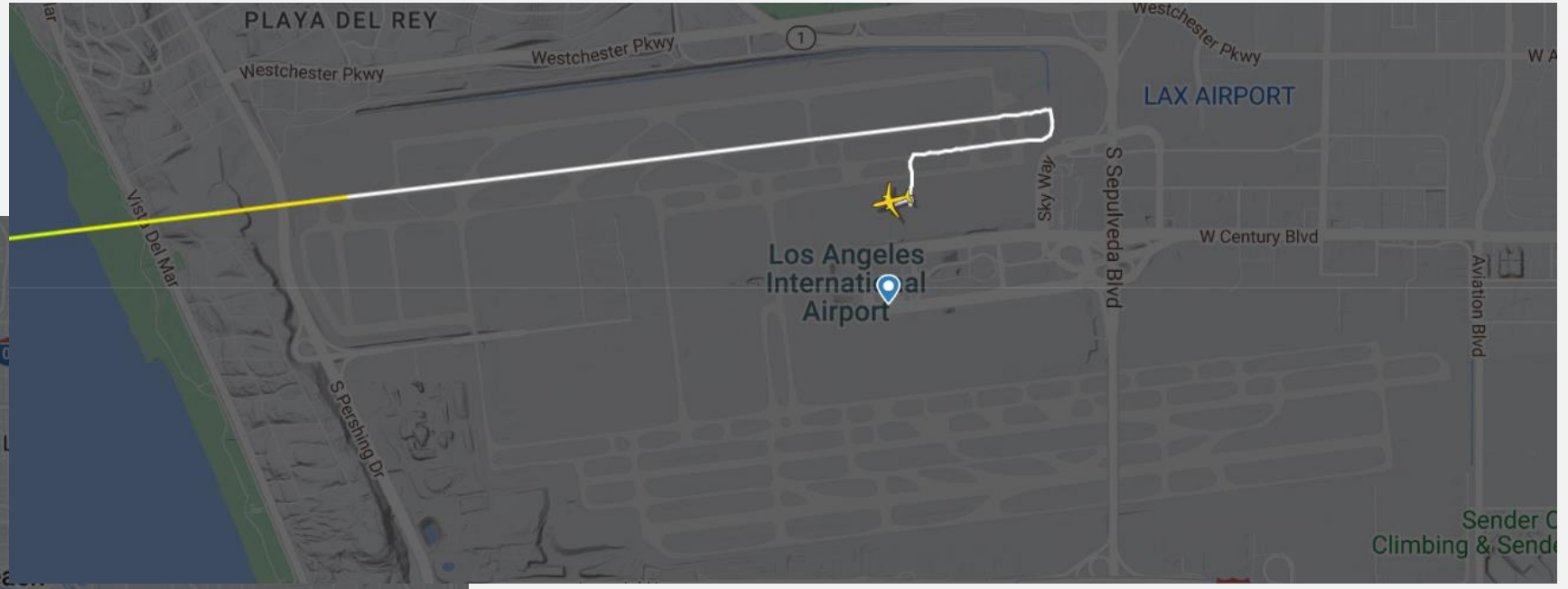
Hint: Large airports have more runways hence bigger turnaround time (part due to the airport)

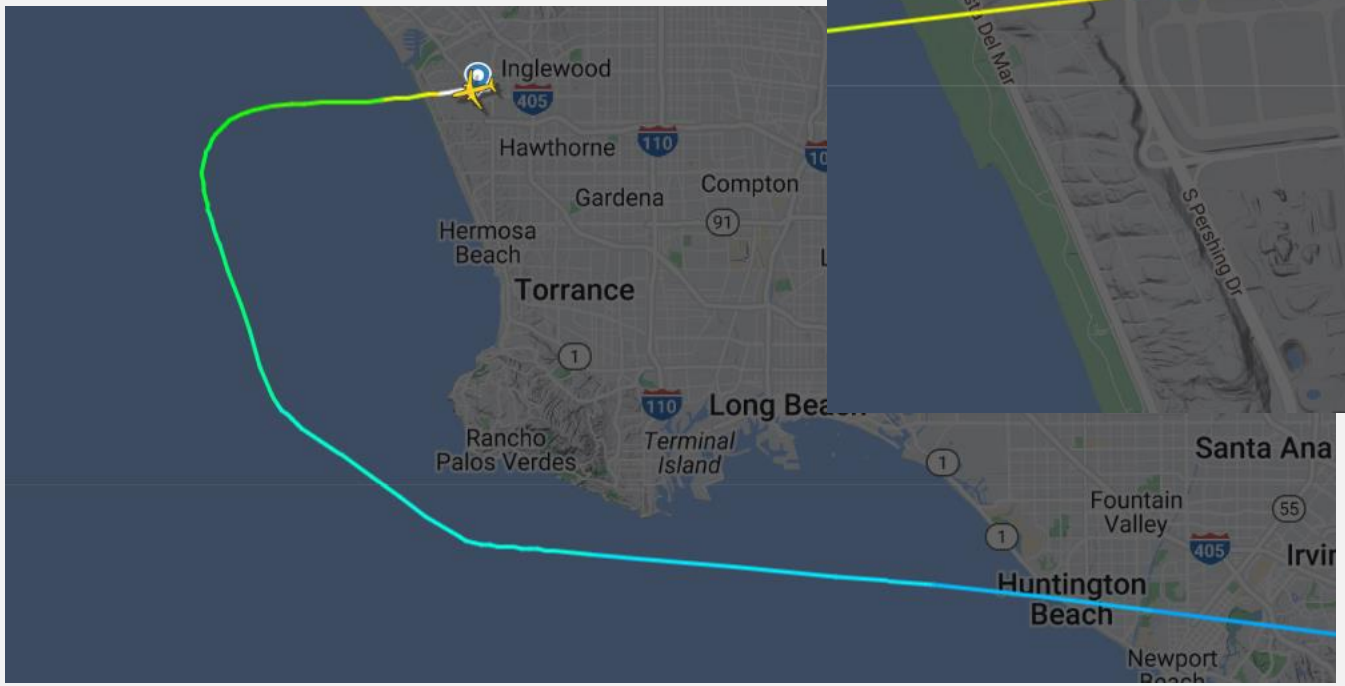
COMPARISON
TRAJECTORY PREDICTION
VERSUS
ADS-B RECORDINGS

COMPARISON KLAX-KATL (FLIGHT RADAR)

