Automated Scenario Generation for Meeting Human-in-the-Loop Simulation Requirements

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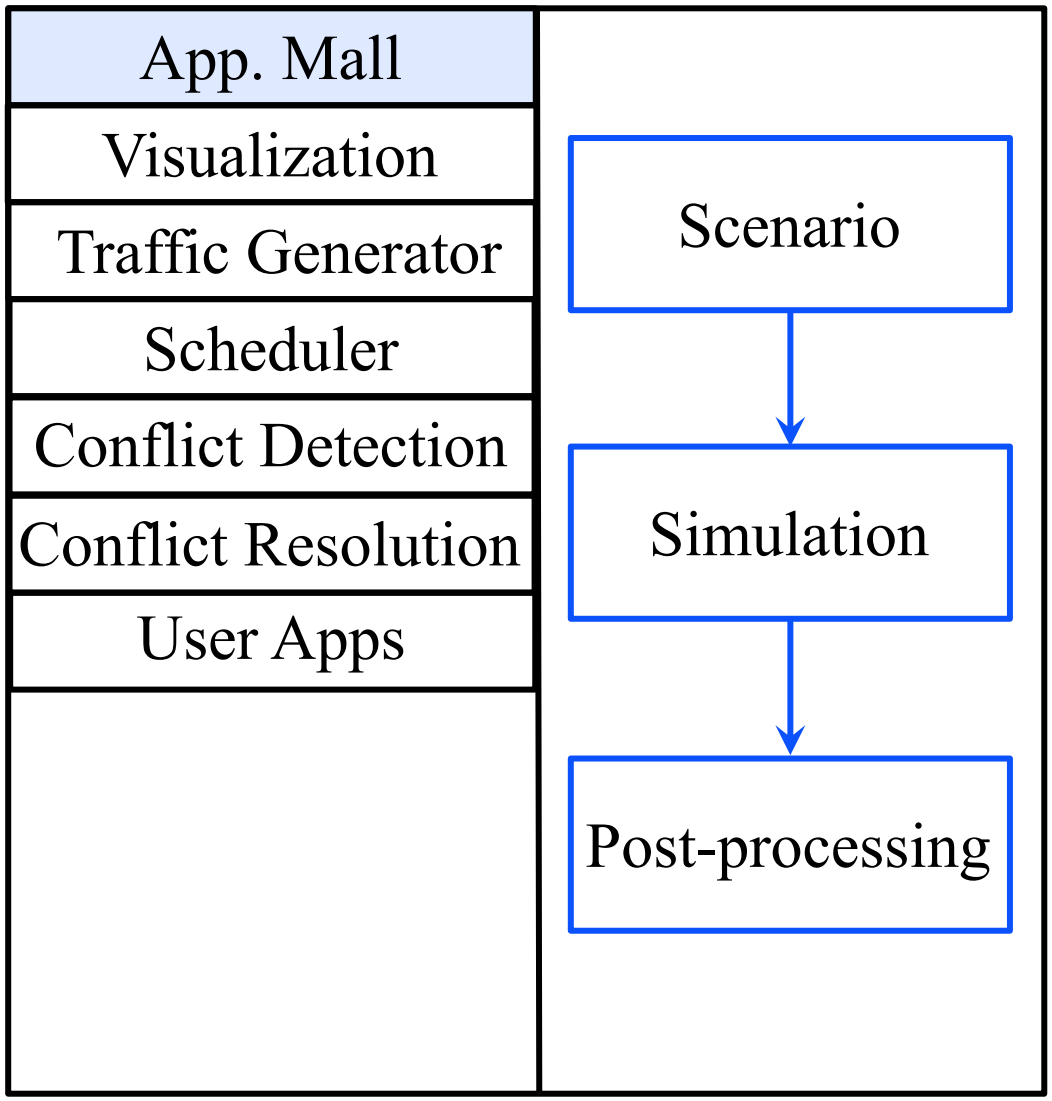
Air Traffic Management Testbed (ATMTB)

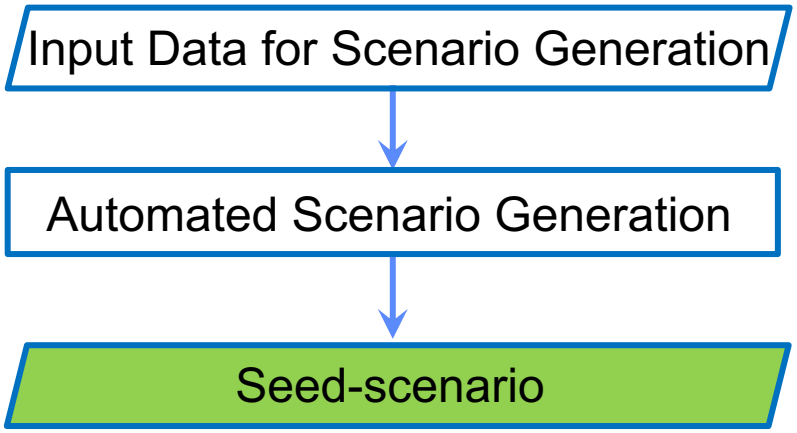


- NASA building testbed to accelerate deployment of ATM concepts into NAS
- Goal of providing access to community
- Provides infrastructure and some applications
- Scenario generation is one of the capabilities of testbed

Motivation

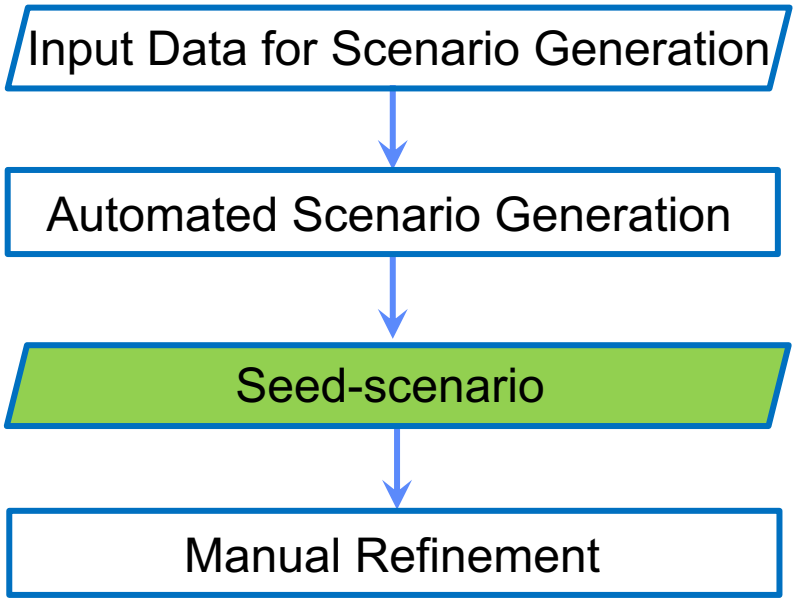
- Manual creation of realistic scenarios for generating traffic for Human-in-the-Loop (HITL) simulation is difficult
  - Missing and erroneous data
  - Manual process is time consuming
  - Difficulties cause studies to be limited to few scenarios
- Automated scenario generation has potential for overcoming limitations
  - Use real air traffic data to create scenario
  - Remove flights with erroneous data
  - Select flights to achieve the desired short-haul to long-haul ratio
  - Alter landing times to shape scenarios

Background: Aviation 2018 Paper



"Automated Scenario Generation for Human-in-the Loop Simulations," *AIAA Modeling and Simulation Technologies Conference*, Atlanta, GA June 25-29, 2018.

