Decision Aid Methodologies In Transportation
Lecture 6: Case Study

Case study: Air Navigation Planning

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Air Navigation Problem

UAV is any aircraft flown without a pilot. Unmanned Aerial Vehicles (UAV) refers to the types of aircrafts that do not carry a human operator and is a cheaper and more capable alternative to the aircrafts that could avoid risk to aircrews.

rt.com

Application-Military

The UAS (Unmanned Aircraft Systems) provide aerial imagery of a search area with the advantage of quick systematically coverage of large areas, access of hard-to-reach or dangerous areas, and lower cost than manned aircrafts. Once the persons are located, the UAS can guide rescue workers to the victims. This helps focus the efforts on the rescue operation instead of the search operation, which can be substantial. Being unmanned they can also operate in dangerous environments such as more severe weather conditions, or environments contaminated by chemical, biological, or nuclear materials.

Their many different applications make for great headlines they are being used for military purposes in Pakistan (US Army), for development aid work in Africa (Matternet).

Andreas Raptopoulos TED Talk:
https://www.ted.com/talks/andreas_raptopoulos_no_roads_there_s_a_drone_for_that?language=en#t-6672

www.unmanned.co.uk

Applications-Retail

German logistics company DHL will launch trials of its ‘parcelcopter’, the first service in Europe authorised to use drones for delivery of goods.

The 5kg quadcopter can carry parcels up to the weight of 1.2kg and reach the maximum speed of 65km/h, covering the distance from 15 to 30 minutes depending on weather conditions.
Although the parcelcopter’s flights will be completely automated, the control teams based on the mainland will be carefully monitoring the whole process.

25 September 2014
By Tereza Pultarova

Applications-Energy

This can be due to the vast size of energy sites (mining), the scale of the infrastructure (power lines, pipelines), or the challenging environment (offshore wind parks).
UAVs can be operated more economically than manned helicopters; they are less limited by weather conditions.
They can be operated in extreme weather conditions and in geographically challenging locations without putting personnel at risk. UAVs can follow a preprogrammed flight path, and fly closer to both the infrastructure and the ground. This allows for highly detailed flight plans, higher measurement accuracy, and increased repeatability.

Inspection of offshore wind power plants in the North Sea; **Source:** Blog Zeit

Applications-Agriculture and Forestry

They allow farmers to gather real-time data on crops, detect irregularities as early as possible, and take better decisions about using fertilizers, herbicides, and pesticides. In forestry, an example of how to use unmanned aerial systems is spotting and mapping forest fires

UAV application in forestry; **Source:** Avinc

Applications- Environmental Protection

UAVs can play a vital role in environmental protection; for example, in the safeguarding of an endangered species. Animal tracking is another task well suited to the capabilities of UAVs. Already, conservation parks and private game reserves in South Africa are using unmanned flying systems to protect endangered rhinos from poachers.

Use of UAVs for environmental purposes; **Source:** Avinc

Applications- Emergency

A double blow of natural disasters hit Fukushima in 2011: The strongest earthquake in Japanese history followed by a tsunami which claimed the lives of more than 15,000 people and a whole region devastated. A big problem in the aftermath of natural disasters is that decision makers often lack information on which to base their decisions. In Fukushima, this was exacerbated by radioactivity leaking from damaged reactors, putting every human being who entered the power plant area at high risk of radioactive contamination.

Police applications of UAVs; **Sources:** Telegraph, Falcon-UAV

Obstacles for using UAS (UAV)s for retail

1- **Traffic**: For now, most UAVs operate outside controlled or restricted airspace, and this minimizes interference with other airspace users. But if UAV operations are to become widespread in logistics and other industries, integration will be essential. UAVs will be operating in all types of airspace and sharing this with airplanes, helicopters, and other flying systems. Airspace is already overcrowded in many regions, especially around major cities, and air traffic control operations typically work near to maximum capability.

Air traffic at 09:30 am in Western Europe
Source: Flightradar24

Obstacles for using UAS (UAV)s for retail

2- **Security:** While trains, boats, and to a lesser extent cars follow restricted pathways, UAVs can move anywhere and everywhere. And because they are airborne, failure of a vital system (e.g., the engine or navigation system) could cause the UAV to fall from the sky at any time and place. However, the chance of a system crashing into pedestrians is highly unlikely, even with today's early UAV designs.

