Alternative Design Configurations to Meet Future Demand
Project 64

Lead investigator: Dimitri Mavris, Georgia Tech
Project manager: Christopher Dorbian, FAA

October 16th, 2025
Alexandria, VA

This research was funded by the U.S. Federal Aviation Administration Office of Environment and Energy through ASCENT, the FAA Center of Excellence for Alternative Jet Fuels and the Environment, project 64 through FAA Award Number 13-C-AJFE-GIT-062 under the supervision of Christopher Dorbian. Any opinions, findings, conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the FAA.

ASCENT

Project 64

Alternative Design Configurations to Meet Future Demand

Georgia Institute of Technology

PI / CO-PI: Dimitri Mavris / Michelle Kirby

PM: Christopher Dorbian

Cost Share Partner(s): Georgia Tech

REs: Jonathan Gladin, Michelle Kirby, Yu Cai, Jiacheng Xie

Students: Salma Benhissoune, Yutong Cheng, Nick Cocoves, Tuna Ergan, Kevin Florian, Felipe Z. Henriquez, Cem Kocer, Nina Kondur, Somto Okonkwo, Akshiti Parashar, Andy Tan, Srikanth T. Varadharajan,

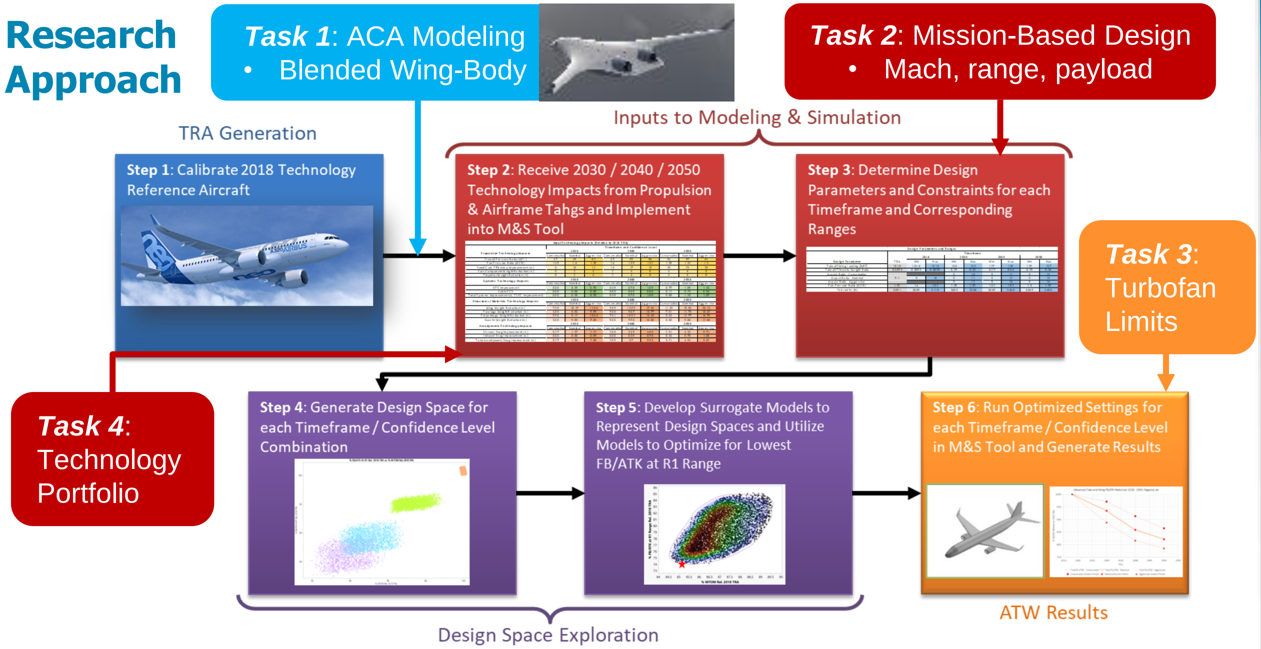
Objective:

1. Facilitate Advanced Concept Aircraft (ACA) modeling capability in Aircraft Environmental Design Tool (AEDT)
2. Investigate alternative design approaches of reducing design range, lowering cruise speed, and increasing design payload for advance tube-and-wing (ATW) aircraft
3. Explore fuel efficiency boundary of turbofan engine architecture
4. Establish aviation technology portfolio to predict near-future performance impact of airframe and engine technologies

Project Benefits:

- Provide insights regarding a more realistic approach to modeling ACAs in existing fleet analysis tools
- Assess potential performance impacts of new design paradigms to minimize fuel burn

Research Approach



Major Accomplishments (to date):

- Established data pipeline between aircraft sizing environment and AEDT and validated process using Technology Reference Aircraft
- Evaluated fuel burn and noise reductions due to sizing and optimizing aircraft with reduced cruise speed, reduced design range, and increased design payload at both vehicle and fleet levels
- Investigated turbofan engine fuel burn reduction potential at 2050 timeframe with advanced technologies infused and cycle optimized

Future Work / Schedule:

- Improve ACA modeling in AEDT and conduct fleet assessment
- Evaluate sensitivity of fleet-level fuel burn reduction due to ATW with respect to flight demand and operational variations

This research was funded by the U.S. Federal Aviation Administration Office of Environment and Energy through ASCENT, the FAA Center of Excellence for Alternative Jet Fuels and the Environment, project 64 through FAA Award Number 13-C-AJFE-GIT-062 under the supervision of Christopher Dorbian.
Any opinions, findings, conclusions or recommendations expressed in this this material are those of the authors and do not necessarily reflect the views of the FAA.

Task 1: Improvement of ACA Representation in MDG/FESG Models

Background

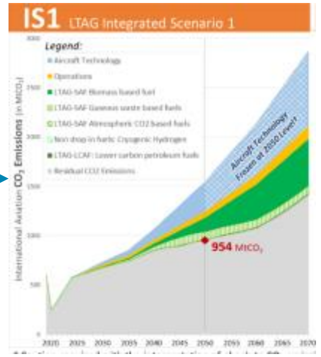
Long Term Aspirational Goals (LTAG) Project:

- Comprehensive feasibility study for civil aviation carbon emission reductions
- Conducted in 2020-2022 for ICAO Committee on Aviation Environment Protection (CAEP)

Report on the Feasibility of a Long-Term Aspirational Goal Appendix M3 APPENDIX M3 LTAG-TG TECHNOLOGY SUB GROUP REPORT

Advanced Tube and Wing (ATW) Assessment

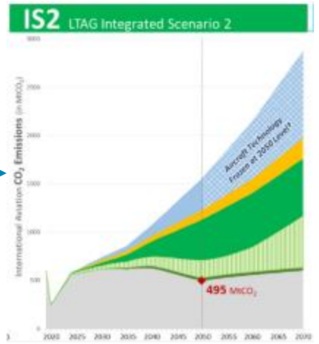
- Business jet, turboprop, regional jet, narrow body, wide body
- 2030-2050 **technology projection and integration** (aerodynamics, structure, propulsion, etc.)



CO_2 reduction scenario 1

Advanced Concept Aircraft (ACA) Assessment

- Based on the potential improvements in the authoritative studies in the literature
- **Not explicitly modelled** because of uncertainties

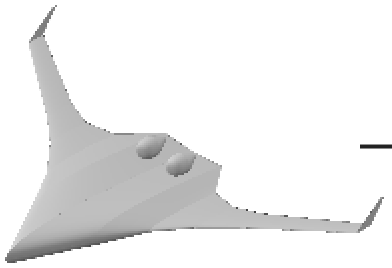


CO_2 reduction scenario 2

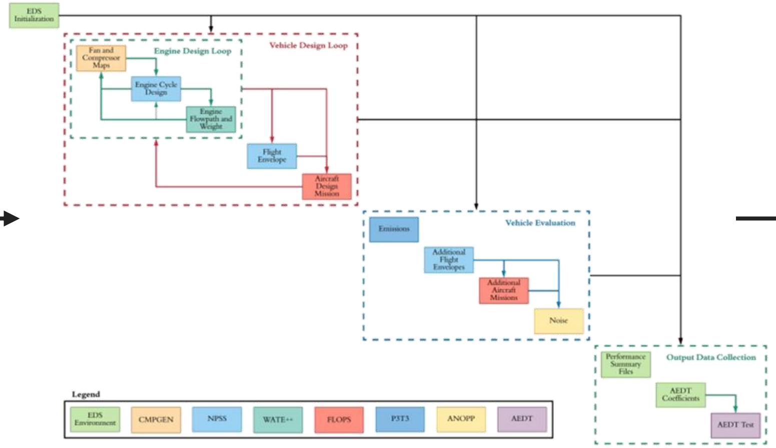
Advanced Concept Aircraft (ACA) Assessment

