CORUS five

Service Delivery Management

Vadim Kramar, Thomas Lutz, Stefan Steinhauser
2nd CORUS five workshop, 1-3 Oktober 2025

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Welcome!

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TOPICS TO BE COVERED

- Recap
- Double check „rest of world“
- Food for thought
- Discuss
- Way forward (Plenary session on Friday)

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Data Integrity, Cybersecurity and Multi-USSP Environment – *Debrief*

Thomas Lutz, Frequentis
Vadim Kramar, VTT Technical Research Centre of Finland

CORUS five First Stakeholder Workshop
Castelldefels, Spain
21st & 22nd of January 2025

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What happened before…

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What role should centralised components take ?

36.0 — High

Can CORUS five create a prioritisation list on standardisation needs taking into account the gaps identified ?

38.5 — High

How can compatibility between U-space services and services provided outside of U-space airspace be achieved ?

37.9 — High

What are the communication requirements between automated and/or autonomous systems and human actors ?

40.7 — High

Collaborative decision making Vs information airspace users don't want to share for competitive reasons

Clear responsibilities for information exchange and centralization. Within U-space and outside. Infrastructure/equipage versus capacity and other limitations

How to share a common situational awareness with the right level of integrity between all stakeholders ?

Cloud architectures with real-time capability

Flexibility in implementation approach (how the concepts are deployed) to allow for states that require centralized service (CAA or ANSP) involvement.

Link between system criticality (e.g., tactical separation of pax carrying ops), latency requirements, and failure response to system loss/compromise.

