DLR-F25 V5
RESEARCH BASELINE

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DLR - German Aerospace Center

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*Wöhler et. al:., ESTABLISHING THE DLR-F25 AS A RESEARCH BASELINE AIRCRAFT FOR THE SHORT-MEDIUM RANGE MARKET IN 2035, *34th Congress of the International Council of the Aeronautical Sciences 2024*, Florence, Italy

DLR-F25 Research Baseline
Need for a common research baseline

Status Quo

- Different European, German national funded and DLR internal research projects addressing a similar market but different aircraft concepts, individual technologies and alternative energy carriers

Challenge

- Comparison and benchmarking against a meaningful conventional aircraft configuration to identify the advantages and disadvantages of each technology, aircraft concept, or energy carrier.

Objective

- Establishment of a common research baseline for an evolutionary conventional aircraft design approach as a common point of comparison

CLEAN AVIATION

Federal Ministry for Economic Affairs and Climate Action

DLR

DLR-F25 Research Baseline
Aircraft Design Process

- Selection of the Airbus A321neo as a suitable reference aircraft to represent the short medium range market
- Design and calibration of the D239 based on public available data of the Airbus A321neo
- Redesign based on 2035 technology assumptions and the wing planform derived in the VIRENFREI LuFo project
- Derivation of an advanced onboard-system architecture with respect to the wing design within the Clean Aviation ACAP Project
- Design of the 2035 engine including a bypass optimization study

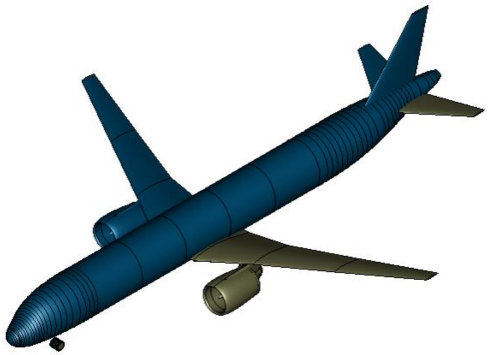
D239 and DLR-F25
Top Level Aircraft Requirements

D239
SMR representative aircraft
2020 technology

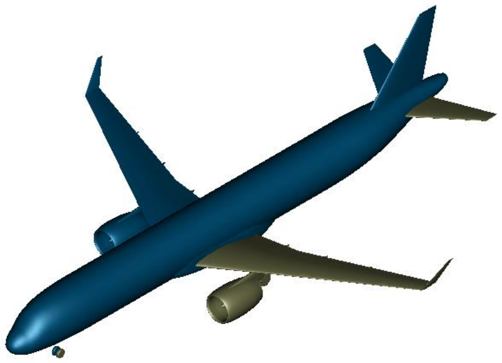
Design Range	[nm]	2500
Design PAX (single class)	[-]	239
Mass per PAX	[kg]	95
Design Payload	[kg]	25000
Max. Payload	[kg]	25000
Cruise Mach number	[-]	0.78
Max. operating Mach number	[-]	0.82
Max. operating altitude	[ft]	40000
TOFL (ISA +0K SL)	[m]	2200
Rate of Climb @ TOC	[ft/min]	>300
Approach Speed (CAS)	[kt]	136
Wing span gate limit	**[m]**	**<36**
Alternate Distance	[nm]	200
Holding Time	[min]	30
Contingency	[-]	3%

DLR-F25 Research Baseline
Reference Aircraft Calibration

- Update of the D239 reference aircraft based on the optimistic reference engine model
- Top down approach set by performance target: SFC L/D
- Modelling of winglets to better assess the high aspect ratio wing of the high aspect ratio wing configuration
- More detailed modelling of the belly fairing to better account for the larger belly fairing
- Clean up of smaller inconsistencies and in depth discussion on the detailed mission trajectory
- Engine design iteration based on aerodynamic adaptations and revised thrust requirements



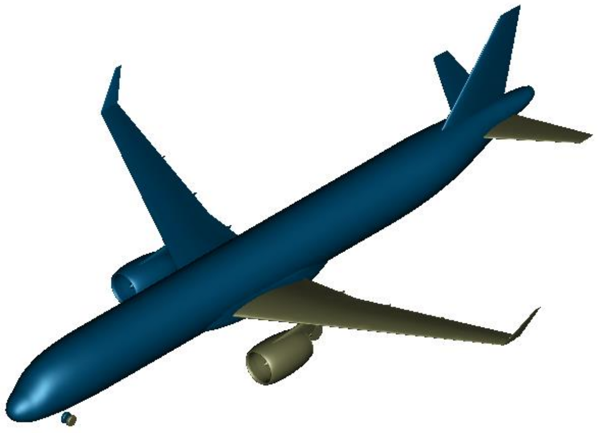
D239 v3
2020 technology



D239 v5
2020 technology

DLR-F25 Research Baseline
Update

- Reference aircraft D239 recalibration and redesign of the DLR-F25 based on feedback from the industry partners on engine performance



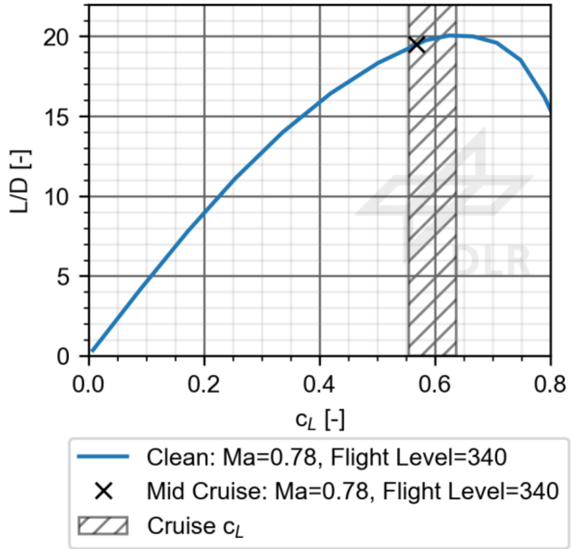
D239 v5

DLR-F25 v5

DLR-F25 Research Baseline

- Updated of the DLR-F25 based on reference aircraft calibration : SFC L/D

DLR-F25 v3:



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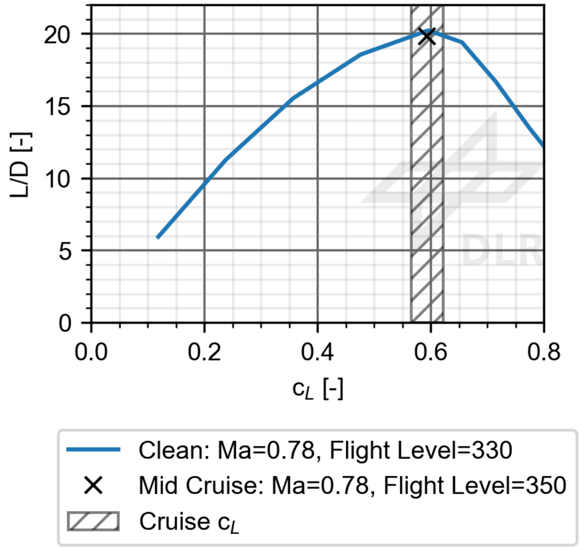

- Adaptation of the onboard system architecture based on TUHH input: 1st results integrated
- Engine redesign and sensitivities updated for design and evaluation mission

