Automated Scenario Generation for Human-in-the-Loop Simulations

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Motivation

- Need for realistic scenarios to study diverse operations
  - Unmanned Aerial Vehicles
  - Urban Air Mobility
  - Supersonic aircraft
- Manual creation of realistic scenarios for generating traffic for Human-in-the-Loop simulation is difficult
  - Missing and erroneous data
  - Repeated creation of scenario and testing in simulation 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
  - Mix data from different days to achieve desired traffic volume

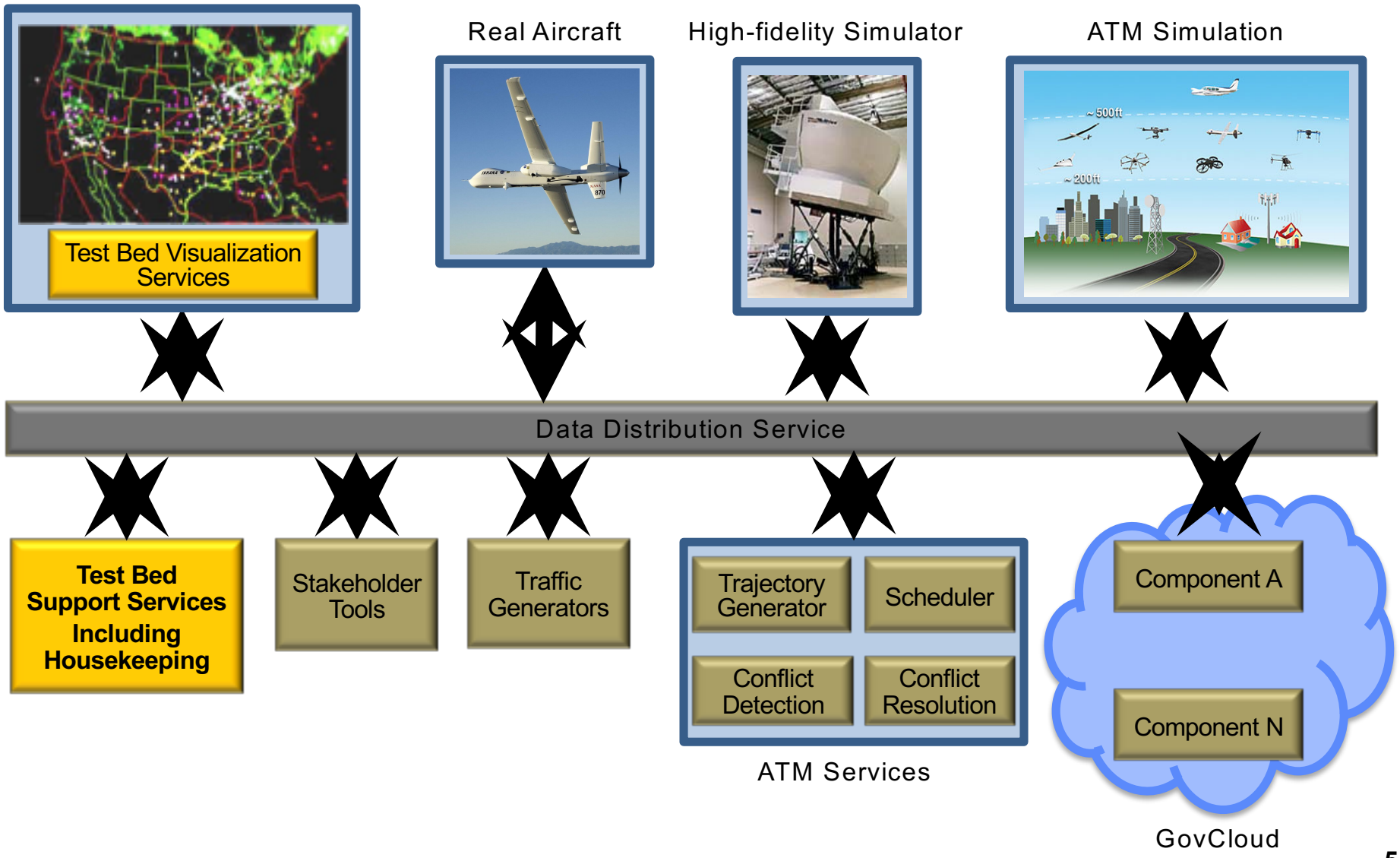
Research Questions

- Can initial traffic scenario be generated using an automated process that runs in Multi-Aircraft Control System (MACS)?
- Can this initial traffic scenario be used as a starting point for building a Human-in-the-Loop (HITL) scenario?
- How does one compare the initial traffic scenario created using the automated process with the manually altered HITL-scenario?
- Can an automated process be used to directly create a HITL-scenario?

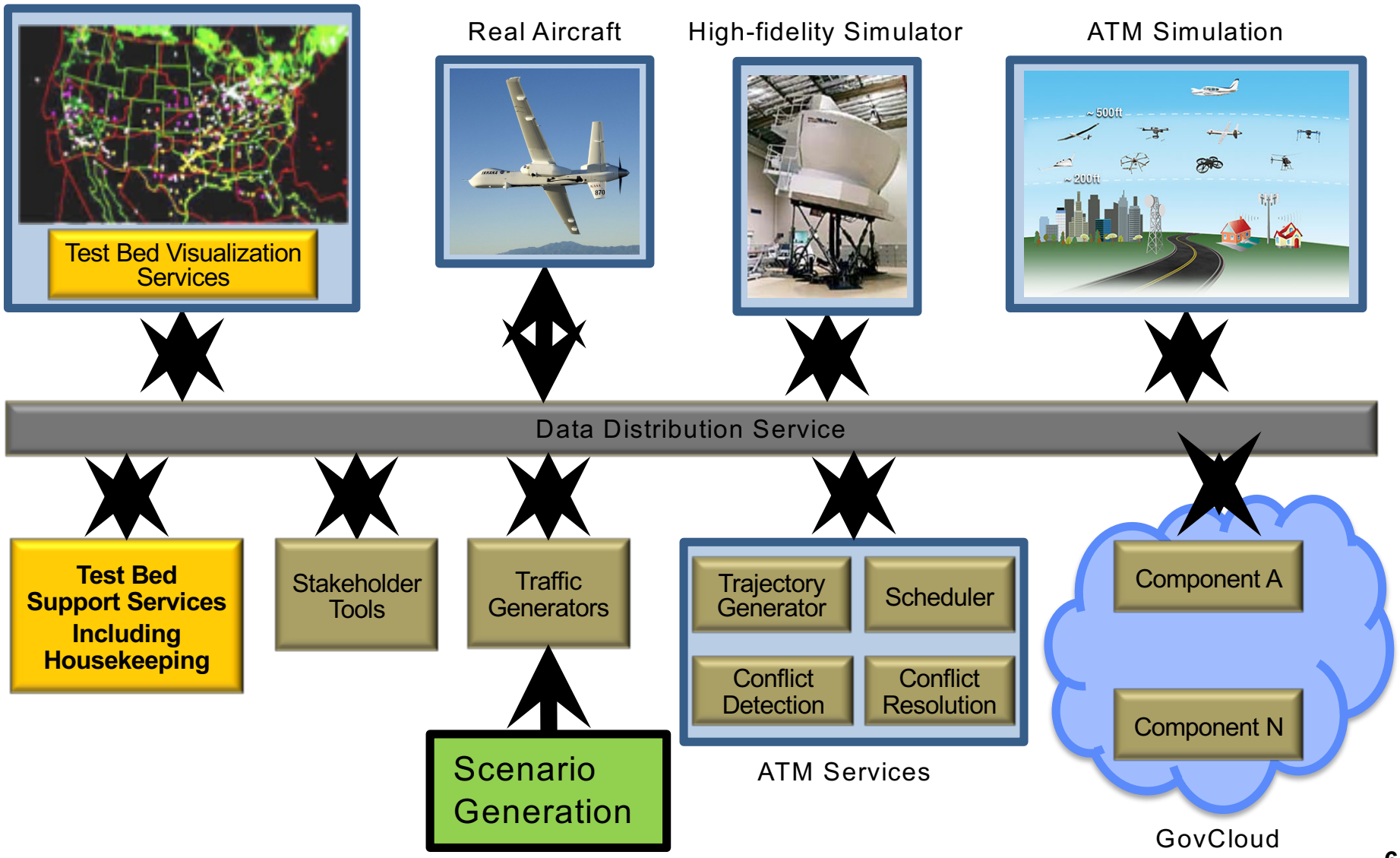
Outline

- Air Traffic Management (ATM) Testbed
- Automated scenario generation using ATM Testbed
- Approach
- Results
- Conclusions

