CORUS five

Thematic Area:
Conflict Management & Demand and Capacity Balancing

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CORUS five 2nd Workshop

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Structure of the session

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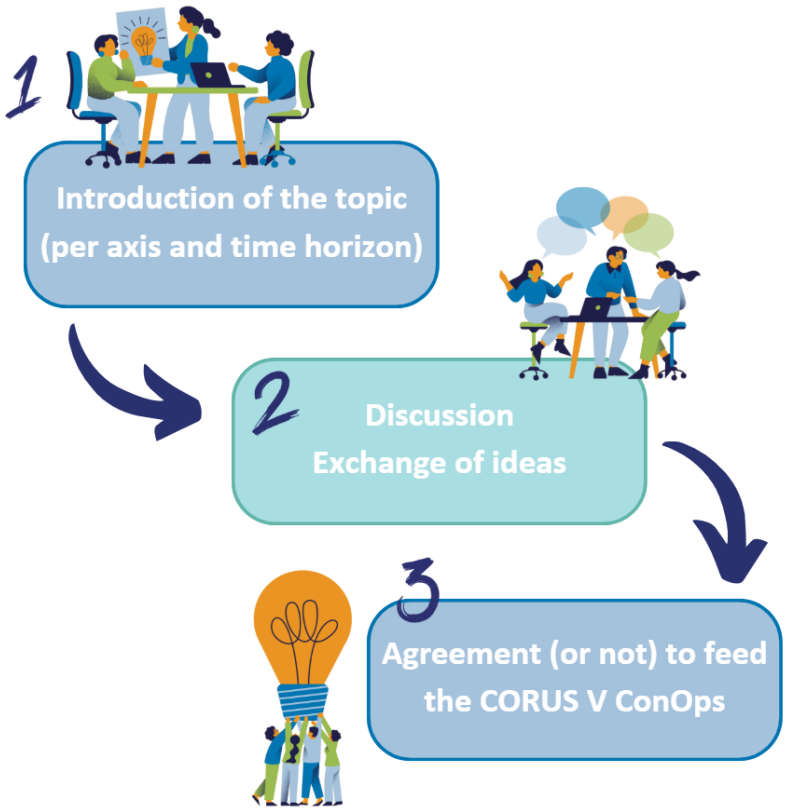
Two axes

Three horizons

	Conflict Management	DCB
Short-term	• Strategic vs tactical • Uncertainty • CA (UAS vs manned) • Electronic conspicuity	• Capacity • DCB initial measures • FC-FS
Medium-term	• U-plans overlap • DAR • Fairness	• Advanced DCB
Long-term	• Flight rules	• Only DCB + tactical



Acronyms

- **ARA**: Airspace Risk Assessment
- **CA**: Collision Avoidance
- **CM**: Conflict Management
- **DAR**: Dynamic Airspace Reconfiguration
- **DCB**: Demand and capacity balancing
- **LTH**: Long term horizon
- **MTH**: Medium term horizon
- **POBA**: Pilot-on-board Aircraft
- **SCM**: Strategic Conflict Management
- **STH**: Short term horizon
- **TI**: Traffic Information
- **UASO**: UAS operator (could be also remote pilot in this presentation)

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Conflict Management

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Conflict management in ATM

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Context

The goal of conflict management is to limit, to an acceptable level, the risk of collision between aircraft and hazards

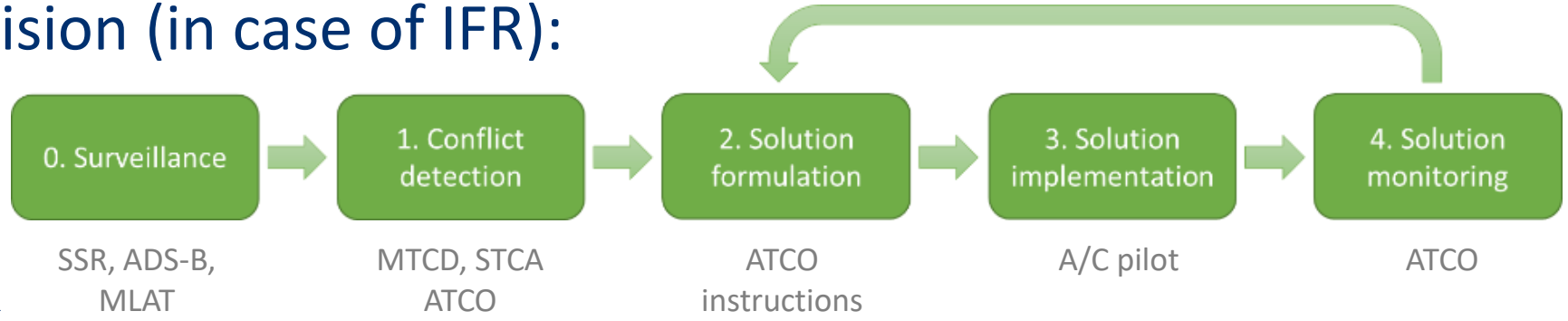
- Conflict management in **ATM nowadays**:

→ Onboard detection and resolution instructions – TCAS/ACAS

→ Separation during flight – IFR: ATC, VFR: Pilot

→ Flight plan checks before flight – ATFM, DCB + airspace structure
In Europe: Network Manager

- Separation provision (in case of IFR):



Conflict Management in U-space today

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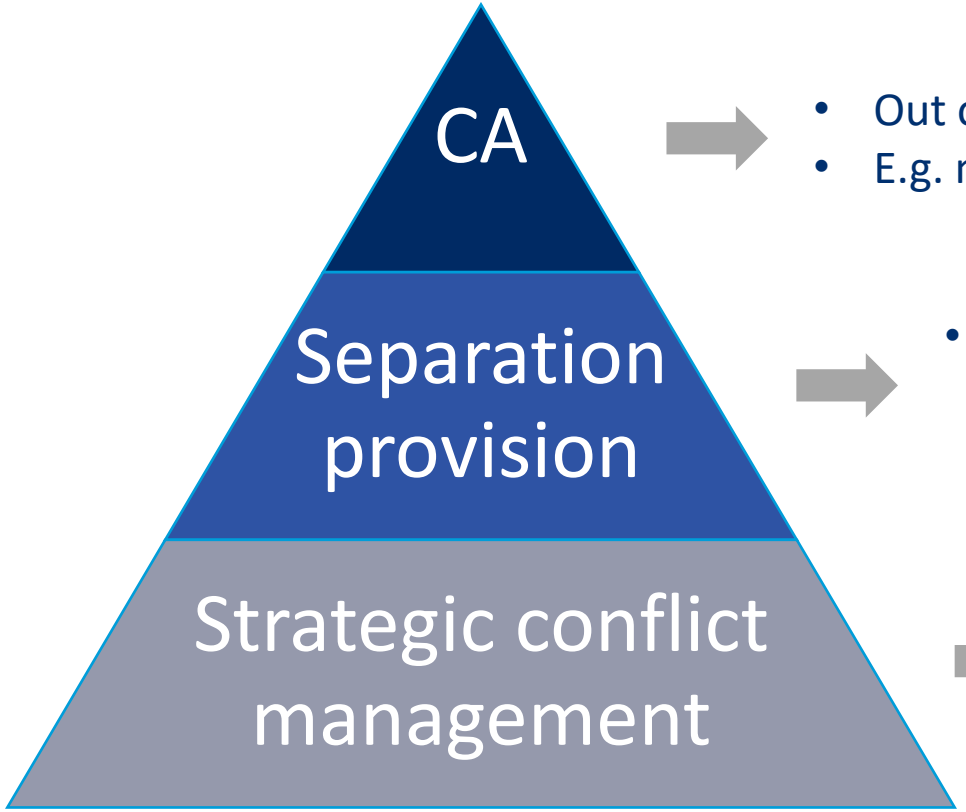

- Out of the scope of U-space regulations: not required but could be used.
- E.g. might be a risk mitigation identified in SORA

- Remote Pilot, supported by
  - Traffic Information
  - Conformance Monitoring

- Flight Authorisation process
- Dynamic Airspace Reconfiguration

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Strategic conflict management in U-space today

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Short-term

Strategic conflict management measures aim to reduce the need to apply the second layer of CM to an appropriate level, as determined by the ARA.

- SCM is achieved through:

Airspace organisation and management	• The design of U-space airspaces and the DAR procedure are implemented to minimise the frequency of encounters with manned traffic
Demand and capacity balancing	• The UAS flight authorisation service must ensure that the capacity of the U-space airspace is not exceeded.
Strategic Deconfliction (Traffic Synchronisation)	• The UAS flight authorisation service must ensure that there is no conflict (overlap) between accepted U-plans.

- *Notes*:
  - The term 'strategic' is understood as 'in advance of tactical'.
  - Strategic actions will normally occur prior to the activation of a flight but may also happen in-flight. It is assumed that a strategic action will result in the amendment of a U-plan.
  - **In the STH, it is expected that most of the collision risk is mitigated through the strategic layer**. NO U-plans overlap allowed.

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Food for thought

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Short-term

Strategic conflict management

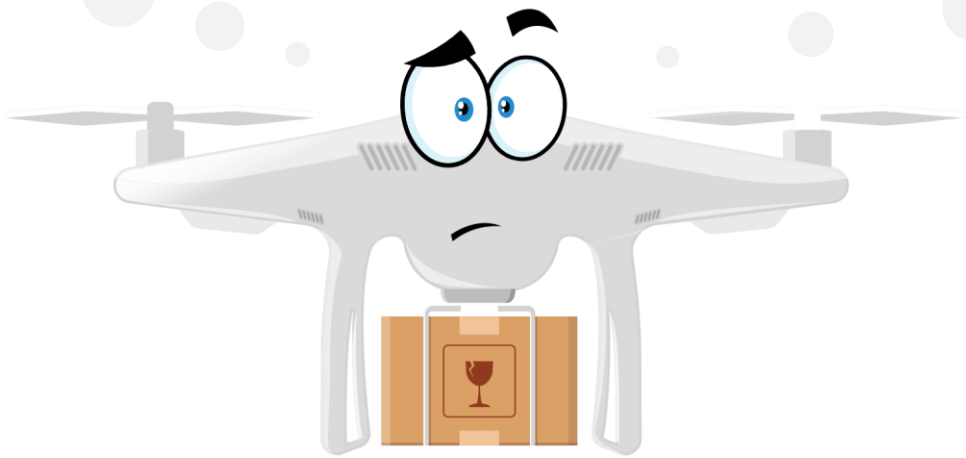
FC-FS

Should we assume in the STH “First Come First Served” or should we apply a fairer method?