D239 → DLR-F25
Technology Assumptions for EIS 2035

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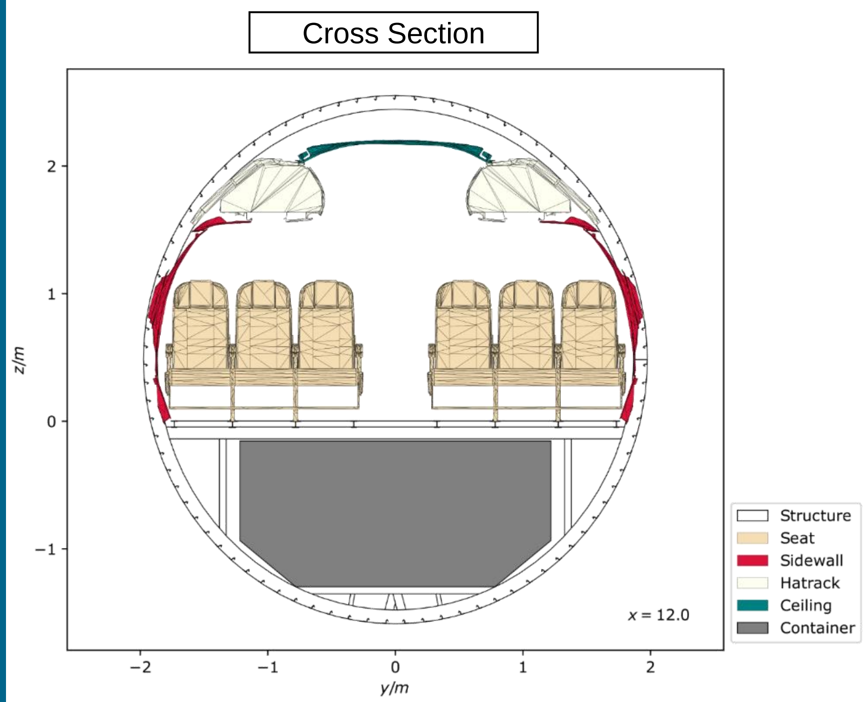
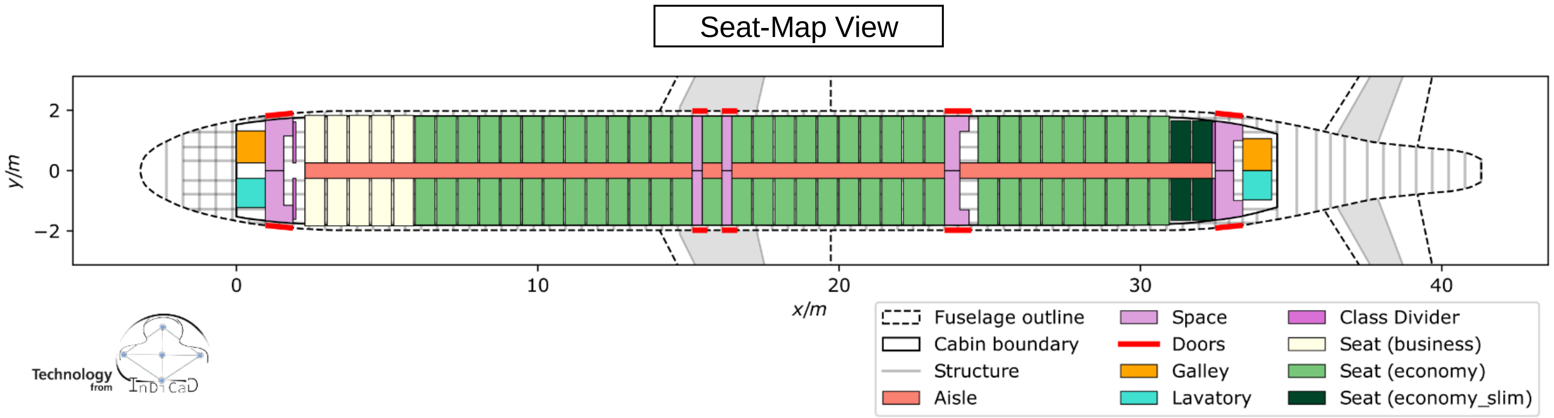
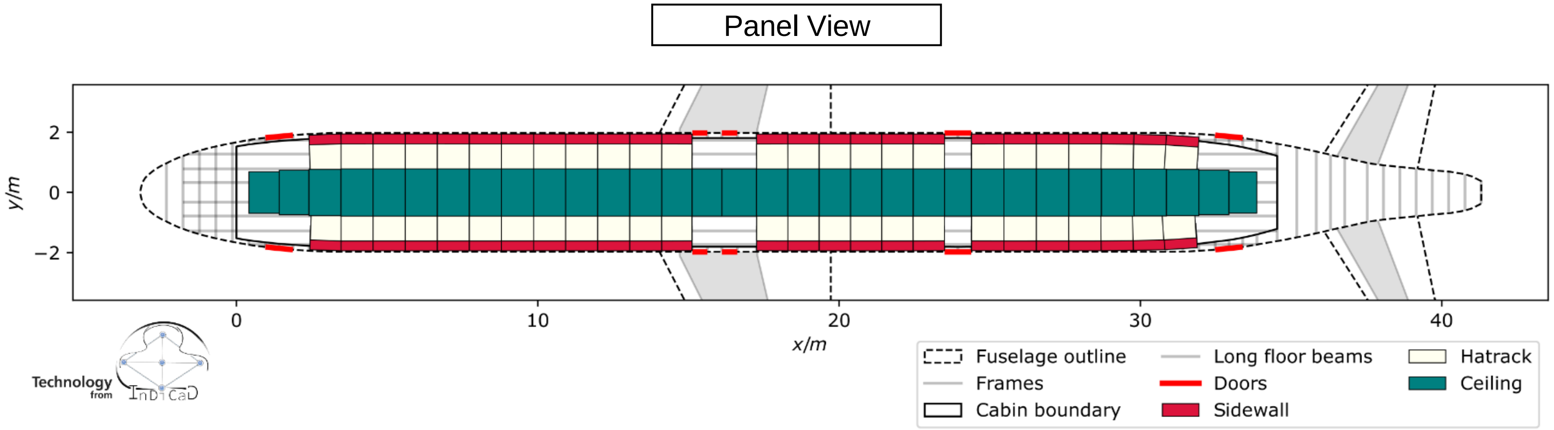
Technology	Assumption	Description
Gas Turbine Efficiency	+4%	Compared to PW1000, Bypass-ratio: 15, improved thermal efficiency.
Empennage Mass Factor	-3%	Compared to D239, New manufacturing and assembly methods.
Fuselage Mass Factor	-5%	Compared to D239, Advanced Al-alloys, manufacturing and assembly methods, revised production and certification requirements.
Wing Mass Factor	-30%	Compared to D239, Application of CFRP, advanced load alleviation, active flutter suppression, advanced drop hinge flaps and foldable wing tips
System Mass Factor	-5%	Compared to D239, Onboard system architecture based on design by TUHH
Furnishing Mass Factor	ISO	Potential mass reductions are mitigated by new requirements and certification rules as well as additional modularity, manufacturability and increased complexity.
Operator Items Mass Factor	ISO	