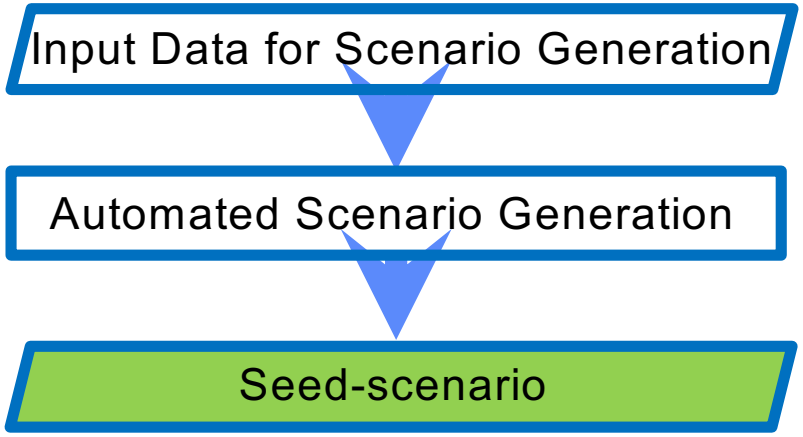
Air Traffic Management Testbed



Air Traffic Management Testbed



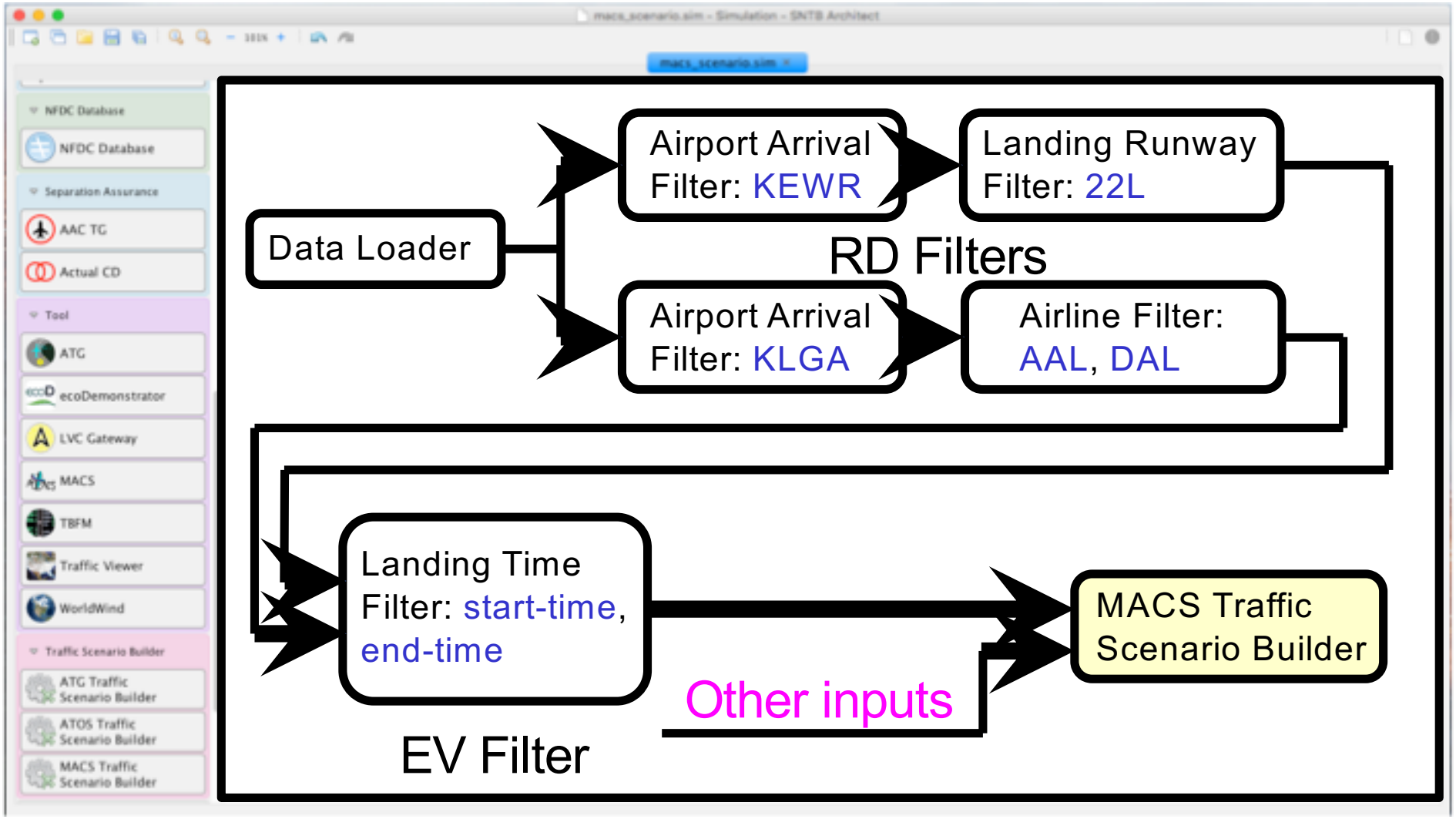
Creation of Seed-scenario



Input Data for Scenario Generation

- 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
    - Example: center crossing from ZOA to ZLA
- Integrated Flight Format (IFF)
  - Multiple records for each flight
    - All flight plans including amended flight plans
    - Position data
- EV and RD useful for filtering and IFF for data augmentation

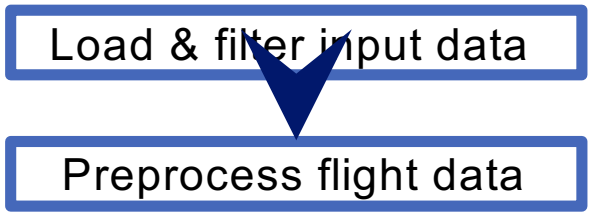
Simulation Architect View for Composing MACS Traffic Scenario



MACS Scenario Generation Steps

Load & filter input data

MACS Scenario Generation Steps



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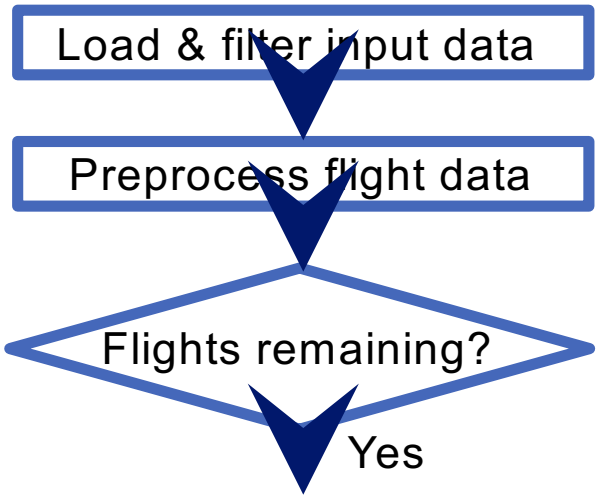

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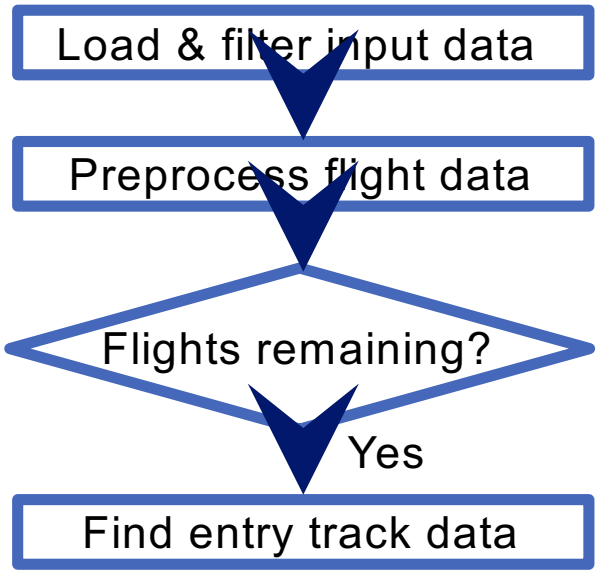

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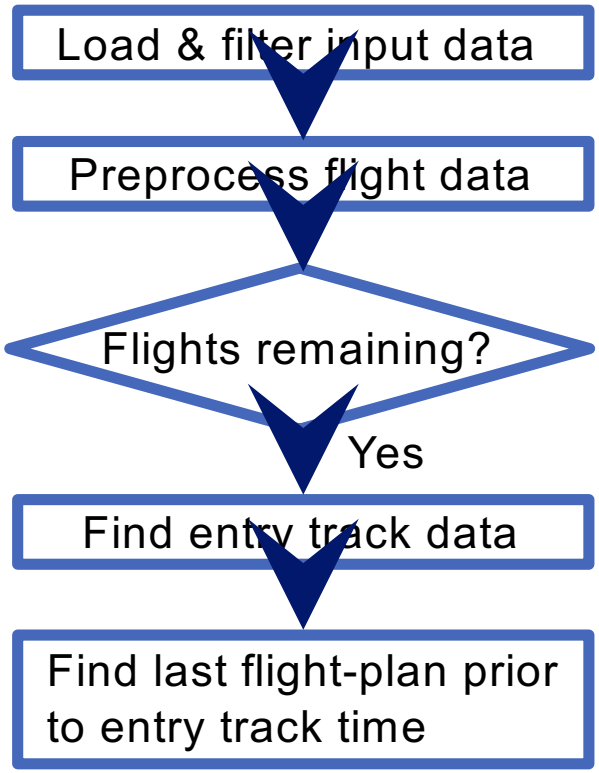

