Aircraft Emergency Trajectory Design

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AMLD

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Agenda

- What is the objective of this work ?
- Resolution Algorithm
- Results
- Conclusions and Perspectives

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Auto-Pilot

Figure – Auto Pilot : manouvers

FMS

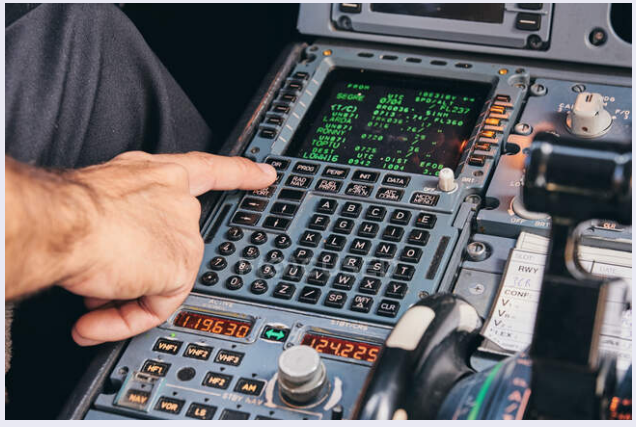

Figure – FMS : navigation

An example of critical situation : US-Airways 1549

Figure – On January 15, 2009, US Airways Flight 1549, an Airbus A320 struck a flock of birds shortly after take-off, losing all engine power.

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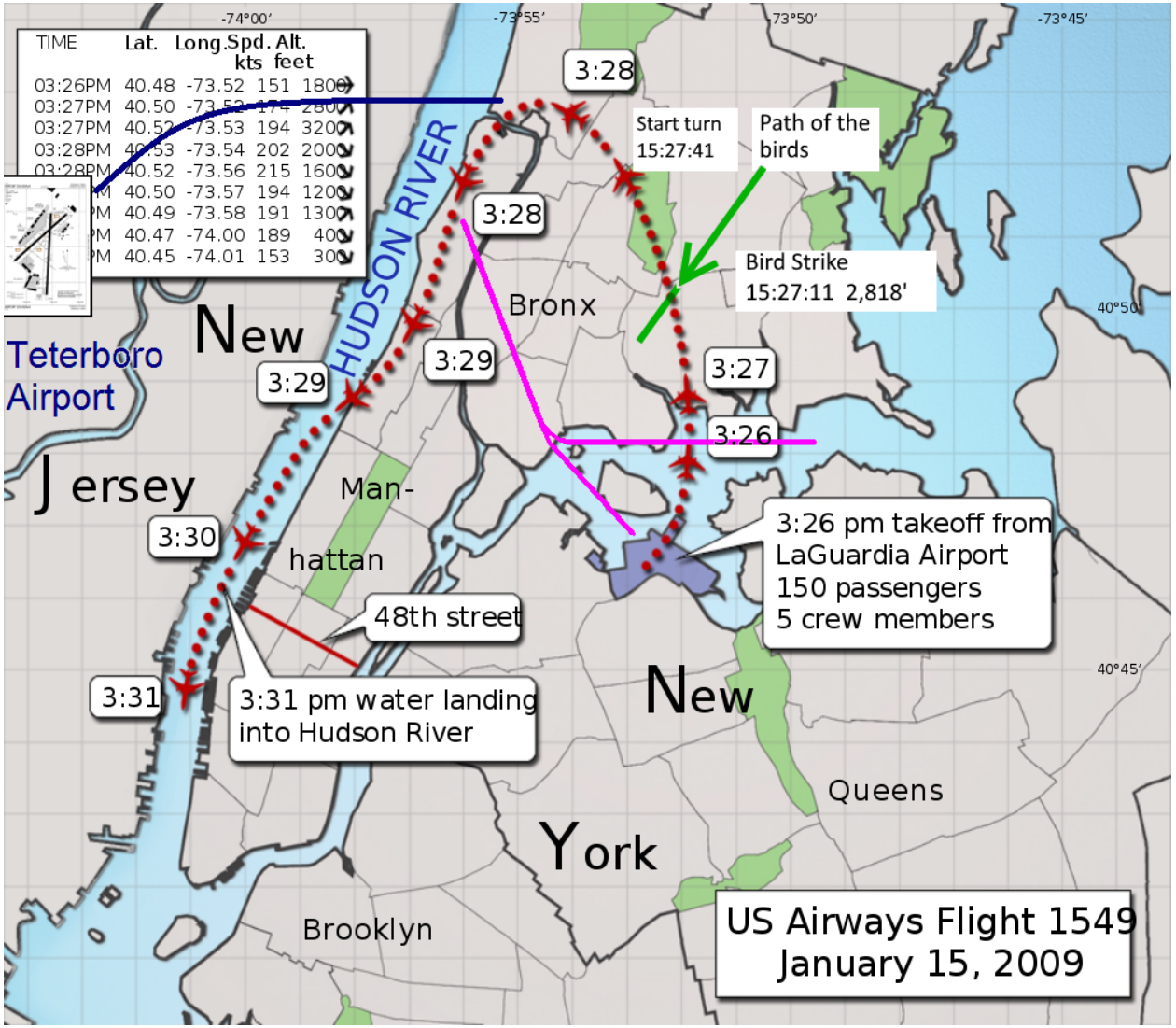
US-Airways 1549



Time : 3 minutes

Two other cases

- Air Transat Flight 236 (2001, Toronto-Lisbon, fuel leak). Glide for 120 km (21 minutes) before reaching Azores Island.
- Swissair flight 111 (1998, JFK-Geneva, fire). Enable to reach Halifax (14 minutes)

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On-Board A/C Optimal Trajectory Generation

- Over 70% of fatal aviation accidents are in **take-off/landing phases**.
- Critical in mountainous terrain (e.g., LinZhi airport in China)
- Must take into acount weather (wind, thunderstorms)

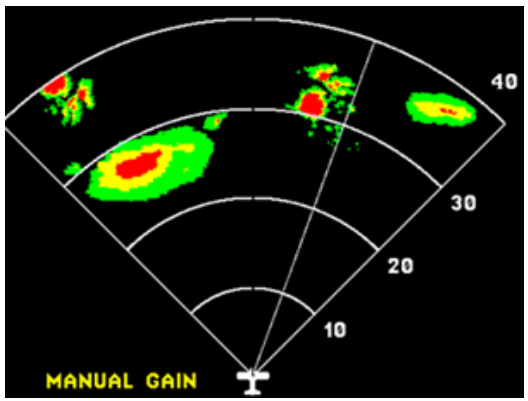

Figure – Thunderstorms avoidance

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Types of Emergencies

As Soon as Possible (ASAP)