- What is a fairer method?
- What is fair?
- ASTM F3548-21 mentions negotiation.
  - What is used outside EU ?

Strategic deconfliction

- How useful is strategic deconfliction?
- What proportion of conflicts are unpredictable? (e.g. POBA)



Uncertainty

How much take-off/U-plan activation time uncertainty should be allowed?

Separation provision in U-space today

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Separation provision

Short-term

Separation provision is the tactical process of keeping aircraft away from hazards by at least the appropriate separation minima.

- Separation provision consists of:

Conflict detection

- Based on traffic information.
- All traffic in U-space airspace is required to be conspicuous:
  - UAS: Network remote ID
  - Manned A/C (no ATC): e-conspicuous
  - Manned A/C (ATC): ATC→ CIS → USSP (TIS) → UASO

Solution formulation

- UAS operators are expected to formulate a solution that is limited to the authorised 4D volume, whenever possible.
- It is expected that a tactical action will result in a change of trajectory, rather than an amendment of a U-plan.

Solution implementation

- Change of trajectory by UAS operator, within the authorised 4D volume, whenever possible.
- Request to USSP for new UAS flight authorisation whenever necessary.

Execution monitoring

- Feedback loop by UAS operator using traffic information.

- *Notes*:
  - The 664 Regulation uses ‘minimum safe spacing’ rather than ‘separation minima’.
  - In the STH, **the separator is the UAS operator**, which relies on the traffic information provided by USSPs to take appropriate action.

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Food for thought

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Separation provision

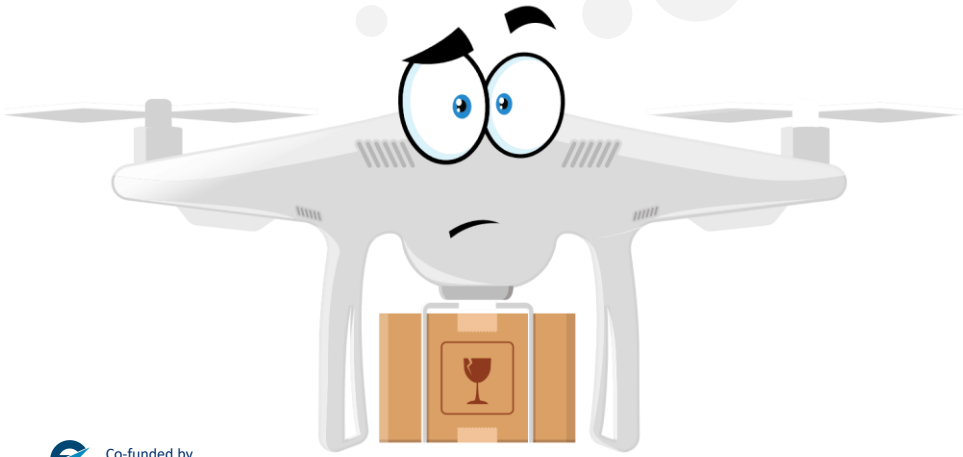
Short-term

Logic strategic vs tactical measures.
UAS is airborne. If a tactical measure is applied and this forces the UAS is out of conformance:

- Should the U-plan be changed?
- By whom? UASO? USSP?

Strategic deconfliction in the tactical phase.
If a UAS is airborne, and out of conformance, and hence the plan changes:

- Should the plan have priority for strategic deconfliction?
- Should there be any strategic deconfliction at all? If not, should the USSP warn the UASO of a conflicting plan?



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Separation provision in U-space today

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DIFFERENT SITUATIONS CONTEMPLATED BY THE IR (EU) 2021/664:

- Conforming UAS vs Conforming UAS
  - In nominal conditions there are no conflicts due to Strategic actions ☺
  - In case of failure of Strategic actions, follow the case for UAS vs non-conforming UAS
- Non-conforming UAS vs UAS {conforming, non-conforming}
  - Traffic Information (TI) supplied to both UAS Operators (UASO)
  - If there is conformance monitoring then non-conforming UAS are indicated in TI
  - Both UASO *shall take the relevant action to avoid any collision hazard.*
- UAS vs Conspicuous POBA
  - Traffic Information supplied to UAS Operator
  - UASO *shall take the relevant action to avoid any collision hazard.*
- Not regulated today
  - What is *the relevant action?*
  - UAS vs Inconspicuous aircraft {POBA, UAS}
  - What is expected of any UAS which is no longer controllable – due to lost link, etc

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Separation provision in U-space today

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TACTICAL CHANGES TO STRATEGIC PLANS

- Tactical changes can force the flight out of conformance
  - e.g Avoidance of POBA, Dynamic Airspace Reconfiguration

- Hence
  - Every flight needs to conform to an authorisation
  - The authorisation can change

IR (EU) 2021/664

- **Article 10(10)**
  Mentions these cases and indicates that the USSP can **update** flight authorisations.

- **Article 6(6):**
  "UAS operators shall comply with the UAS flight authorisation, including the authorisation deviation thresholds referred to in Article 10(2)(d), as well as with any changes thereto. The U-space service provider may introduce changes to the authorisation during any phase of the flight and, in such case, shall inform UAS operators about them."

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Food for thought

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Separation provision

Short-term

Right of way for UAS?

Relevant Action

UAS can vary greatly in size, speed and manoeuvrability, also when compared to POBA.

- Should / can UAS follow the right of way defined in ICAO Annex 2, as all other aircraft?

Network Remote ID

Traffic information is derived from Network Remote ID and Electronic Conspicuity.

- Are these consistent and precise enough surveillance to be the basis for tactical conflict detection?

Tracking

- Should the USSP perform tracking on network ID before generating traffic information?

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Collision avoidance in U-space today

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Collision avoidance is the third and final layer of conflict management and must activate when the separation mode has been compromised.

- Assumptions in C5 ConOps:
  - In the STH, there are no requirements for the CA layer.
  - We assume that **CA will be unusual**, apart from VLOS 'see and avoid'.
  - BVLOS 'see and avoid' (e.g. through FPV) is assumed to be unreliable and not an appropriate for CA unless integrated in a CA system (e.g. computed-based visual detection capabilities).
  - UASO may install CA systems, in which case the CA systems should be independent of the provision of U-space services, acting as a safety net.
  - The ARA should not consider the use of CA systems when determining the required UAS performance and capabilities, and U-space services performance requirements.

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Food for thought

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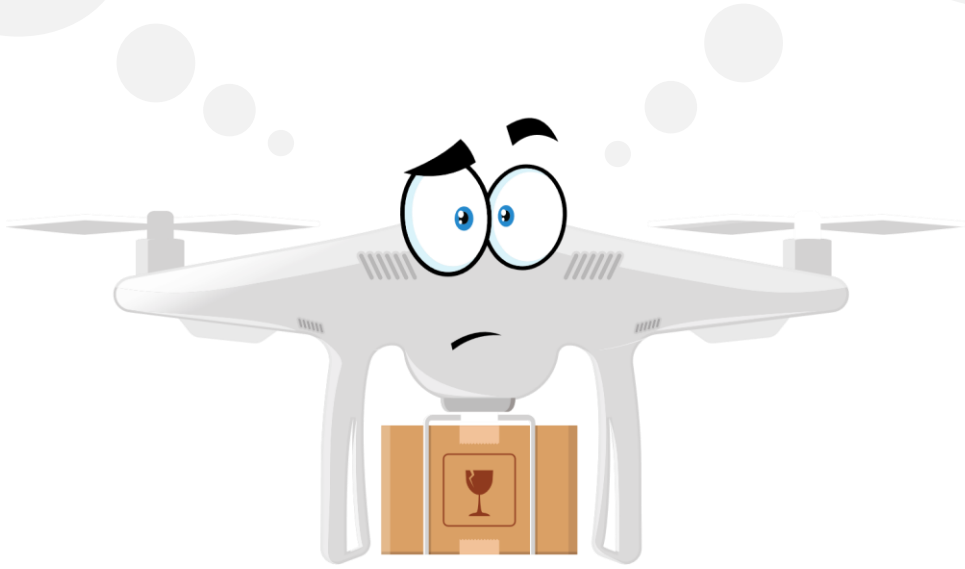
Short-term CA

Collision avoidance
What is the purpose?
UAS vs UAS?
UAS vs POBA?
UAS vs obstacle?

VLOS ‘see and avoid’ can be assumed as a CA capability? Assuming that visual range is too limited to be considered a separation provision capability. In which time frame is this needed/expected?



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Conflict management in U-space - MTH

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Medium-term

- Delta compared to short-term horizon:
  - **Strategic Conflict management:** U-plan *deviation thresholds* will be allowed to overlap to increase capacity.
    - In Z airspaces: reduced conformance confidence, down to 95%, additional risk compensated by tactical manoeuvres
  - **Separation provision** could be achieved by:
    - *In airspace X and Y:* RWC, where UAS operator is the separator with the support of U-space services for the detection of conflicts (advisory guidance?).
    - *In airspace Z:* Separation provision by USSPs/ATC, where these provide clearances (orders) to operators for tactical deconfliction.
  - **Collision avoidance** systems may be required to further enhance capacity.
    - Or as a safety net?

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How would the overlap work?

Context

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Medium-term

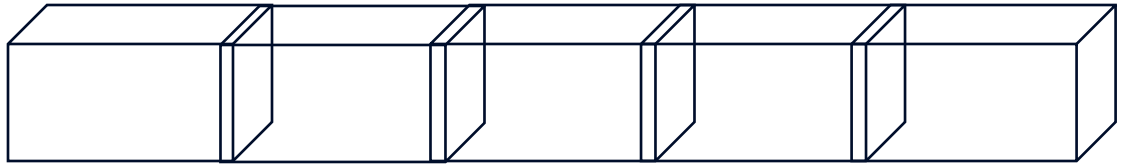
The 4D trajectory is a series of one or more 4D volumes.

How would the overlap work?

Context

CORUS five

Medium-term



The volumes overlap to express uncertainty. Earliest entry time, latest exit…

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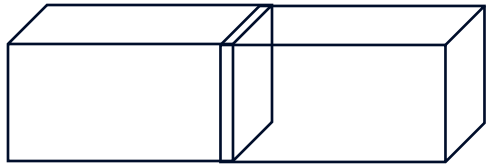
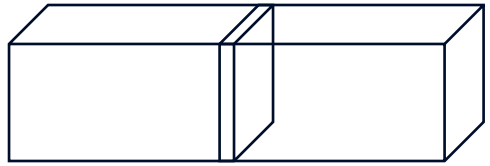
How would the overlap work?

