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# Aspects of Longitudinal Airflow Control in Road Tunnels

10<sup>th</sup> International Conference 'Tunnel Safety and Ventilation' 2020, Graz

# Content

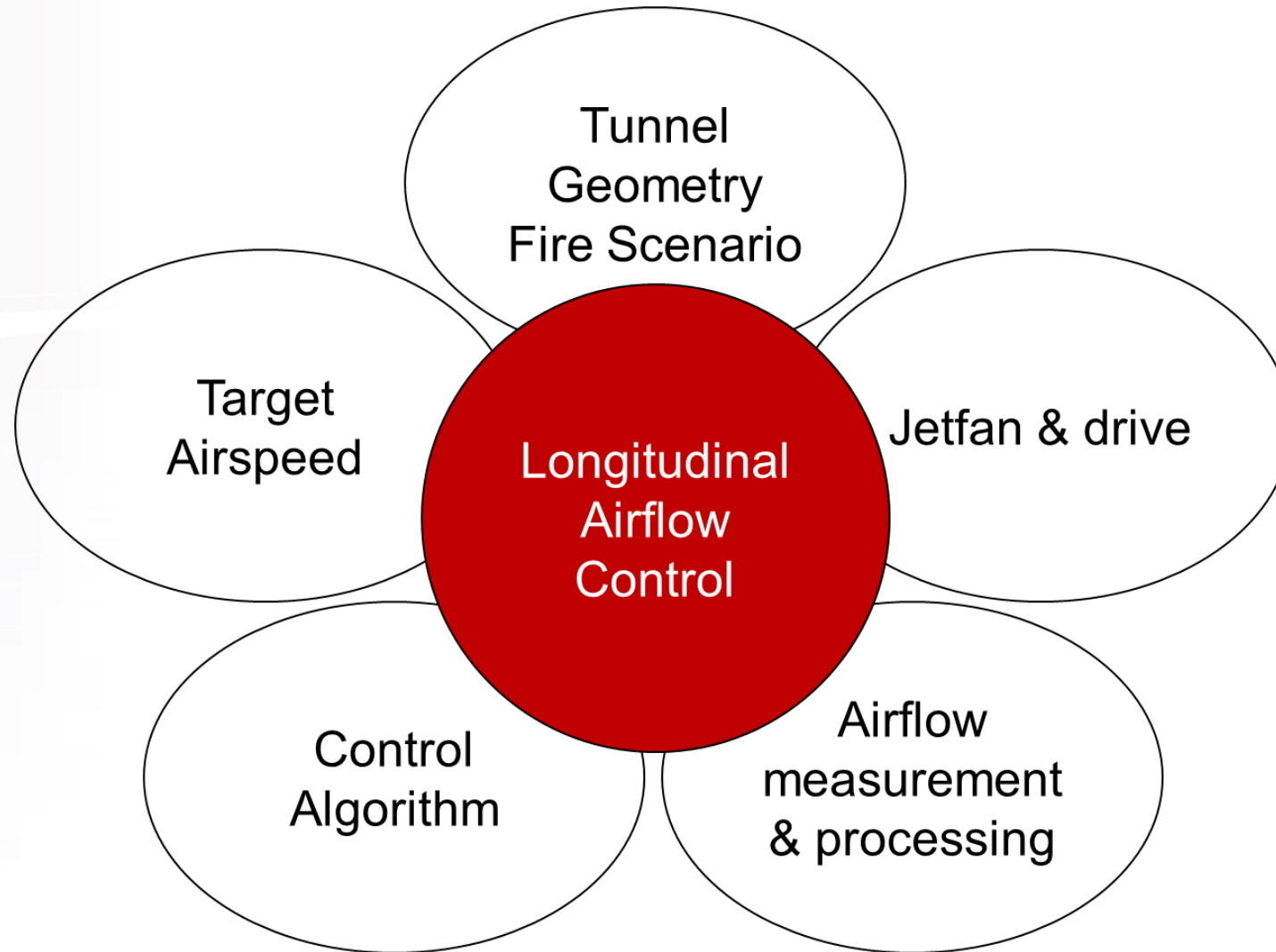


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# Introduction

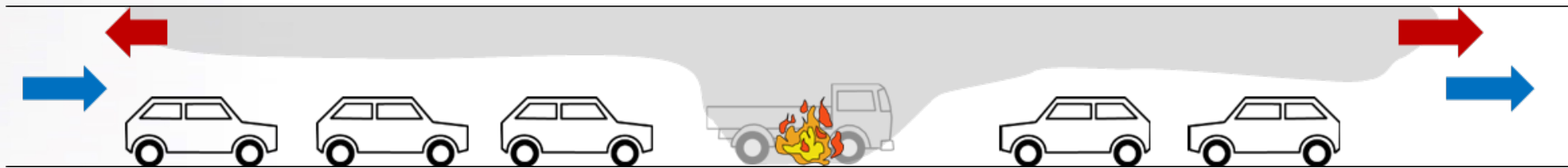
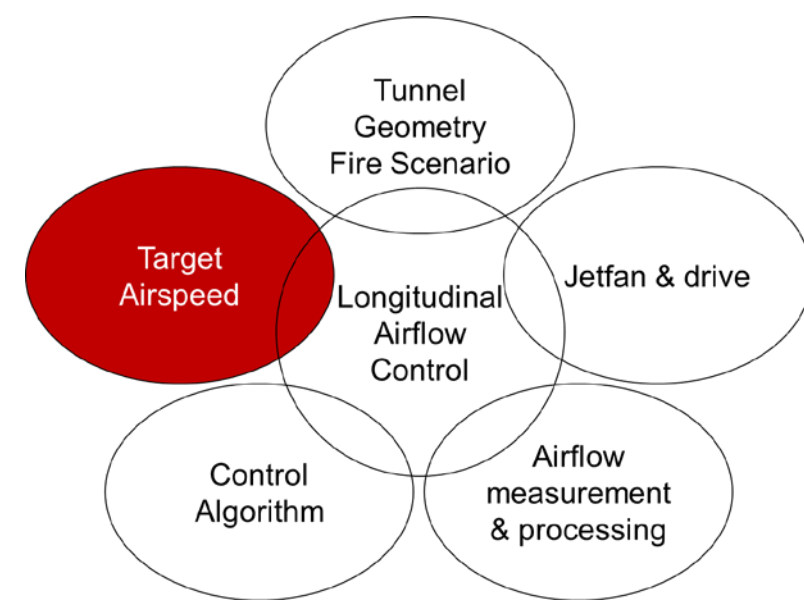
- In case of a fire incident, smoke management is crucial for the safety of the tunnel users:
  - » In tunnels with unidirectional, non congested traffic, tunnel users are only present on one side (upstream) of the fire location. To protect them from smoke, the airspeed must be superior to the critical velocity. As long as the airspeed remains moderate, no sophisticated controls are required.
