Deconfliction and Separation Management: Manned-Unmanned and Unmanned-Unmanned

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Part A – Manned-Unmanned Separation

- ❑ Problem Definition
- ❑ Methodology and Example Results

Part B – Unmanned-Unmanned Separation

- ❑ Problem Definition
- ❑ Methodology and Example Results

Part A
Manned-Unmanned Separation

Simplified Exclusion Zones

LAANC-like Systems/Zones

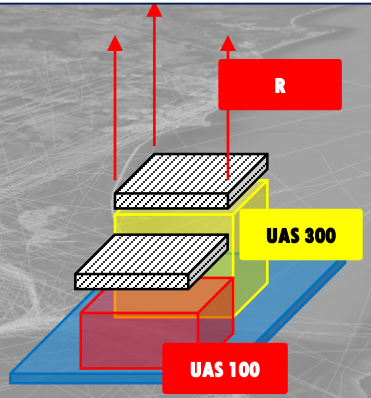
AEC/ARC (JARUS)

Airport, Heliport

Manned Traffic
(1 Day)

Google earth

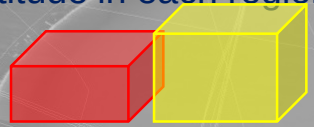
Strategic Separation



What separation/buffer

Results in how much collision risk

And therefore, what safe altitude in each region?



Implicit Collision Risk Modeling:

- Non-uniform/subjective (harmonization)
- Time-consuming/costly (manual)
- Communication/transparency

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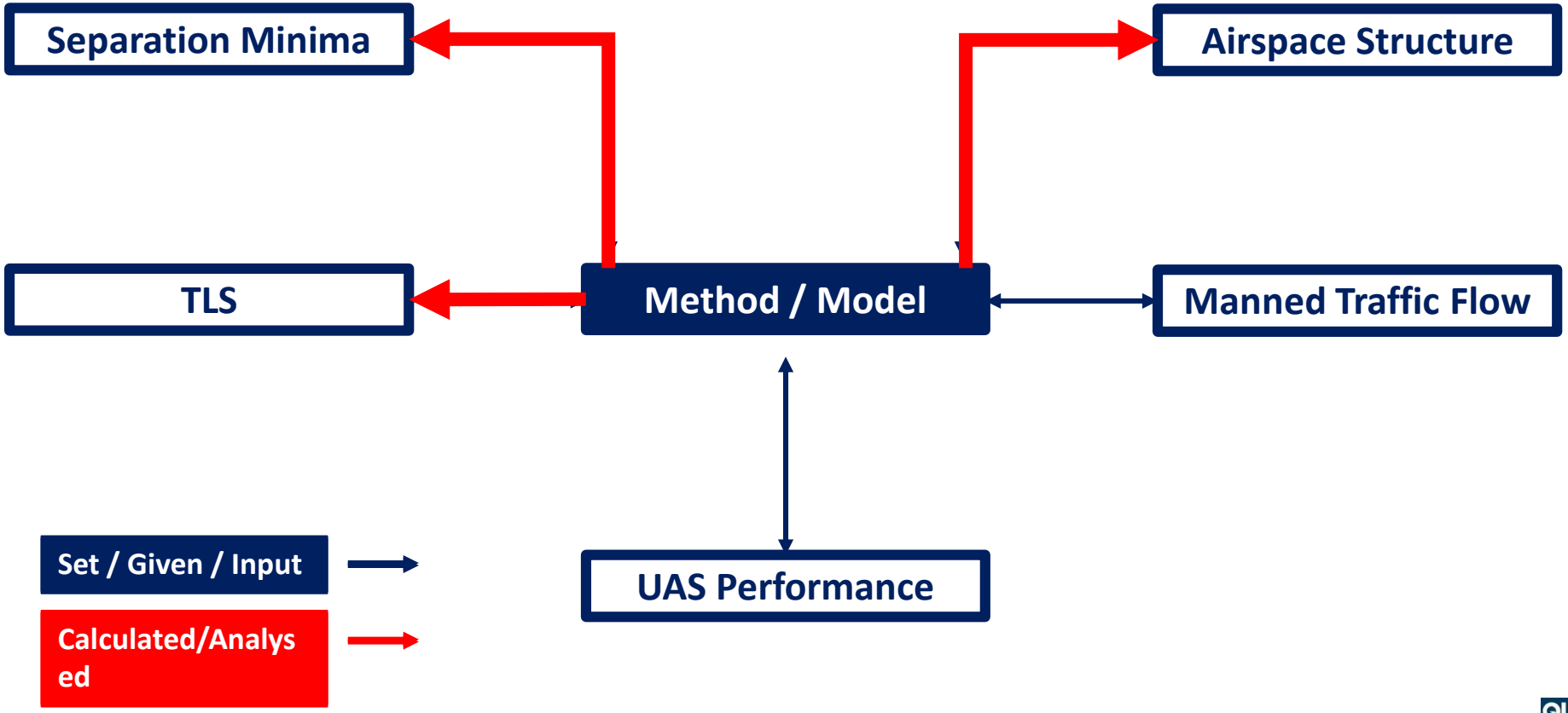
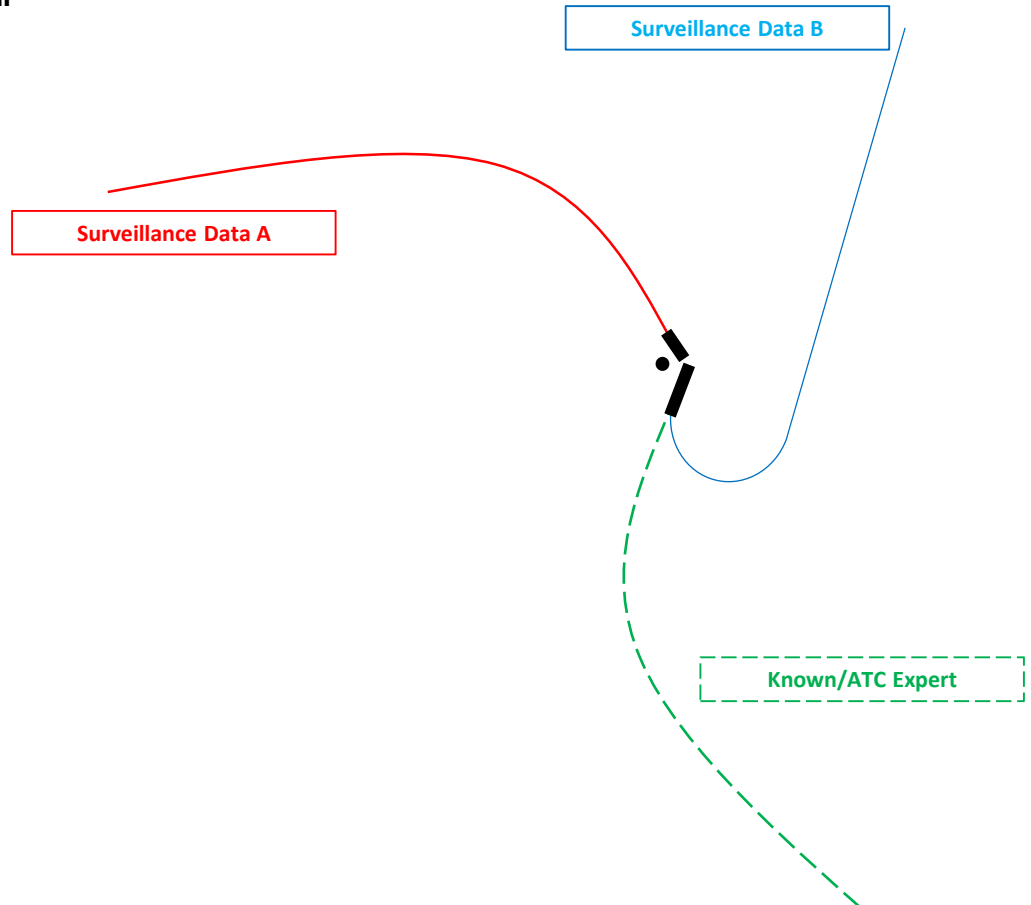