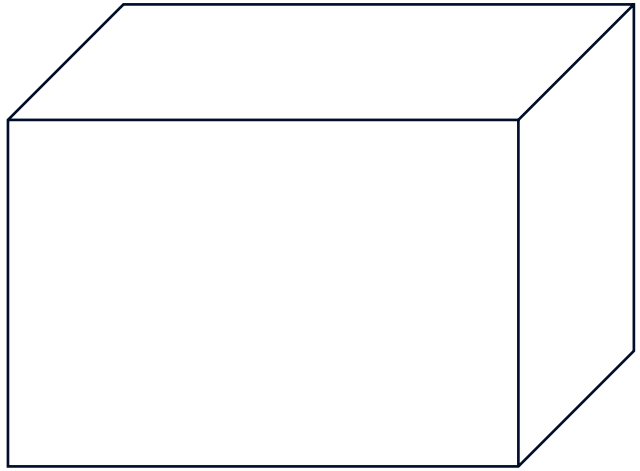
Context

CORUS five

Medium-term







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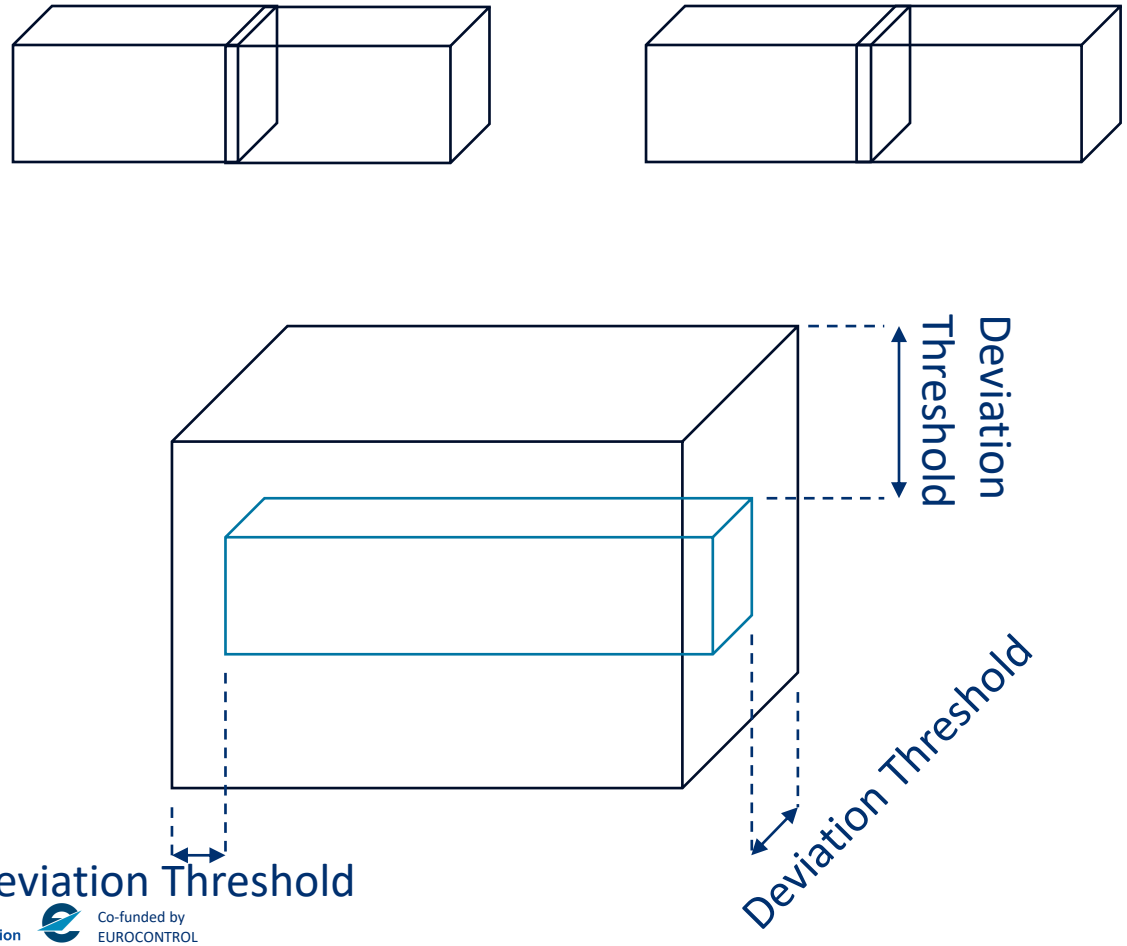
How would the overlap work?

Context

CORUS five

Medium-term



The deviation threshold is added to the volume requested by the UASO. Both are 4 dimensional.

The deviation threshold is set during the Airspace Risk Assessment

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How would the overlap work?

Context

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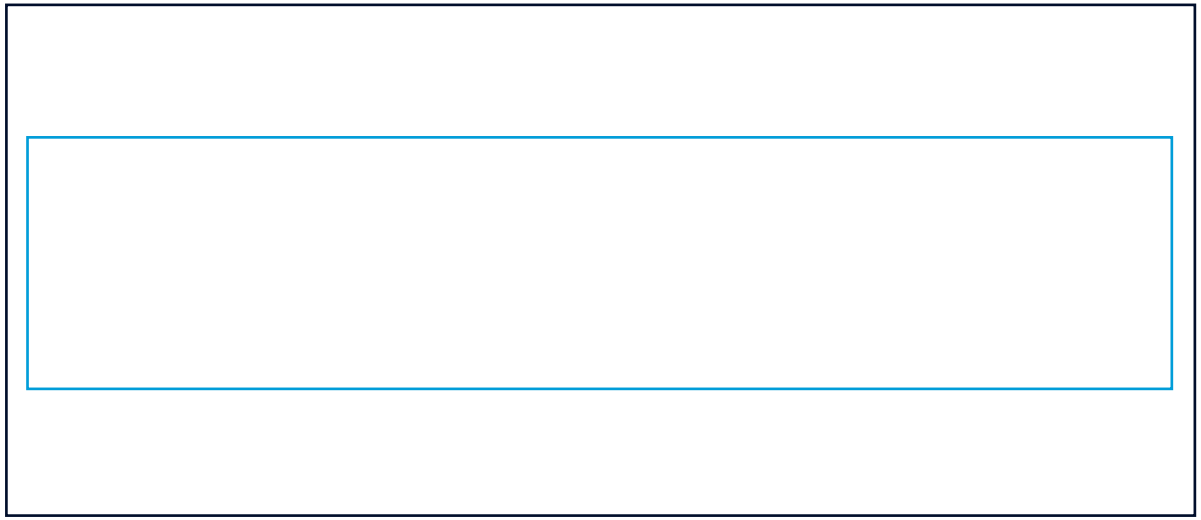
Medium-term

Flight authorisation request



Flight authorisation request + deviation threshold

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How would the overlap work?

Context

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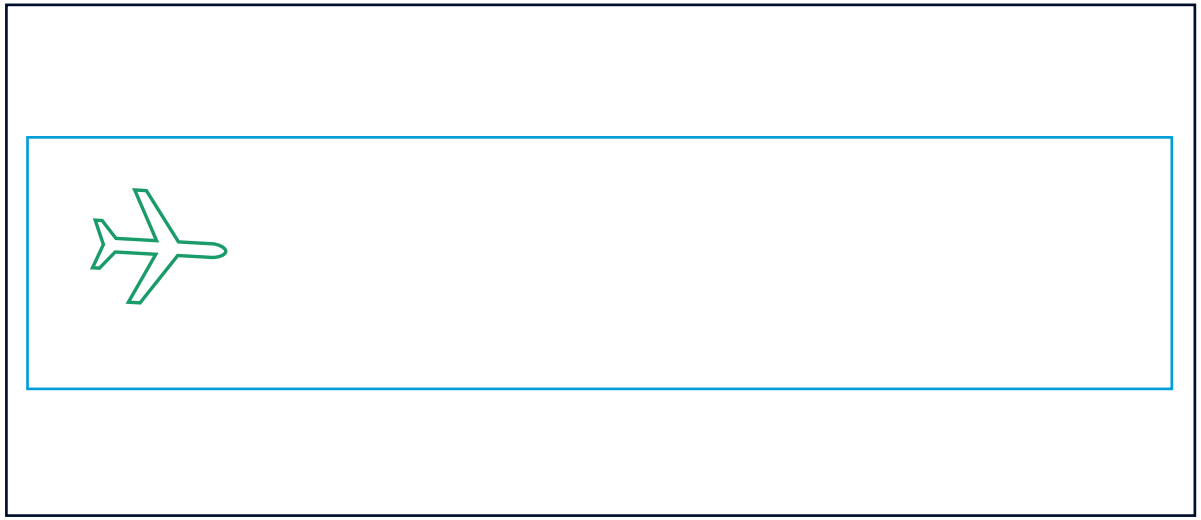
Medium-term

Flight authorisation request

UAS



UAS should conform with flight authorisation request with 95% probability

Flight authorisation request + deviation threshold

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How would the overlap work?

Context

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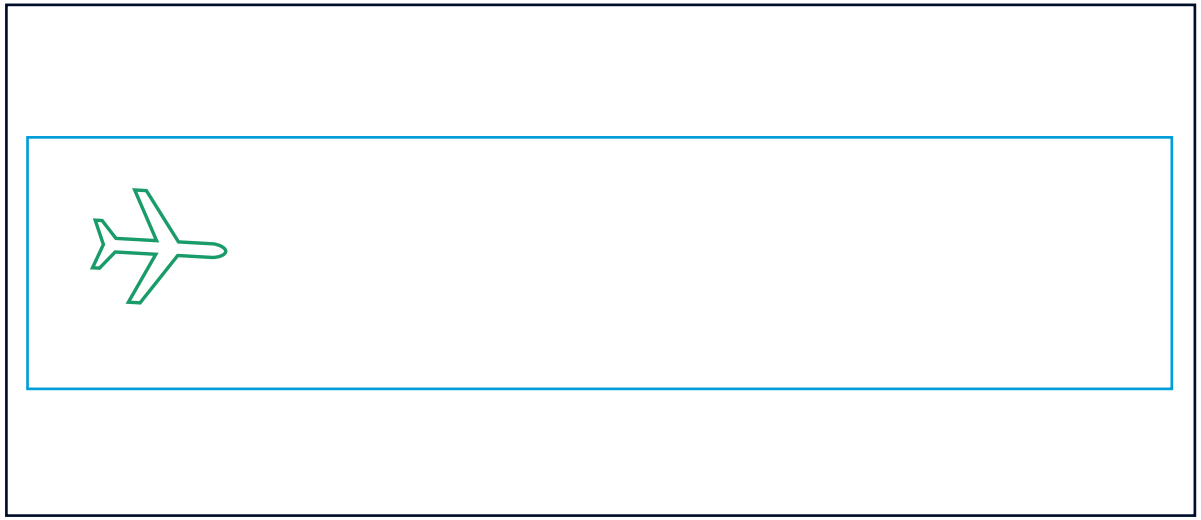
Medium-term

Flight authorisation request

UAS
Conforming



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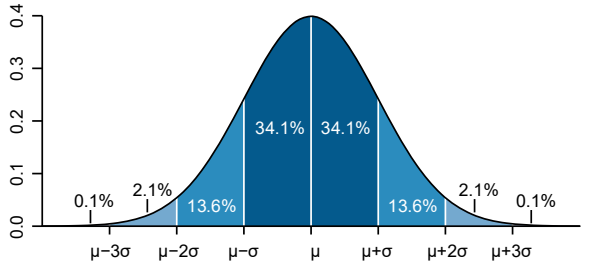

Flight authorisation request + deviation threshold

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How would the overlap work?

