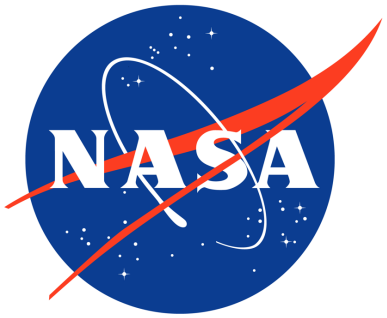
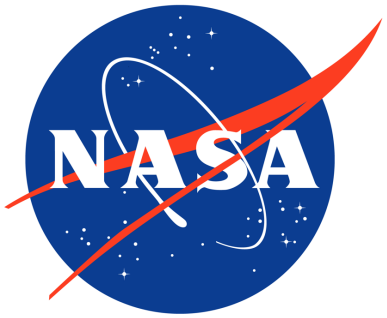


Operating Hybrid Electric Aircraft in the National Airspace System

Robert Windhorst, Todd Lauderdale, Andrew Cone, Robert Fong, Kee Palopo, Dahlia Pham, and Jim Phillips

July 30, 2024

Background and Motivation



- NASA's Electrified Powertrain Flight Demonstration (EPFD) project is conducting ground and flight tests of electrified aircraft propulsion (EAP) technologies to enable a new generation of electric-powered aircraft.

- Electric aircraft will have different
  - Fuel-burns
  - Flight times
  - Passenger loads
  - Ranges

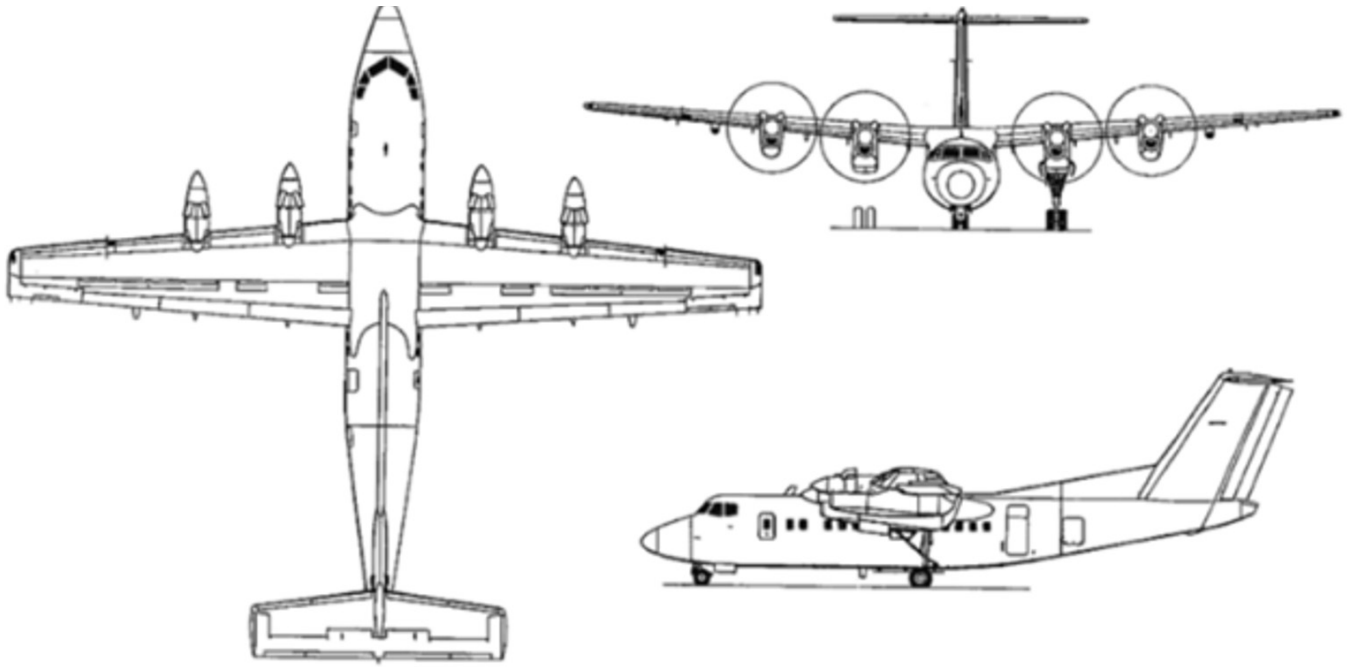
Study Objective

To study how hybrid electric vehicles will impact flight operations in the National Airspace System

- Fuel burn
- Flight times
- Airport operations

Future Hybrid Electric Concept

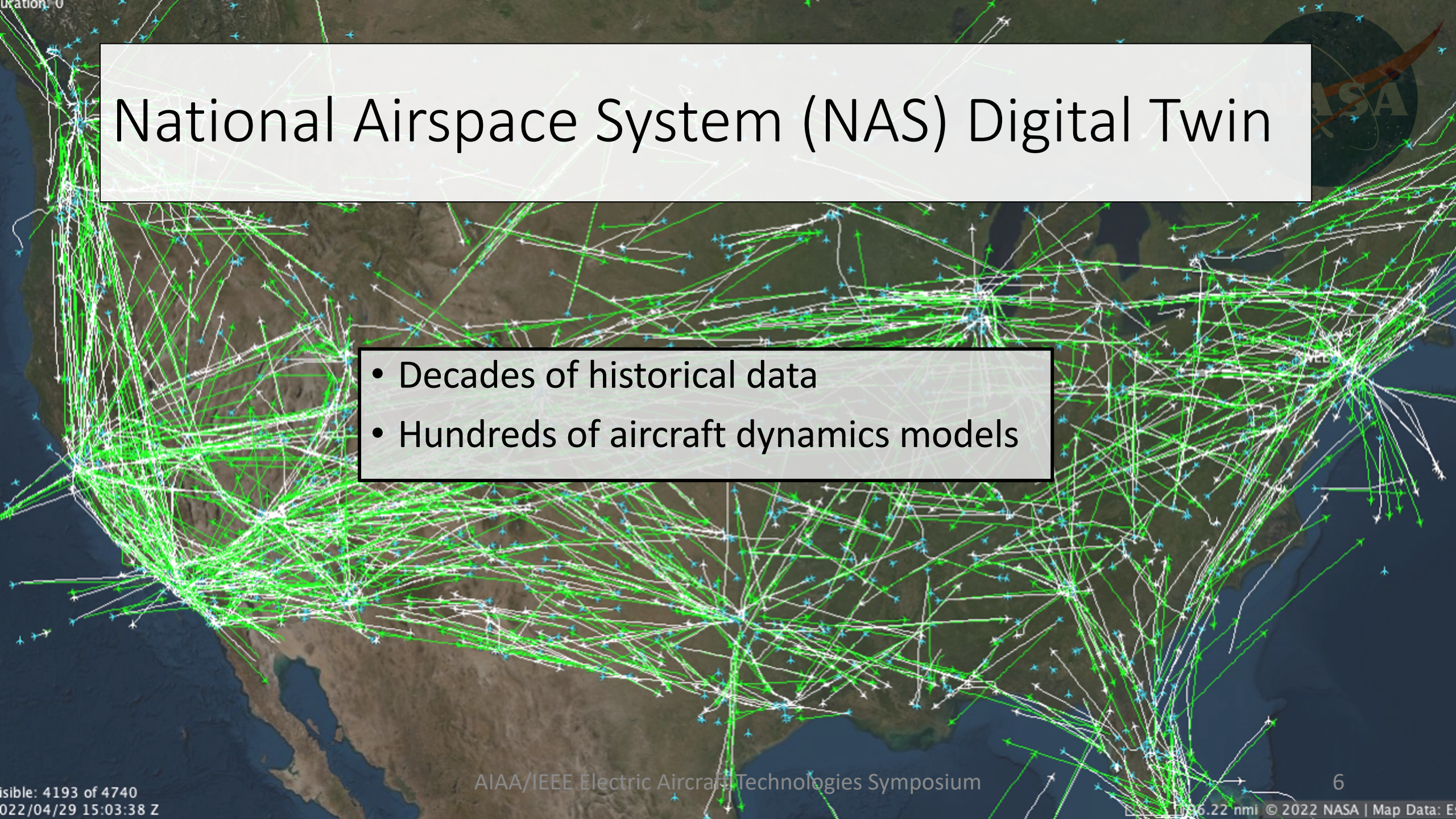
- Based on modified de Havilland Canada DHC-7 (Dash 7)
- Outboard electric motors and inboard turboprops
- 50 passengers
- 300 nm range
- Cruises at 21,000 ft and 220 knots