Task 1: Improvement of ACA Representation in MDG/FESG Models

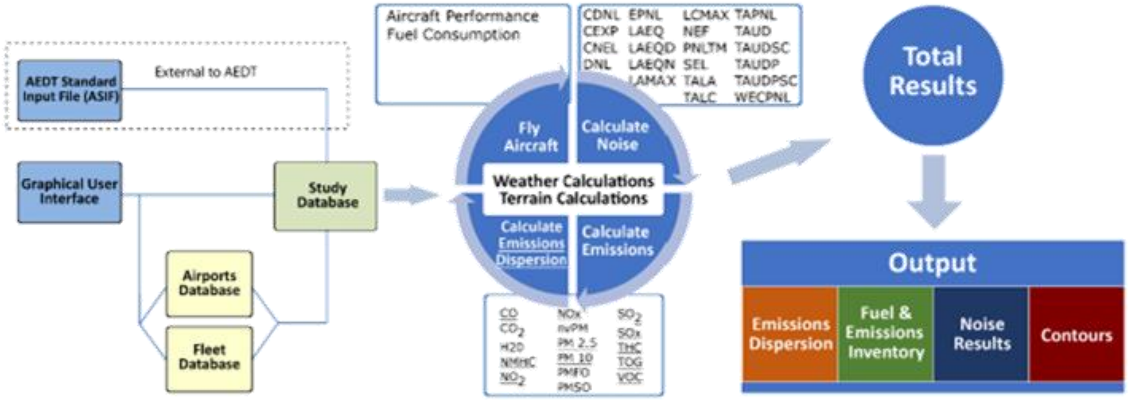
- Motivation: AEDT supported by existing aircraft performance database but no ACA data available
- Research Objective: Facilitate ACA vehicle modeling and fleet assessment in AEDT
- Approach: Two-stage development and evaluation
  1. Establish and validate data pipeline between Environmental Design Space (EDS) and AEDT
  2. Enable ACA modeling capacity in AEDT using a Blended Wing-Body (BWB) model developed in EDS



ACA: BWB

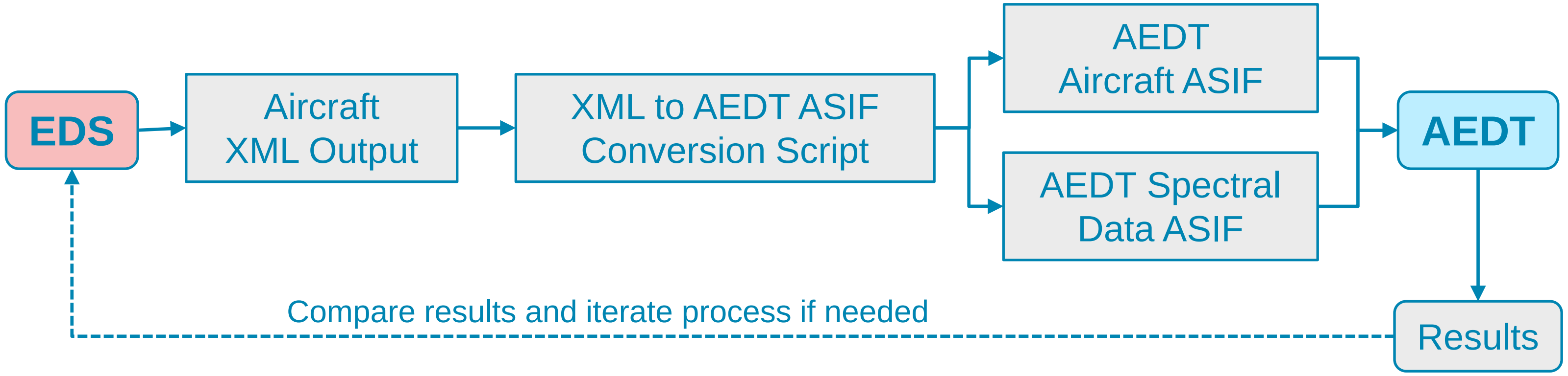


EDS: engine and aircraft modeling



AEDT: fleet-level environmental assessment

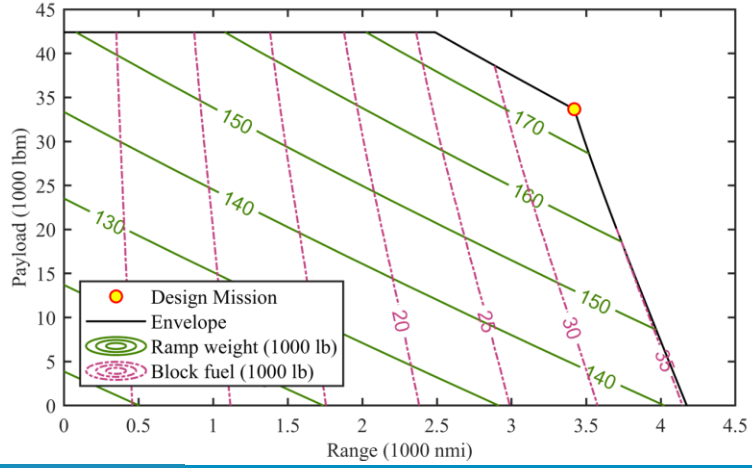
EDS-AEDT Data Pipeline and Validation



Technology Reference Aircraft (TRA)

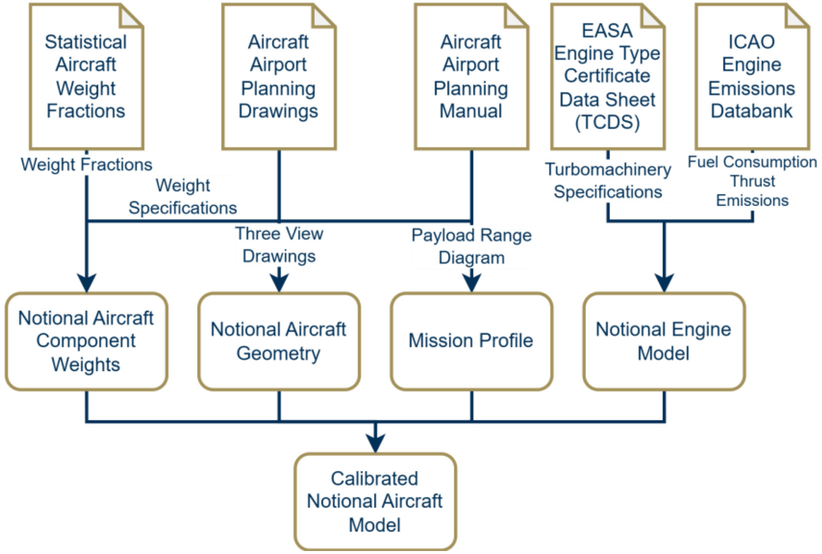
- Notional A320neo with PW1127G engine

  - 150-pax single-aisle aircraft
  - Design range: 3420 nmi
  - Maximum ramp weight: 175,047 lbm
  - Sea-level takeoff thrust: 2 x 27,080 lbf



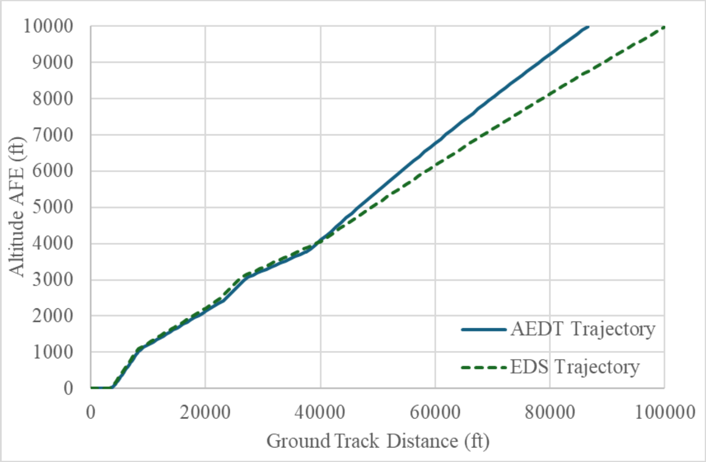
- Established Technology Reference Aircraft (TRA) as a control case for validation
  - Based on public-domain data
  - Conventional aircraft with known trajectory and performance in AEDT
  - Ensure connectivity and consistency between EDS and AEDT before applying to ACA