- Most critical emergencies, the pilot has to find the fastest way to land
- Examples : cabin fire, depressurization

At Nearest Suitable Airport (ANSA)

- Safest landing
- Example : dual engine failure

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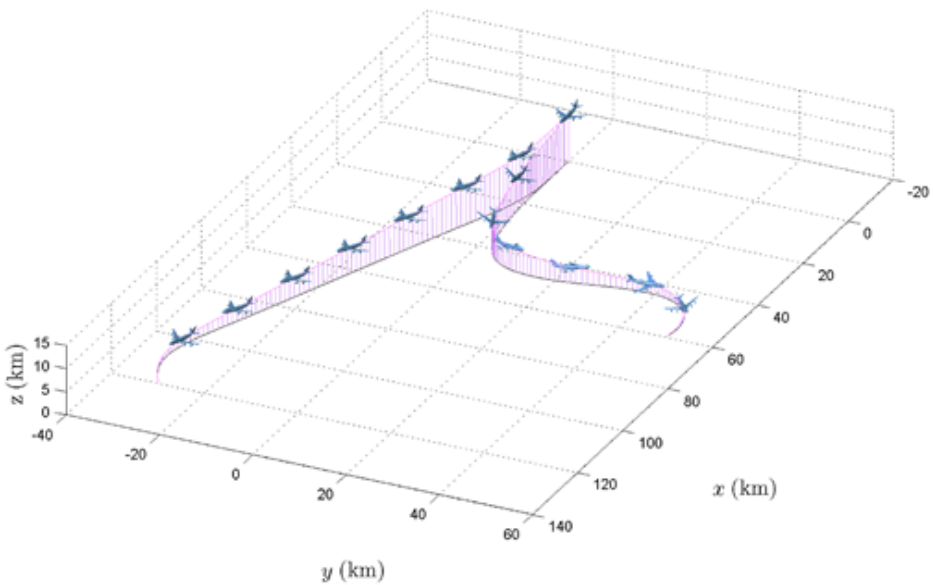
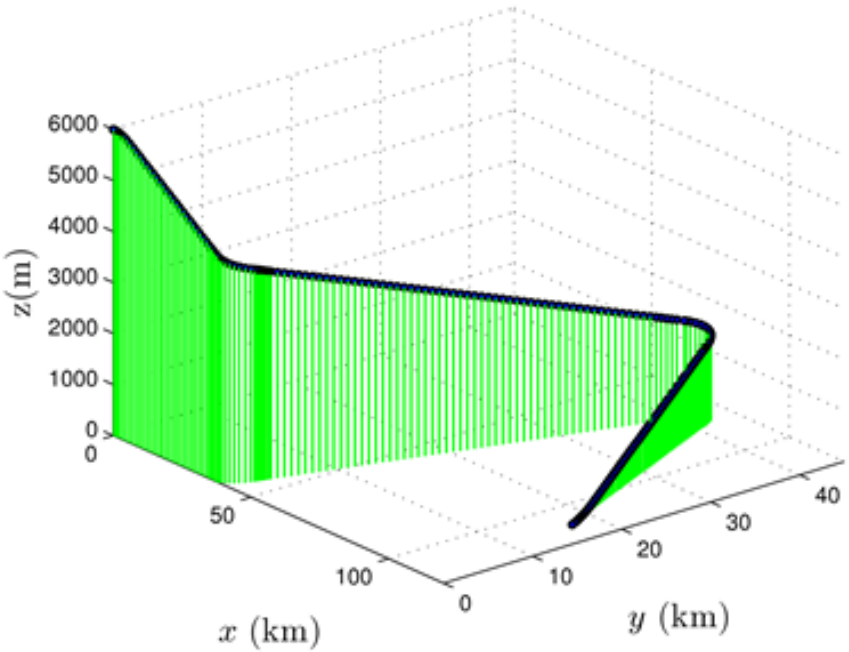
Aircraft Emergency Landing

- **Time** is the most critical factor
  - US Airways flight 1549 : 3min
- **Fuel** may be a limiting factor too
- **Challenges**
  - **Real-Time** requirement
  - **Convergence** guarantees



Principle : hierarchical approach

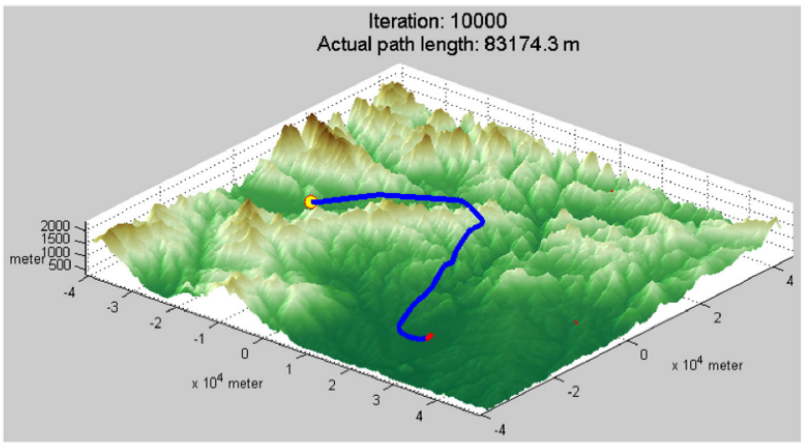
1. **Geometric planner**
   - State constraints, obstacles
   - Path generator

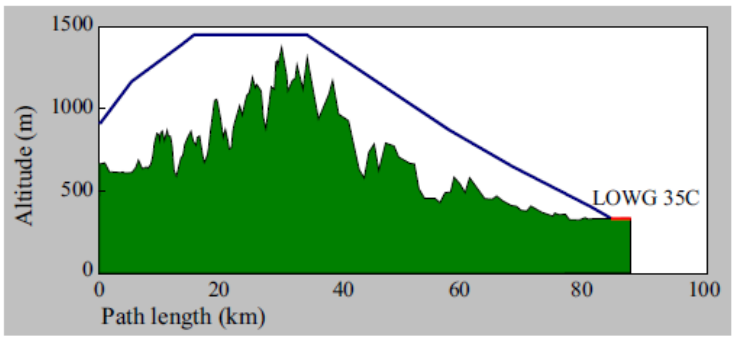


2. **Motion planner**
   - Time parameterization
   - Trajectory generator

$\Rightarrow$ **Key Idea :** First find flyable **path** to avoid obstacles ; then find a feasible **trajectory** to follow along this path.