ICAO, Manual on airspace planning methodology for the determination of separation minima, *Doc 9689, 1998*

Manned Traffic Flow

- Runway
- Aerodrome Ref. Point



Manned Traffic Flow

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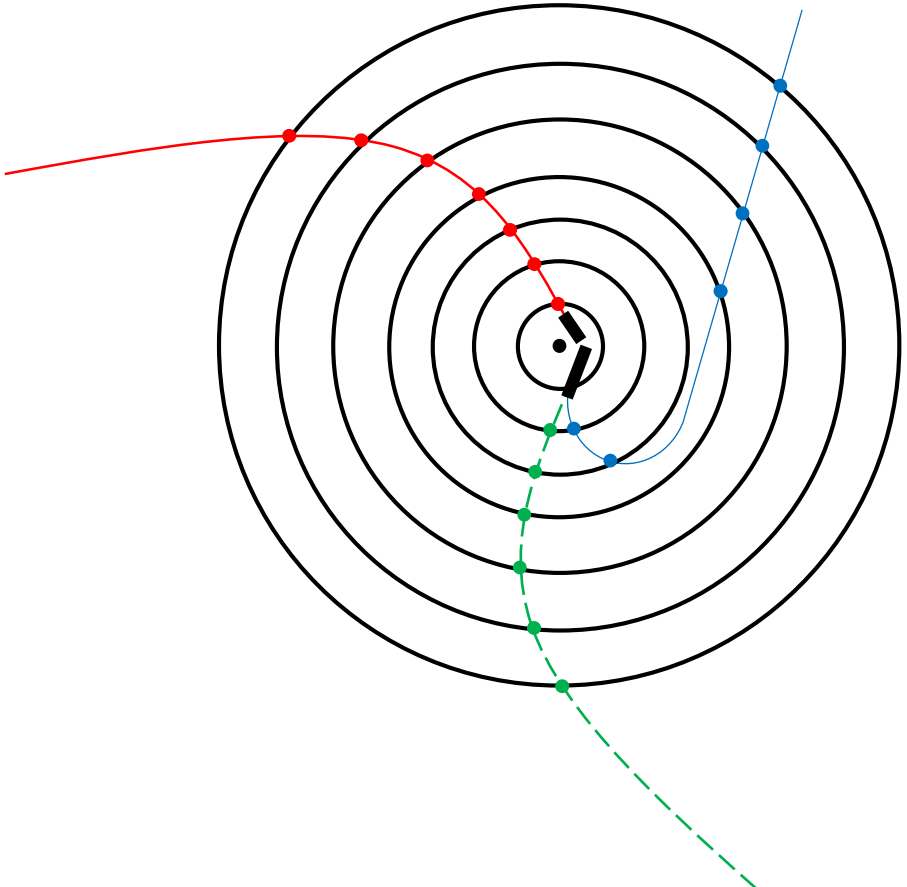
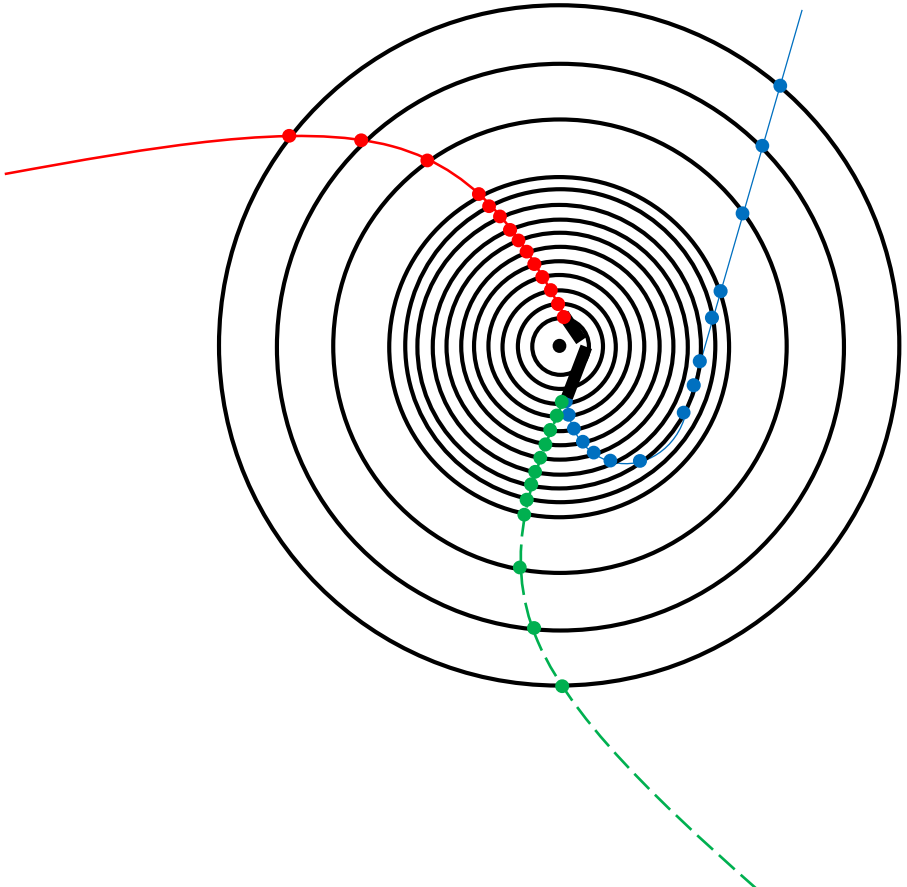
- Aerodrome Ref. Point