  - » For bidirectional or congested traffic tunnels, users on both sides of the incident position must be protected. The longitudinal airflow needs to be kept low, even under changing conditions, i.e. longitudinal airflow control is required.

# Introduction



# Target Airspeed and Threshold

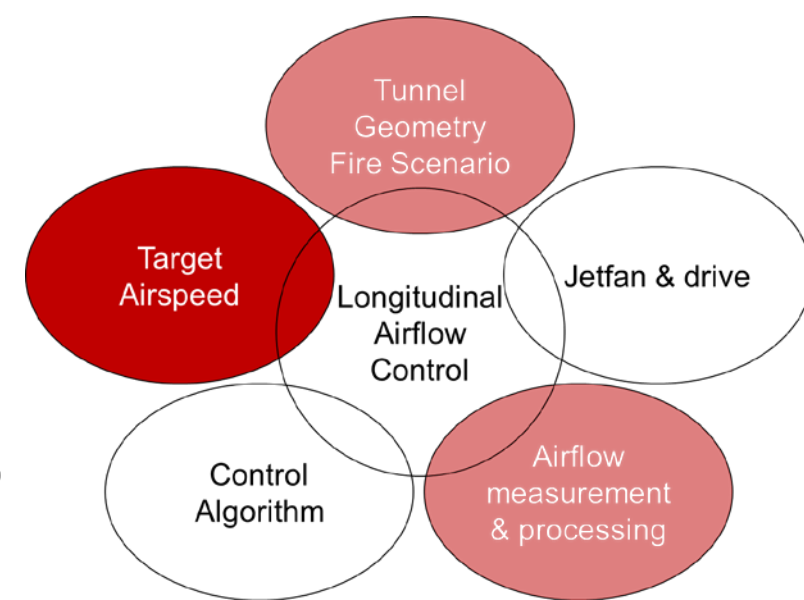
- Tunnel users on both sides of the incident must be equally protected:
  - » by limiting the backlayering "upstream"
  - » by keeping the smoke spread "downstream" slower than evacuation and to prevent de-stratification



- Values for target airspeed suggested by design codes (RVS, EABT, CETU, FEDRO) vary from 1.0 m/s up to 2.0 m/s, PIARC recommends 1.2 +/- 0.2 m/s