Study Approach

- Create future flight operations scenarios
- Simulate future scenarios in the NAS Digital Twin
- Calculate fuel burn, flight time, and airport operations

National Airspace System (NAS) Digital Twin



- Decades of historical data
- Hundreds of aircraft dynamics models

Flight Operations Scenarios

- A flight operations scenario is a list of flights
  - Callsign
  - Route, which includes origin and destination airports
  - Cruise conditions
  - Aircraft type

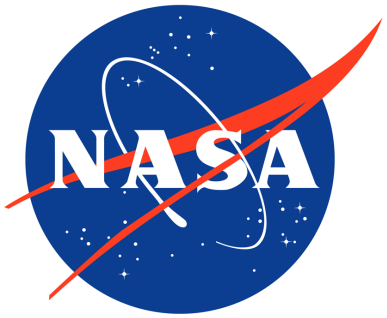
- Created future scenario by modifying 8/1/22 scenario

Modifying 8/1/22 Scenario

Step 1 - Select flights in 8/1/22 scenario that had

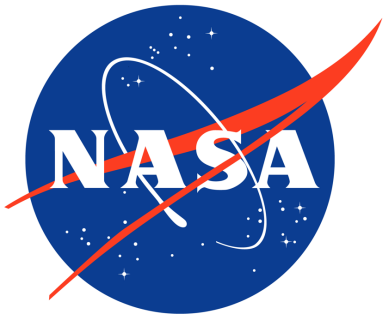
- Range between 50 and 300 nm
- Were serviced by an aircraft in the Replacement Aircraft Types Set

Replacement Aircraft Types Set



Turboprop	8/1/22 Scenario Count	Seats
Embraer 120	33	30
Short 360	39	36
ATR 42	36	48
De Havilland Dash 8	101	79
Turbofan	**8/1/22 Scenario Count**	**Seats**
Embraer 135	49	37
Embraer 145	395	50
Bombardier CRJ2	395	50
Embraer 170	149	72
Boeing 717-200	128	134
Boeing 737-800	267	162
Boeing 737	351	139
Airbus 320	112	168
Bombardier CRJ7	320	70
Bombardier CRJ9	329	83
Embraer 75L	293	83

Modifying 8/1/22 Scenario



Step 1 - Select flights in 8/1/22 scenario that had

- Range between 50 and 300 nm
- Were serviced by an aircraft in the Replacement Aircraft Types Set

Step 2 - Replace aircraft that serviced flight with hybrid electric aircraft

Step 3 – If hybrid electric aircraft carries fewer passengers than aircraft it replaced add flights to keep passenger capacity equal

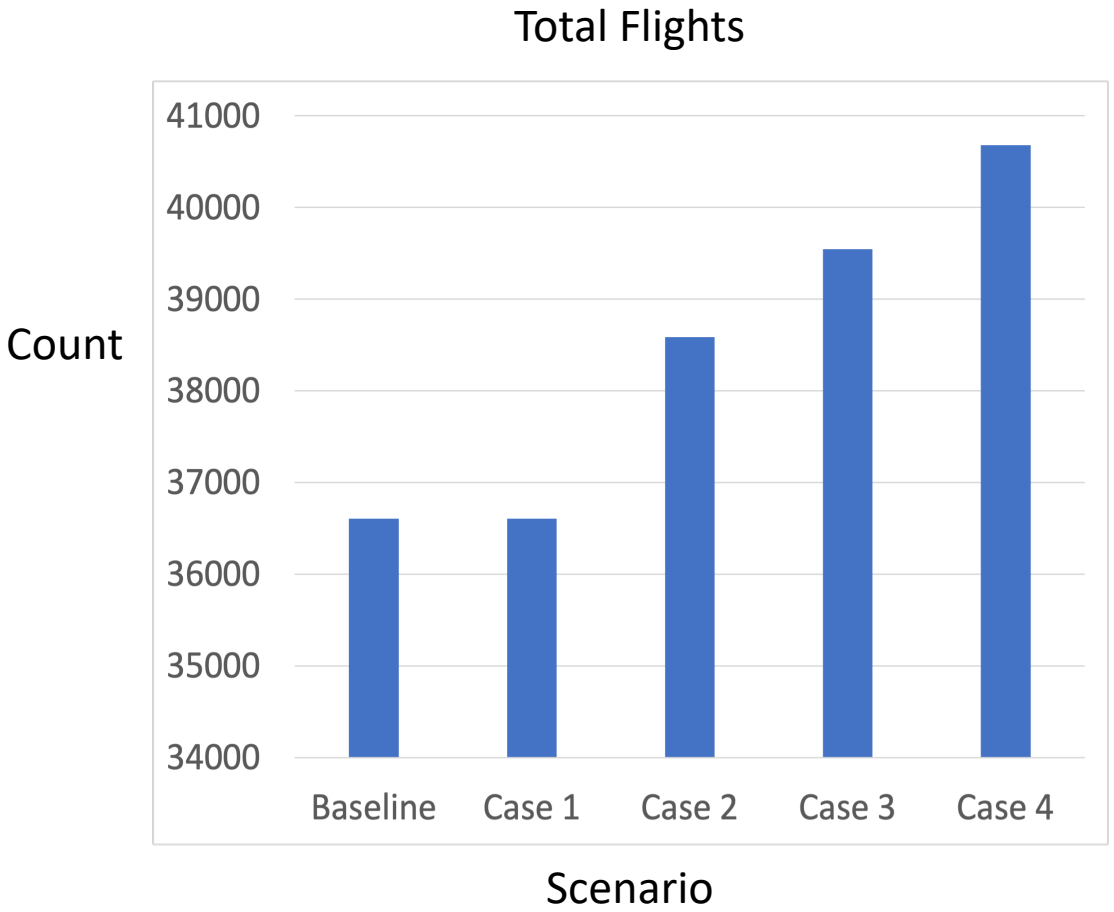
Keeping Passenger Capacity Equal

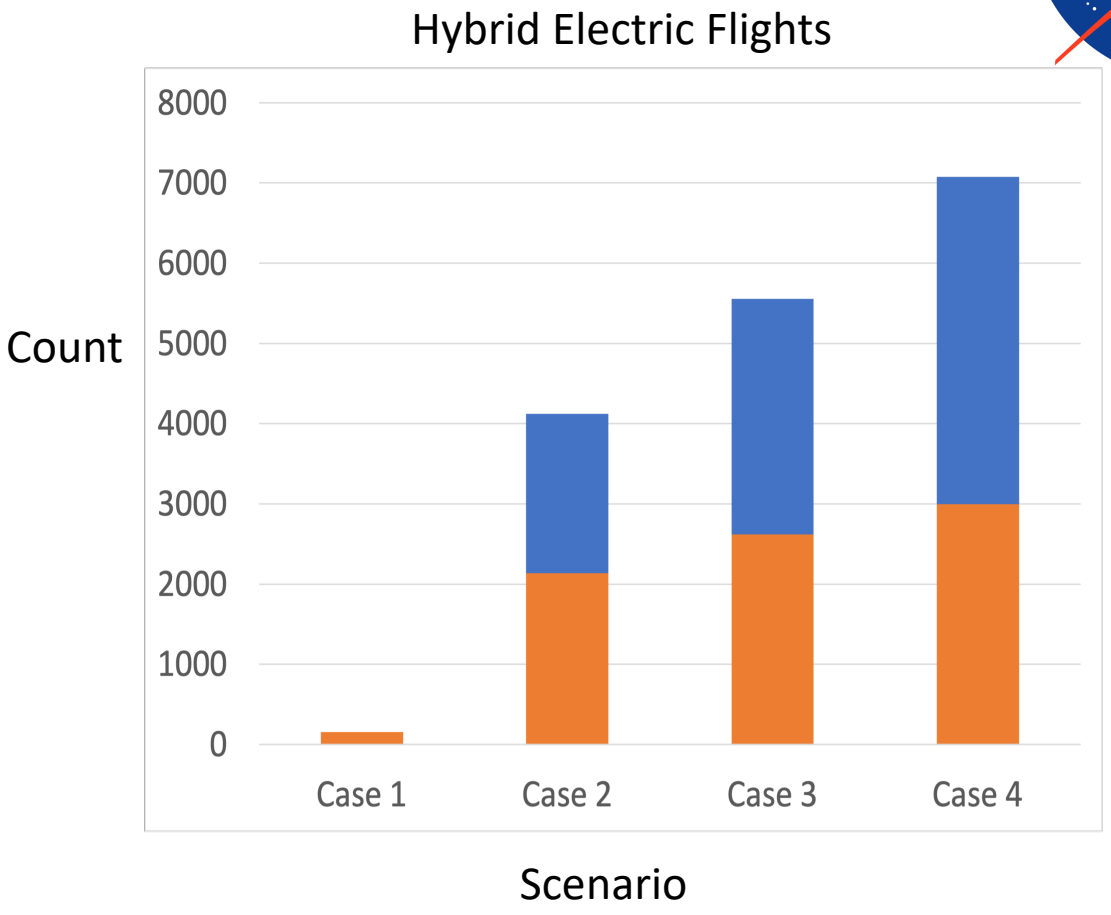
Original Airplane Number of Seats	Additional Hybrid Electric Flights
Between 30-50	0
Between 51-100	1
Between 101-150	2
Between 151-200	3