Background: Aviation 2018 Paper



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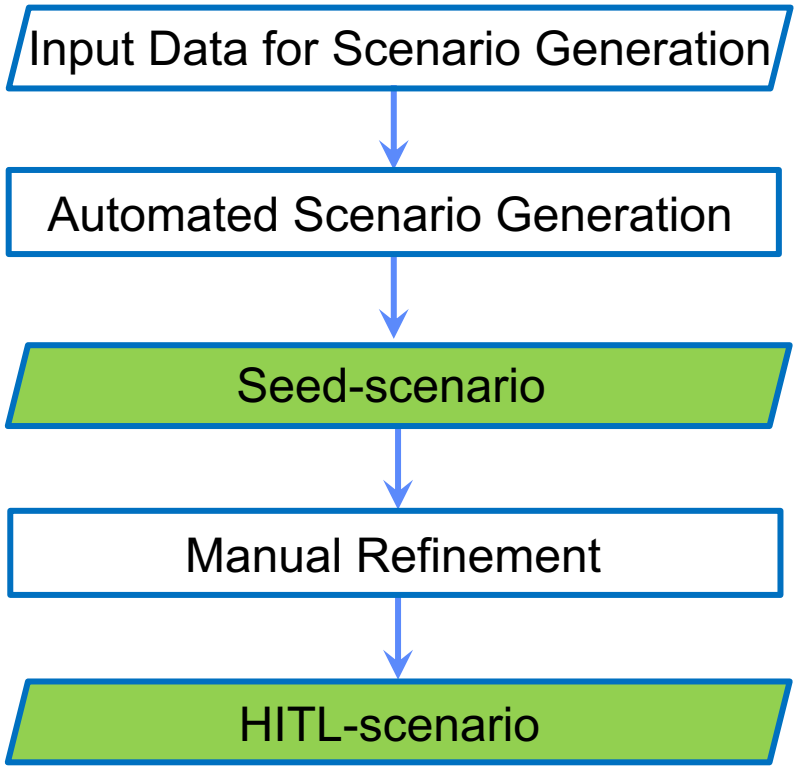


- Simulations can be run with ATM Testbed created seed-scenario
- Seed-scenario found to be a good starting point for creating HITL-scenario
- Experience showed that many of the manual adjustments can be automated to directly create the HITL-scenario

Outline

- Step 1: Automated scenario generation using ATM Testbed
- Step 2: Automated scenario refinement
- Traffic scenario selection
- Results
- Conclusions

Input Data Source for Scenario Generation

- System-Wide Information Management (SWIM) data processed into files, and stored in Sherlock data-warehouse
- Reduced Record (RD)
  - Single record for each flight
    - Beacon-code, flight-plan, takeoff/landing runway, departure/arrival time, sector/center transition list
- Event Data (EV)
  - Multiple records related to events for each flight
    - Event time and type- landing, crossing (sector, center, TRACON)
- Integrated Flight Format (IFF)
  - Multiple records for each flight
    - All flight plans including amended flight plans & position data
- RD and EV useful for filtering and IFF for data augmentation

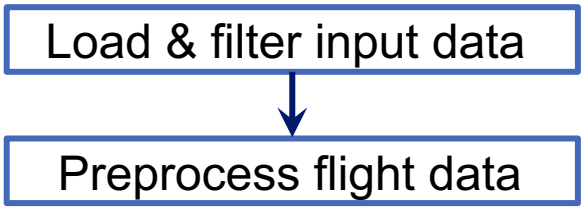
Multi-Aircraft Control System (MACS) Scenario Generation

- MACS is a distributed system with multiple-pseudo pilot and air traffic controller stations
- It is frequently used at NASA for HITL evaluations of ATM concepts
- MACS traffic scenario consists of
  - Flight route
  - Initial conditions

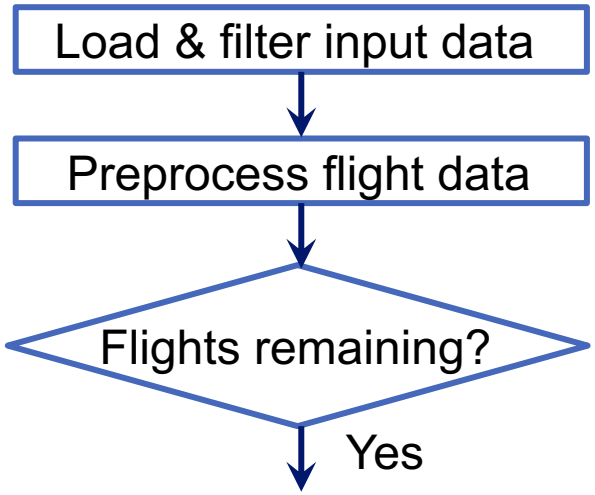
ATMTB Scenario Generation Steps

Load & filter input data

ATMTB Scenario Generation Steps



ATMTB Scenario Generation Steps



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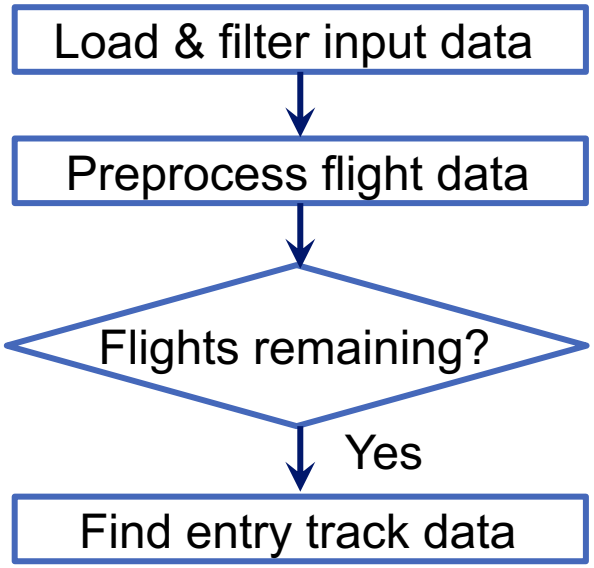

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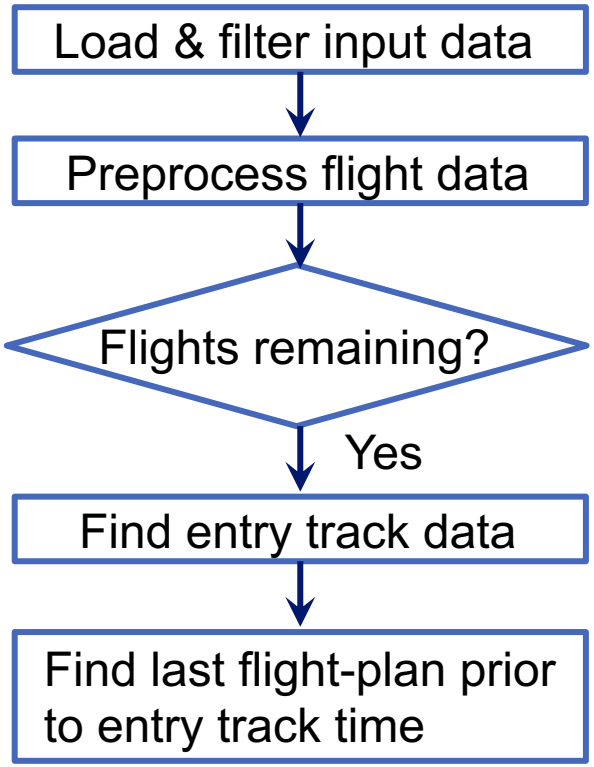

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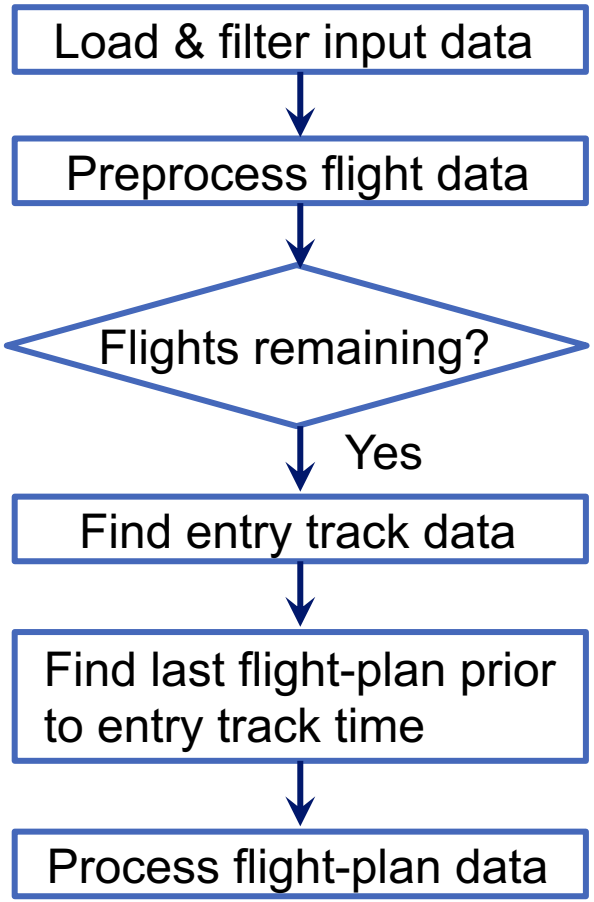