DL395
Call sign in flight radar

Departure runway 24L

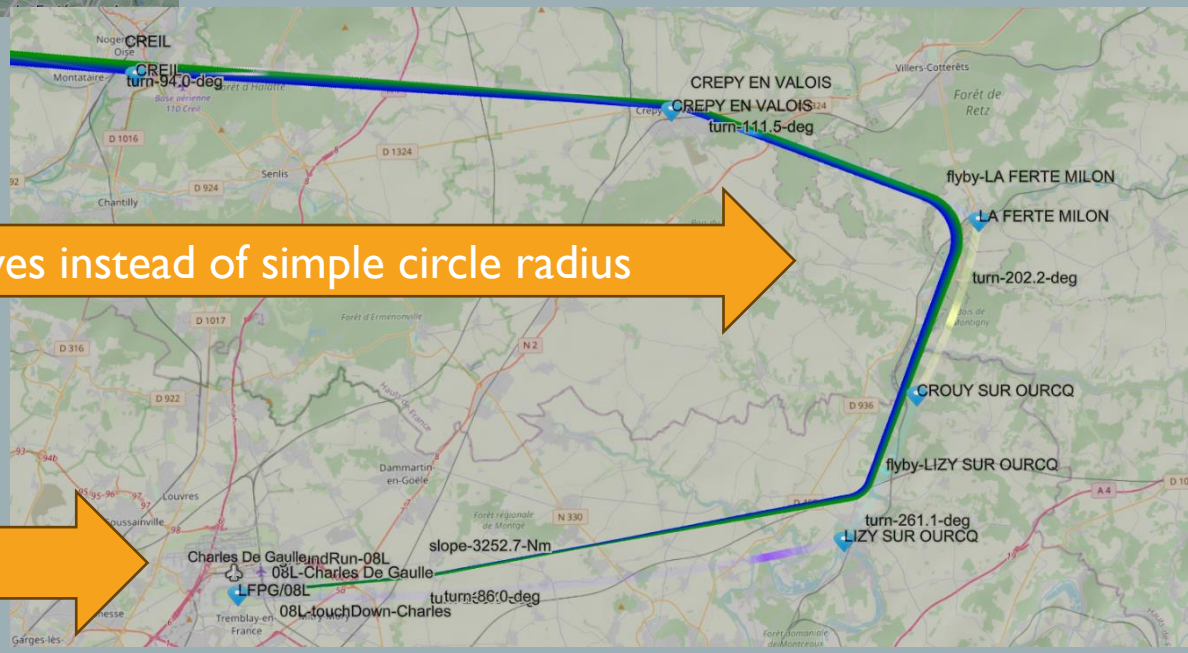




COMPARISON KJFK -> LFPG/08L

Smoothing turns for improved passenger comfort

Turn leg with smooth turn radius



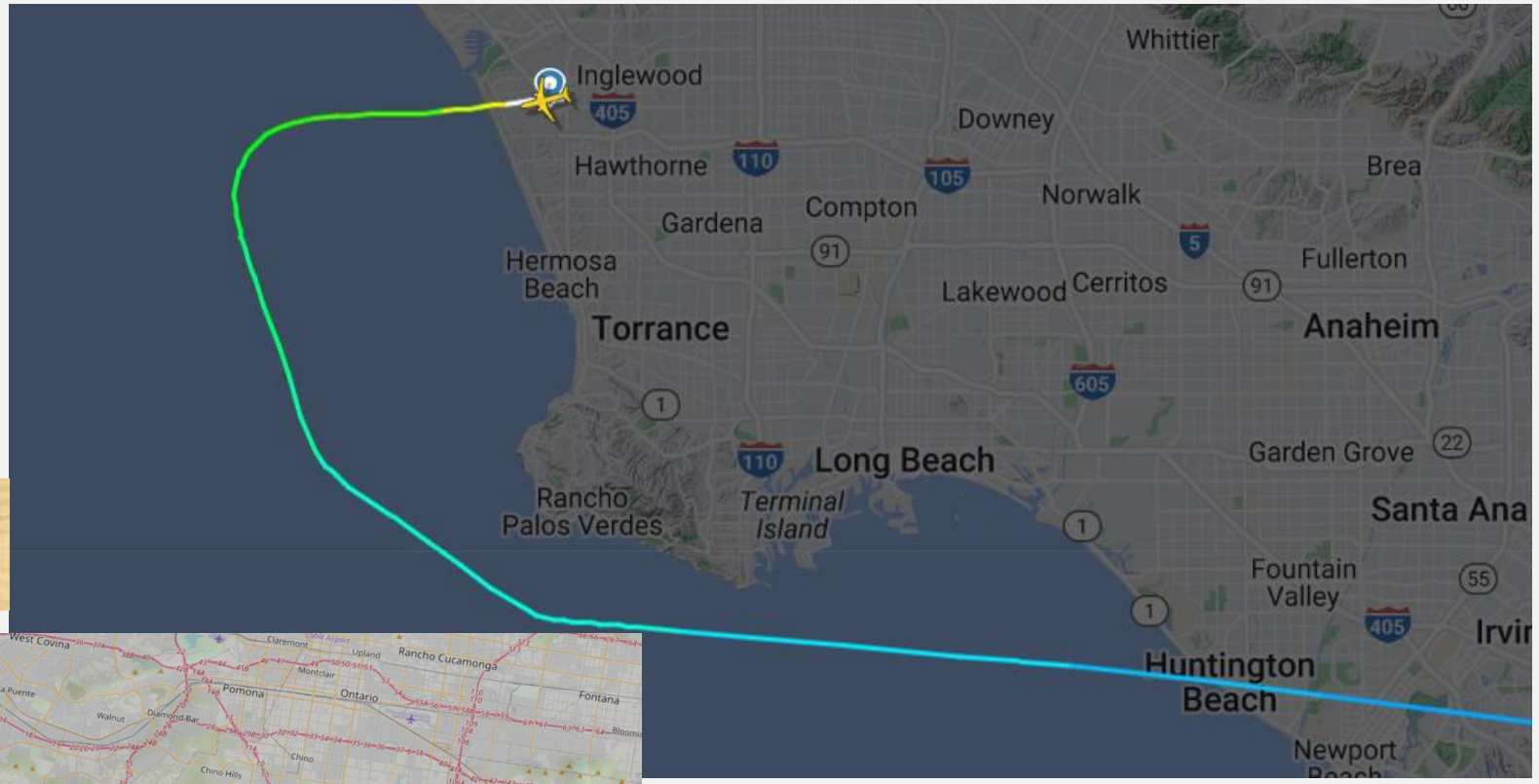
Proposal: experiment Bézier curves instead of simple circle radius

Proposal: align to the arrival runway at more than 10 NM

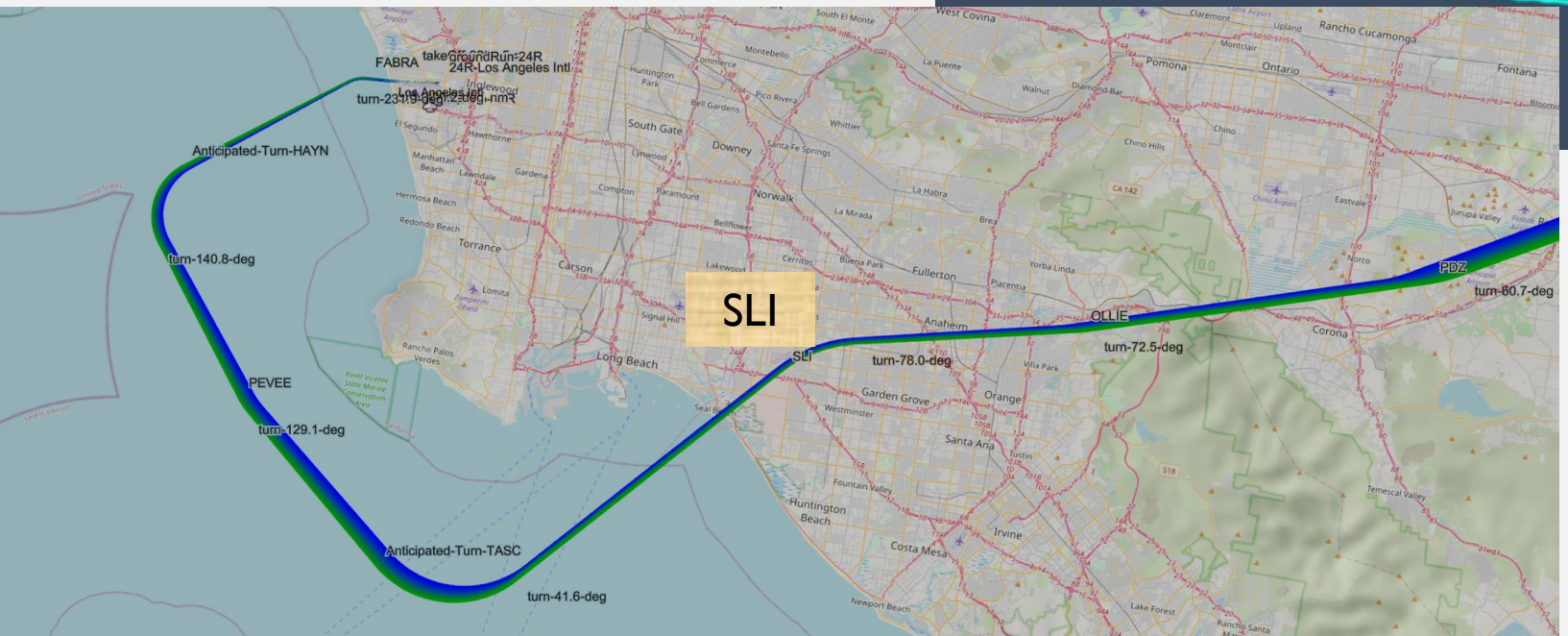
COMPARISON DEPARTURE KLAX-KATL (FLIGHT RADAR)

