



Accelerating  
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# **Collision Risk in extended 500 ft RVSM Airspace with geometric altimetry**

Ingmar Boshuizen | 04-12-2025



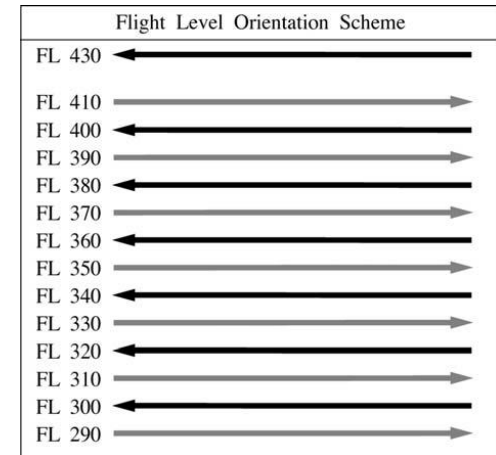
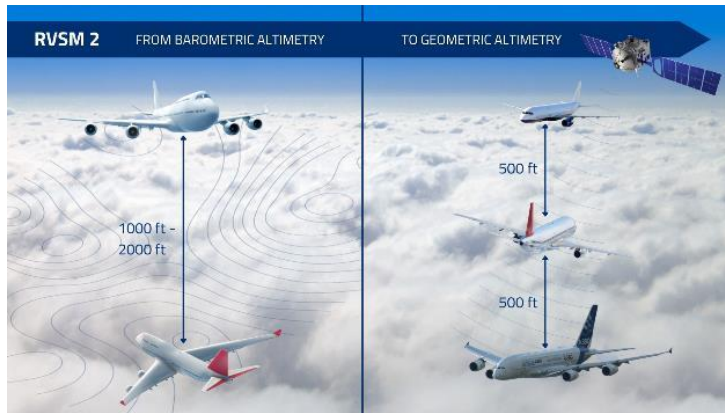
# Content

- Introducing the concept
- Goal of the study
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- Expected performance
- Discussion
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# The RVSM-2 concept

# RVSM-2

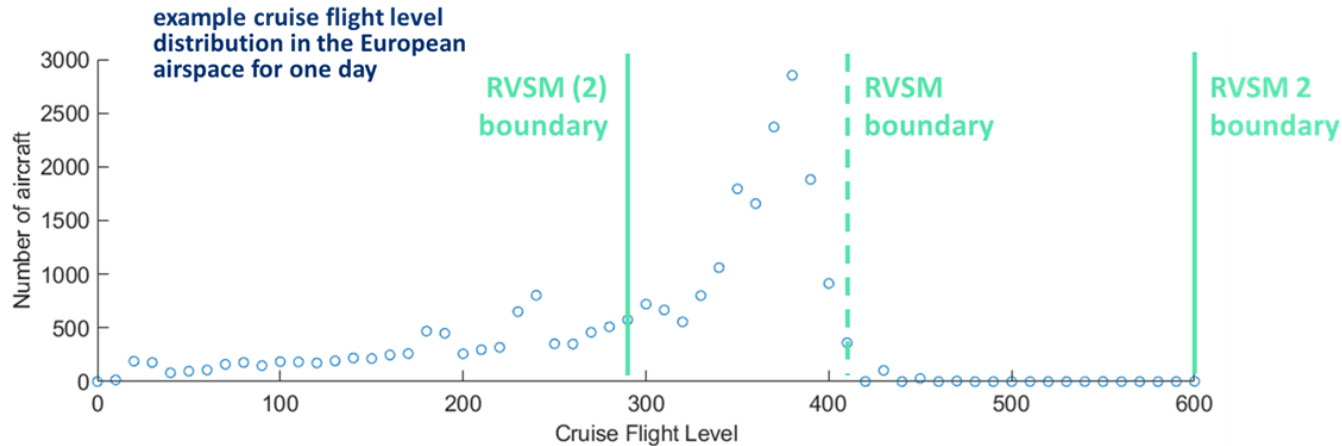
- An en-route airspace (e.g. EUR region FL290 – FL600)
- Reduced Vertical Separation Minima of 500 ft
- Geometric altimetry → using GNSS measurements