Context

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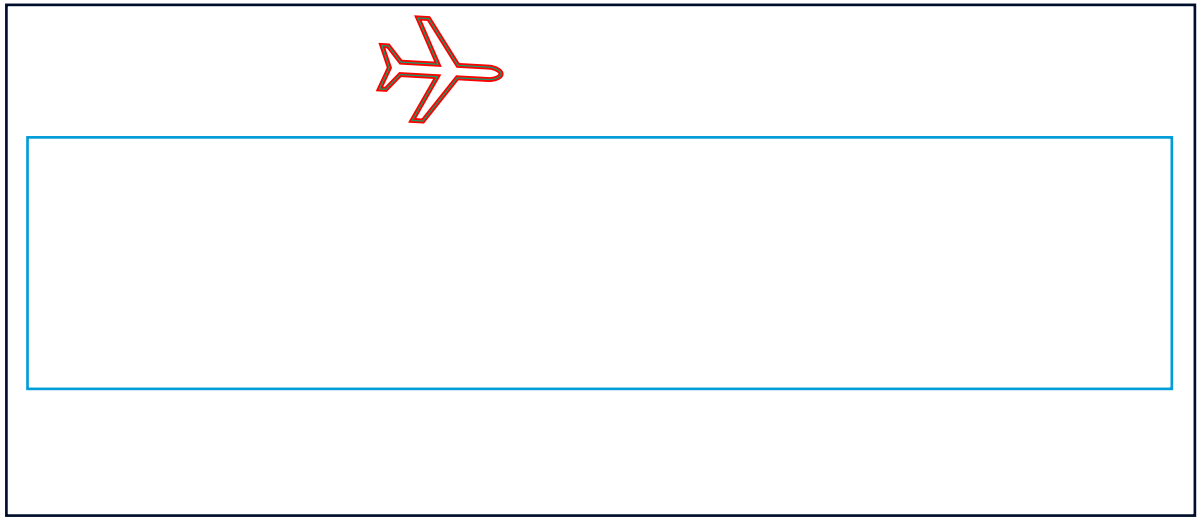
Medium-term

Flight authorisation request

UAS

Non-conformance warning



Conformance Monitoring Service: Operator of non-conforming UAS is warned to steer back into flight authorisation.

Conformance with deviation threshold is more probable than 95%.

Flight authorisation request + deviation threshold

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How would the overlap work?

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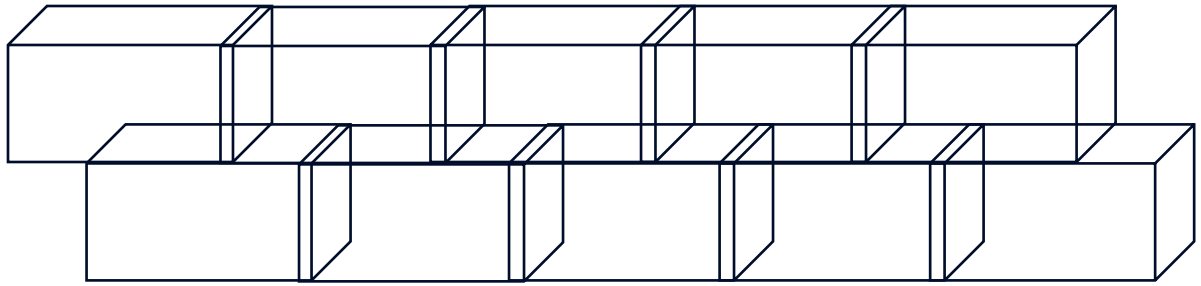
Medium-term



Short-term

Flights are deconflicted so that the deviation thresholds do not overlap
In 4D

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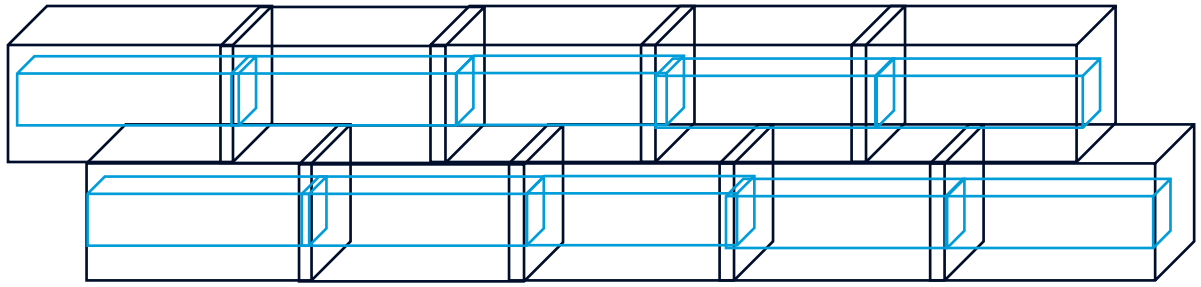
How would the overlap work?

CORUS five

Medium-term



Short-term

Flights are deconflicted so that the deviation thresholds do not overlap
In 4D
The flight authorisation requests are spaced by two deviation thresholds

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How would the overlap work?

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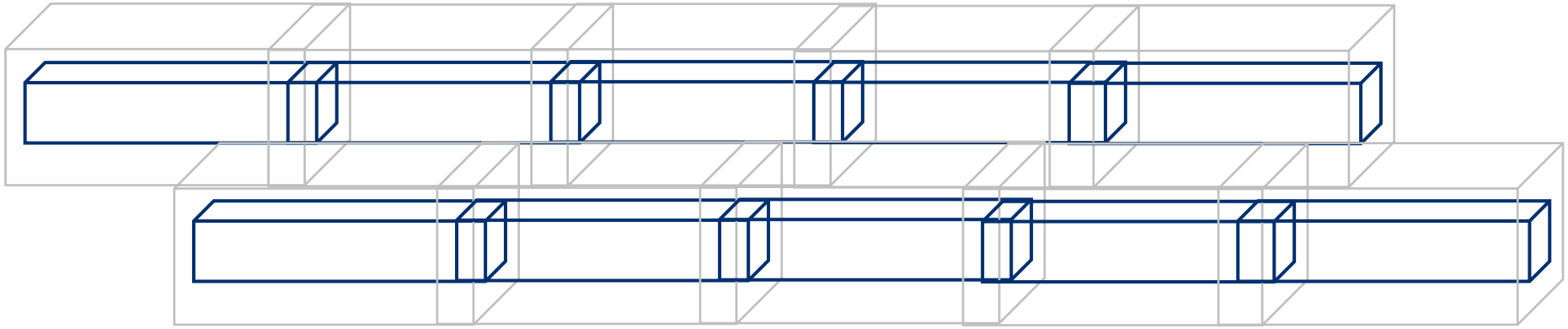
Medium-term



Medium-term

Thanks to tactical deconfliction, deviation thresholds can overlap

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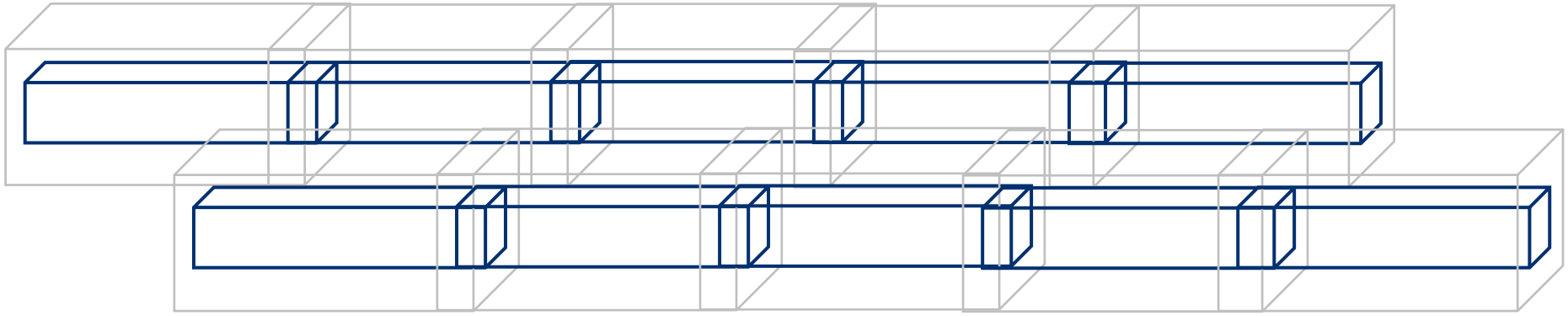
How would the overlap work?