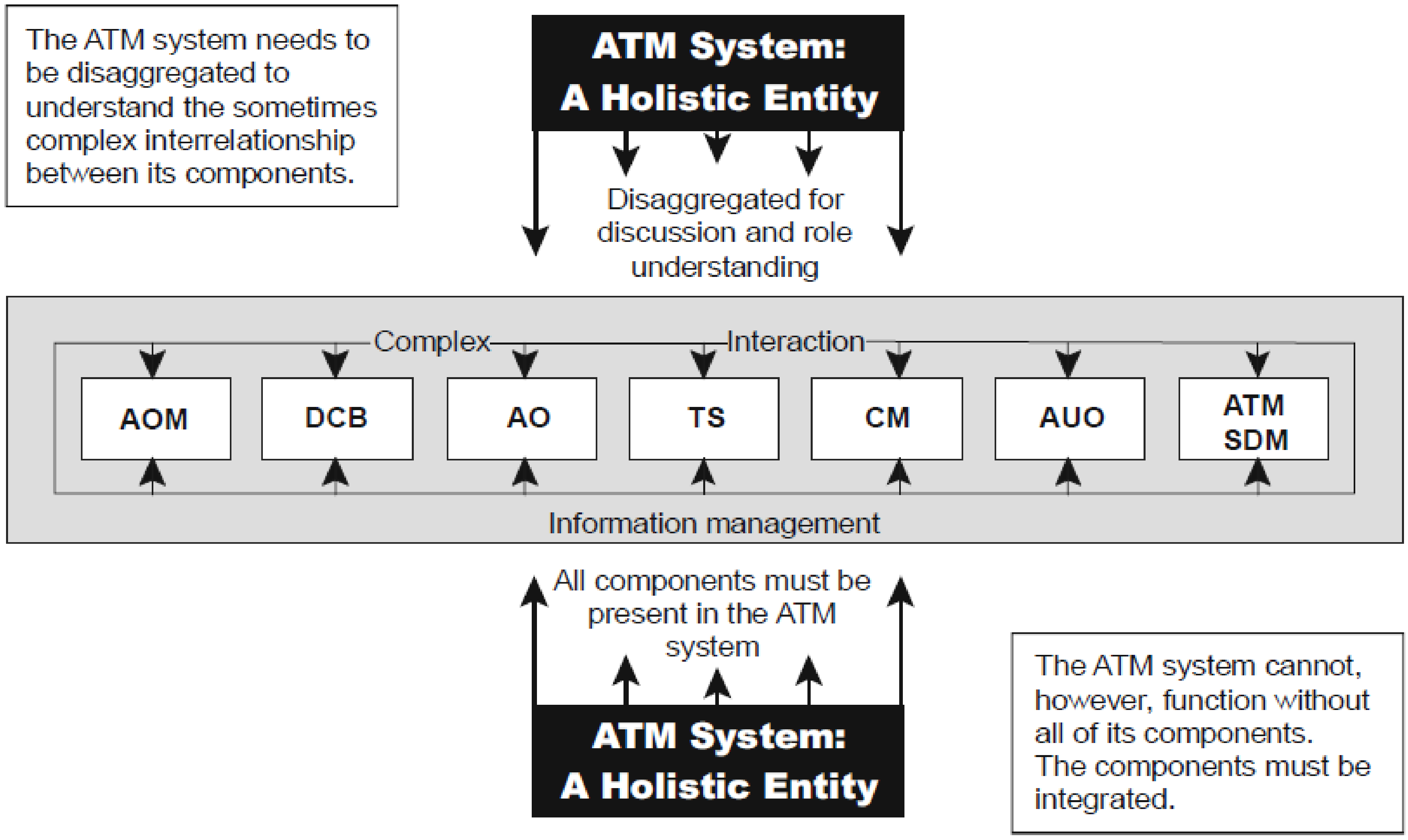
GATMOC

„Complex interaction“

… enabled by

„Information Management“

Doc 9854 AN/458 – Figure 2-1



AOM — Airspace organization and management
DCB — Demand/capacity balancing
AO — Aerodrome operations
TS — Traffic synchronization
CM — Conflict management
AUO — Airspace user operations
ATM SDM — ATM service delivery management

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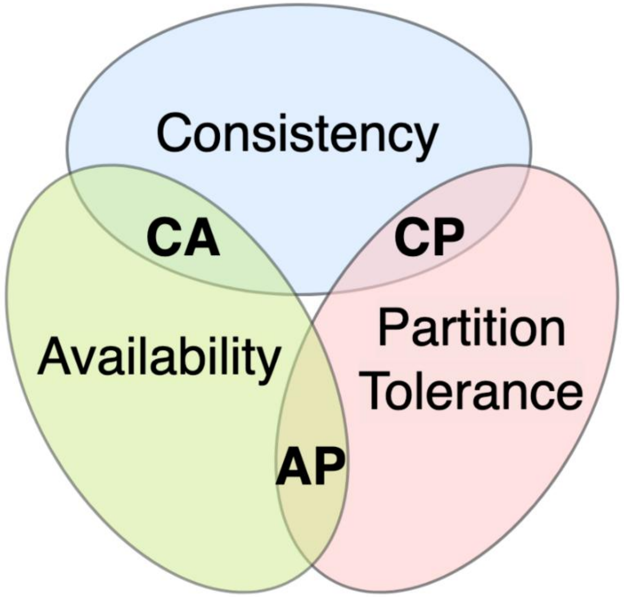
Complex interaction with limited magic

In database theory, the CAP theorem states that any distributed data store can provide at most two of the following three guarantees:



Consistency

Every read receives the most recent write or an error.

