Simulated Evaluation of Strategic Conflict Management Capabilities for Urban Air Mobility Operations

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Introduction

- Urban Air Mobility (UAM): emerging air transportation service concept carrying passengers or cargo in metropolitan areas

- FAA's UAM Concept of Operations
  - Evolution of UAM operations (initial, midterm, mature states)
  - UAM Cooperative Areas (e.g., UAM Corridors)
  - Provider of Services for UAM (PSU)
  - UAM Cooperative Operating Practices (COPs)
  - Notional system architecture for UAM ecosystem

- NASA develops and implements a reference architecture to validate the FAA's UAM Concept of Operations through X-series of simulations

X5 Simulation

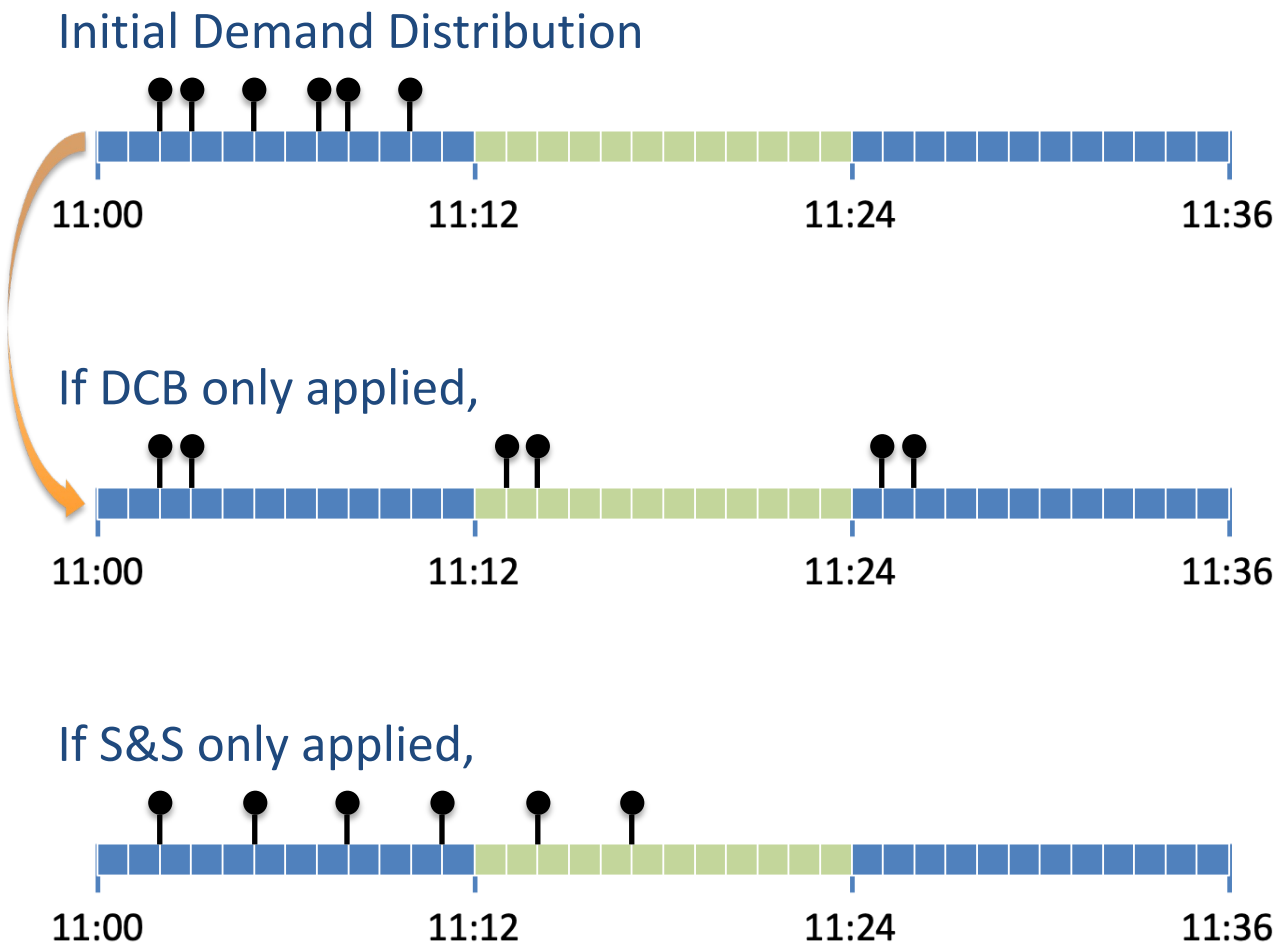
- Objectives
  - Evolve strategic conflict management capabilities for cooperative UAM operations
  - Test and validate requirements for PSU / airspace automation
  - Develop a reference implementation of the UAM airspace system for future research

- Approach
  - Build upon the initial industry-vetted capabilities and testing environment from previous simulations
  - Define information exchange between PSU and other services
  - Develop NASA prototype as reference implementation to test requirements and APIs
  - Evaluate strategic conflict management capabilities for safe UAM operations
    - Demand-Capacity Balancing (DCB)
    - Sequencing & Scheduling (S&S)

← **Focus topic in this paper**

Research Objectives

- Strategic conflict management for UAM
  - **Demand-Capacity Balancing (DCB)** to ensure operators coordinate usage of shared resources and distribute UAM demand less than or at the given capacity at resources
  - **Sequencing & Scheduling (S&S)** to ensure an orderly flow of UAM traffic and meet the sequencing and spacing criteria
- Research questions
  - Does each strategic conflict management approach work for UAM flight planning?
  - How can DCB and S&S effectively interact with each other?



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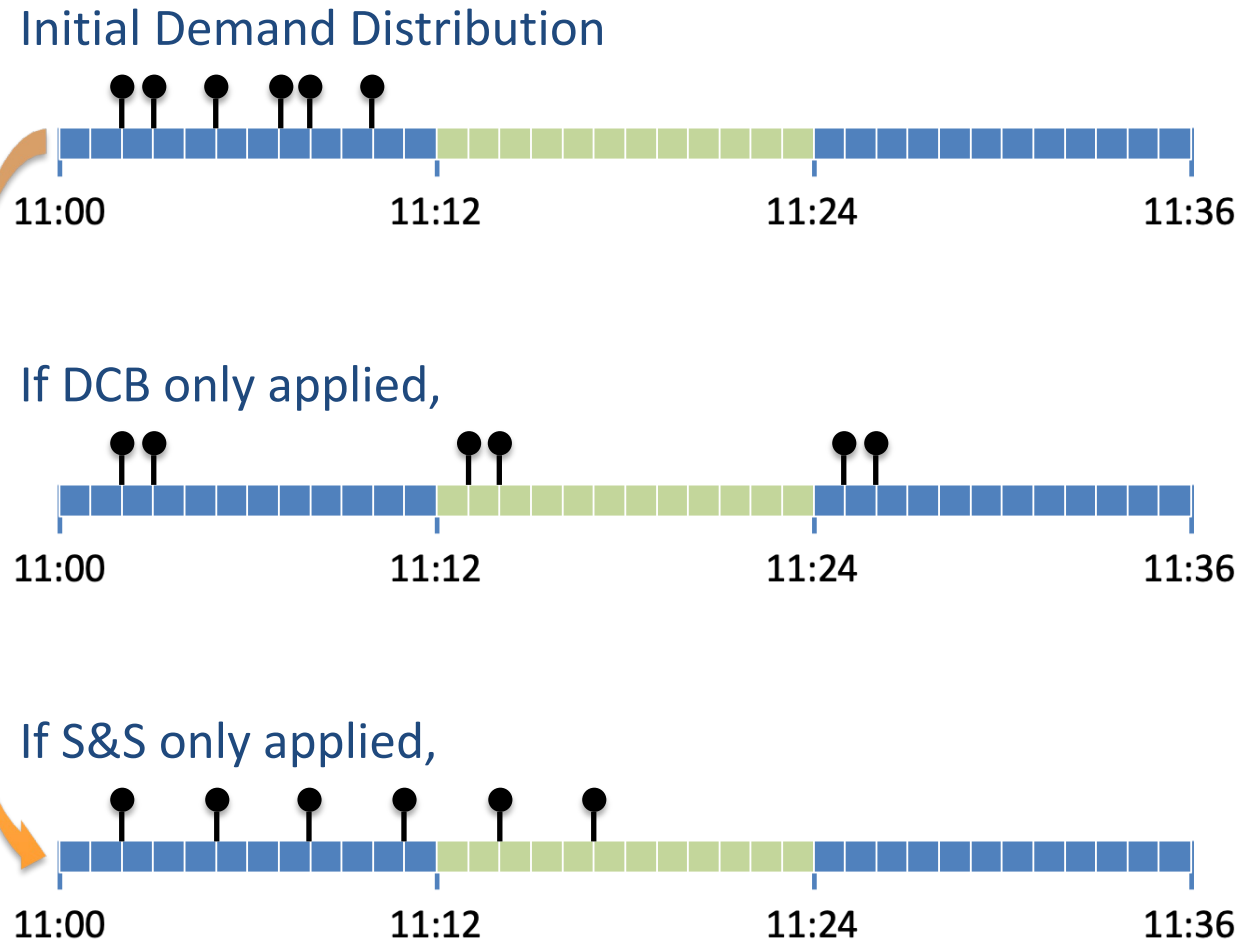
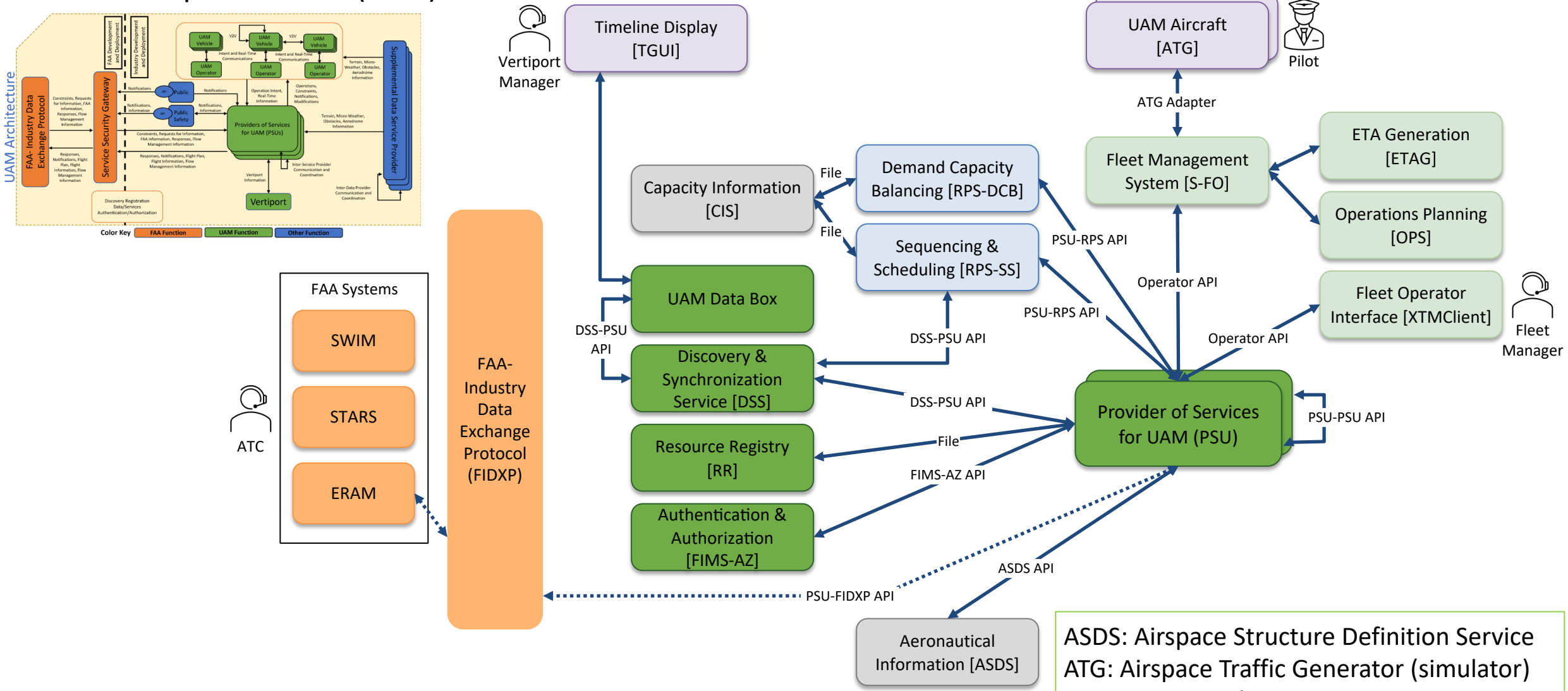


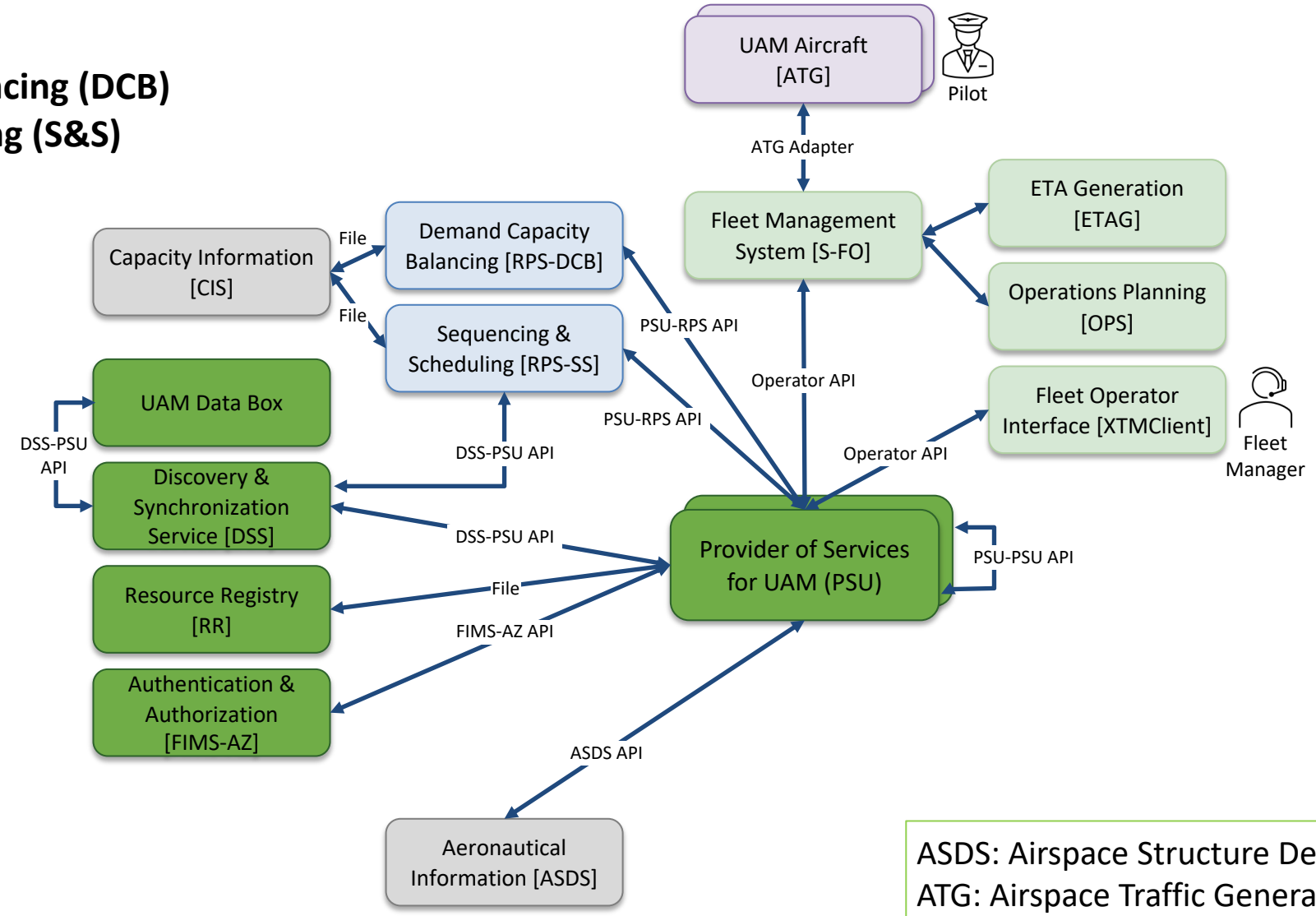
X5 System Architecture (Level 1)