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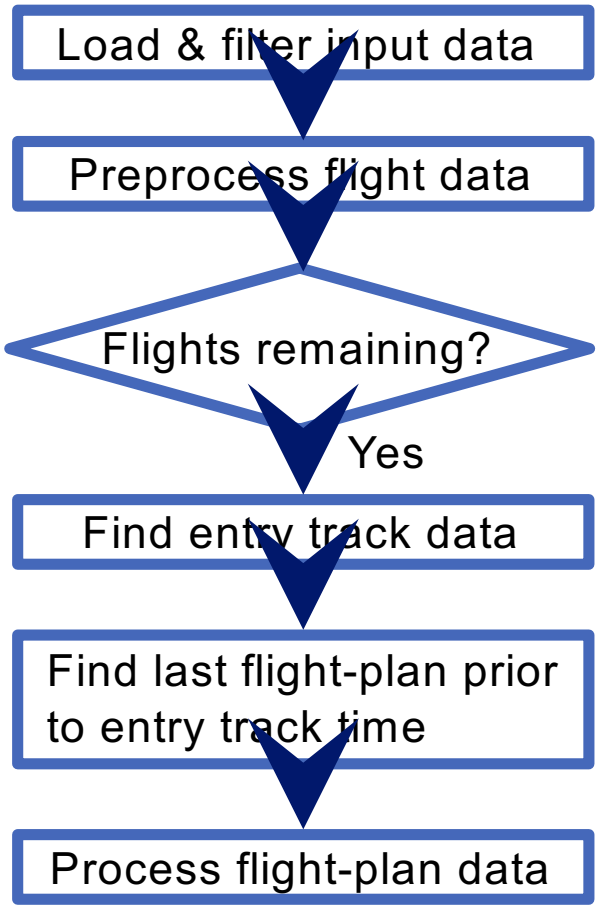

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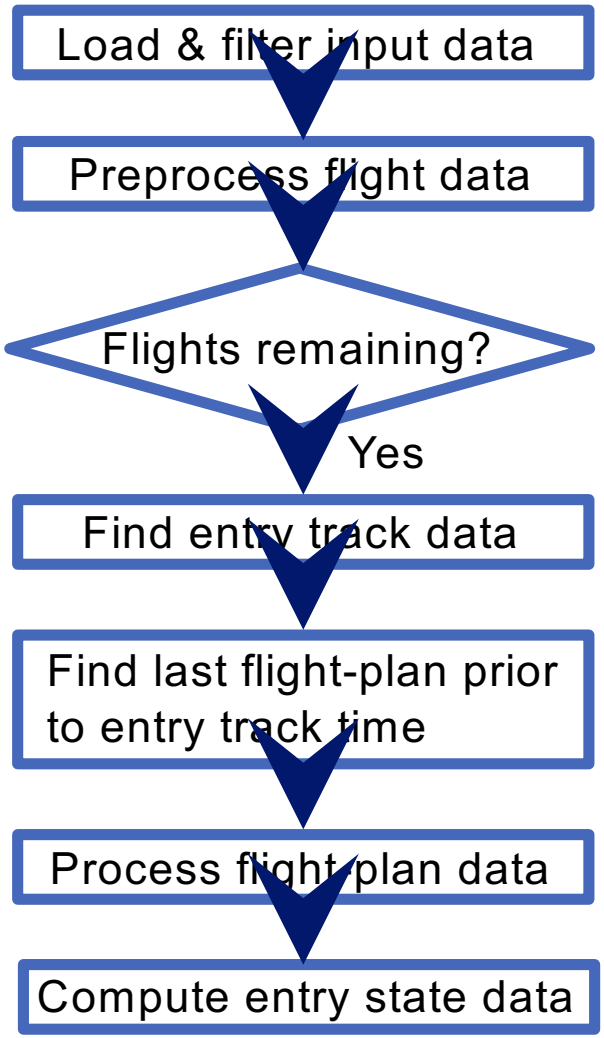

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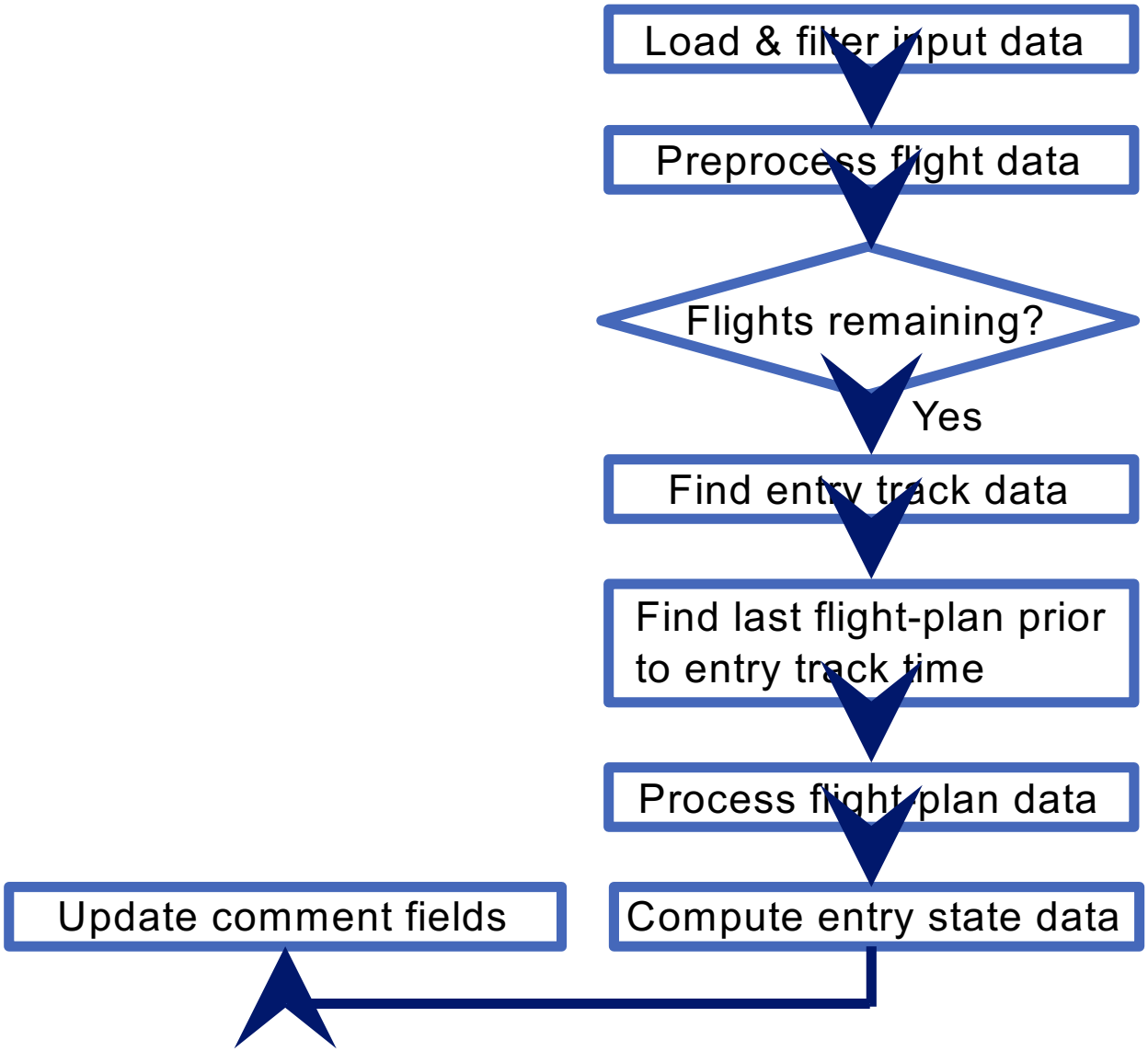