Availability

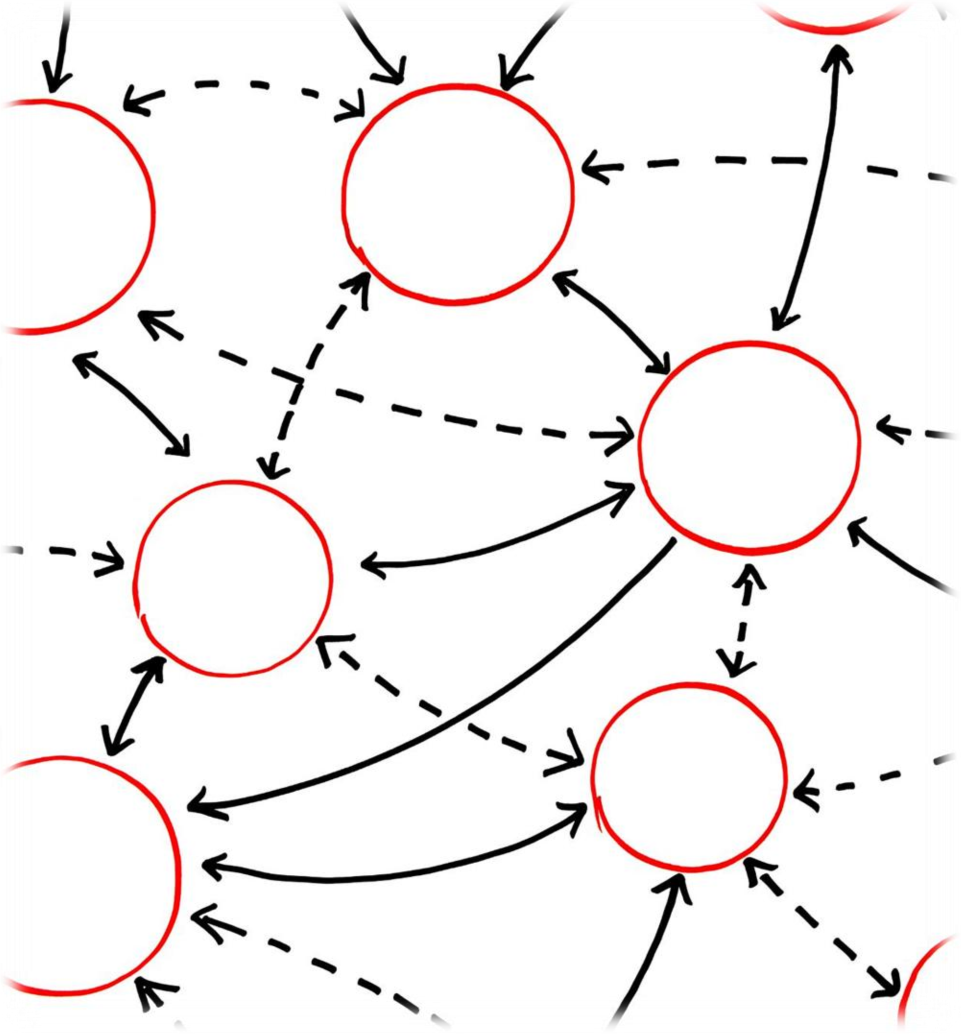
Every request received by a non-failing node in the system must result in a response.

Partition tolerance

The system continues to operate despite an arbitrary number of messages being dropped (or delayed) by the network between nodes.

https://en.wikipedia.org/wiki/CAP_theorem

Consistency, Availability, and Partition Tolerance II



Consistency in Distributed Systems

Consistency guarantees all users see the most recent data simultaneously, critical for accuracy in applications like banking.

Availability Assurance

Availability ensures every request receives a response, even if some servers fail, essential for user-facing applications.

Partition Tolerance Explained

Partition tolerance enables systems to continue operating despite network failures between geographically distributed servers.

Choosing Two Out of Three

CAP Theorem Basics

Distributed systems cannot guarantee consistency, availability, and partition tolerance simultaneously.

Consistency and Availability Systems

CA systems prioritize consistency and availability, but do not handle network partitions well.

Consistency and Partition Tolerance Systems

CP systems ensure consistency and partition tolerance but may sacrifice availability during network failures.

Availability and Partition Tolerance Systems

AP systems maintain availability and partition tolerance, but might serve outdated data.

Living the CAP Theorem

… setting up a Conference Social Event

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The Scenario

A group of friends at a conference wants to meet for a drink at night.

They need to agree on:

- A place
- A time
- A way to communicate

But not everyone is always reachable or responsive.

Characteristics in this system:

- Consistency: Everyone agrees on the same pub (place).
- Availability: Everyone gets a response, even if it's not final.
- Partition Tolerance: Some friends are unreachable, but plans still proceed.

Each component (place, time, communication) may "trade off“ differently.

Trade-off Examples

- If everyone must agree on the pub (Consistency), some may not get the message (low Availability).
- If everyone gets a message (Availability), some may end up at different pubs (low Consistency).
- If some are unreachable (Partition), the rest will still meet (Partition Tolerance). There might be two or more venues.

The system might have different trade offs depending on „time left to meet“.

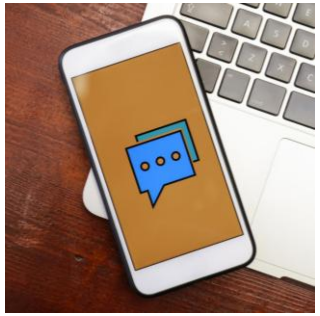
Other Examples

Consistency in Banking

Banking systems maintain consistent account balances across all branches and ATMs ensuring accurate financial information.

Availability in Online Shopping

Online shopping platforms stay accessible during peak hours, allowing uninterrupted browsing and purchases.



Partition Tolerance in Messaging

Messaging apps keep delivering messages even when parts of the network are temporarily unreachable.