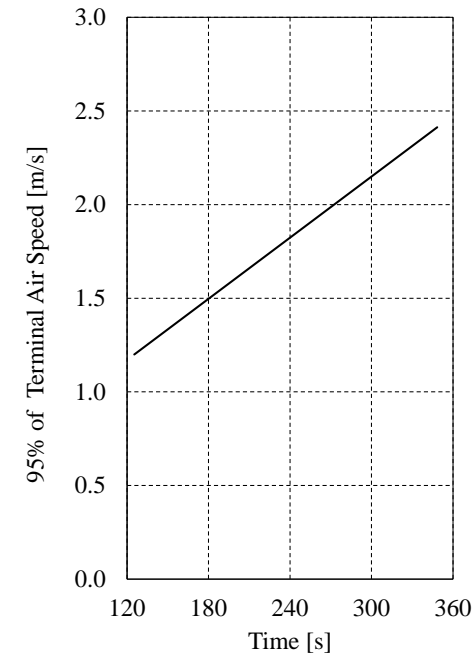
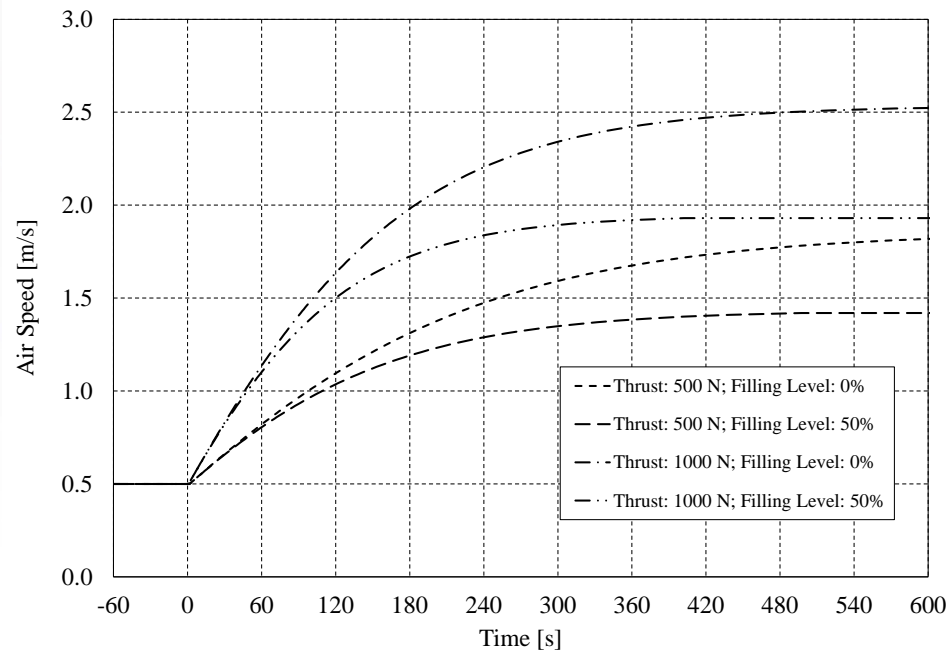
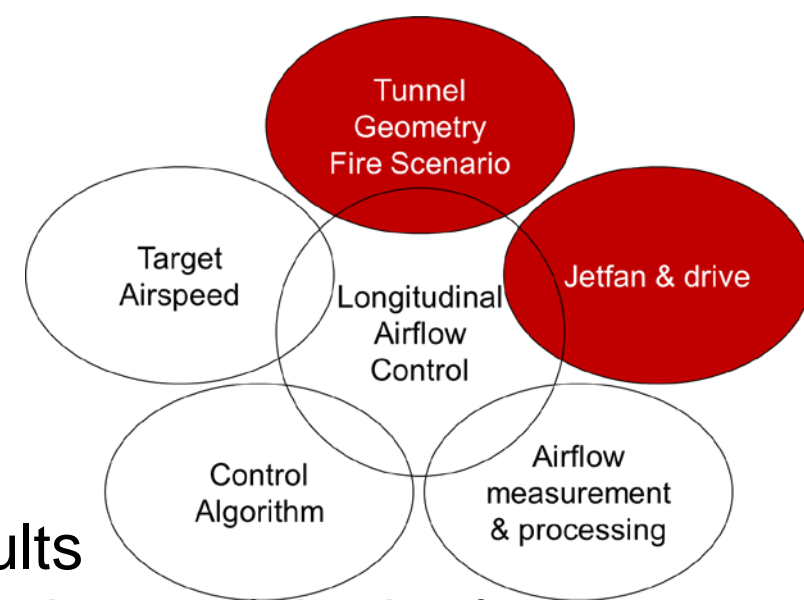
# Target Airspeed and Threshold

- When assessing the safety of tunnel users, the airflow should be :
  - »  $> 0.5$  m/s (dilution, inversion of flow direction)
  - »  $< 1.5$  m/s (egress speed, de-stratification)
- When defining the target airspeed range for longitudinal airflow control:
  - » The measurement uncertainty (at best  $\pm 0.1$  m/s)
  - » The inertia of the system and the time lag of the jet fans must be considered
- The suggested target airspeed is therefore:  $1.0 \pm 0.3$  m/s



