A Simulation Study of Bin-and-Sort Policies in a Distributed System for Flight Scheduling

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Motivation

- Facilitate cross-airline collaboration in flight scheduling
- Enable automated scheduling without:
  - unwanted disclosures airline to airline
  - double-booking a part of airspace (violating separation)
  - putting all hardware and software requirements on a centralized entity

Past research

- Collaborative scheduling of flights
  (e.g., Collaborative Trajectory Options Programs, aka CTOP)
- Scheduling by a multi-operator system
  (UAS Traffic Management, aka UTM)

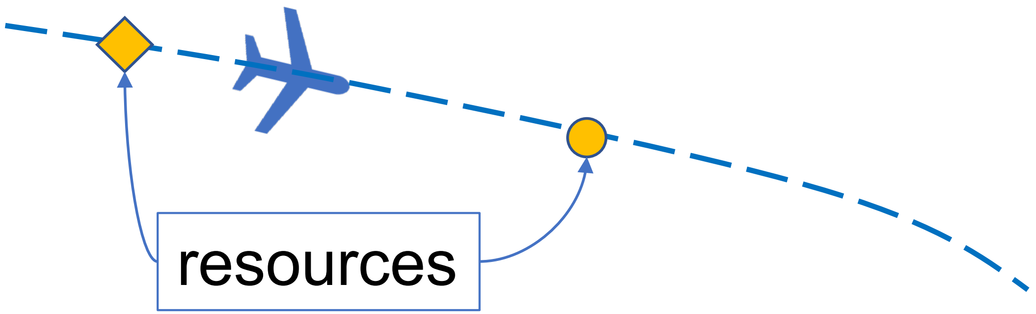
Approach

- Simulate airlines scheduling their flights by using:
  - Different autonomous software agents, provided by operators
  - An interface for agents to interact & meet traffic constraints
- Study the performance and costs of such a system