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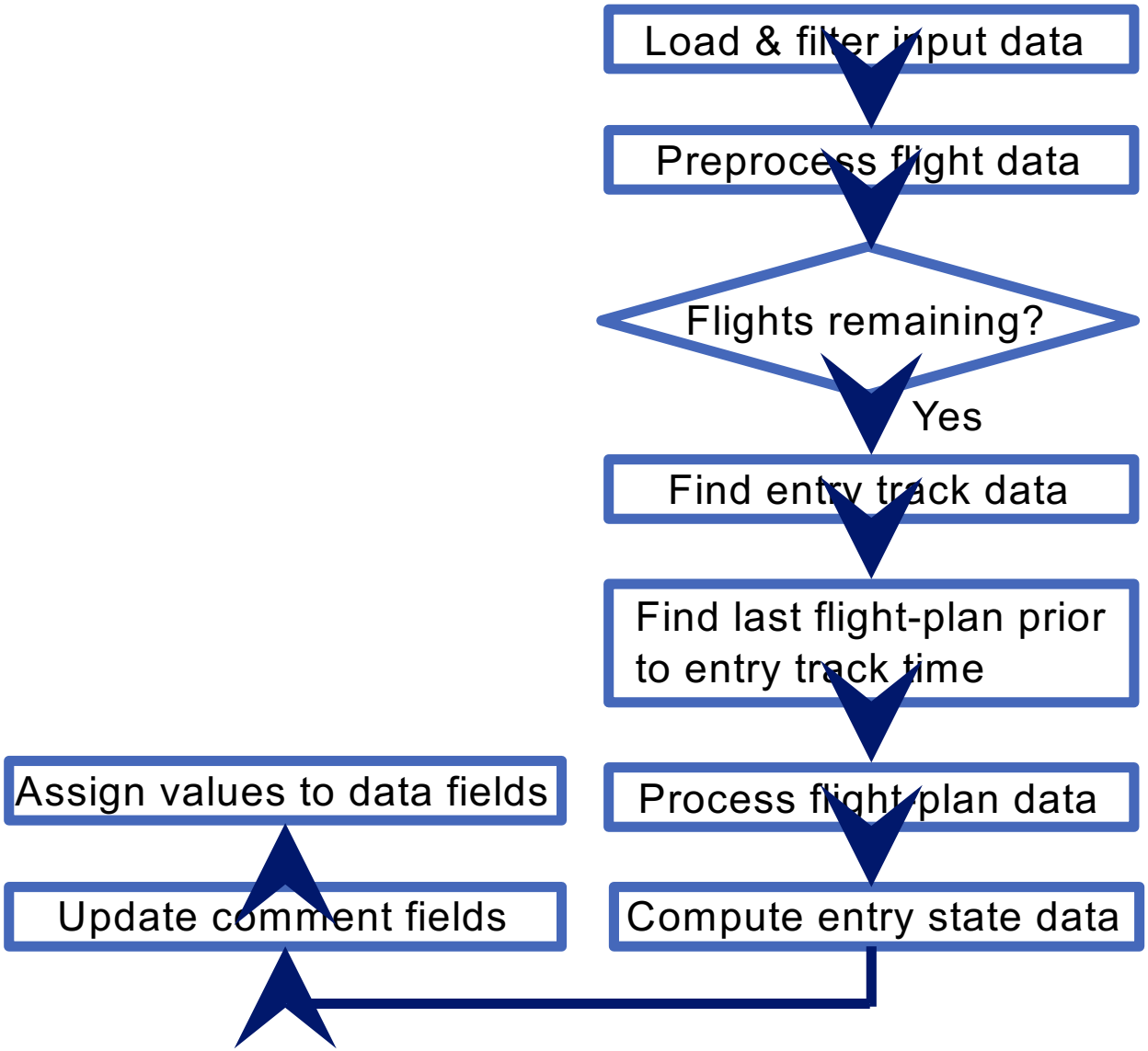

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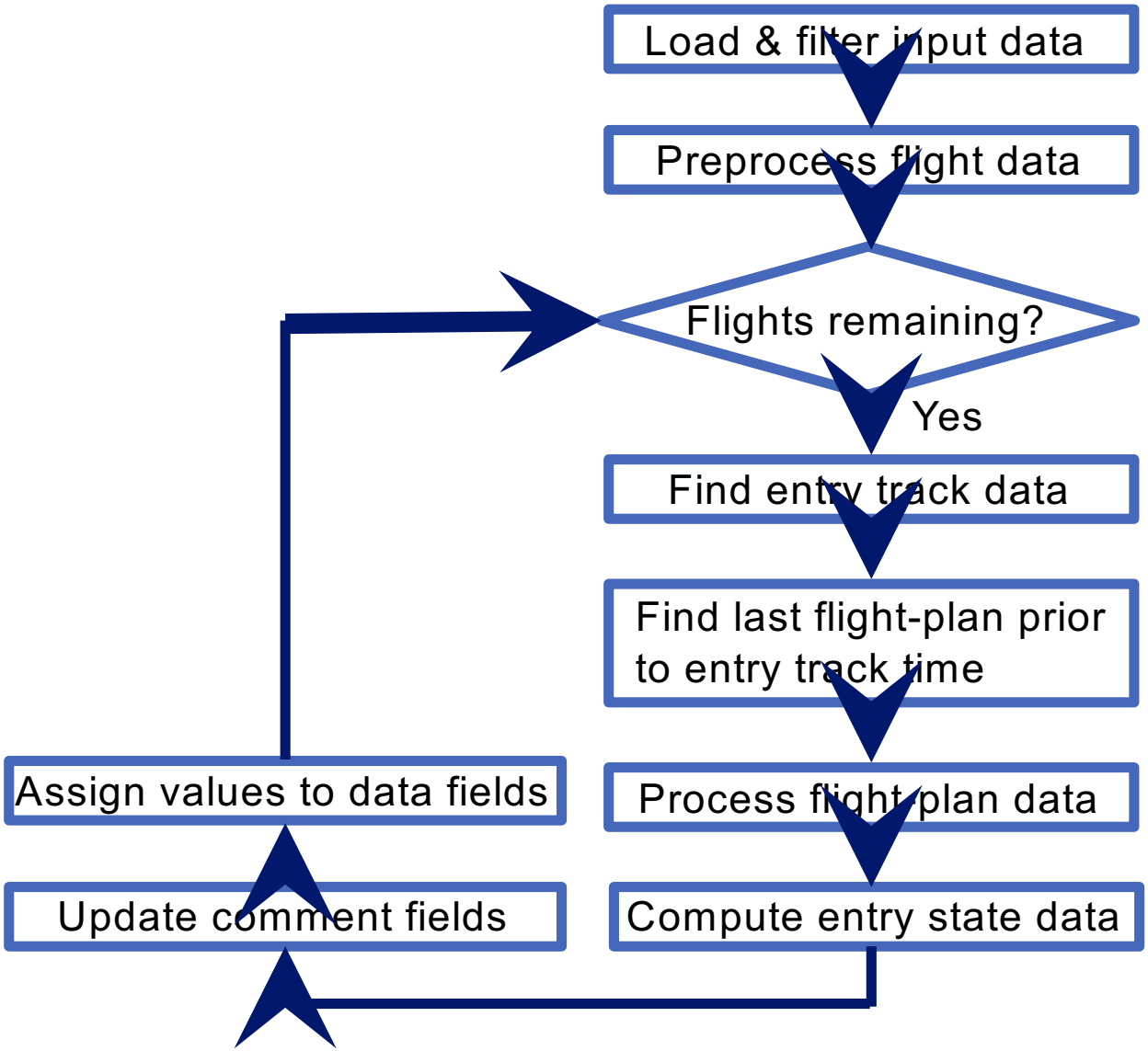

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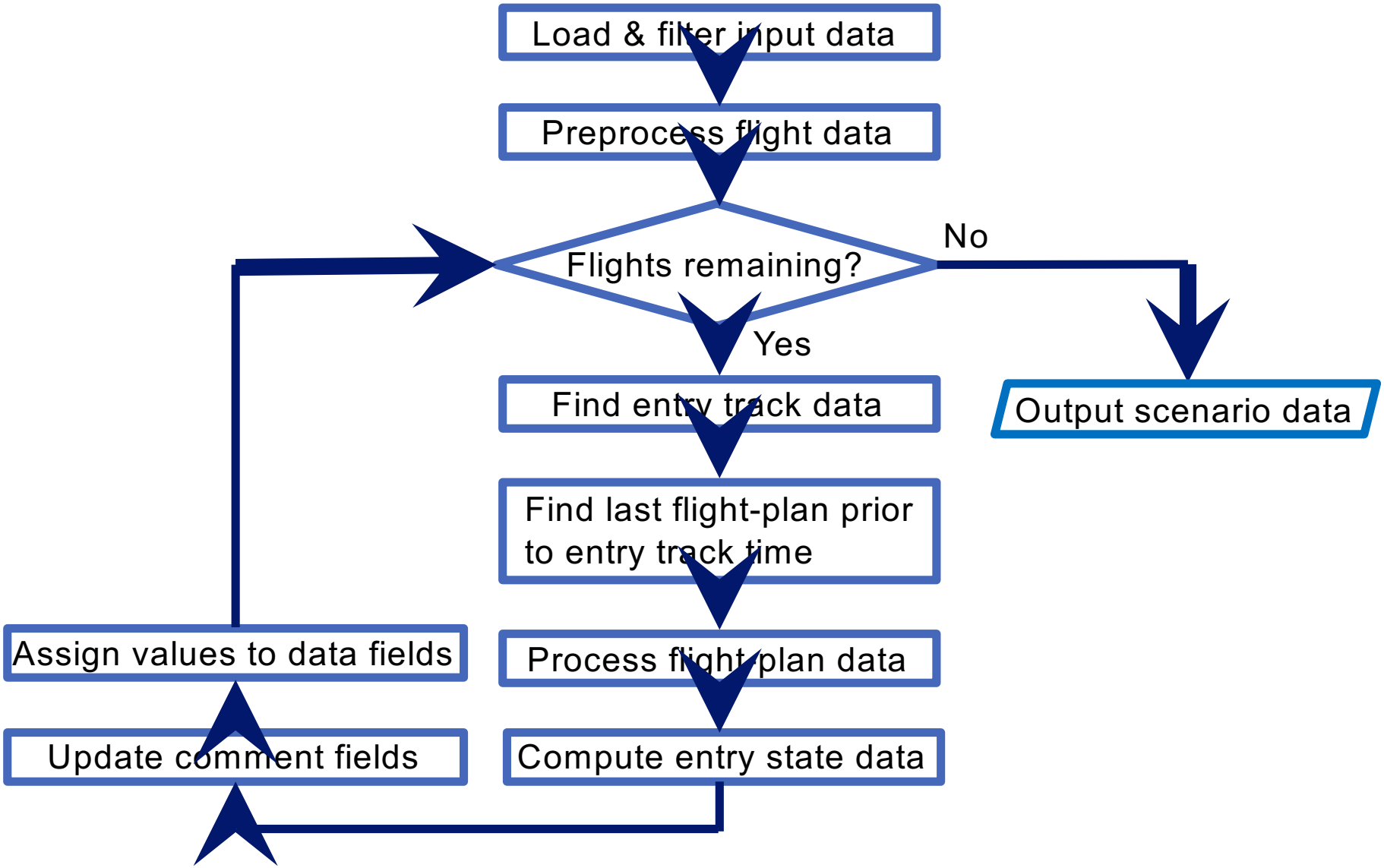