DLR-F25 and D239
Cabin Layout

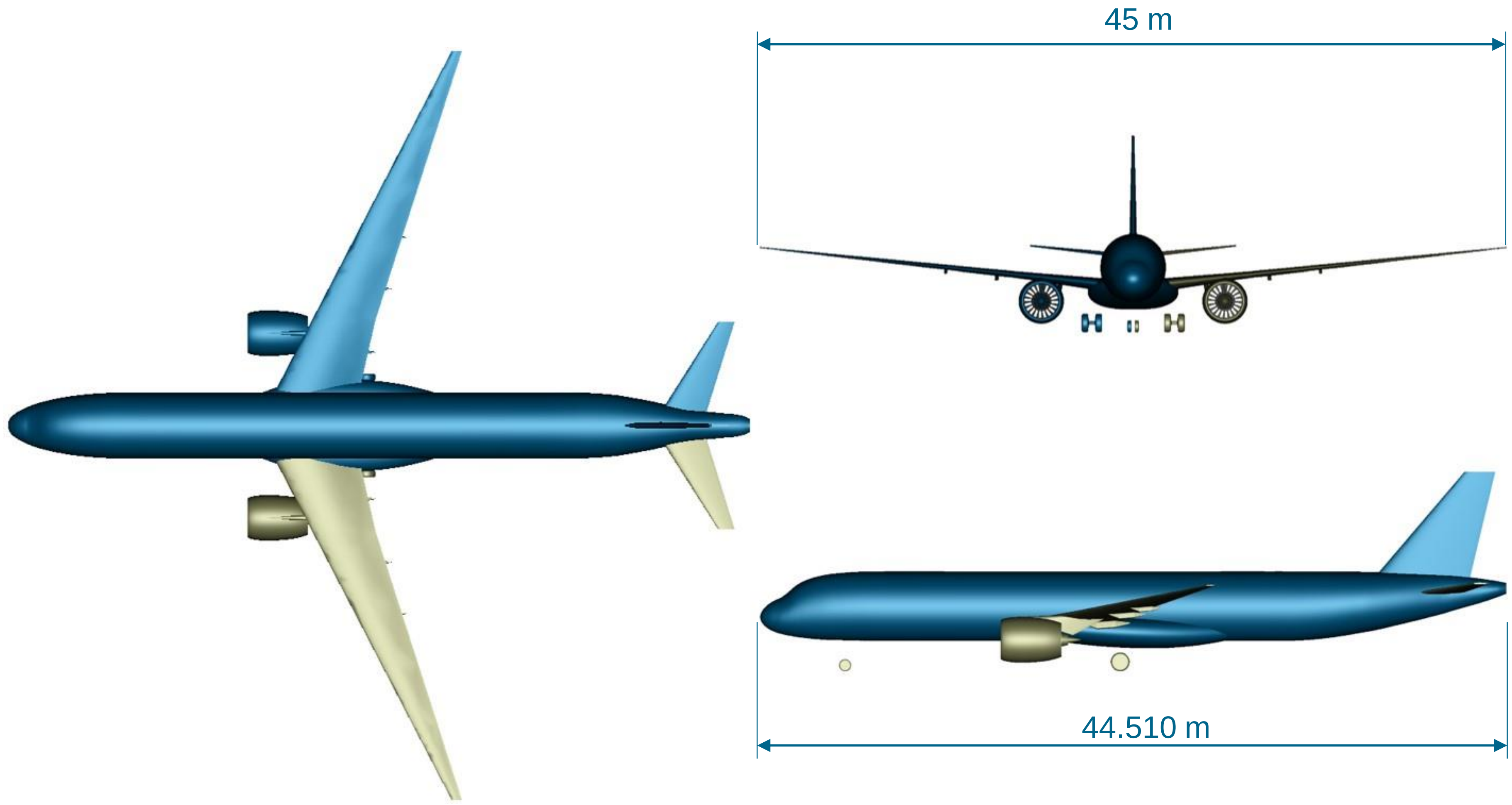




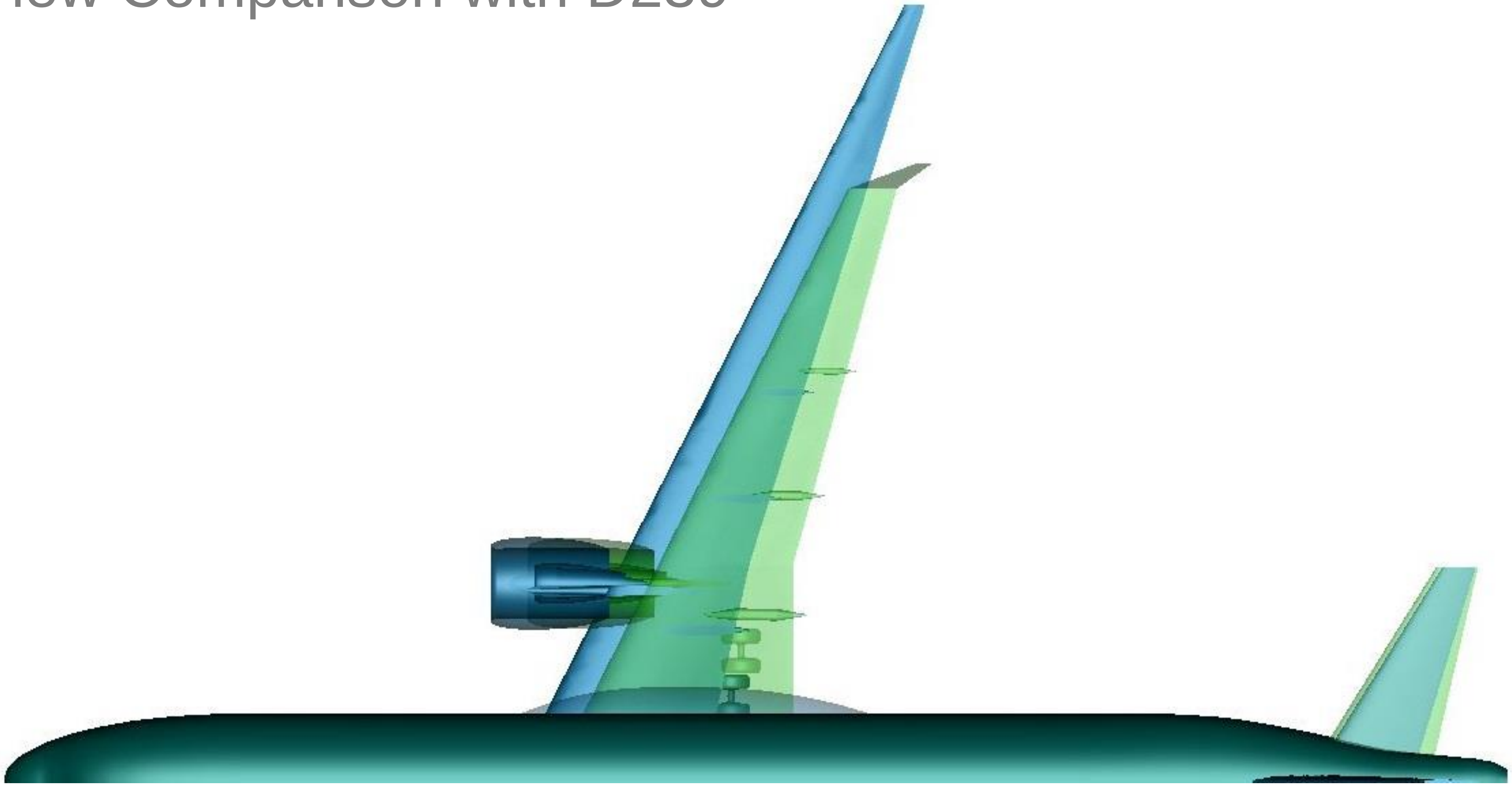


Constant fuselage geometry while resizing of internal primary and secondary structure