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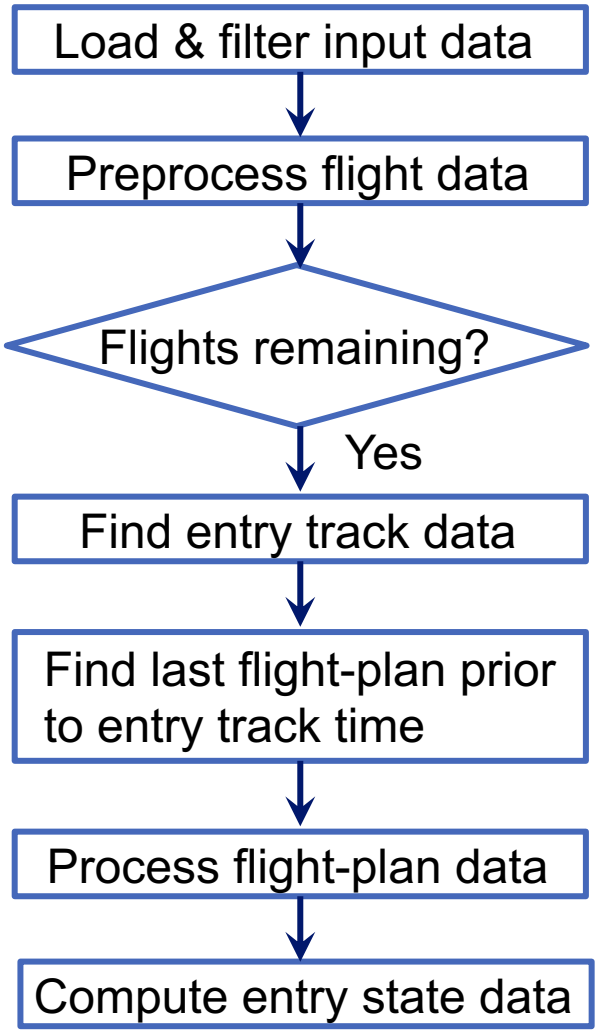

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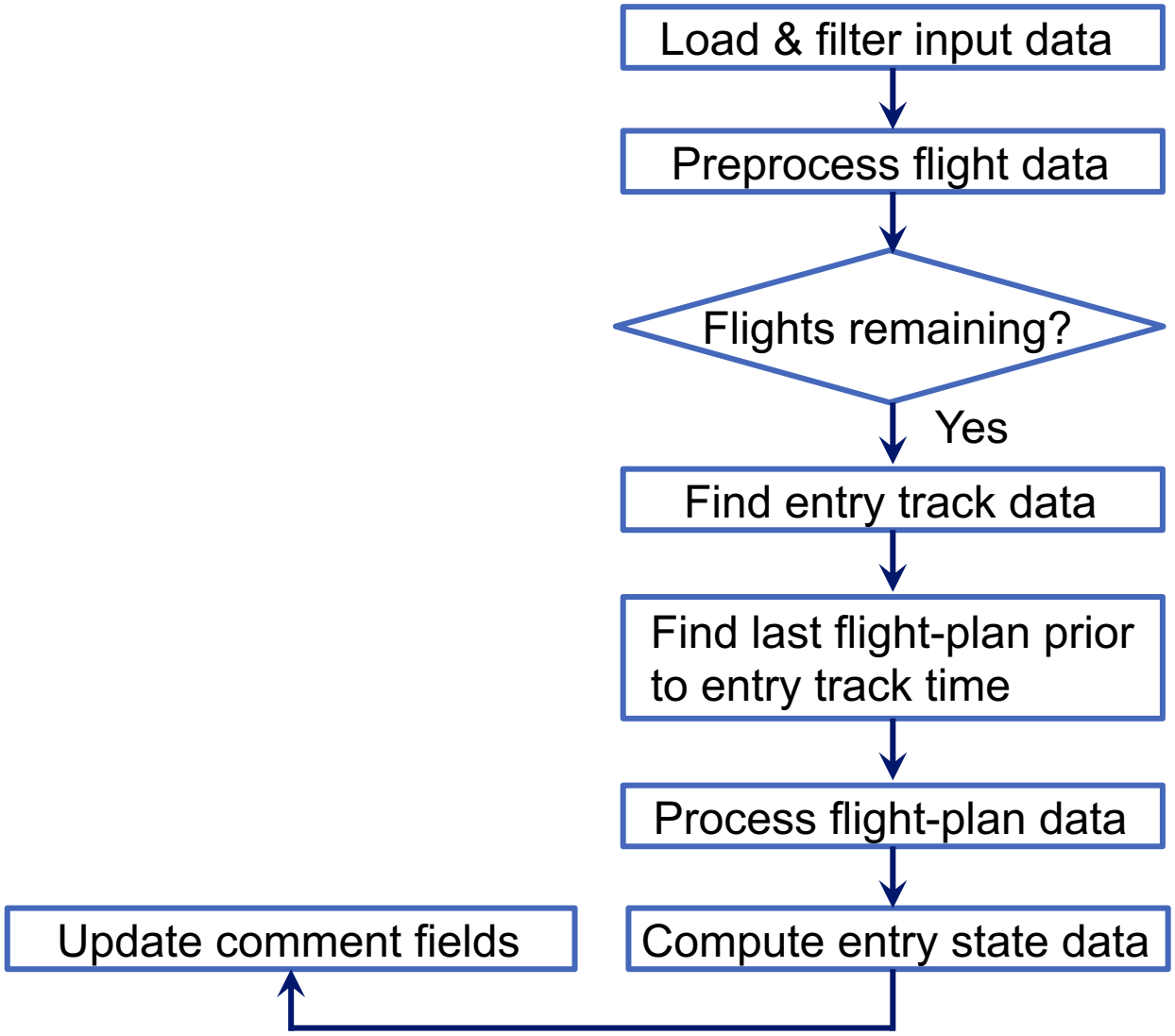

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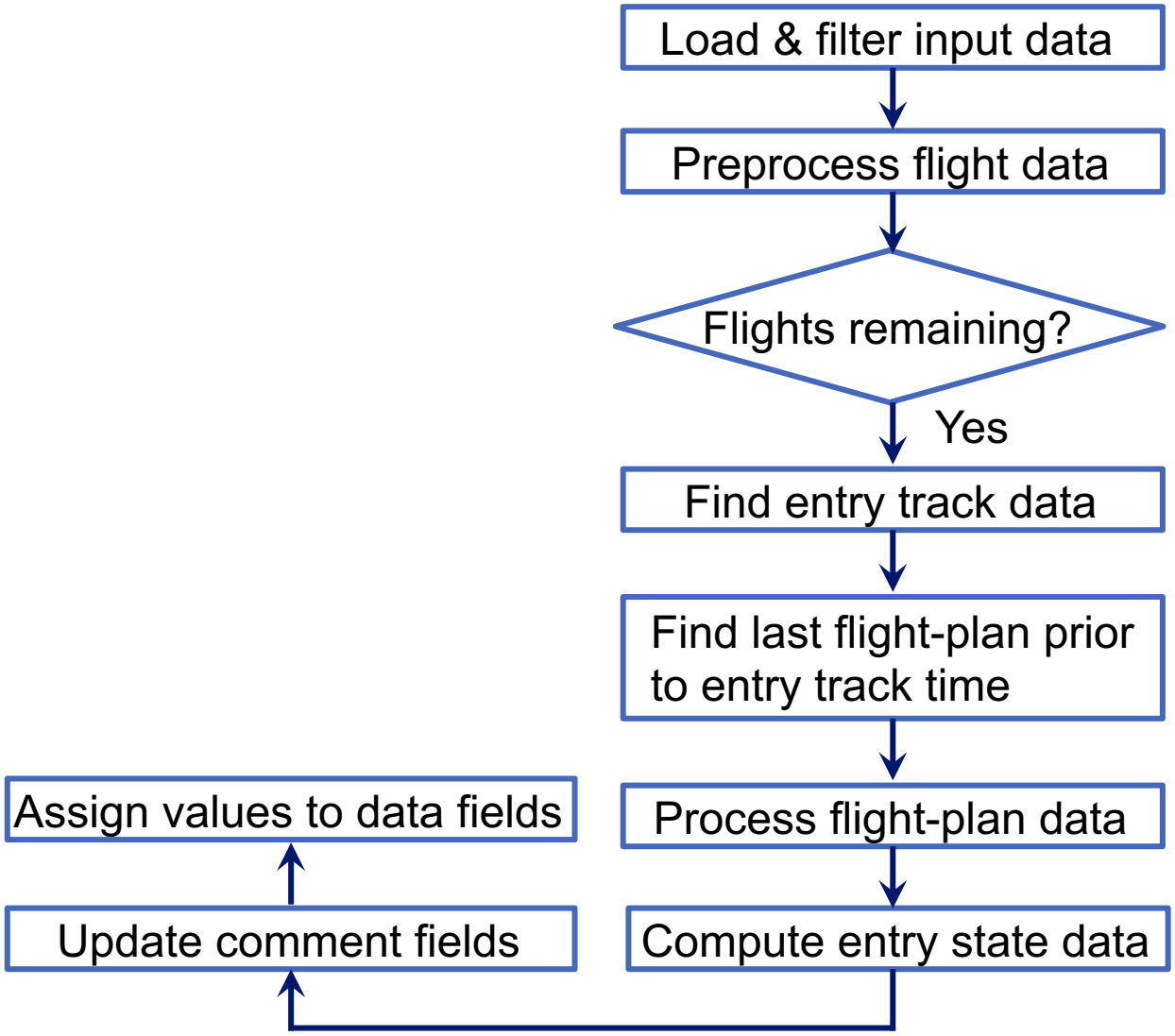