Source: Youtube.com

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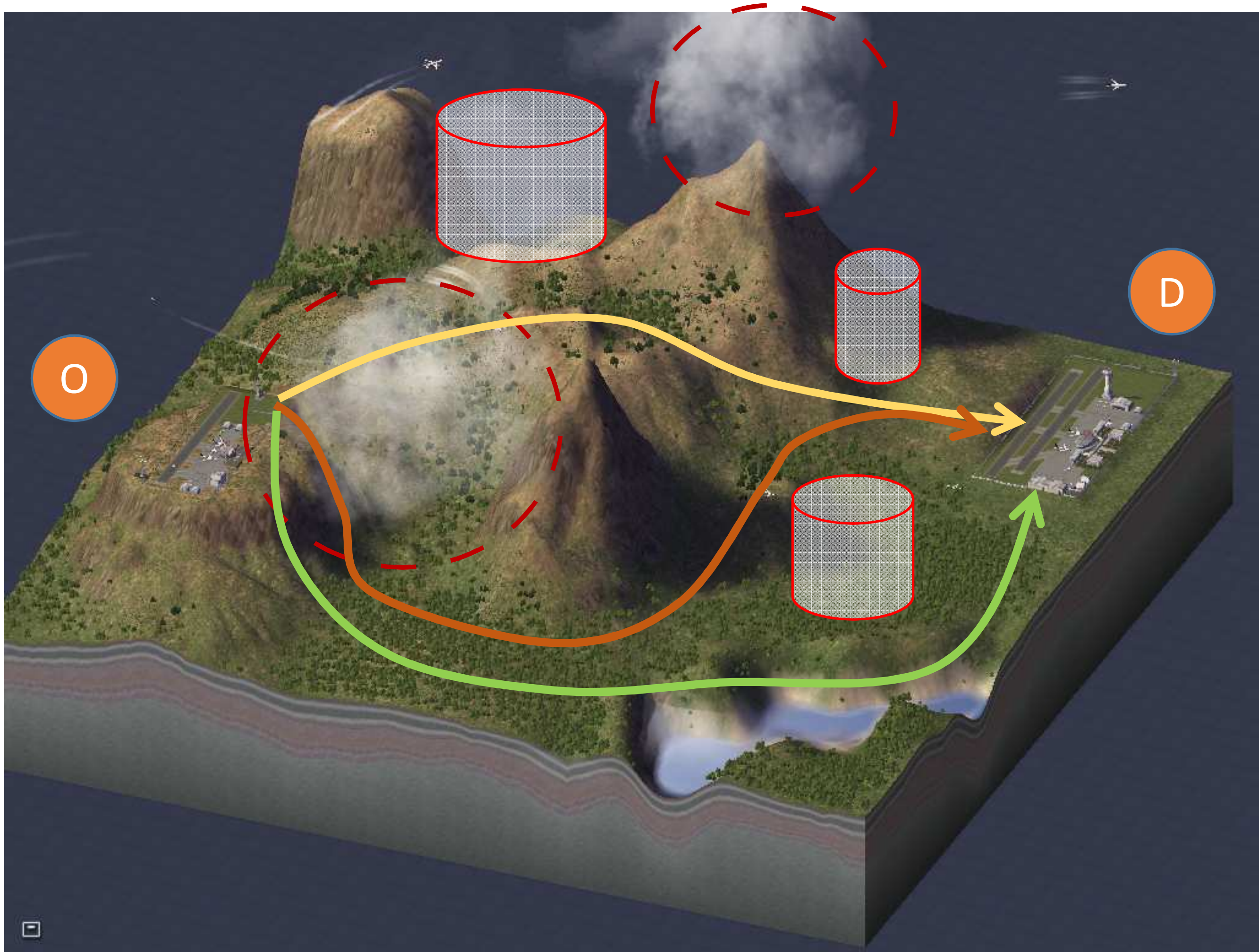
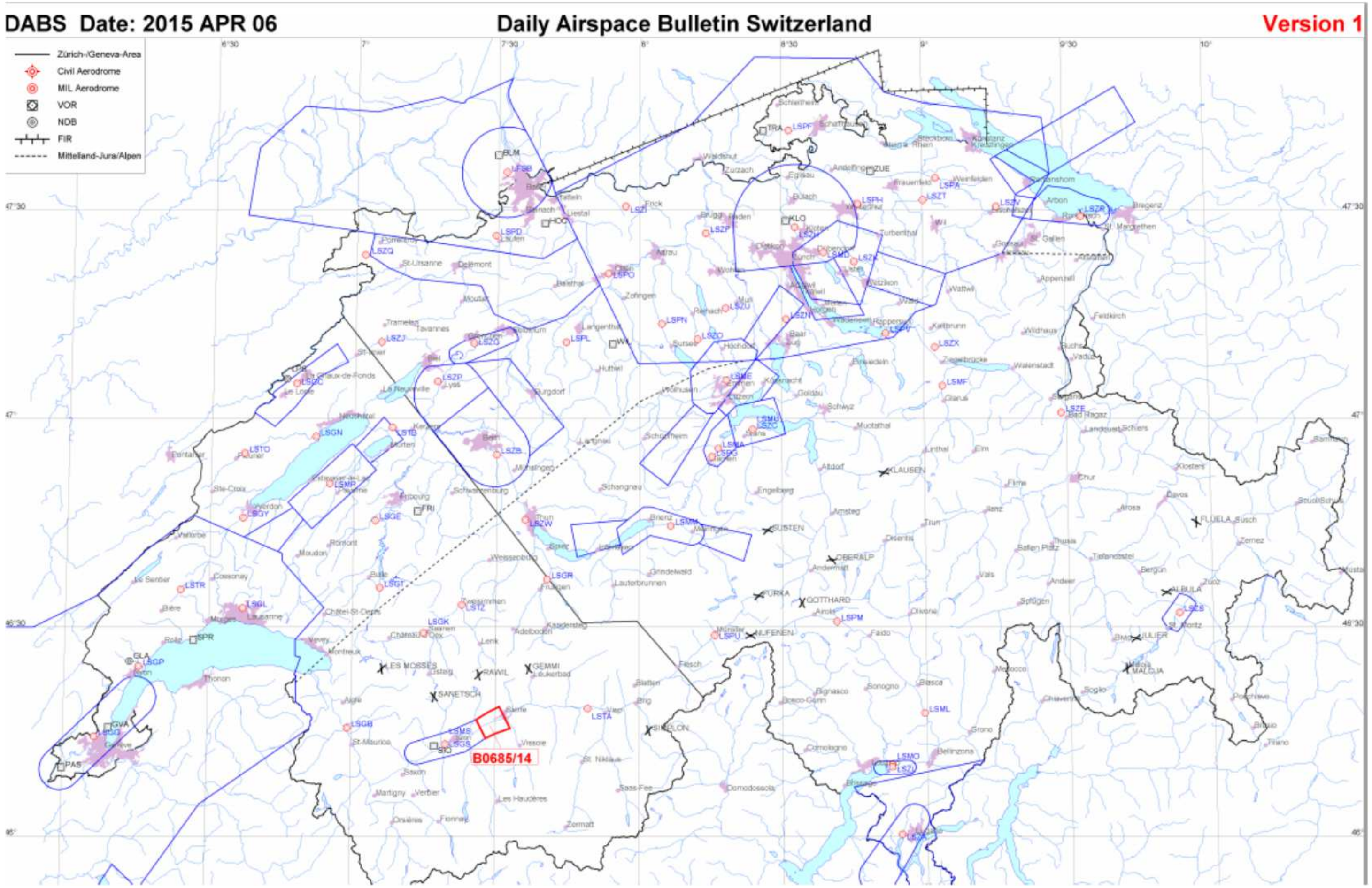
Air Navigation-Path finding