FAA UAM ConOps v2 Architecture (Level 0)



Flight Planning with Strategic Conflict Management

1. **Initial Flight Plan**
2. **Demand-Capacity Balancing (DCB)**
3. **Sequencing & Scheduling (S&S)**
4. **Flight Execution**



Color Key: PSU Function | UAM Function | SCM Function | Other Function

ASDS: Airspace Structure Definition Service
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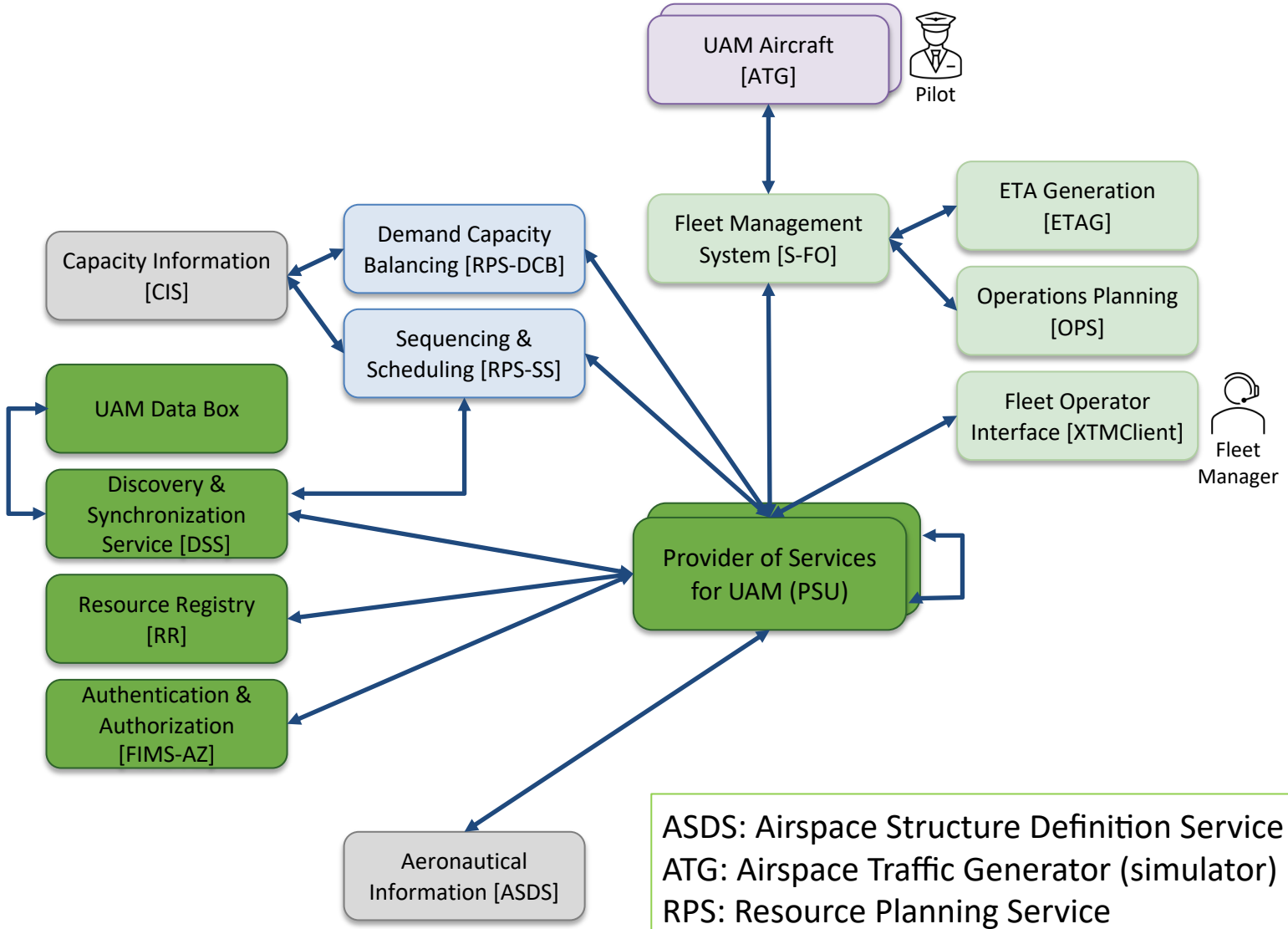

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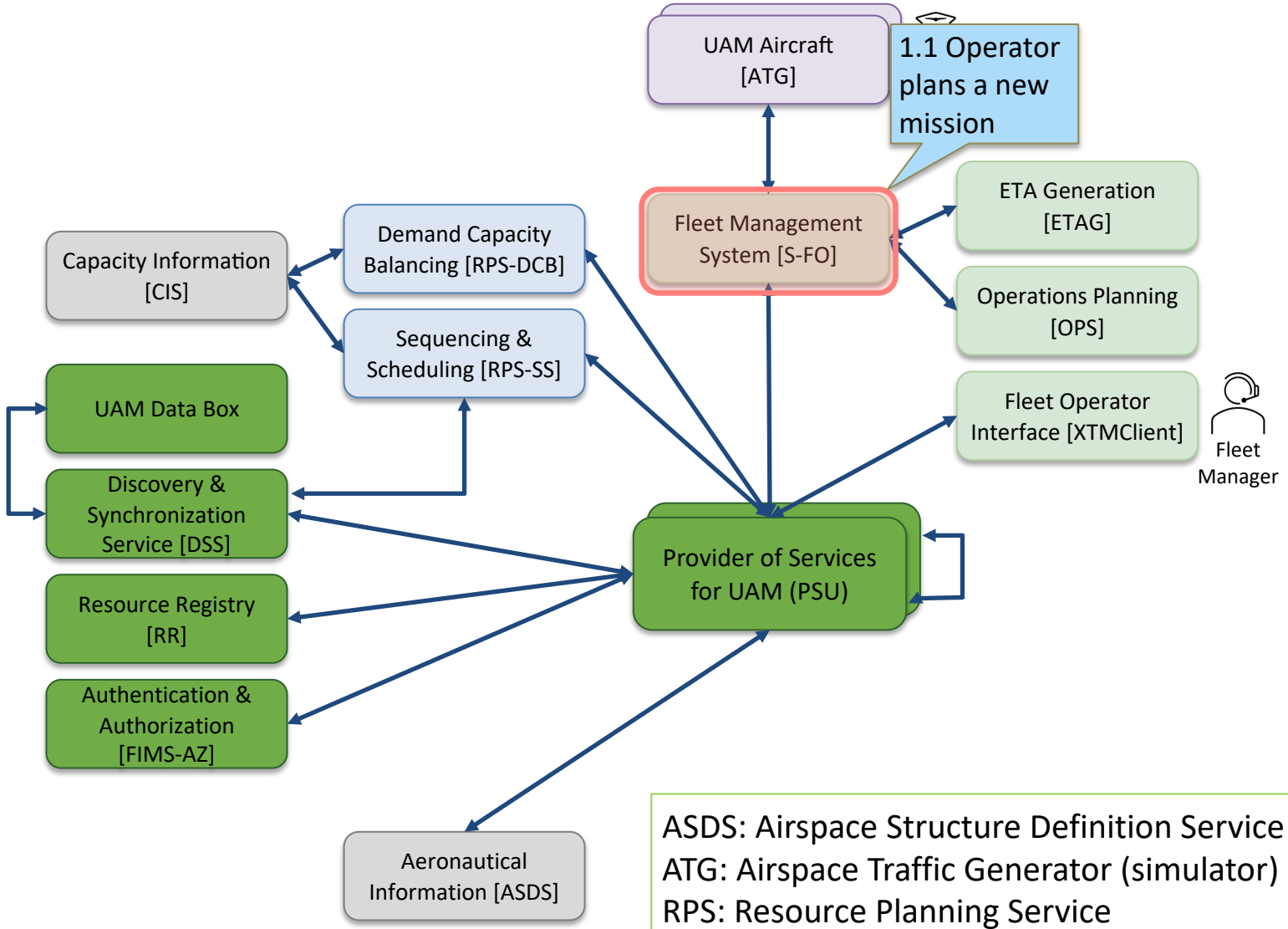

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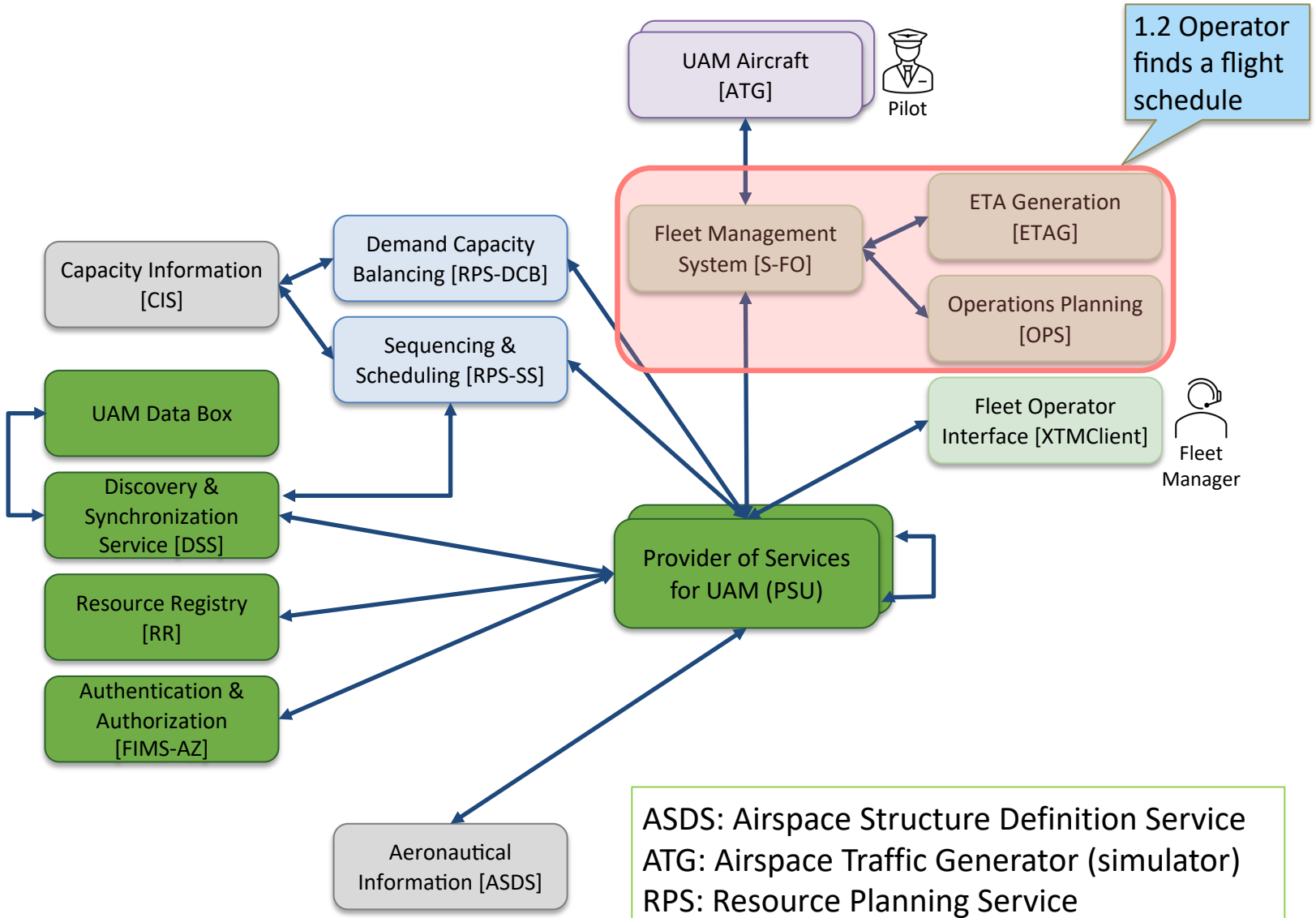

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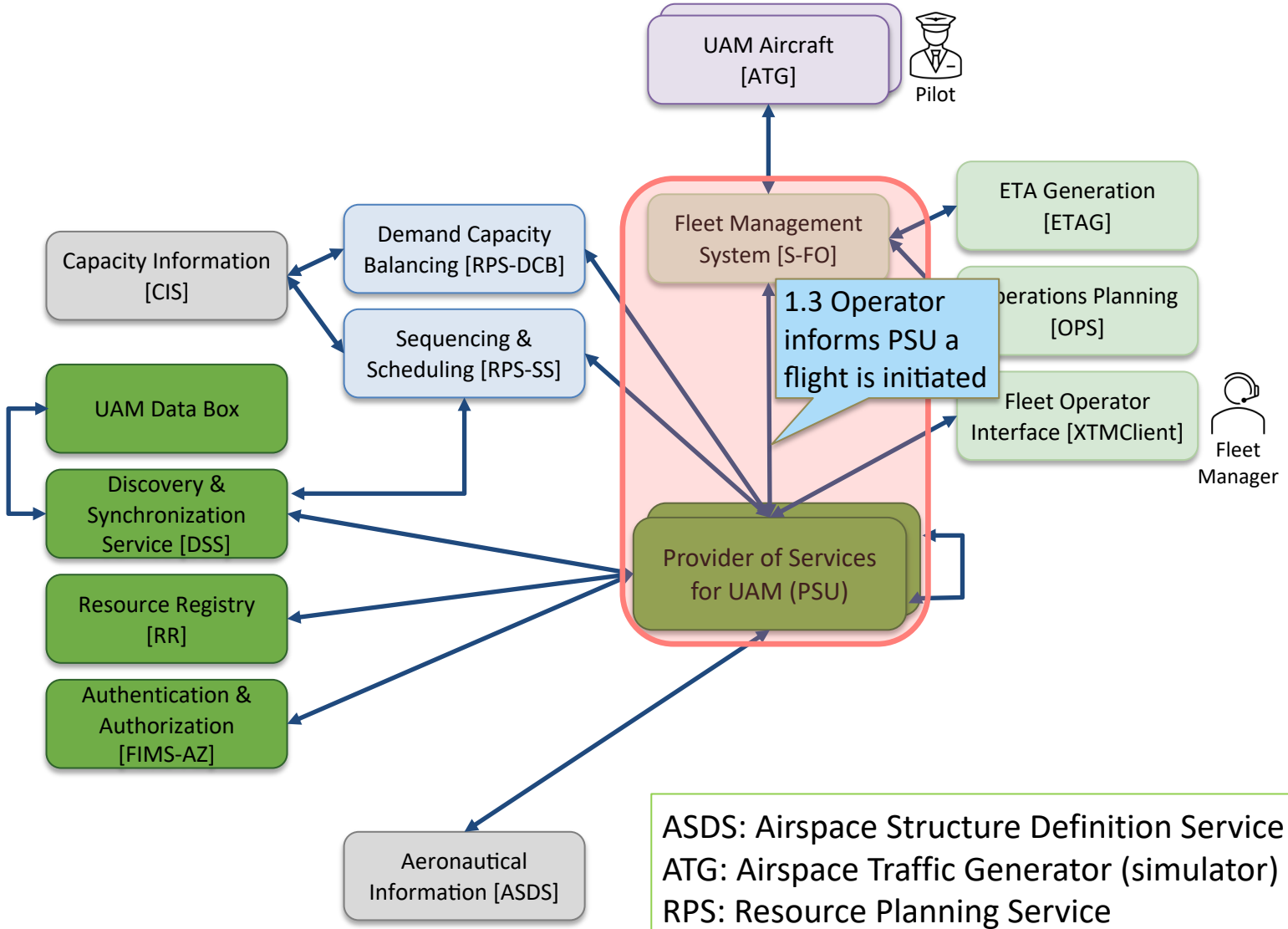