DLR-F25 Research Baseline
General Arrangement

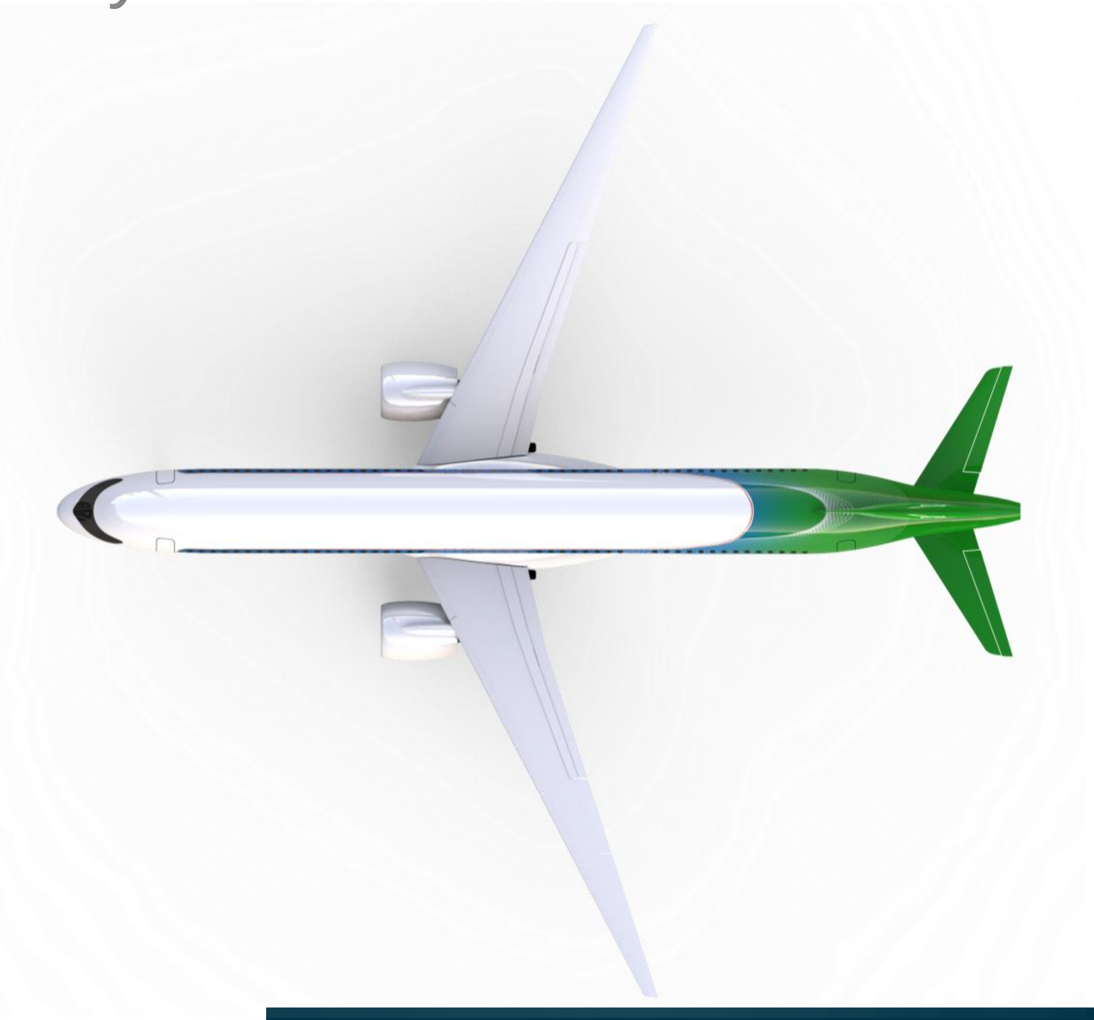


DLR-F25 Research Baseline
Top-View Comparison with D239



Wing mounted landing gear is not feasible with respect to the location of the center of gravity and the wing attachment point

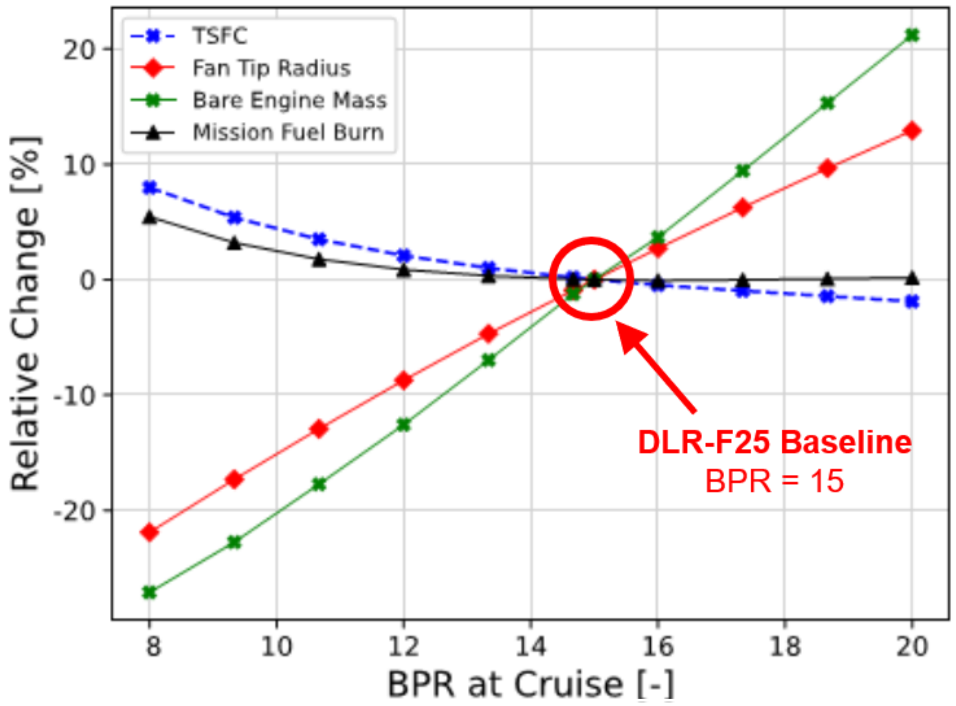
DLR-F25 Research Baseline
Key Characteristics

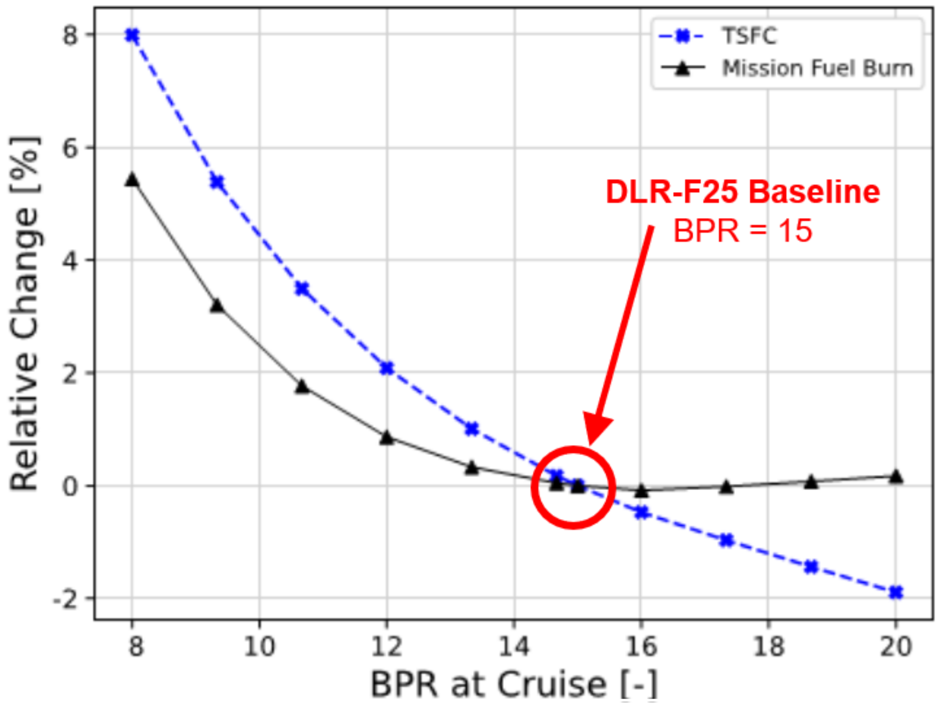


DLR-F25			
Key Sizing Parameters		F25_v3	F25_v5
W/S=MTOW/Sref	[kg/m2]	660	658.6
T/W=SLST/MTOW	[-]	0.283	0.296
Masses			
MTOM	[t]	86.0	85.7
MLM	[t]	74.8	74.2
MZFM	[t]	72.0	71.3
OEM	[t]	47.0	46.3
MFW	[t]	16.7	16.7
Block Fuel (Design Range)	[t]	11.6	12.1
Block Fuel (Evaluation Range)	[t]	4.0	4.1
Geometry			
Wing Span	[m]	45	45
Wing Aspect Ratio	[-]	15.6	15.6
Wing MAC	[m]	3.54	3.54
Wing Ref. Area	[m2]	130	130.1
Propulsion			
Equivalent static thrust (Sea-level/ISA)	[kN]	114	124.4
TSFC avg. cruise (800nm)	[kg/s/kN]	0.0135	0.0143
Aerodynamic			
cL cruise (800nm)	[-]	0.589	0.593
L/D cruise average (800nm)	[-]	19.6	19.5
cL max TO	[-]	2.3	2.3
cL max LDG	[-]	2.845	2.845

The DLR-F25 achieves a 18% block fuel reduction compared to the D239 2020 reference aircraft on the evaluation mission of 800nm

DLR-F25 Research Baseline
Engine Bypass Optimization





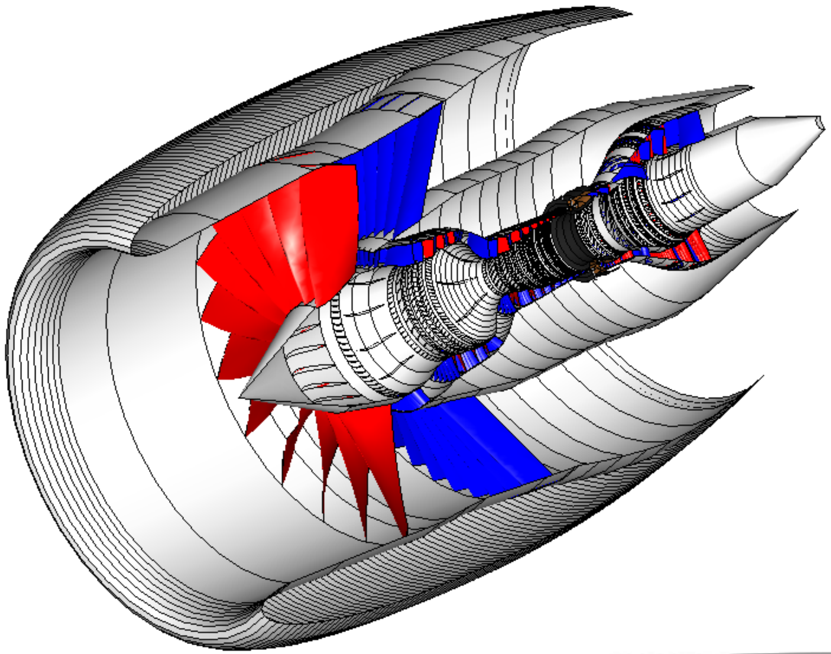
Sensitivities on design mission (2500nm):