Runway

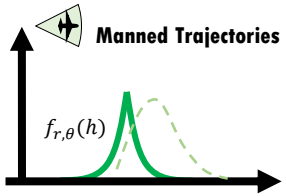
Aerodrome Ref. Point

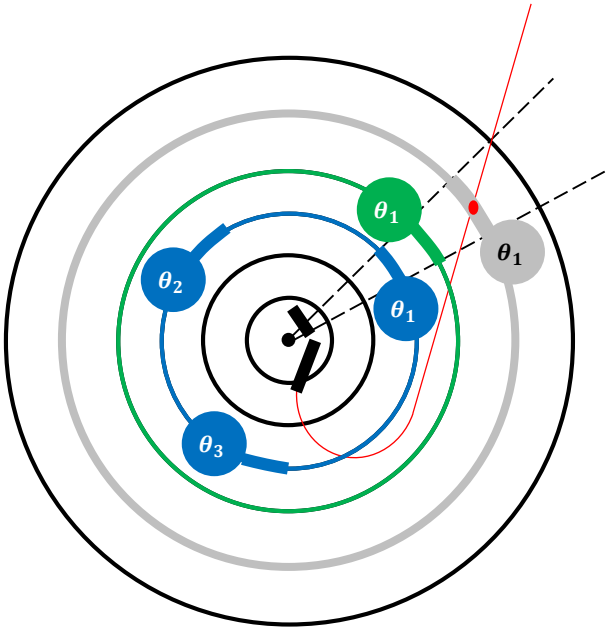


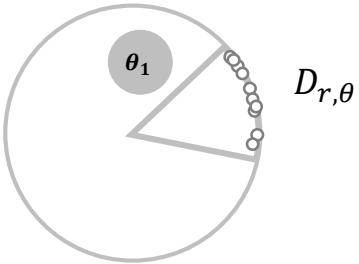
Manned Traffic Flow

Radius 2, Bearing 1

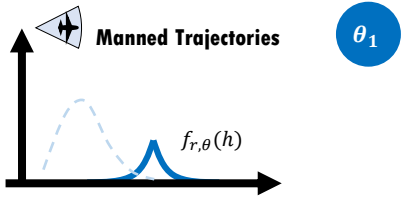
Radius 1, Bearing 1

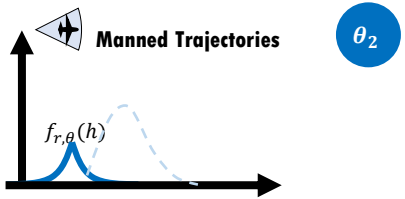






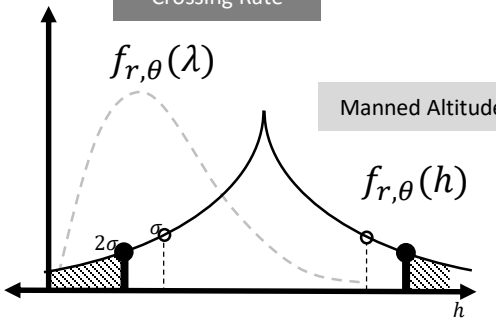
Polar grid
(radial and azimuth bins)





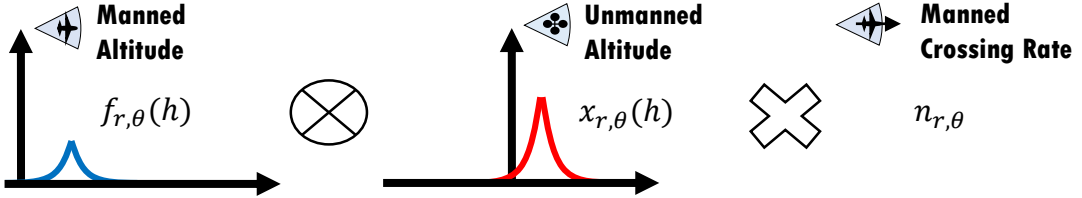
Radius 3, Bearing 1,…,N

Crossing Rate



Given a UAS altitude and nav. performance, what is the likelihood the vertical displacement between manned and unmanned is less than a specified separation buffer?

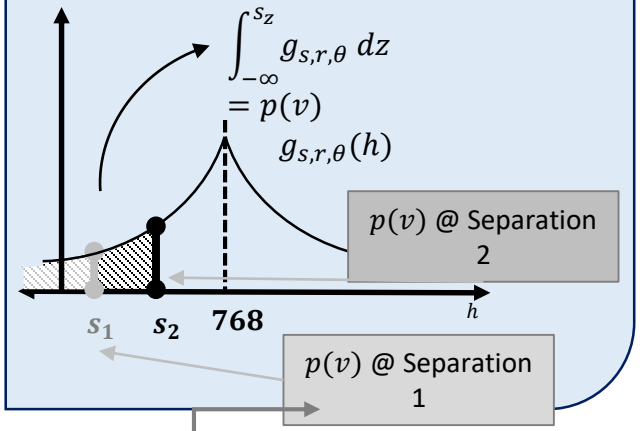
Find (Data/Experts)



Set (Nominal Alt, Nav. Perf./Variances)

NB: Horizontal Overlap = 1 (thus worst case)

Vertical Overlap - $p(v)$



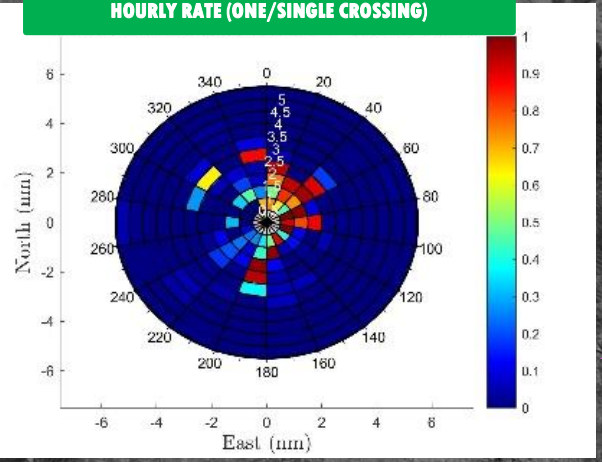
Calculate Likelihood with Associated Separation

Separation Analysis – Example A (Aerodrome Cells)

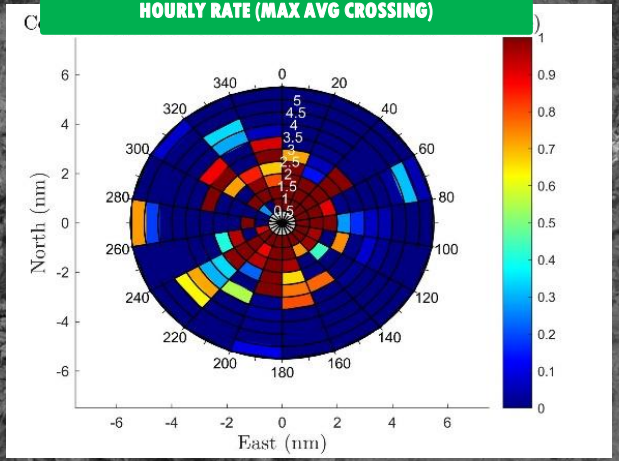
Part A

TLS and Separation

HOURLY RATE (ONE/SINGLE CROSSING)

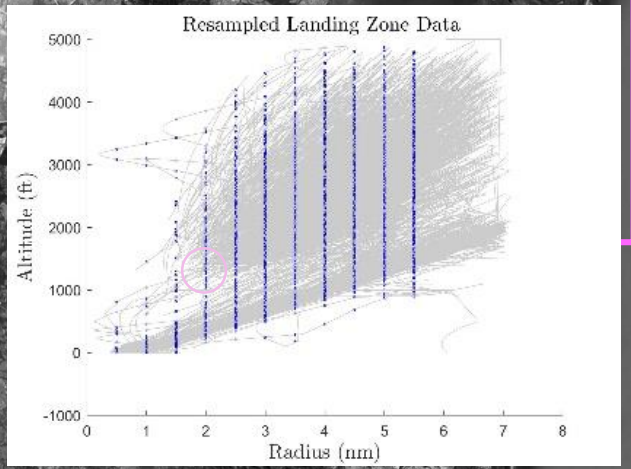


HOURLY RATE (MAX AVG CROSSING)



$\mu_u = 400$ (UAS Nom. Alt.)
$\sigma_u = 30$ UAS (UAS Alt. Error)
$s_z = 200$ (Sep./Buffer)
$n = 1,25$ (crossing rate)