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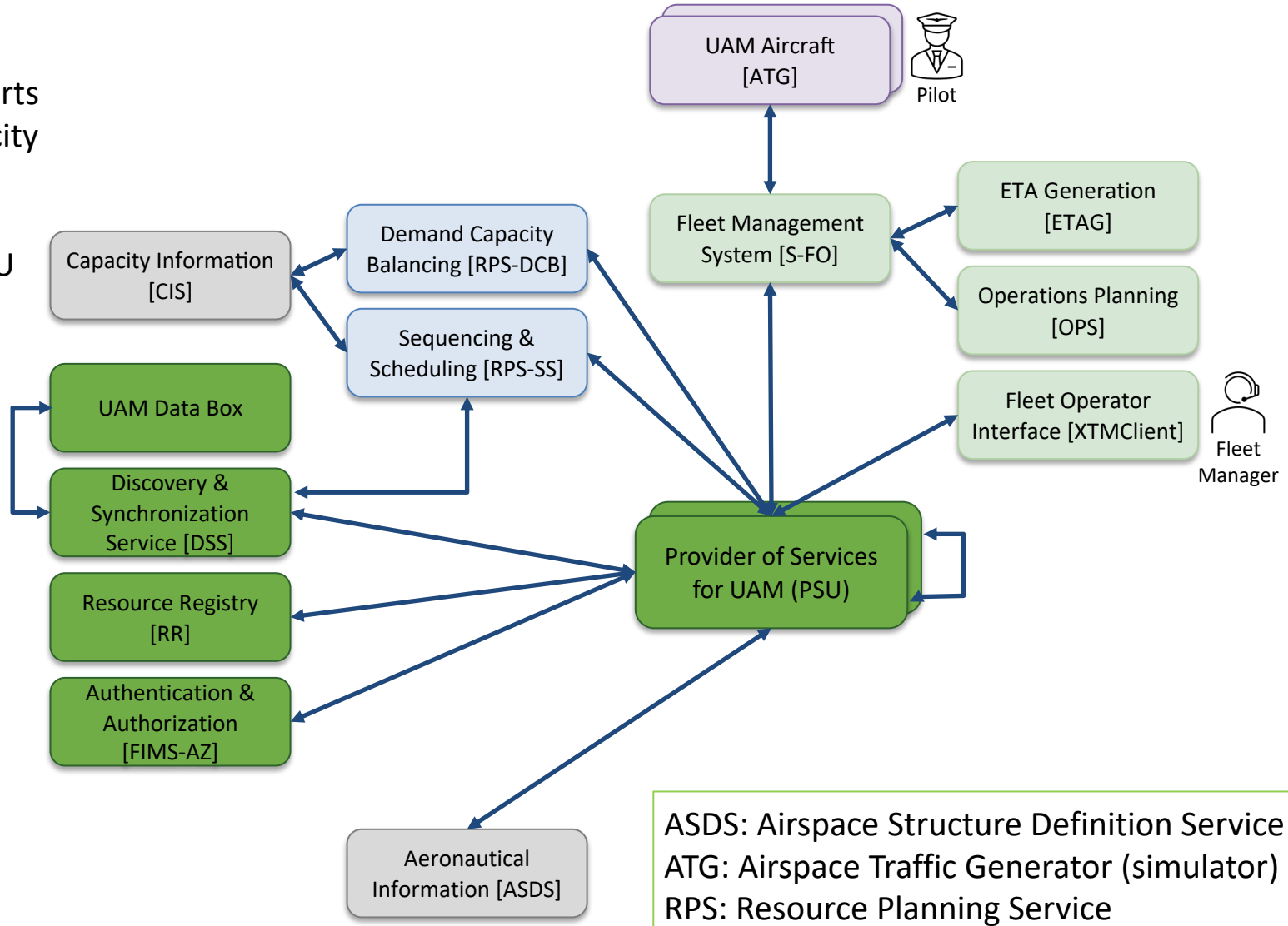

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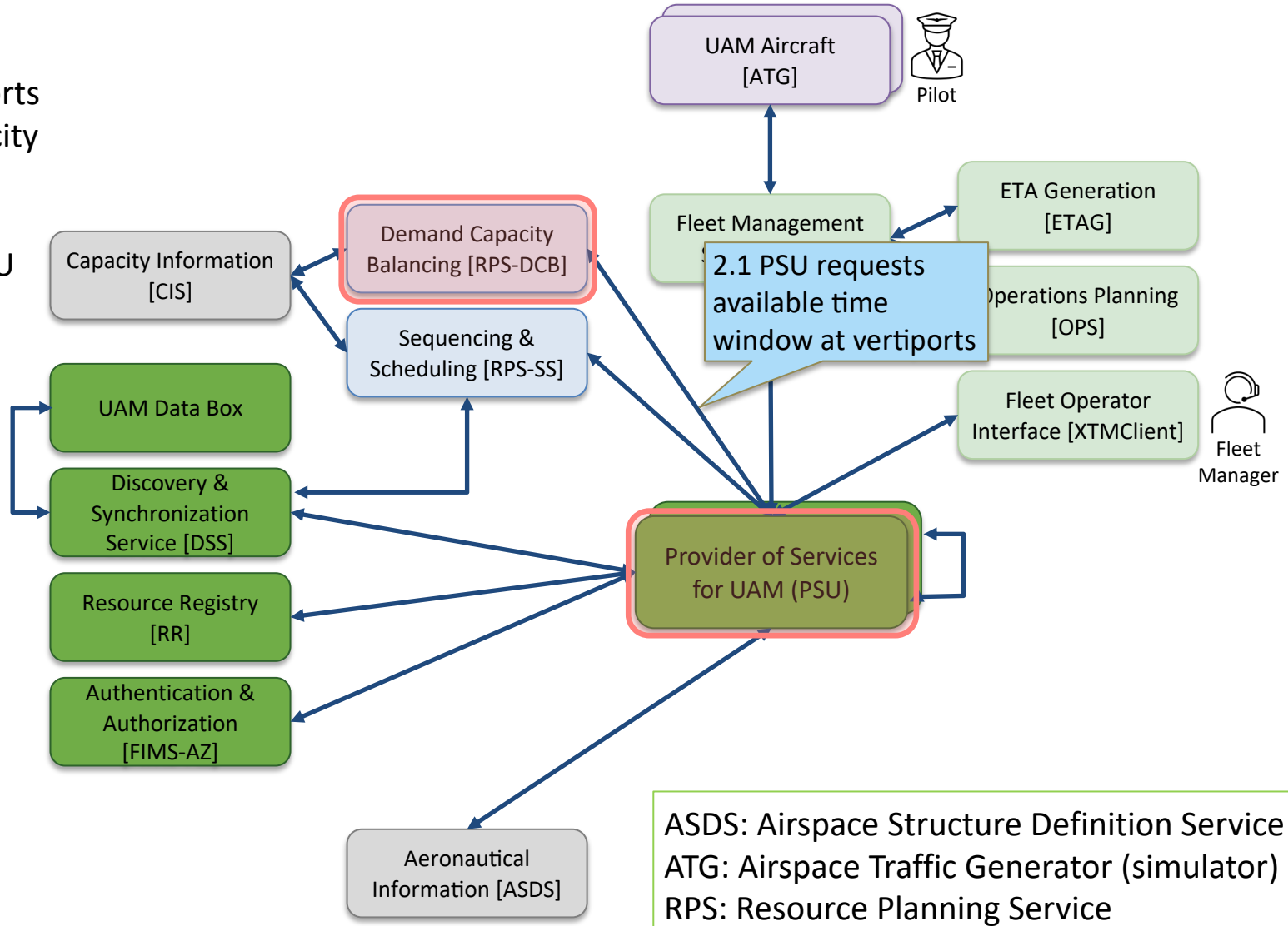

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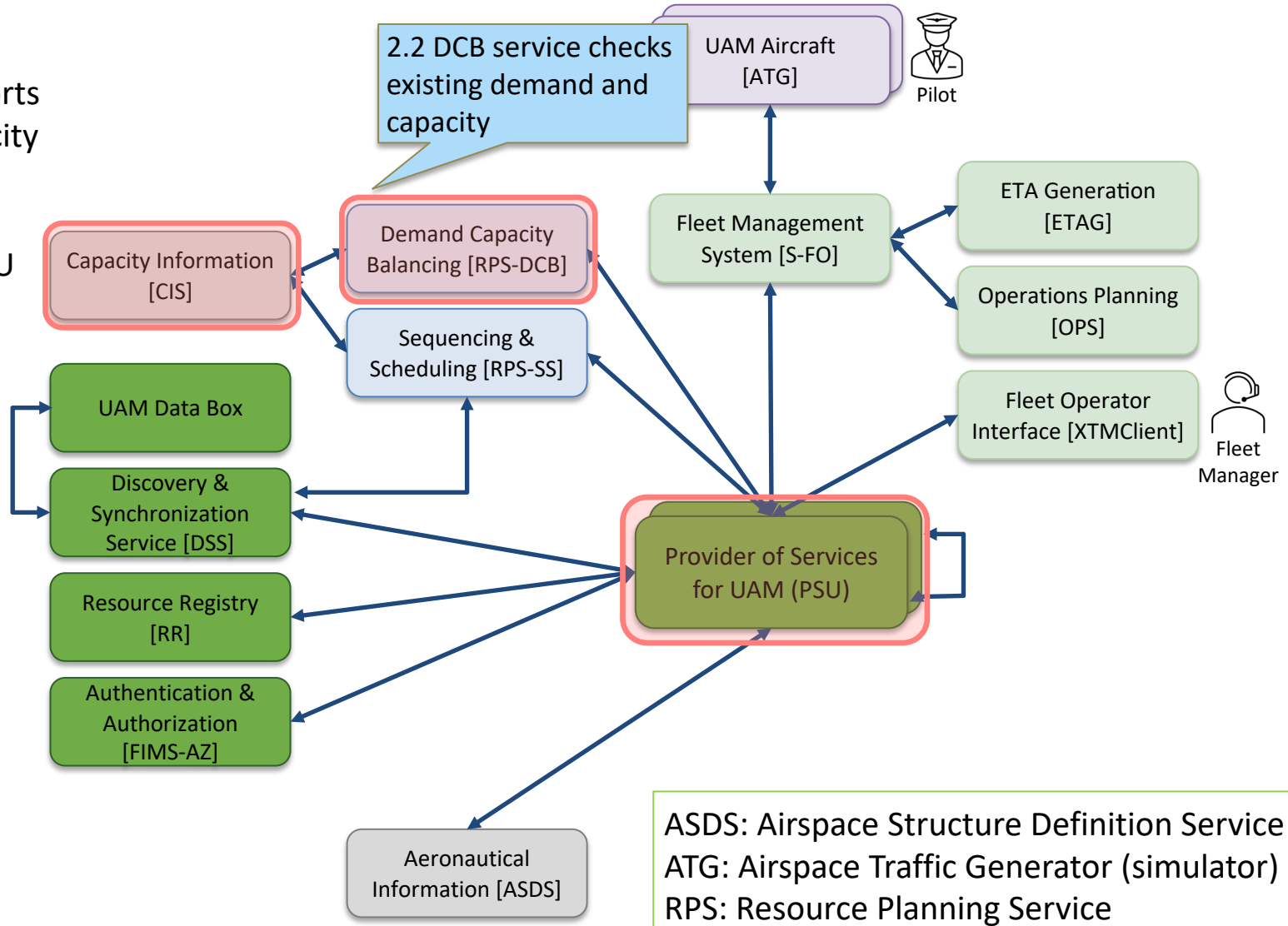

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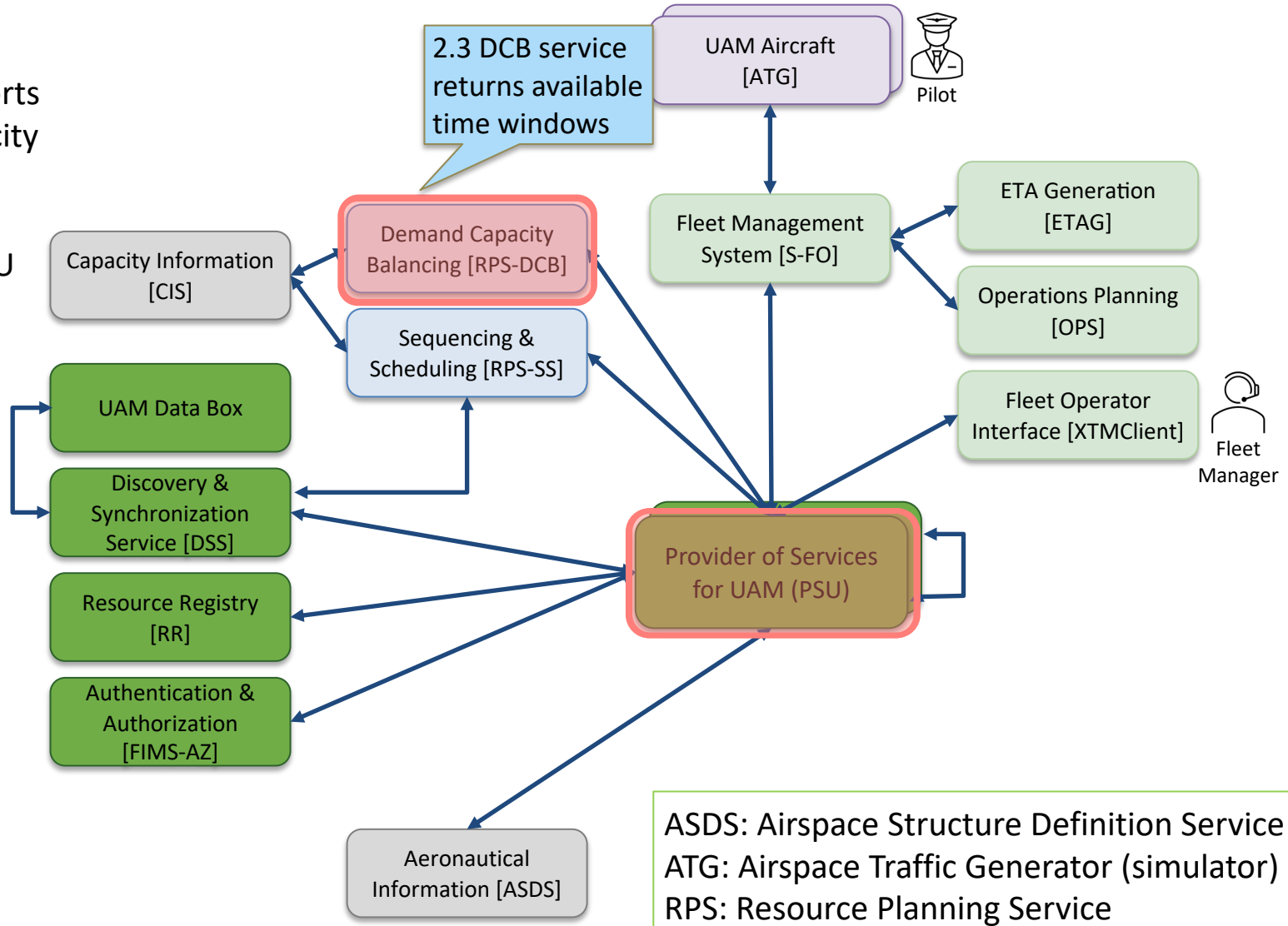