FB: Fuel Burn
M: Bare Engine Mass
dc: drag counts
TSFC: Thrust Specific Fuel Consumption

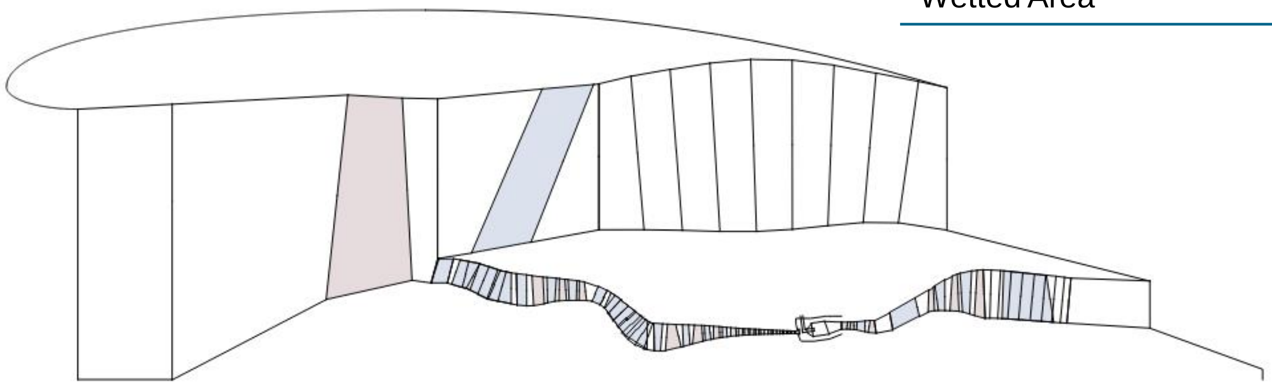
$$\frac{\partial FB}{\partial TSFC} = 1.33 \left[\frac{\%}{\%}\right] \qquad \frac{\partial FB}{\partial M} = 2.04 \left[\frac{\%}{t}\right] \qquad \frac{\partial FB}{\partial dc} = 3.31 \left[\frac{\%}{10dc}\right]$$

Selection of an bypass ratio of 15 for the final engine design

DLR-F25 Research Baseline
Engine Characteristics

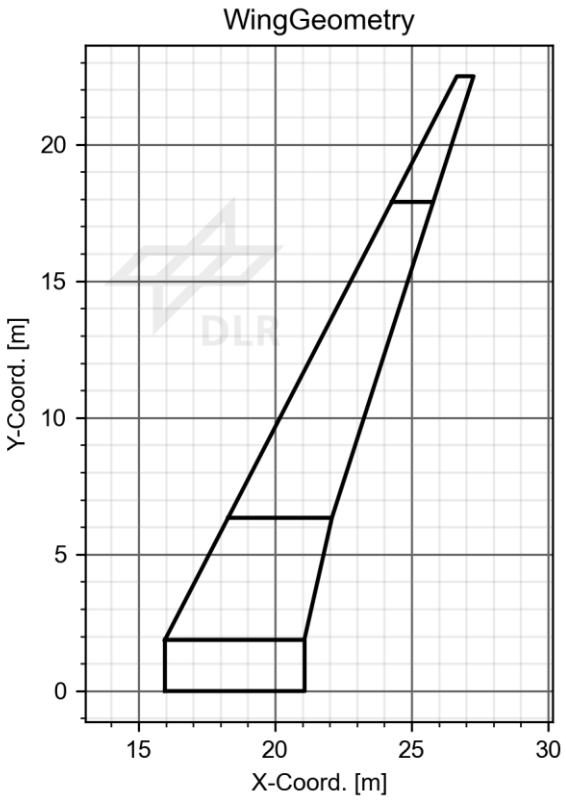


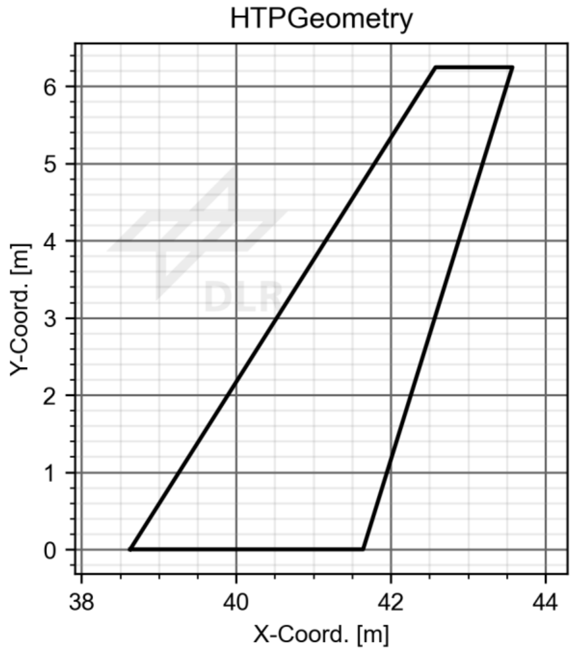
Parameter	Unit	Value
Engine GTF		
Fan radius	[m]	1.04
Mass Gasturbine	[kg]	2580
Bypass-Ratio	[-]	15
OPR	[-]	41.1
Equivalent static thrust (Sea-level/ISA)	[kN]	124.7
Nacelle		
Length	[m]	3.62
Diameter	[m]	2.73
Wetted Area	[m2]	27.98