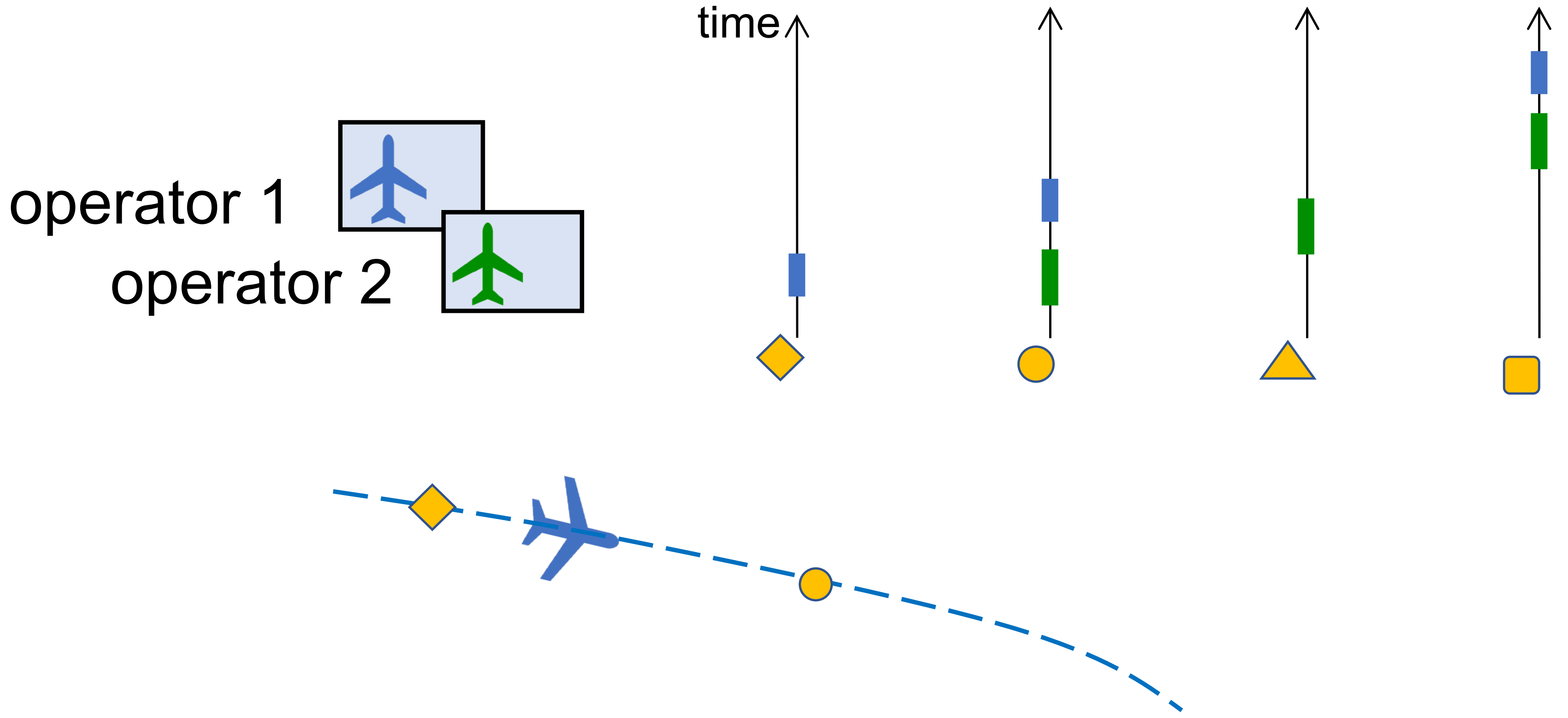
Outline

- Context & Problem Statement
- Operators sharing airspace
- Simulation experiment