DL395

KLAX/24L -> SID -> southern route over Huntington Beach

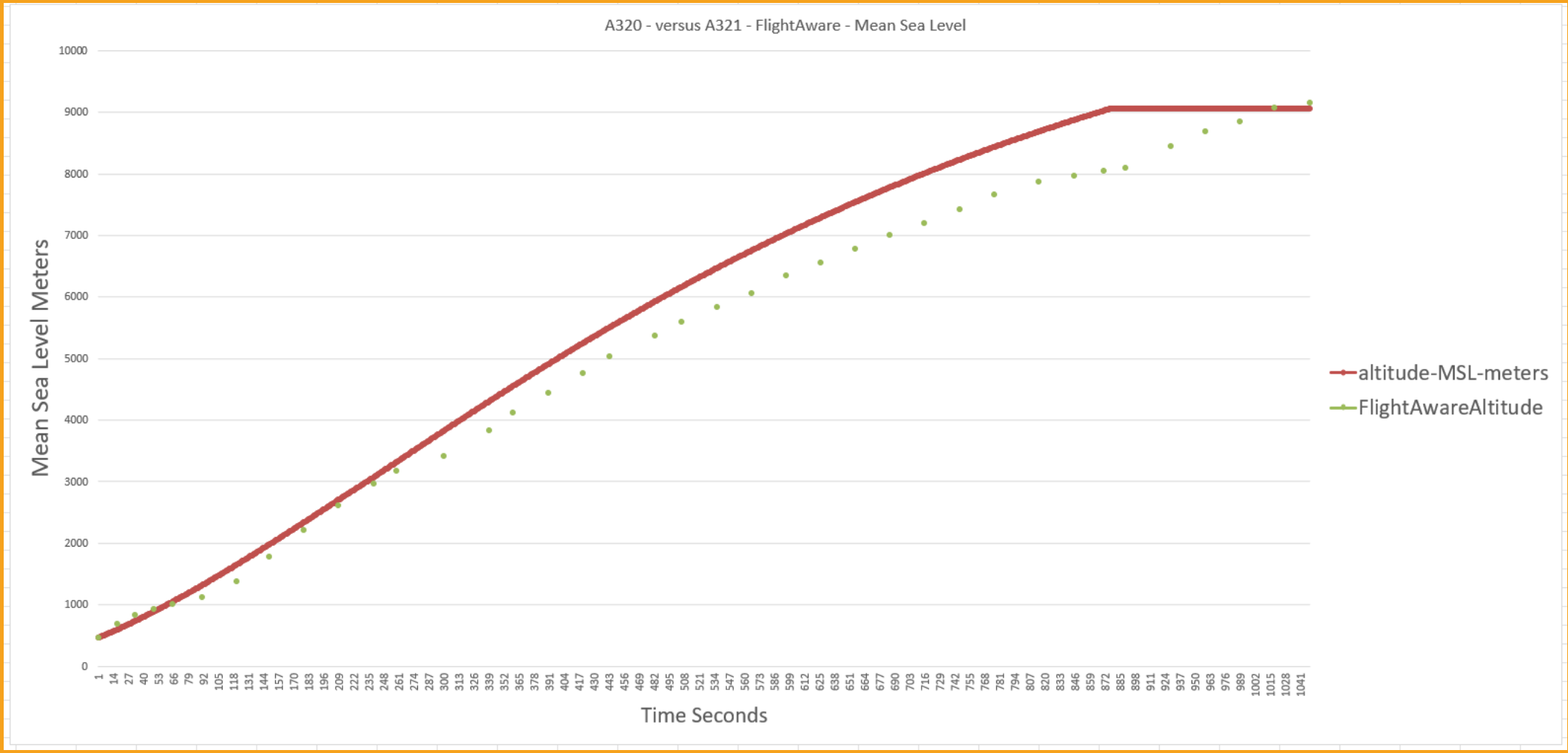


KLAX/24R -> SID -> SLI -> northern route towards MEMPHIS -> ATLANTA



VERTICAL PROFILE DURING CLIMB

A320 climb compared to A321 recorded in Flight Aware.



ABORTED COMPUTATIONS

NO MORE FUEL -> ABORTED COMPUTATION

Click here to move -> Flight Profile Computation | Click to hide

Select the aircraft -> Airbus A320 | Enter Reduced Climb Power % -> 0

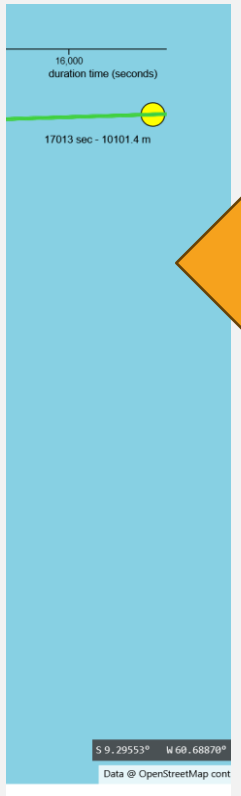
min -> 39000 | TakeOff Mass (kg) -> 57000 | max -> 77000 | Requested Flight Level (feet) -> 39000 | max -> 39000

KJFK | Route Selector -> New York Kennedy Intl -> Paris Charles-De-Gaulle France Intl | LFPG

Departure RunWay -> 04L -> 3 ... ding | Arrival RunWay -> 08L -> 85 degrees True Heading

Compute Flight Profil | Download Vertical Profile | Download KML

Insufficient takeoff mass hence insufficient fuel



Vertical profile doesn't show the descent phase

Aircraft cannot reach its destination

Status -> Flight is aborted = True

Click here to move -> Flight Leg Costs Computation | Click to hide

Airline	Aircraft	Seats	Adep	RunWay	Ades	RunWay	Is Aborted	Initial Mass Kg	Final Mass Kg	Lost Mass Kg	Fuel Costs US$	Flight Duration Hours	Flying Costs US$	Crew Costs US$	Total Costs US$
AmericanWings	A320	157	KJFK	13L	LFPG	26R	true	57000	38999.3	18000.7	19306	5.0228	14265	8323	41893

<u>Future enhancement:</u> define configuration data for aircraft available operational fuel liters

RUNWAY OVERSHOOT -> ABORTED COMPUTATION

Takeoff mass

Click here to move -> Flight Pr… Click to hide

…ect the aircraft -> Airbus A330-200

A330-200

min -> 120600 TakeOff Mass (kg) -> 230000 max -> 230000

Requested Flight Level (feet) -> 41000 max -> 41000

KATL Route Selector -> Atlanta-Hartsfield Jackson Intl -> Los Angeles Intl KLAX

Departure RunWay -> 08L -> 90 degrees True Heading

Departure Runway -> length = 2743 meters

Compute Flight Profile | Compute Costs | Download Vertical Profile | Download KML

click

click

Results for compute profile

Results for compute costs

Status -> Flight is aborted = True

Hint: aircraft does not leave the ground -> it overshoots the runway
All vertical profile points have the same altitude corresponding to the airport altitude

Click here to move -> Flight Leg Costs Computation Click to hide

Airline	Aircraft	Seats	Adep	RunWay	Ades	RunWay	Is Aborted	Initial Mass Kg	Final Mass Kg	Lost Mass Kg	Fuel Costs US$	Flight Duration Hours	Flying Costs US$	Crew Costs US$	Total Costs US$
AmericanWings	A332	234	KATL	08L	KLAX	06L	true	230000	229727.2	272.8	293	0.0192	63	36	391

FUEL EFFICIENCY
&
FUEL PLANNER

FUEL EFFICIENCY
LITERS PER LEG LENGTH PER SEAT

Generates an EXCEL file with one EXCEL sheet per aircraft and per flight leg

In one sheet, for one aircraft and one flight leg, 15 trajectories are computed with a Reduced Climb Power Coefficient varying from 0 to 15. If the table is sorted according to Mass Loss or Fuel Efficiency (min to max), then the best Reduced Climb Power Coeff is identified