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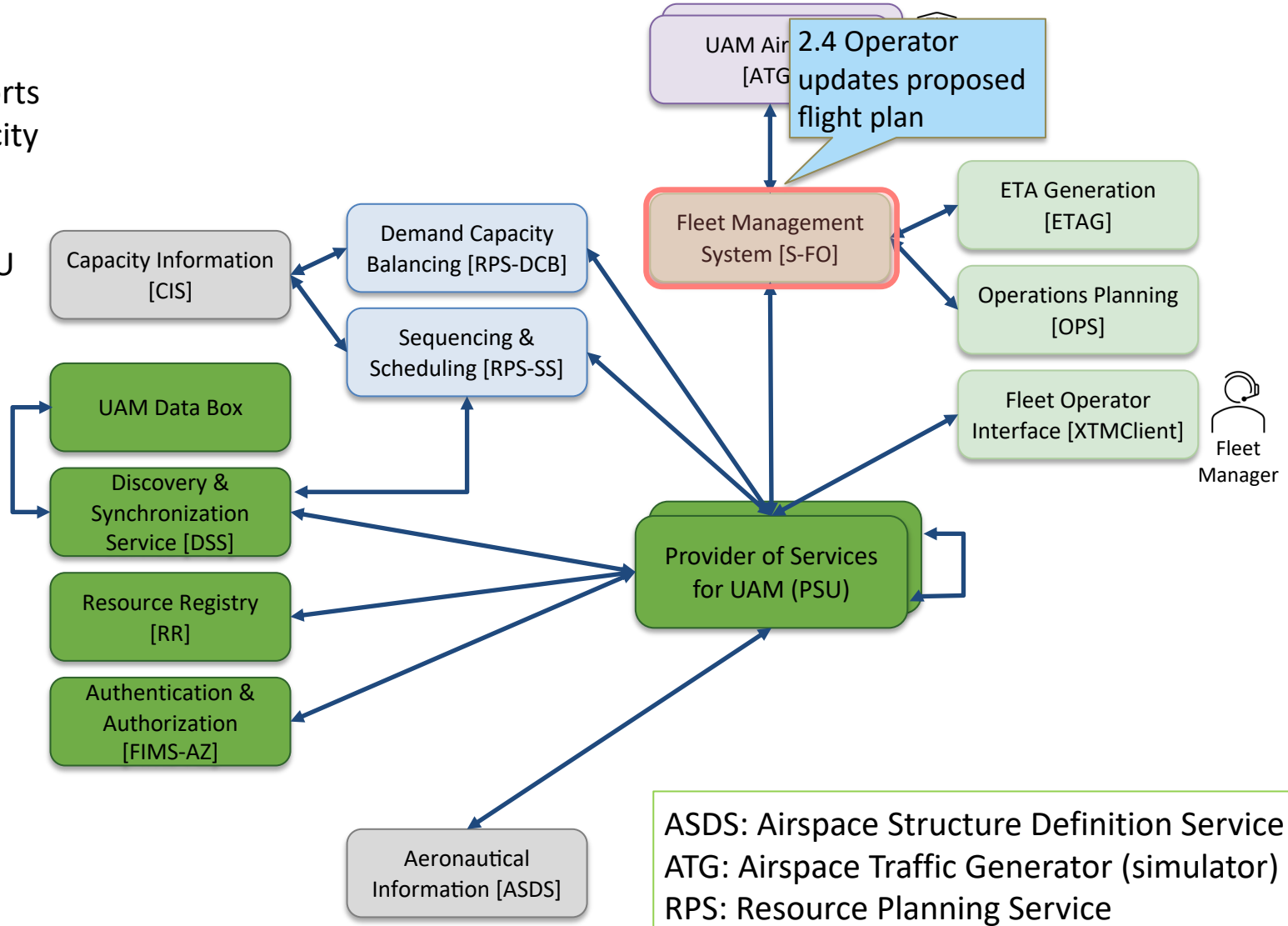

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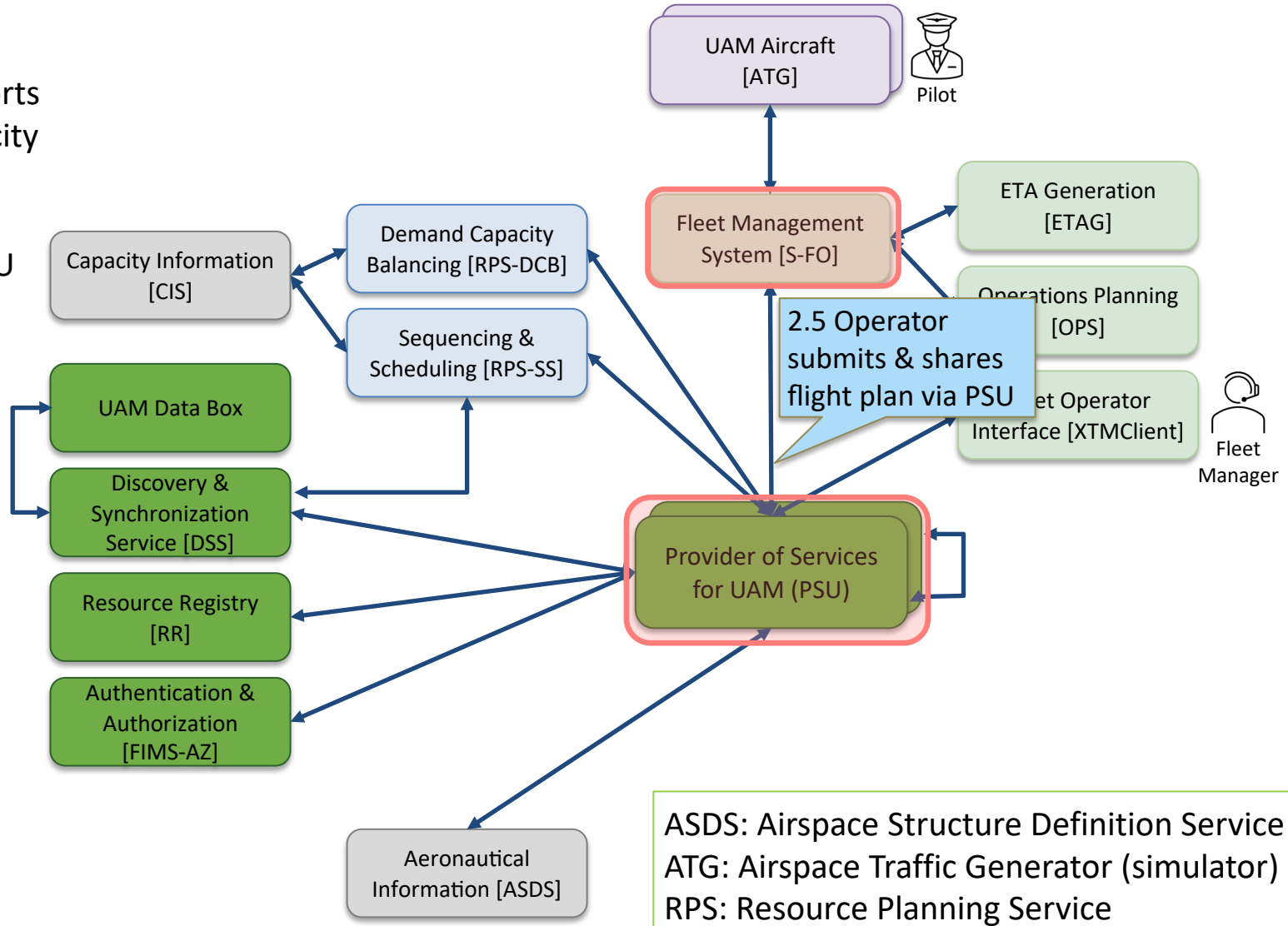

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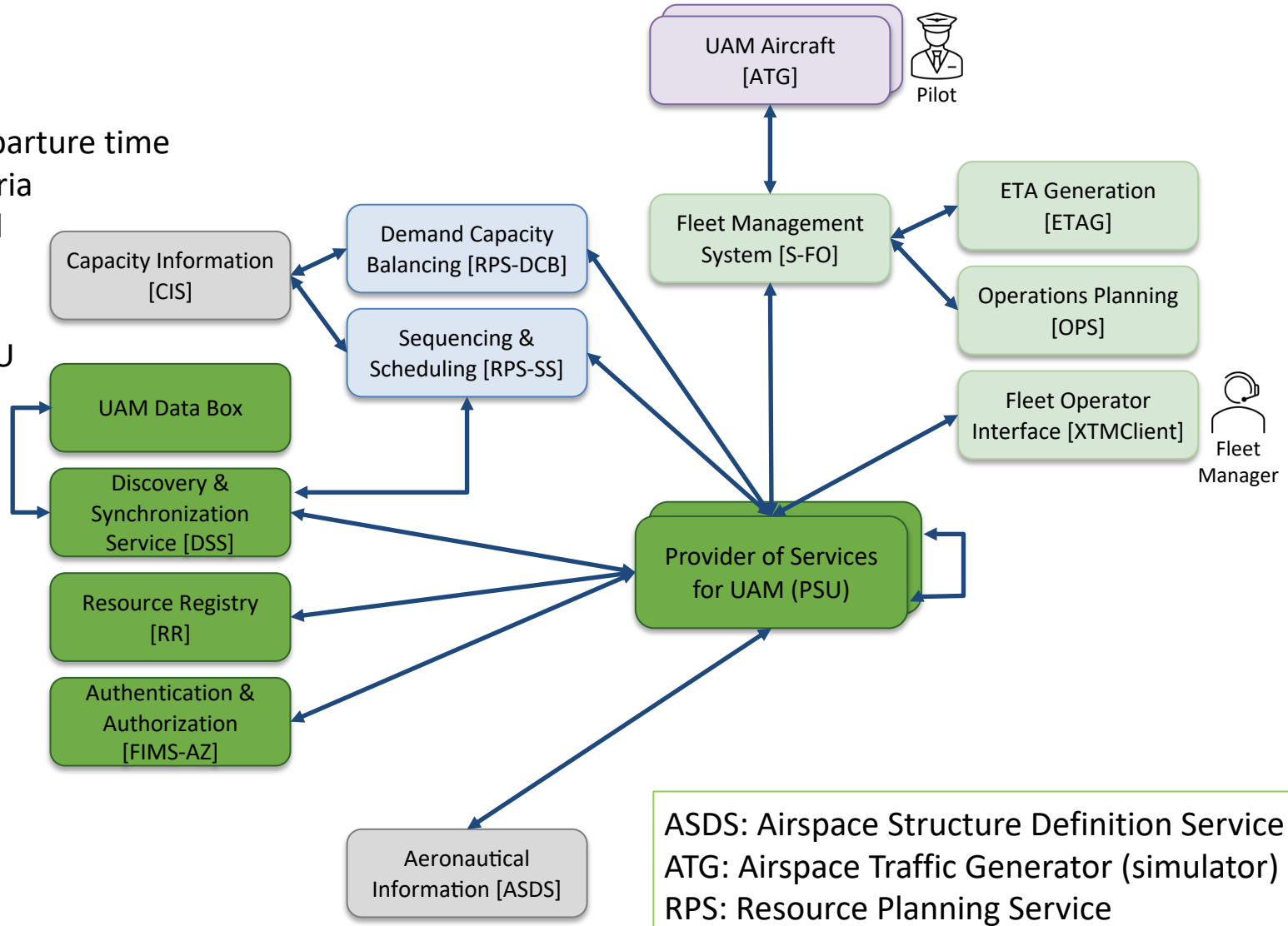

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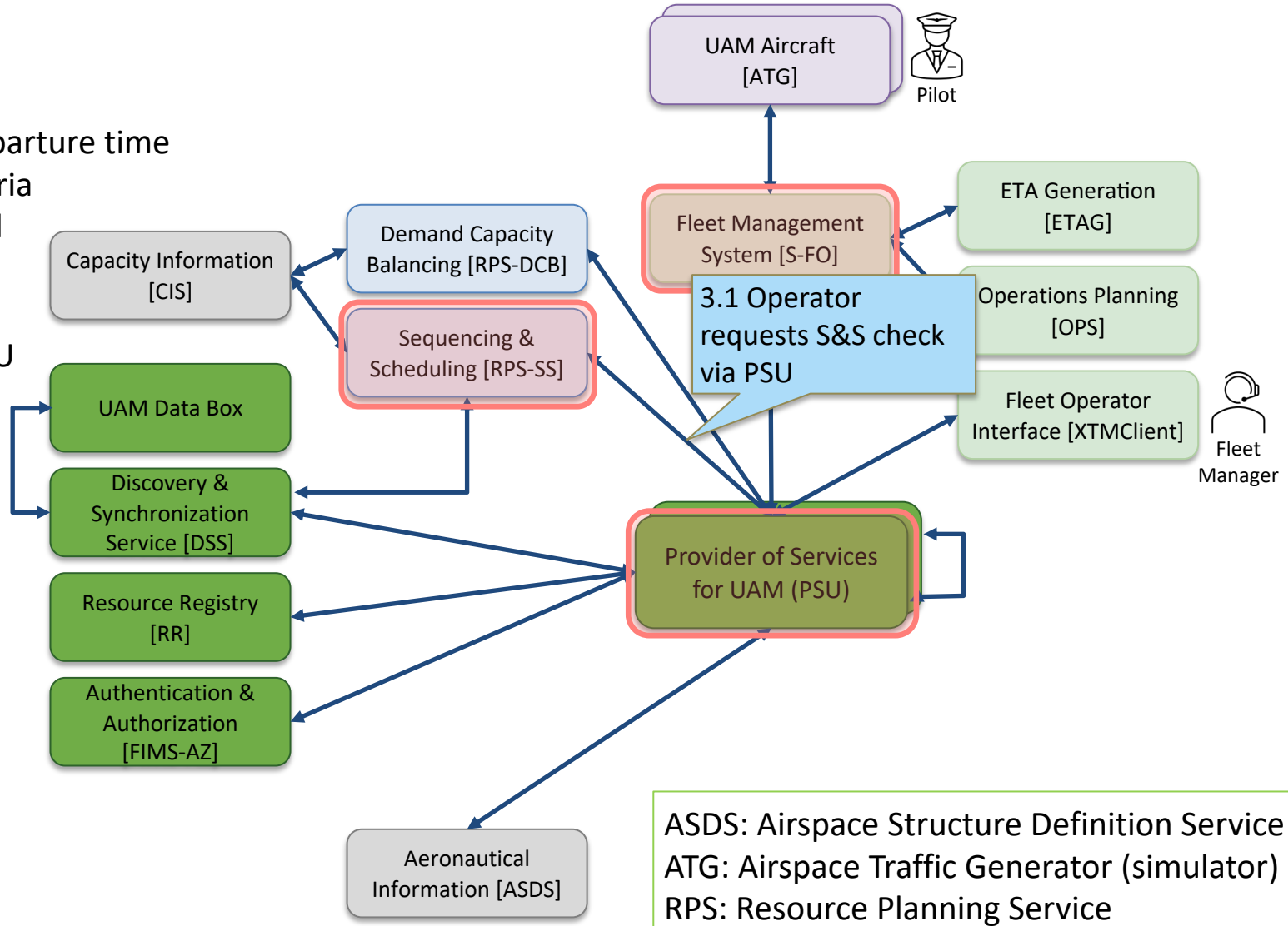