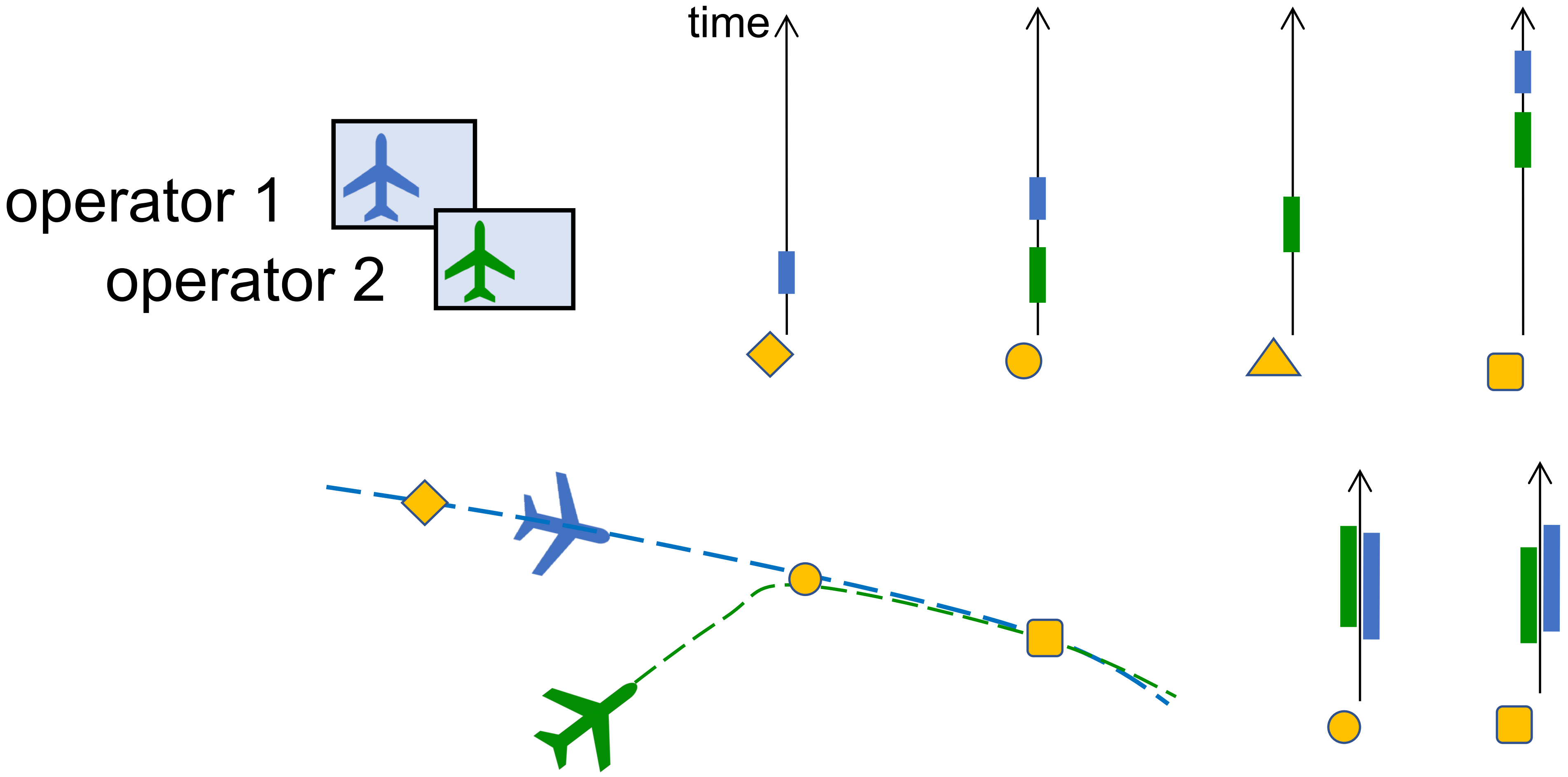
Context & Problem



Context & Problem



Context & Problem



Outline

- Context & Problem Statement