# Modulation of airflow by jet fans

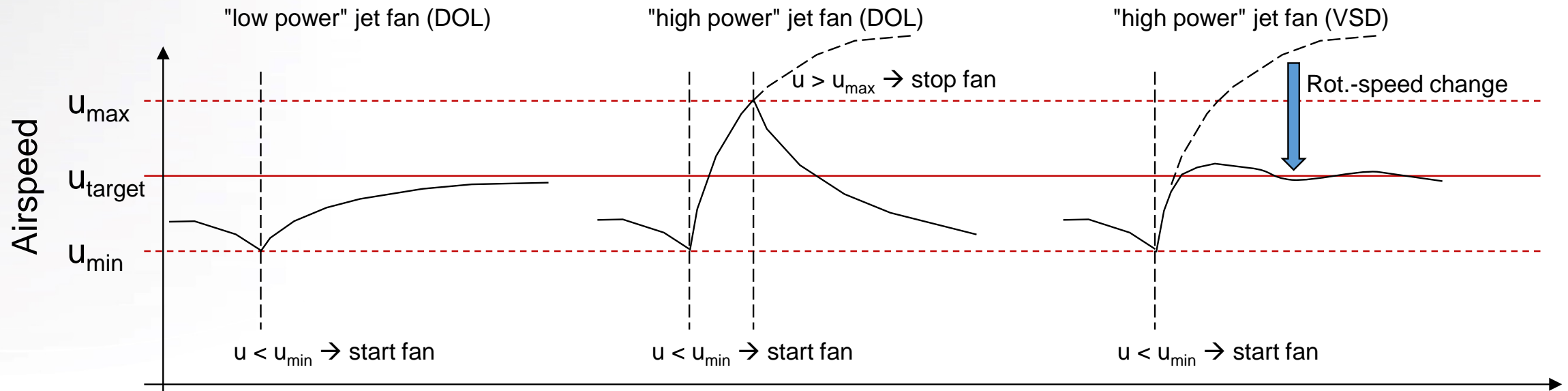
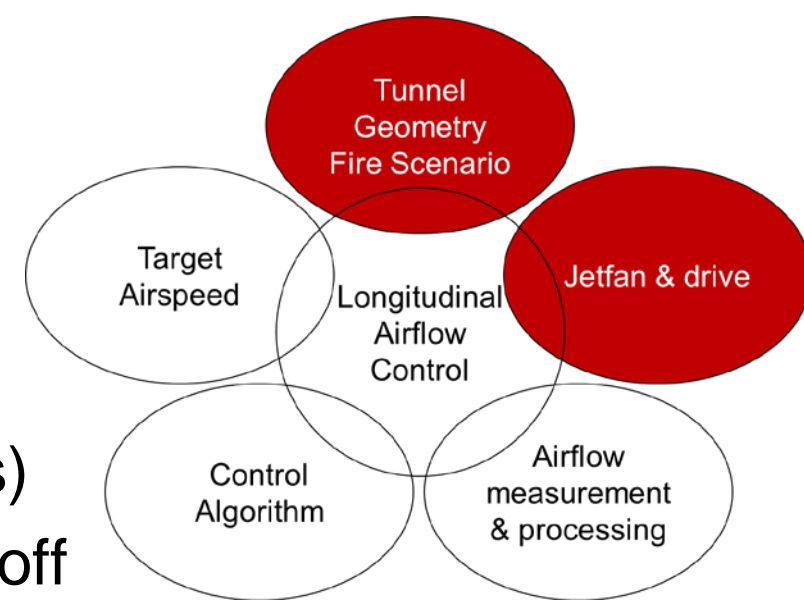
- When trying to control the airspeed, one has to know the effect of the "actuators" (jet fans)
- The change in airspeed can be calculated using different degrees of complexity whereas the results is governed by tunnel characteristics and unitary thrust of the jet fan.



# Modulation of airflow by jet fans

- For proper control:

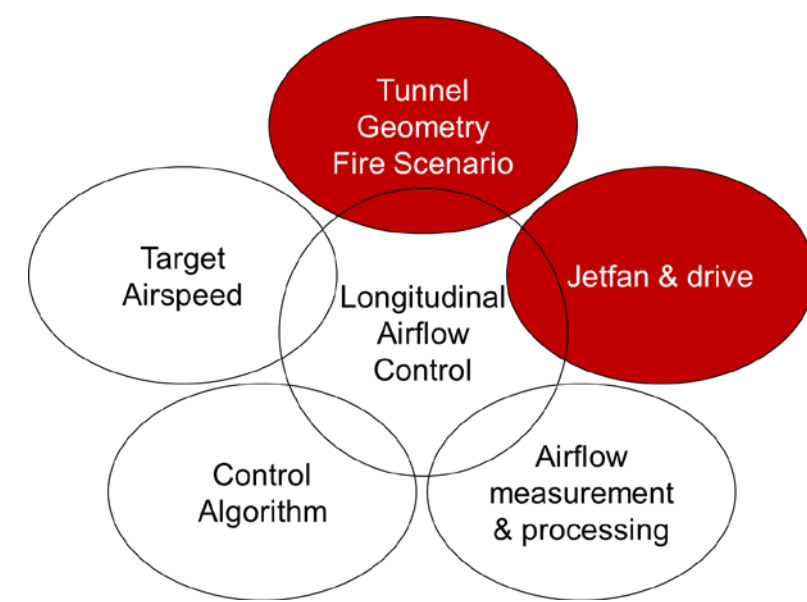
- » The effect of one jet fan must about 50% of the target airspeed range (i.e. 0.4 m/s)
- » The jet fan has to be repeatedly switched on/off
- » The thrust must be controlled by variation of rotational speed