MAP NOT TO SCALE – NOT FOR NAVIGATIONAL PURPOSES

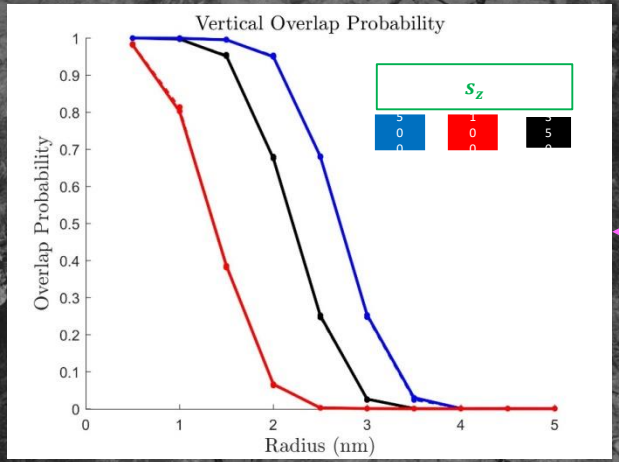


Conflict Probability Likelihood LOW HIGH

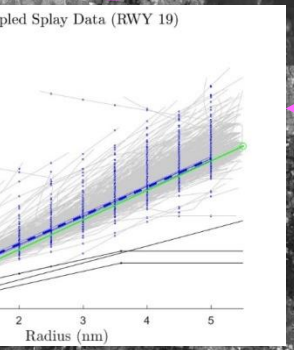
QUT

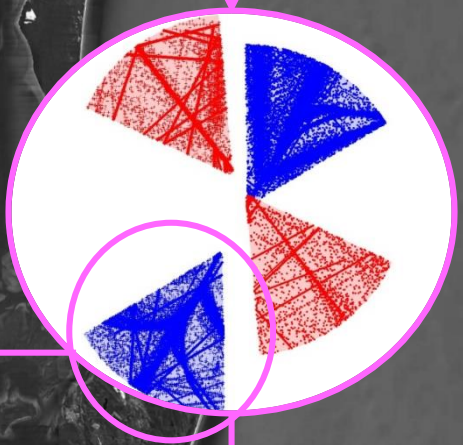
TLS and Separation

$\mu_u = 400$ (UAS Nom. Alt.)
$\sigma_u = 30$ UAS (UAS Alt. Error)
$s_z = 500, 350, 100$ (Sep./Buffer)



Approach Splay





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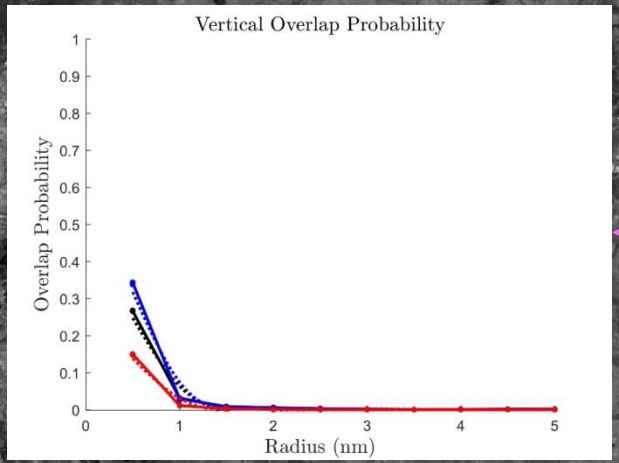
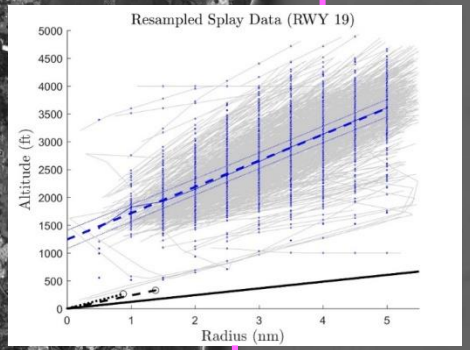
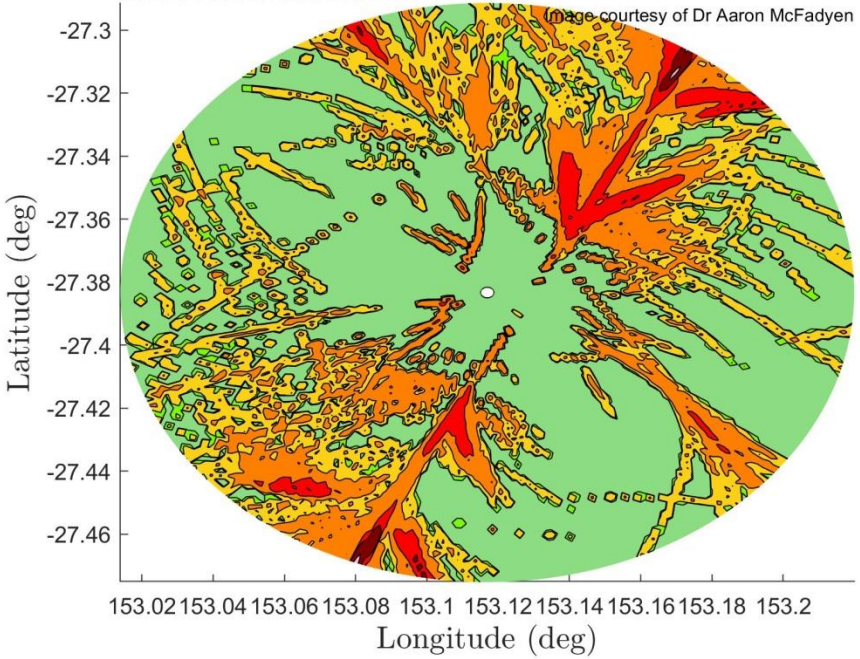