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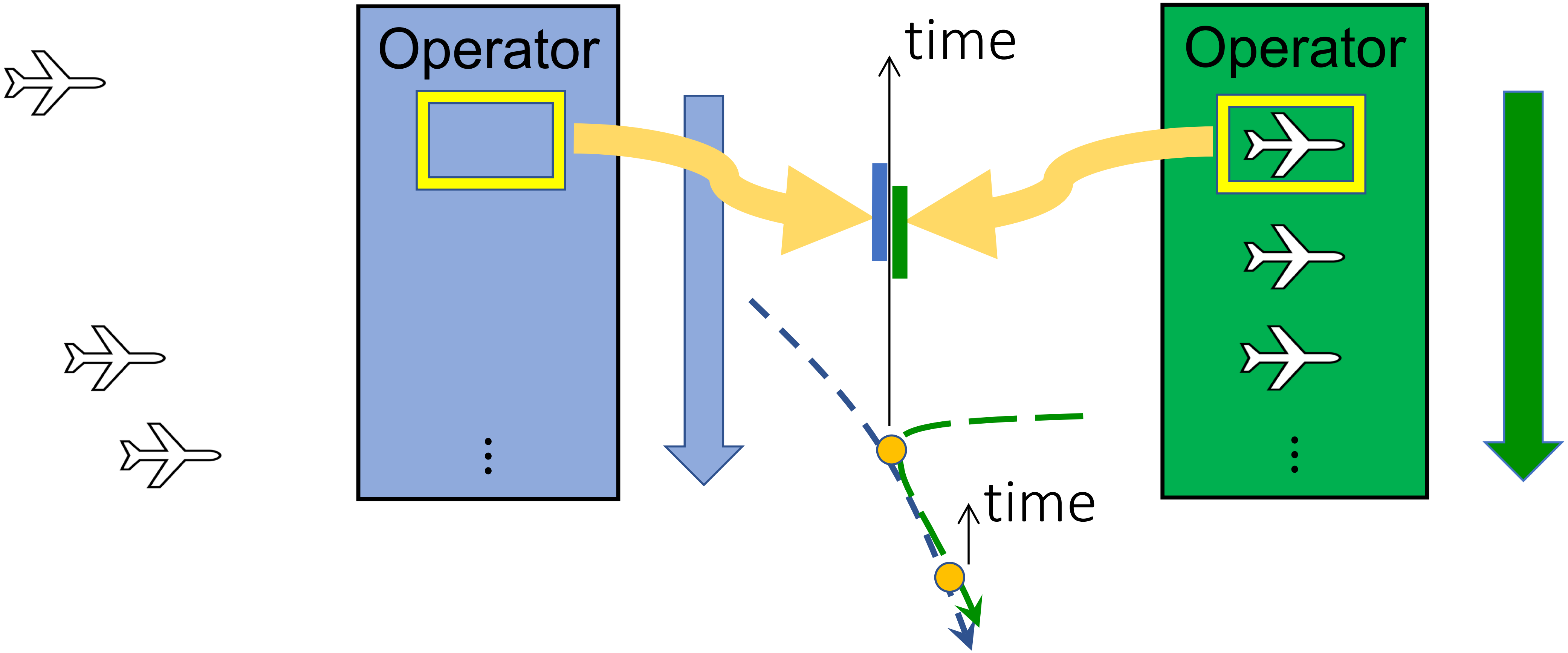
- Two talks by Windhorst et al., this session
- Applicable to new vehicles; e.g., eVTOL