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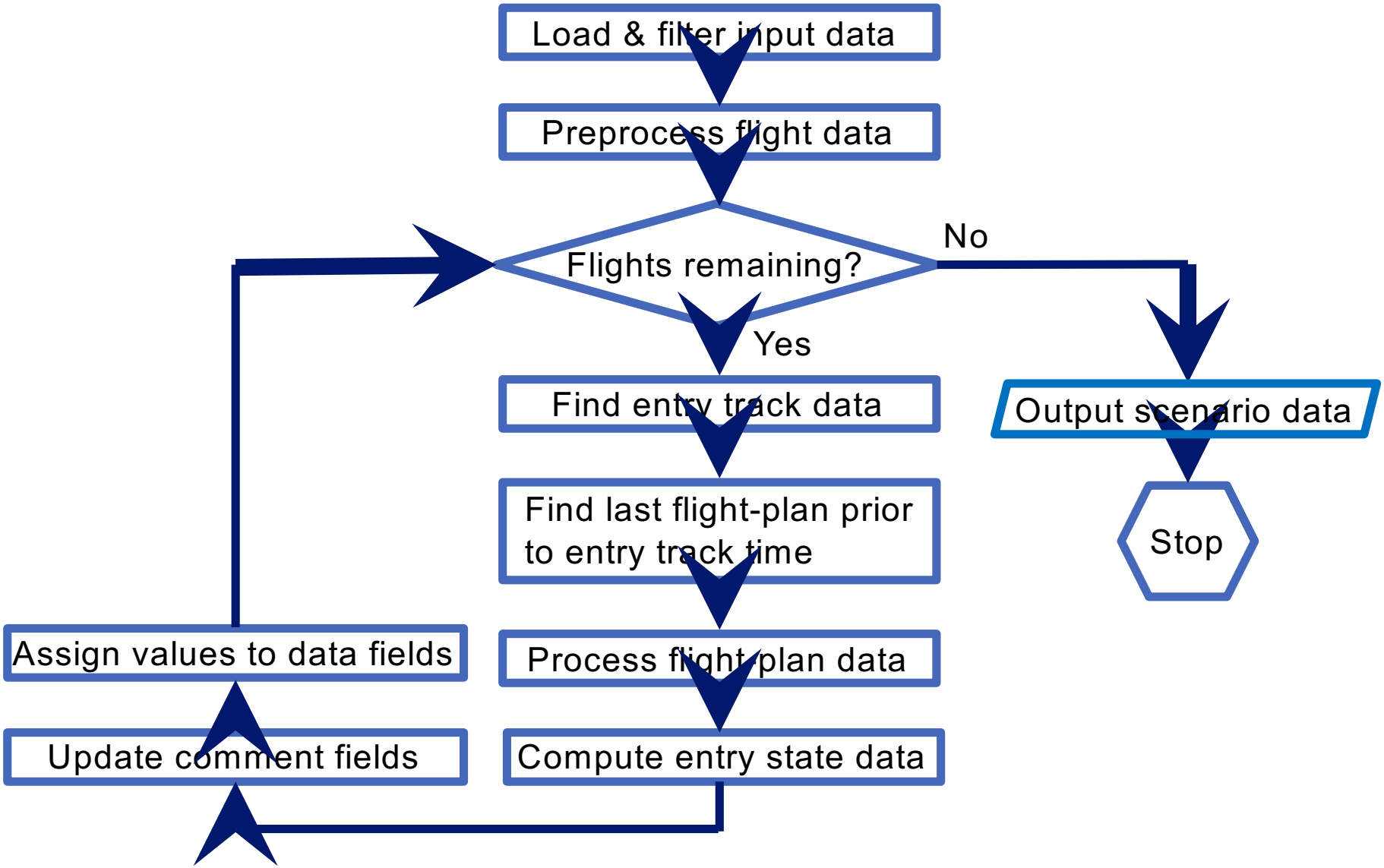
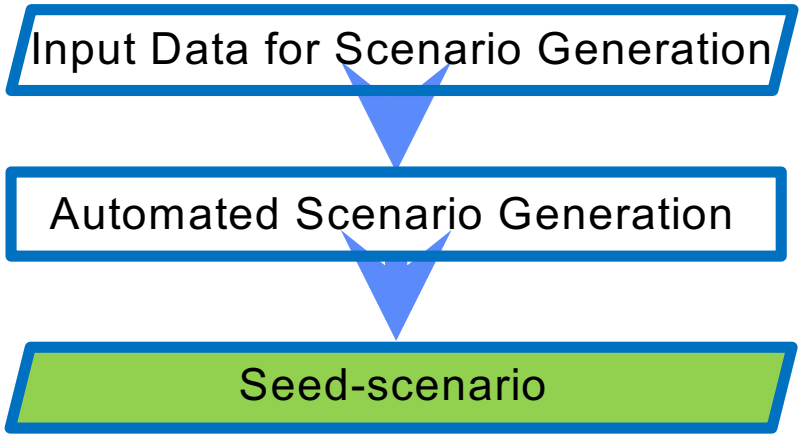


Approach: Seed-scenario versus HITL-scenario



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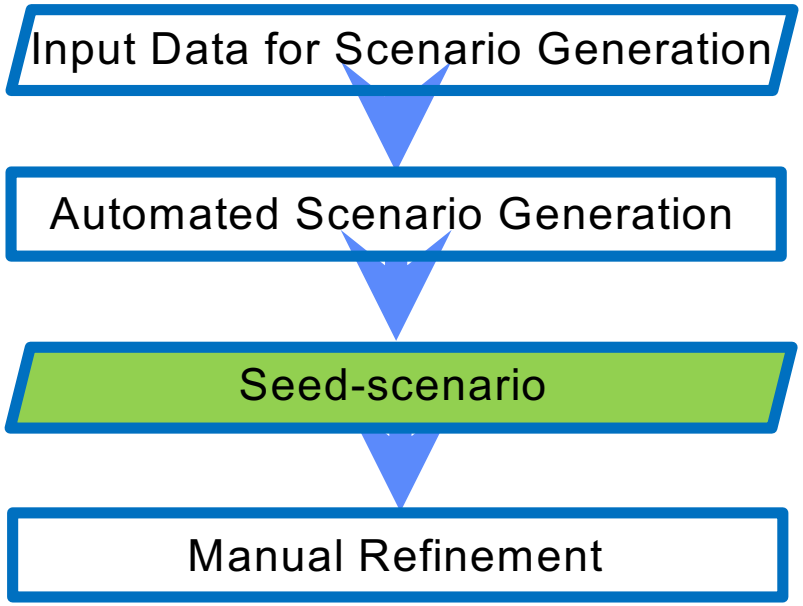