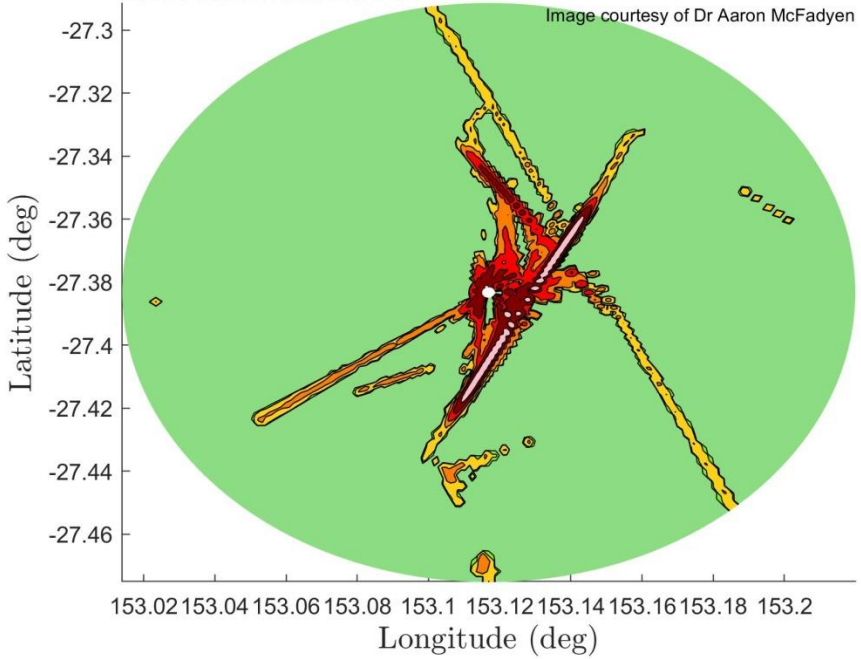
Departure Splay



UAS ALT 450m



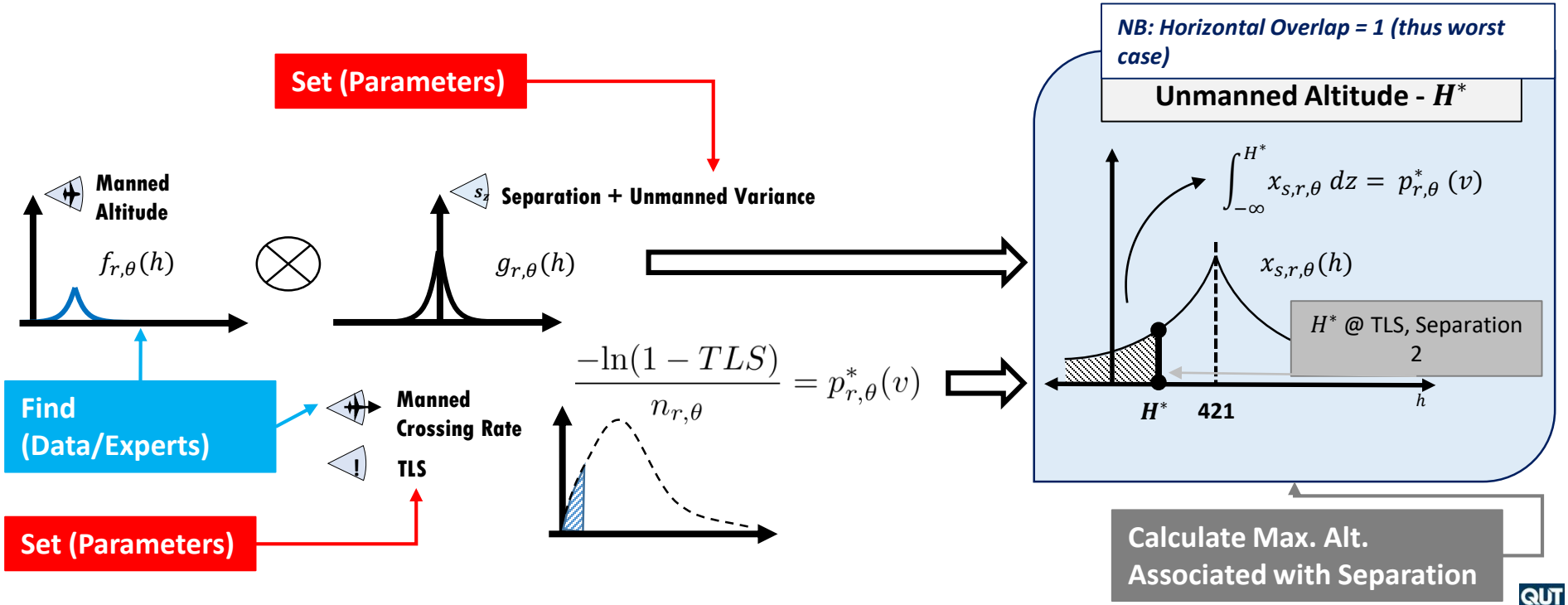
UAS ALT 50m



Collision Likelihood 10^{-2} 10^{-3} 10^{-4} 10^{-5} 10^{-6}

NB: Preliminary Results (limited data/unverified, no crossing rate addition)

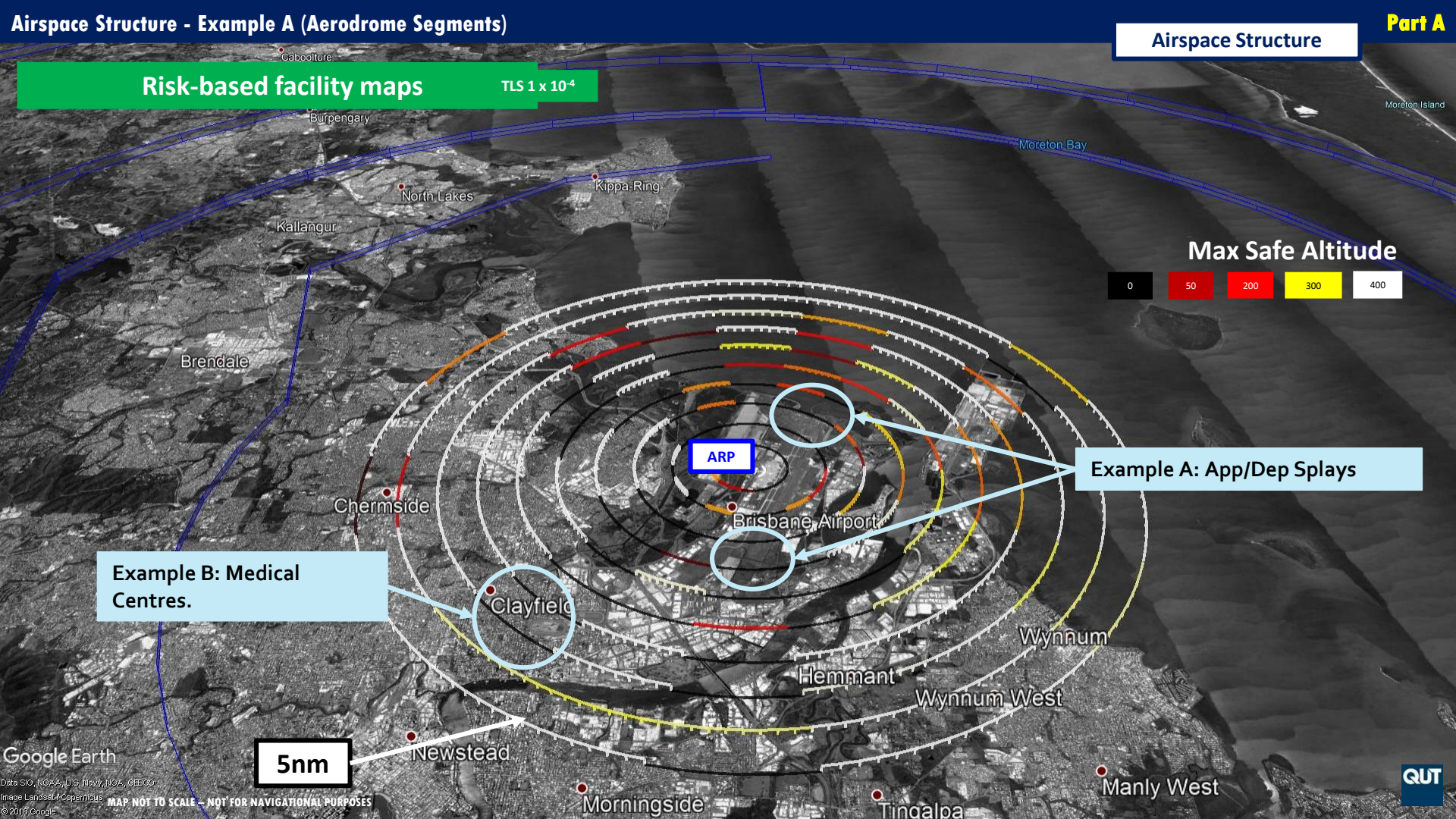
Given a separation buffer (S_Z) and UAS nav. perf., what is the max. UAS altitude such that the likelihood that the vertical displacement between manned and unmanned being less than (S_Z) is equal to a specified TLS?



Airspace Structure - Example A (Aerodrome Segments)

Risk-based facility maps

TLS 1 x 10^{-4}



Airspace Structure - Example A (Aerodrome Segments)