Clouds

Airspace

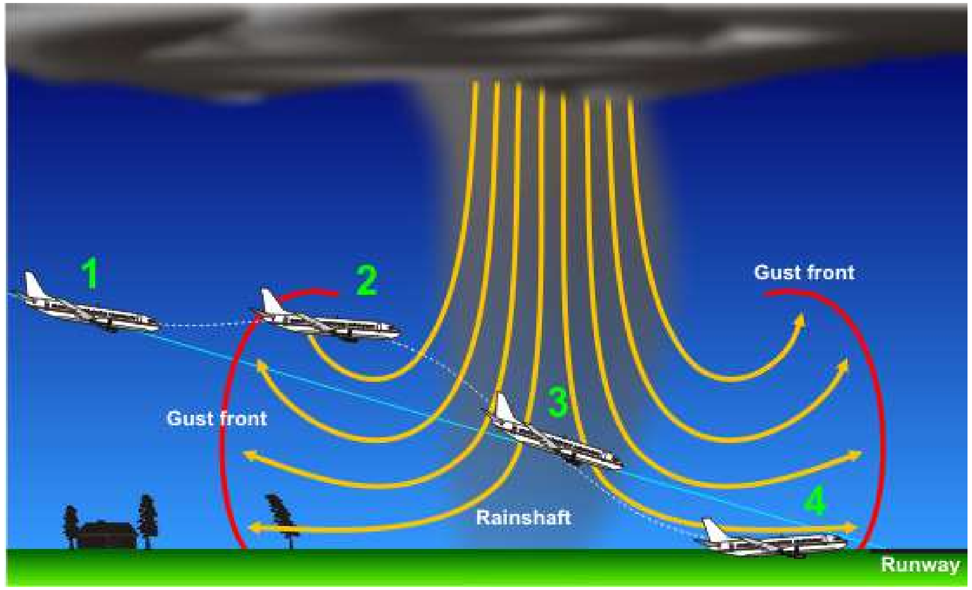


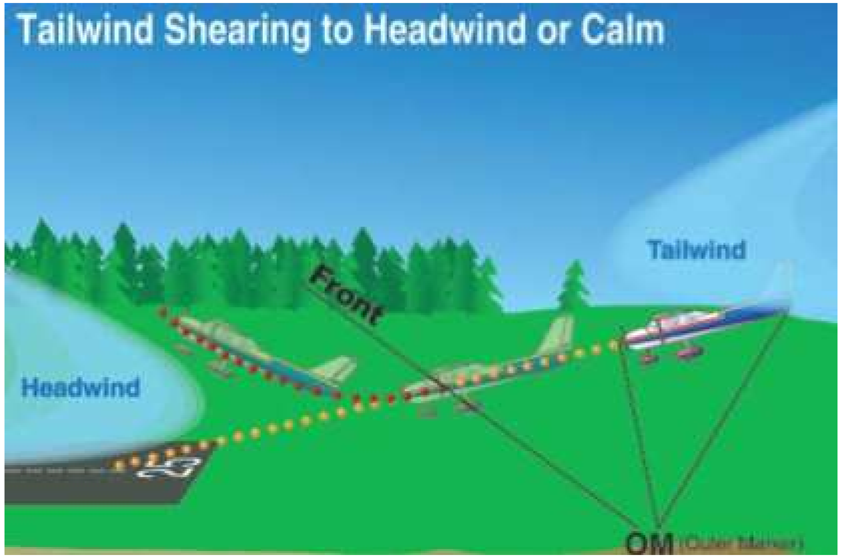
Constraints-Airspaces (different classes)