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CAP Key Takeaways

Understanding CAP Theorem

CAP Theorem defines the trade-offs between consistency, availability, and partition tolerance in distributed systems.

Strategic Design Choices

System designers must prioritize system properties based on application needs and constraints.

Trade-Off Implications

No system can perfectly satisfy all three CAP properties; trade-offs affect system behavior and reliability.

Stakeholder Awareness

Understanding CAP helps stakeholders appreciate design challenges and intentional system behaviors.

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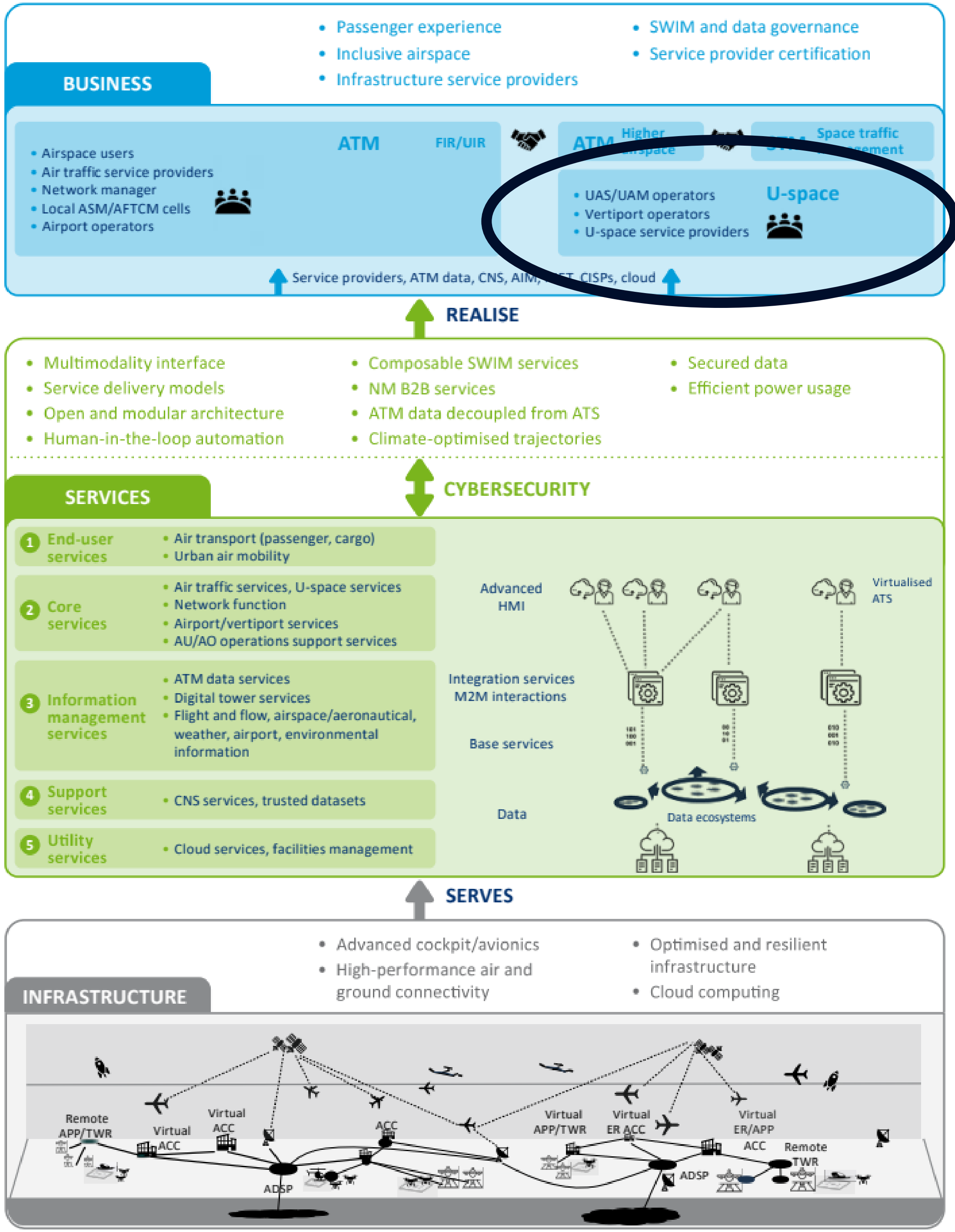
Service Delivery Model

- Business
- Services
  - End User
  - Core
  - **Information Management**
  - Support and Utility
- Infrastructure