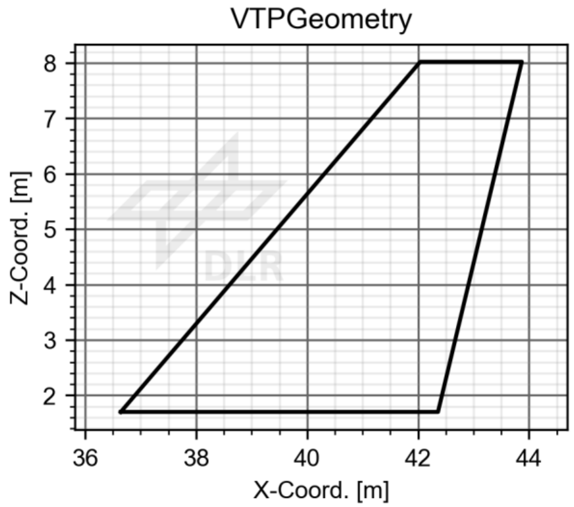


DLR-F25 Research Baseline
Lifting Surface Geometry Overview

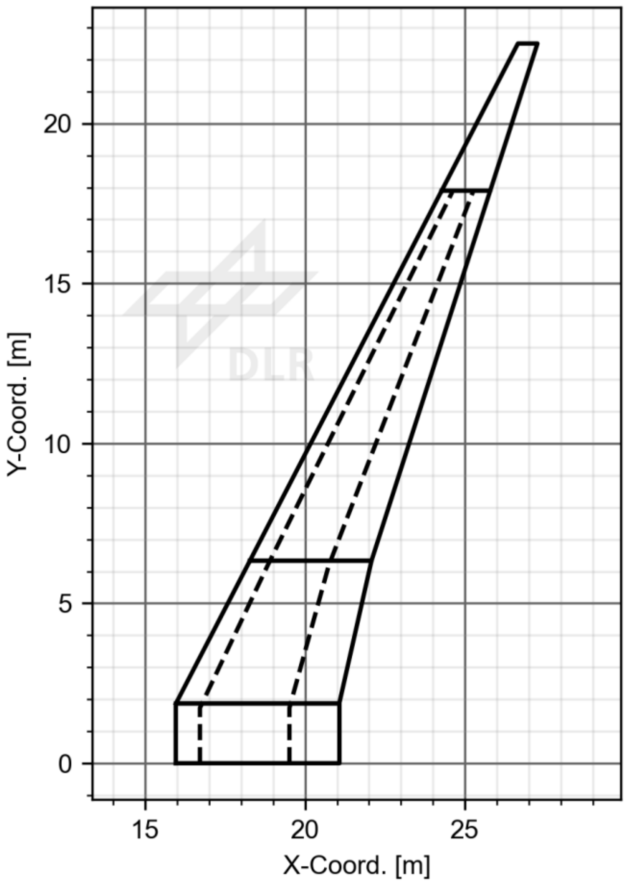
Parameter	Unit	Wing	HTP	VTP
Reference Area	m^2	130.09	24.88	23.85
Span	m	45.00	12.42	6.32
Aspect Ratio	-	15.57	6.20	1.68
Taper Ratio	-	0.12	0.33	0.32
Mean Aerodynamic Chord	m	3.54	2.17	4.11
Avg. 1/4 Chord Sweep	deg	25.04	28.85	35.00
Avg. Dihedral	deg	7.15	6.00	-
Lever Arm	m	-	20.61	19.71
Volume Coefficient	-	-	1.1150	0.0803





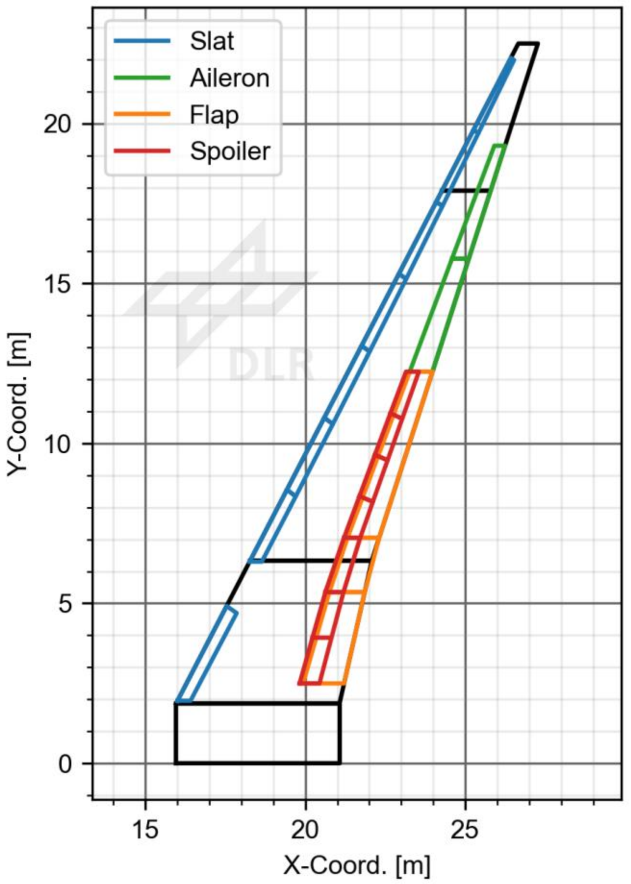


DLR-F25 Research Baseline
Wing Box Geometry Overview



Wing Section	Unit	Center	Root	Kink	Mid	Tip
Position	m	0.00	1.87	6.33	17.90	22.50
Rel. Position	%	0.00	8.30	28.15	79.56	100.00
Chord	m	5.10	5.10	3.80	1.52	0.61
1/4 Chord Sweep	deg	0.00	0.00	24.02	25.13	25.13
LE Sweep	deg	0.00	0.00	27.40	27.40	27.40
TE Sweep	deg	0.00	0.00	12.80	17.80	17.80
Dihedral	deg	0.00	0.00	8.30	6.40	6.40
Twist Angle	deg	3.00	3.00	1.50	0.78	-1.00
Thickness Ratio	%	15.30	15.30	11.60	11.00	11.00
Rel. Spar Position						
Front Spar	%	14.70	14.70	16.40	23.10	27.10
Rear Spar	%	69.50	69.50	66.10	65.40	61.90

DLR-F25 Research Baseline
Wing Movable Arrangement Overview

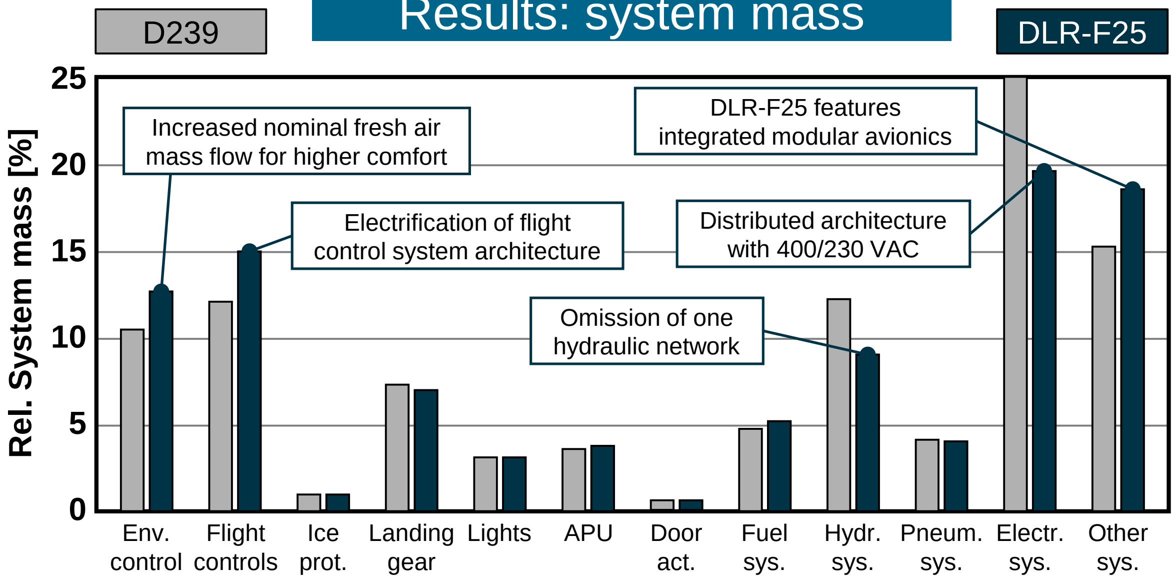


Control Surface	y Inboard	y Outboard	Chord Inboard	Chord Outboard
Slat1	1.954	4.915	0.41	0.42
Slat2	6.302	8.552	0.38	0.38
Slat3	8.552	10.801	0.38	0.37
Slat4	10.801	13.051	0.37	0.34
Slat5	13.051	15.301	0.34	0.31
DroopNose1	15.301	17.551	0.31	0.26
DroopNose2	17.551	19.801	0.26	0.2
DroopNose3	19.801	22.051	0.2	0.13
Flap1	2.495	5.351	1.28	1.1
Flaperon1	5.351	7.052	1.1	0.99
Flap2	7.052	12.241	0.99	0.71
Flaperon2	12.241	15.773	0.71	0.52
Flaperon3	15.773	19.305	0.52	0.33
Spoiler1	2.495	3.923	0.62	0.59
Spoiler2	3.923	5.351	0.59	0.56
FlaperonSpoiler	5.351	7.052	0.56	0.51
Spoiler3	7.052	8.349	0.51	0.48
Spoiler4	8.349	9.647	0.48	0.46
Spoiler5	9.647	10.944	0.46	0.43
Spoiler6	10.944	12.241	0.43	0.4