Previous Related Works





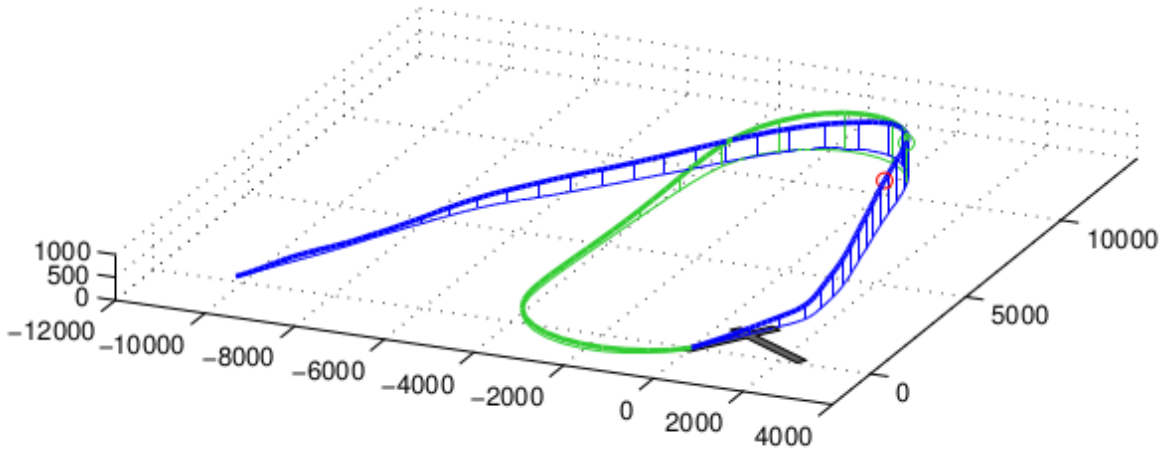
Fallast, A. ; Messnarz, B.

Automated trajectory generation and airport selection for an emergency landing procedure of CS23 aircraft.

DEAS Aeornautical J. **2017**, *8*, 481–492.

Computation time limitation

Previous Related Works



Zhao, Y.Efficient and Robust Aircraft Landing Trajectory Optimization. Ph.D. Thesis, Georgia Institute of Technology, Atlanta, Georgia 2012.

Do not take into account obstacles

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Problem features

Objectives

- Find a **safe** flyable trajectory
- ASAP or ANSA
- Fast computation

Constraints

- Current heading and landing site direction
- Terrain and weather avoidance
- Curvature (radius turn and number of turns)
- Descent profile
- Wind
- Failure feature

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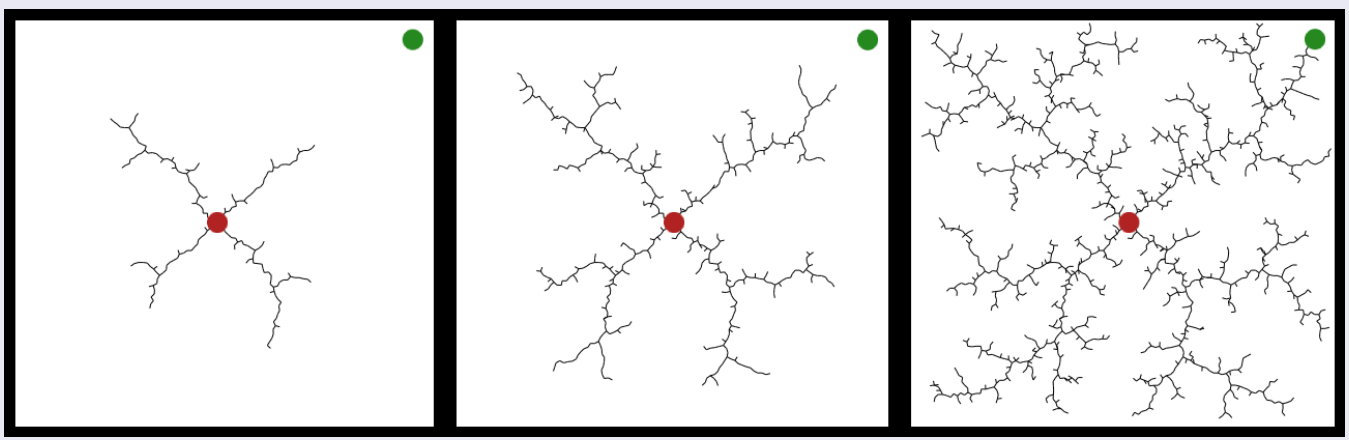
Algorithm

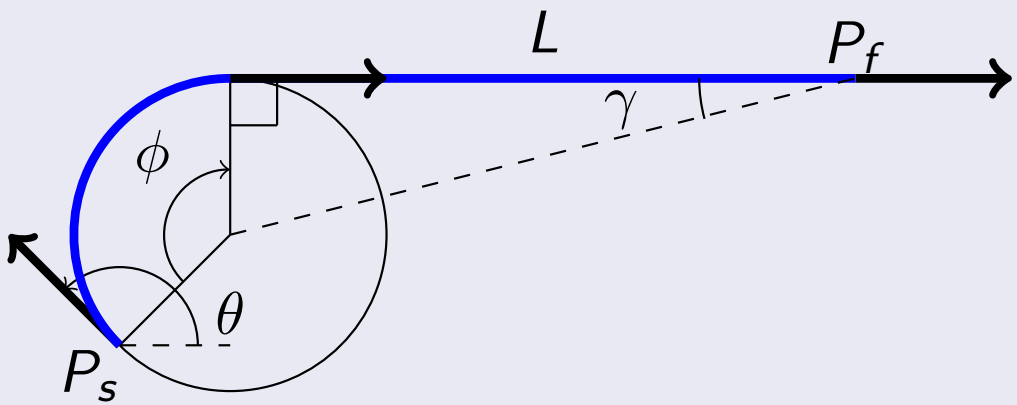
Rapidly-Exploring Random Tree

- Generation of a random point at each iteration
- Search for the path in parallel with the creation of the graph. For each new node, the father of the node is retained to determine the path.