European ATM Master Plan 2025 Edition– Figure 5

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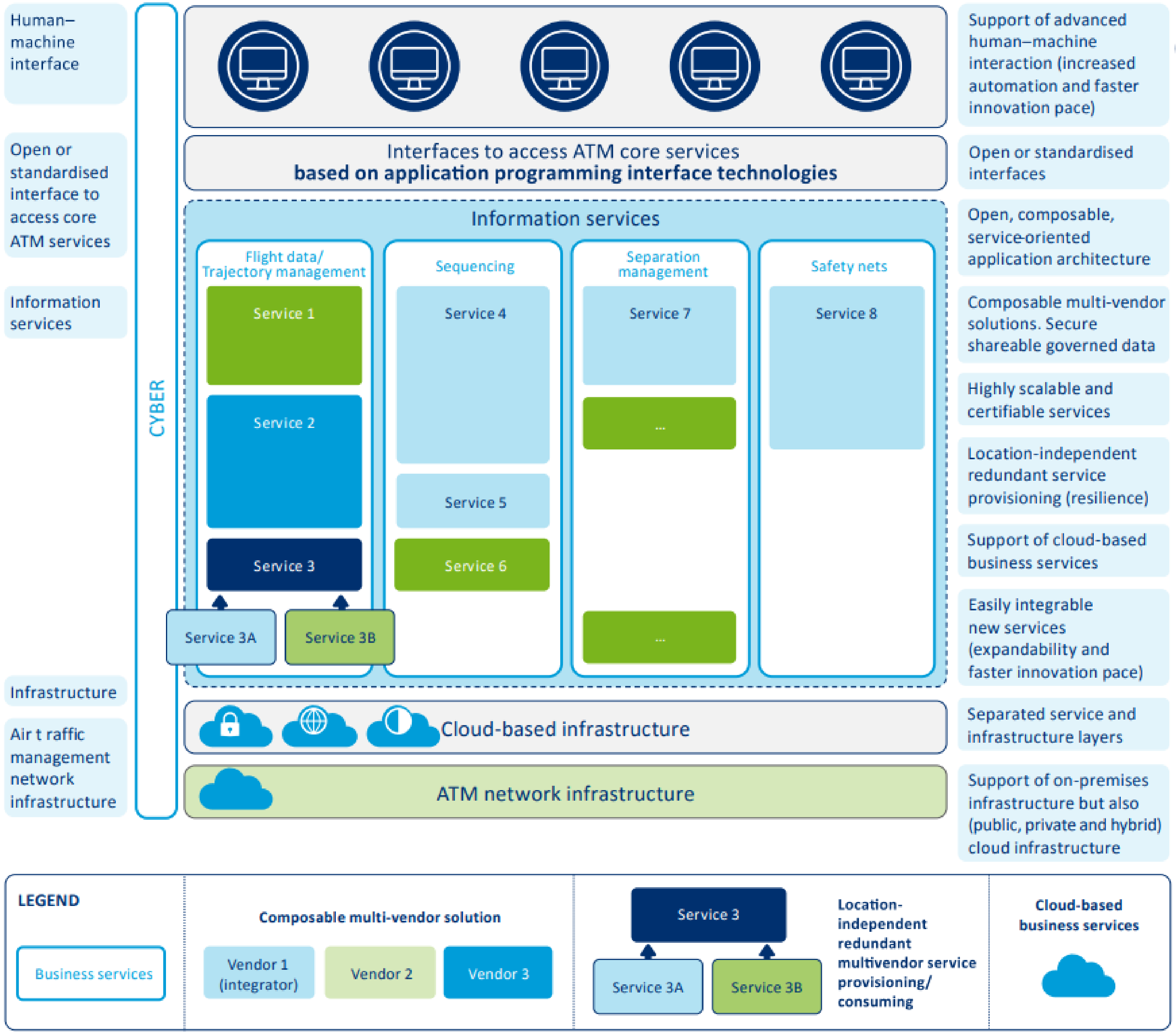
ATM Masterplan Typical ACC

- Incorporating both on-premises components and leveraging various cloud types (i.e. private, public and hybrid).
- Support multiple deployment models,
- Scale service delivery more efficiently, integrate new technologies seamlessly and benefit from faster innovation.
- Increase resilience



European ATM Master Plan 2025 Edition - Figure 4

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Information Management

- GATMOC
  - Chapter 2.9
- ATM
  - Chapter 3.4.2 in Master Plan
- TBO
- U-space
  - AMC6 Article 7(5)
    U-space service providers
- ASTM
  - F3548

… it's set for near, mid & long term.