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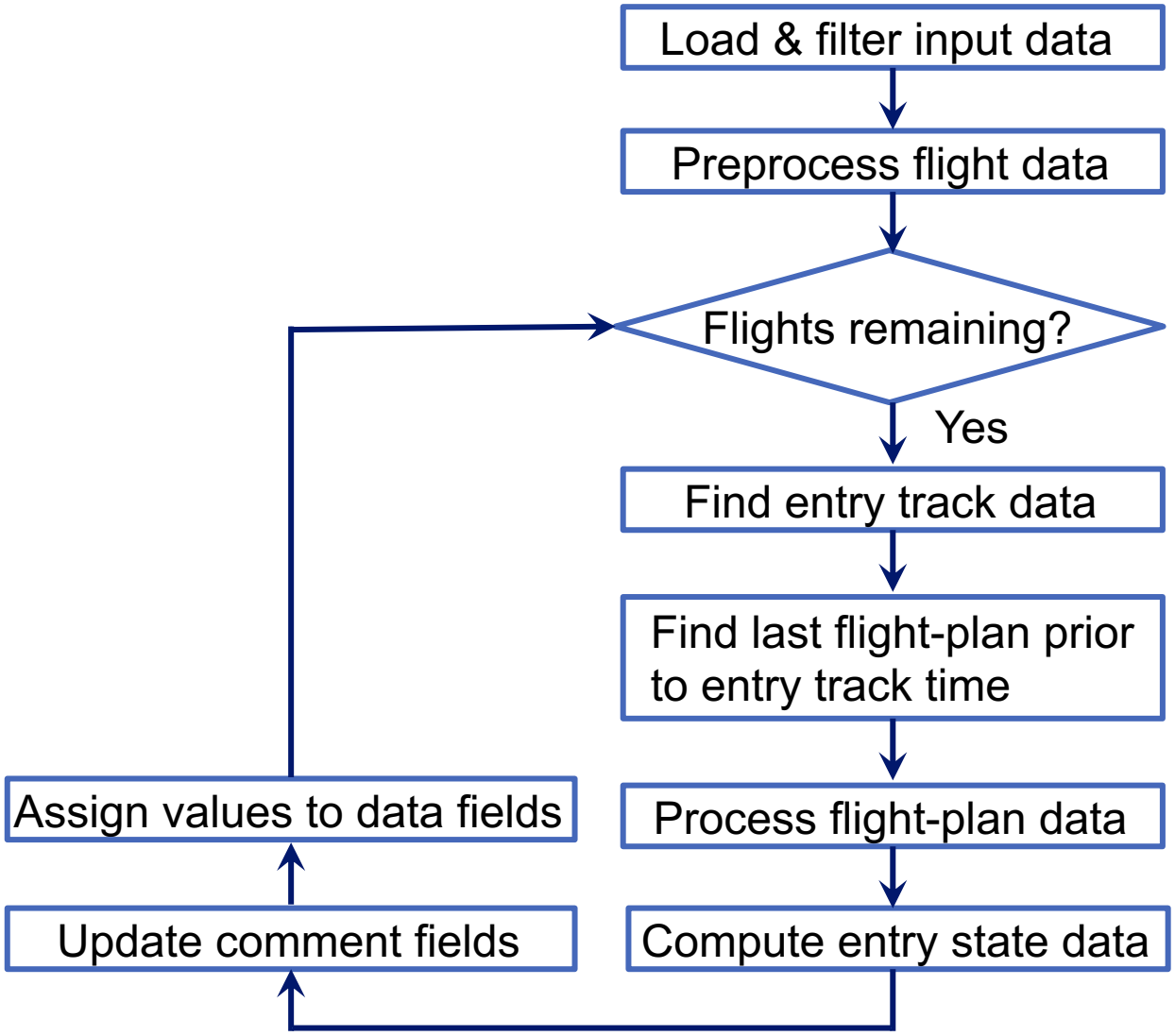

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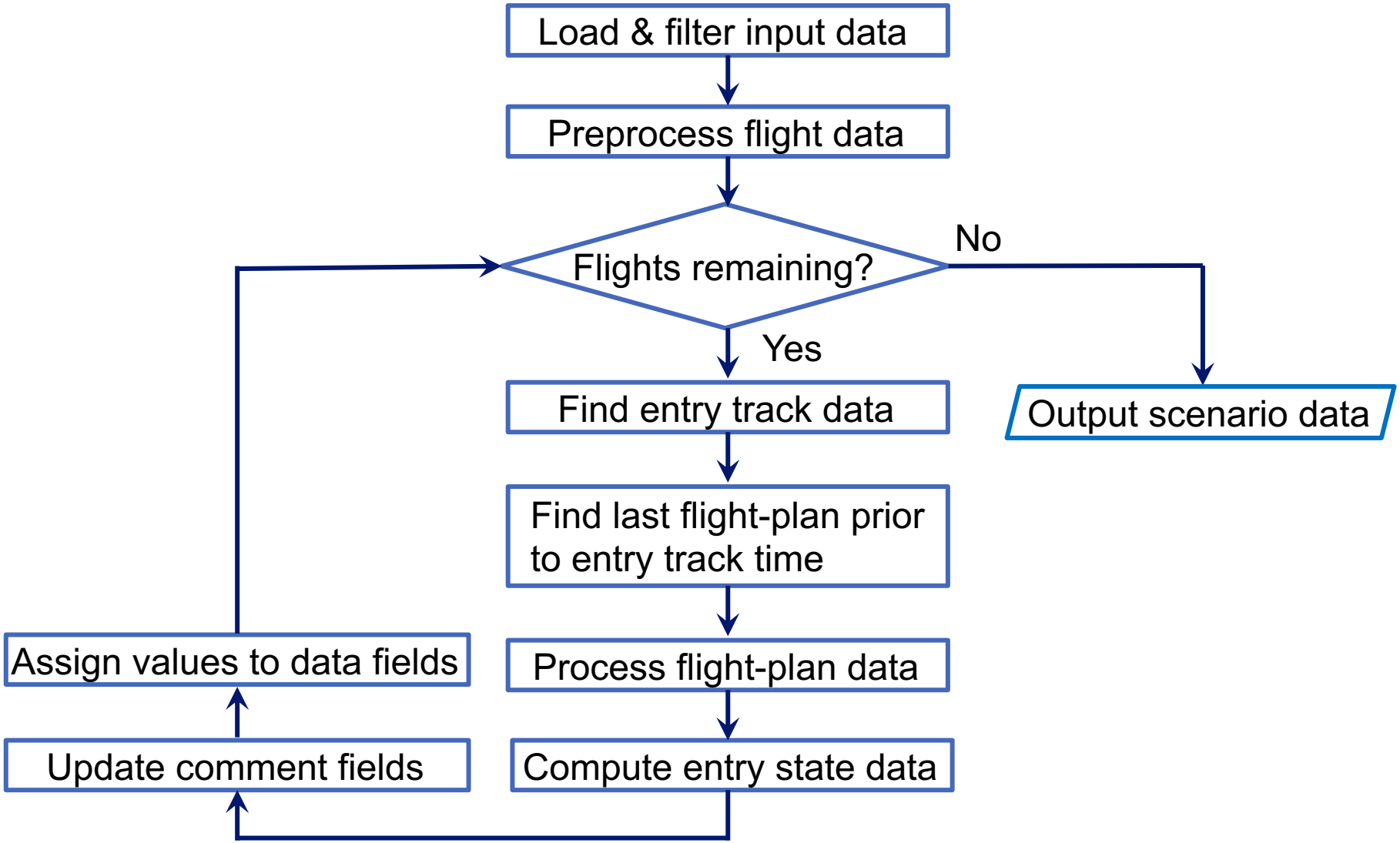