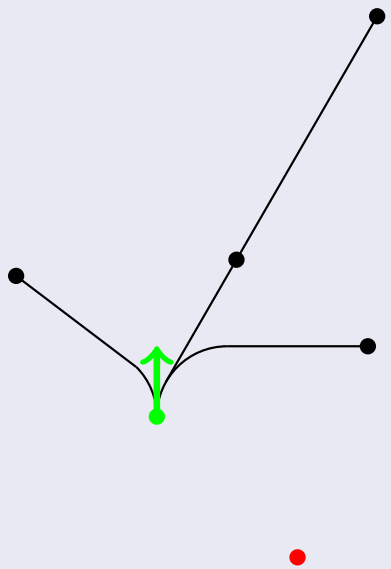
Algorithm

Single Turn Curve



Algorithm

Node connection



Algorithm

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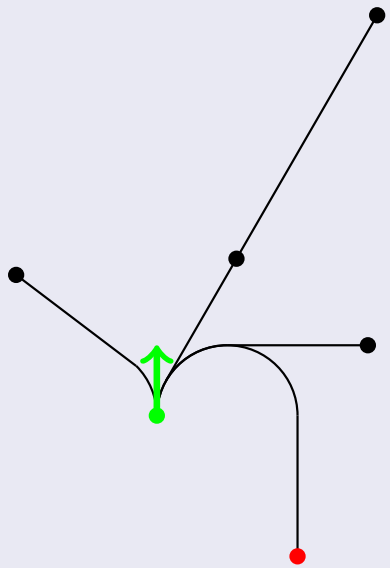
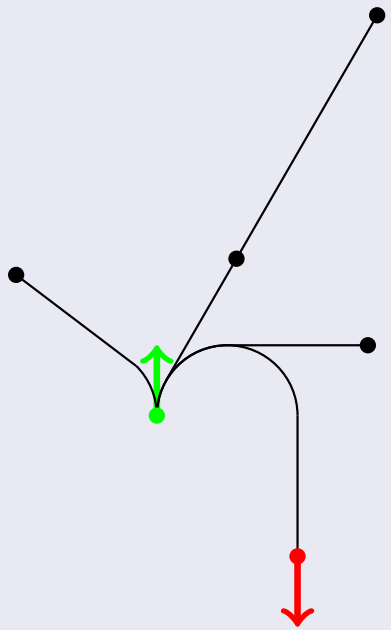
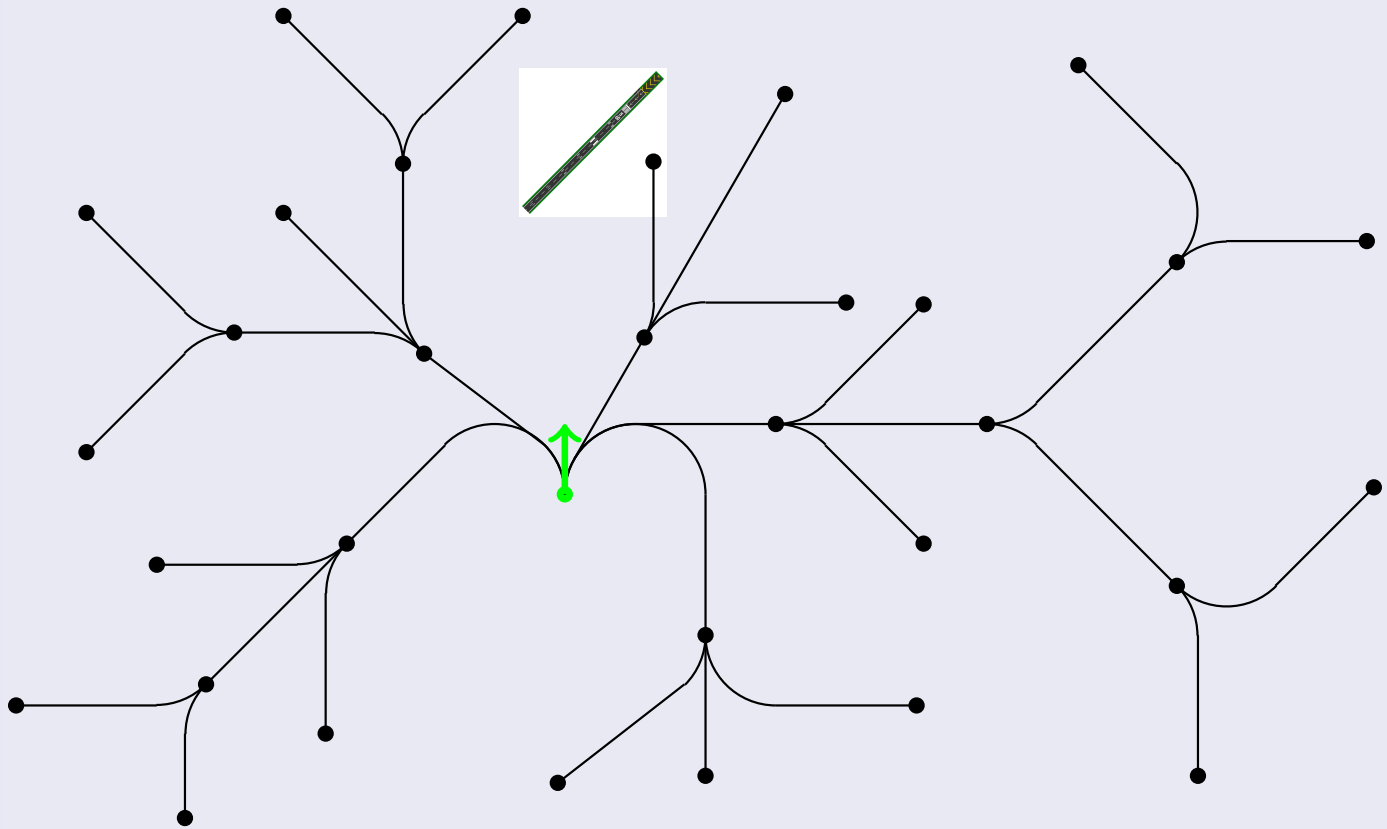