Simulation Matrix

Case	Flights with Airplane replaced by Hybrid Electric
Baseline	8/1/22
Case 1	Only those serviced by an airplane with less than 50 seats
Case 2	Only those serviced by an airplane with less than 100 seats
Case 3	Only those serviced by an airplane with less than 150 seats
Case 4	Only those serviced by an airplane with less than 200 seats

Flight Counts



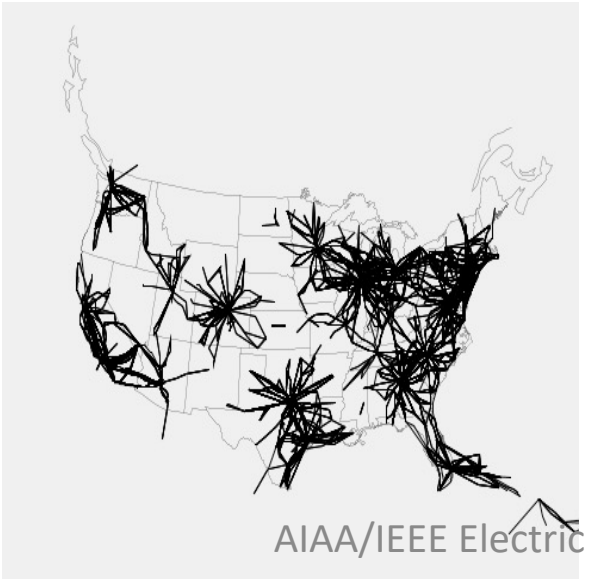


Hybrid Electric Flight Routes

Case 1

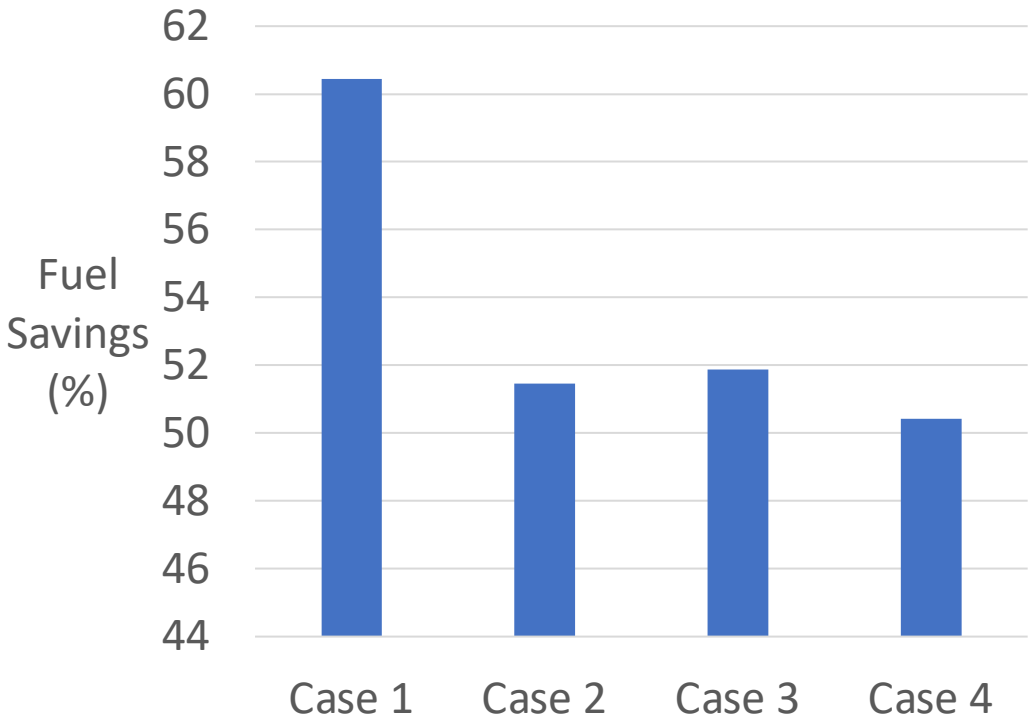
Case 2

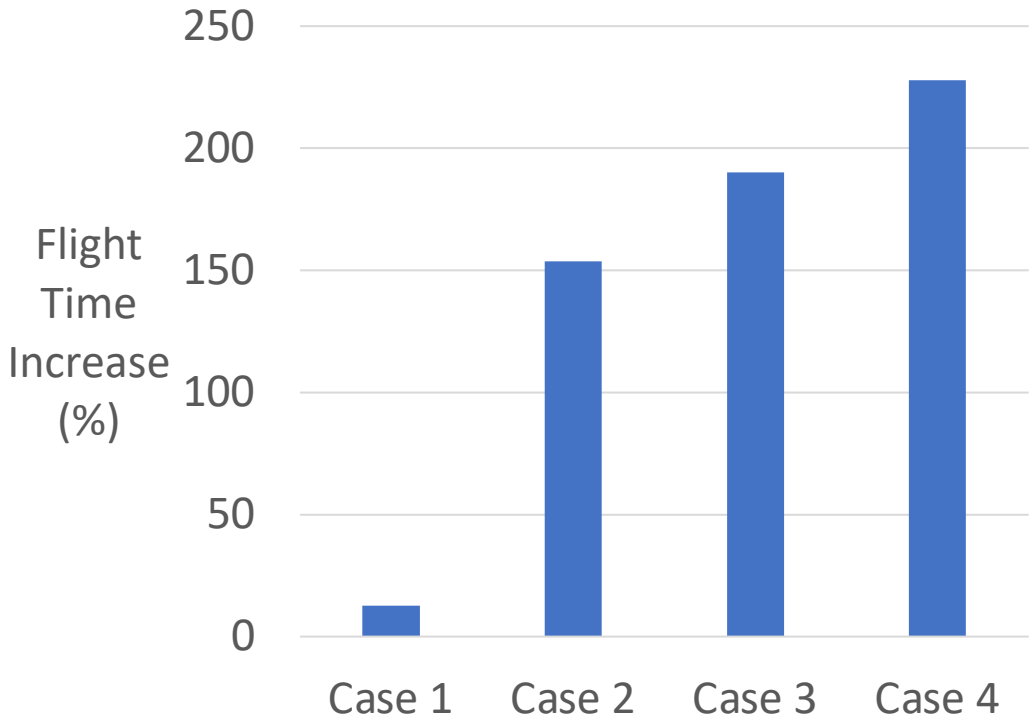
Case 3



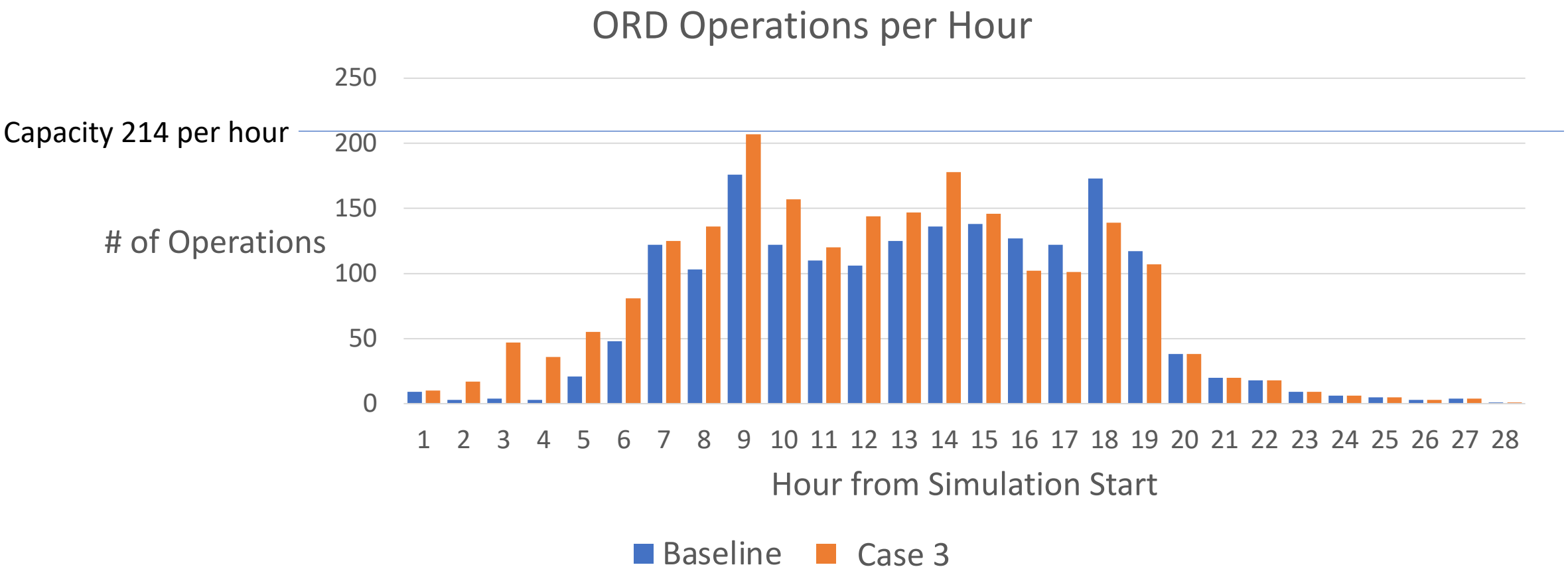
Case 4

Replacement Flights Fuel Burn and Time

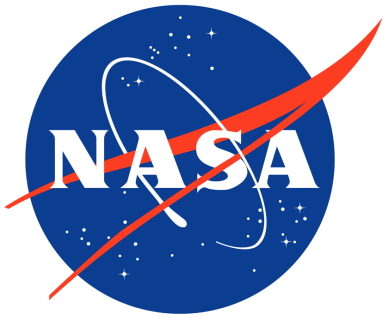




Hourly Operations at Chicago Airport



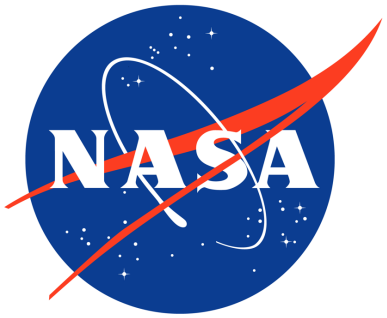
Reagan National to Newark – Case 3



- Baseline: 18 United Express (GoJet) CRJ7 aircraft (70 seats)
- Case 3: Substituted with 36 Hybrid Electric flights
- Similar data for southbound flights

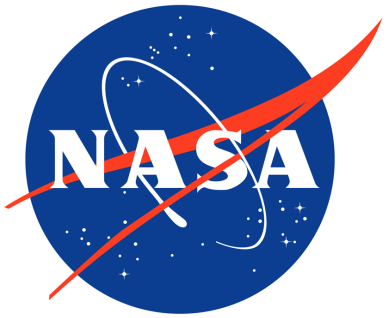
	Baseline	Case 3
Total Fuel Burn (pounds)	30,678	12,957
Point to Point Time (minutes)	36	53