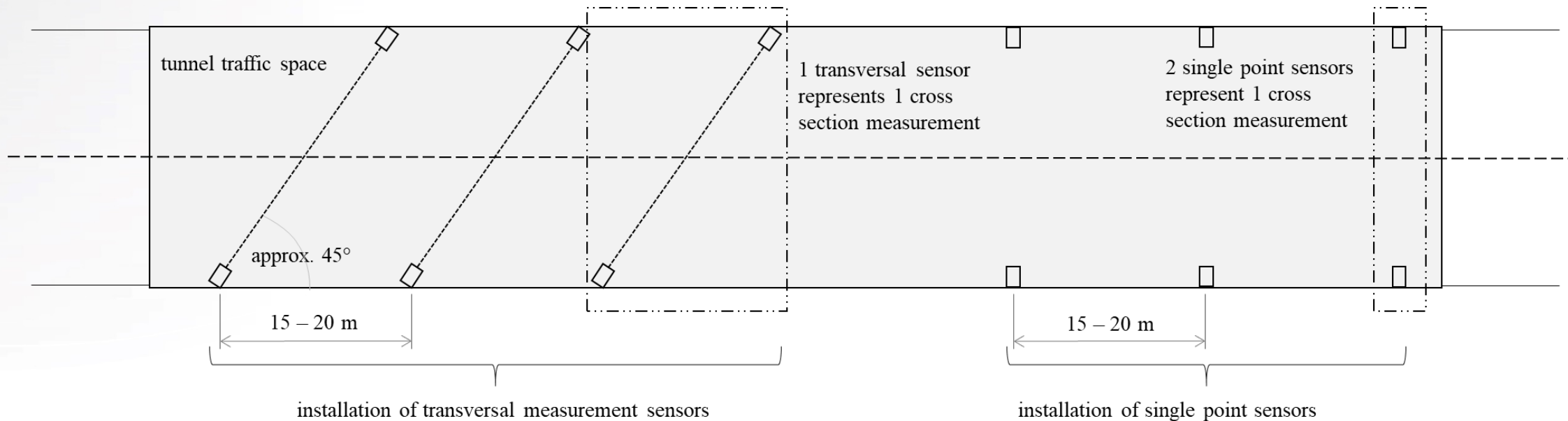
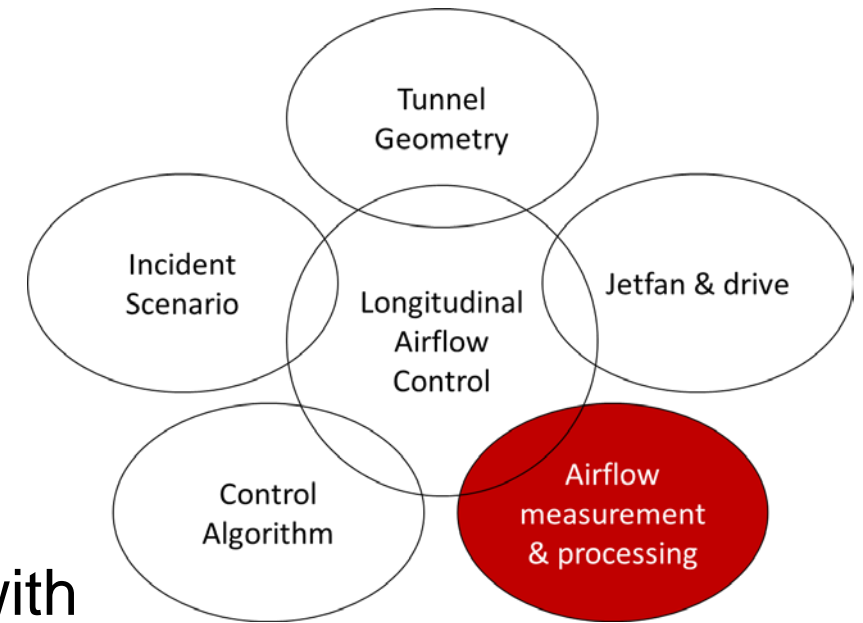
# Modulation of airflow by jet fans

- Each of the solutions has pro's and con's:
  - » Quality / speed of airflow control
  - » Technical simplicity and technical limits
  - » Space requirements
  - » Life cycle cost
- When searching for the optimal solution for a specific project, all of the above points should be considered in the design phase. The importance of the aspects may vary from project to project.