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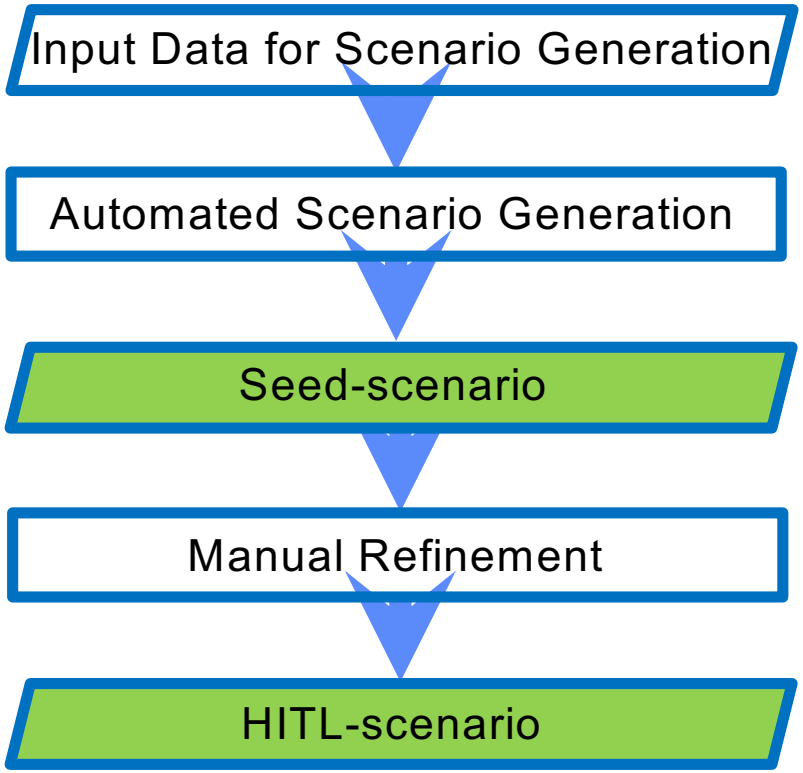
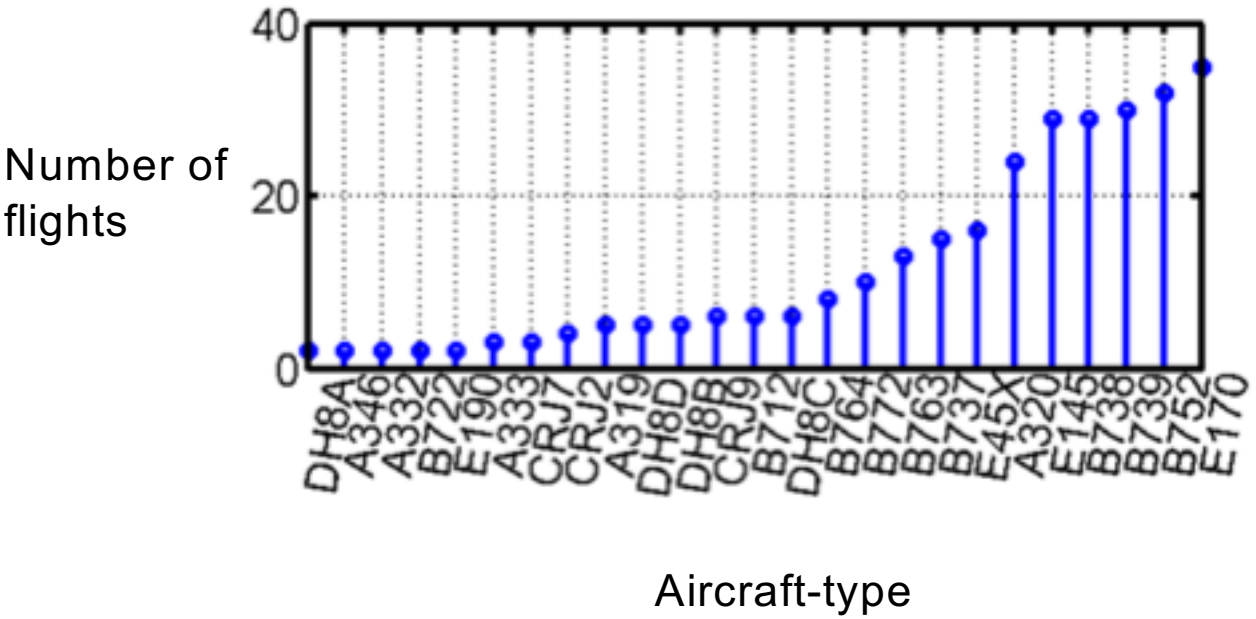


Traffic Scenarios

- Seed-scenario generated using automated process
  - June 6, 2016 RD, EV and IFF files
  - Arrivals to Newark, New Jersey
  - Six-hours traffic starting at 17:00 UTC
  - 299 flights; 274 landing on 22L, six on 22R, one on 29 and 18 not assigned
- Manually altered HITL-scenario
  - Entry times altered to squeeze six-hours of traffic to five-hours to exceed arrival capacity of 40 aircraft/hour
  - Flights within 40 nautical miles surrounding airport removed
  - Some flights at the beginning of scenario removed
  - Flights removed to maintain ratio of internal (400 nautical miles) to total number of flights
  - 191 flights, all landing on 22L

Data Analysis I: Number of Flights with Same Parameter Value

#	Parameter
1.	Call-sign
2.	Aircraft-type
3.	Destination airport
4.	Landing runway
5.	MACS flight-plan
6.	ATC flight-plan
7.	Beacon-code
8.	Departure airports
9.	Entry point altitude
10.	Entry point airspeed
11.	Entry point sector-ID
12.	Aircraft weight



Seed-scenario Results

#	Parameter	Once	Repeated	Total
1.	Call-sign	281	9	290
2.	Aircraft-type	11	24	35
3.	Destination airport	0	1	1
4.	Landing runway	1	3	4
5.	MACS flight-plan	148	47	195
6.	ATC flight-plan	174	41	215
7.	Beacon-code	256	21	277
8.	Departure airports	50	68	118
9.	Entry point altitude	73	61	134
10.	Entry point airspeed	77	58	135
11.	Entry point sector-ID	47	23	70
12.	Aircraft weight	5	24	29

HITL-scenario Results

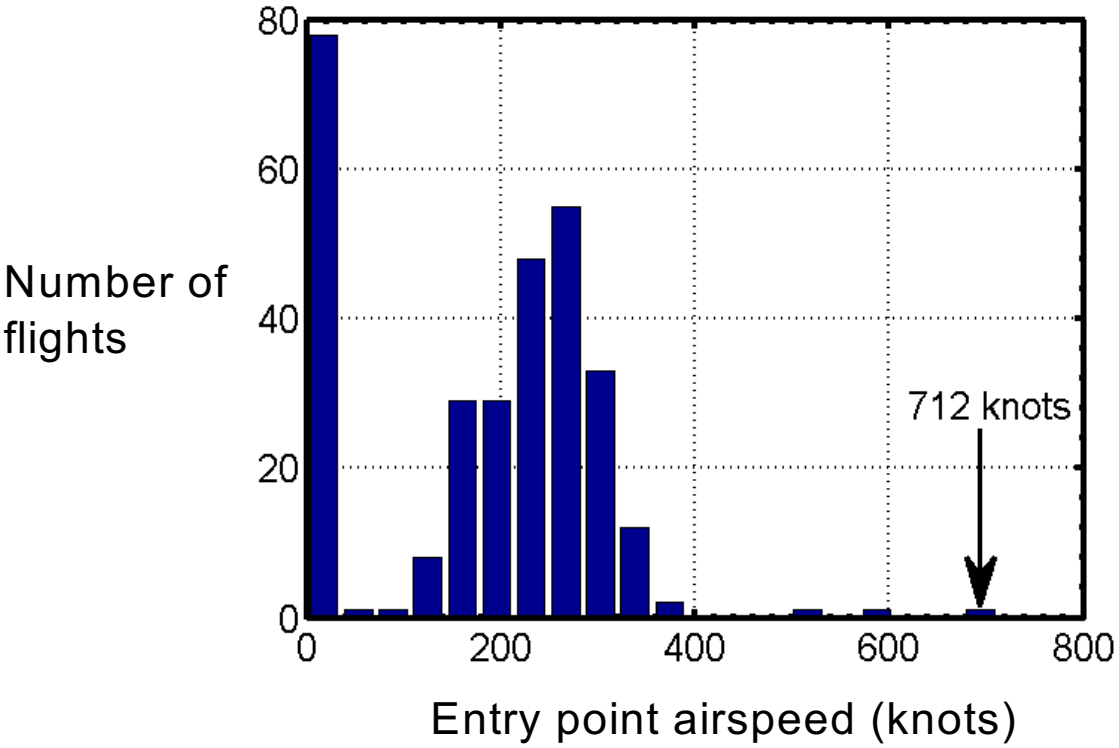
#	Parameter	Once	Repeated	Total
1.	Call-sign	191	0	191
2.	Aircraft-type	10	20	30
3.	Destination airport	0	1	1
4.	Landing runway	0	1	1
5.	MACS flight-plan	64	41	105
6.	ATC flight-plan	80	40	120
7.	Beacon-code	181	5	186
8.	Departure airports	41	50	91
9.	Entry point altitude	35	46	81
10.	Entry point airspeed	23	14	37
11.	Entry point sector-ID	0	3	3
12.	Aircraft weight	3	16	19