Total Crew Time (hours)	10.3	30.4

Summary



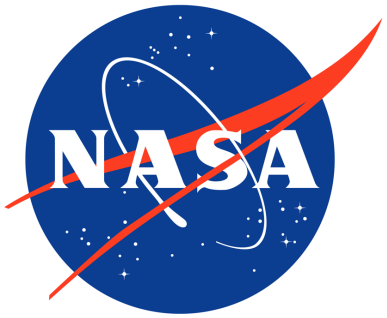
- Simulated Hybrid Electric flights operating in the National Airspace System
  - Captured the majority of flight traffic
  - Calculated flight time and fuel burn
  - Studied airport congestion

- Demonstrated creating and assessing future national airspace operating scenarios, which included hybrid electric aircraft. The outputs support
  - Cost studies
  - Environmental impact studies
  - Traffic studies



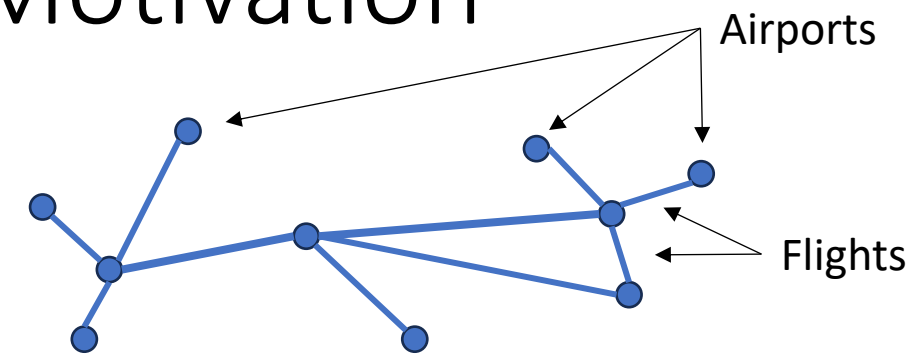
Backup

Next Steps

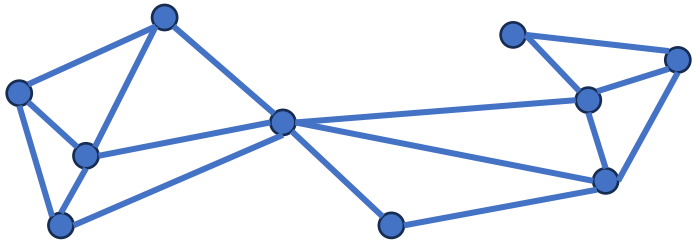


- Incorporate tail tracking
  - It may be difficult to identify replacement flights because short legs may be followed by long legs
- Explore issues with business cases
  - Networks could be readjusted to allow more frequent connections between nearby airports
  - Purchasing new aircraft can be a big investment in training and maintenance
- Look at different novel aircraft
  - Look at larger ranges and greater payloads
  - Each new aircraft type will have different considerations and characteristics