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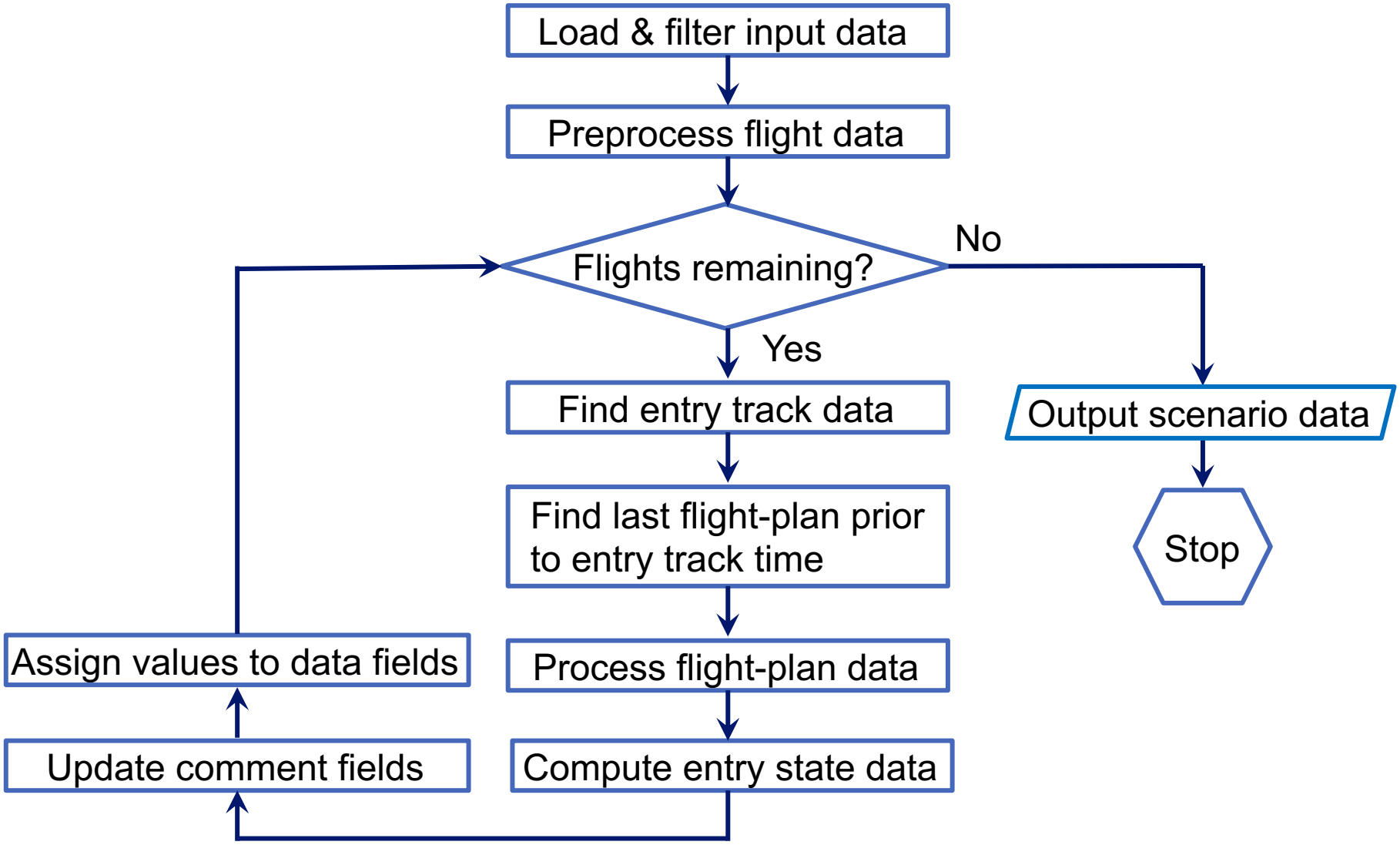
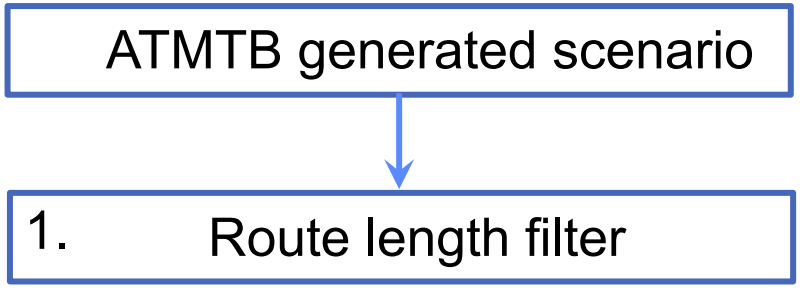


New Automated Scenario Generation Process

ATMTB generated scenario

New Automated Scenario Generation Process



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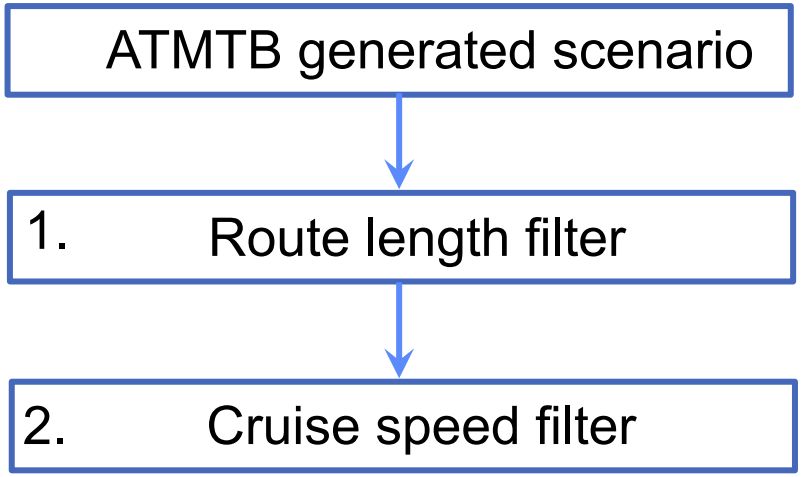

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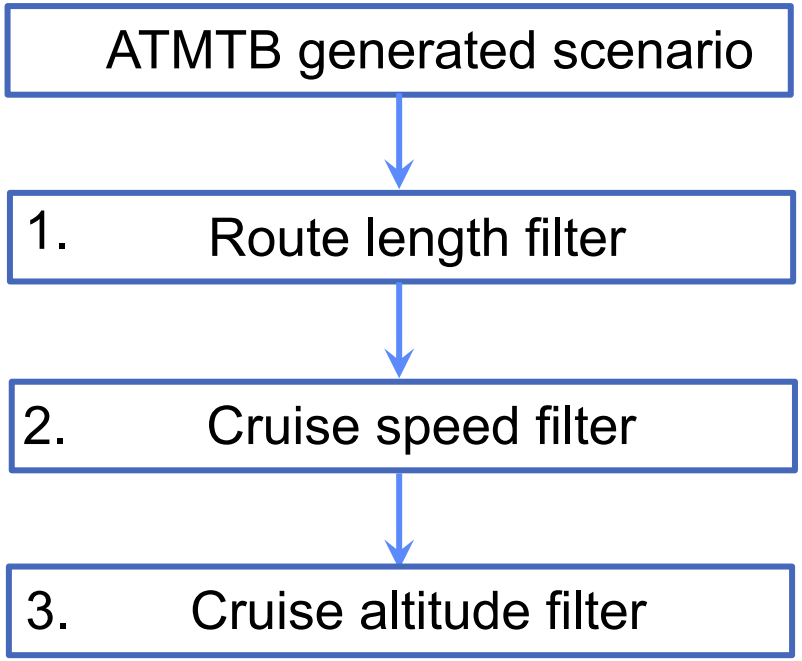

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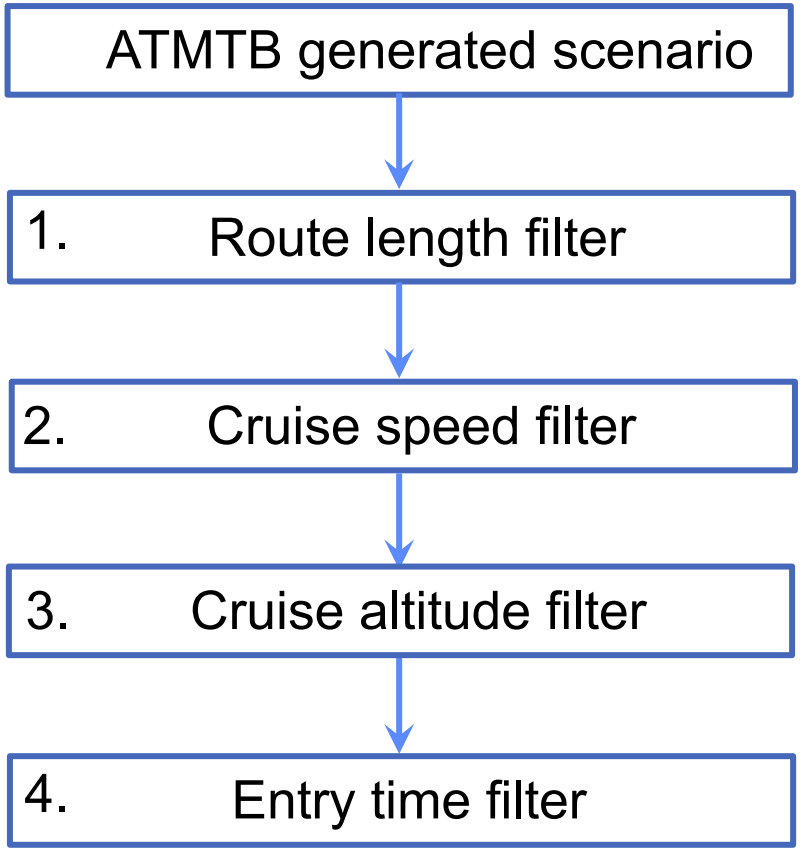