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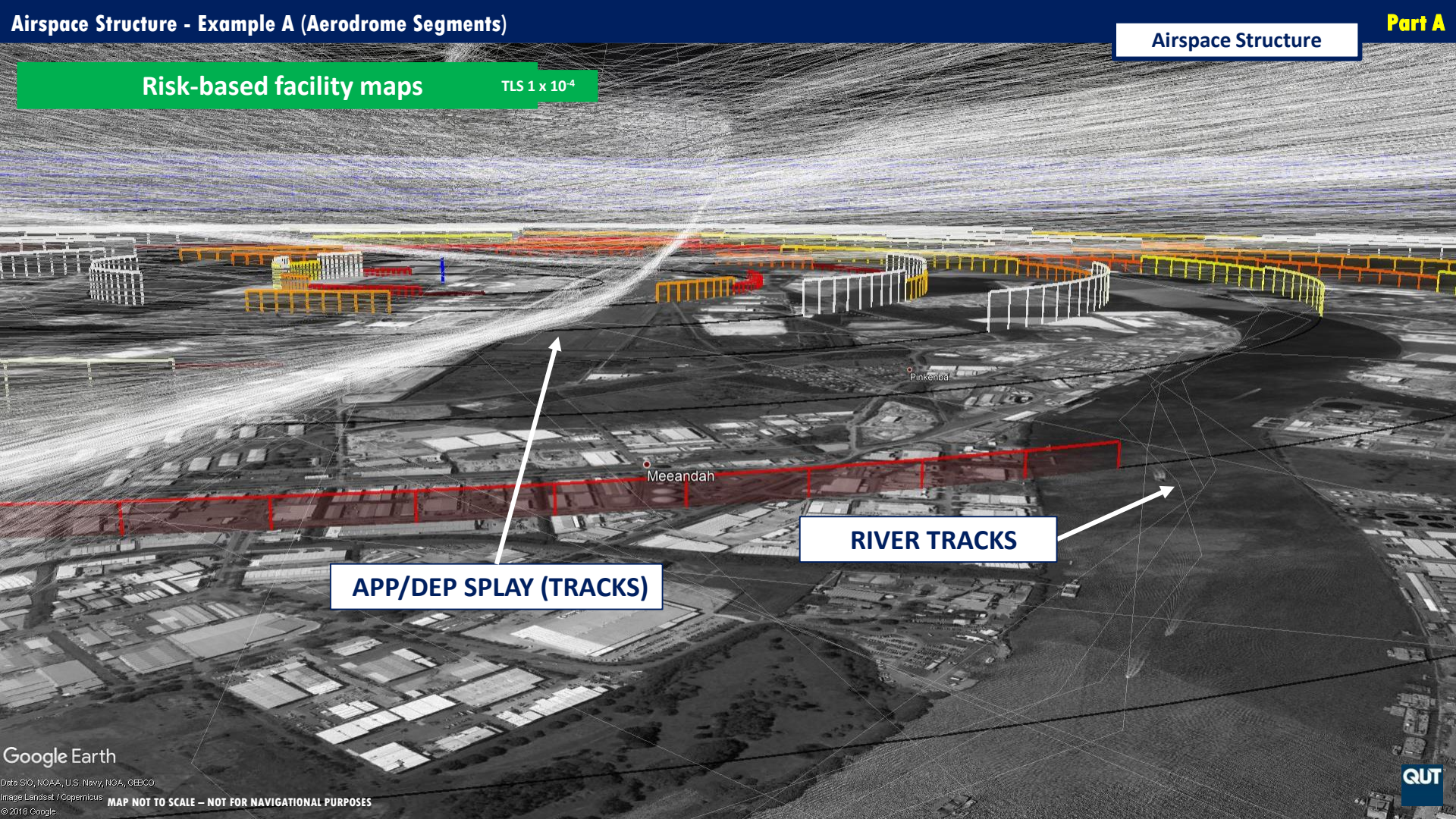

Risk-based facility maps

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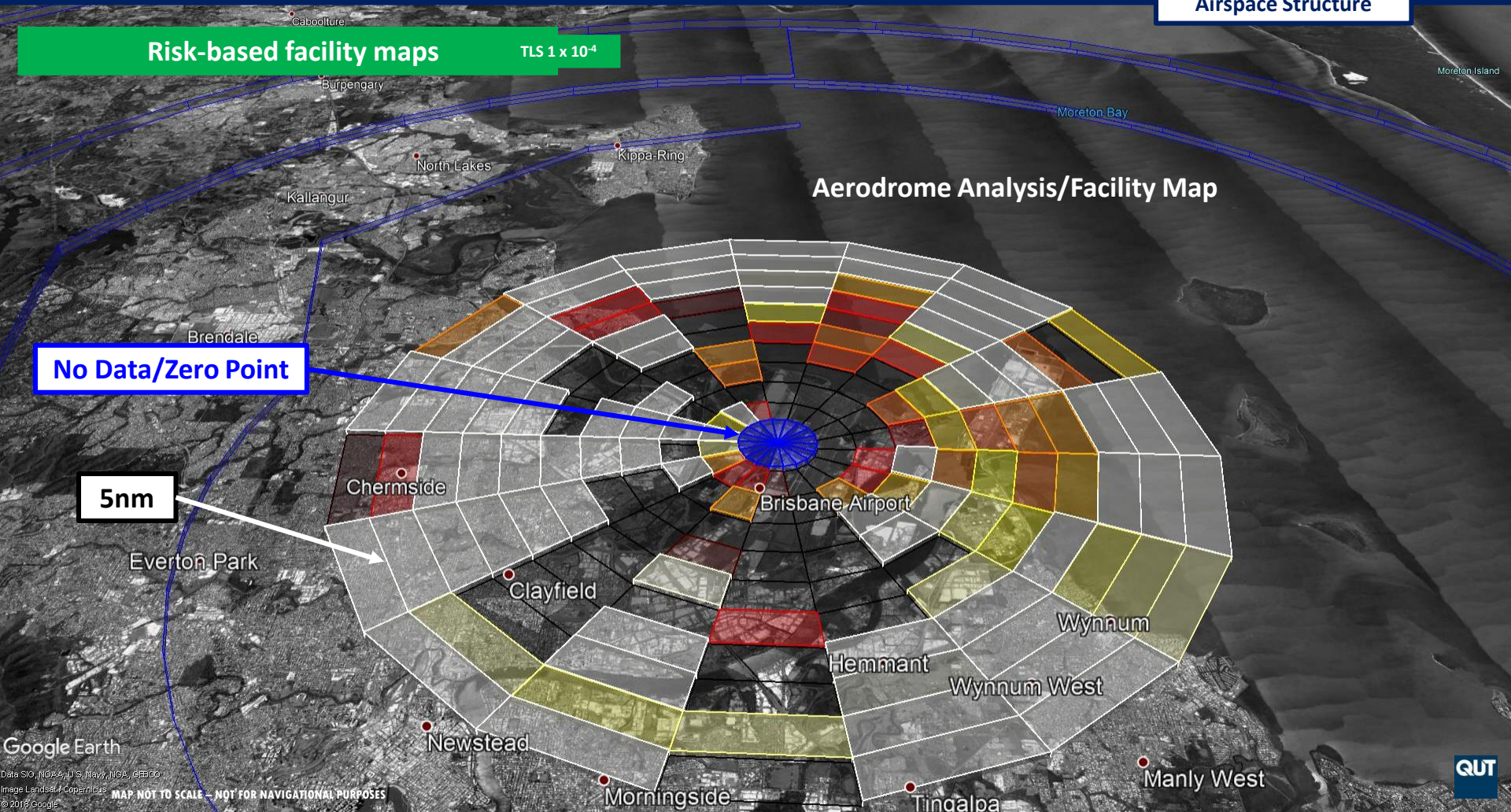
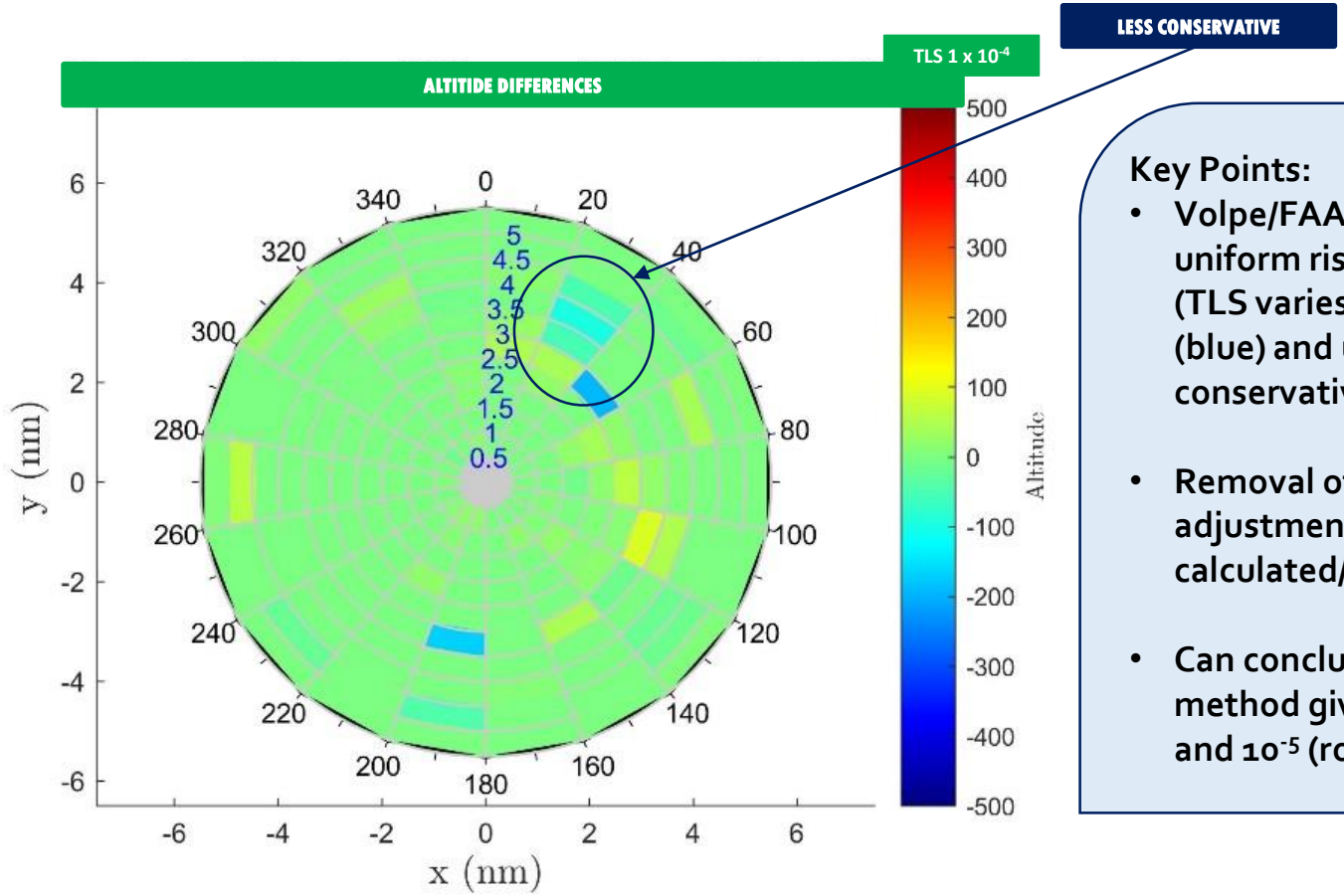