CORUS five

Medium-term



Medium-term

Thanks to tactical deconfliction, deviation thresholds can overlap

Increasing capacity

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Food for thought

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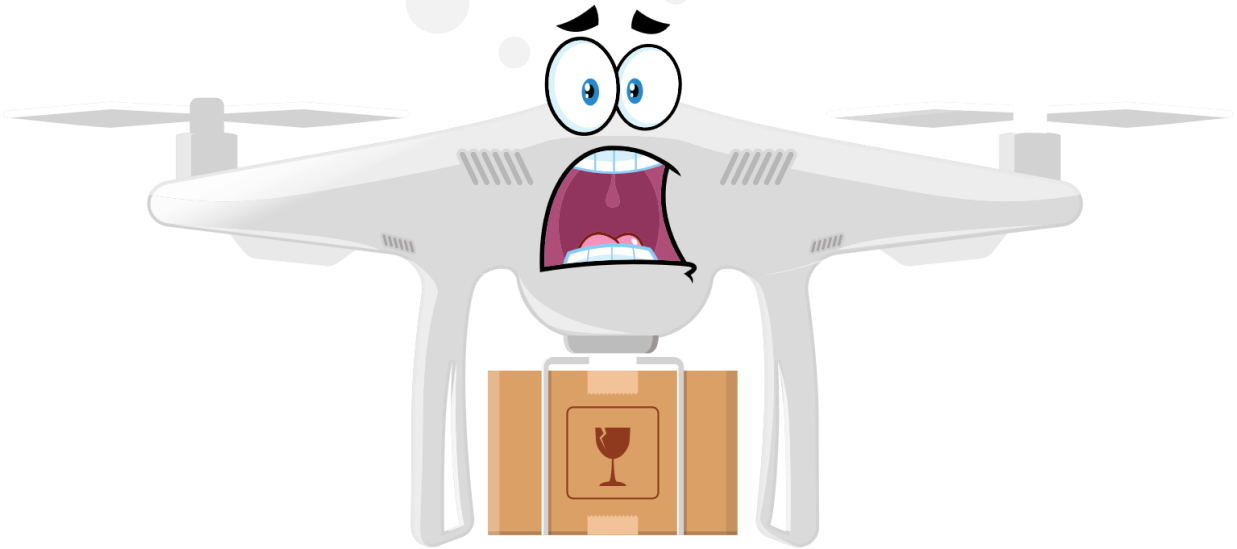
Medium-term

Should a conflict between a POBA and a UAS be resolved by:

- ❑ Separation provision
- ❑ Conflict Avoidance
- ❑ Both
- ❑ Other?

Overlap of U-plans

- Should we consider a % of overlap of U-plans?
- Only the overlap of deviation thresholds?



Conflict management in U-space - Future

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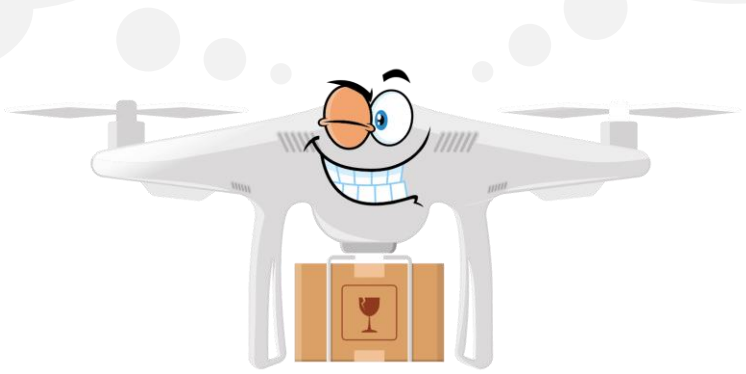
Long-term

- **Flight rules** are a core element of the LTH.
- New flight rules could cover aspects such as:
  - What airspace users can follow different flight rules.
  - What services are provided to airspace users following different flight rules.
  - How airspace users following different flight rules interact with each other.

- *BUT, before starting with Flight rules…*

Do we need Strategic service or could be enough with DCB measures + tactical (as UAM concept from NASA)?

While deconflicting U-plans, priority should be given to BVLOS U-plans over VLOS U-plans?



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Flight rules – the way ahead

- Today we have Visual Flight Rules and Instrument Flight Rules
- These are described in ICAO Annex 2.
  - Annexes to the Chicago Convention are hard to change.
- UAS cannot fly VFR as currently described due to lack of vision
  - No, FPV isn't good enough – anecdotal reports
- IFR today is flown by certified (or exempted) aircraft
  - In controlled airspace unless able to "see and avoid"
- Options:
  1. Alternative means of compliance & environment to allow IFR
  2. Modify VFR to base detection on electronic means
  3. A completely new flight rule

Not in CORUS five

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“Low altitude” IFR

+ve ☺

- No change to ICAO Annexes.
- IFR can be flown above 1000 feet, apart from take-off & landing

-ve ☹

- Requirements
  - Certified aircraft
  - Qualified pilot
  - Current equipage: Mode S / ADS-B
- Capacity
  - 5NM separation, 3 in some situations
  - ATCOs are needed for controlled airspace
- Implications
  - Need a means to land in IMC
  - Current infrastructure isn’t sufficient.
    - The lower the aircraft the closer the horizon – limit to radio propagation
  - Voice comms is an issue for remotely piloted vehicles

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Significant change implies changes to ICAO Documents + standards

Food for thought

Low altitude IFR

Low altitude IFR seemed like a good idea in WS1.

- Do we still think so?

New flight rule

- Is it better to look forward to a new flight rule? And until then fly in restricted airspace

Demand & Capacity Balancing

Demand and capacity balancing in ATM

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Context

In the context of ATM, the function of DCB is to minimise the effects of ATM system constraints. DCB ensures that air traffic demand does not exceed the available capacity of airspace or airports, maintaining safety and efficiency.

- The traditional ATM capacity limits is based on the performance of human air traffic controllers.
- In **ATM**, DCB is implemented in three phases:

Strategic stage	• Long-term planning to address schedule fluctuations, global traffic patterns, and seasonal/weather changes.
Pre-tactical stage	• Short-term (day-before or hours-before) evaluation of resources versus projected demand. • Adjusts assets, trajectories, airspace organization, and entry/exit times to prevent imbalances.
Tactical stage	• Real-time management of demand and capacity during operations. • Responds to weather conditions, infrastructure status, and disruptions in schedules with dynamic adjustments to airspace organisation, schedules, and resource allocation.

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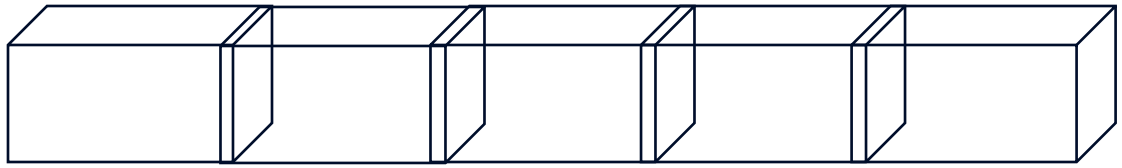
DCB in U-space today

- Compared to ATM, U-space has key differences, such as the distributed provision of highly automated services.
  - Therefore, the **traditional ATM capacity** limits based on the performance of human ATCOs are **not applicable** in the U-space environment.
- In STH, each U-space airspace is assumed to have a maximum capacity/density defined by the ARA. There are two main drivers to this limit:
  - Capacity constraint imposed by the **collision risk** of having multiple aircraft simultaneously operating in the same airspace volume. The more aircraft, the higher the risk.
  - Capacity constraint imposed by the **strategic deconfliction** of 4D trajectories, disallowing overlaps.
- The **UAS flight authorisation** service is employed to ensure that capacity/density limits are not exceeded, rejecting U-plan requests when appropriate,

How capacity is determined?

CORUS five



The 4D trajectory is a series of one or more 4D volumes.

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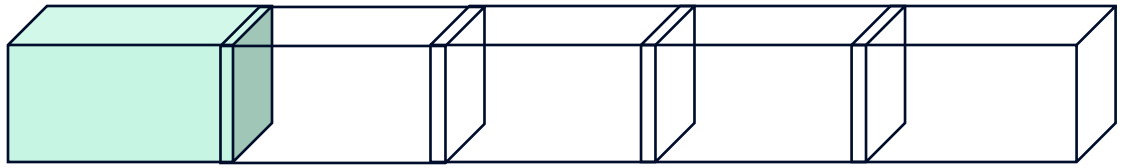
How capacity is determined?

CORUS five



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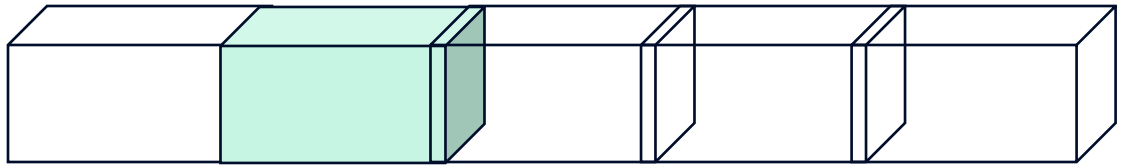

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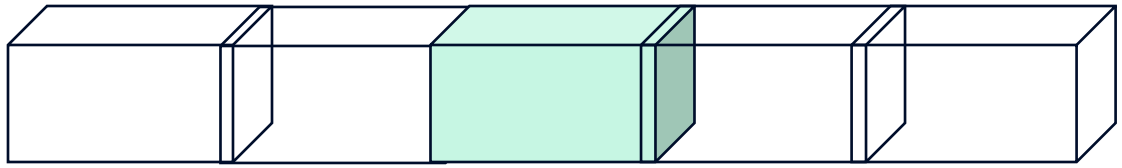

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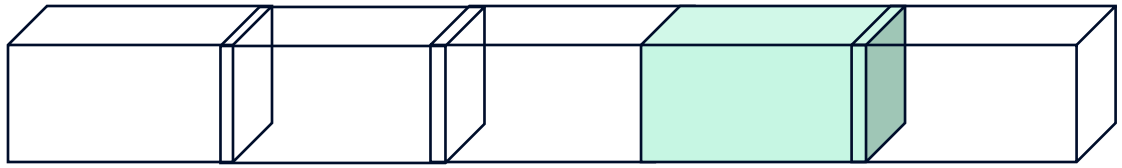

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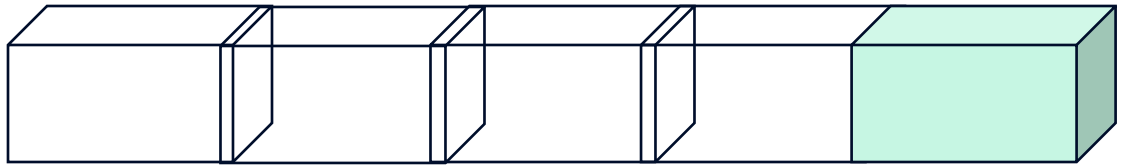

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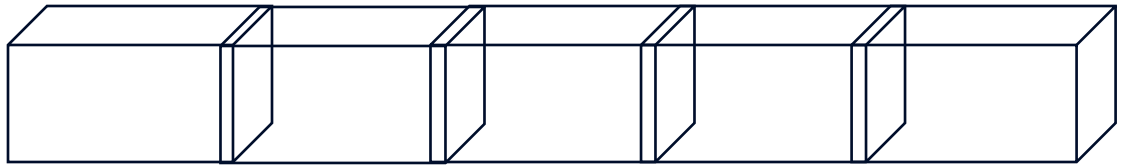