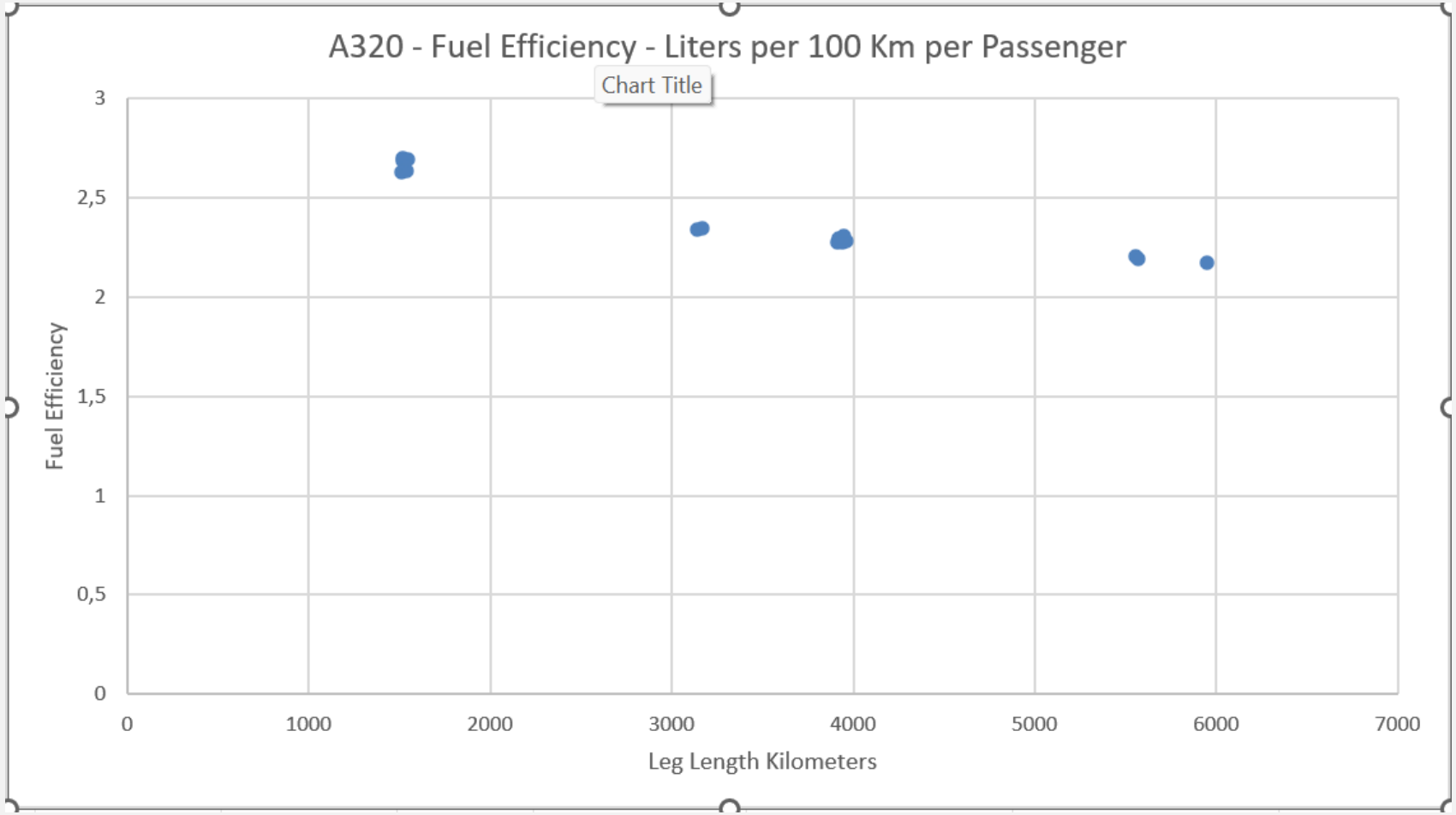
airline	aircraft	nb Seats	Departure Airport	Departure Runway	Arrival Airport	Arrival Runway	isAborted	Reduced Climb Power Coeff	takeOff Mass Kg	final Mass Kg	mass Loss Kg	Kerosene Liter	Leg Length Km	Fuel Efficiency - Liters per 100 Km per Seat
AmericanWings	Airbus A320	157	KATL	27R	KLAX	07L	False	9	64000	54687,48125	9312,5188	11496,937	3140,933698	2,331437191
AmericanWings	Airbus A320	157	KATL	27R	KLAX	07L	False	11	64000	54686,90698	9313,093	11497,646	3140,929983	2,331583719
AmericanWings	Airbus A320	157	KATL	27R	KLAX	07L	False	10	64000	54686,82249	9313,1775	11497,75	3140,934278	2,331601683
AmericanWings	Airbus A320	157	KATL	27R	KLAX	07L	False	8	64000	54686,40663	9313,5934	11498,263	3140,927031	2,331711176
AmericanWings	Airbus A320	157	KATL	27R	KLAX	07L	False	12	64000	54686,22735	9313,7727	11498,485	3140,927724	2,331755547
AmericanWings	Airbus A320	157	KATL	27R	KLAX	07L	False	7	64000	54684,77531	9315,2247	11500,277	3140,926247	2,332120169
AmericanWings	Airbus A320	157	KATL	27R	KLAX	07L	False	13	64000	54684,67394	9315,3261	11500,403	3140,935158	2,332138931
AmericanWings	Airbus A320	157	KATL	27R	KLAX	07L	False	6	64000	54683,26095	9316,7391	11502,147	3140,923126	2,332501616
AmericanWings	Airbus A320	157	KATL	27R	KLAX	07L	False	14	64000	54682,69637	9317,3036	11502,844	3140,928708	2,332638815
AmericanWings	Airbus A320	157	KATL	27R	KLAX	07L	False	15	64000	54680,93409	9319,0659	11505,02	3140,926713	2,333081494
AmericanWings	Airbus A320	157	KATL	27R	KLAX	07L	False	5	64000	54680,39879	9319,6012	11505,681	3140,921475	2,3332194
AmericanWings	Airbus A320	157	KATL	27R	KLAX	07L	False	4	64000	54676,95414	9323,0459	11509,933	3140,920833	2,334082266
AmericanWings	Airbus A320	157	KATL	27R	KLAX	07L	False	3	64000	54674,05616	9325,9438	11513,511	3140,916811	2,334810784
AmericanWings	Airbus A320	157	KATL	27R	KLAX	07L	False	2	64000	54670,38097	9329,619	11518,048	3140,916881	2,335730838
AmericanWings	Airbus A320	157	KATL	27R	KLAX	07L	False	1	64000	54665,87255	9334,1274	11523,614	3140,913016	2,336862427
AmericanWings	Airbus A320	157	KATL	27R	KLAX	07L	False	0	64000	54660,68742	9339,3126	11530,016	3140,912021	2,3381613

FUEL EFFICIENCY

Follow for instance this link

https://airlineservices.eu.pythonanywhere.com/airline/airlineFuelEfficiency/AmericanWings

Liters of Kerosene needed to fly distance as multiple of 100 Kilometers per seat

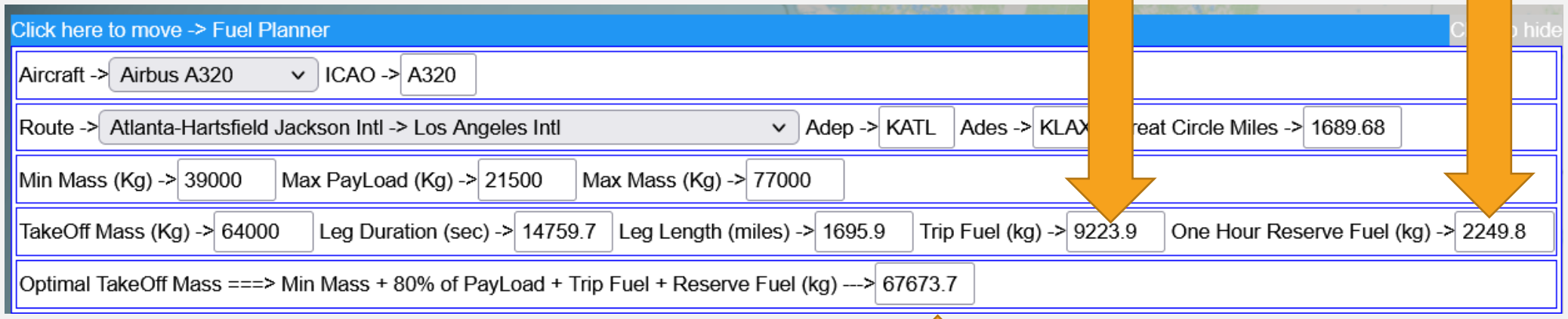


*Computation -> ((Kerosene Liters / leg length kilometers) / seats) * 100.*

FUEL PLANNER (TAKEOFF MASS ESTIMATION)