Node connection



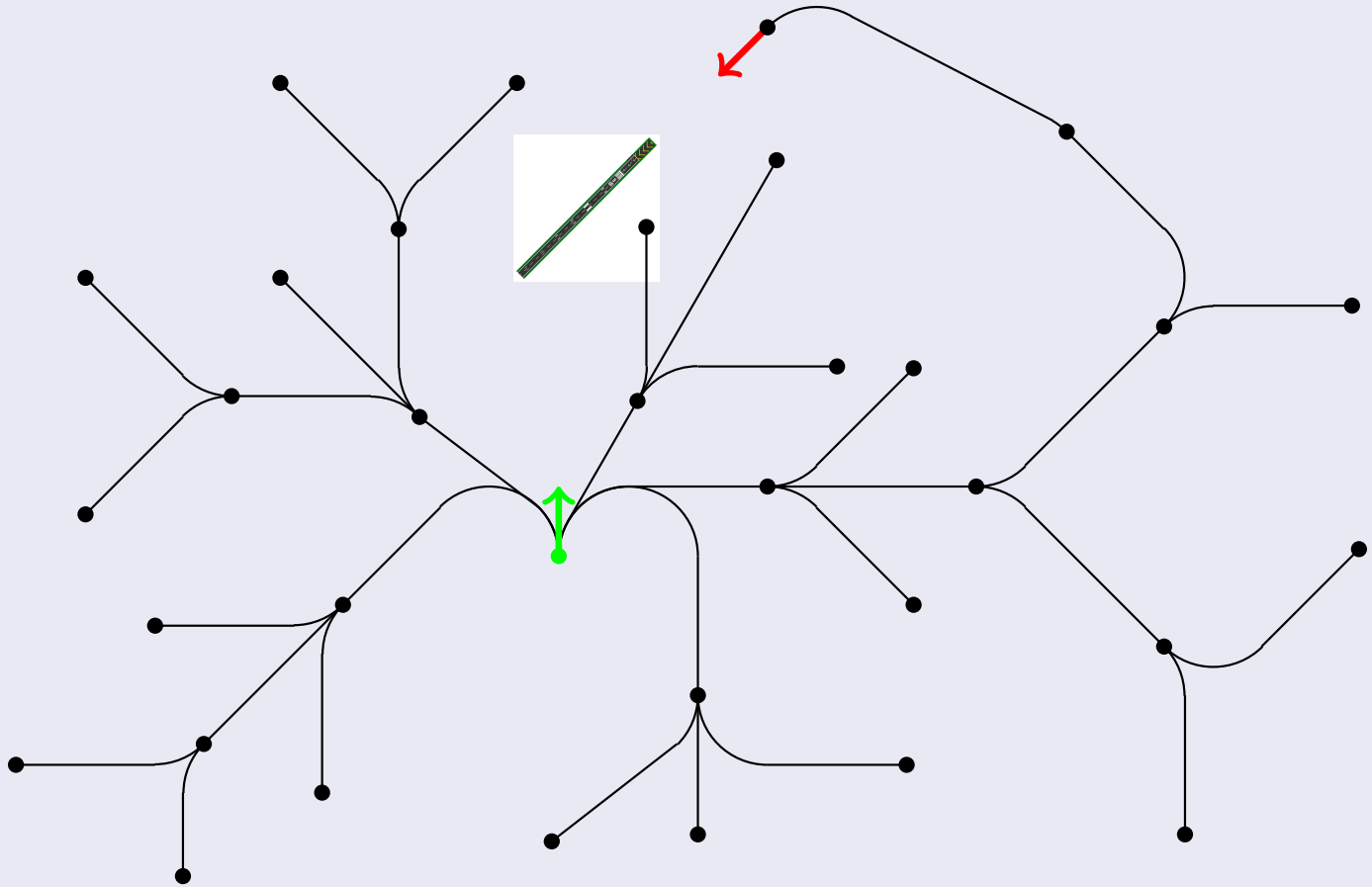
Algorithm

Graph of curves



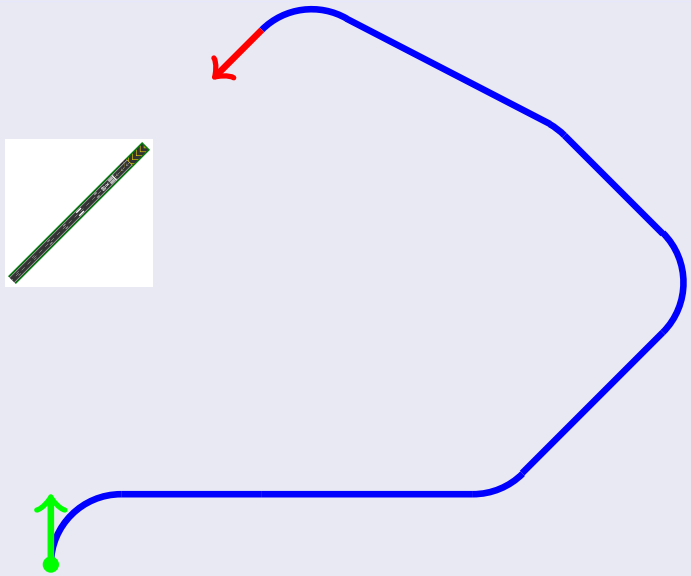
Algorithm

Graph of curves



Algorithm

Computed path



Algorithm

Objective function : Minimization of the curvature

- Trajectory composed of n curves $c_1, c_2, ..., c_n$
- ϕ_i the turn angle of the curve c_i