Ordering flights for scheduling

Priority: internal to each operator

Arbitration: between operators



Outline

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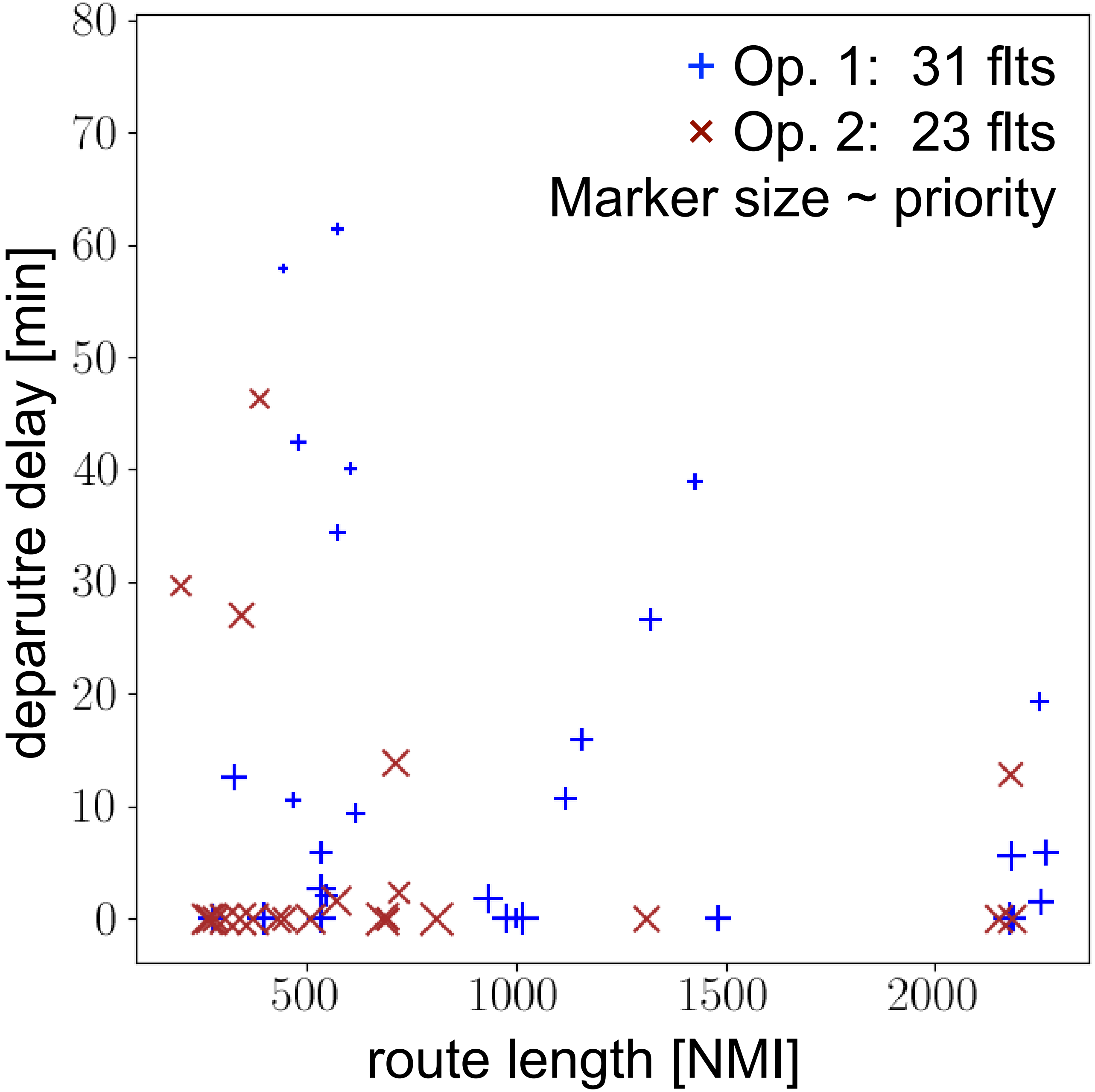
Experiment Setup: Two Operators

Run	Prioritization, Operator 1	Prioritization, Operator 2	Abitration
1	N/A	N/A	Flight route length
2 - 6	Random ordering	Random ordering	Flight route length
7-11	"	"	Earliest scheduled departure time
12-16	"	"	Earliest estimated landing time
17	One operator, centralized scheduling		Earliest estimated landing time