(Source: FAA)

# Advantages of RVSM-2

- Accuracy not as dependent on altitude
- Increased airspace capacity
- Increased flight efficiency



# Goal of the study



# Objective and assumptions

*"To assess the feasibility of introducing RVSM-2 in terms of the technical vertical collision risk."*

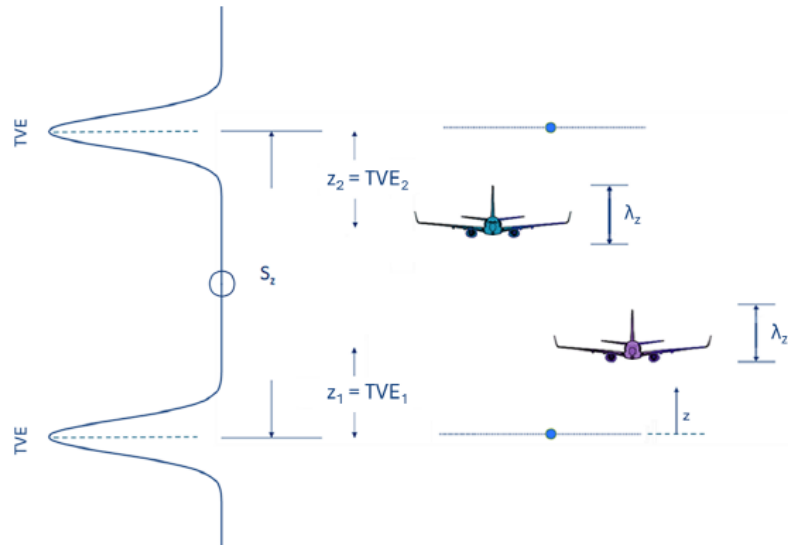
## Assumptions:

- Nominal operations
- No collision avoidance
- Geometric altimetry introduced and **always** available
  - Integrity, availability and continuity of GNSS

# Collision Risk Analysis

# ICAO Collision Risk Model in RVSM-2 environment

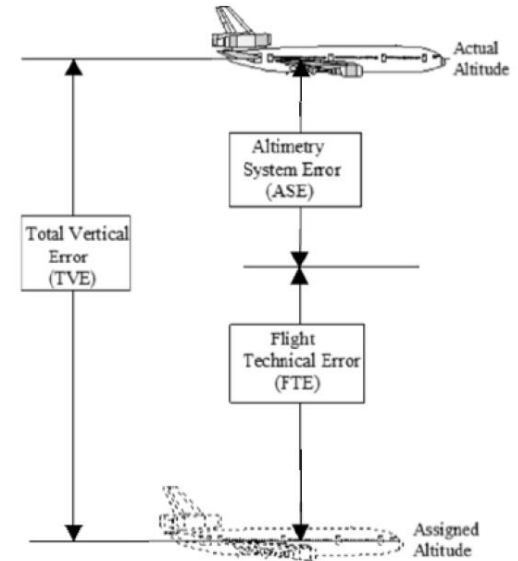
- Assessment of risk of a mid-air collision against a TLS of  $2.5 \cdot 10^{-9}$
- Nominal risk:
  - Natural variations in altimetry and height-keeping