$$min \quad f(c_1, c_2, ..., c_n) = \sum_{i=1}^{n} e^{\phi_i}$$

Minimization of the curvature

- Penalize trajectories with big turns

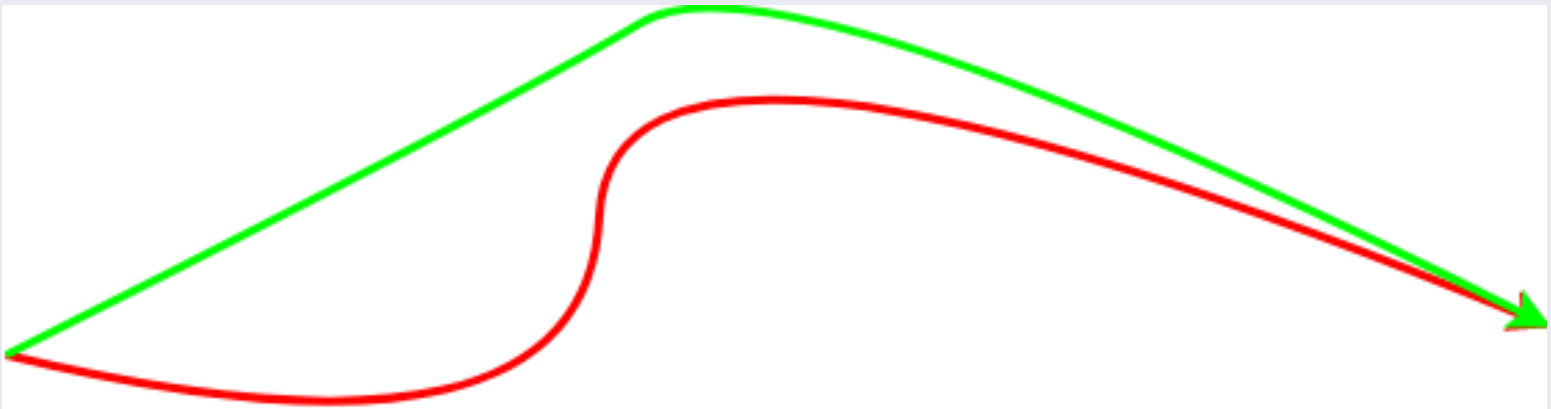


Figure – Red trajectory cost $>$ Green Trajectory cost

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Results

Emergency Example

- A320
- Emergency near to Grenoble in France
- ASAP
- ANSA

Results

Emergency Example

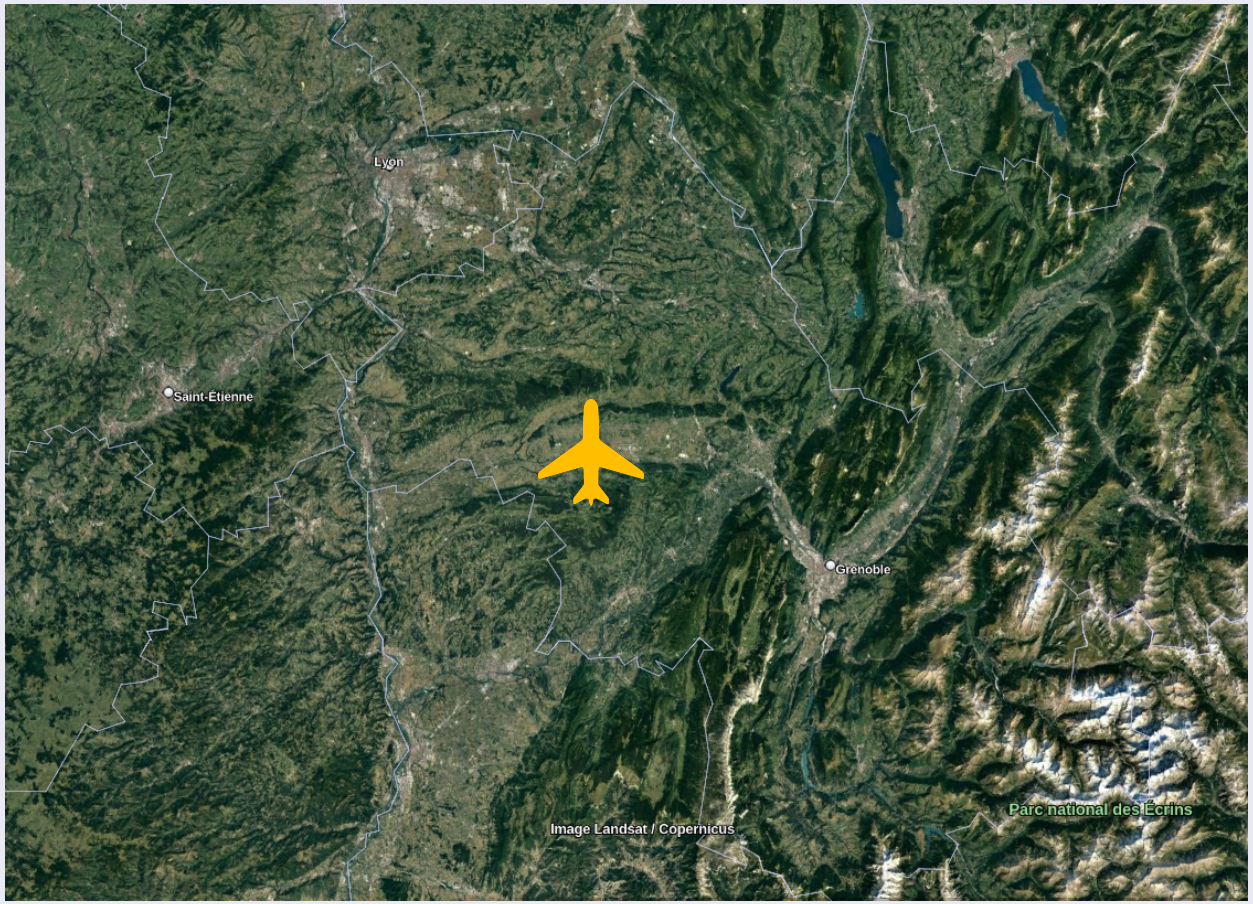
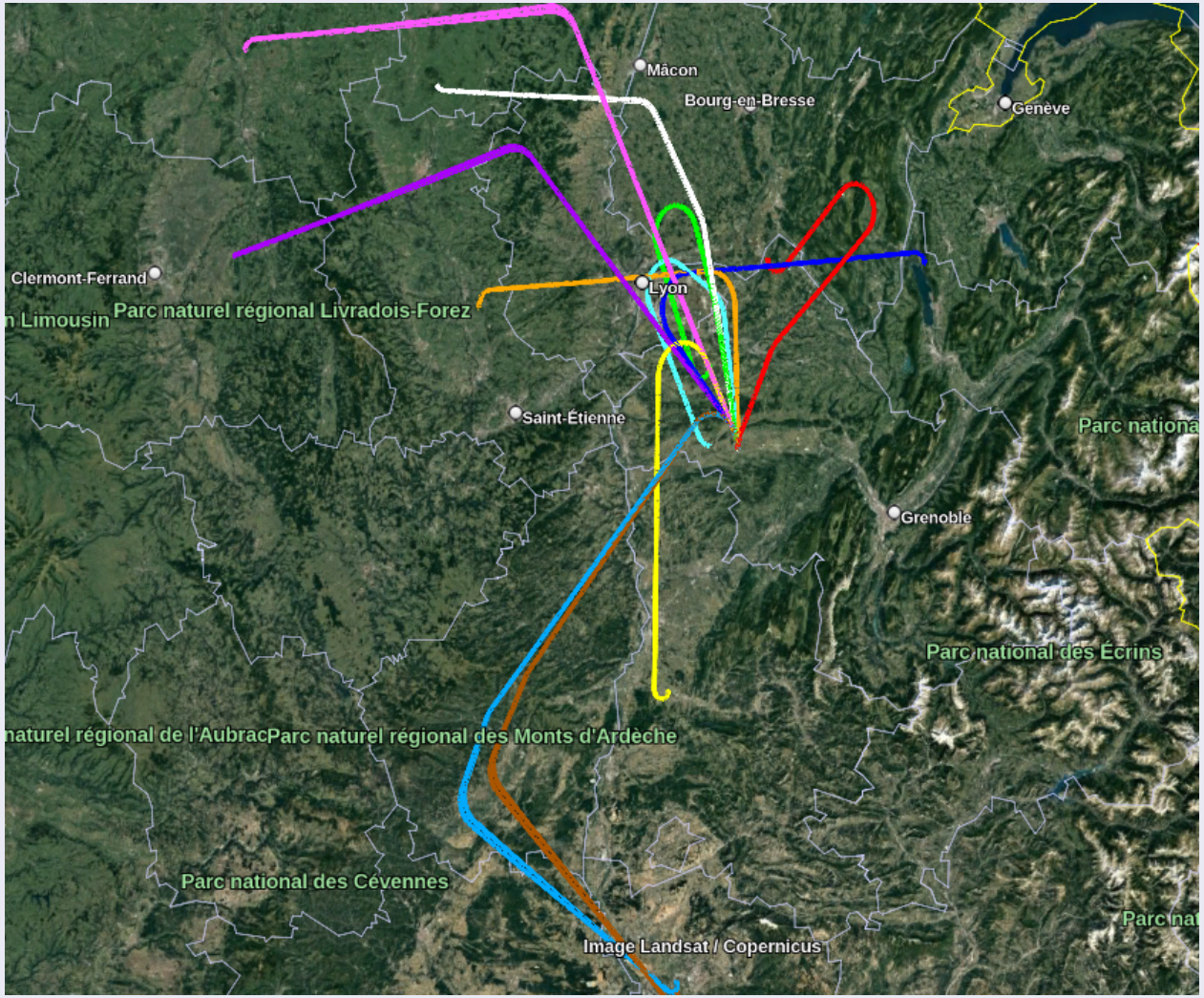