Constraints-Elevation

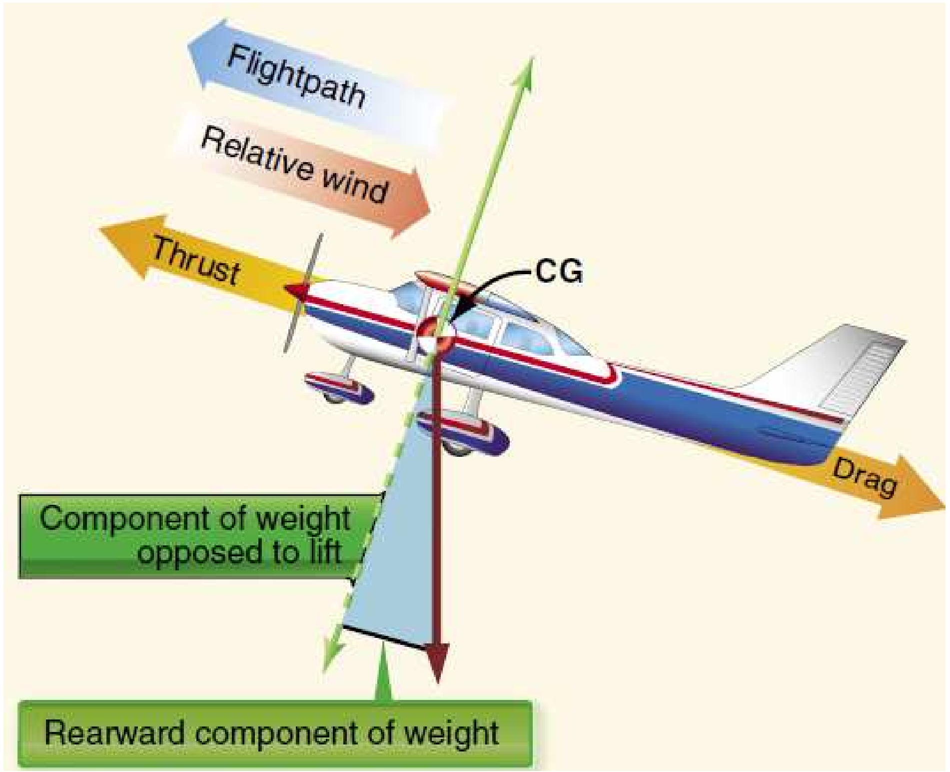
Constraints-Storm





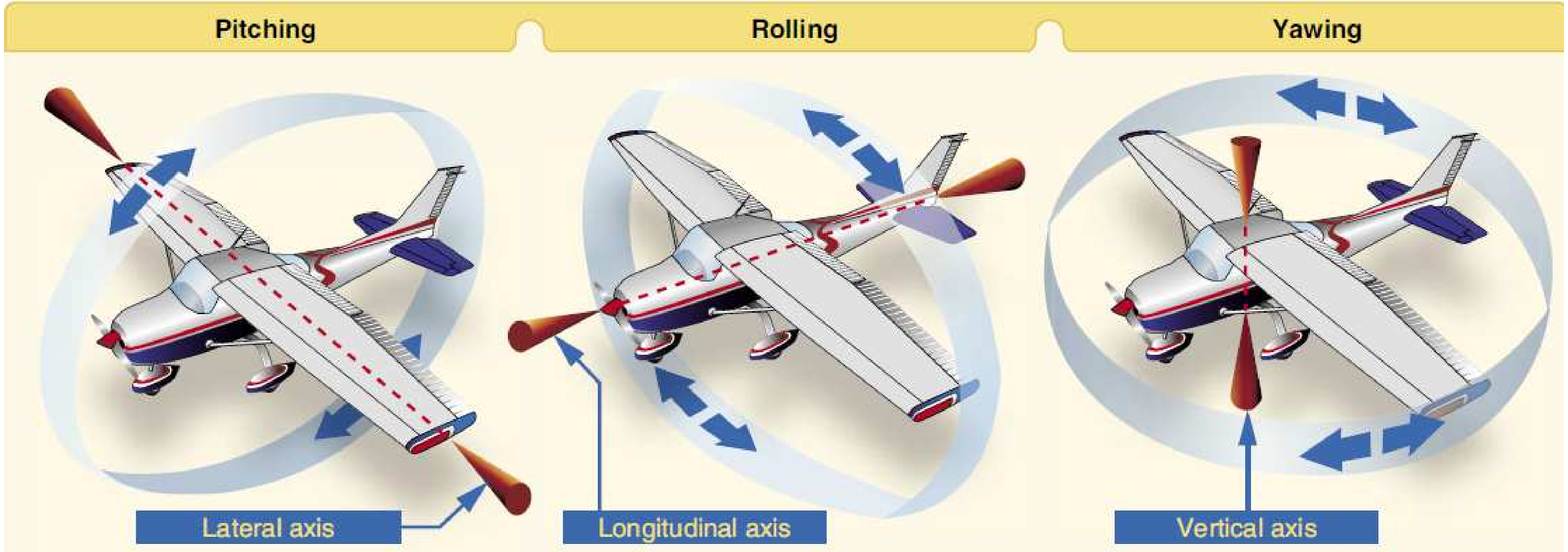
http://www.srh.noaa.gov/jetstream/tstorms/wind.htm
http://www.remoteaircraft.com.au/2014/09/windshear-invisible-threat.html