TRA Calibration in EDS



Thrust Modelling Inconsistency

- TRA departure trajectory discrepancy due to thrust modeling inconsistency between EDS and AEDT:

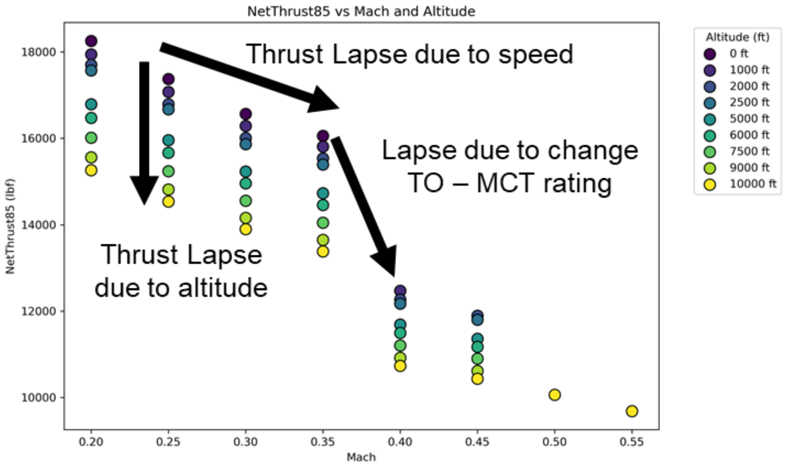


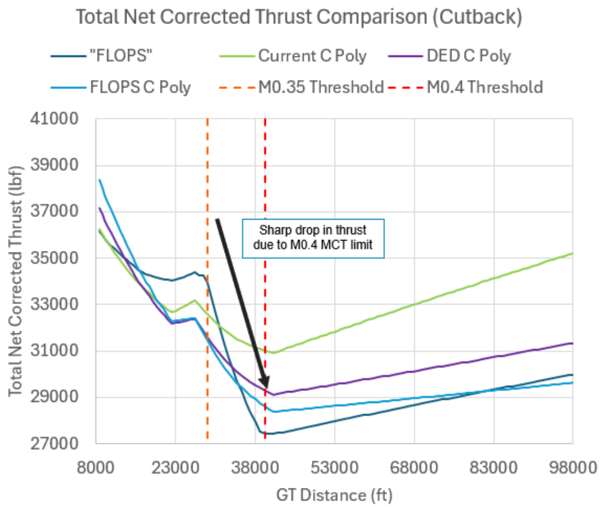
Mach	Altitude	EDS 85% Cutback	AEDT Cutback	Error
0.25	5000	19178	19606	-2.23%
0.3	5000	18302	18456	-0.84%
0.35	5000	17702	17306	2.24%
0.4	5000	14050	16156	-14.99%
0.45	5000	13650	15006	-9.93%
0.25	10000	21134	22125	-4.69%
0.3	10000	20206	21079	-4.32%
0.35	10000	19460	20034	-2.95%
0.4	10000	15607	18988	-21.66%
0.45	10000	15176	17943	-18.24%
0.5	10000	14638	16898	-15.44%
0.55	10000	14083	15852	-12.57%

- EDS relies on a single lookup table (engine deck) of flight conditions, thrust, fuel flows for all phases of flight, but no time-dependency in EDS engine model
- AEDT relies on different polynomials / models for different throttle settings (takeoff, cutback ANP thrust polynomials below 10k ft, BADA3 above 10k ft)

- AEDT polynomial cannot reproduce sharp changes in EDS engine performance:
  - M0.4 transition from Max. Takeoff Thrust (TO) to Max Cont. Thrust (MCT) Rating in EDS

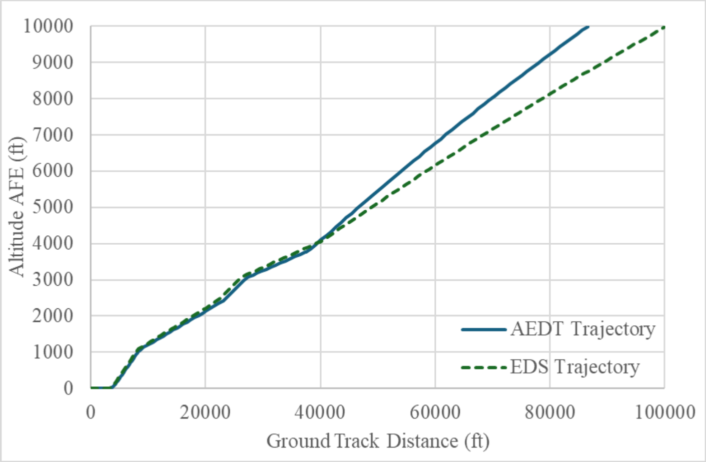
- **Step 1:** Improve AEDT polynomial coefficients fit from EDS





Thrust Modelling Inconsistency

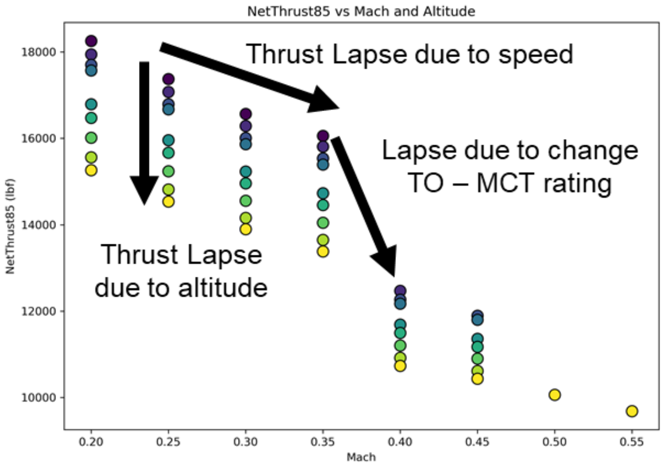
- TRA departure trajectory discrepancy due to thrust modeling inconsistency between EDS and AEDT:

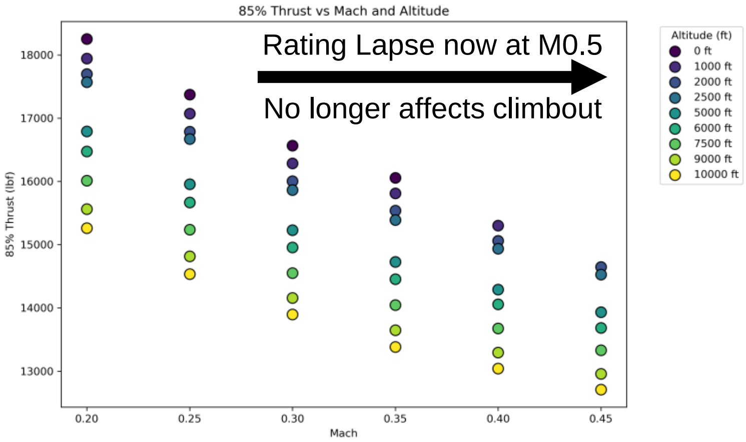


Mach	Altitude	EDS 85% Cutback	AEDT Cutback	Error
0.25	5000	19178	19606	-2.23%
0.3	5000	18302	18456	-0.84%
0.35	5000	17702	17306	2.24%
0.4	5000	14050	16156	-14.99%
0.45	5000	13650	15006	-9.93%
0.25	10000	21134	22125	-4.69%
0.3	10000	20206	21079	-4.32%
0.35	10000	19460	20034	-2.95%
0.4	10000	15607	18988	-21.66%
0.45	10000	15176	17943	-18.24%
0.5	10000	14638	16898	-15.44%
0.55	10000	14083	15852	-12.57%