Seed-scenario versus HITL-scenario

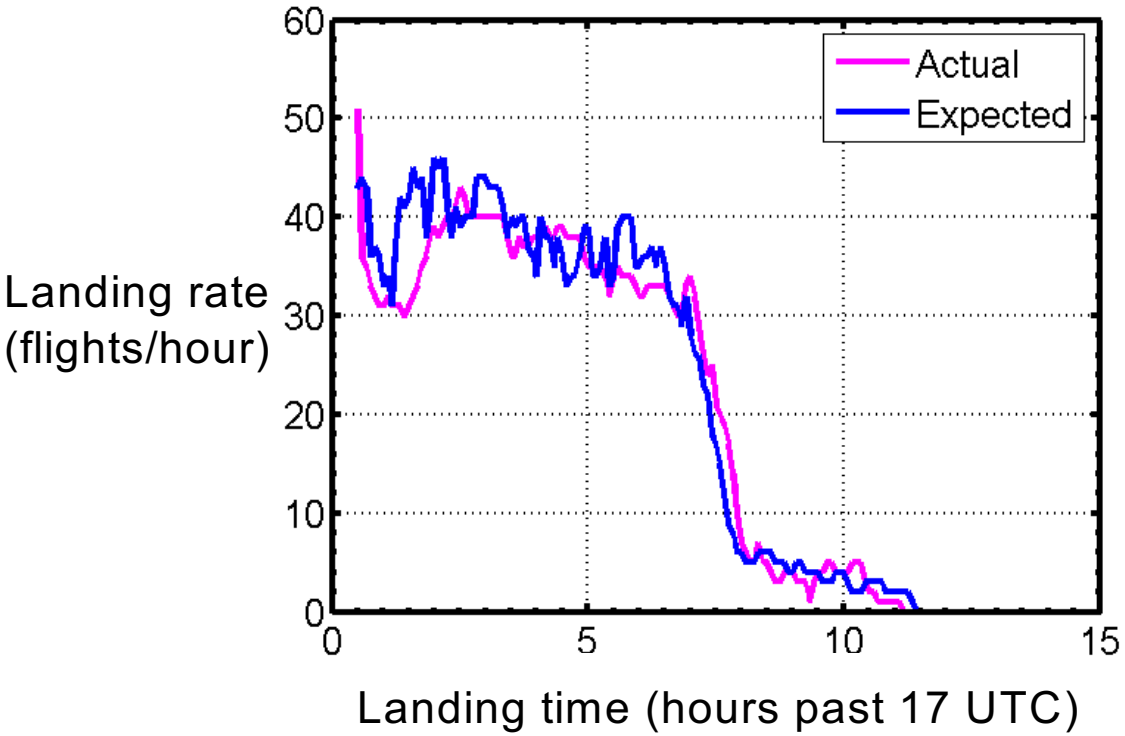
		Seed-scenario		HITL-scenario	
#	Parameter	Once/ Total (%)	Repeated/ Total (%)	Once/ Total (%)	Repeated/ Total (%)
1.	Call-sign	97	3	100	0
2.	Aircraft-type	31	69	33	67
3.	Destination airport	0	100	0	100
4.	Landing runway	25	75	0	100
5.	MACS flight-plan	76	24	61	39
6.	ATC flight-plan	81	19	67	33
7.	Beacon-code	92	8	97	3
8.	Departure airports	42	58	45	55
9.	Entry point altitude	54	46	43	57
10.	Entry point airspeed	57	43	62	38
11.	Entry point sector-ID	67	33	0	100
12.	Aircraft weight	17	83	16	84

Data Analysis II: Distribution

#	Parameter
1.	Route length
2.	Cruise speed
3.	Cruise altitude
4.	Actual landing time
5.	Predicted landing time
6.	Aircraft weight
7.	Entry time
8.	Entry point airspeed
9.	Entry point altitude