Use Trip Fuel

Add Reserve Fuel



Compute Optimal TakeOff Mass → Min Mass + 80% of Max Payload + Trip Fuel + Reserve Fuel

METAR – METEO DATA ON AIRPORTS

METAR -> SEE WEBSITE -> AVIATIONWEATHER.GOV

Table sorting column

Since version 4.0 -> table has clickable headers allowing to sort according to the content of one table column

Click here to move - Metar

Click to hide

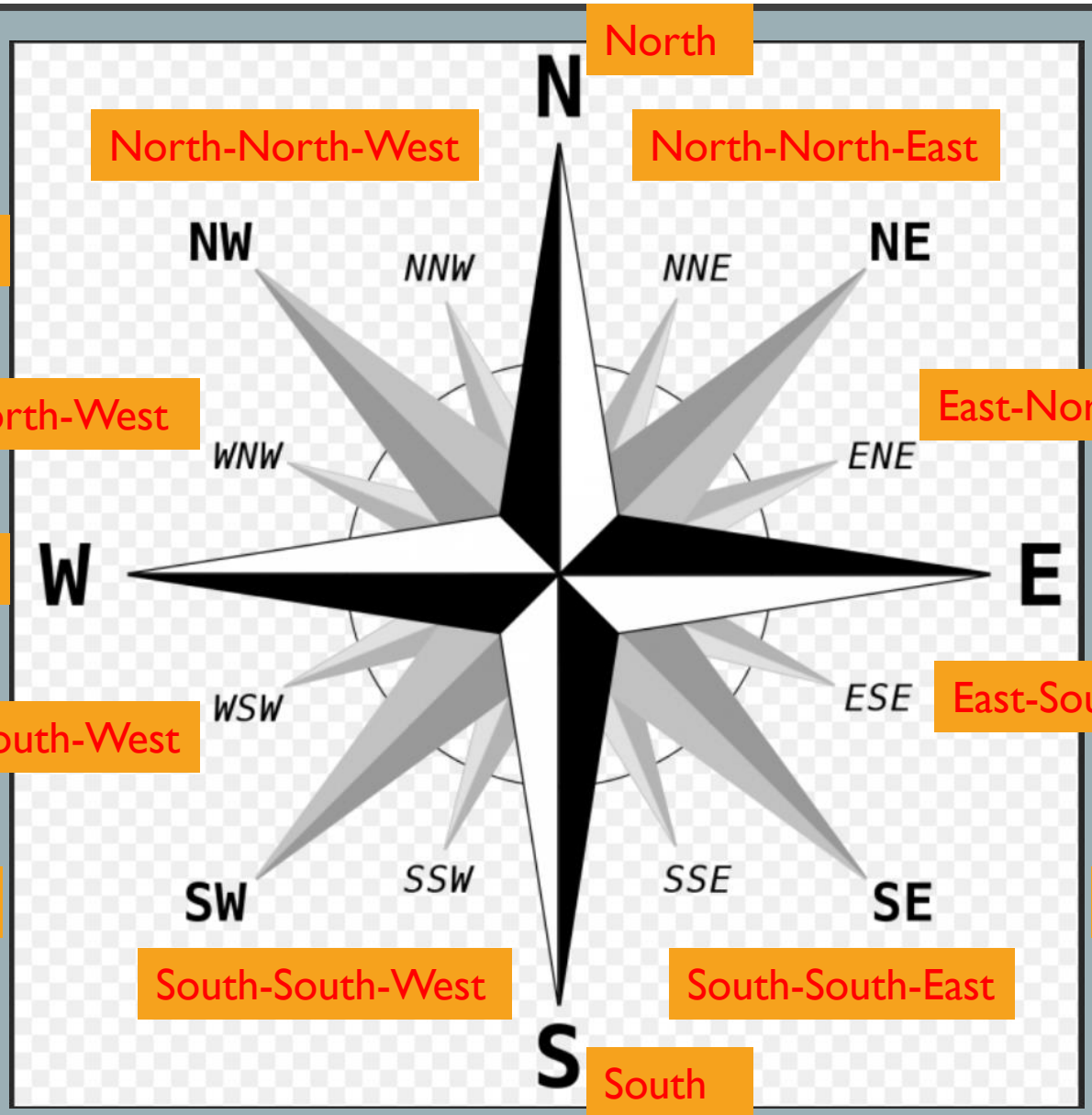
ICAO	Airport Name	Date Time UTC	Metar Type	Temperature Celsius	Dew Point Celsius	Wind Speed Kt	Wind Direction Compass	Wind Direction Degrees	Wind Gust Kt	Sea Level Pressure Hpa
KSFO	San Francisco Intl	2023-10-07T09:56:00Z	METAR	20.6	10.6	0	N	0		1011.9
LFPG	Charles De Gaulle	2023-10-07T10:00:00Z	METAR	20.0	12.0	5	SW	220		
KIAH	Houston George Bush Intl	2023-10-07T09:53:00Z	METAR	20.0	15.6	3	N	350		1020.1
KJFK	New York-John F Kennedy Intl	2023-10-07T09:51:00Z	METAR	18.9	18.3	7	E	80		1008.4
KLAX	Los Angeles Intl	2023-10-07T09:53:00Z	METAR	18.9	16.7	0	N	0		1010.5
KIAD	Washington Dulles Airport Intl	2023-10-07T09:52:00Z	METAR	18.3	16.1	5	N	10		1008.9
KBOS	General Edward Lawrence Logan Intl	2023-10-07T09:54:00Z	METAR	17.8	17.2	8	E	80		1011.7
MMMX	Licenciado Benito Juarez Intl	2023-10-07T09:45:00Z	METAR	17.0	11.0	4	N	10		
KATL	Atlanta-Hartsfield Jackson Atlanta Intl	2023-10-07T09:52:00Z	METAR	15.6	12.8	9	NW	320		1014.7
KSEA	Seattle Tacoma Intl	2023-10-07T09:53:00Z	METAR	12.2	10.0	5	N	360		1015.6
KORD	Chicago O'Hare Intl	2023-10-07T09:51:00Z	METAR	8.3	4.4	8	WNW	290		1018.7
KMSP	Minneapolis St Paul Intl	2023-10-07T09:53:00Z	METAR	6.7	2.8	7	W	280		1024.1
PANC	Alaska Anchorage-Ted Stevens Anchorage Intl	2023-10-07T10:00:00Z	SPECI	6.1	5.0	3	N	360		