Key Points:

- Volpe/FAA Report does not apply uniform risk to each grid location (TLS varies between grid). See over (blue) and under (yellow) conservative grids
- Removal of data not constitute 'risk adjustment' as no risk is calculated/known.
- Can conclude that the Volpe/FAA method gives values between 10^{-3} and 10^{-5} (roughly).

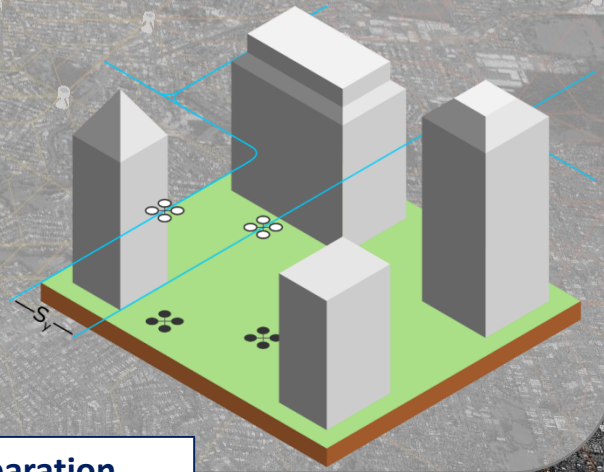
Part B
Unmanned-Unmanned Separation

Unmanned Only Network

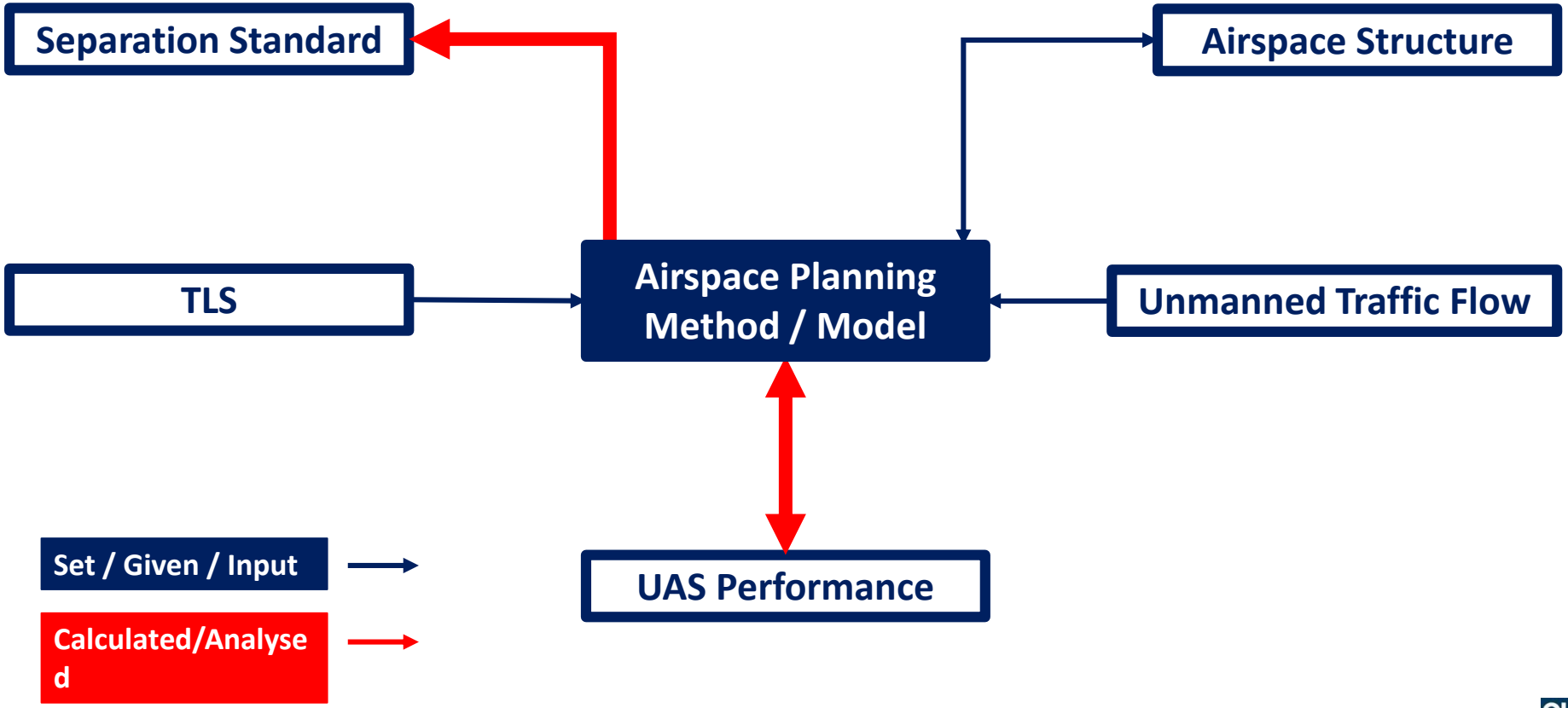
Node/Waypoint

Link/Track

What separation/buffer results in how much collision risk and therefore, what is required nav. performance?