# Errors and their distributions

# Error sources

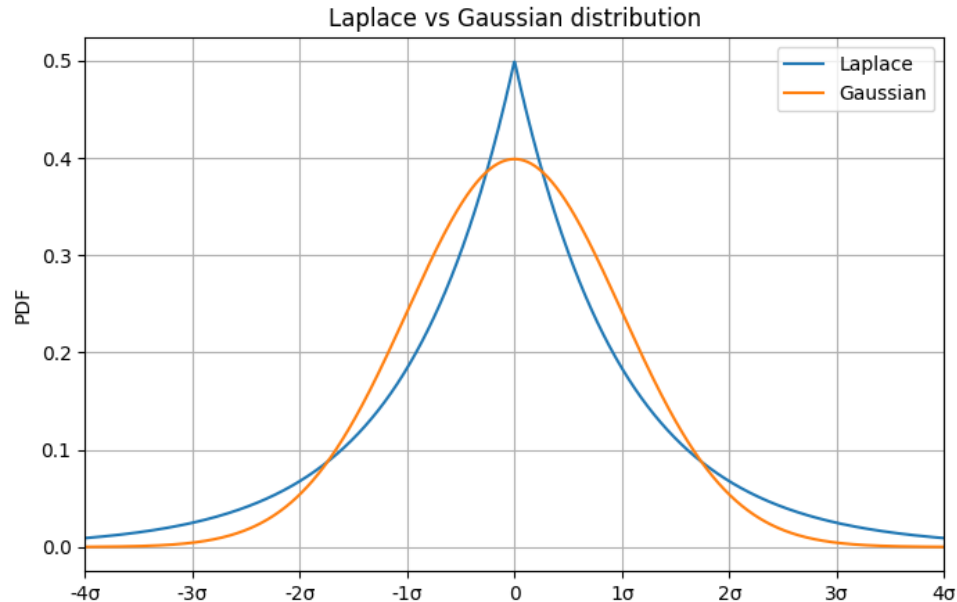
- Aircraft deviate from their assigned altitude due to:
  - Height-keeping deviations (FTE)
  - Navigation errors (ASE)
- Errors have a distribution



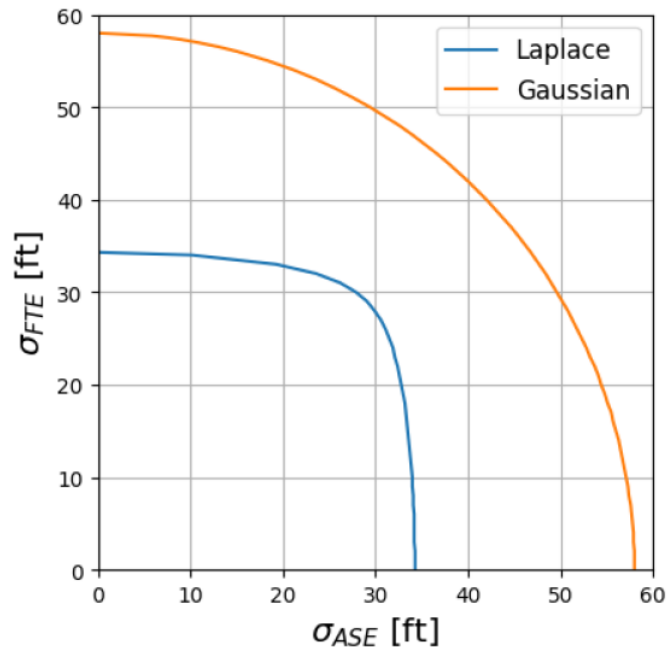
(Source: ICAO)

# Laplace or Gaussian

- The Gaussian distribution decays faster → smaller tails.
- Tail behaviour is important!

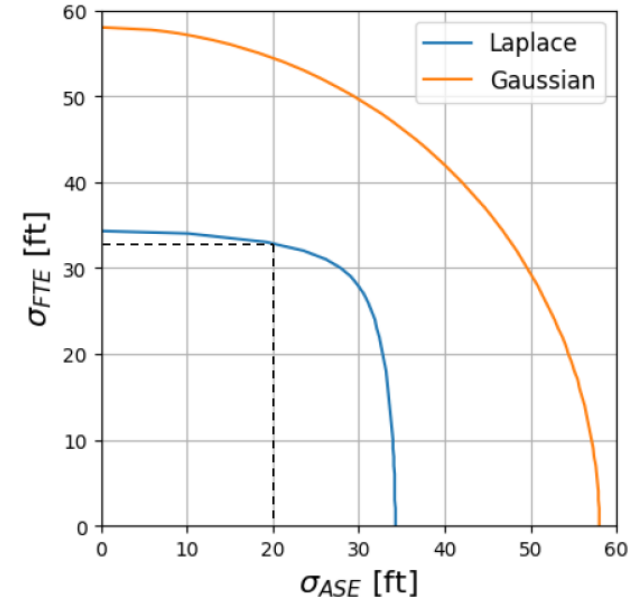


# Conditions on the FTE and ASE



# Expected performance

- MASPS for RVSM:
  - *The FTE has a distribution with an exponential decay, or a possibly faster decay.*
- Current estimations in the ICAO EUR region indicate a  $\sigma_{FTE}$  of 33 ft.
  - This is lower than the value of 43 ft prescribed by the current MASPS for RVSM.