- EDS relies on a single lookup table (engine deck) of flight conditions, thrust, fuel flows for all phases of flight, but no time-dependency in EDS engine model
- AEDT relies on different polynomials / models for different throttle settings (takeoff, cutback ANP thrust polynomials below 10k ft, BADA3 above 10k ft)

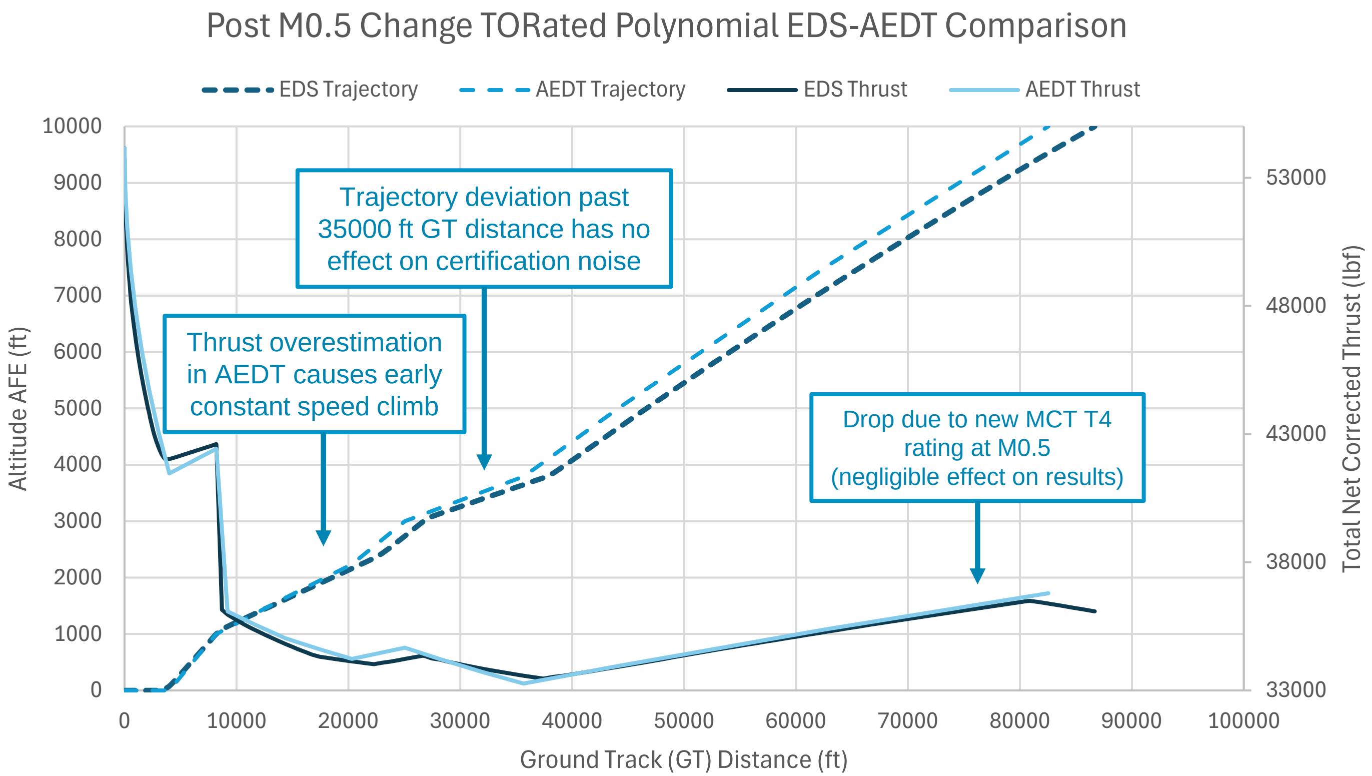
- AEDT polynomial cannot reproduce sharp changes in EDS engine performance:
  - M0.4 transition from Max. Takeoff Thrust (TO) to Max Cont. Thrust (MCT) Rating in EDS
- **Step 1:** Improve AEDT polynomial coefficients fit from EDS
- **Step 2:** Increase TO-MCT transition Mach number to 0.5 in EDS





Solution and Results

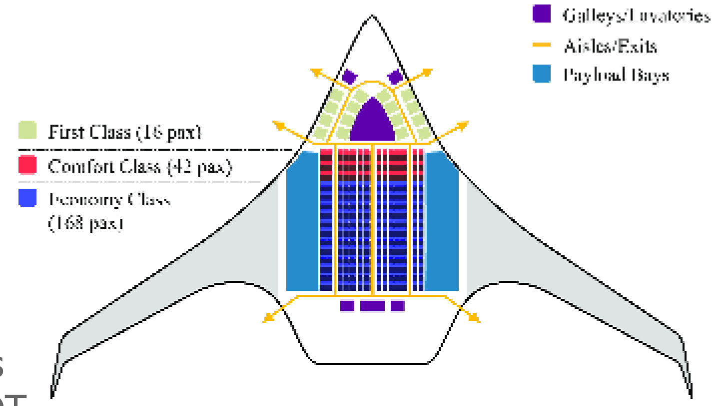
- Changing EDS rule on Mach Number from M0.4 ⟶ M0.5 produced smoother surface for fitting with ANP's THR_JET polynomial
- Fitting technique: RMSE / SSE minimization procedure to determine coefficients to AEDT (ANP) net corrected thrust polynomial
- Tested on all departure procedures formulated by 3 profiles and 6 stages

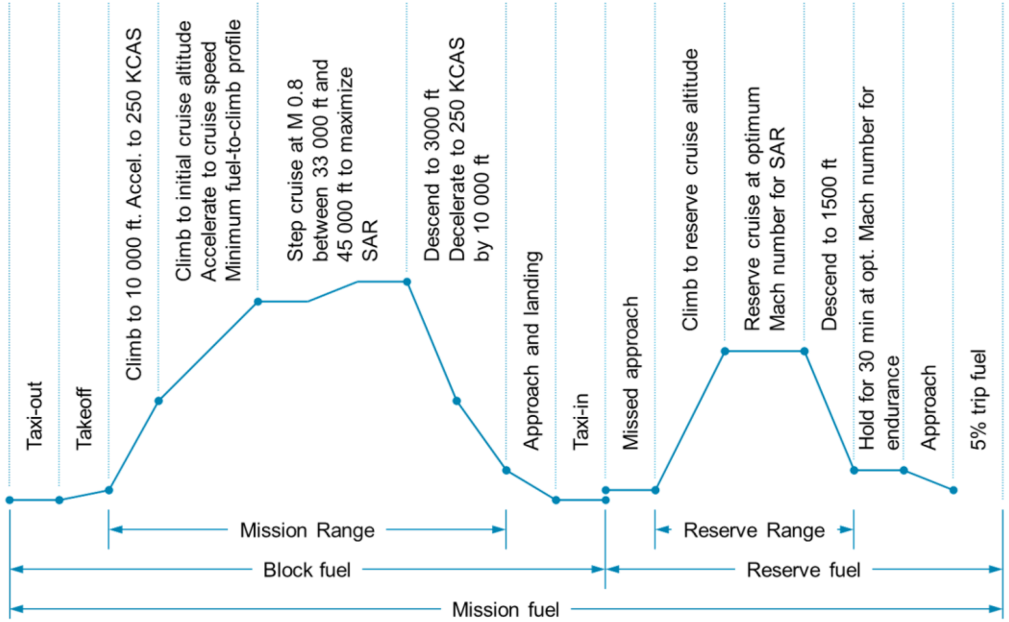


Stage Length	Profile	Max Altitude Deviation (ft)	Start Weight Difference (lbs)	End Weight Difference (lbs)	Final Distance Error (nmi)
1	STANDARD	463	1	2	0.682
1	ICAO A	501	1	9	0.742
1	ICAO B	469	1	6	0.691
2	STANDARD	458	2	4	0.706
2	ICAO A	489	2	10	0.761
2	ICAO B	448	2	5	0.682
3	STANDARD	456	2	5	0.725
3	ICAO A	484	2	13	0.785
3	ICAO B	426	2	5	0.684
4	STANDARD	520	2	17	0.898
4	ICAO A	503	2	20	0.871
4	ICAO B	408	2	6	0.715
5	STANDARD	564	2	29	1.068
5	ICAO A	526	2	32	1.006
5	ICAO B	401	2	10	0.767
6	STANDARD	567	3	32	1.093
6	ICAO A	540	3	35	1.053
6	ICAO B	404	3	11	0.793