Strategic Separation



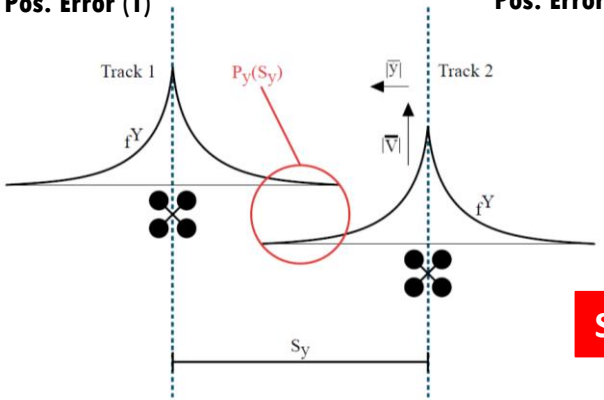
ICAO Doc 9689. "Manual on airspace planning methodology for the determination of separation minima," *Washington D.C, 2016*

Given a UAS nav. performance, scaled velocity/params and a TLS, what is the required lateral displacement (separation) between unmanned aircraft on parallel tracks?

NB: Only Lateral Calculated

Set (Data/Experts)

- **Unmanned Pos. Error (1)**
- **Unmanned Pos. Error (2)**

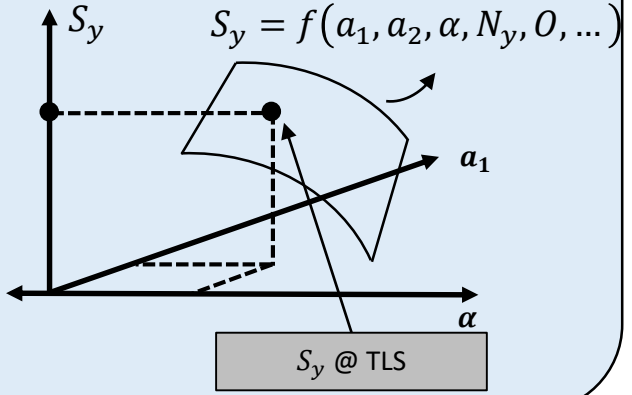


Lateral Model (Reich)

- **Adjusted a_2 Param - f(a_1)**
- **Scaled Params (for UAS)**
- **One-N and N-N tracks**
- **Airspace Capacity and Flow Rate**

Set (Scaled Params)

Separation Surfaces @ TLS



Calculate S_y for TLS and Nav. Perf

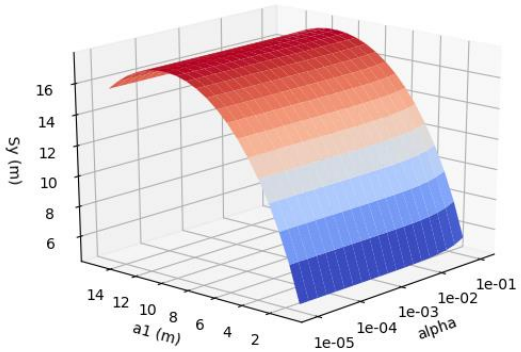
TLS and Separation

Strategic Separation

Separation Surface @ $TLS = 10^{-2}$

Sub 10 metre track separation

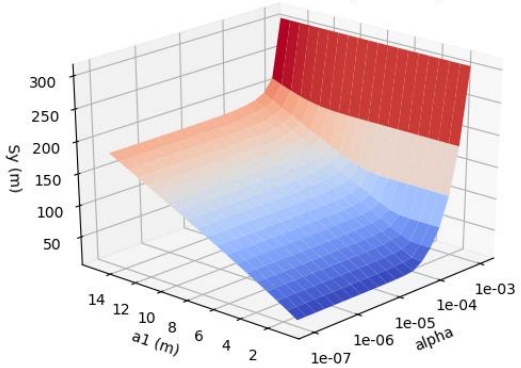
Dominated by nominal navigating UAS. Proportion of poorly navigating UAS (α) and degree (a_2) has limited impact.



Separation Surface @ $TLS = 10^{-6}$

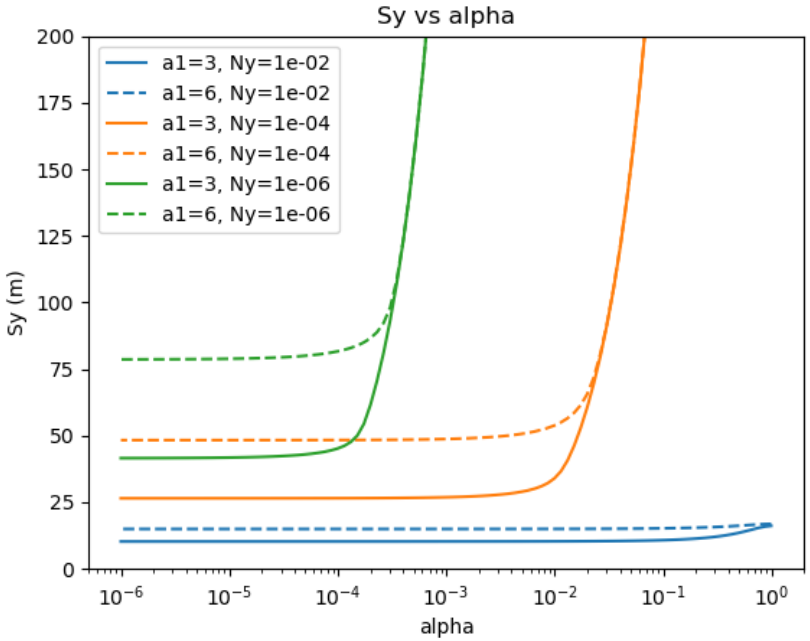
Sub 100 metre track separation if proportion of poorly navigating UAS $\alpha < 1/10,000$.

Dominated by nominal navigating UAS (a_1) for $\alpha < 1/10,000$



$\Delta V = 0.8\ m/s$
$V = 20\ m/s$
$|\dot{y}| = 1.77\ m/s$
$\lambda_{y,x} = 0.3\ m, \lambda_z = 0.2\ m$

Strategic Separation



Separation Curves

Compares the separation standards (S_y) for 10^{-2}, 10^{-4} and 10^{-6} target levels of safety (N_y in the figure).

Highlights the importance of maintaining a low proportion of poorly navigating aircraft.

Exact TLS for unmanned operations is not clear, but results can be used to investigate navigation requirements and separation for different types of unmanned operations (i.e. packages vs people).

$\Delta V = 0.8\ m/s$
$V = 20\ m/s$
$|\dot{y}| = 1.77\ m/s$
$\lambda_{y,x} = 0.3\ m, \lambda_z = 0.2\ m$

Manned-Unmanned Separation Development

- Method to **quantify vertical collision risk** (terminal areas) aligned to manned aviation practise that can be used for multiple analysis types (separation/segregation standard/buffer, navigation perf. etc.)

- Method to **derive max safe altitudes** (terminal areas) that explicitly considers navigation perf., separation/segregation standard/buffer, data error via collision risk modelling.

Unmanned-Unmanned Separation Development

- Method based on manned approaches to investigate navigation perf. requirements and associated separation standards/buffers.

General

- Useful for ANSP's, regulators and operators alike - with applications in airspace design (low-level/UTM/U-Space) and development of navigation perf. requirements/definitions/standards.

- Software (**semi-automated**) created and being further extended, tested and validated

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Thanks!

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