2.9 INFORMATION SERVICES

2.9.1 The function of information services deals with the exchange and management of information used by the different processes and services. It will ensure the cohesion and linkage between the seven concept components described above.

Information management

2.9.2 Information management provides accredited, quality-assured and timely information used to support ATM operations. Information management will also monitor and control the quality of the shared information and provide information-sharing mechanisms that support the ATM community.

2.9.3 Information management will assemble the best possible integrated picture of the historical, real-time and planned or foreseen future state of the ATM situation. Information management will provide the basis for improved decision making by all ATM community members. Key to the concept will be the management of an information-rich environment.

2.9.4 Information management will contribute to meeting the expectations of the ATM community through all operational services. Its more direct contribution to improvements in the ATM system will be in the quality of the information that will, in turn, provide significant additional benefits. In particular, the wide availability of high-quality, relevant aeronautical data presented to all airspace users in a usable format will contribute to increased aviation safety.

2.9.5 The ATM community will depend on information management, shared on a system-wide basis, to make informed collaborative decisions for best business and operational outcomes. Within the ATM system, based on this operational concept, it will be the information itself that will be of significance and not the technology that supports it.

2.9.6 For the ATM system to operate at its full potential, pertinent information will be available when and where required.

2.9.7 ATM data has temporality and will change over time, but to varying degrees in terms of frequency or magnitude, varying from almost static to very dynamic. Information management will recognize and accommodate this temporality of data. This will impact the organization and issuance of data.

2.9.8 Information may be personalized, filtered and accessed as needed. The initial quality of the information provided will be the responsibility of the originator; subsequent handling will not compromise its quality.

2.9.9 The information management function will allow all participants to adjust information sharing to mitigate any proprietary concerns. Sensitivity with regard to some data will continue to exist and will be managed within the information management function. Once an ATM community member agrees to release information, the data will be available to the extent required and will be made accessible to specified parties.

2.9.10 Information management will achieve a seamless transfer of relevant information between parties in a flexible, adaptable and scalable information environment.

2.9.11 Information management will use globally harmonized information attributes.

Sharing airspace = sharing information

Crewed aircraft

- Dynamic airspace information
- Flight intent
- Traffic information / conspicuity
- Separation procedures
- …

Uncrewed aircraft

Specific information	Shared information	Specific information

US/Europe vs? Australia/UK

<u>Segregated</u> airspace for UAS

- Federated UTM services – same assurance level
- U-space operations ”black box” to ATC

“How to manage an airspace in which lots of drones are flying?”

<u>Integrated</u> airspace & ATC involvement

- Different levels of safety assurance need to co-exist with UTM in between
- Australia – FIMS
- NATS UK OpenAir outlines a federated UTM between USS with a centralised flight board and ATC interaction

“How can some drones be added to an existing airspace with crewed traffic?”

What‘s next – aiming for Integration

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- High level of Automation is set
- Information Management is set

- Assumption:
  - Revolutionary changes in ATM are unlikely
  - Future AAM/IAM/… will neither be full centralized nor fully federated
    - Role of Operator as just one example

SO … ?

Hey AI, what is the difference between federation of service providers in u-space and collaborative decision making in ATM TBO ?

Federation in U-space

is about enabling multiple, competing service providers to safely manage drone traffic through interoperability.

CDM in ATM TBO

is about all stakeholders in manned aviation working together to make the best possible decisions for the entire system.

Can CDM guide long term architecture?

- ✓ Combining input from many stakeholders to make the best decision for a group.
- ✓ In collaborative decision making, the goal is always to reach a consensus.
- ✓ Often, the solution is selected from a set of a few proposed options.

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Maybe Collaborative Decision Making ? CORUS five

2.2 Collaborative decision-making (CDM) in the context of ATFM

2.2.1 CDM is the process which allows decisions to be taken by amalgamating all pertinent and accurate sources of information, ensuring that the data best reflects the situation as known, and ensuring that all concerned stakeholders are given the opportunity to influence the decision. This in turn enables decisions to best meet the operational requirements of all concerned.

- ICAO, Air Traffic Flow Management, Part II

Collaborative Decision Making (CDM) will improve air traffic management by sharing information and data between airport operators, aircraft operators, ground handlers and air traffic control.