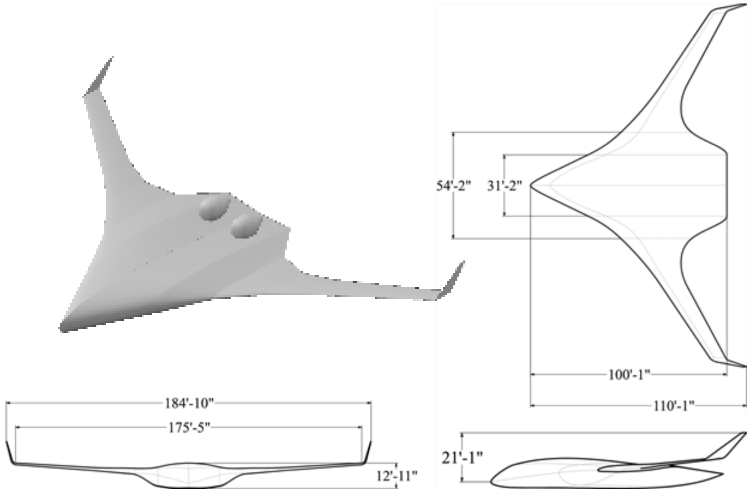
Advanced Concept Aircraft (ACA) Model

- ASDL 225-pax BWB model: Inspired by BWB concept proposed by JetZero
  - Aerodynamics: RANS CFD for clean configuration
  - Weight estimation: NASA's FLOPS BWB module
  - Propulsion: Advanced PW-1133G engine with 2030 technologies
- ACA model developed in EDS to eventually enable ACA modeling in AEDT
  - Current status: Engine and vehicle models sizing finished, working on low-speed aerodynamics
  - Next step: Generate coefficients from EDS and test all departure and arrival procedures in AEDT





Passenger capacity	225
Design range	5000 nmi
Cruise Mach number	0.8
Max. ramp weight	263,849 lb
SLS Thrust	2 x 43,000 lb
Wing-body span	184.8 ft
Planform area	5,738 sqft
Fuselage length	100.1 ft
Fuselage width	31.2 ft
Fuselage depth	12.9 ft



Task 2:
Alternative Design Approaches for Future Demand

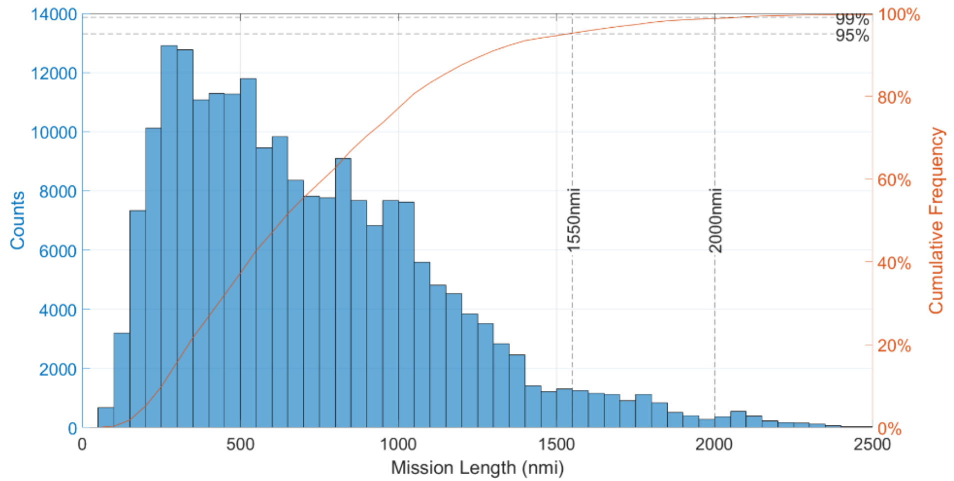
Motivation

Task 2 Research Objective

Evaluate fuel burn benefit by designing single-aisle aircraft with reduced design range, reduced cruise speed, and increased design payload

Why reducing design range?

- Design range significantly higher than operating mission range
  - E.g., A320 design range 3420 nmi but 80% of its operations less than 1000 nmi
- Reduced design range → Smaller vehicle → Less fuel burn in operating missions



Why increasing design payload?

- Higher future air travel demand
- Empty weight reduction due to reduced design range allows for increased payload

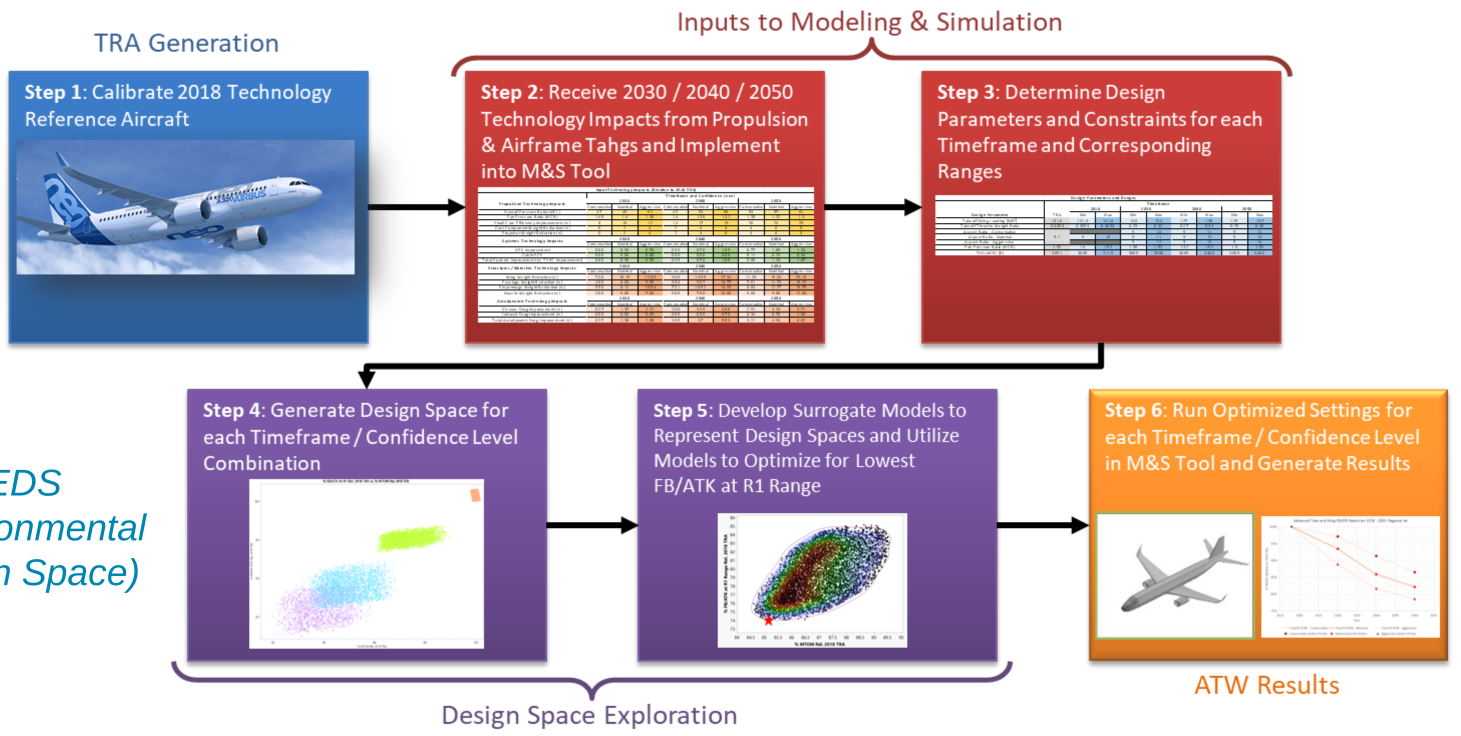
Why reducing cruise speed?