Departure & Arrival Airports

Wind direction Compass

See next slide

CARDINALS – COMPASS DIRECTION OF INCOMING WINDS



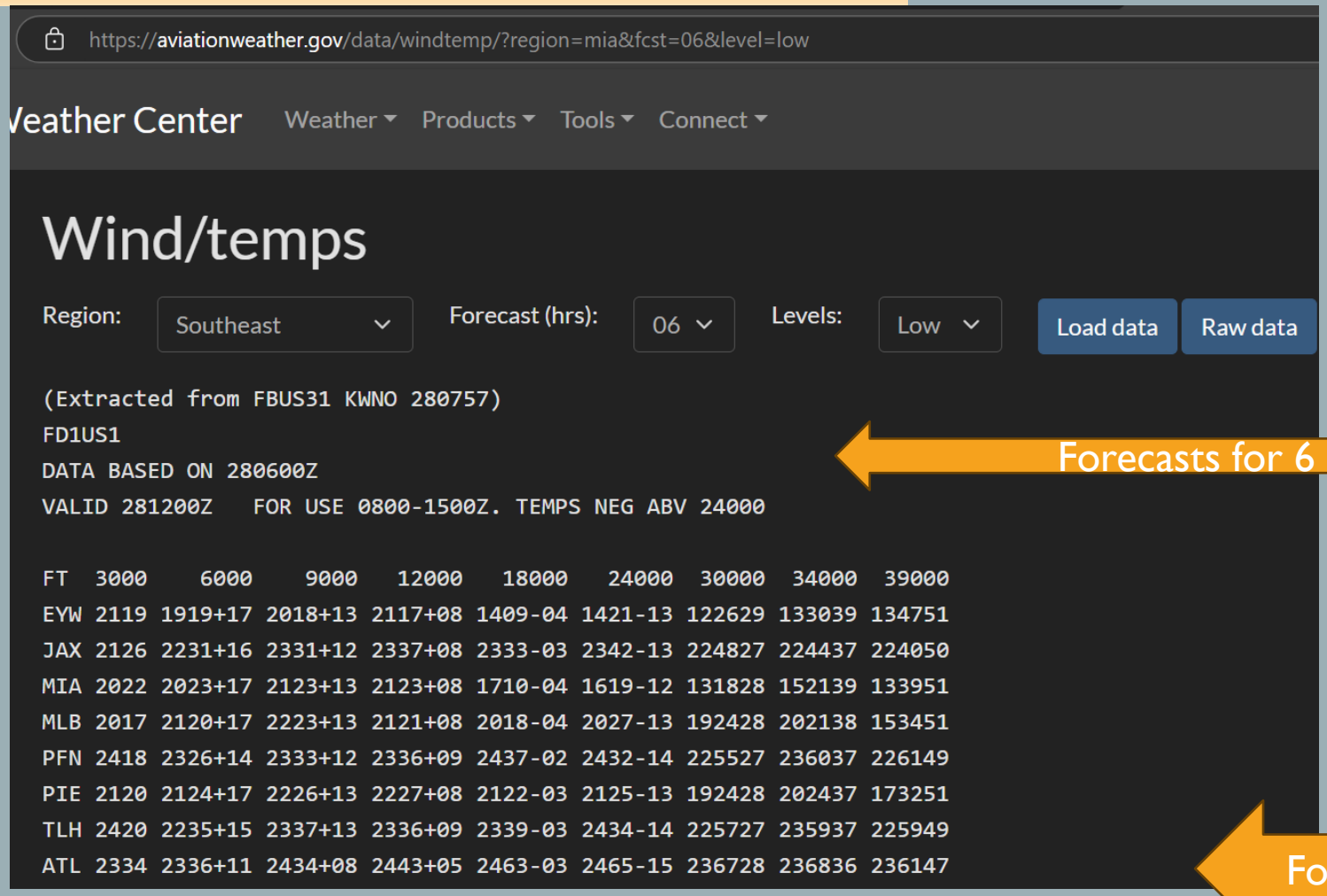
METEO FORECASTS DATA ALOFT

NOAA WEATHER FORECASTS

Chapter 13: Aviation Weather Services | Federal Aviation Administration (faa.gov)

Aviation Weather Services chapter 13

AWC Wind/temp: mia (aviationweather.gov)



Forecasts for 6 Hours on 28th September 2024

Forecasts for Atlanta (ATL)

WEATHER FORECASTS DATA MODEL

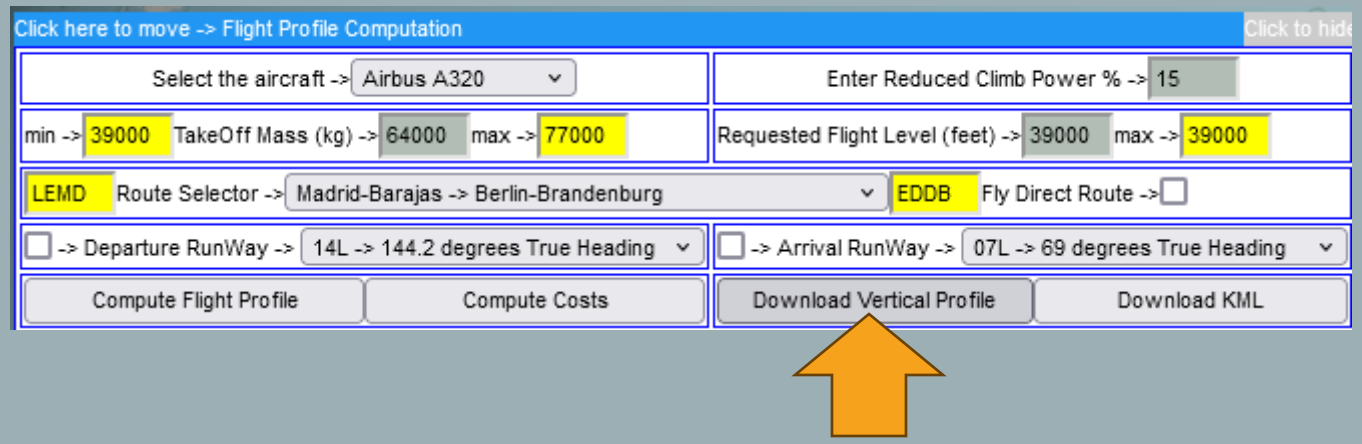
	FAAid [PK] character varying	ICAOid character varying	LatitudeDegrees double precision	LongitudeDegrees double precision	ElevationMeters double precision	Site character varying	State character varying	Country character varying
333	ATL	KATL	33.6297	-84.4422	309	Atlanta/Hartsfield-Jackson Intl	GA	US

ATL = FAA weather station id for Atlanta

Forecasts values updated once a day and given for 9 flight levels 3000 feet to 39000 feet

	id [PK] integer	LevelFeet double precision	WindSpeedKnots double precision	WindDirectionTrueNorthDegrees double precision	TemperatureDegreesCelsius double precision	NoaaWeatherStationInstance_id character varying
91	11467	3000	21	220	11	ATL
92	11468	6000	40	240	11	ATL
93	11469	9000	34	230	10	ATL
94	11470	12000	41	230	5	ATL
95	11471	18000	60	230	-1	ATL
96	11472	24000	66	230	-15	ATL
97	11473	30000	75	230	-28	ATL
98	11474	34000	81	220	-37	ATL
99	11475	39000	80	220	-48	ATL

EXCEL VERTICAL FLIGHT PROFILE



Generated EXCEL file to download with interpolated Temperature forecasts

Atlanta weather station

elapsed-t	characteristic-point	altitude-MSL-	altitude-MSL-feet	true-air-s	true-air-s	calibrated	mach	rate-of-cli	distance-f	distance-t	aircraft-m	flight-patl	thrust-nev	drag-new	lift-newtc	load-factc	nearest-w	temperature-degrees-celsius	end of simulation
0	Atlanta-Hartsfield Jackson	312,7248	1026,000002	0,1	0,194384	0,191647	0,000295	0	0	0	64000	0	0	0	0	0	None	0	False
1	departure-ground-run	312,7248	1026,000002	1,914728	3,721933	3,669518	0,005647	0	0,001034	1694,945	63998,54	0	138091,4	0,029093	0,07329	1,15E-06	ATL	11	False
2	departure-ground-run	312,7248	1026,000002	3,729353	7,249282	7,147196	0,010998	0	0,003048	1694,944	63997,07	0	138091,4	10,66614	26,86955	0,00042	ATL	11	False
3	departure-ground-run	312,7248	1026,000002	5,543603	10,7759	10,62416	0,016349	0	0,006041	1694,942	63995,59	0	138091,4	40,4632	101,9327	0,001593	ATL	11	False

Flight level input used for interpolation

Interpolated Temperature at the given flight level

WEATHER STATION PERFORMANCE OPTIMIZATION

Search for the nearest weather station occurs each time

distance flown is greater to 50 Kilo meters to distance flown for the previous weather station search

Temperature interpolation occurs each time

Absolute value of Flight level difference is greater to 300 feet

from the previous Temperature interpolation

APPLICATION PROGRAMMING INTERFACE

APPLICATION PROGRAMMING INTERFACE

Benefits of API : tool may be queried programmatically & inserted in an eco-system of a more larger tool set

Click on Help Button

In the last help section, see examples of URL to retrieve a JSON answer in the browser

▼API - Application Programming Interface

It is possible to query programmatically the service and retrieve a result in Json format.
Use the following URL : Fleet Definition to retrieve the fleet definition.
Use the following URL : Routes Definition to retrieve the routes.
Use the following URL : Costs to retrieve the costs.
Use the following URL : WayPoints to retrieve the wayPoints.
Use the following URL : Airports to retrieve the airports of the airline.
Use the following URL : Runway overshoot to retrieve the ground run length.