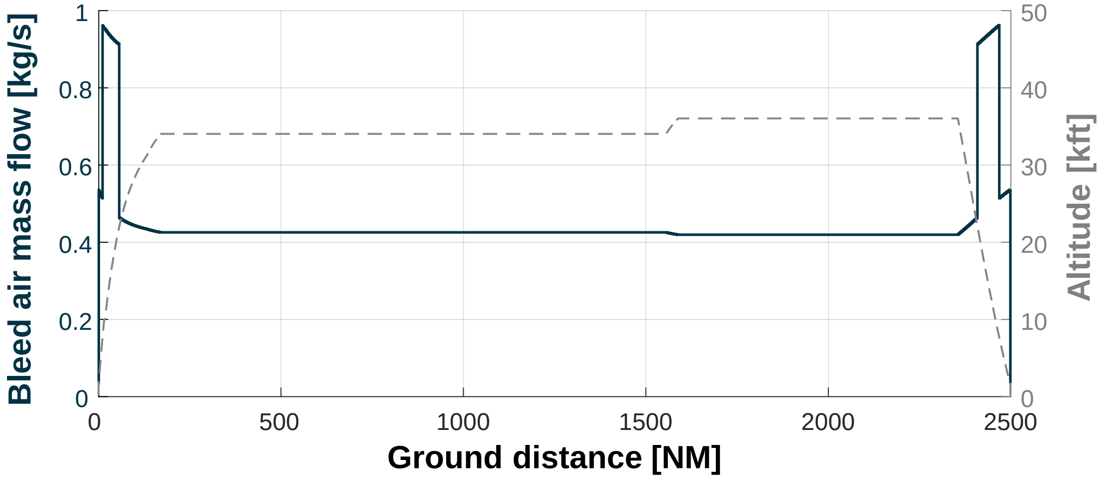
DLR-F25 Research Baseline
Onboard System Design

- Parametric physics-based sizing
- Mass scaling laws for components
- Quasi-static mission simulation for power consumption estimation