- Less wave drag and improved specific air range
- Beneficial to natural laminar flow technology

Vehicle Design and Optimization

Follow LTAG study Advanced Tube-and-Wing (ATW) design process with projected 2035 technology infused

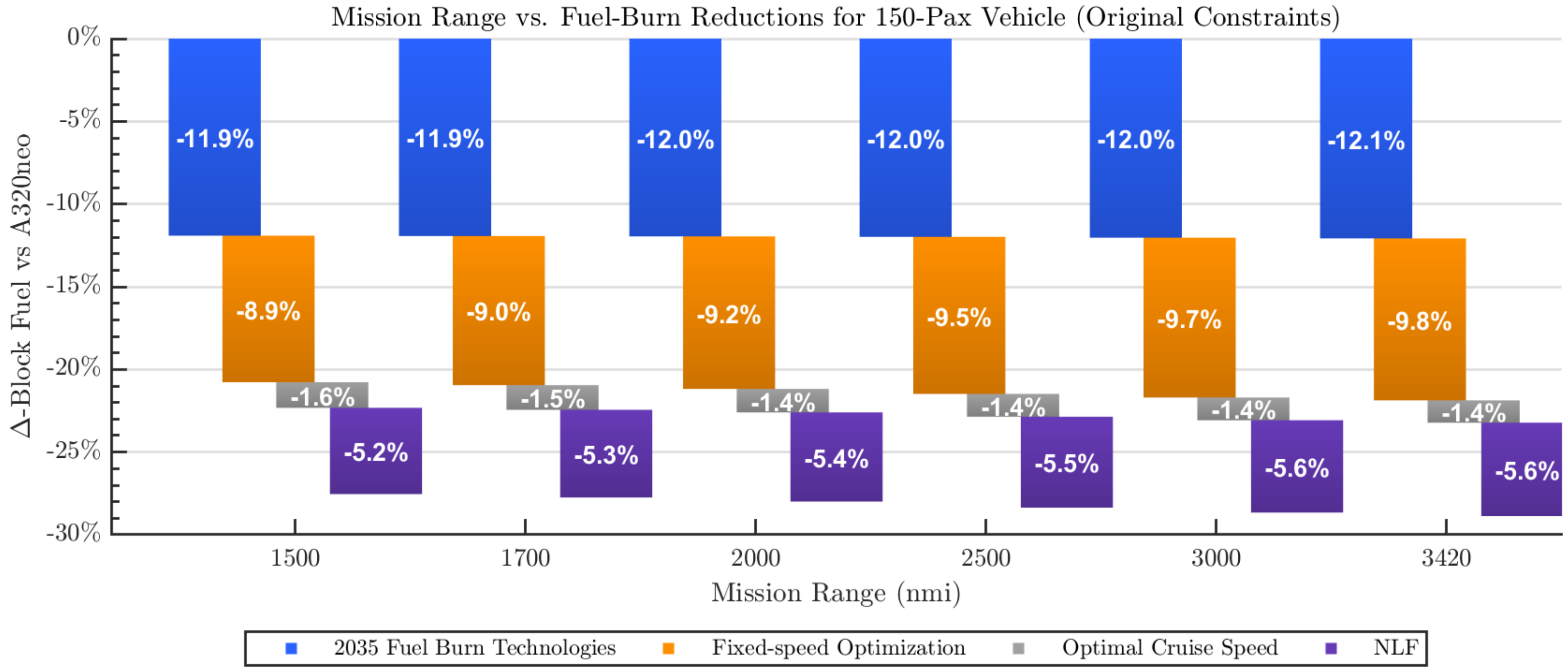
Tool: EDS (Environmental Design Space)



Technology	Improvement
Propulsion	
Small core efficiency	+13.50%
Core component weight	-3.00%
Propulsor weight	-3.00%
Power extraction (TSFC)	-0.525%
Structure / Material	
Wing weight	-11.85%
Fuselage weight	-8.35%
Empennage weight	-9.52%
Nacelle weight	-6.25%
Aerodynamics	
Viscous drag	-2.38%
Induced drag	-0.175%

- Baseline aircraft: Notional A320neo with PW1127G engine developed in Task 1
- Design variables: Design range, Design payload, Cruise Mach, OPR, FPR, Ext_ratio, T4max, T/W, W/S, AR, TR, Sweep
- Constraints: Takeoff and landing field length, Span, Fan diameter, Engine core size, T3max

Reducing Cruise Speed



- Design range and payload fixed as baseline A320neo
- Fuel burn reduction evaluated at design and off-design missions
- Natural laminar flow (NLF) technology:
  - Shaping airfoil shape to delay transition
  - Move effective at lower speed and smaller sweep angle

Reducing cruise Mach number from 0.78 to 0.71 with NLF applied decreases fuel burn by about 7%

- **Vehicle 1:** Resize A320neo baseline with projected 2035 technologies infused
- **Vehicle 2:** Optimize engine cycle and wing planform and resize aircraft with 2035 technologies
- **Vehicle 3:** Simultaneously optimize cruise speed with airframe and engine, and resize aircraft
- **Vehicle 4:** Apply natural laminar flow on top of optimizing cruise speed and re-optimize airframe and engine

Reducing Design Range and Increasing Payload

Determine optimal designs for various combinations of design ranges and payloads while reducing cruise speed

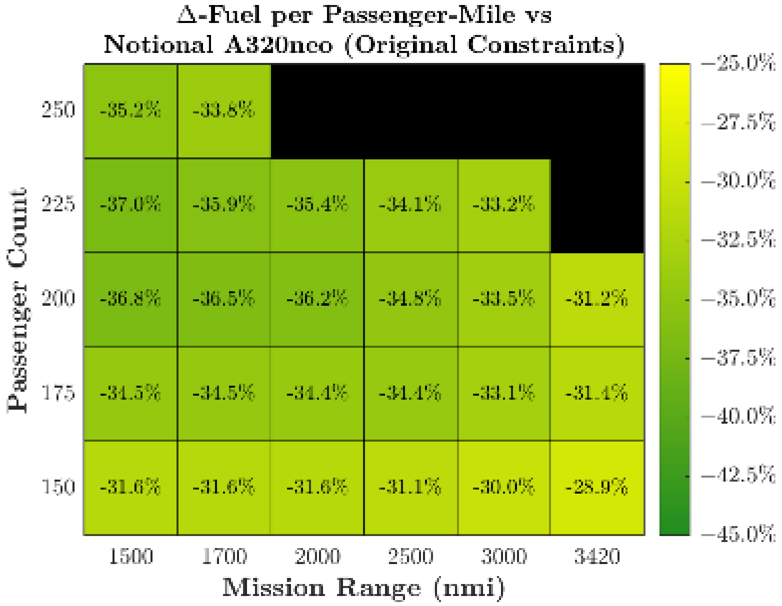
Feasibility Evaluation

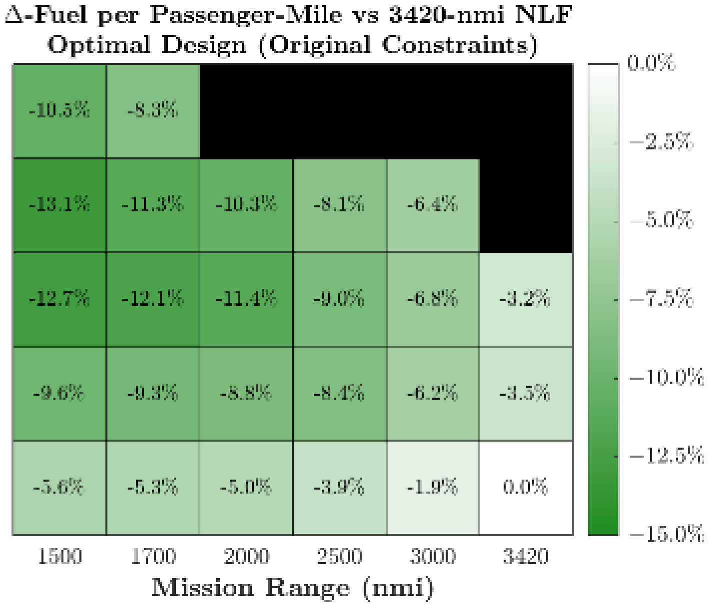
- Check if a feasible design in design space exists satisfying all constraints

Range\Pax	150	175	200	225	250
1500 nmi					
1700 nmi					
2000 nmi					
2500 nmi					
3000 nmi					
3420 nmi					