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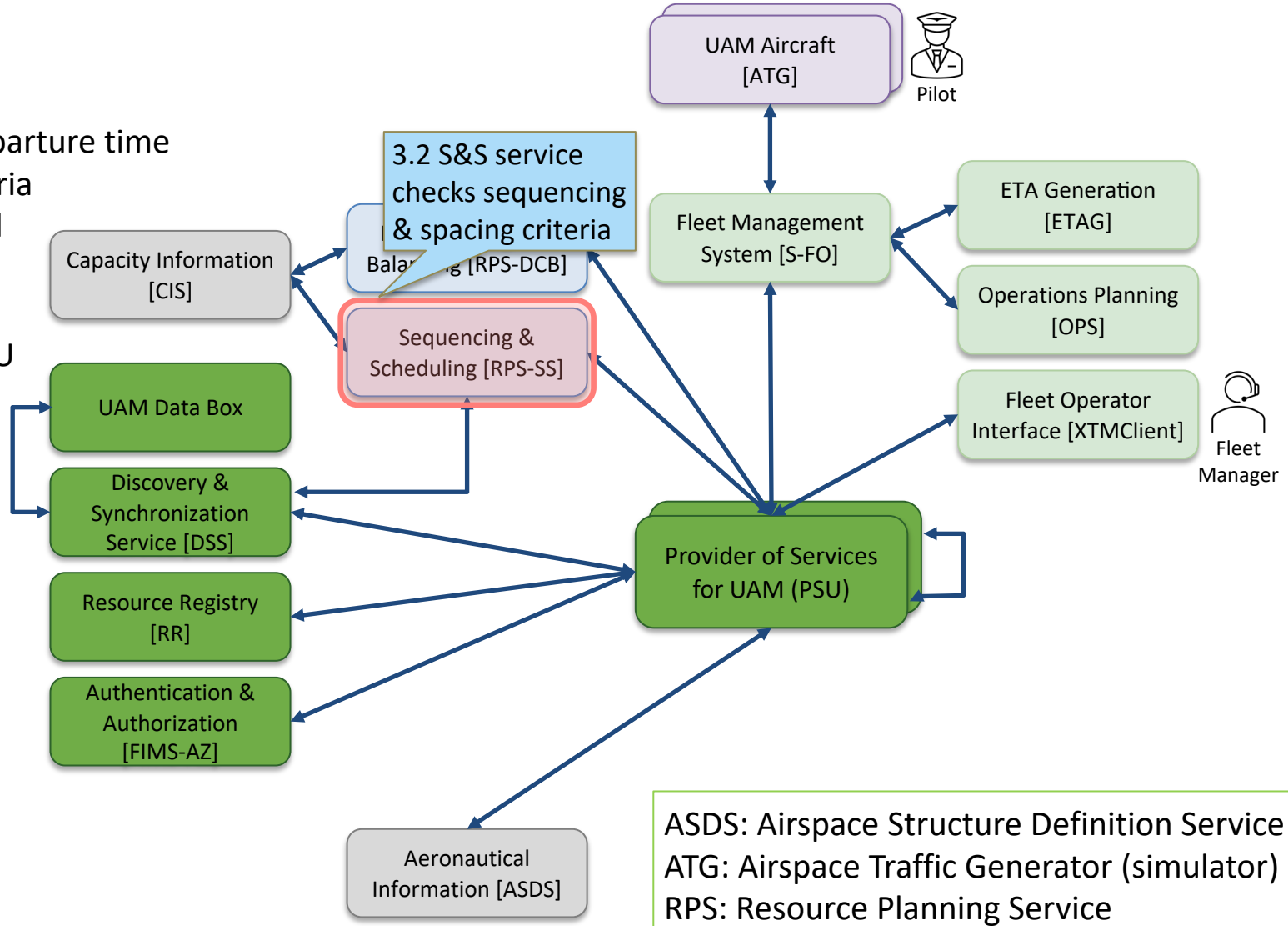

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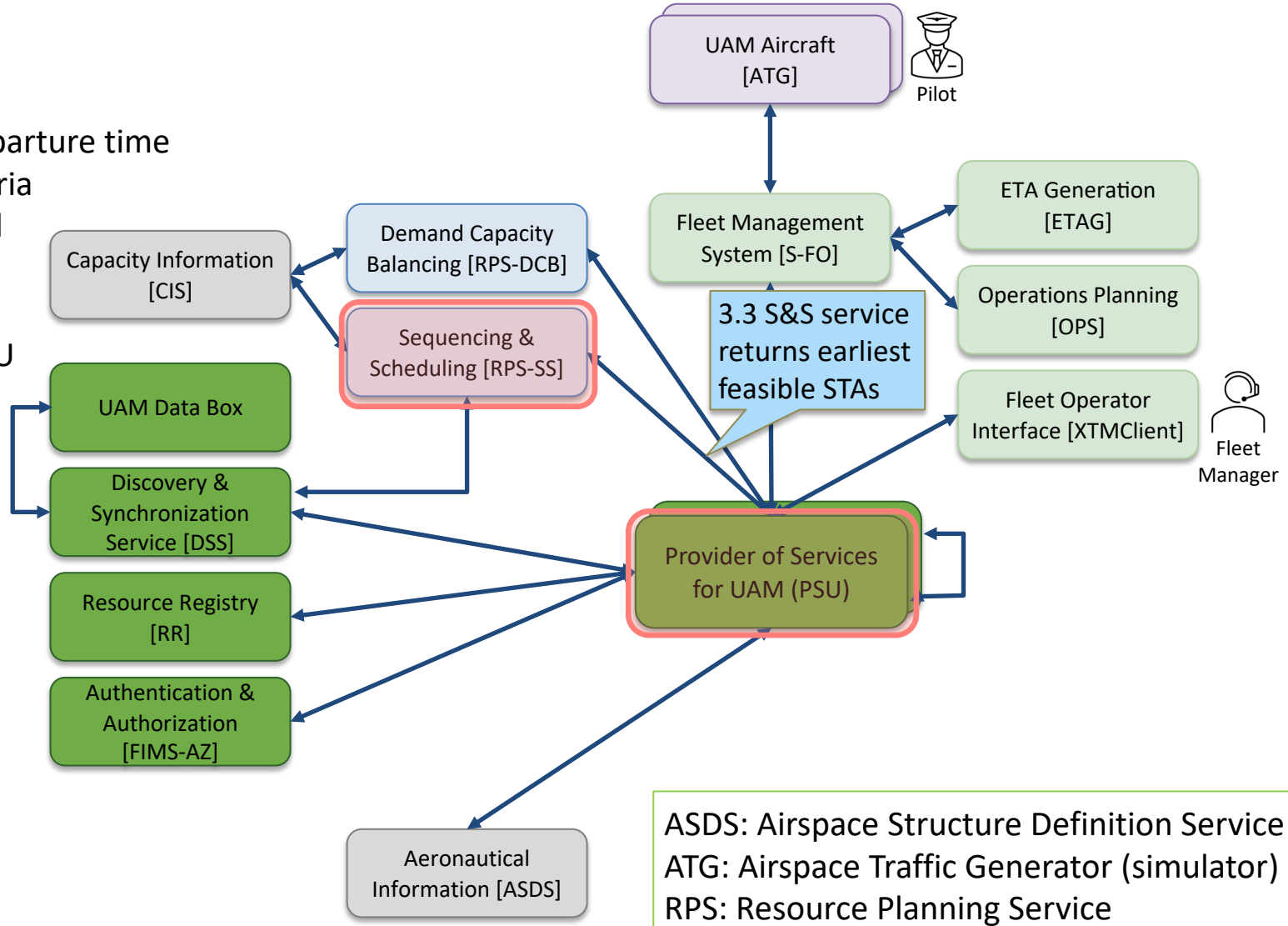

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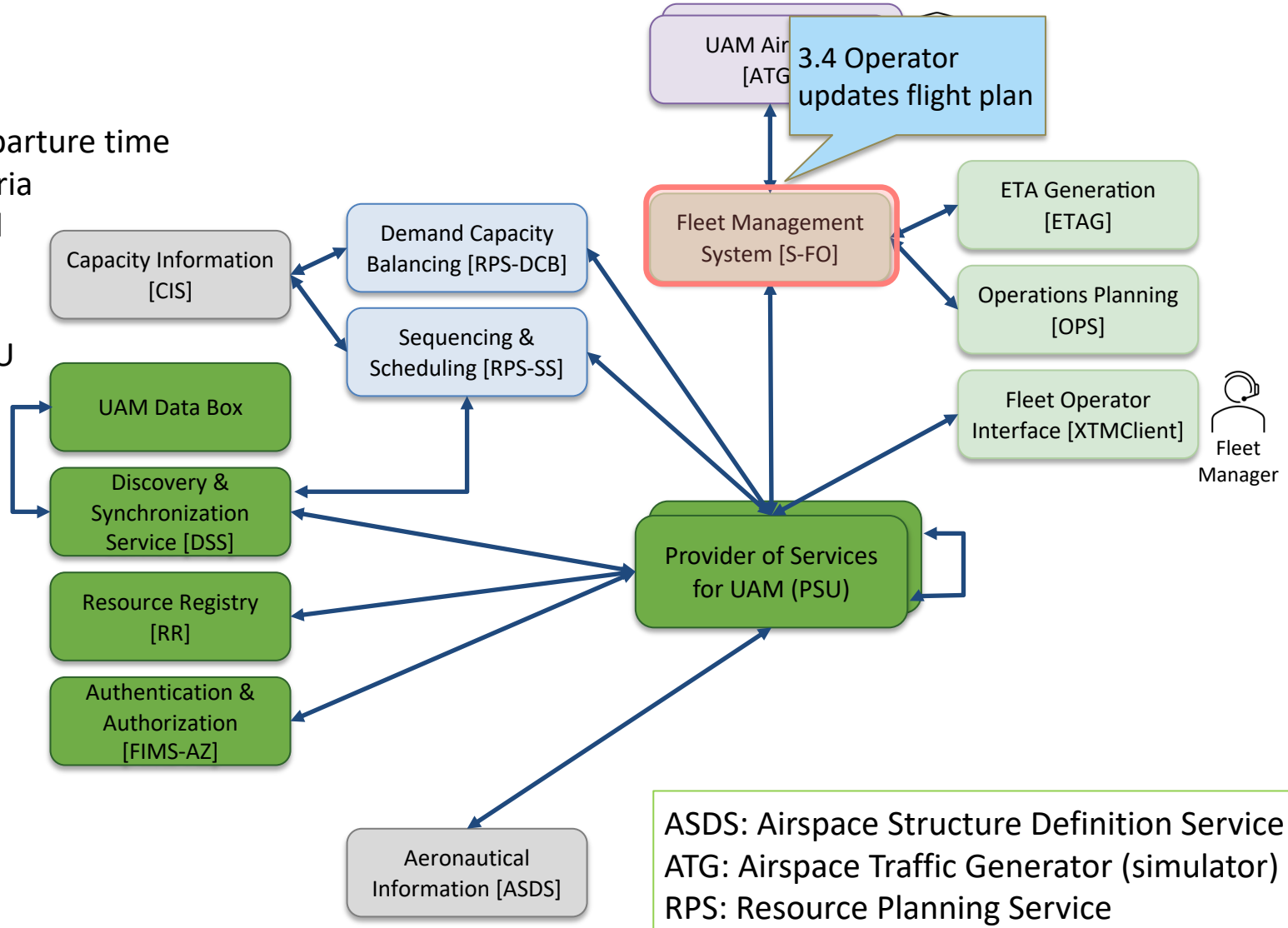

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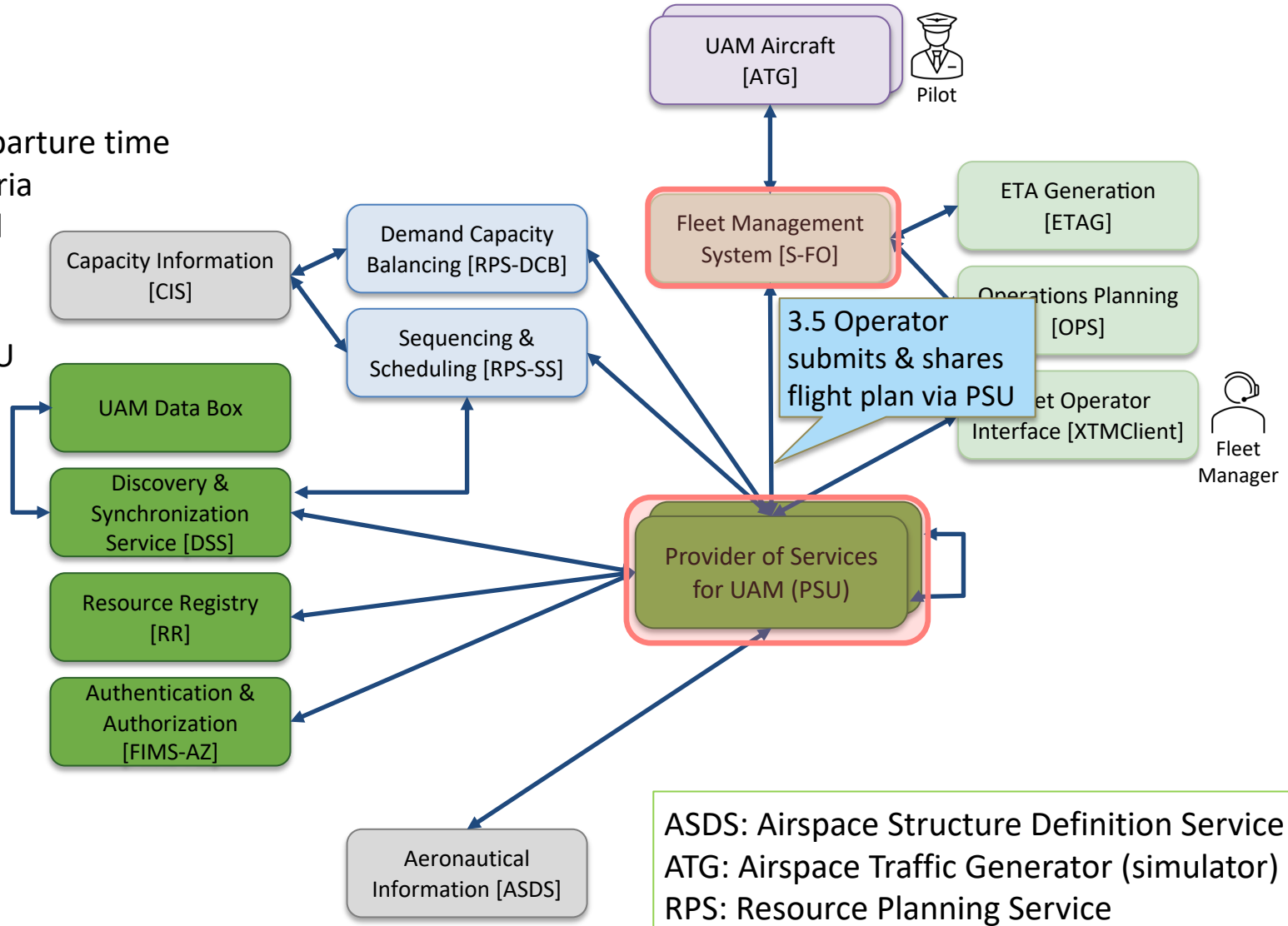