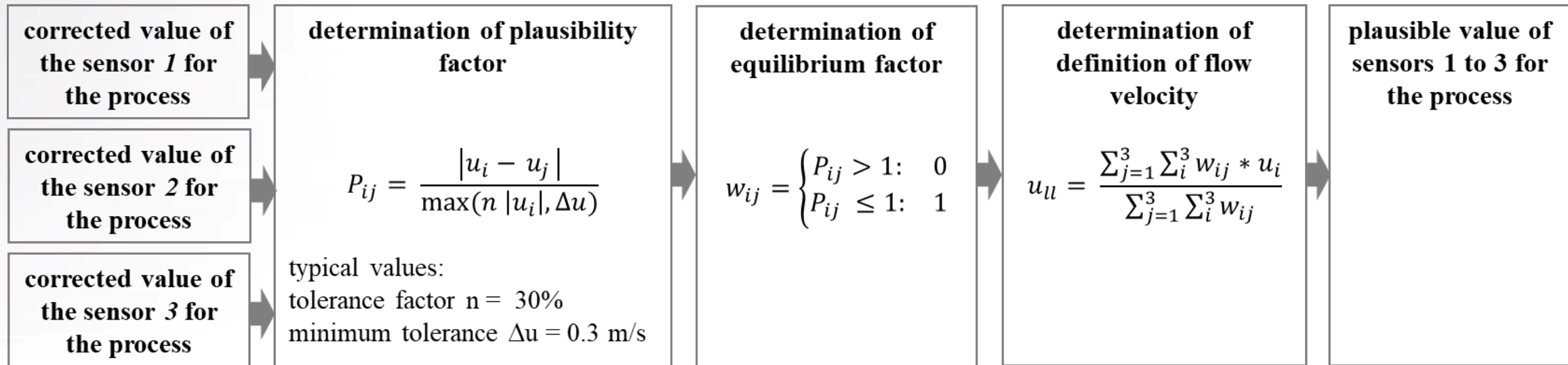
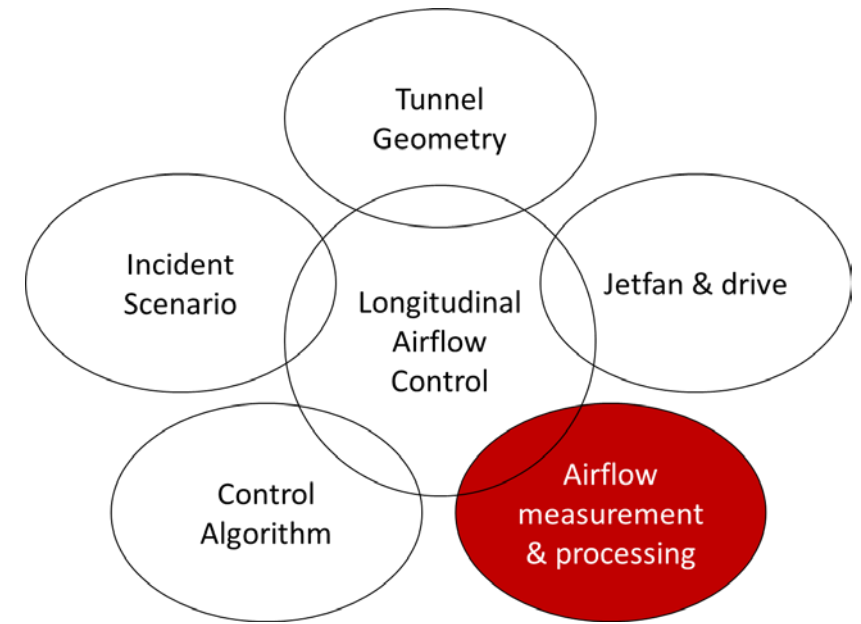
# Airflow Measurement

- Controls can only be as good as its input, so, reliable and accurate airflow information is needed. No input equals no control.
- Measurement devices have to be installed at least at two different locations, each one with three independent measurements (transverse or point-wise)



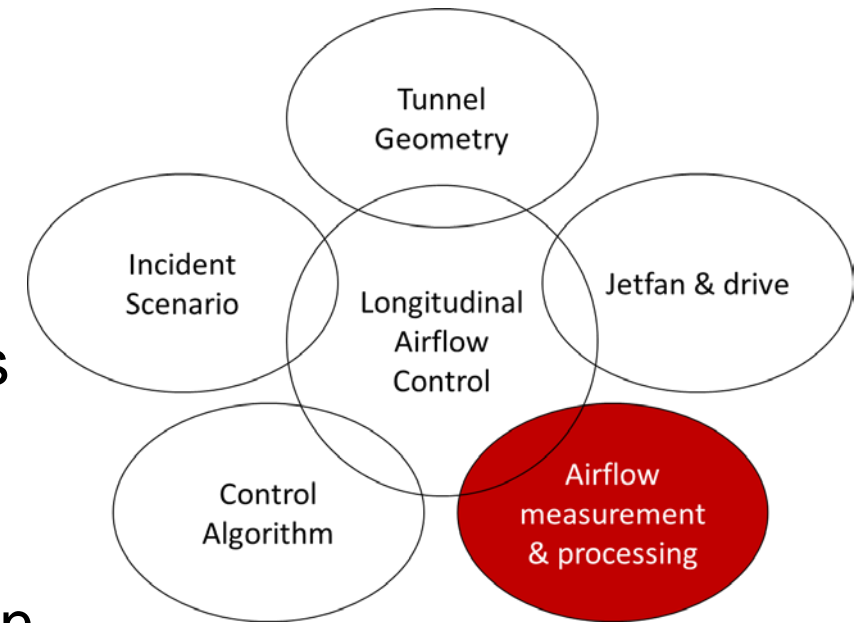
# Airflow Measurement

- The measurement data has to be processed in order to maximise its use:
  - » Time-averaging to smoothen spikes
  - » Correction for the representative flowrate
  - » Average including plausibility-check