Motivation



Before new aircraft



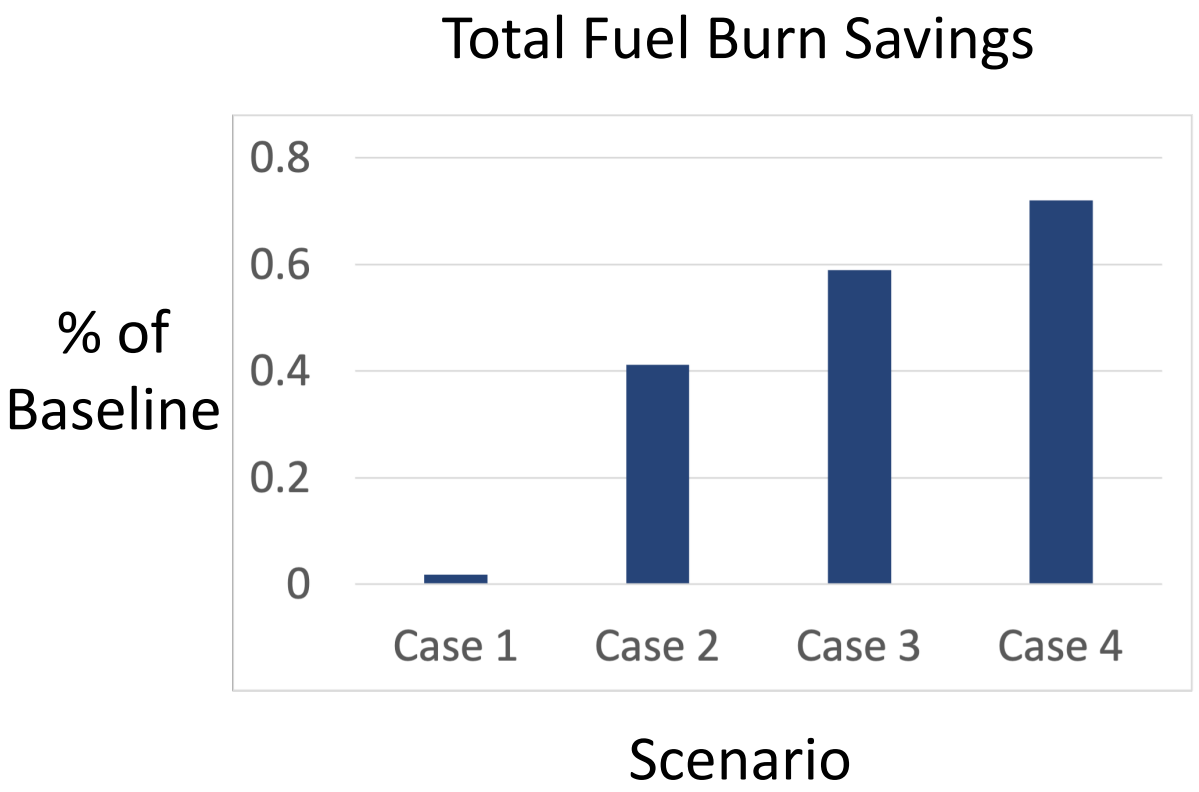
After new aircraft

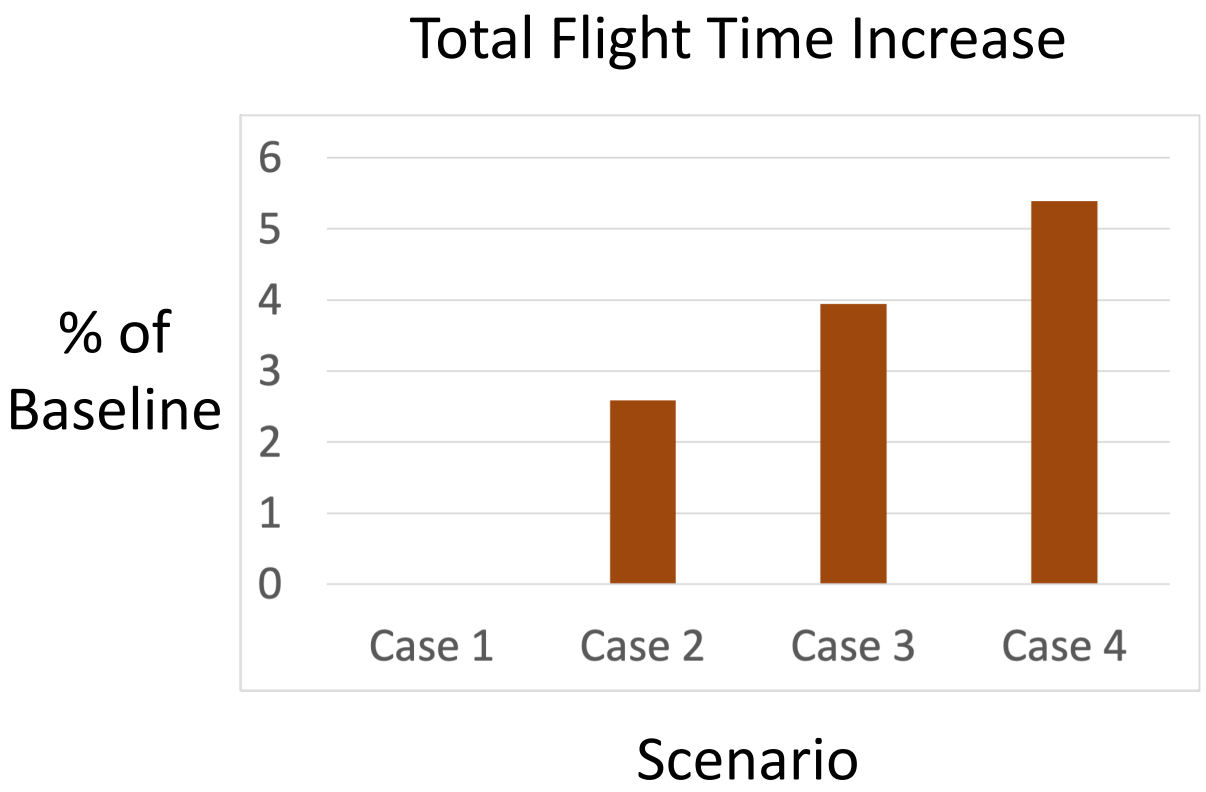
- NASA is developing new aircraft concepts
- These concepts may cause significant changes to operations in the National Airspace System
- Flight fuel-burns, times, and passenger loads may change
- Resulting economic disruptions may may change the flight network

Peak Operations per Hour

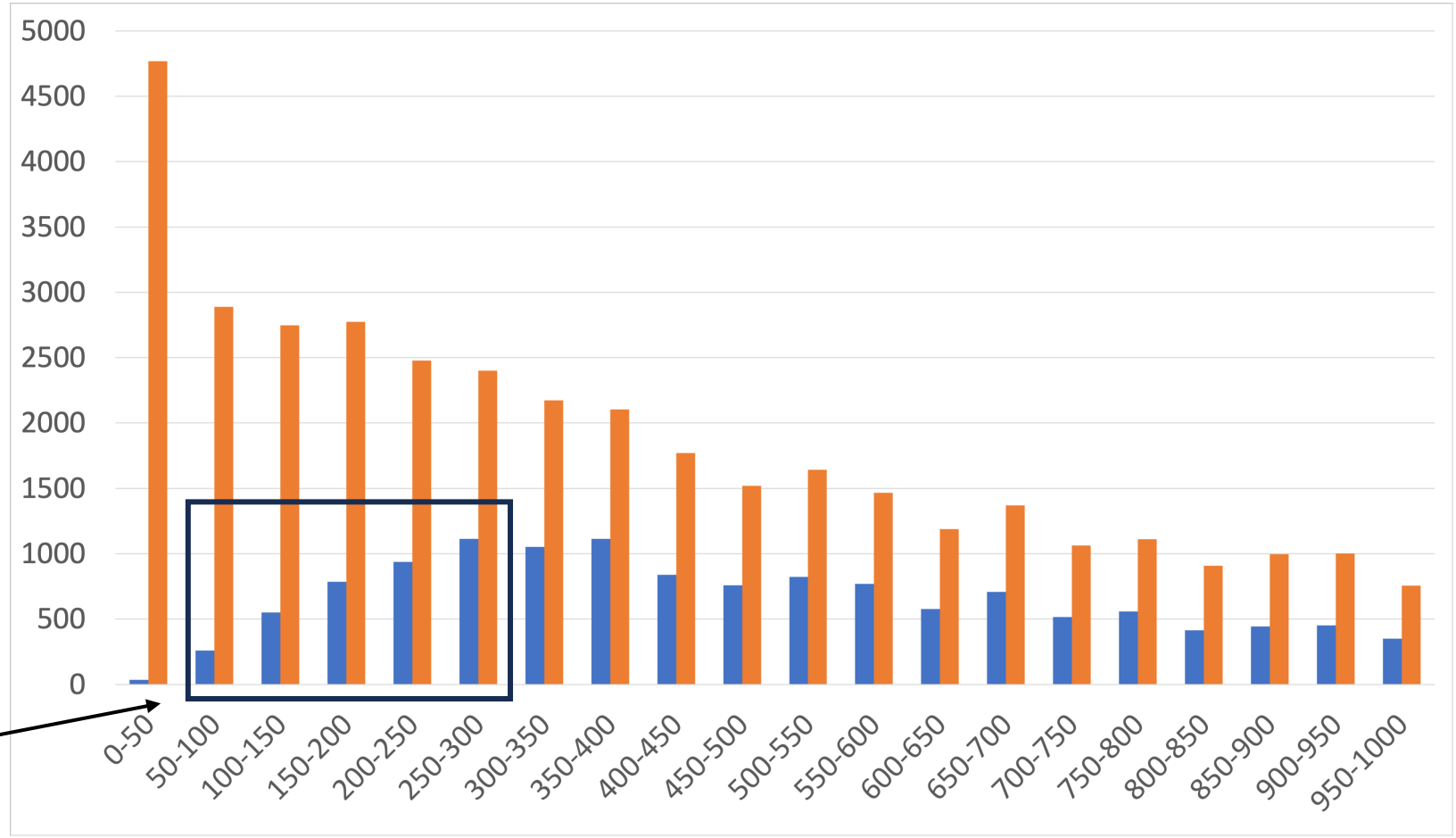
Airport	Baseline Peak Operations	Case 3 Peak Operations	Max Percent Increase	Capacity in High Visibility
ATL	146	175	16.6%	250
DFW	152	162	6.2%	204
DEN	143	163	12.3%	266
ORD	172	193	10.9%	214
LAX	103	114	9.6%	176
JFK	84	85	1.2%	90
LAS	81	95	14.7%	118
MCO	67	68	1.5%	160
MIA	84	82	-2.4%	132
CLT	134	155	13.5%	172