- Airservices Australia, Collaborative Decision Making, AUG10-118

… continued …

- **FAA AFTM -** https://cdm.fly.faa.gov/ *„CDM is an operating paradigm where ATFM decisions are based on a shared, common view of the NAS and an awareness of the consequences these decisions may have on the system and its stakeholders.*
  There are two central tenets to CDM: that better information will lead to better decision-making, and tools and procedures need to be in place to enable air navigation service providers and the flight operators to more easily respond to changing conditions.
  By sharing information, values and preferences, stakeholders learn from each other and build a common pool of knowledge, resulting in ATM decisions and actions that are most valuable to the system."
- **A-CDM** (https://www.eurocontrol.int/concept/airport-collaborative-decision-making) *"encouraging the airport partners (airport operators, aircraft operators, ground handlers and ATC) and the Network Manager to work more transparently and collaboratively, exchanging relevant accurate and timely information."*
- **Logistics** „ Collaboration in supply chain and logistics means building supply chain operations on a culture of visibility and collaboration across all the partners.
  In today's supply chains disruptions are inevitable. Professionals involved in the process need to deal with unanticipated changes on a daily or weekly basis. However, since they need to navigate around different siloed and functional supply chain applications, they are not always able to mitigate the risks associated with these disruptions. Major losses can be avoided if we build working connections.

Mid term …

- ***Will Collaborative Decision Making scale?***

- **Why CDM Alone Isn’t Enough**
- **Collaborative Decision Making** ensures transparency, fairness, and shared situational awareness, but can be slow or unwieldy if not automated—especially with thousands of drone operators.
- Traditional CDM is designed for a small number of powerful stakeholders (airlines, ANSPs, airports), not for a highly dynamic drone ecosystem.

- ***Will Federation remain for segregated portions of airspace?***

- **Why Federation Alone Isn’t Enough**
- **Federation** (multiple USSPs, operator choice) brings competition and innovation, but risks fragmentation, inconsistent user experience, and—without strong standards—potential vendor lock-in.
- Operators may still feel like “customers” rather than empowered participants, especially if proprietary features or market dominance emerge.

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Align with Service Delivery Management

- Technology Agnostic Service Definitions (based on CORUS XUAM and recent work)
- Help to define fact-based criteria for each service
  - Introduce performance levels depending on risk
  - Using safety/security/scalability input to decide which information needs to be
    - Consistent
    - Highly Available
    - Partition Tolerant
  - Decide on governance
    - For Master Data Service, avoid monopolies
    - For Highly Competitive Services, ensure a fair/safe/secure operator-focused market

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Keep it simple and open on ConOps level

- Information Management
  - Which information flows need further work/standardisation (e.g. operator <-> service provider)
- Check main workflows and involved stakeholders – who needs to collaborate to take which decision
  - Coordination might be described
- Allow flexibility in architecture - how stakeholders share and consume is not as important as technical details
- Aiming for integration and the best possible decision.

SWIM Models for Core Services

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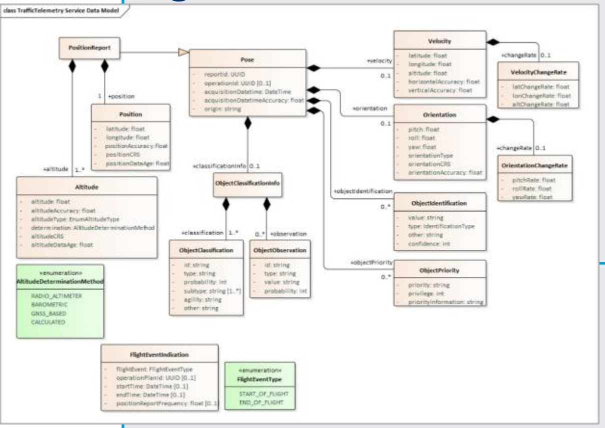
- Service definitions (as identified by CORUS-XUAM and its successors) must be grounded in observable, measurable facts required for operational safety.