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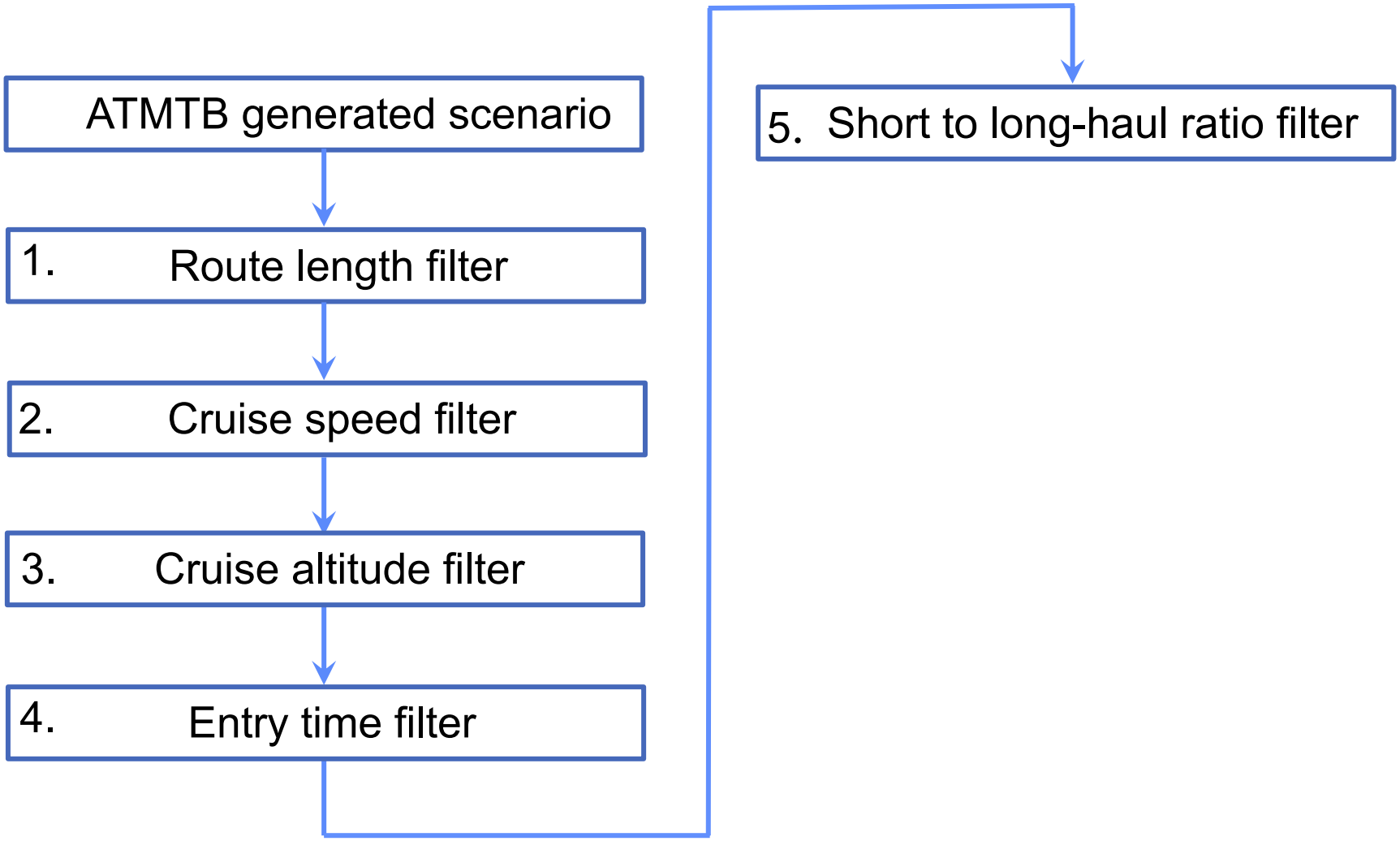

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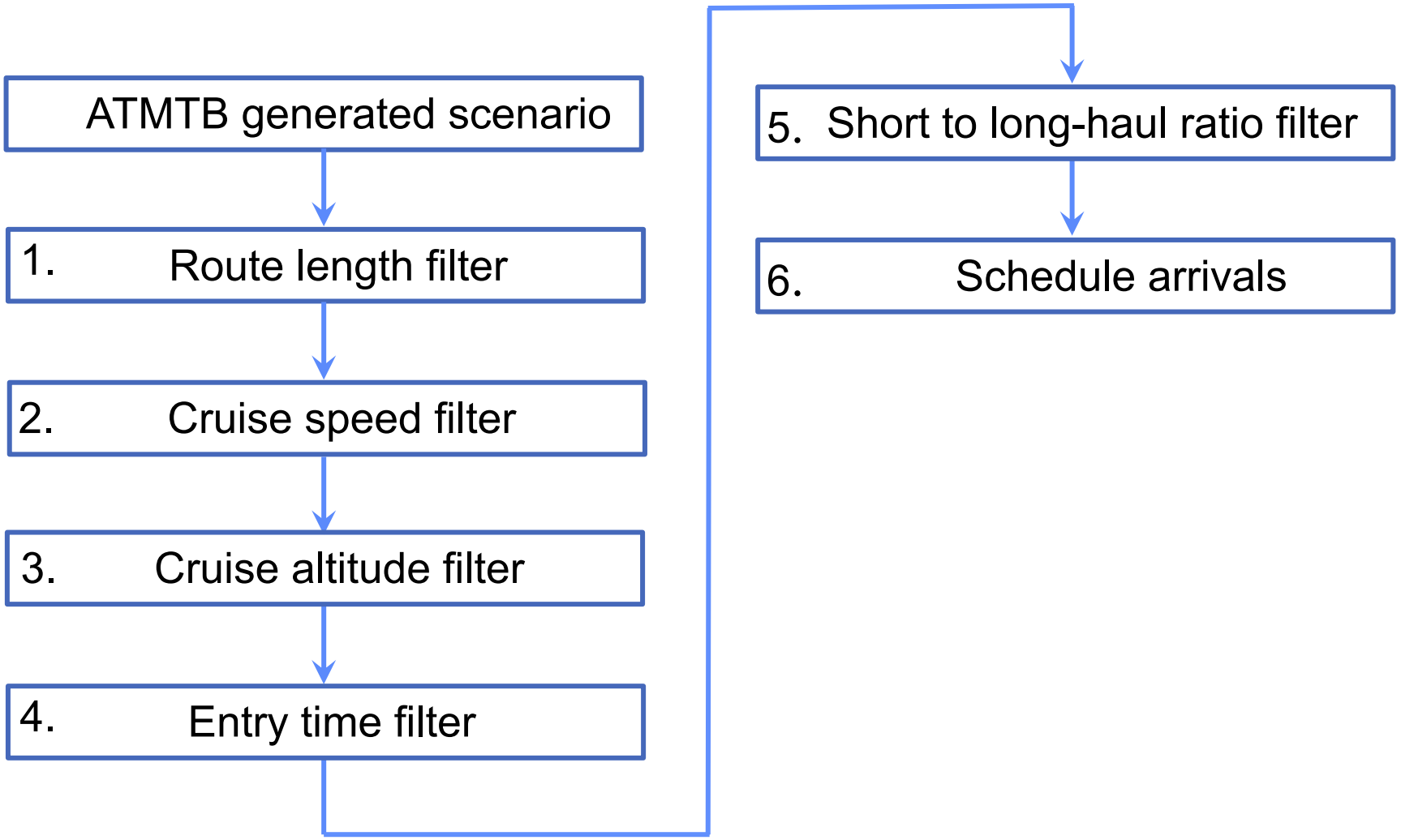