Constraints-Plane aerodynamics



Force vectors during a stabilized climb

Constraints-Plane aerodynamics



Axes of an airplane

http://www.aboutflight.com/handbook-of-aeronautical-knowledge/ch-4-aerodynamics-of-flight/axes-of-an-aircraft

Model-Characteristics of small size airplanes

<u>**Objective: Traveling time**</u>

s.t. Turn angle
- Stalls
- Spins
- Velocity and speed
- Acceleration
- Aerodynamic characteristic of the plane
- Obstacle avoidance
- Elevation
- Storm

<u>Decision variables:</u>

t: Traveling time

$\dot{x}(t), \dot{y}(t)$: Airplane position at time t

$v(t)$: Airplane speed at time t

$a(t)$: Accerelation at time t

$x(t)$: Position at time t

Characteristics of small size airplanes-Example

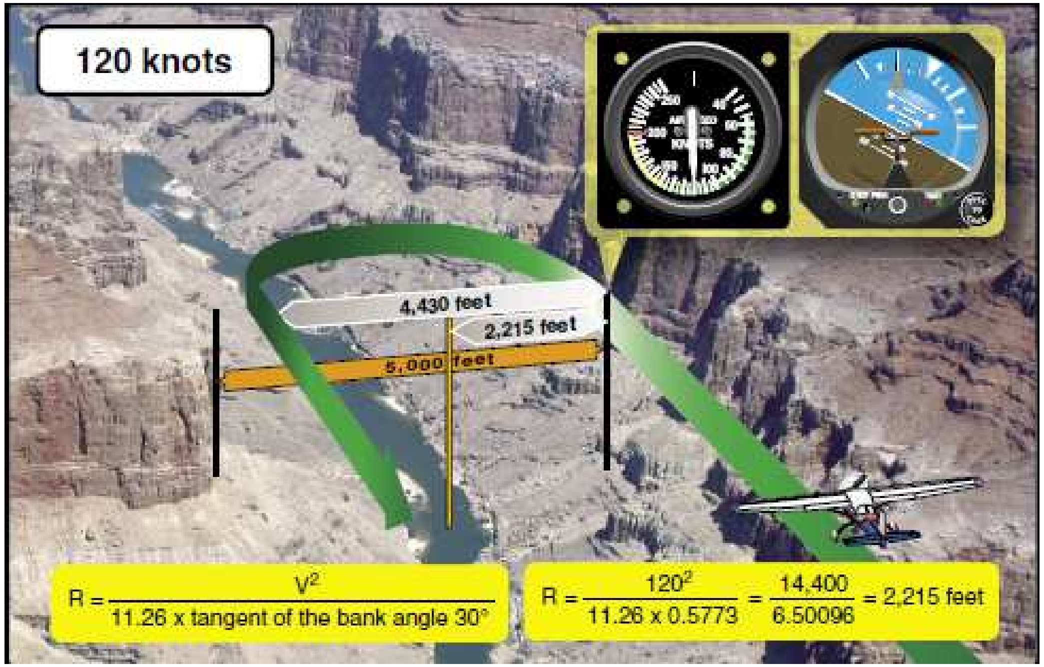
Radius of turn:

If the bank angle is held constant and the airspeed is increased, the radius of the turn changes (increases). A higher airspeed causes the aircraft to travel through a longer arc due to a greater speed. An aircraft traveling at 120 knots is able to turn a 360° circle in a tighter radius than an aircraft traveling at 240 knots. In order to compensate for the increase in airspeed, the bank angle would need to be increased.
The radius of turn (R) can be computed using a simple formula. The radius of turn is equal to the velocity squared (V2) divided by 11.26 times the tangent of the bank angle.

$$R = \frac{V^2}{11.26 \times tangent\ of\ bank\ angle}$$

Ref: Pilot's Handbook of Aeronautical Knowledge: FAA-H-8083-25A

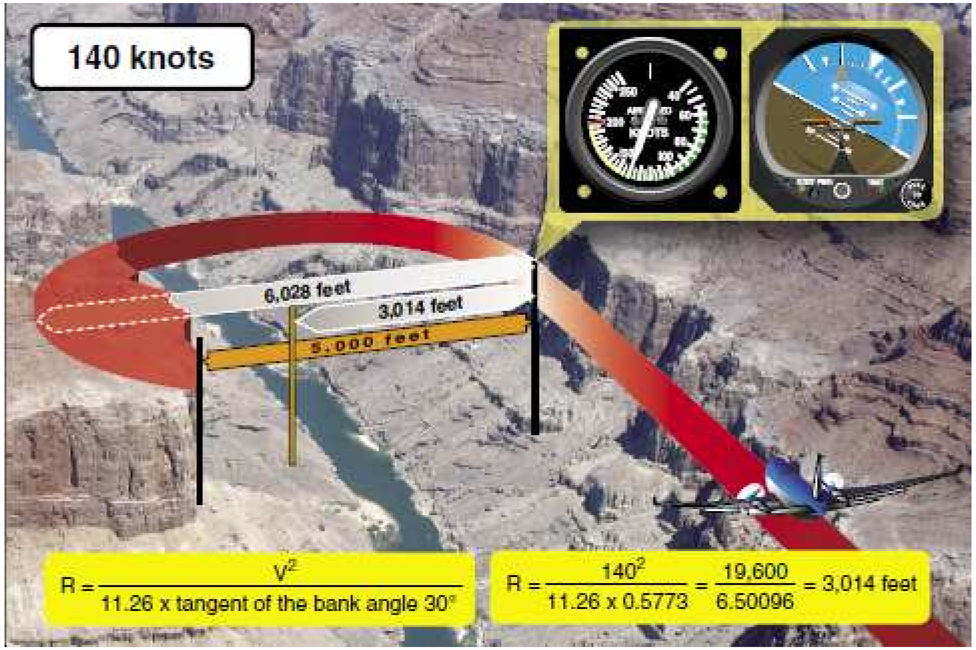
Characteristics of small size airplanes-Example