Service Area	Fact-Based Criteria	CORUS-XUAM Relevance
Identification/Tracking	4D Trajectory Data: Position (x, y, z), time (t), velocity, and acceleration.	Crucial for Accepted Launch Window (ALW) calculation and conflict resolution.
Geo-Awareness Provision	Airspace Definition (XYZ Volume): Precise 3D coordinates and associated validity time.	Basis for U-space airspace management and dynamic changes.
Flight Authorization	Conflict-Free Trajectory (Binary/Boolean): A definitive statement (Yes/No) that the planned 4D trajectory is deconflicted from all other active or authorized trajectories.	The core decision point in the Strategic Conflict Resolution Service.
Contingency Management	Emergency Status (Enumerated): A definitive, categorized state (e.g., Lost Comms, Lost Propulsion, RTL-requested).	Required for all tactical decision-making and interaction with ATM.



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Introducing Performance Levels Based on Risk

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- Performance (Service Level Agreements/SLAs) should be tied to the risk and integrity of the service/information.

Risk Category (EASA/SORA)	Performance Metric	Example Performance Level
Safety-Critical / Tactical (High)	Latency (End-to-End): Time between sensor input and system output (e.g., Conflict Resolution Advisory).	≤1 second
Regulatory / Strategic (Medium)	Data Integrity (Consistency): Percentage of time all nodes hold the same value (e.g., Geo-Fence version).	→100% consistency
Efficiency / Planning (Low)	Availability (Uptime): Total system availability.	→100% availability

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Information Consistency Classification (Safety/Security/Scalability)

- This framework applies the CAP Theorem trade-off (Consistency, Availability, Partition Tolerance) based on the criticality of the information to Safety of Flight (SoF). Given the need for a distributed system (Partition Tolerance is a must), the trade-off is primarily between Consistency and Availability.

Information Type	**Risk Profile**	**Priority Classification (CAP)**	**Rationale for Choice**
UAS Position & Emergency Status	Safety-Critical (High Risk)	Consistency > Availability	Tactical decisions (up to collision avoidance) require knowing the exact current state. Better to return an error than stale data.
Flight Authorization (Clearance)	Safety-Critical (High Risk)	Consistency > Availability	A flight must operate under the most recent authorization; conflicting authorization is a severe safety breach.
Geo-Awareness (Static)	Security/Safety (Medium Risk)	Consistency > Availability	Integrity is essential. The latest definition must be applied universally before any operation.
Weather Information	Scalability/Efficiency (Medium Risk)	Availability > Consistency	Data is probabilistic and changes constantly. Availability is key for planning, even if it's eventually consistent.
Flight Plan/Registration Data	Scalability/Efficiency (Low Risk)	Availability > Consistency	Strategic data (used for planning, not tactical flight). A few minutes of latency is tolerable.

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Master Data Service (MDS) Governance (avoiding Monopolies)

The MDS (e.g., registration data, static airspace data) must be treated as a **public utility** or an essential facility.

- **Model:** Federate the data. U-Space Coordinator?
- **Mandate:** Ensure data access is governed by **Fair, Reasonable, and Non-Discriminatory (FRAND)** terms.
- **Access:** Mandate **write access** only by regulatory bodies/certified entities (e.g., U-space Service Providers (USSPs) and ANSPs) and **read access** for UAS Operators.
- **No Competitive Advantage:** The consortium managing the MDS must be prohibited from offering any competitive services that rely on the data it manages.

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Highly Competitive Services Governance

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Competitive services (e.g., Conflict Resolution, Dynamic Geo-Fencing, Weather Services) must be managed to ensure a fair, safe, and operator-focused market.

- **Open Architecture:** Mandate **open APIs** and **interoperability standards** to allow multiple USSPs to seamlessly connect and compete, preventing lock-in.
- **Safety Priority:** Certification of these competitive services must be strictly tied to achieving the **Safety-Critical Performance Levels** defined above. Safety certification, not market share, must be the main barrier to entry.
- **Operator Focus:** Decisions made by USSPs must prioritize the **Approved Launch Window (ALW)** and the safe execution of the UAS Operator's mission (optimizing efficiency for the operator, not for the service provider).
- **Data Portability:** Ensure UAS Operators can easily switch between USSPs, preventing monopolies by allowing for quick and seamless data migration.

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Let’s discuss!

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- Which stakeholders are collaborating in decision making processes
  - Pre-flight(e.g. Flight Planning, Authorisation,..)
  - In-flight (e.g. Surveillance, Conflict Prediction, Conflict Resolution,...)
  - Post-flight (e.g. Incident reporting..)
- Thinking of U-space services – how would you design consistency / availability / partition tolerance trade offs
- Which information exchanges do we miss (e.g. Involving authorities, defense, ..)
- ...

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