Links to be clicked

DEPARTURE RUNWAY OVERSHOOT

DEPARTURE RUNWAY OVERSHOOT (PROGRAMMATIC FEATURE)

Feature to be used programmatically -> Enter the URL below in the browser

Modify arguments such as aircraft, airport, departure runway, takeoff mass

Aircraft Takeoff mass unit = tons

Aircraft Takeoff mass = 230 tons

Paste the following URL in the browser

https://airlineservices.eu.pythonanywhere.com/trajectory/computeRunwayOvershoot/A332/KATL/08L/230

Aircraft ICAO = A332

Departure ICAO = KATL

Departure runway = KATL/08L

Receive an answer in JSON format


```
{
  "aircraft": "A332-AIRBUS-A330-200",
  "aircraftReferenceMassKg": "190000.0",
  "aircraftInitialMassKg": "230000.0",
  "airport": "Airport: Airport: KATL - Atlanta-Hartsfield Jackson Atlanta Intl - lat= 33.64 degrees - long= -84.43 degrees - field elevation= 312.72 meters",
  "runway": "RunWay: runway= 08L -  airport ICAO code= KATL -  length= 9000.00 feet -  true heading= 90.00 degrees -  latitude= 33.65 degrees -  longitude= -84.44 degrees",
  "runwayLengthMeters": "2743.2",
  "TakeOffStallSpeedCasKnots": "128.73",
  "groundRunLengthMeters": "2915.39"
}
```


Runway length from configuration data = 2743 meters ⟹ ? ⟸ Runway length from computation of departure ground run = 2915 meters

Ground run computed runway length **is greater** than configured runway length -> Choose another departure runway or reduce the aircraft takeoff mass

COMPUTATIONS PERFORMANCE

PERFORMANCES – ON PREMISE (CPU TIME NEEDED TO COMPUTE ONE FLIGHT LEG)

Processor = i3th Gen Intel(R) Core(TM) i7-1360P 2.20 GHz
RAM = 32,0 Go (31,7 Go usable)

Only 4D trajectory computations

Aircraft	Initial mass	Cruise Mach / Ceiling (feet)	Flight leg	Distance flown (nautical miles)	4D Computation duration	Real time flight duration
A320	67000 kg	0,82 / 39000	Madrid LEMD/36R -> Berlin EDDB/25L	1070 NM	0,86 sec	9664 sec 2 hours 41 minutes
A320	67000 kg	0,82 / 39000	Los Angeles KLAX/24R -> Atlanta KATL/27R	1755 NM	1.0 sec /	15804 sec 4 hours 23 minutes
A320	67000 kg	0,82 / 39000	Mexico MMMX/05L -> Seattle KSEA/16C	2161 NM	2.83 sec	18276 sec / 5 hours 4 minutes

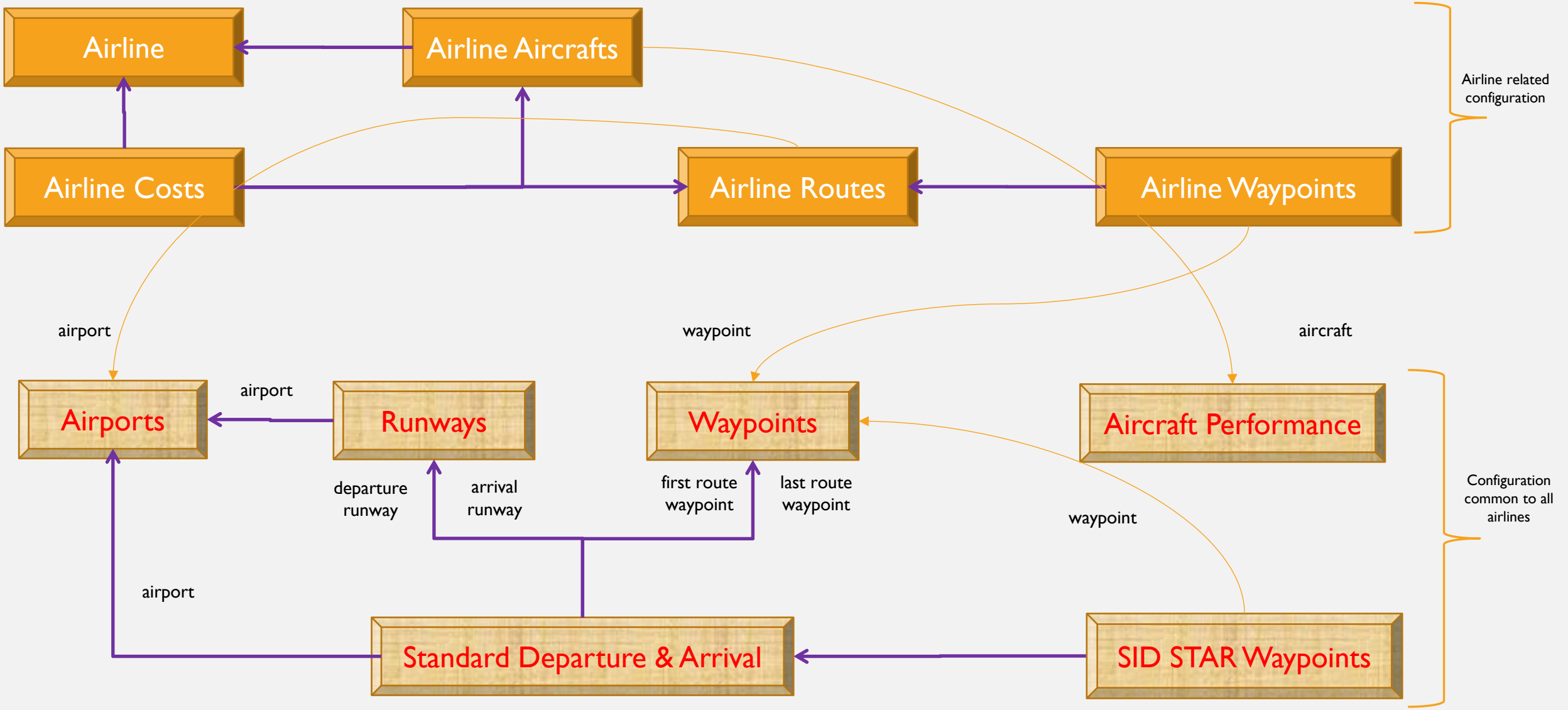
On one leg, performances computation is mostly dependent upon number of waypoints in the fix list