Total Fuel Burn and Flight Time Results



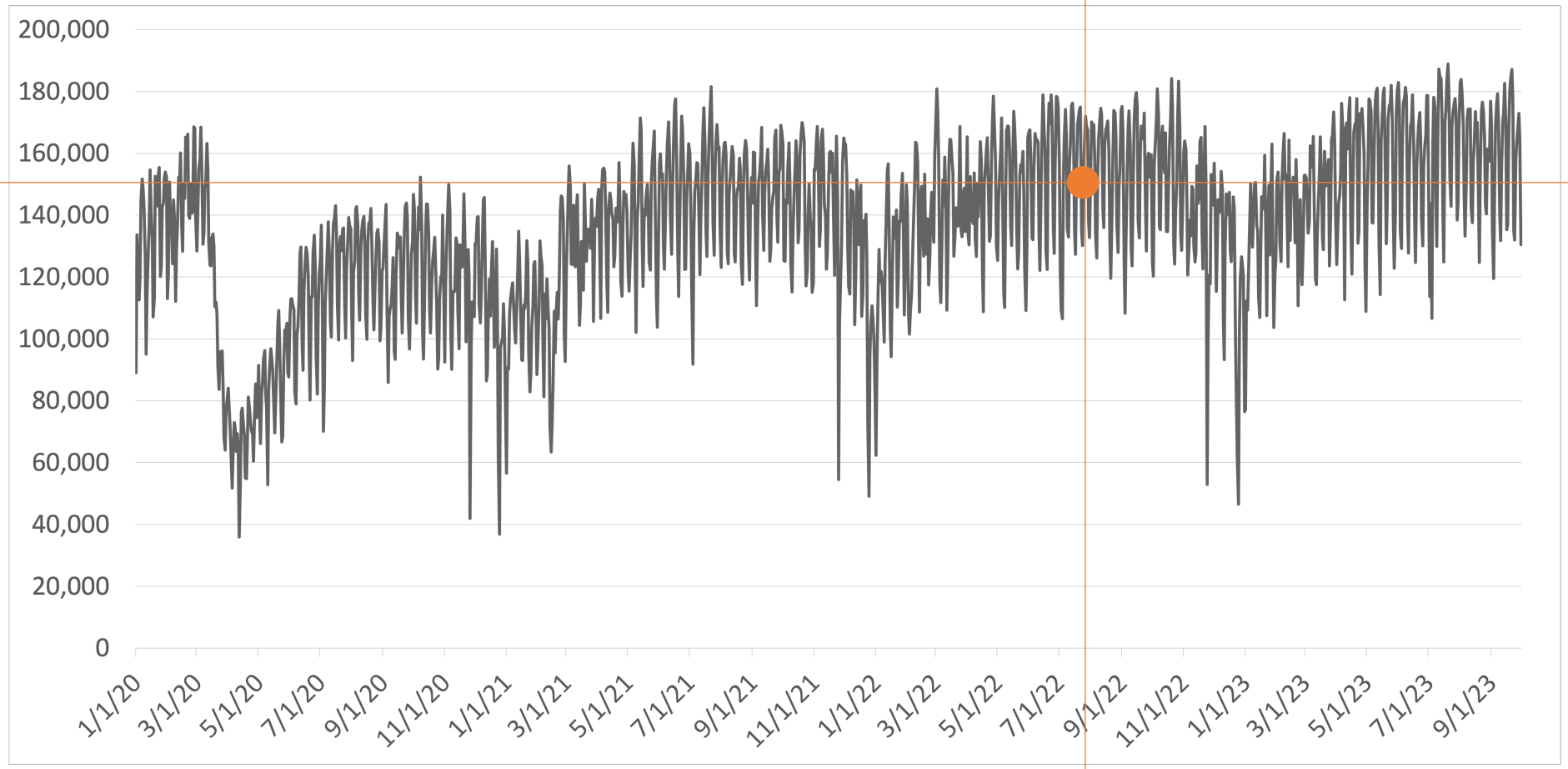


Baseline Scenario Flight Range Histogram

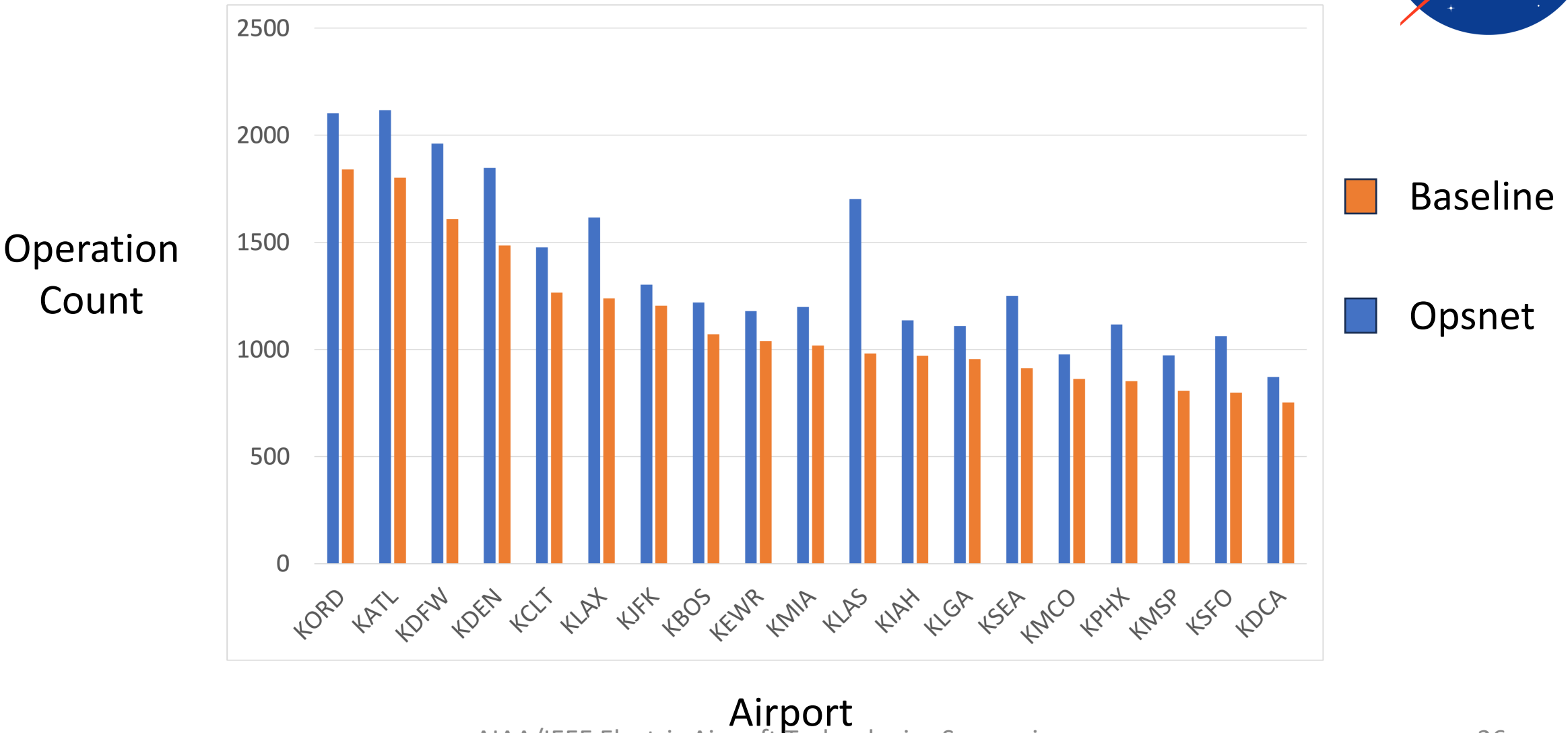


NAS Airport Operations

8/1/22 – 153,881 airport operations

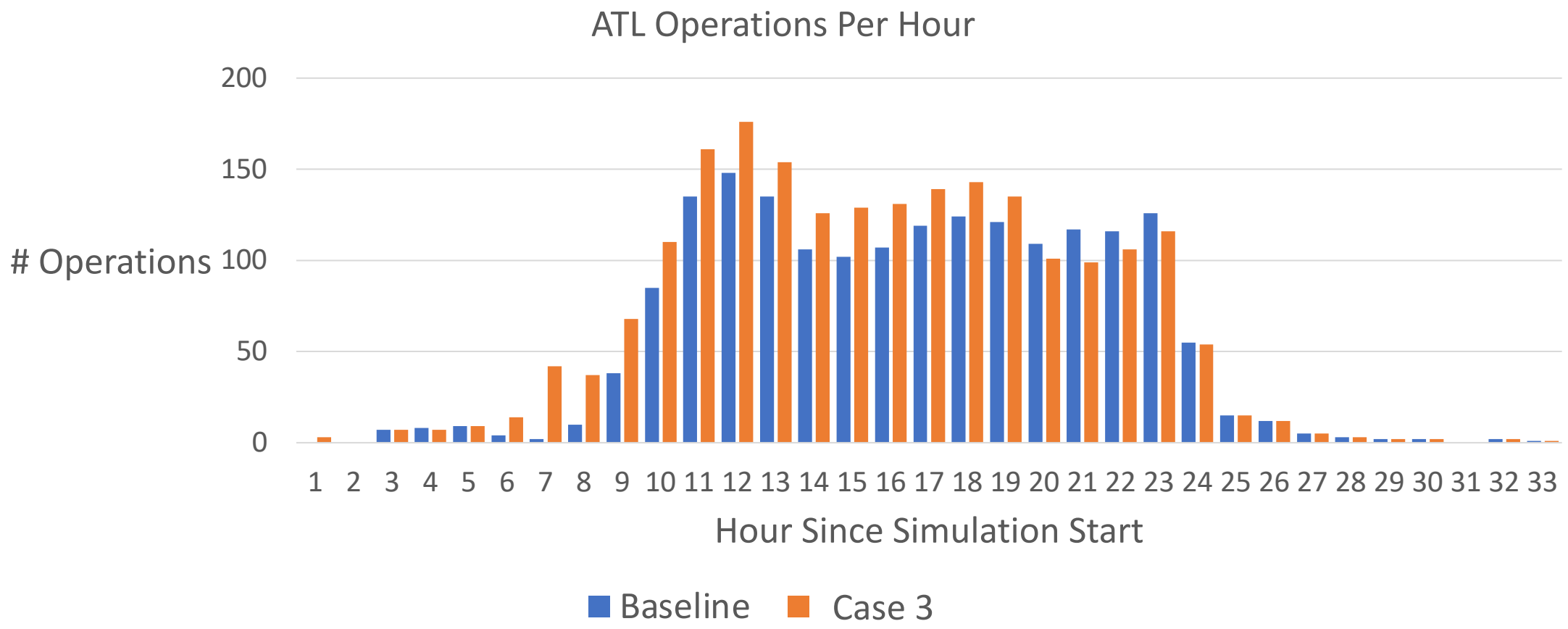


Airport Operations (Arrival or Departure)

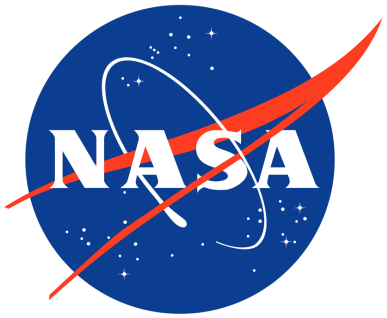


Hourly Operations at Atlanta Airport

Capacity 250 per hour

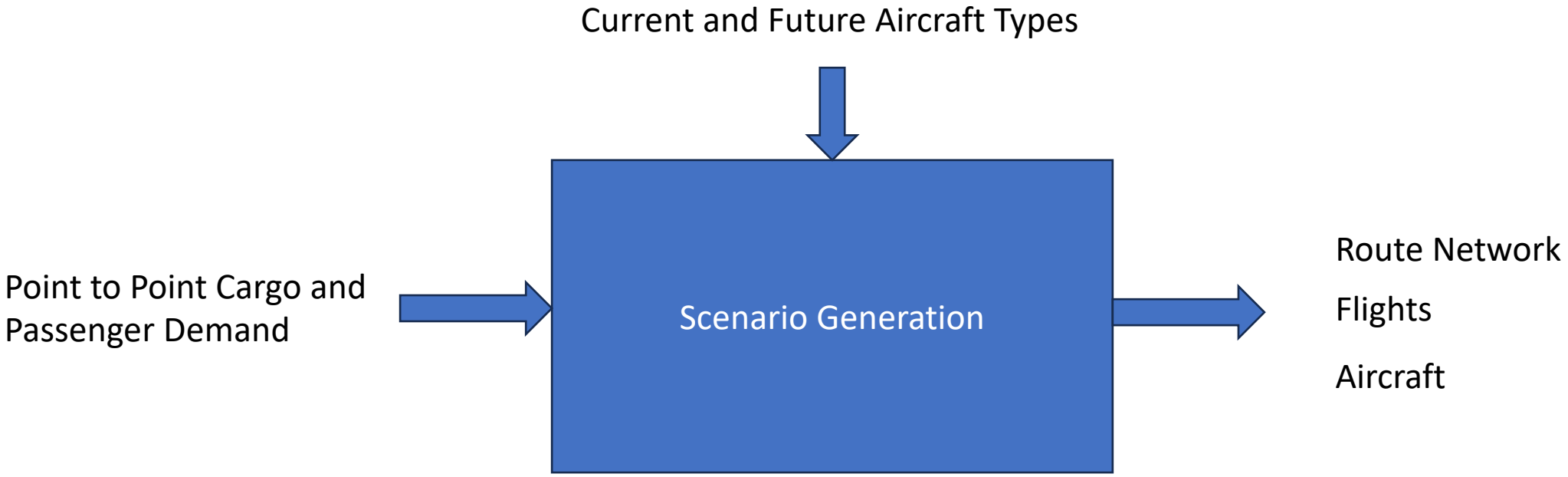


Exploring potential scope of impact

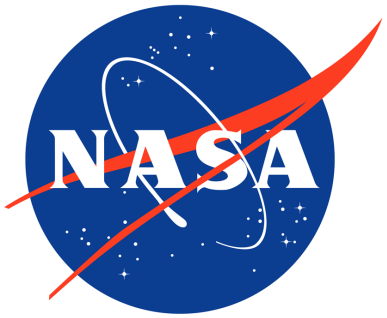


- As we explore these potential EPFD routes and replacement options, we can look for notable changes to the scope of impact
  - Example, replacing 30 to 50 seat aircraft with ranges less than 300 nmi does not affect many flights or routes
  - Keeping the same range but increasing the passenger count to 100 seats drastically increases the number of routes for potential replacement
  - Keeping the range and expanding past 100 seats has a much smaller effect on the number of new potential routes for replacement
- We can look for similar shifts with more factors to see what parts of the current network might provide a large increase in the pool of potential replacement routes