An aircraft has flown into a canyon by error. The canyon is 5,000 feet across and has sheer cliffs on both sides. The pilot in the image is flying at 120 knots. After realizing the error, the pilot banks hard and uses a 30° bank angle to reverse course.

This aircraft requires about 4,000 feet to turn 180° and makes it out of the canyon safely.

Characteristics of small size airplanes-Example



The pilot in the image is flying at 140 knots and also uses a 30° angle of bank in an attempt to reverse course. The aircraft, although flying just 20 knots faster than the aircraft in the previous image, requires over 6,000 feet to reverse course to safety. Unfortunately, the canyon is only 5,000 feet across and the aircraft will hit the canyon wall. The point is that airspeed is the most influential factor in determining how much distance is required to turn. Many pilots have made the error of increasing the steepness of their bank angle when a simple reduction of speed would have been more appropriate

Model

Input

- Using the information of airspace as constraints and traveling time as the objective function in 2D.
- Origin Configuration: Position (Longitude, Latitude, Altitude), Direction (Angle)
- Destination Configuration: Position (Longitude, Latitude, Altitude)

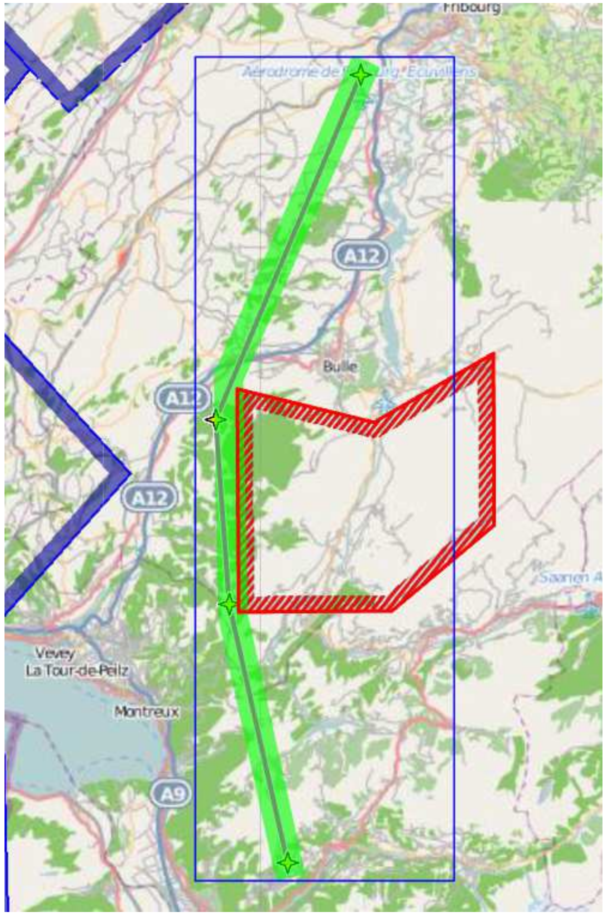
Output

The path finder modul returns the shortest itinerary (in terms of travel time) between an origin and a destination.

Path characteristics

- The path provides a near optimal solution that is competitive with the one that is drawn by experience.
- The path respects the restriction of airspaces.
- The path respects aircraft restrictions on changing directions.