Data Analysis III: Seed-scenario Landing Rate



$$t_L = t_E + \frac{l_R}{\bar{V}_{CR}}$$

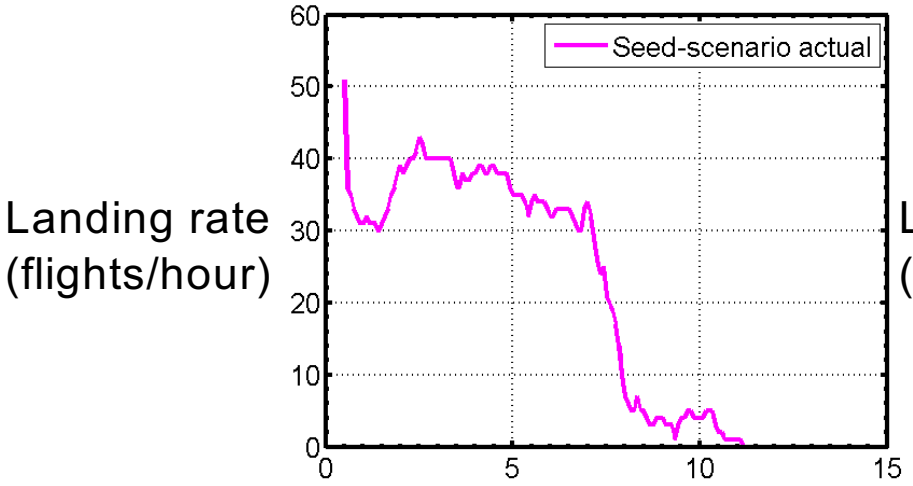
t_L – Expected landing time

t_E – Entry time

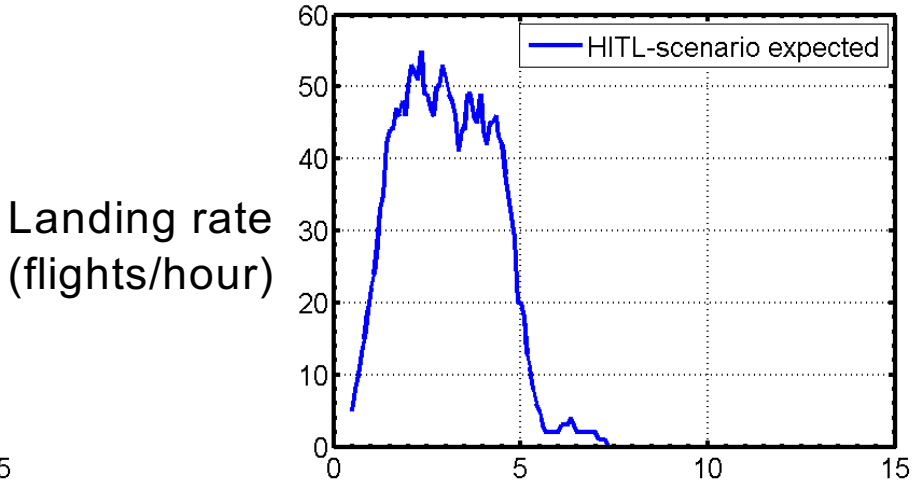
l_R – Route length

$\bar{V}_{CR}$ – Average cruise speed

Seed-scenario v/s HITL-scenario Landing Rate Results

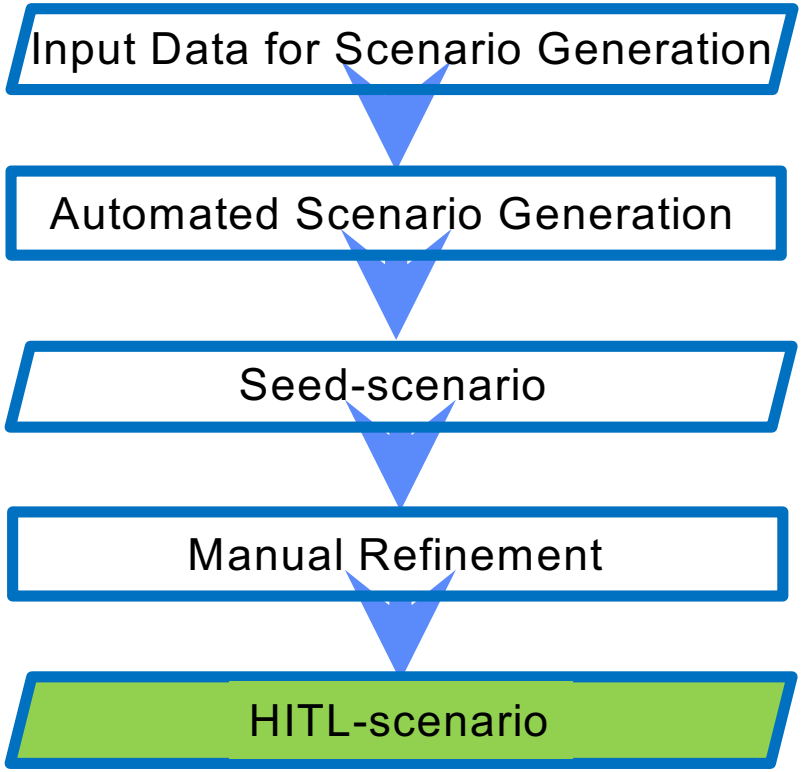


274 flights



191 flights

Approach: HITL-scenario versus MACS Output



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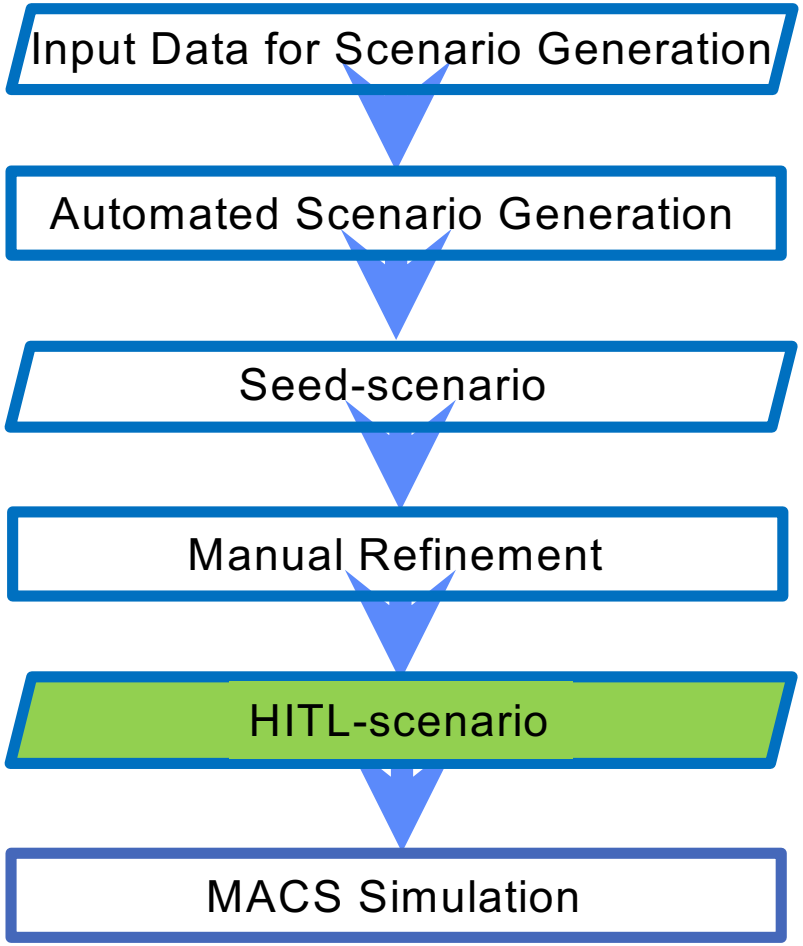

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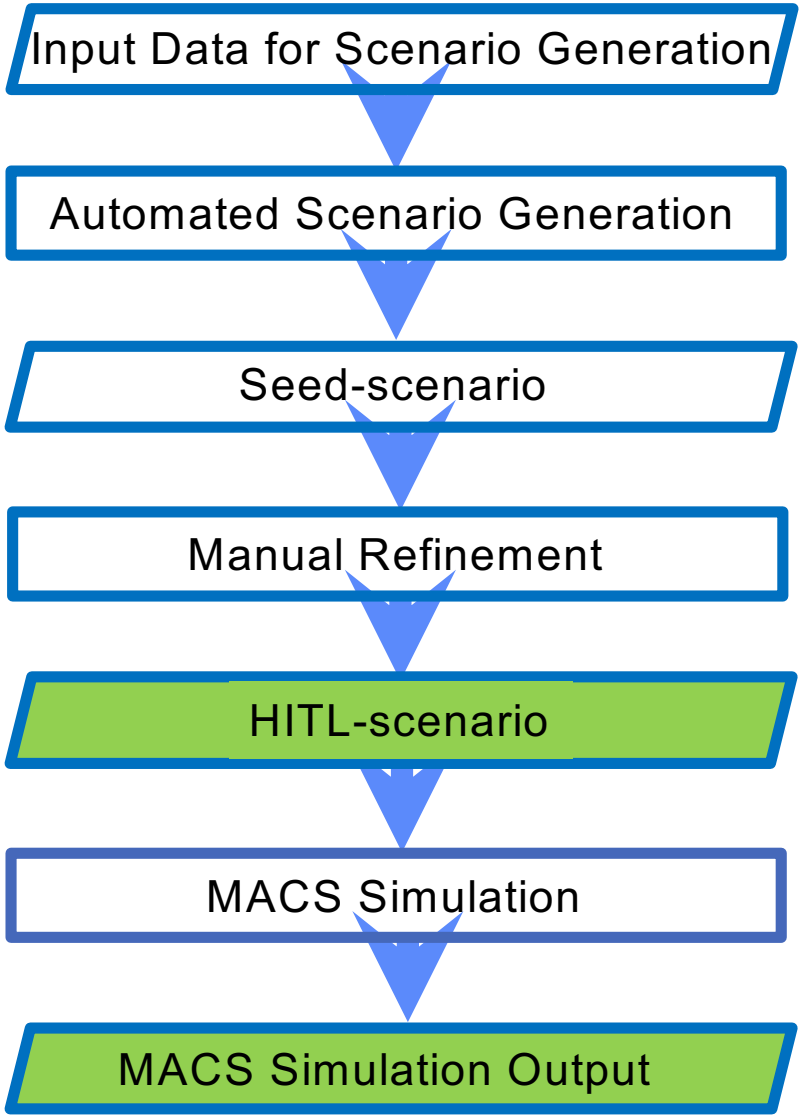
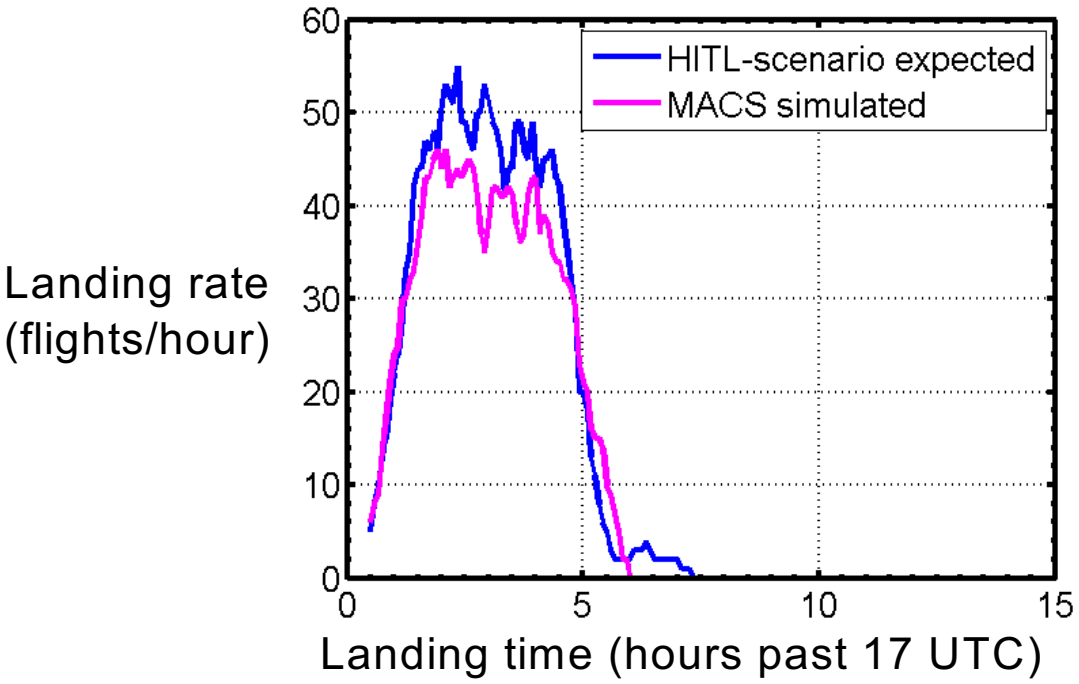


HITL-scenario v/s MACS Output
Landing Rate Results



- Expected landing rate graph is sensitive to cruise speed
  - Faster shifts left
  - Slower shifts right
- Errors due to
  - 18 aircraft did not land in MACS
  - Aircraft performance models in MACS
  - Conversion of Mach to cruise speed using standard atmosphere

Conclusions

- MACS simulations can be run with seed-scenario created using the ATM Testbed
- Seed-scenario was found to be a good starting point for creating HITL-scenario
- Duplicate flight and distribution analysis useful for data quality and eliminating flights with unreasonable parameter values
- Analysis showed that many of the manual adjustments can also be included in the automated process to directly create the HITL-scenario

Extra Slides

Future Work

Enhance Scenario Generation to create Human-in-the-Loop scenarios

- Eliminate flights with erroneous parameter values
- Select flights to achieve the internal to total ratio
- Alter the landing times to achieve the desired landing rate