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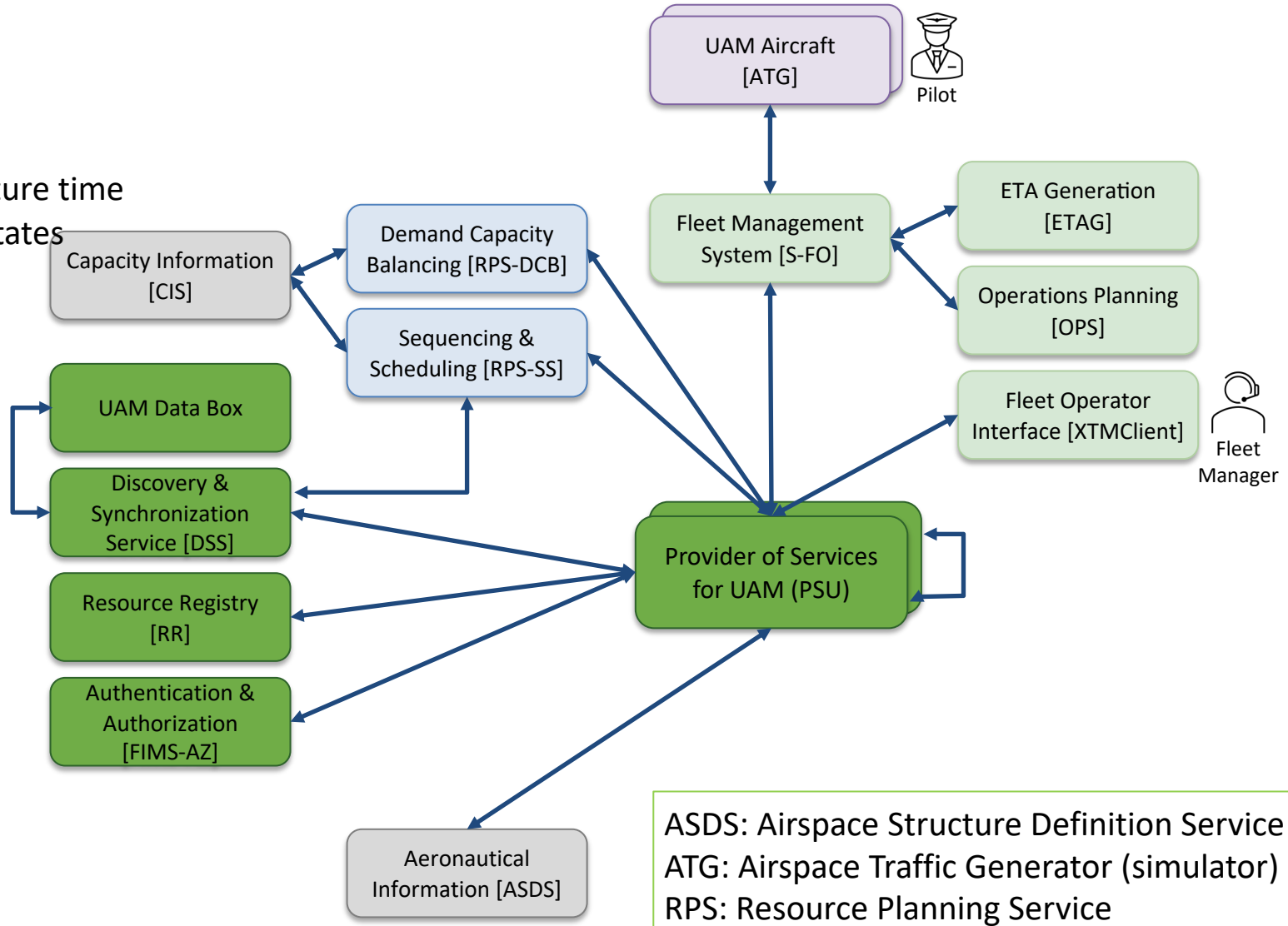

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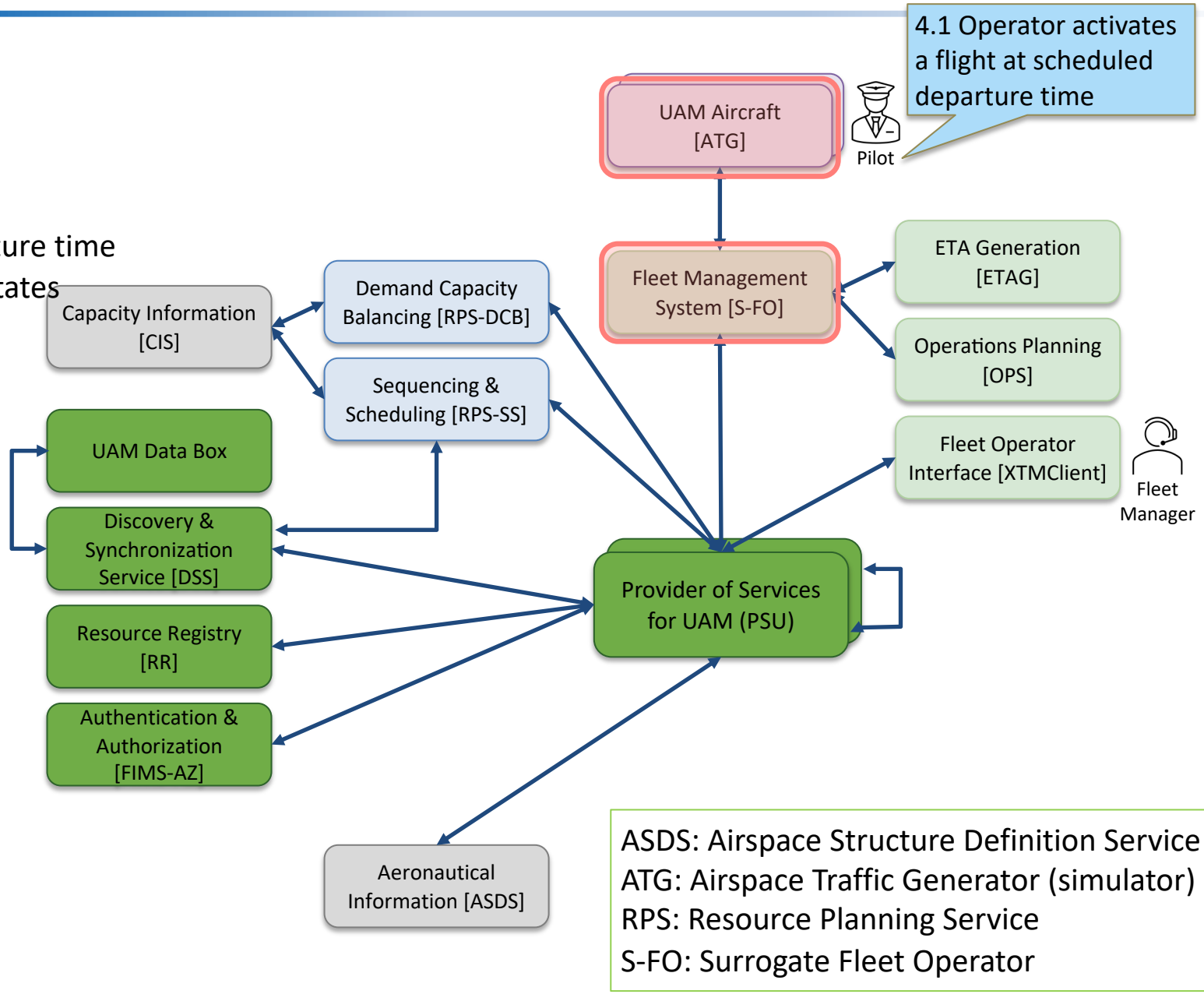

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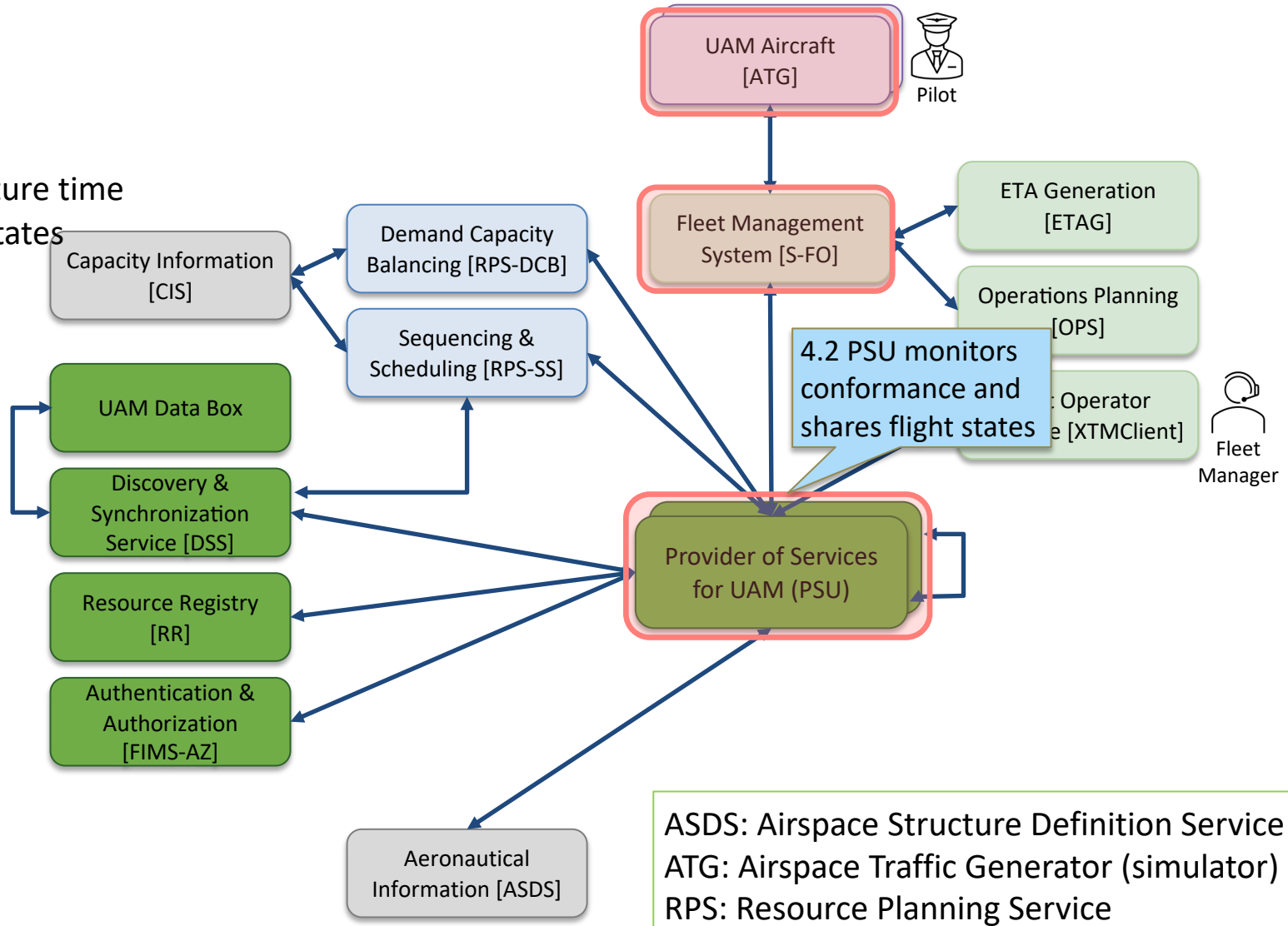

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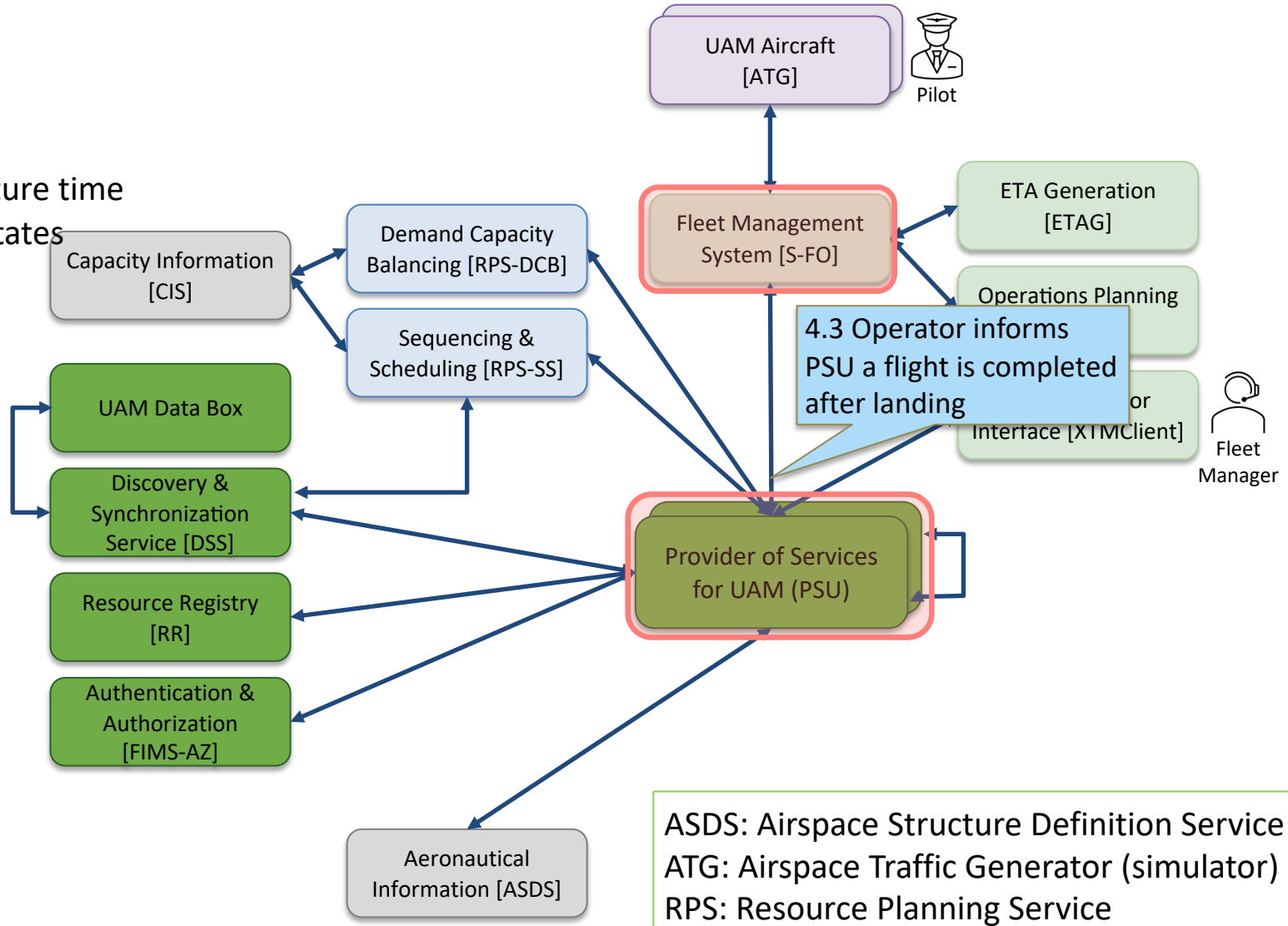