Air Navigation-Path finding 2D



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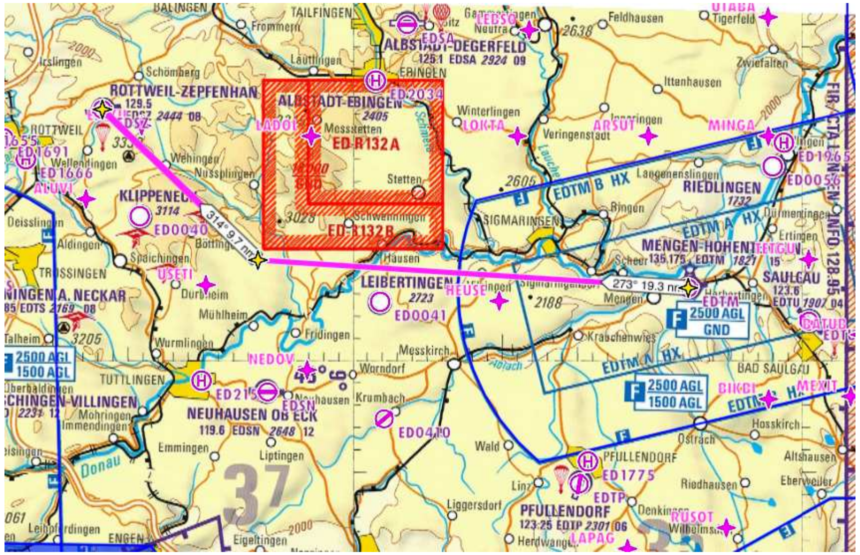
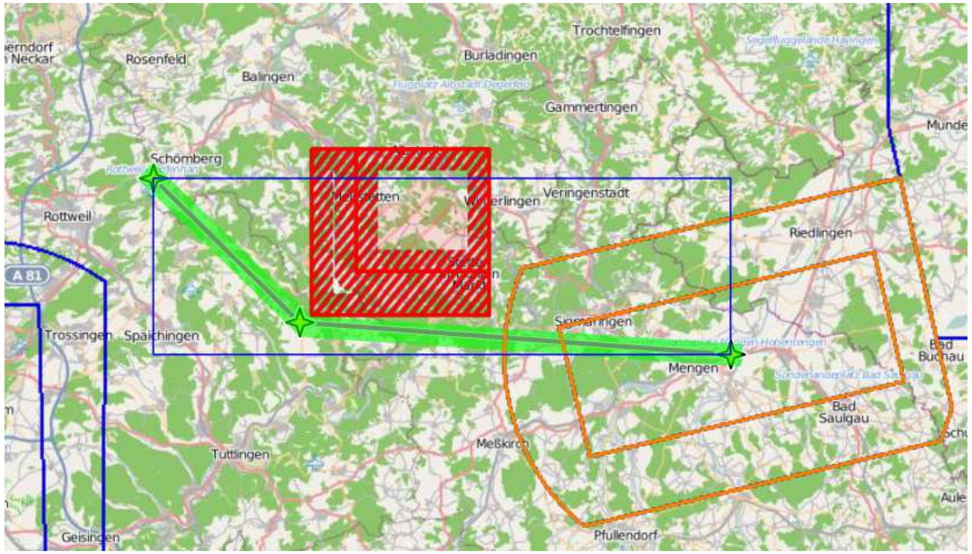
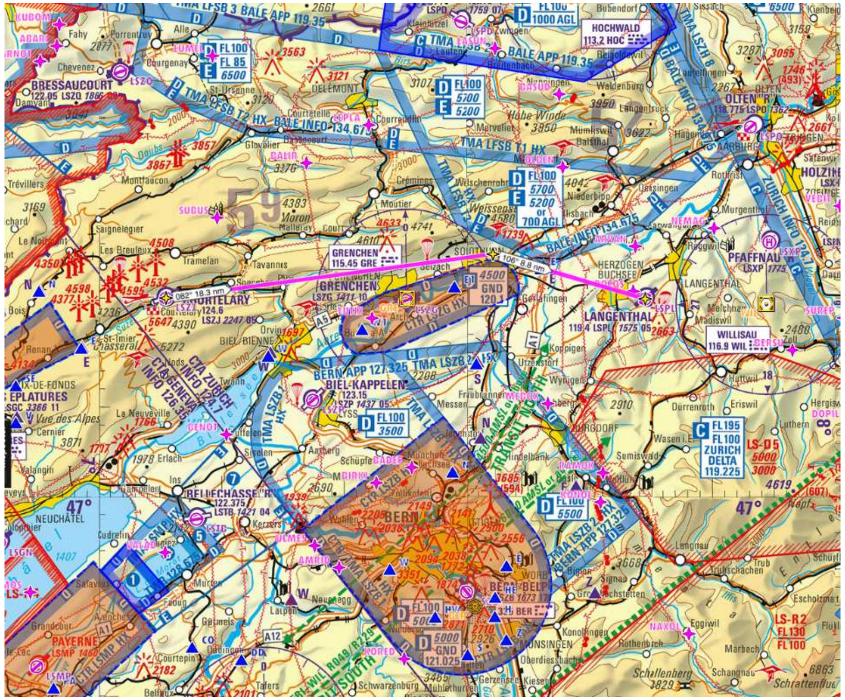
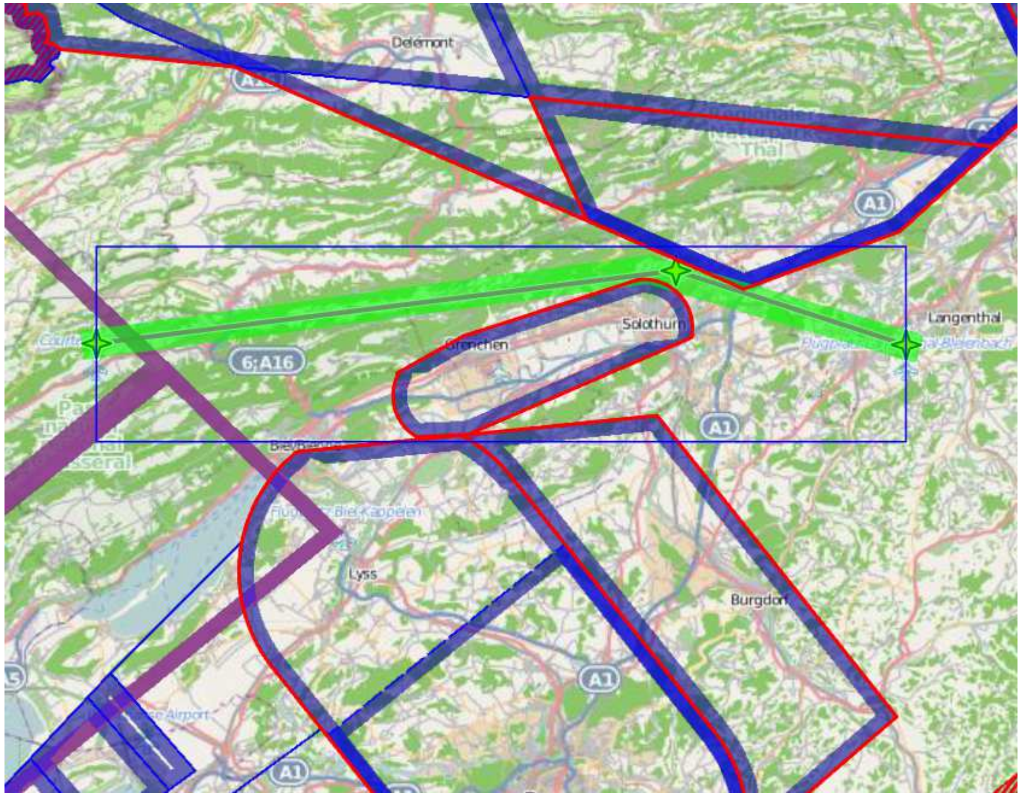
Air Navigation-Path finding 2D