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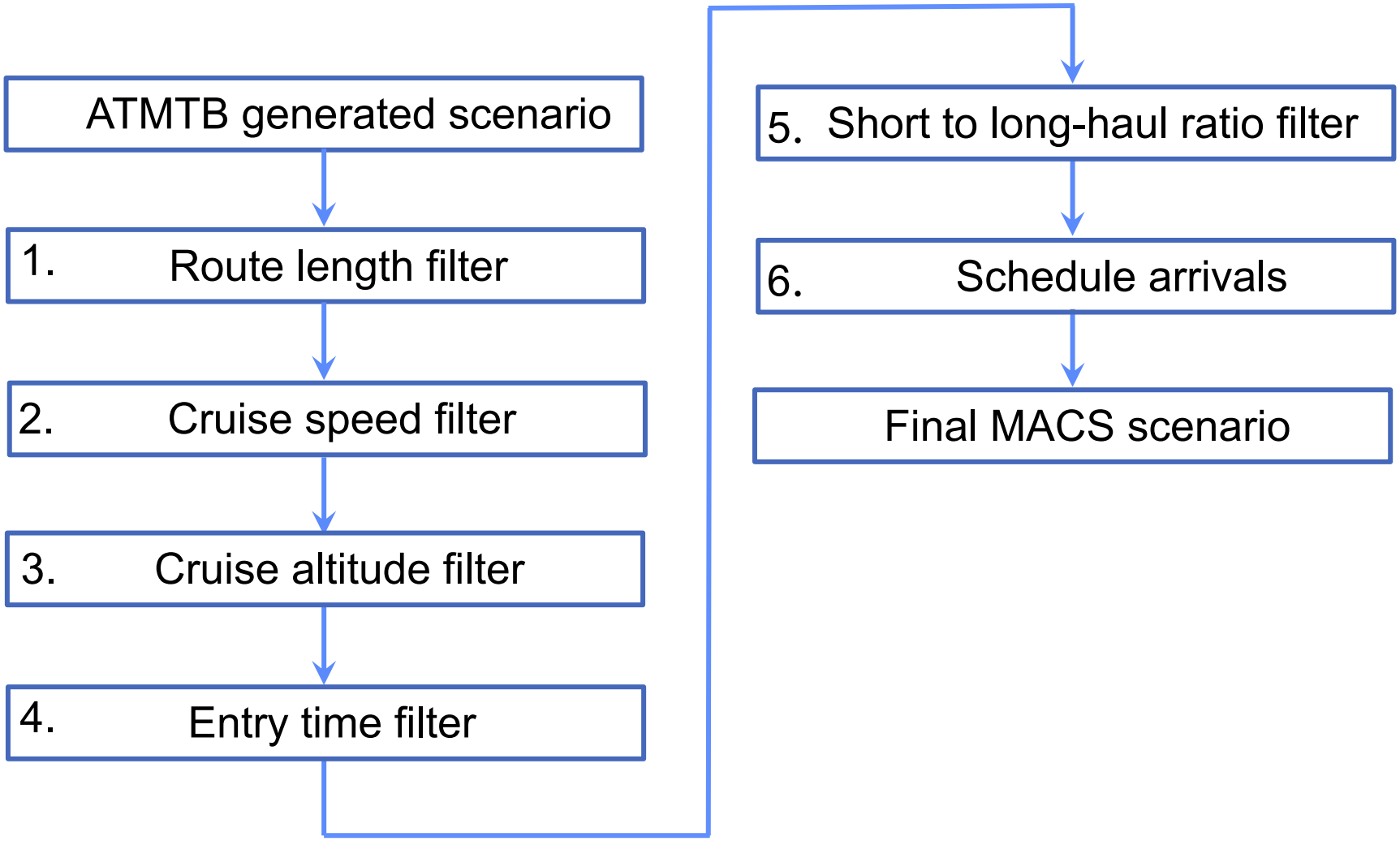


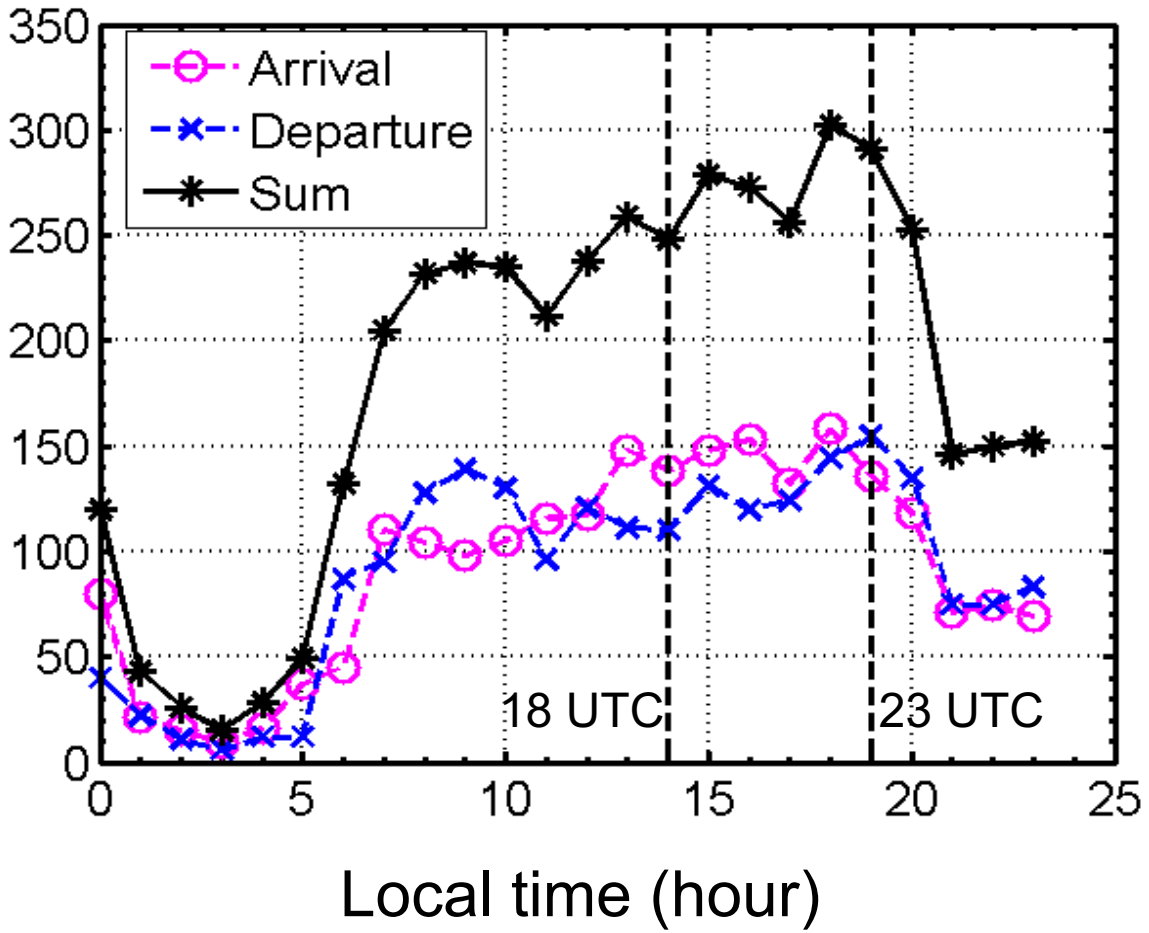
Northeast Region Traffic Scenario

- Obtained JFK, EWR, LGA and TEB runway configuration data from FAA's Aviation System Performance Metrics (ASPM) database

- Examined hourly JFK, EWR, LGA and TEB runway configuration data every day of 2017 to identify
  - Most frequently used configurations individually
  - Most frequently used configurations together
  - Hours with the most operations taken together
  - Selected 5/23/2017 for traffic scenario
  - Chose six-hours from 18 UTC (14 local) to 23 UTC (19 local)

5/23/2017 Traffic Scenario

Landing rate
(# aircraft/hour)



Filtering Results

Filter	Criteria	# Aircraft
ASPM	None	865
ATMTB	MACS scenario generation	808
Route length	< 20 nautical-miles	791
Cruise speed	< 120 knots	791
Cruise altitude	< 600 feet	769
Entry time	< 30 minutes w.r.t start time	769