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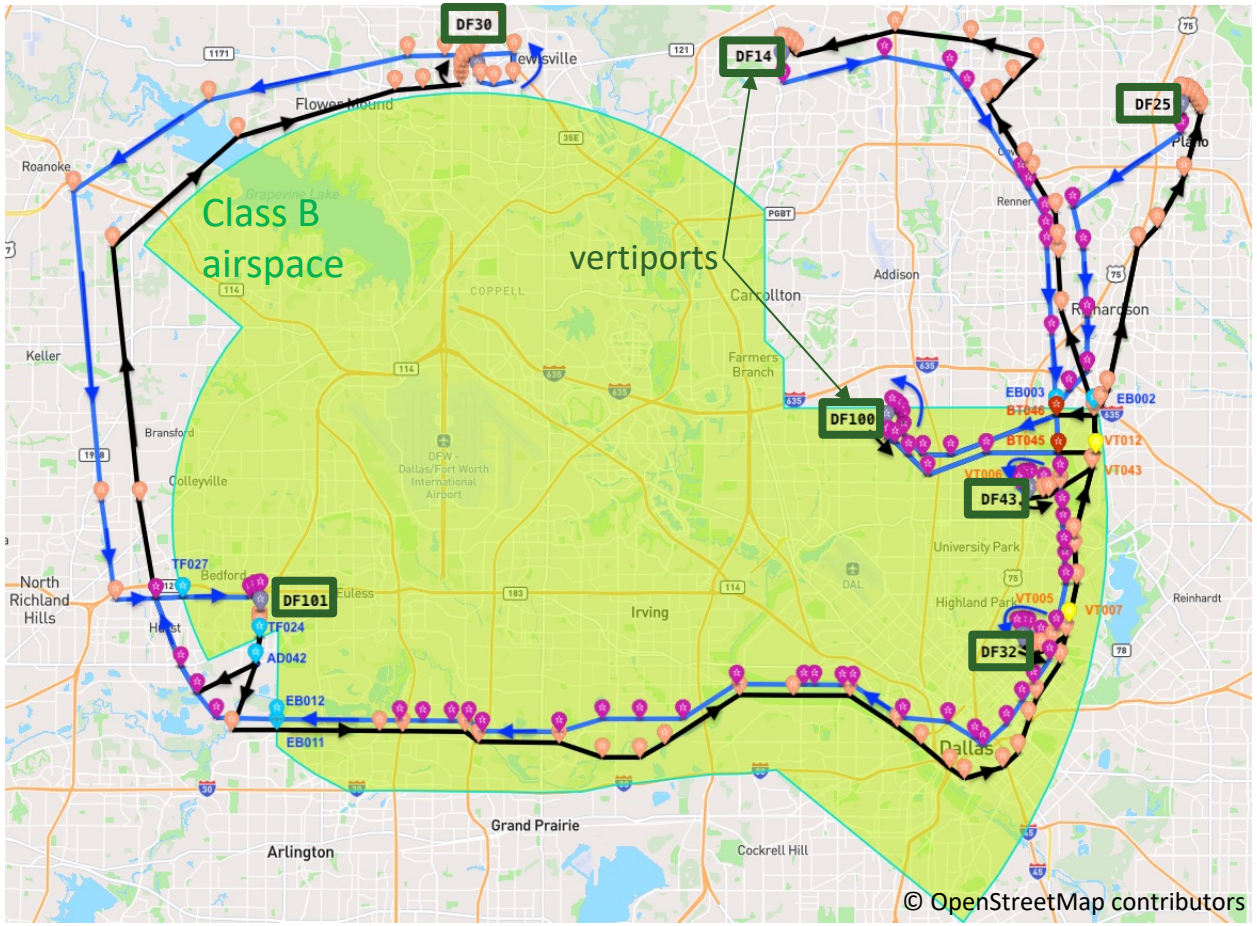
Simulation Setup

- Simulated airspace at Dallas/Fort Worth area
  - 7 vertiports
  - 10 Origin-Destination pair routes
  - Pre-defined routes with a series of waypoints
- Traffic scenario
  - Total 40 flights over 1.5-hour long simulation
  - 2 Operators with 20 flights, evenly distributed
- Constraints
  - Vertiport capacity: 2 ops per 12-min time bin
  - Sequencing constraints at cross/merging points
  - 2-min separation at entry/exit points
    at boundaries of Controlled airspace



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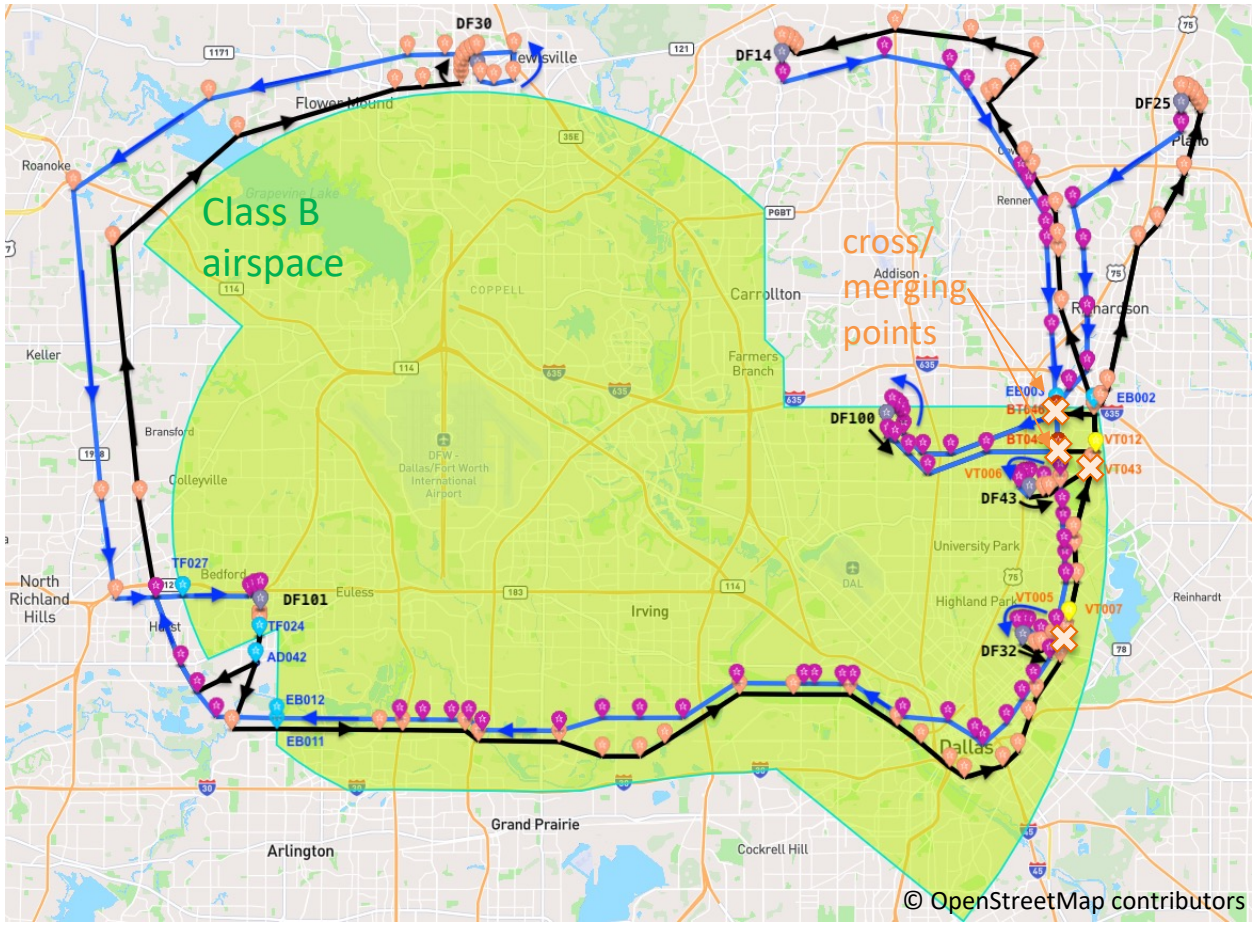

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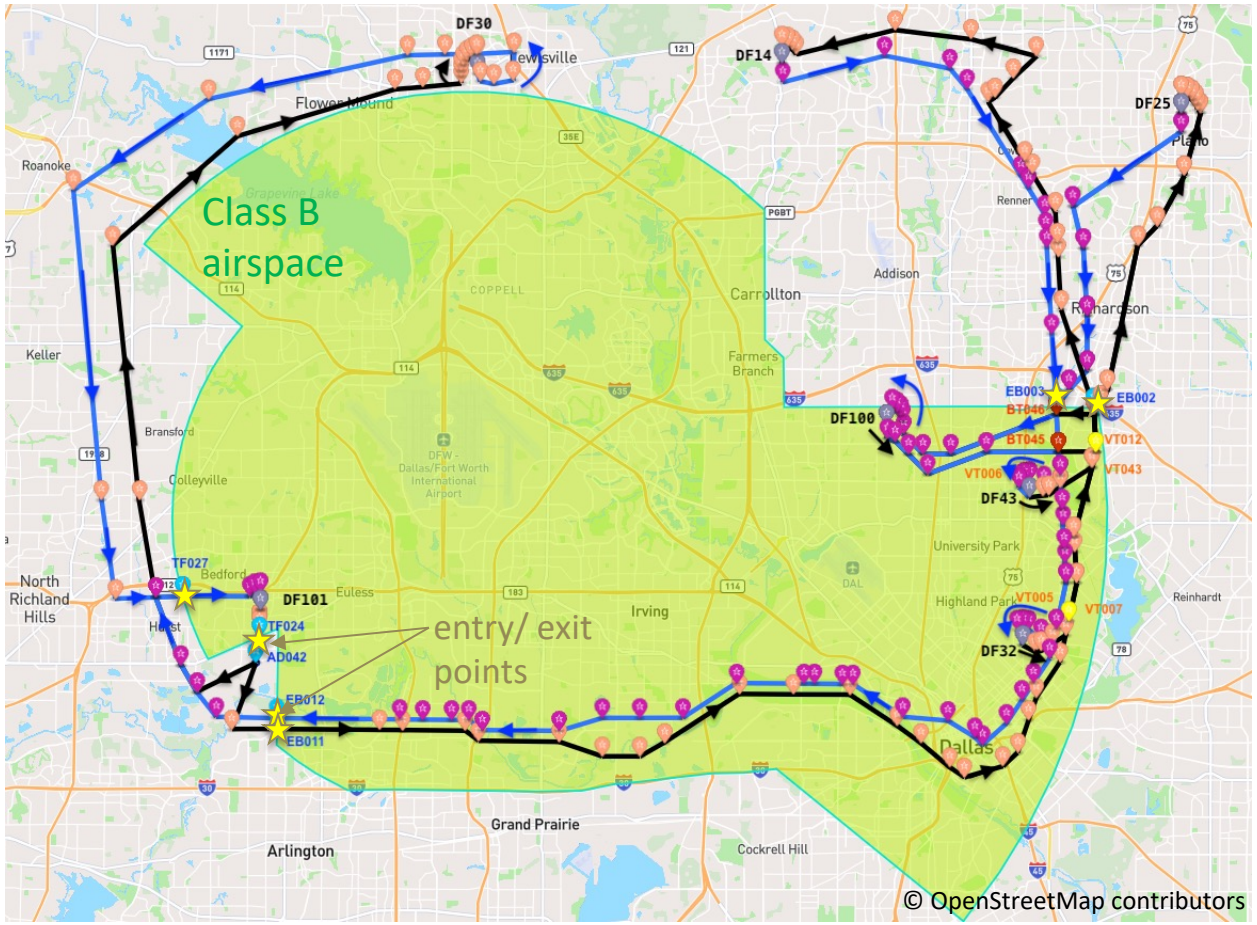


Test Cases

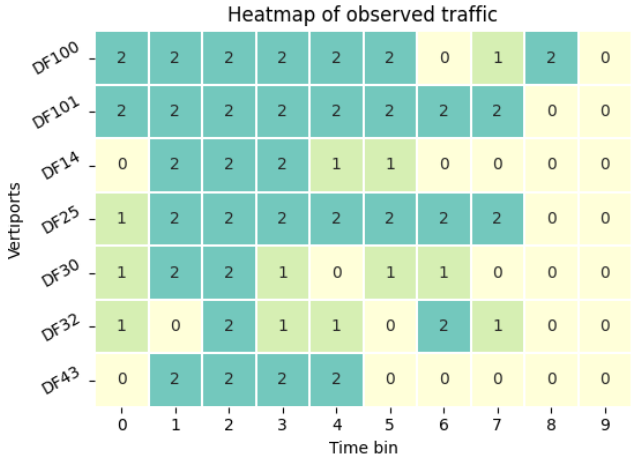
- Simulation configurations

No	Configuration	Demand-Capacity Balancing (DCB)	Sequencing & Scheduling (S&S)
Case 1	DCB only	6min before departure time	Off (0sec spacing)
Case 2	S&S only	Off (large capacity)	1min before departure time
Case 3	DCB, then S&S	6min before departure time	1min before new departure time modified by DCB
Case 4	DCB, then S&S without gap	6min before departure time	Immediately after DCB

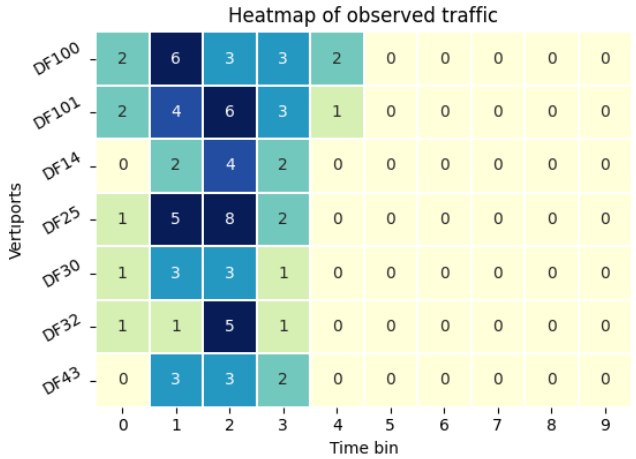
- Evaluation metrics
  - Number of demand-capacity imbalances detected and resolved
  - Ground delay assigned
  - Number of simultaneous operations

Simulation Results (1/3)

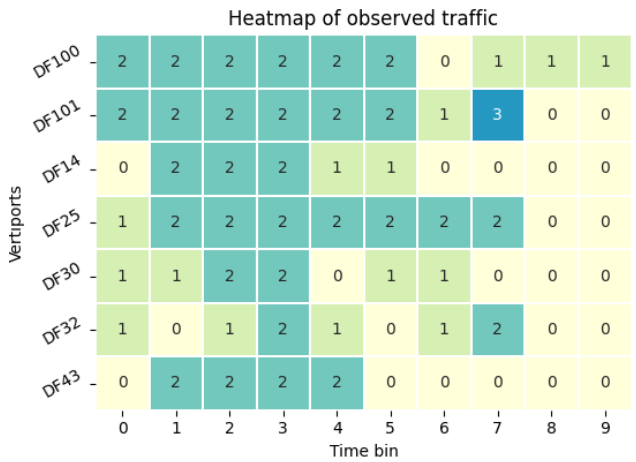
- Number of demand-capacity imbalances detected and resolved
  - Heatmap showing the observed traffic at each vertiport in 12-min time bin
  - Pre-departure delay assigned by DCB to meet the given capacity constraints
  - If DCB is applied (Cases 1, 3, & 4), demand is properly distributed
  - Additional delay assigned by S&S can cause DCB violations, if a scheduling gap between DCB and S&S exists.