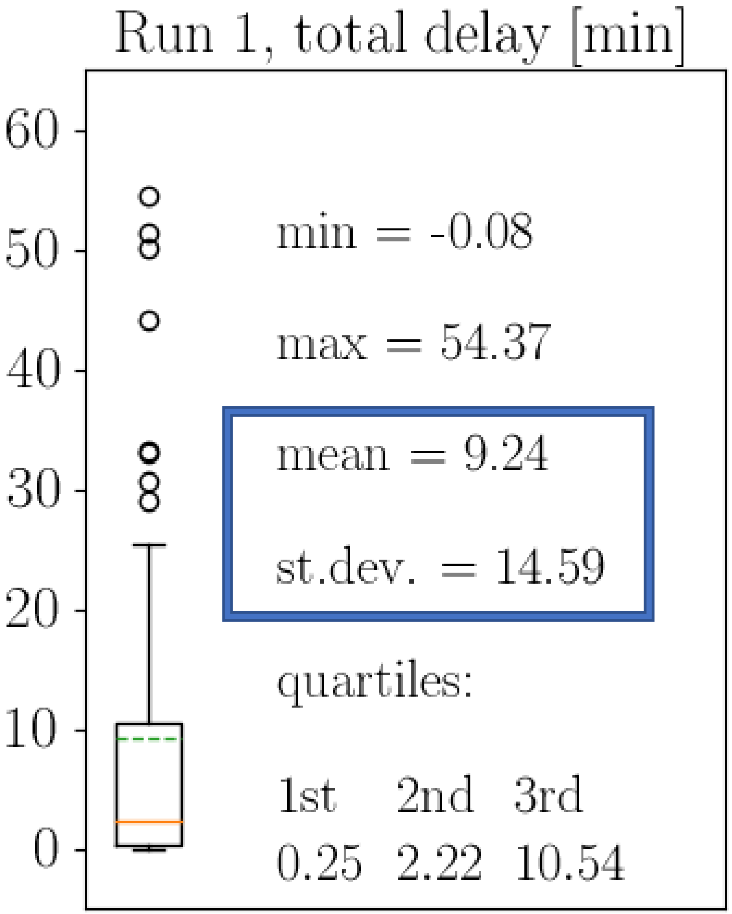
Select results on priority

Run 2

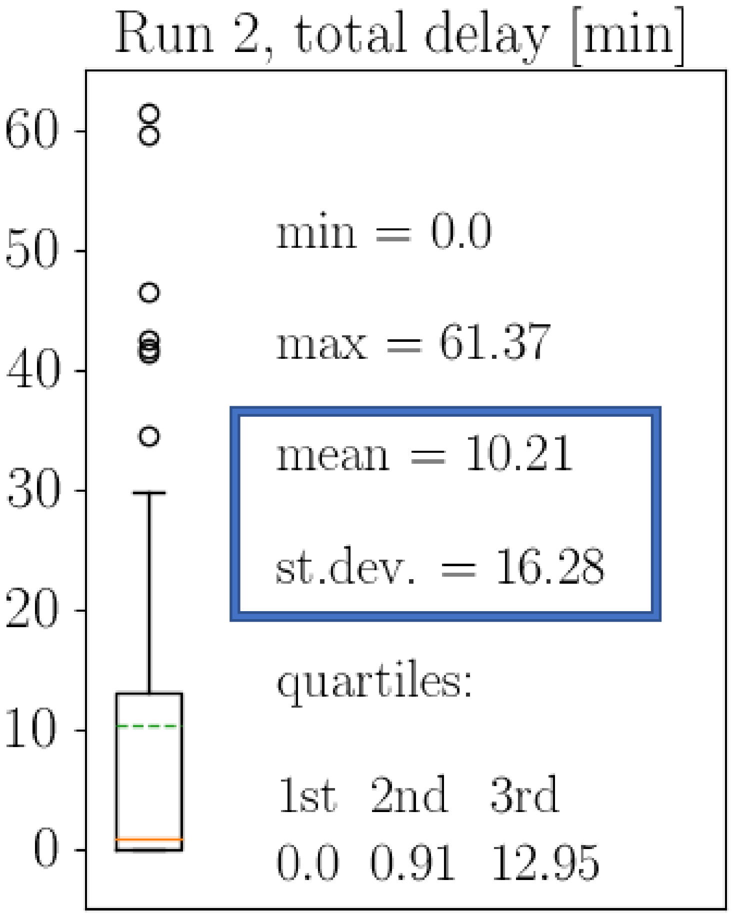


Select Costs

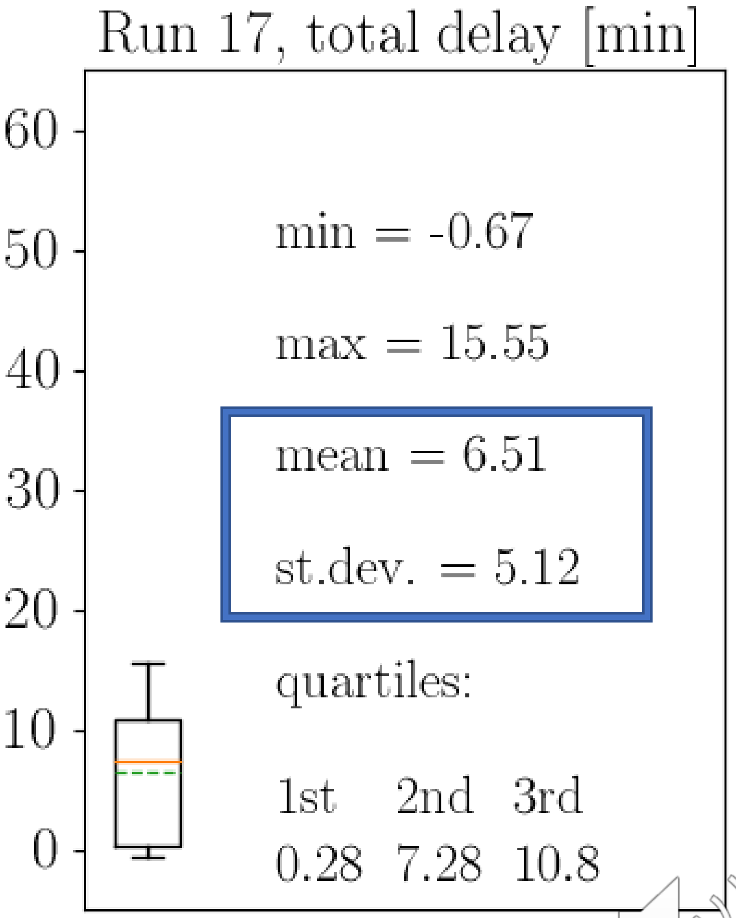
Pri.: N/A
Arb.: route length



Pri.: random perm.
Arb.: route length



Single operator



Summary

- Larger fleets get more delay (mean & st.d.)
- Priority by route length or scheduled departure time is honored fairly well
- Centralized system better minimizes delay, since has all information
- The multi-operator system spaces departures to match the landing runway capacity (data not shown)

Next Steps

- Address the higher delay incurred by the larger fleets in arbitration
- Apply multi-agent scheduling to future air transportation

Thank you!

Priority and Arbitration: definitions

Examples of prioritization criteria:

- By earliest scheduled departure time
- Random permutation (modeling the proprietary policies of the airline)