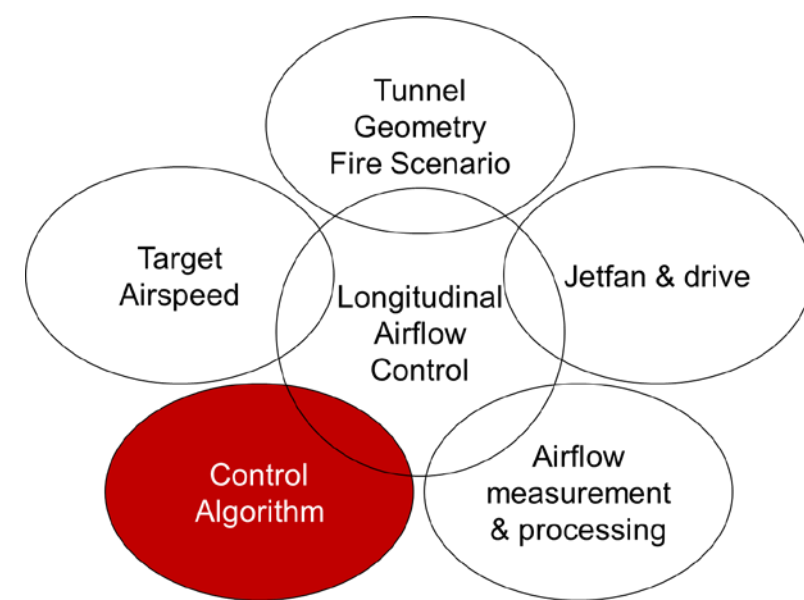
# Airflow Measurement

- Points to account for
  - » Two positions, each with 3 measurements
  - » Obstacle-free position, without influence of jet fans
  - » Proper commissioning and parametrization (correction factors, time-average)
  - » Appropriated choice of thresholds used for the plausibility check (availability of data versus accuracy)



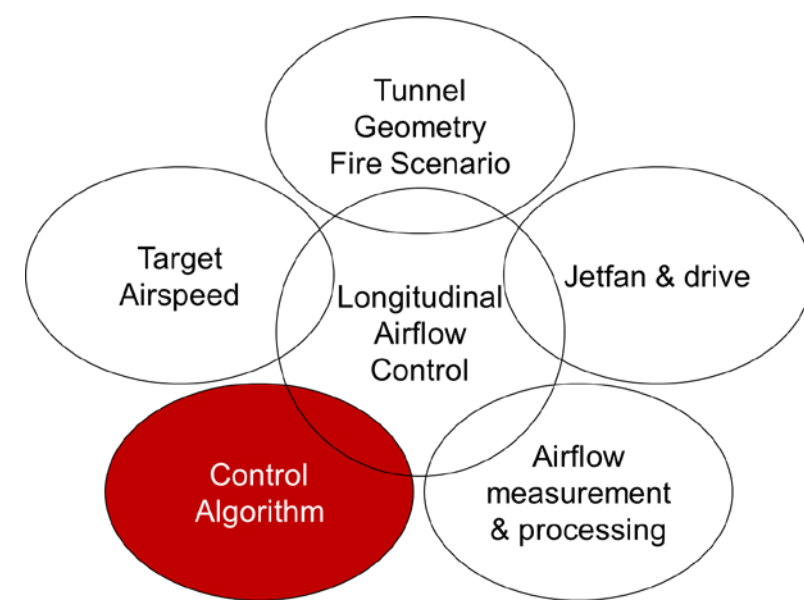
# Control Algorithm

- According to research MPC returns best results regarding performance
- PI-controllers are a widely spread standard and are still "good enough" for our purpose
- Controllers calculating the needed thrust based on the difference in airspeed are OK but less robust than PI-controllers.
- The controllers cycle time (update frequency) must account for
  - » The inertia of air (e.g. 140 tons for a 2000 m tunnel)
  - » The jet fan / drive combination (start-up delay in case of DOL, Dahlander-type motor, VSD)