Figure – Emergency declared near to Grenoble at an altitude of 32000ft

Results

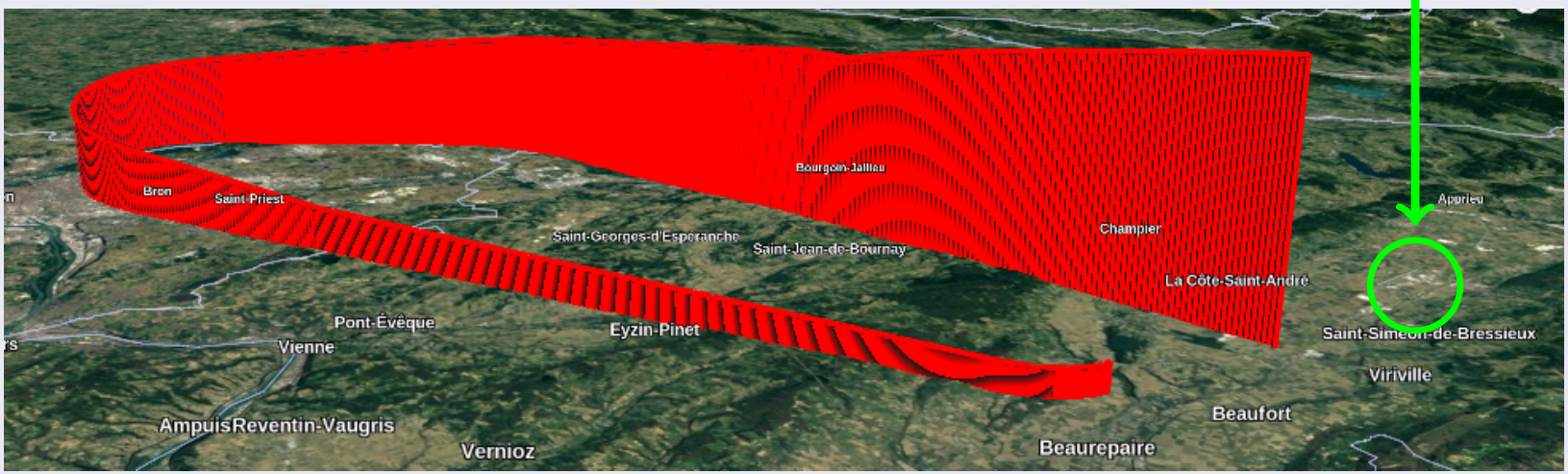
As Soon As Possible (ASAP)