Performances are reduced when code is deployed on PythonAnyWhere

DESIGN

Basic design relies upon the python Django Framework

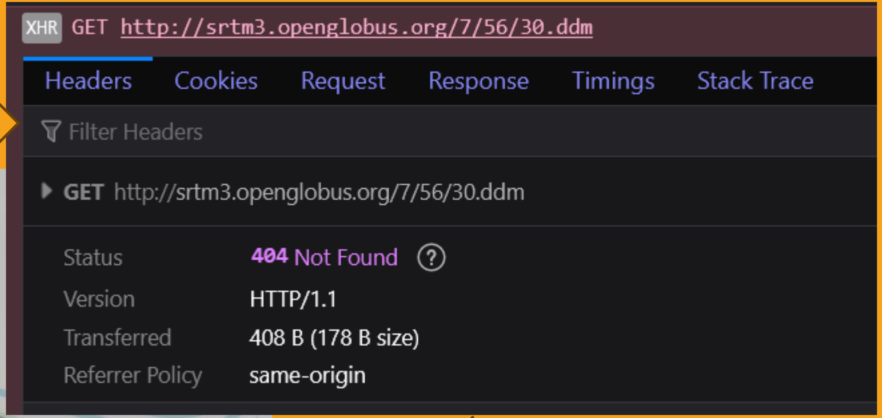
DATABASE SCHEMA

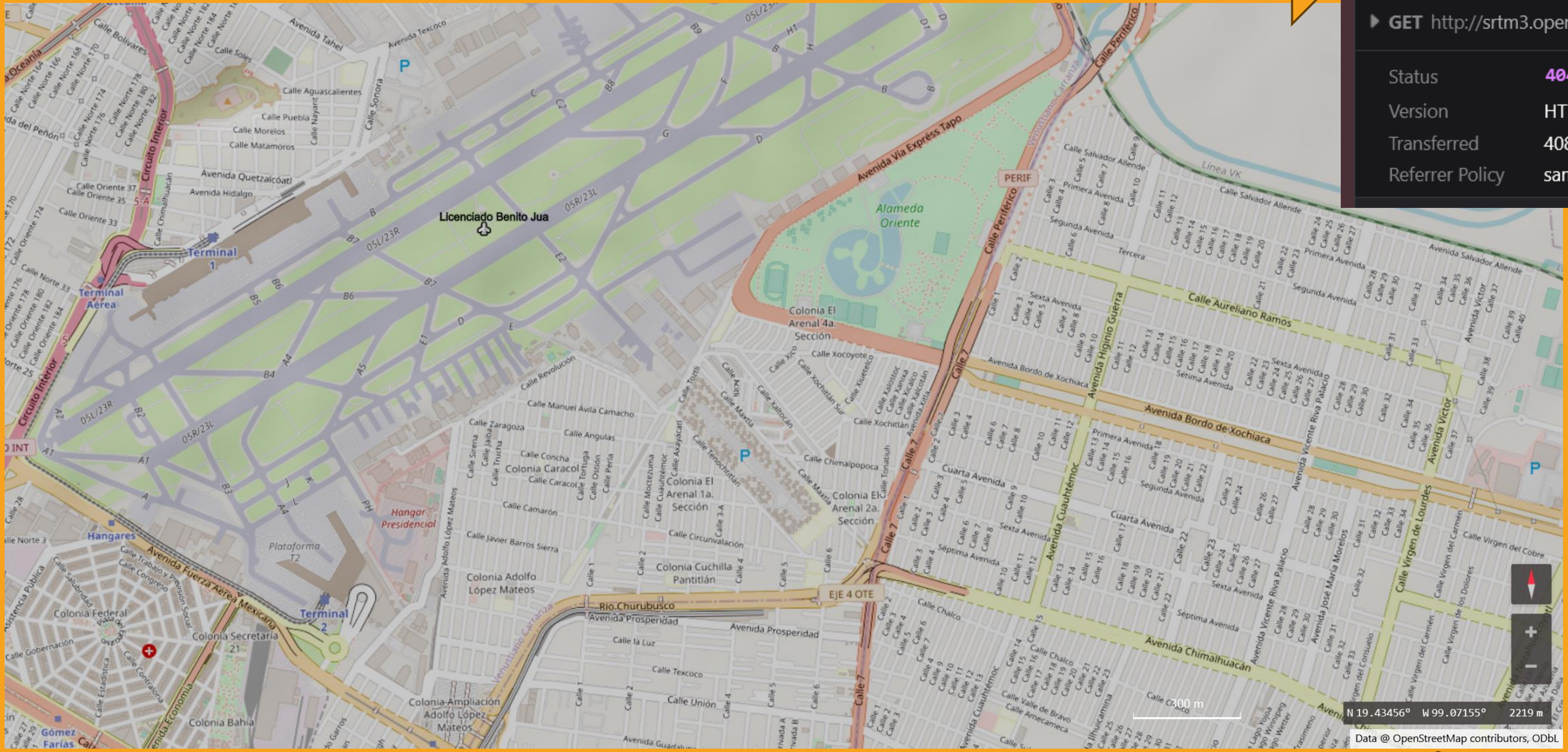


OPENGLOBUS JAVASCRIPT MAP LIBRARY

Featuring : KML format, rays, events, ruler, etc.

Case where there is no data for terrain in the coordinates z=7, y=56, x=30, where z is the zoom level, and x, y - Mercator grid coordinates





Zoom using mouse wheel

control map orientation

Zoom in & out

Ground altitude above Mean Sea Level

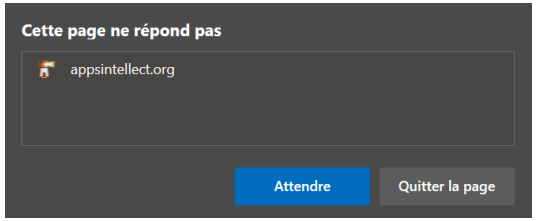
Tile provider

Earth model - Wgs84 – Map projection - Universal Transverse Mercator coordinate system

FUTURE IMPROVEMENTS (BACKLOG CONTENT)

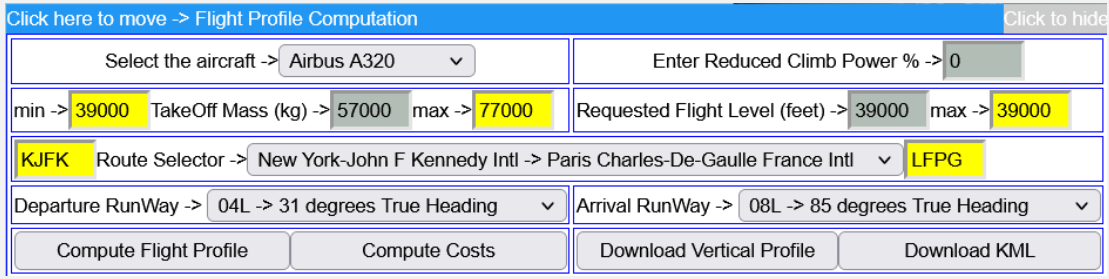
- Capacity in the vertical profile to meet speed restrictions (below 10,000 feet above ground) when arriving on a certain airport with applicable noise reduction restriction
- Capacity to compute an optimized vertical profile with a time / duration minimization constraint, leading to climb with max thrust , reach top of climb as soon as possible, reach operational Cruise Mach achieve a minimal flight duration (optimizing the crew costs or ensuring arrival on time).
- Align airport names -> in the route selector, departure airport is “Aeropuerto Mexico Cuidad” and on the map it is named “Licenciado Benito Juarez”
- Define precisely the amount of available fuel -> case where “no more fuel” event occurs
- Compute “Block Hour” : currently only trip duration is computed (from departure ground run to arrival ground run)
- Number of runways per airport will be used to compute “Block Hour” (time from doors closure to departure runway) from trip duration

KNOWN ISSUE

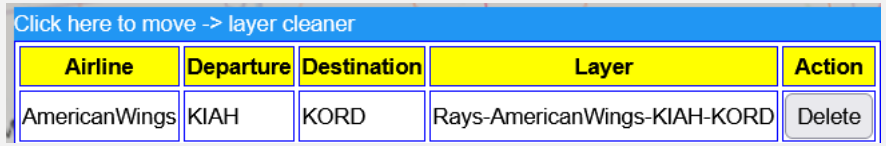


Title : Removal of open globus ray layers leads temporarily to "frozen" browser when second flight profile follows same departure & same destination airport

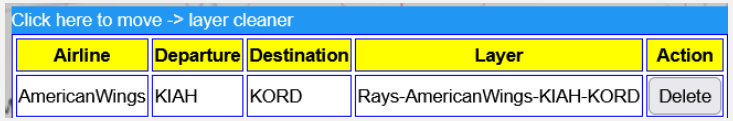
- **Condition** : Open profile menu and select a flight leg between 2 airports.
- **Action** : launch the computation of the profile -> Compute Flight Profile



- **Results** :
  - the vertical profile is displayed on top of the map
  - a ray layer cleaner window is displayed



- **Action** : click to close the vertical profile and zoom on the map to the selected departure airport / selected departure runway
- **Action** : without changing the airports, select a different departure runway
- **Action** : click to launch the computation of the profile again
- **Results** : the "FireFox" browser gets stuck / frozen temporarily while trying to delete the previous Open Globus ray layer
- Alternative action (to obtain the frozen browser):
  - In the Layer Cleaner menu, click on the Delete action button of the displayed route that you wish to suppress
  - Consequence is identical -> Browser freezes temporarily (a couple of minutes)



ACRONYMS

Acronym	Definition	Link
CAS	Calibrated Air Speed	The indicated airspeed corrected for instrument and position error.
CASM	Costs per Available Seat Miles	
ICAO	International Civil Aviation Organization	Home (icao.int)
ISA	International Standard Atmosphere	International Standard Atmosphere – Wikipedia
KML	Keyhole Markup Language	Keyhole Markup Language — Wikipédia (wikipedia.org)
MSL	Mean Sea Level	
SID	Standard Instrument Departure	SIDs and STARs | SKYbrary Aviation Safety
STAR	Standard Terminal Arrival Route	SIDs and STARs | SKYbrary Aviation Safety
TAS	True Air Speed	The speed of the aircraft relative to the air mass through which it is flying.

FLEET MANAGEMENT
THANK YOU

For any question, please follow this link
https://www.appsintellect.org/contact-card