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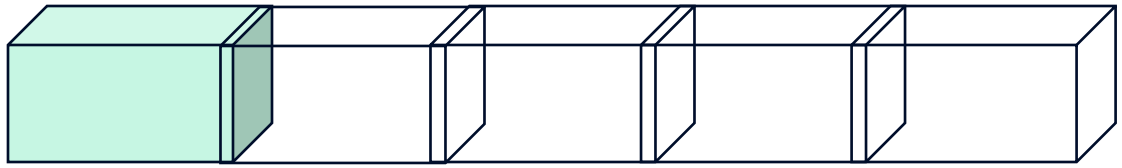

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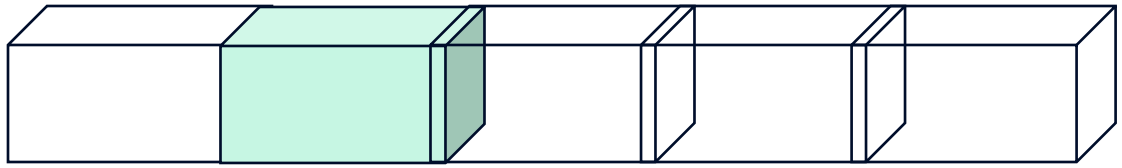

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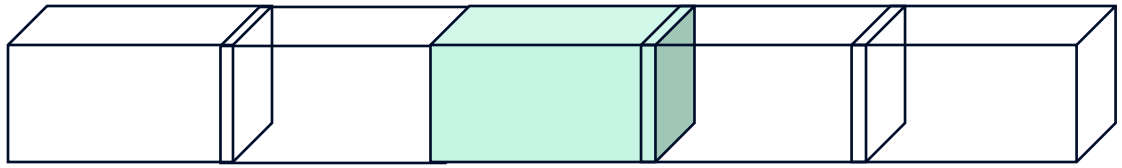

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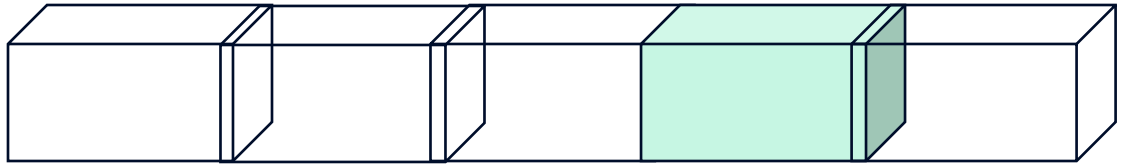

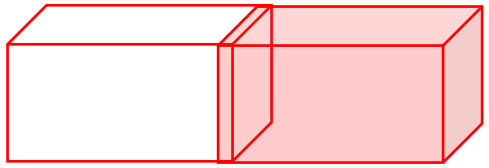

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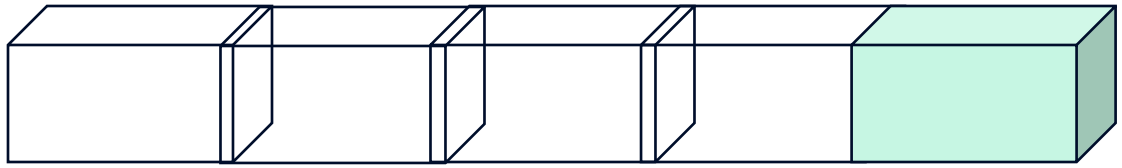

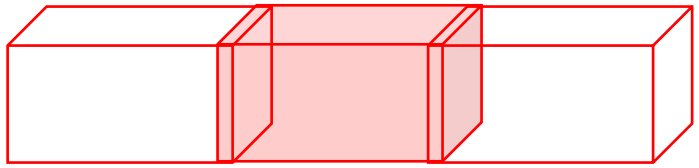

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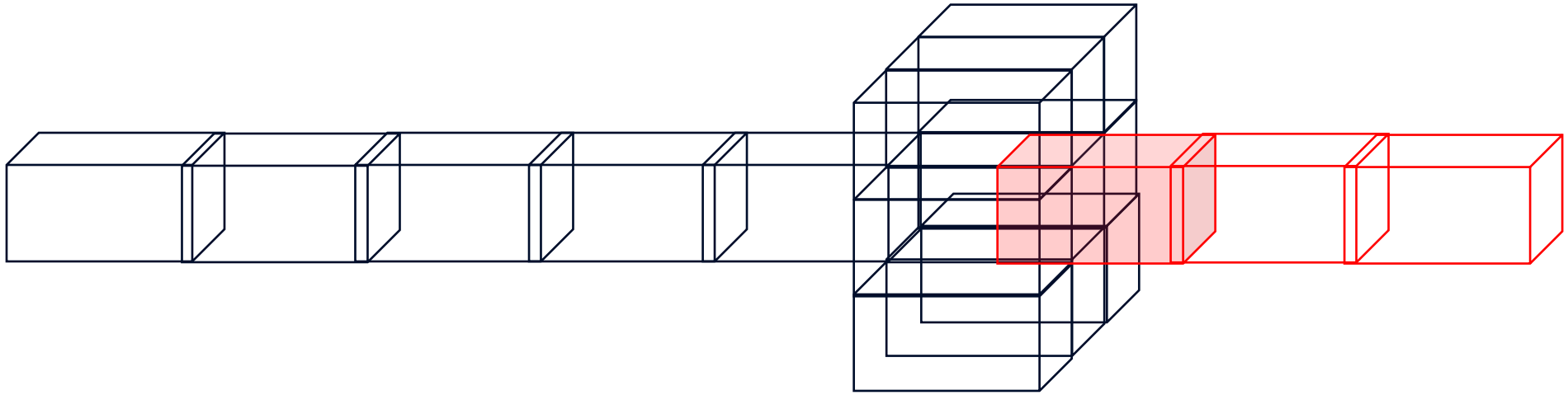

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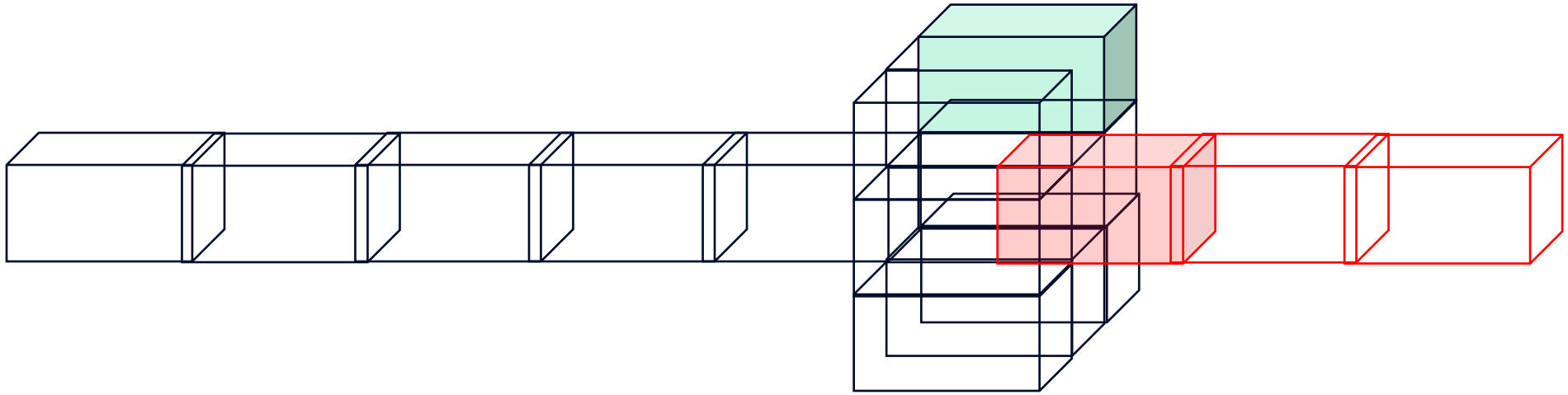

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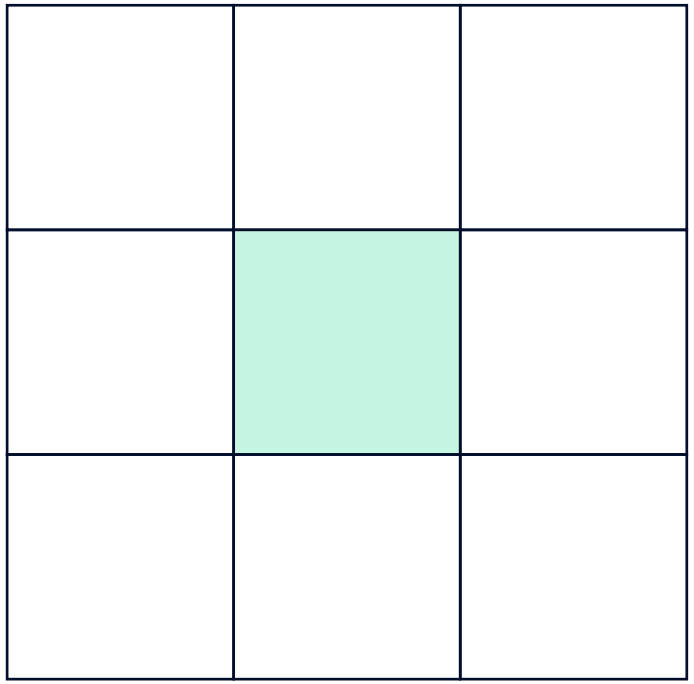