Experiment Setup and Research Questions

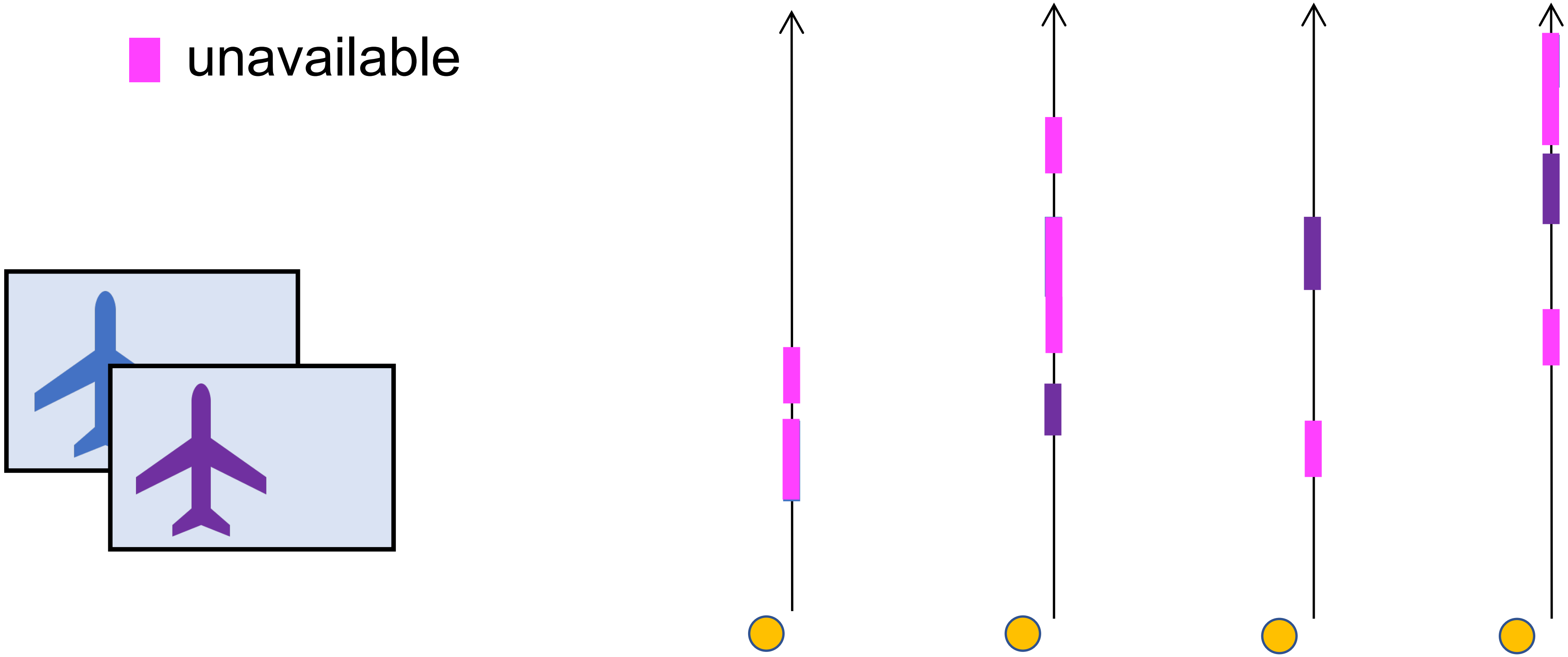
- Experiment Setup summary:
  - Based on historical arrivals to EWR on Apr 26 2018
  - 17 Runs
  - Two operators (runs 1-16), one operator in run 17
  - Criteria of priority:
    - Earliest scheduled departure time (run 1)
    - “Black box”: random orderings (runs 2-16)
  - Criteria of arbitration:
    - Earliest scheduled departure time (runs 1, 7-11)
    - Flight route length (runs 2-6)
    - Earliest estimated landing time (runw 12-16)
- Research questions: how does distributed (runs 1-16) vs. centralized (run 17) affect…
  - …departure delays?
  - …airborne delays?