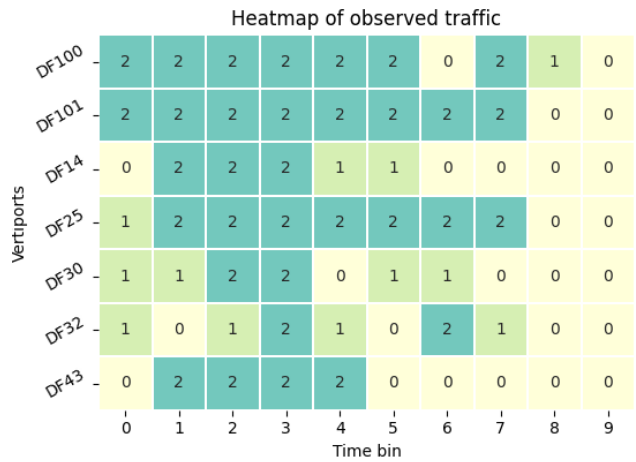
Case 1: DCB only



Case 2: S&S only



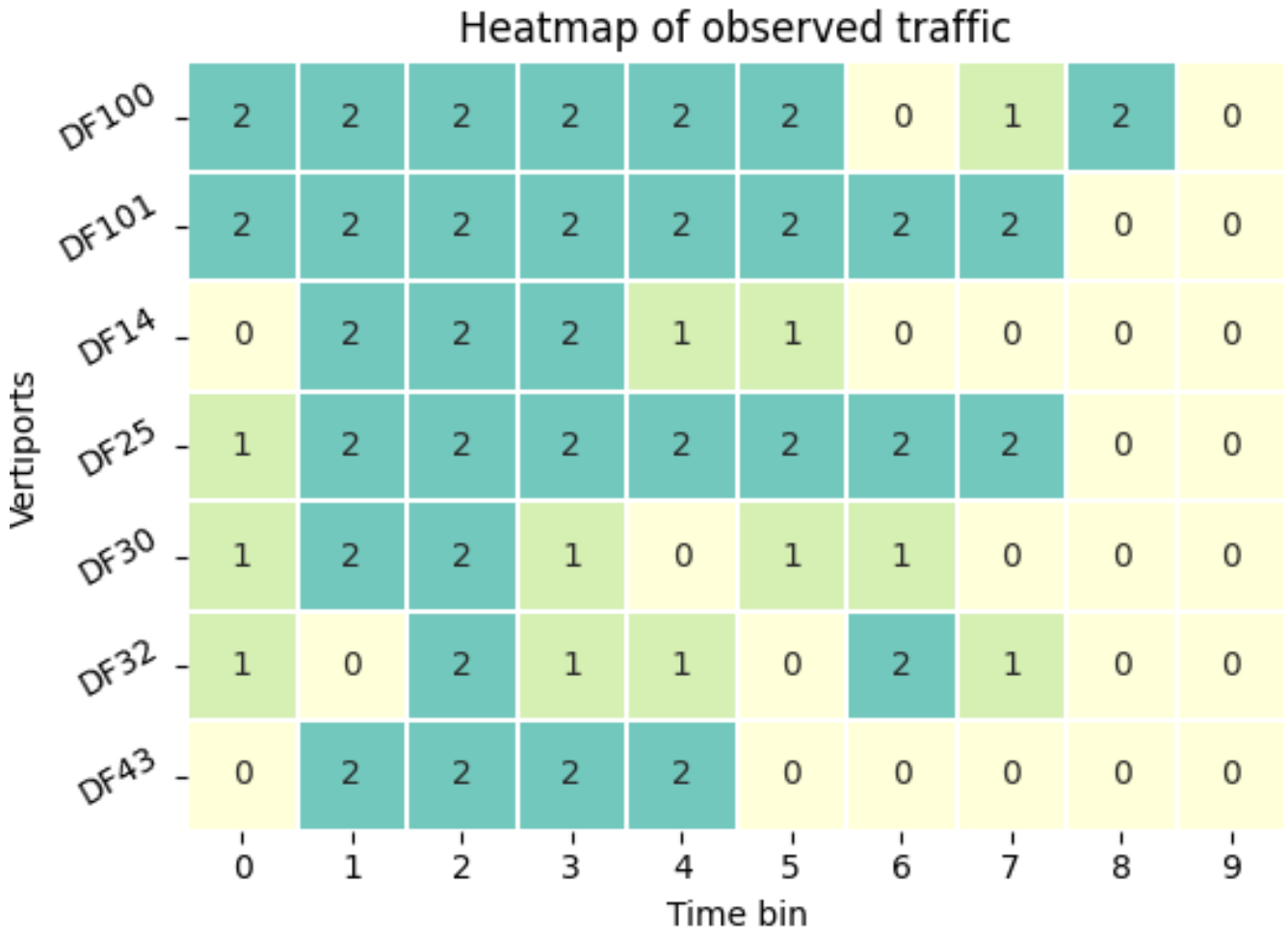
Case 3: DCB + S&S with time gap



Case 4: DCB + S&S without gap

Simulation Results (1/3)

- Number of demand-capacity imbalances detected and resolved
  - Heatmap showing the observed traffic at each vertiport in 12-min time bin
  - Pre-departure delay assigned by DCB to meet the given capacity constraints
  - If DCB is applied (Cases 1, 3, & 4), demand is properly distributed
  - Additional delay assigned by S&S can cause DCB violations, if a scheduling gap between DCB and S&S exists.



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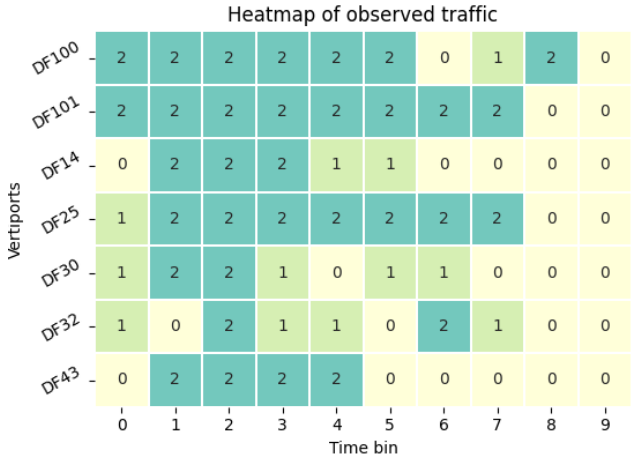
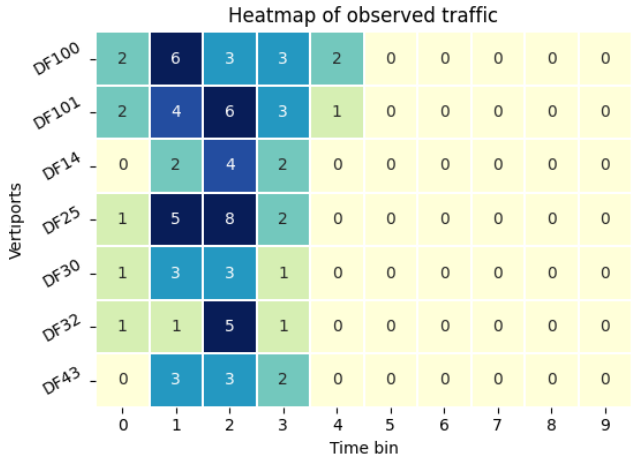
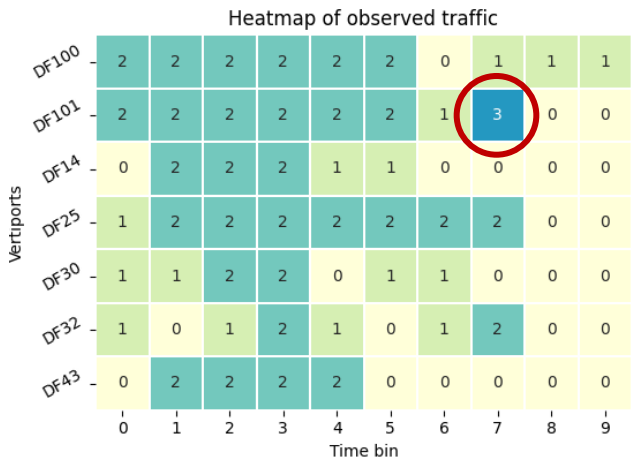


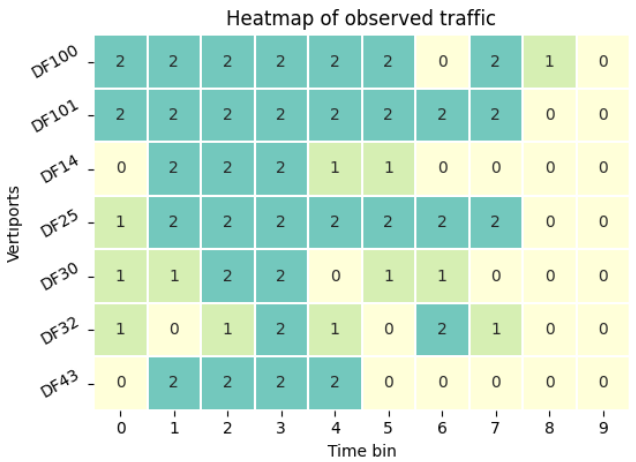
Case 1: DCB only



Case 2: S&S only



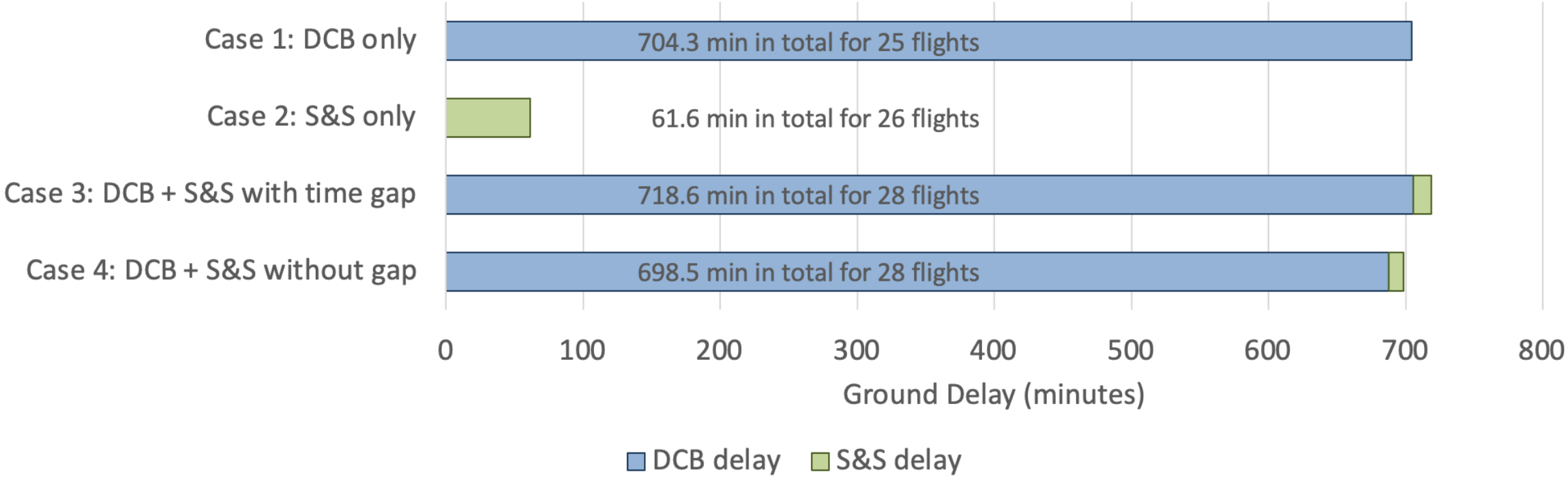
Case 3: DCB + S&S with time gap



Case 4: DCB + S&S without gap

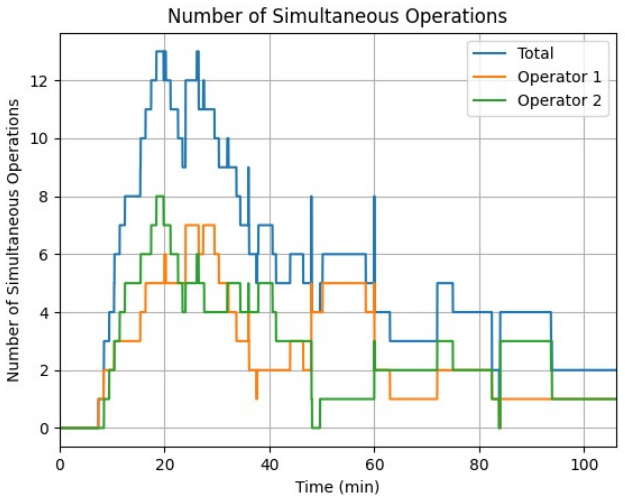
Simulation Results (2/3)

- Pre-departure ground delay assigned by DCB and S&S
  - Large delay by DCB due to the packed demand in given scenario and low vertiport capacity
  - S&S put additional delay to meet the minimum separation requirements at pre-tactical level
  - In Case 4, total delay is reduced as flights would fix their departure times early

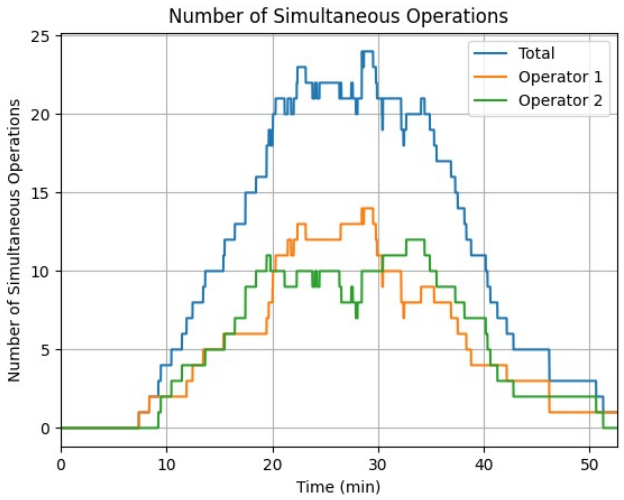


Simulation Results (3/3)

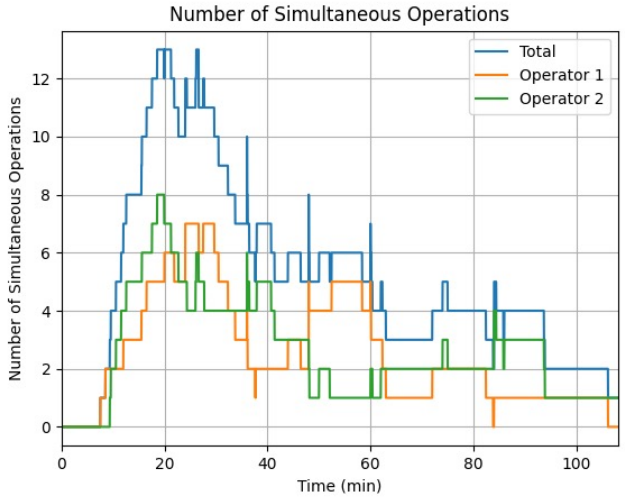
- Number of simultaneous operations
  - If DCB applied (Cases 1, 3, & 4), no differences are observed
    - Average 5 aircraft
    - Maximum 13 aircraft in total
  - If S&S only applied (Case 2), traffic pattern is different
    - Higher number of concurrent operations
    - Shorter time to complete the given scenario due to small delay



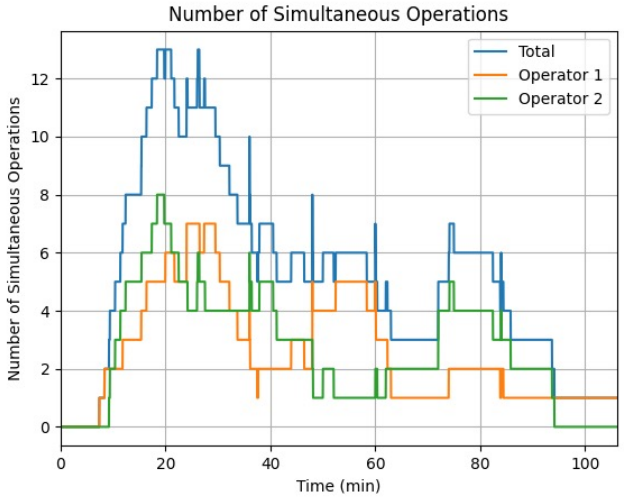
Case 1: DCB only



Case 2: S&S only



Case 3: DCB + S&S with time gap



Case 4: DCB + S&S without gap

Conclusions

- Developed a reference architecture for UAM airspace system and conducted simulations to evaluate UAM concept of operations

- Assessed two strategic conflict management methods and their interaction
  - Demand-Capacity Balancing (DCB) at vertiports
  - Sequencing and Scheduling (S&S) at control waypoints

- Verified that DCB and S&S worked well as expected and identified issues to be improved
  - Large ground delay by DCB
  - Lead times of DCB and S&S for efficient flight scheduling

Q & A

Thank You!

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