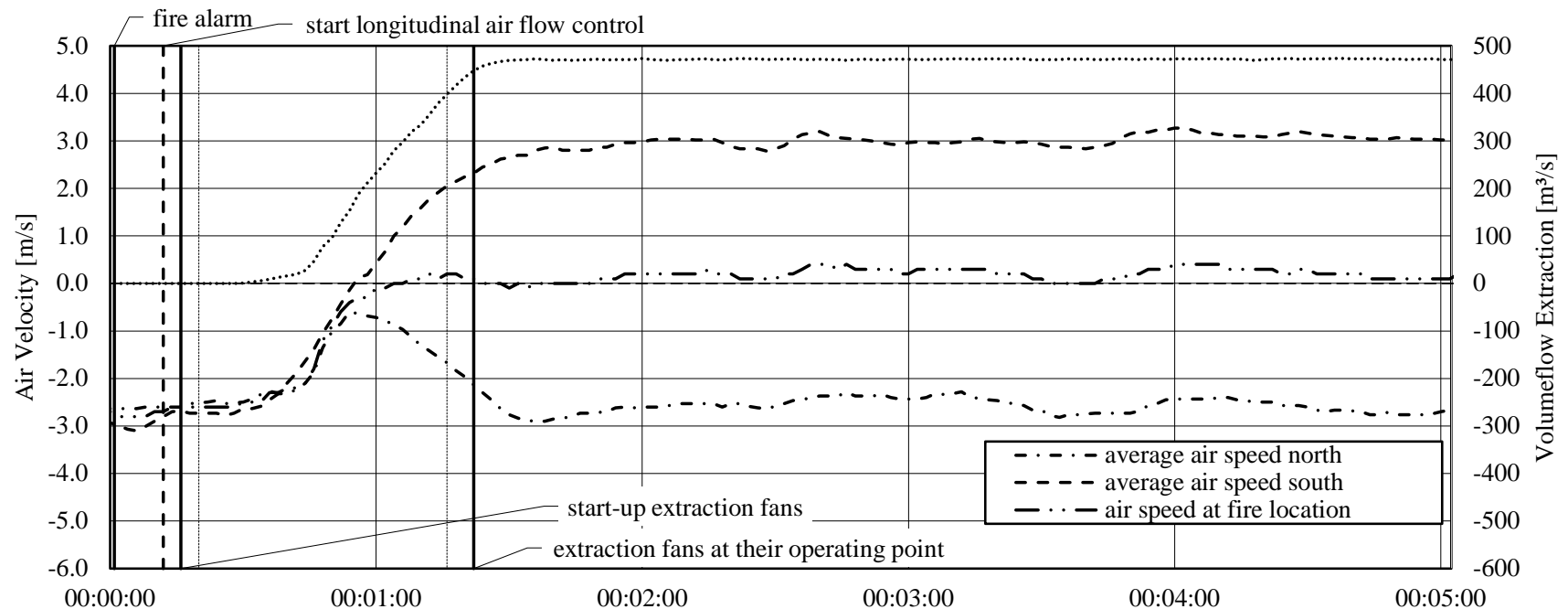
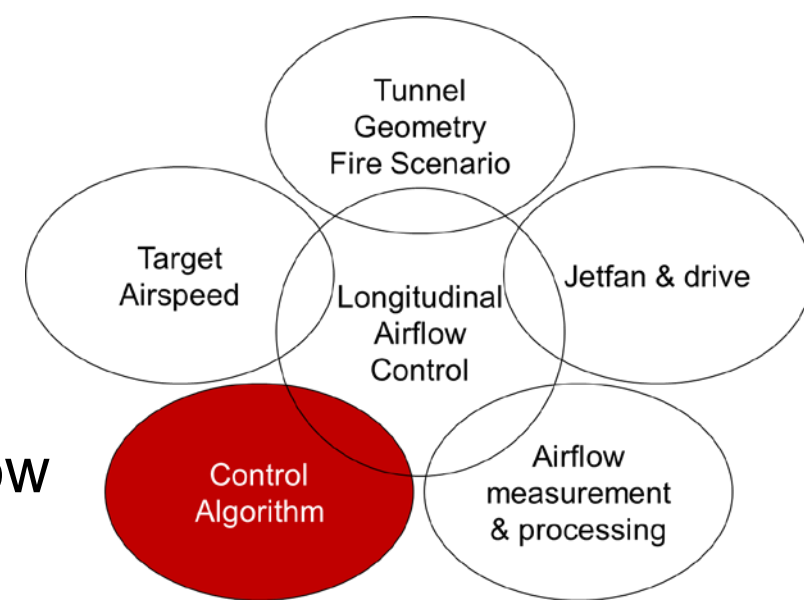
# Control Algorithm

- P and I parameters can be determined using Ziegler-Nichols method;
- Parameter tuning on site is difficult due to changes in ambient and initial conditions
- Parametrization can be optimized when using Hardware in the loop systems, simulating the tunnels (aerodynamic) response to the control systems input



# Control Algorithm

- Having a properly set-up controller as well as a suitable ventilation system:
  - » The time needed for achieving the desired flow is significantly lower than 5 minutes
  - » The deviation in desired airspeed is lower than 10%



# Conclusion

- A properly designed and built system accounts for multiple aspects governing the performance
  - » Choice of target airspeed and threshold
  - » Choice of jet fan power / drive aiming at the airflow control
  - » Reliable and accurate measurement of the airflow
  - » Selection and parametrization of the controller
- Only when considering all of the above aspects, response times can be kept low, deviations from target airflow can be limited and the system is robust and reliable.