Results

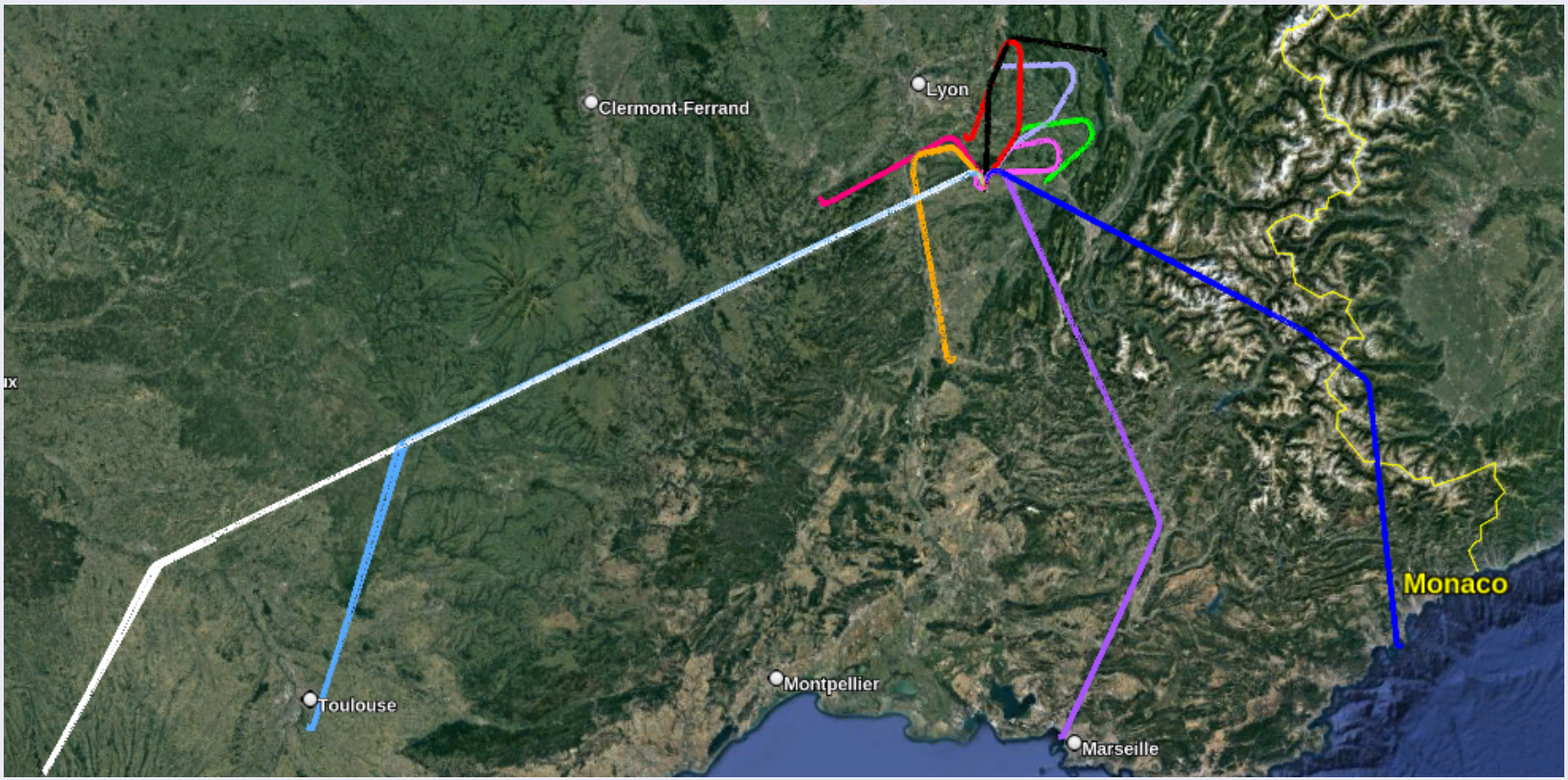
Vertical Profile (ASAP)

Grenoble airport



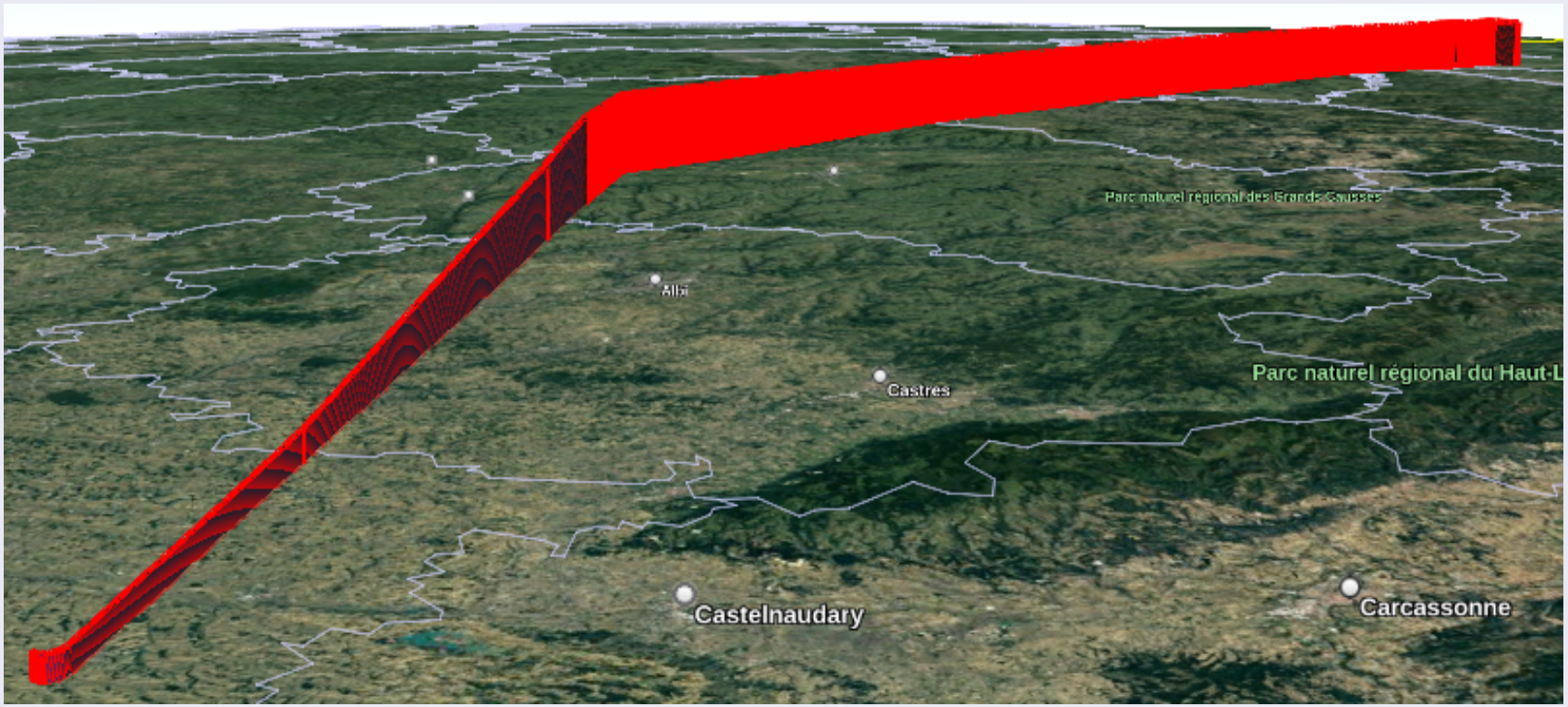
Results

At Nearest Suitable Airport (ANSA))



Results

Vertical Profile (ANSA)



Results

Computing time

Emergency type	ASAP	ANSA
Computing time (s)	10	15

Table – Computing time in seconds to generate 10 trajectories

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Conclusions and Perspectives

Conclusions

- Emergency $\Rightarrow$ huge workload for pilots
- $\Rightarrow$ new DST
- Efficient algorithm has been proposed
- Extended with a landing sites selector (Clean Sky project : Safency)

Perspectives

- Real case tests
- UAV
- SID-STAR design

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Questions ?

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