Short-haul to Long-haul Ratio

x_1 – # long-hauls

x_2 – # short-hauls

x_{1s} – # selected long-hauls

x_{2s} – # selected short-hauls

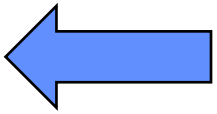
r – desired ratio

$$\frac{x_{2s}}{x_{1s}} = r$$

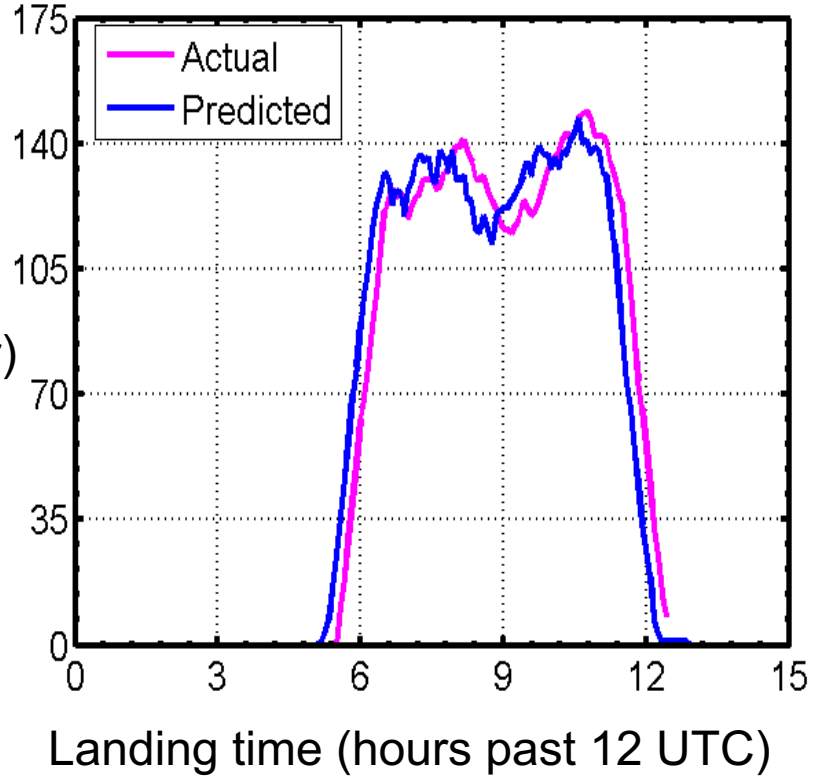
$$x_{1s} = x_1 \text{ and } x_{2s} = \lfloor r x_1 \rfloor \text{ if } r \le \frac{x_2}{x_1}$$

$$x_{1s} = \left\lfloor \frac{x_2}{r} \right\rfloor \text{ and } x_{2s} = x_2 \text{ if } r > \frac{x_2}{x_1}$$

#	r	Short-haul	Long-haul
1	0	0	531
2	0.25	132	531
3	0.5	238	476
4	0.75	238	317
5	1	238	238
6	300	238	0



Scenario Landing Rate



$$\hat{t}_L = t_E + \frac{l_R}{\bar{V}_{CR}}$$

$\hat{t}_L$ – Expected landing time

t_E – Entry time

l_R – Route length

$\bar{V}_{CR}$ – Average cruise speed

Scheduling Arrivals

t_p – Proposed landing time

t_E – Entry time

t_f – Flight time

t_s – Scheduled landing time

t_{sE} – Scheduled entry time

$$\Delta t = 60 / \dot{n} \text{ minutes}$$

$$t_s(1) = t_p(1)$$

$$t_s(i) = t_s(i-1) + \max(\Delta t, t_p(i) - t_s(i-1))$$

$$\delta(i) = (\Delta t - t_p(i) + t_s(i-1))\left[t_p(i) - t_s(i-1) < \Delta t \right]$$

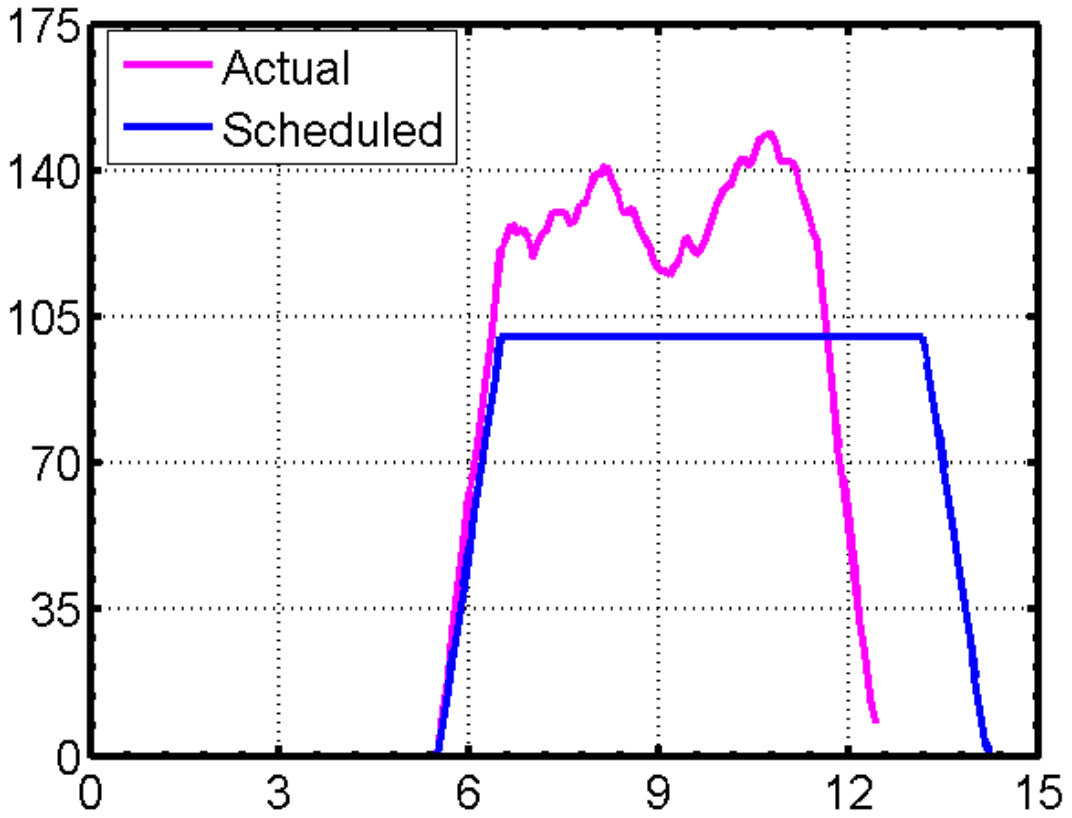
$$t_f = t_p - t_E$$

$$t_{sE} = t_s - t_f$$

$$t_s(i) = t_s(i-1) + \Delta t$$

Results of Scheduling Arrivals

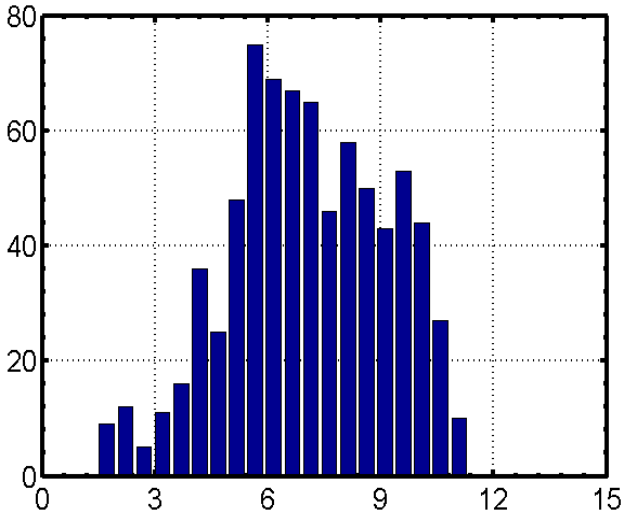
Landing rate
(# aircraft/hour)



Landing time (hours past 12 UTC)

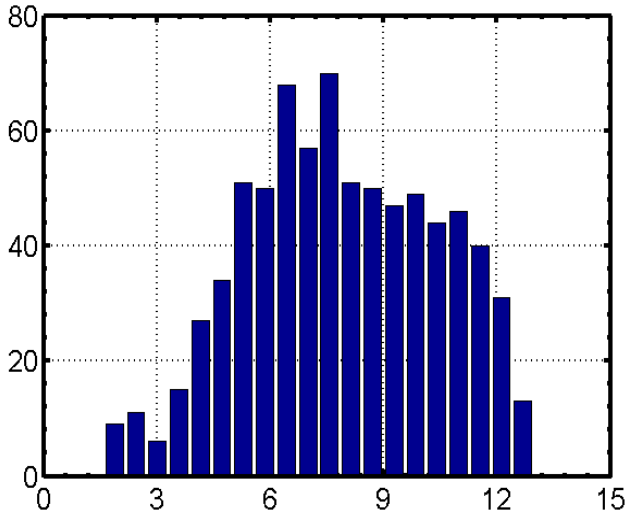
Histograms of Entry Times

Number of Flights



Original entry times

Number of Flights



Scheduled entry times

Conclusions

- New automated scenario generation process can create MACS scenarios for meeting HITL simulation requirements
  - Selecting flights to achieve the desired short-haul to long-haul ratio
  - Altering landing times
- The two-step process is
  - Less error prone
  - Faster and efficient
  - Repeatable
- New process will be added to enhance ATMTB scenario generation capability