- Limiting constraints:
  - Span ≤ 118 ft (ADG III): Severely limiting
  - Fan diameter ≤ 86.04 ft: Limiting
  - Takeoff field length ≤ 7000 ft: Lightly limiting
  - Excess Fuel Capacity: Active, not limiting
- Propose relaxing span constraint by folded wingtip technology

Fuel Burn Reduction

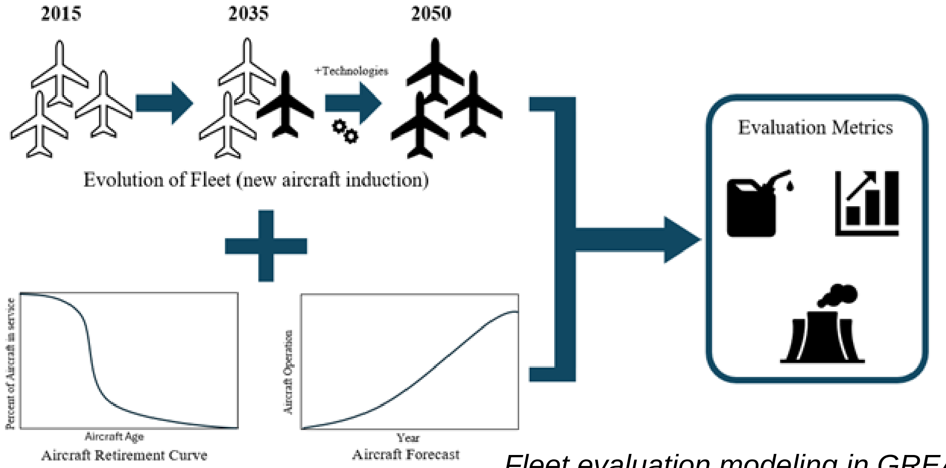




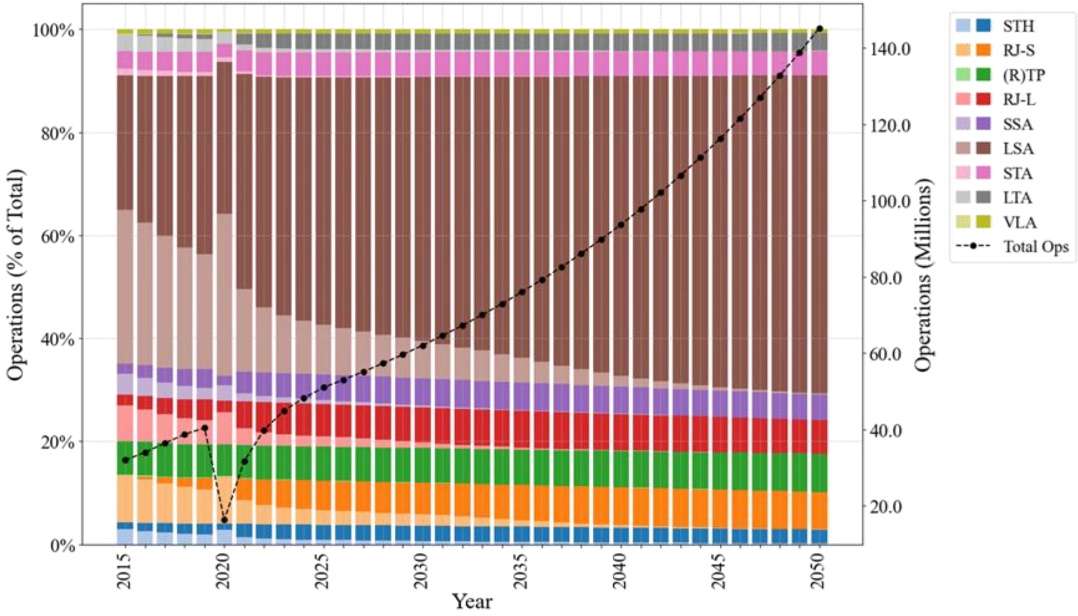
- Sizing for lower range reduces fuel burn but fuel saving per nmi design range reduction diminishes with decreased design range
- Optimal design payload for fuel burn decreases from 225 pax to 175 pax as design range increases

Fleet-Level Assessment

- Motivation: Reduced design range compromise aircraft operational capability while increased payload decreases number of flights to meet travel demand
- GREAT: Global and Regional Environmental Aviation Trade-off
  - In-house fleet analysis capability, applied in other projects
  - Demand forecast: Boeing Commercial Market Outlook (CMO)



Fleet evaluation modeling in GREAT



Seat class	No. of seats	Example aircraft
Short Thin Haul (STH)	1 – 20	B1900D, DO-228
Regional Jet-Small (RJ-S)	20 – 50	CRJ-200, E145
Turboprop (TP)	50 – 100	Dash 8, ATR 72
Regional Jet-Large (RJ-L)	50 – 100	CRJ-700, E170-E2
Small Single Aisle (SSA)	100 – 150	A319, B737-7
Large Single Aisle (LSA)	150 – 210	A320, A321, B737-8/9
Small Twin Aisle (STA)	210 – 300	B767, B787-8/9
Large Twin Aisle (LTA)	300 – 400	A350-900, B777-300ER
Very Large Aircraft (VLA)	400+	B747-8, B777X, A380

Fleet Analysis Scenarios

Baseline Scenario: Business as Usual

- No progress in technology, state-of-the-art LSA (i.e., TRA A320neo model) keeps producing and replaces retired aircraft

Replacement Scenarios: 26 scenarios in total

- ATWs start to replace large single-aisle aircraft fleet at 2035
- Long-range missions that are above cutoff design range are assumed continuously operated by TRA A320neo
- Increased design payload for less operations required for same flight demand:
  - Option 1: Operations scaled down proportional with design payload increase:

$$N_{\text{new},1} = \frac{150}{Pax} \cdot N_{\text{original}}$$

  - Option 2: Add penalty factor p for conditions where aircraft not fully loaded

$$N_{\text{new},2} = N_{\text{new},1} \cdot [1 + p \cdot (1 - \frac{150}{Pax})]$$

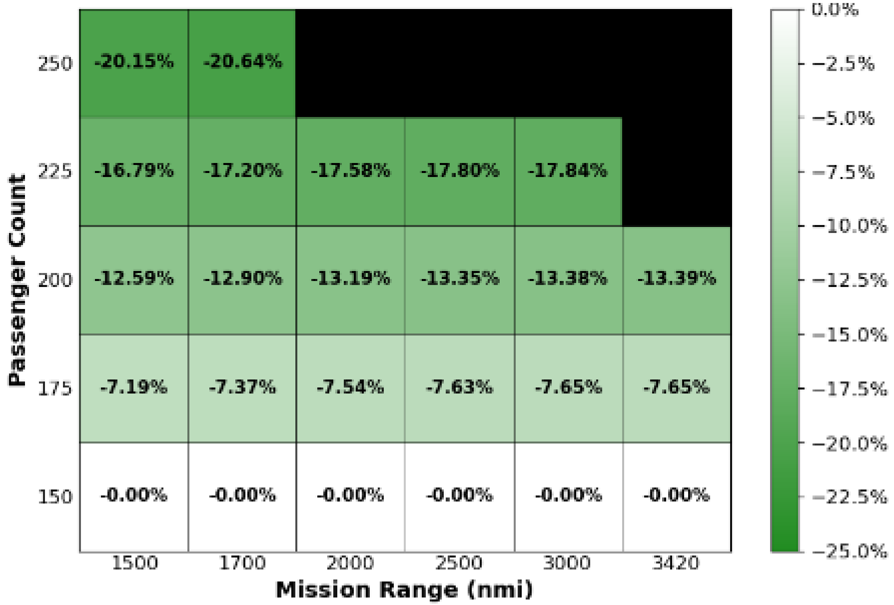
Scenario	Aircraft	Design Payload	Cutoff range
1	Business as usual		
2	ATW 1	250 pax	1500 nmi
……			
6	ATW 5	150 pax	1500 nmi
7	ATW 6	250 pax	1700 nmi
……			
11	ATW 10	150 pax	1700 nmi
12	ATW 11	225 pax	2000 nmi
……			
15	ATW 14	150 pax	2000 nmi
16	ATW 15	225 pax	2500 nmi
……			
19	ATW 18	150 pax	2500 nmi
20	ATW 19	225 pax	3000 nmi
……			
23	ATW 22	150 pax	3000 nmi
24	ATW 23	200 pax	Default range
25	ATW 24	175 pax	Default range
26	ATW 25	150 pax	Default range