Air Navigation-Path finding 2D

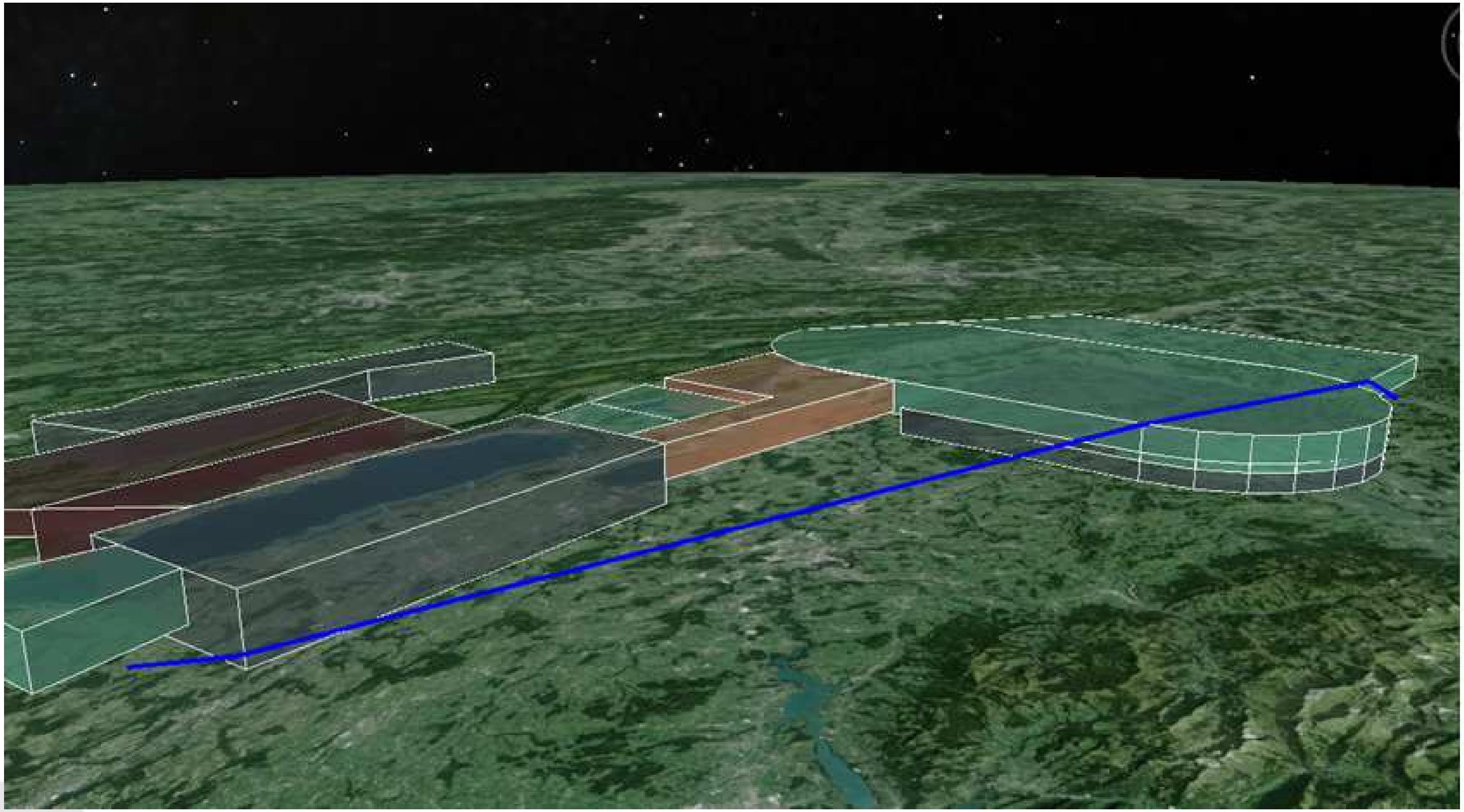




Air Navigation-Airspace 3D

Air Navigation-Elevation 3D

Air Navigation-Airspace 3D



Air Navigation-Path finding 3D