# ASE

- GPS and Galileo
  - Specified vs actual performance
  - Single Frequency vs Dual Frequency

|         | AUL            | WUL             |   | VPE (95%) | VPE (1 $\sigma$ ) |
|---------|----------------|-----------------|---|-----------|-------------------|
| GPS     | 13 m / 42.7 ft | 33 m / 108.3 ft | → | GPS       | 3.98 m / 13.1 ft  |
| Galileo | 8 m / 26.2 ft  | 16 m / 52.5 ft  |   | Galileo   | 3.17 m / 10.4 ft  |

- Gaussian distribution describes most navigation system error distributions fairly well to the 95<sup>th</sup> percentile.
- Tail behaviour not well known due to rarity of the events.
- Assume Laplace distribution

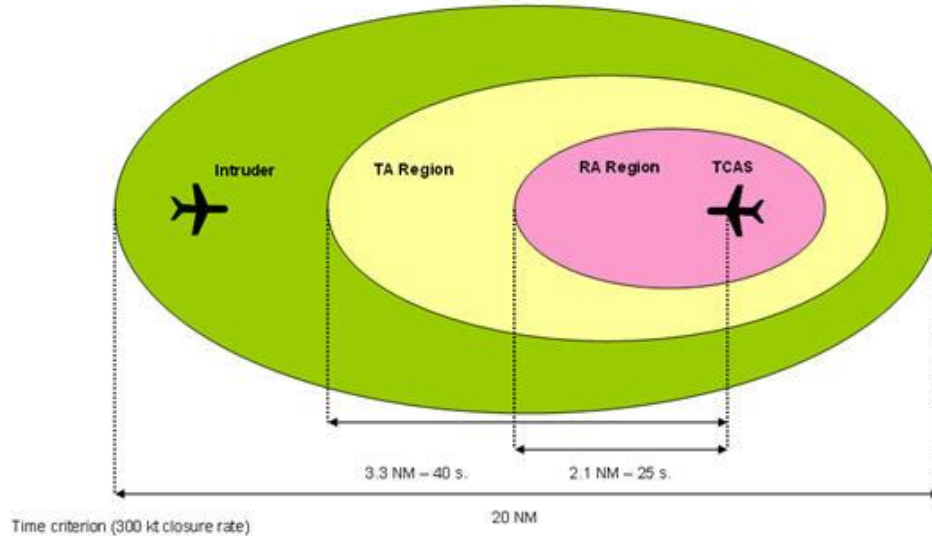
# Discussion

# Meeting the TLS

- Tail behaviour of the ASE and FTE remains uncertain.
- If  $\sigma_{\text{FTE}} = 33$  ft and  $\sigma_{\text{ASE}} = 5.3$  ft, the TLS could theoretically be met.
- A  $\sigma_{\text{FTE}}$  of 33 ft is just sufficient to meet the TLS
  - Updating requirements in MASPS -> aircraft would have to comply to this increased accuracy.
- Other issues have to be overcome as well!

# Collision avoidance

- ACAS Traffic Alerts and Resolution Advisories issued at 850 ft and 700 ft separation.





# GNSS integrity

- Reliability of GNSSs
- Jamming and spoofing
- GNSS outage applies to **all** airspace users



# Liability of GNSS performance

- Responsibility and accountability not at the GNSS provider
- *"The provider shall not be held responsible or liable for any damages resulting from the use of, misuse of, or the inability to use the Galileo Open Service."*

# Conclusion

# Conclusion

- TLS can theoretically be met by a small margin from a technical vertical collision risk perspective.
- Regulatory and legislative aspects
  - Liability of GNSS
- Operational issues
  - ACAS
  - Jamming and spoofing



*Thank you for your attention!*



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