Summary

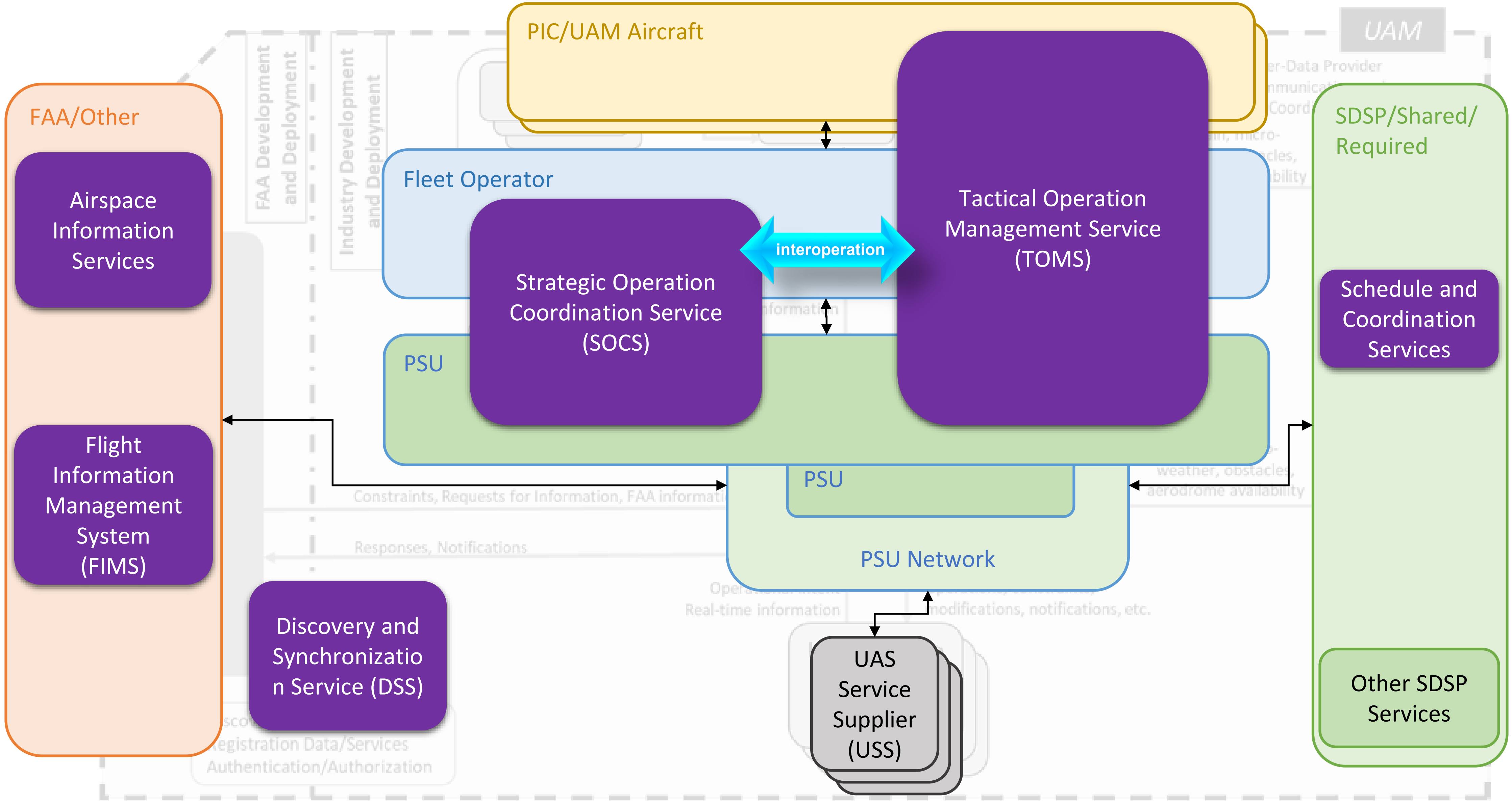
- CSMART, the proposed system:
  - Multiple *Operators* schedule their flights, coordinating via *arbitration* to share resources with fairness and equity.
  - *Resource Schedule* is constantly updated and accessible by all operators. Gives all the time windows of unavailability at each resource.
  - This enables coordination and information exchange required for feasible predeparture schedules.
- OUTPUT: time-parameterized trajectories of simulated flights
- IMPACT:
  - Identification and development of CBRs for interaction between operators
  - Estimates of operational efficiency attainable under the proposed system with the assumed aircraft performance envelopes
  - Insights into the safety of the system, its robustness to perturbations, and the risks

Backup slides

An inherent asymmetry:
The earlier reservations have an advantage



Candidate Services Mapping



Connection to Roadmap

- UML 3/UML 4 – Medium/High Vertiport Demand – 30 – 60 aircraft / vertiport / hour
- 2.14. Shared Services (FA: AS)
  - Schedule and Coordination Services
    - Provides **shared resource availability and usage information** (e.g., schedule services for TBD vertiports or other non-operator managed resources)
    - Provides **coordination information and/or functions as required by multiple operators**

Connection to Roadmap - continued

- 2.15. Operator Services (FA: AS)
  - Strategic Conflict Management
    - **CBRs or requirements will likely need to be set** to ensure that Strategic Conflict Management Systems implemented (or used) by different operators are compatible.
    - Functionality of Strategic Conflict Management capabilities is designed to facilitate traffic management at the Separation Provision layer as uncertainty is reduced.
    - **Capable of planning/scheduling operations given constraints** (in particular, constraints related to Demand Capacity Balancing) at vertiports, waypoints associated with published tracks, regions of airspace, etc.
  - Operations Planning and Scheduling
    - **Operation planning may implement inter-operator negotiations**
    - Operational plan filing required if accessing any route/vertiport
    - Operational plans are generated and submitted automatically

Connection to Roadmap - continued

- Demand Capacity Balancing
  - Additional flow constraints would be imposed beyond the capacity constraints to condition flow given expected demand, **to enable fair and equitable use of resources**, to improve system efficiency etc.
  - Vertiports implement the scheduling required for their resources in scheduling /reservation services hosted by each vertiport entity as part of the vertiport's management systems (capacities are determined from the resources at the vertiport; demand balancing is managed implicitly by the scheduling/resource state)
  - Vertiport scheduling is **extended to the arrival and departure points from/to the terminal area of a vertiport as required to implement terminal ariival/departure routes and procedural separation**, especially for larger vertiports (those with many vertipads)
  - Capacity-constrained airspace regions (how is this identified?) may require implementation of strategic flow management in pre-departure planning **by limiting access or requesting delay based on proposed operations plans** (except for sources/sinks such as vertiports, explicit point-in-space scheduling is not used)