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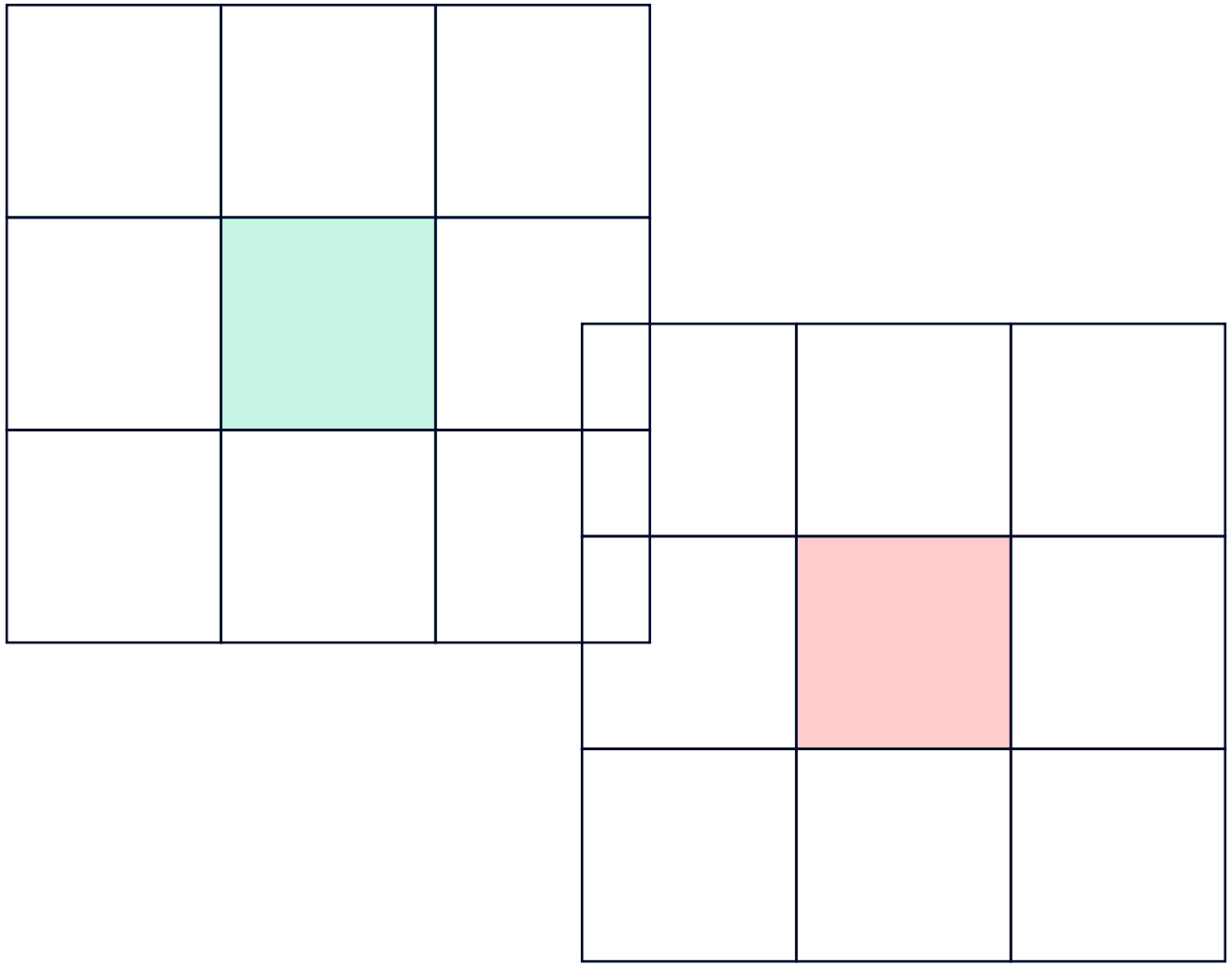

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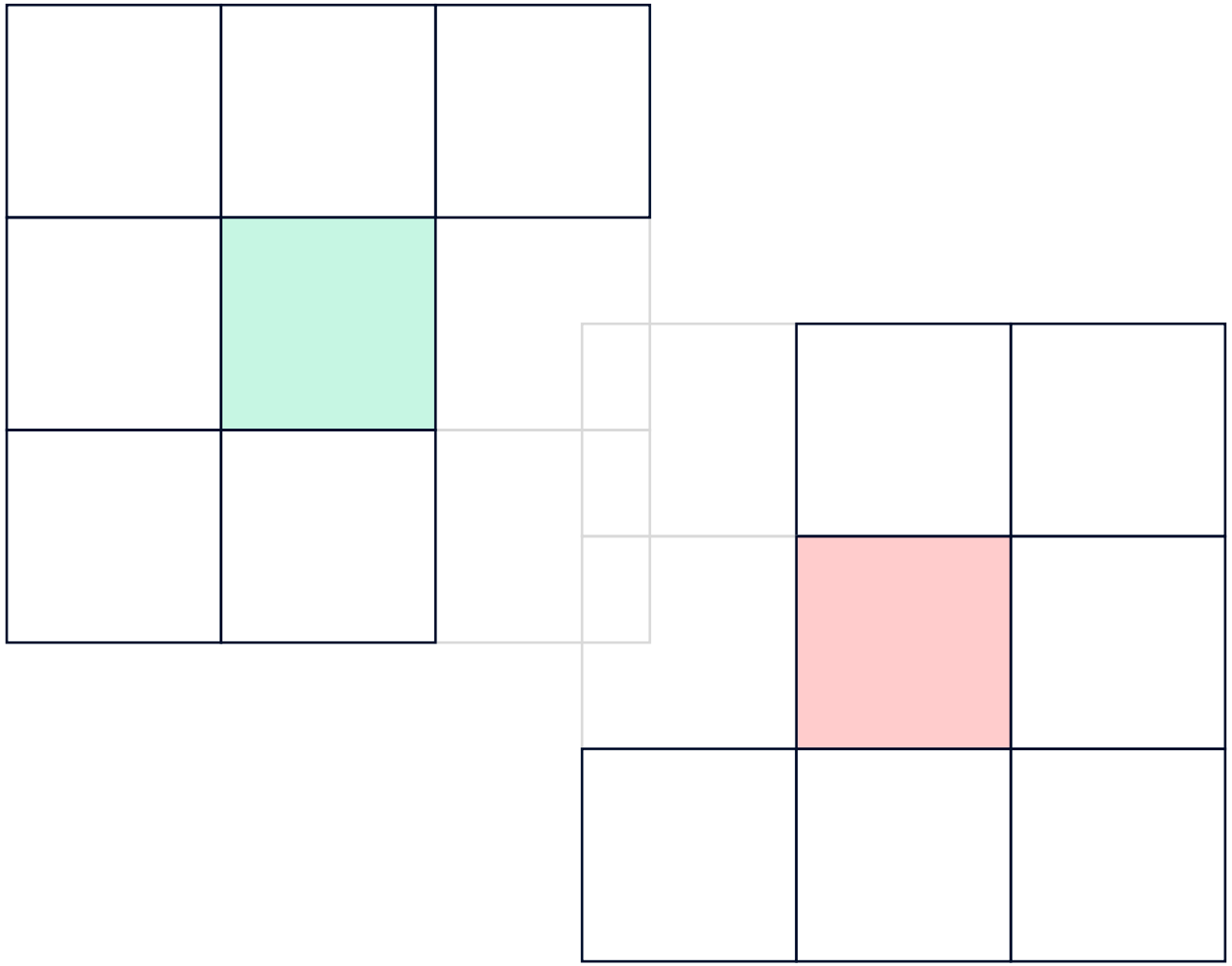

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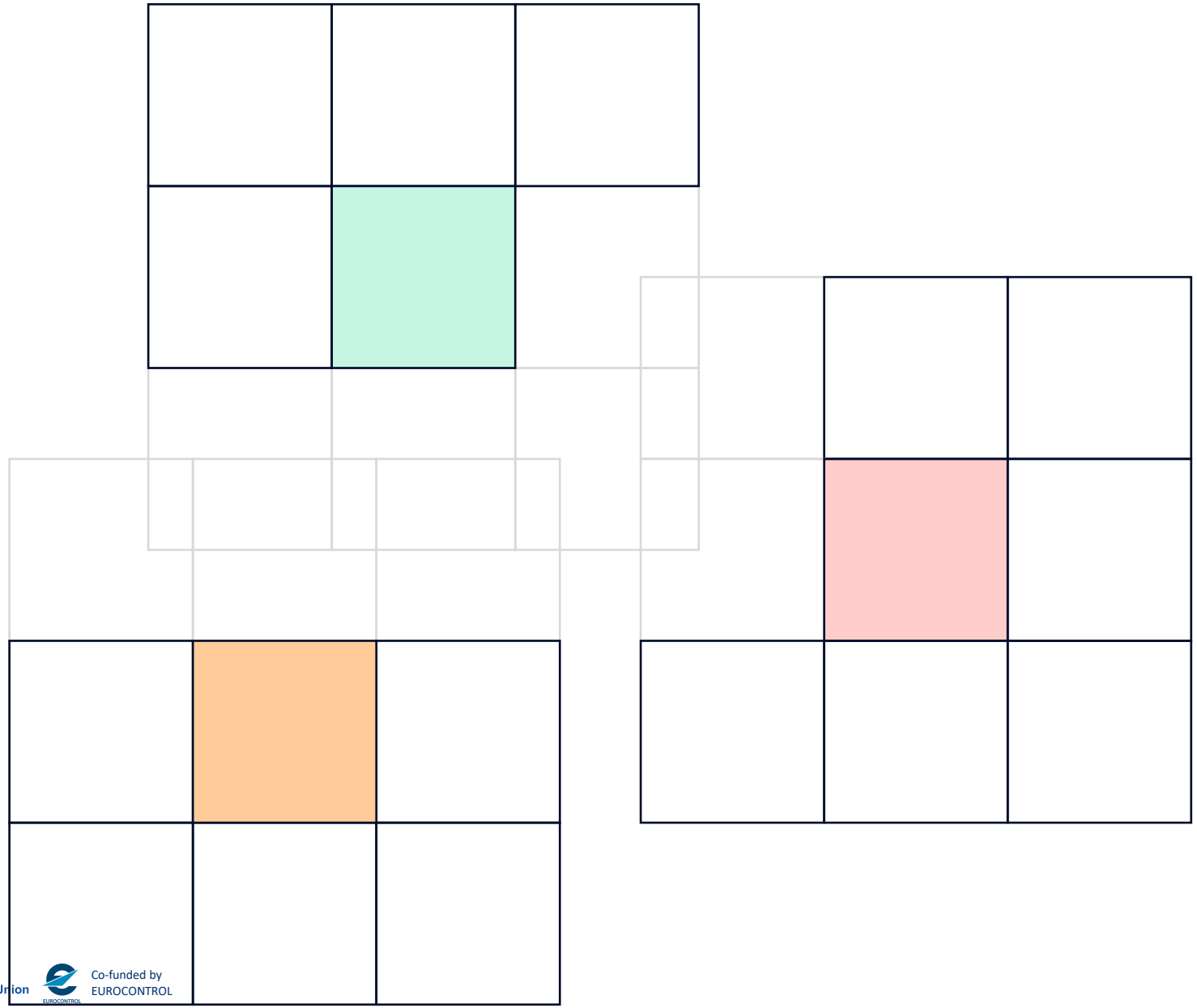