ATW: Advanced Tube and Wing

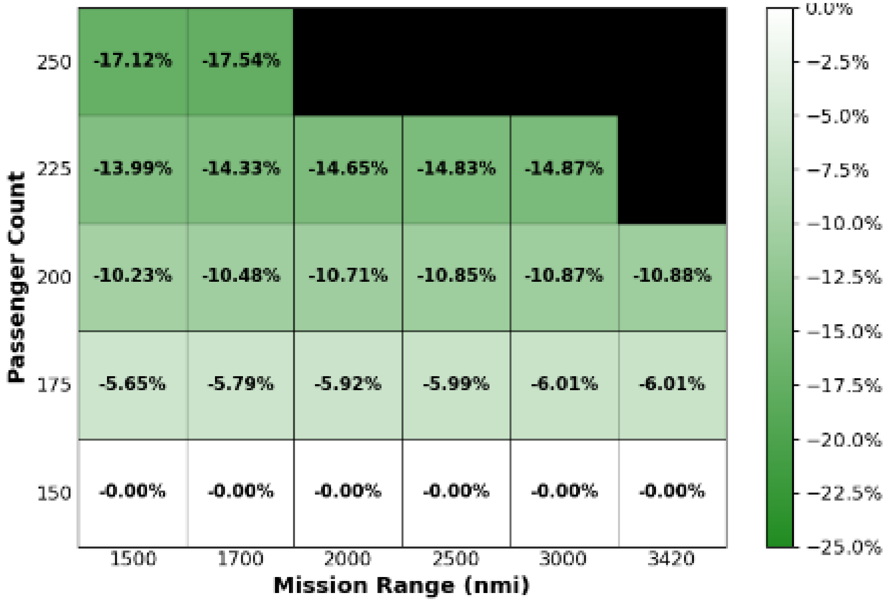
Fleet Analysis Results - Operations

- Change in LSA flight operations in 2050 assuming increased-payload and shorter-range vehicles replacing LSA fleet aircraft starting from 2035:

Operations reversely scaled down with design payload $p = 0$



With penalty factor $p = 0.25$ applied to operations



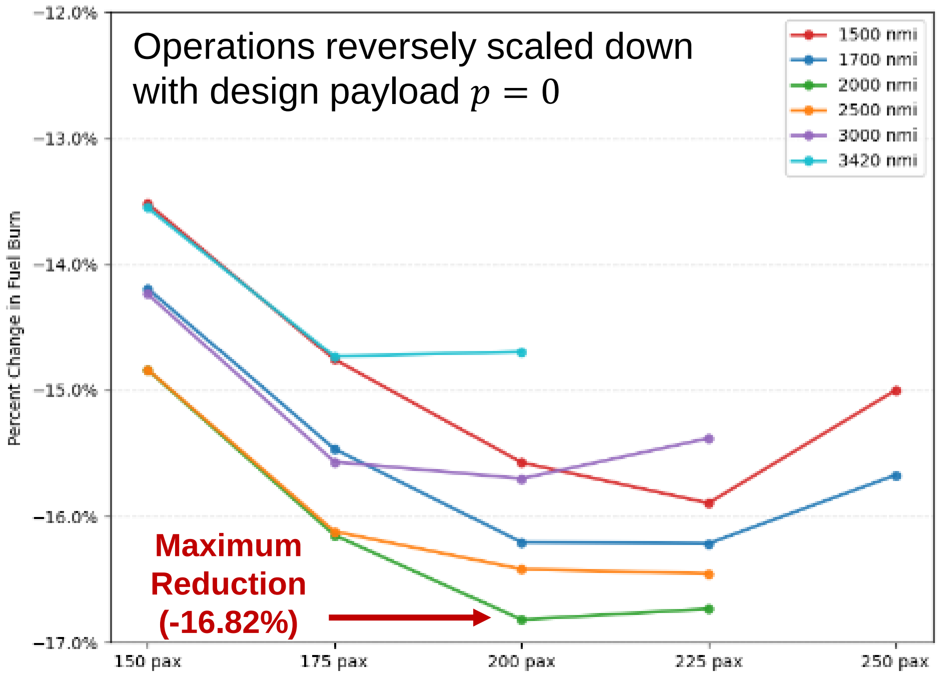
LSA operation coverage

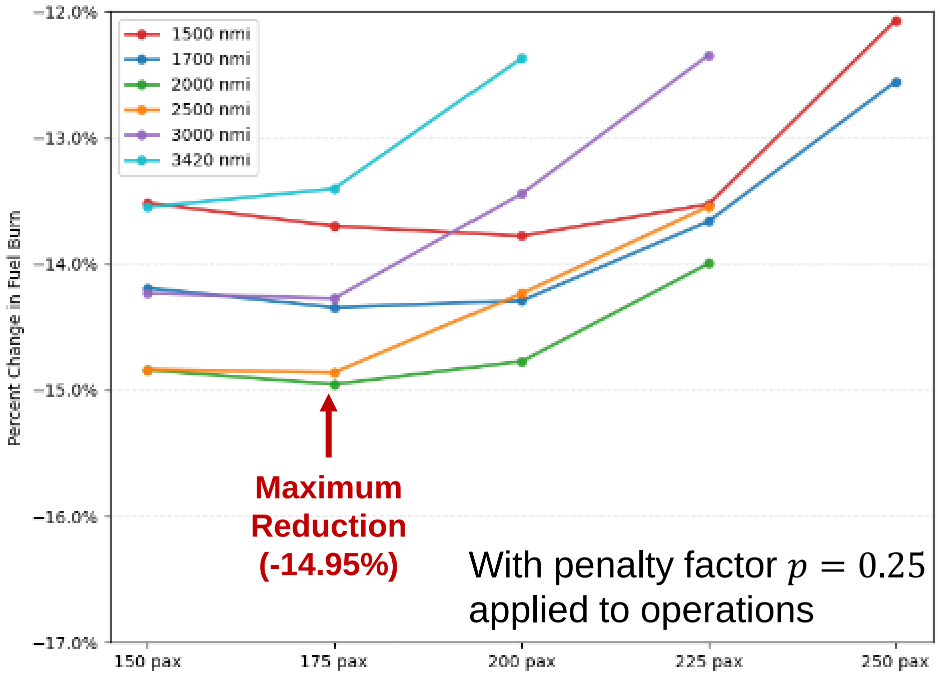
Cutoff Range	Operations
3420 nmi	100%
3000 nmi	99.959%
2500 nmi	99.722%
2000 nmi	98.509%
1700 nmi	96.353%
1500 nmi	94.059%

- Increased passenger capacity requires less flight operations to satisfy same level of transportation demand
- Less reduction in the number of operations if design range is reduced
  - Long-range missions need to be continuously operated by TRA A320neo

Fleet Analysis Results – Fuel Burn

- LSA fleet accumulative fuel burn reduction in 2050 assuming increased-payload and shorter-range vehicles replacing LSA fleet aircraft starting from 2035:





LSA operation coverage

Cutoff Range	Operations
3420 nmi	100%
3000 nmi	99.959%
2500 nmi	99.722%
2000 nmi	98.509%
1700 nmi	96.353%
1500 nmi	94.059%

- For same passenger capacity, maximum fuel burn reduction generally occurs at a reduced design range of 2000 nmi
- Optimal design passenger capacity for fleet burn burn reduction increases as design range decreases
  - Optimal point is sensitive to penalty factor applied

Observations and Next Steps

- Summary of findings
  - Thrust polynomial model in AEDT is sensitive to the transition from maximum takeoff thrust to max continuous thrust rating
  - Reducing cruise Mach number from 0.78 to 0.71 for single-aisle aircraft with NLF applied decreases fuel burn by about 7%
  - Sizing for lower range reduces fuel burn but fuel saving per nmi design range reduction diminishes with decreased design range
  - Optimal design payload and design range for LSA fleet fuel burn reduction are around 200 pax and 2000 nmi, respectively

- Next steps
  - Finish Advanced Concept Aircraft tests and perform fleet analysis in AEDT
  - Include small single-aisle aircraft replacement in fleet analysis
  - Evaluate sensitivity between fleet fuel burn reductions and penalty factor applied on operations