Generate New Scenarios

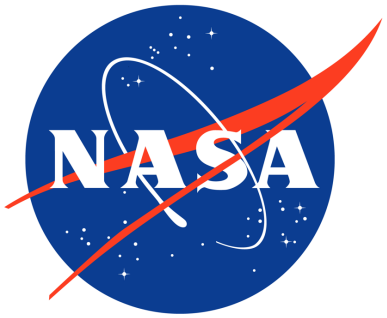


Agenda



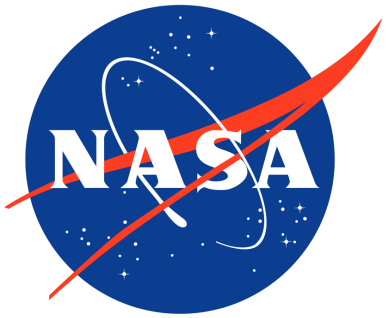
- Background
- Approach
- Scenario generation
- Experiment matrix
- Results

For each Study, need to flesh out:



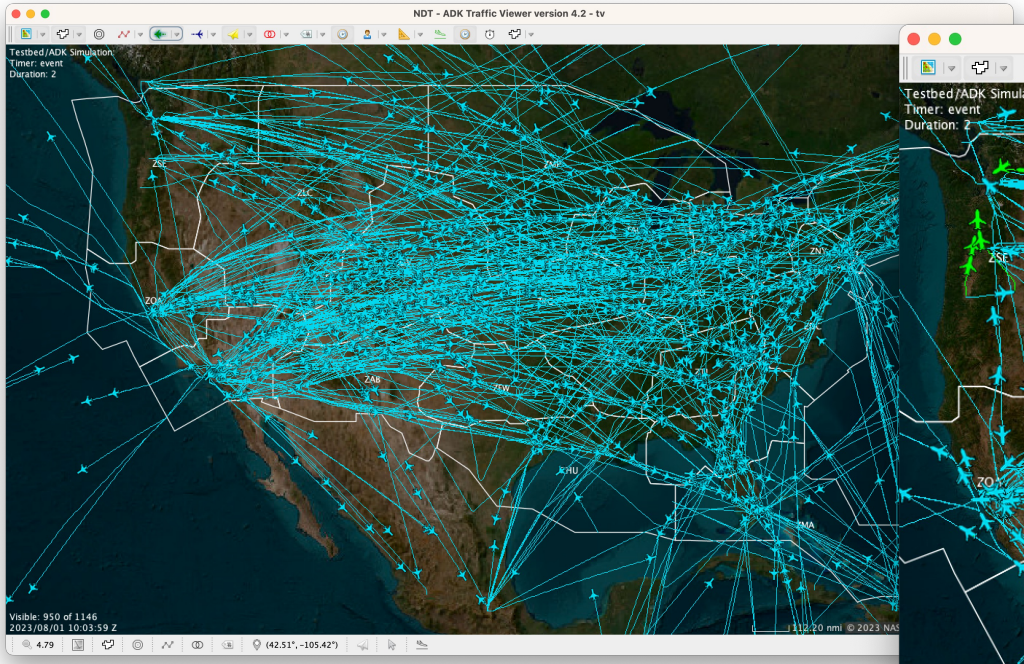
- Rationale
- Objective
- What Results are expected
- What Conclusions are expected
- Scenario Development Needs
- ~~Capability Development Needs~~
- ~~Deliverables: presentation, papers,…~~
- ~~Schedule~~

Issues to Consider when Replacing the Aircraft Type used by a Flight

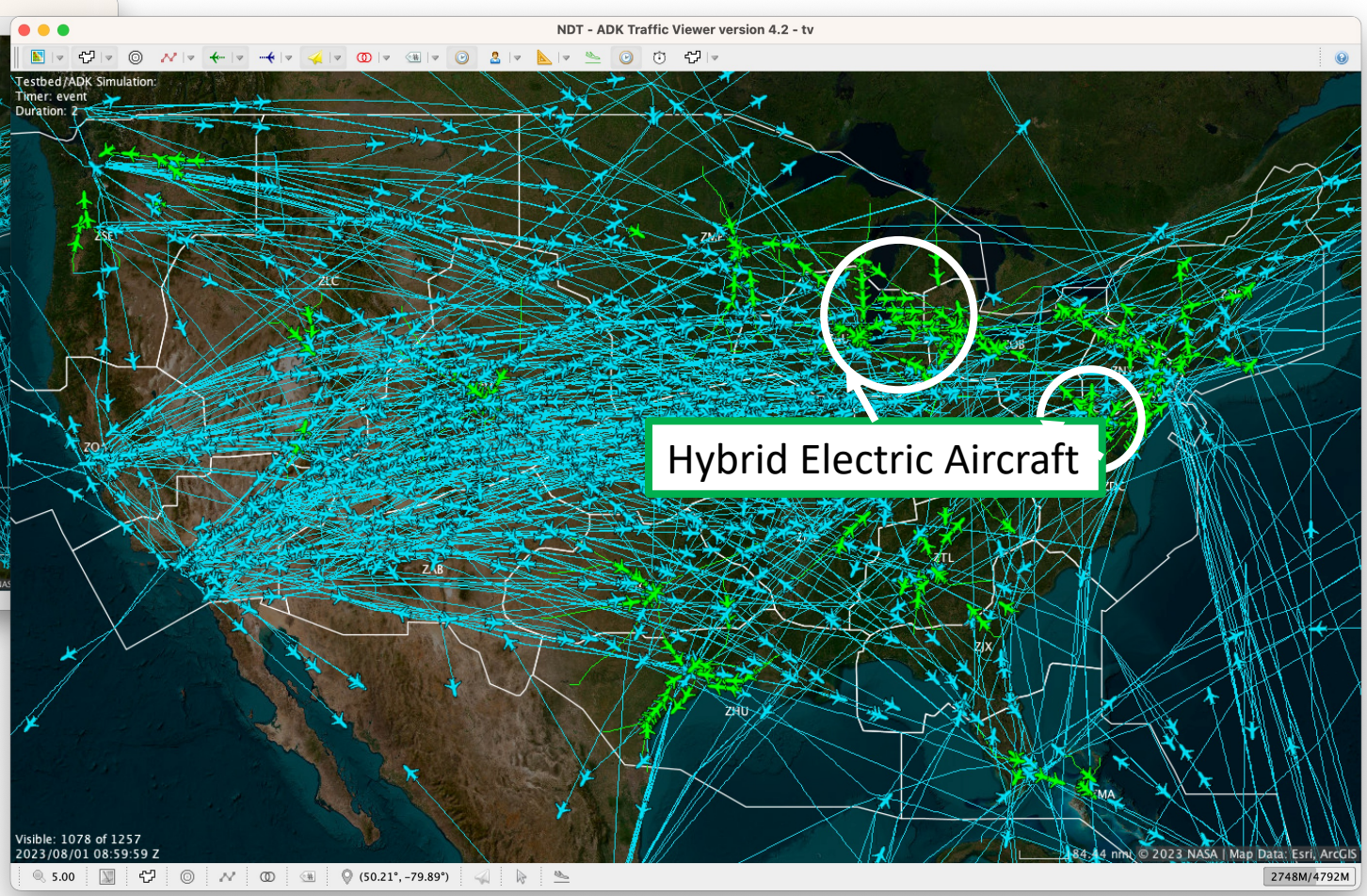


- Economic
  - City-pair demand
  - Operator business model
  - Connecting flight legs
- Aircraft Performance
  - Range
  - Speed
  - Payload
  - Cruise conditions
  - Engine type
- Infrastructure
  - Charging capacity
  - Tarmac space

Running the Simulation

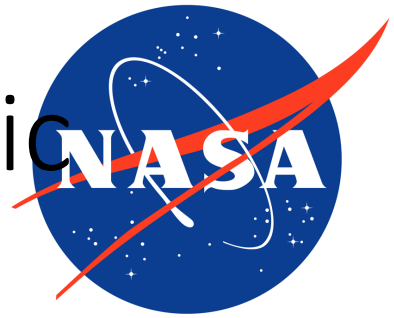


Baseline



1 to 2 Case

Preliminary Modeling of the Hybrid Electric Vehicle



- Initial approach used while more detailed model is being made
  - Used a Dash 8 model
  - Reduced fuel flow rate by half
  - Matched range, passenger count, cruise speed, and cruise altitude
  - Climb and descent rates unmatched

- Working with aircraft designers to incorporate more detailed models as they become available