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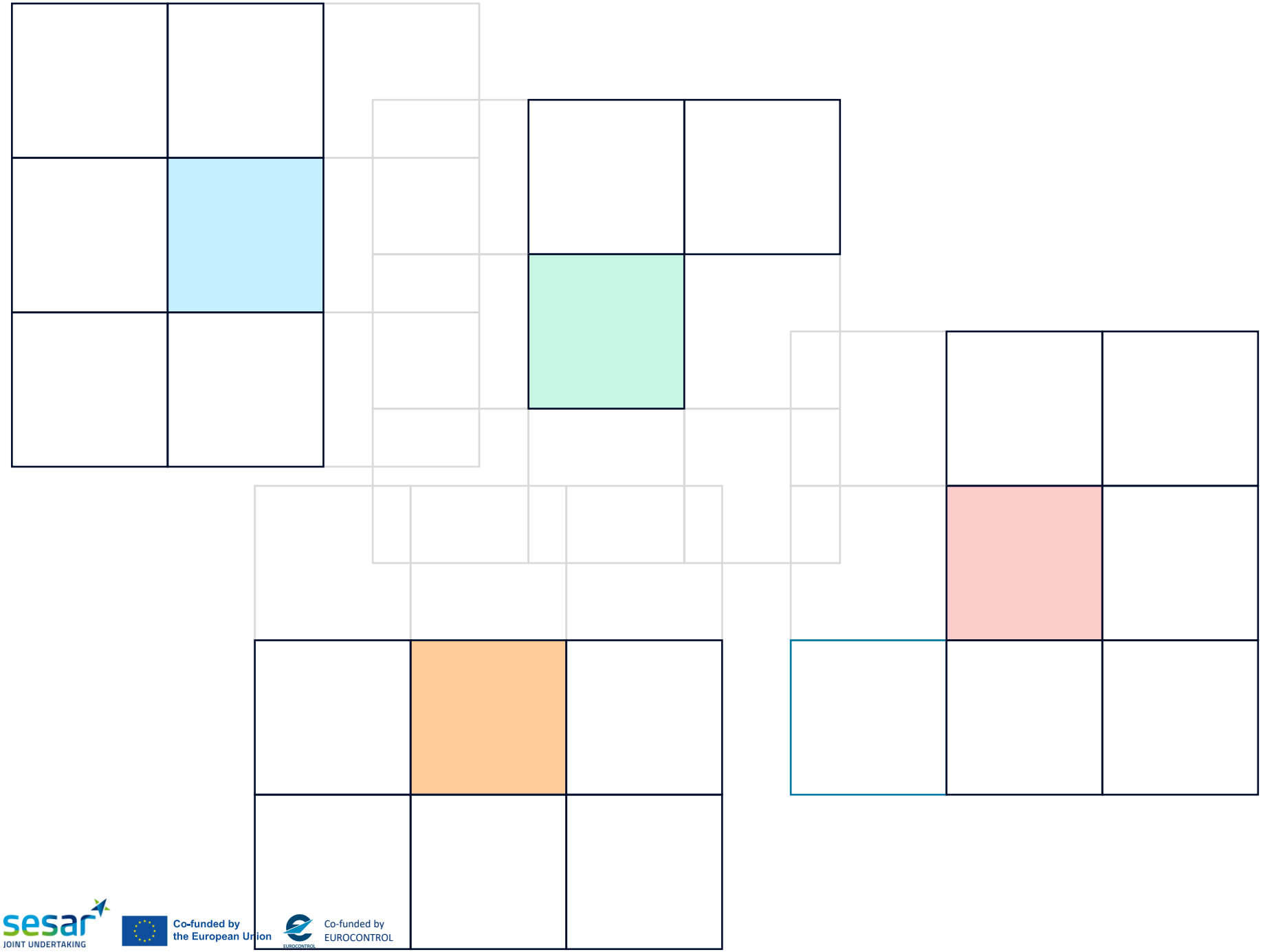

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DCB in U-space today

U-SPACE CAPACITY LIMITS - SAFETY

- There should be sufficient margin for manoeuvre for aircraft.
- This will limit the number of other aircraft that can be in proximity.

- The number of potential conflicts is the number of combinations of 2 from the total number of aircraft in proximity.
- Any SCM service is imperfect. There is always a residual risk of conflict. This is expressed through the risk reduction ratio.
- If the risk reduction ratio of the SCM service is, say, 100 for a pair of aircraft, then if there are 5 aircraft in proximity, benefit falls to 10.
- There will be a number of aircraft in proximity for which the target level of safety is not achievable.

Aircraft	Potential conflicts
1	0
2	1
3	3
4	6
5	10
6	15
7	21

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DCB in U-space today

U-SPACE CAPACITY

- Capacity for reasons of safety is a function of local traffic density, depending on a notion of *proximity.*

- Capacity for reasons of social acceptability would depend on other metrics such as noise level or “accumulated noise dose” or similar.

DCB in U-space today

CORUS five

Short-term

- DCB in U-space today is mentioned in the AMC to Article 10 but not explicitly the regulation
  - *AMC1 Article 10(2)(a);(b) UAS flight authorisation service*
  - *The USSP should…only accept the UAS flight authorisation request when…The maximum capacity and density of UAS flights in the U-space airspace … is not yet reached.*

- UAS flight authorization service = tactical phase (for DCB)

Strategic stage	• Periodic revision of ConOps and performance requirements for any U-space airspace
Pre-tactical stage	• None
Tactical stage	• UAS flight authorisation service

Food for thought

How can DCB be implemented in U-space by a federation of service providers?

Can a DCB service scale adequately if it is not implemented by a federation of service providers?

DCB in ATM is referred to as “flow management” or “network management”.

- Is DCB in U-space analogous to ATM? Are there flows? Is there a network?

DCB in U-space in MTH

CORUS five

Medium-term

- Demand Capacity Balancing is needed to **protect** tactical conflict resolution.
- DCB needs to be better described in regulation or Acceptable Means of Compliance.
- Key gaps include:
  - A business process that allows UASO to update the U-plan that also enables robust DCB.
- Expected innovations:
  - Dynamic deviation thresholds – to manage the balance between the weight of strategic and tactical mitigations and ensure that the efficiency and safety constraints are as equal as possible.
  - System-wide actions considering flights that span multiple U-space airspaces / constrained resources.
  - Shift from FC-FS to something more fair

DCB in U-space in MTH

Efficient use of U-space airspace

- The U-plan is a series of one or more 4D volumes
- “Demand” is reduced by subdividing the flight into more volumes.
  - Benefit – traffic management knows more precisely where the aircraft is
  - Cost – UASO has to more precisely control where the aircraft is
  - May be limited by needs of contingency processes

Food for thought

How to use airspace efficiently?

- ❑ Per U-space airspace: maximum dimensions for any 4D volume
- ❑ DCB measure: “replan with more volumes”
- ❑ Any other idea?

Is delay a useful measure for DCB in U-space?

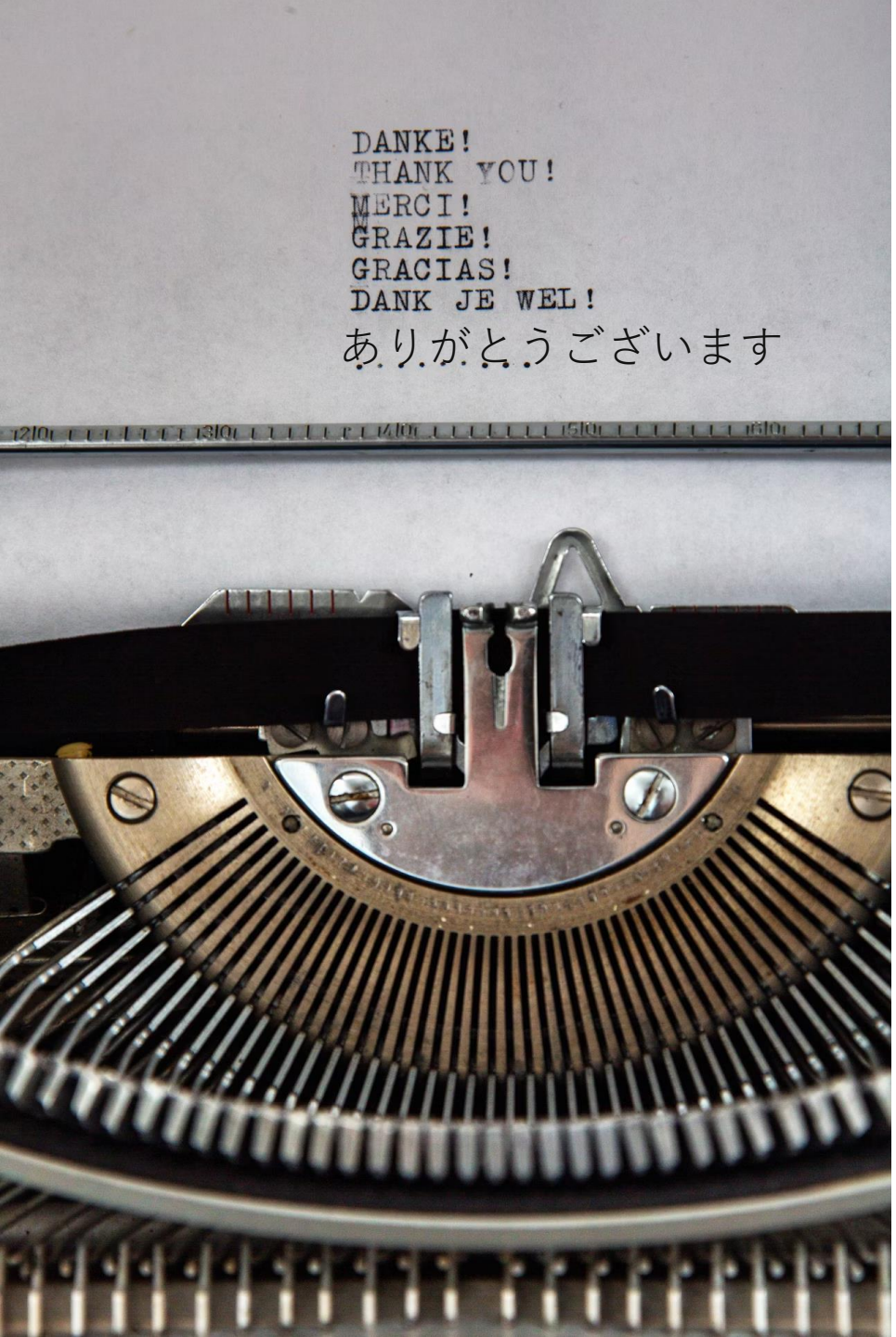
Will aircraft operators change their plans?

DCB in U-space in Future

CORUS five
Long-term

- DCB more advanced, with further functionalities, better density model, etc.
- DCB in current ATM in Europe uses forecasting (prediction) and DCB planning
  - *Is anything like this needed for U-space?*
- Robust, scalable DCB architectures and business processes.
  - *The door is open here for research.*

- In LTH, it is supposed that manned and unmanned traffic DCB will be under a common paradigm.
  - *How to manage this, if demand of manned traffic is influenced by take-off time uncertainty?*



Thematic Area 5: Conflict Management & Demand and Capacity Balancing