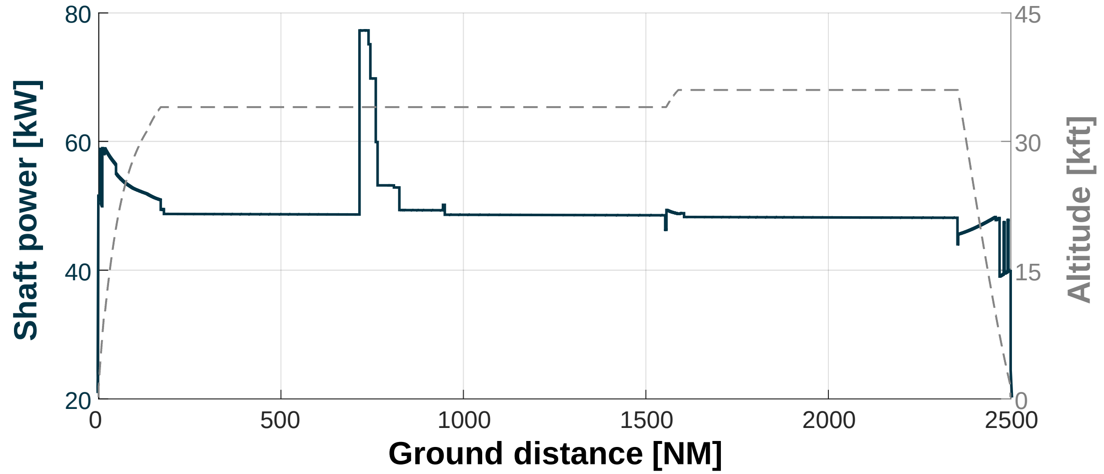
Results: system mass



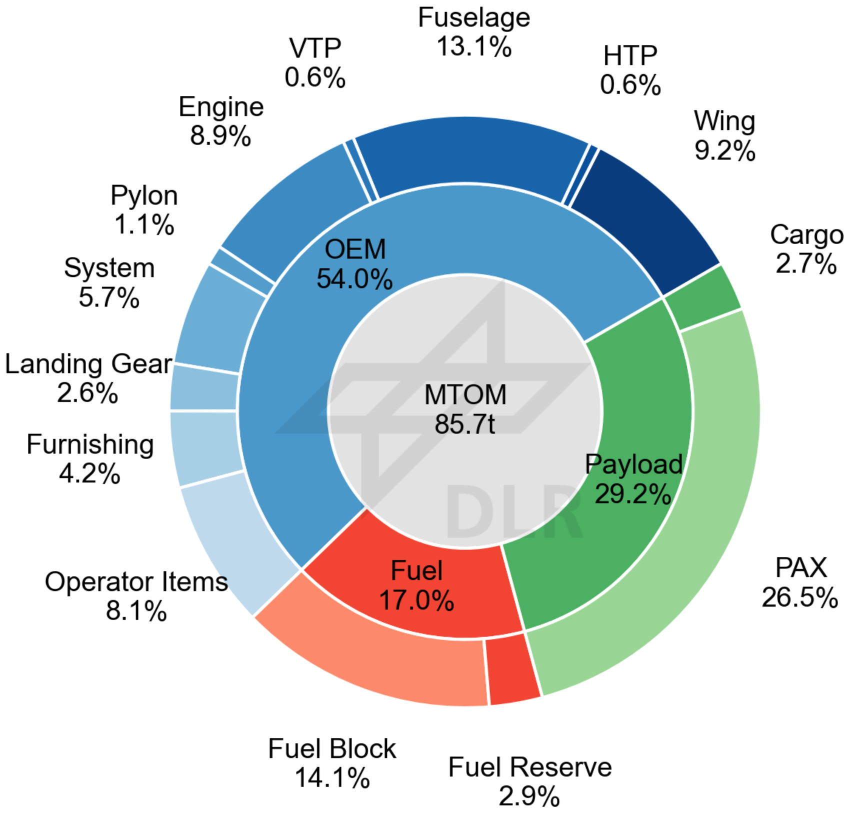
Results: bleed air demand



Results: shaft power off-take demand

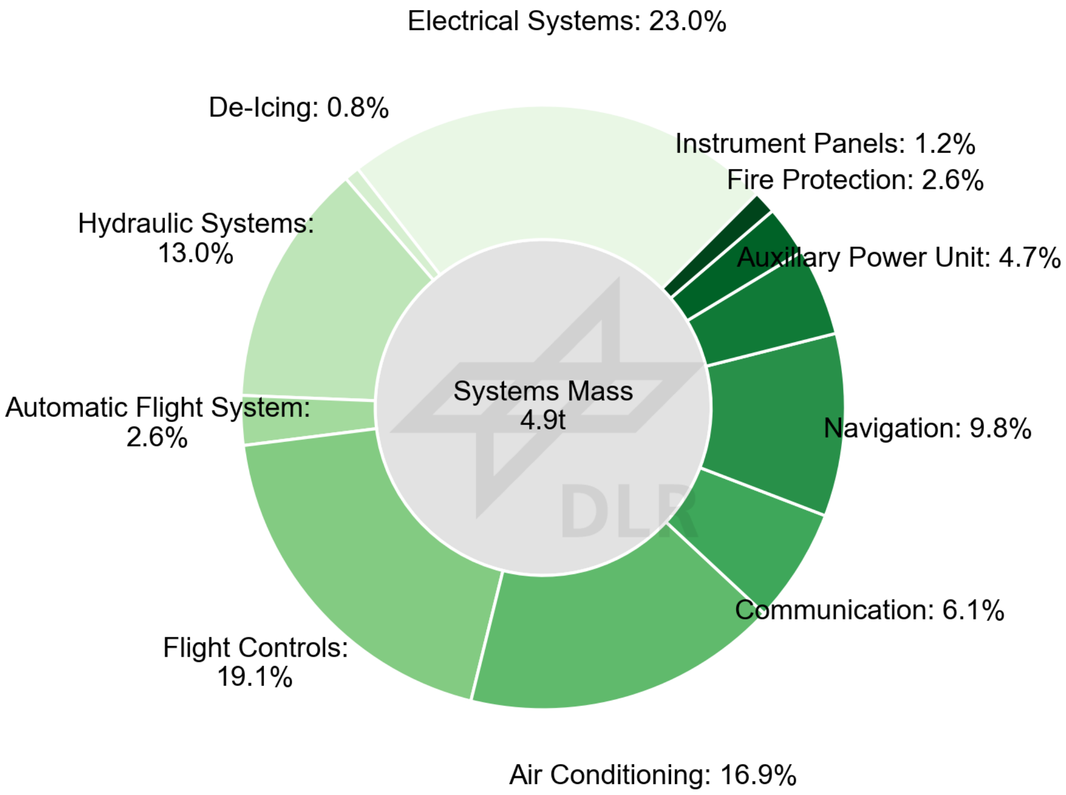


DLR-F25 Research Baseline
Mass Properties



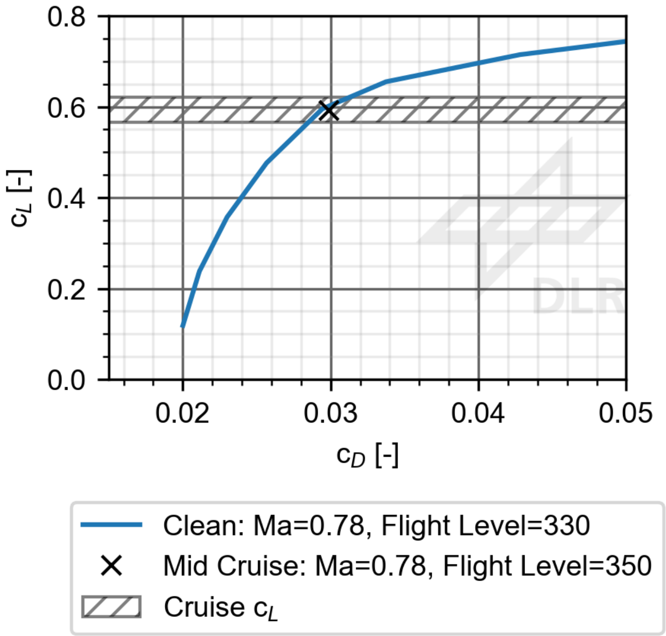
Component	Mass [kg]	x-Pos [m]
Wing	7866	21.08
Fuselage Structure	11261	20.03
HTP	480	41.06
VTP	498	41.11
Pylons	920	18.16
Power Units	7591	16.62
Main Gear	1842	21.48
Nose Gear	370	5.07
Systems	4910	15.8
Furnishings	3600	20.75
Manufacturer Empty Mass (MEM)	39337	-
Operating Items	6934	-
Operating Empty Mass (OEM)	46271	19.71
Maximum Payload	25000	20.75
Maximum Fuel	16725	19.02
Maximum Zero-Fuel Mass (MZFM)	71271	-
Maximum Landing Mass (MLM)	74170	-
Maximum Take-Off Mass (MTOM)	85688	19.94

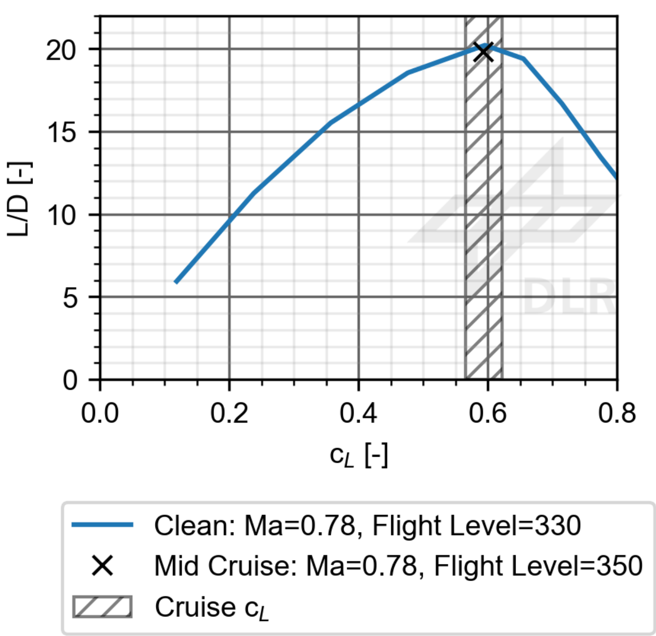
DLR-F25 Research Baseline
System Mass Breakdown



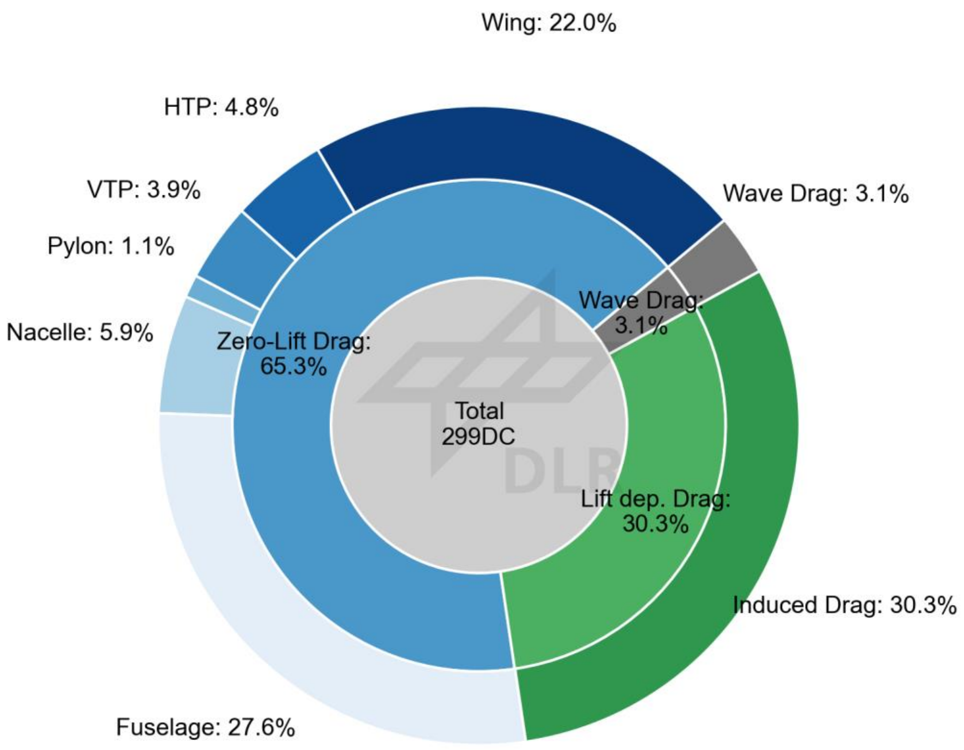
Component	Mass [kg]	Portion [%]
Air Conditioning	830	16.9
Auxiliary Power Unit (APU)	230	4.7
Automatic Flight System	130	2.6
Communication System	300	6.1
De-Icing	40	0.8
Electrical System	1130	23.0
Flight Controls	940	19.1
Fire Protection	130	2.6
Hydraulic System	640	13.0
Instrument Panels	60	1.2
Navigation	480	9.8
Miscellaneous	0	0.0
Systems	4910	100.0

DLR-F25 Research Baseline
Aerodynamic Performance





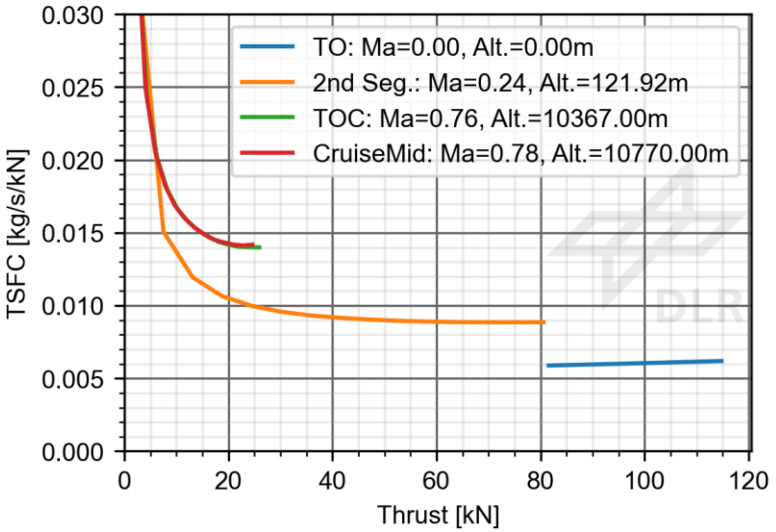
DLR-F25 Research Baseline
Mid-Cruise Aerodynamic Drag Breakdown (Ma=0.78, Flight Level350)



Parameter	Drag Breakdown [DC]	Relative [%]
Zero-Lift Drag	**195.4**	**65.3**
Wing	65.8	22.0
HTP	14.4	4.8
VTP	11.7	3.9
Fuselage	82.5	27.6
Pylon	3.4	1.1
Nacelle	17.7	5.9
Lift dep. Drag	**90.6**	**30.3**
Induced Drag	90.6	30.3
Wave Drag	**9.1**	**3.1**
Total Drag	**299.2**	**100.0**

DLR-F25 Research Baseline
Engine Performance Requirements

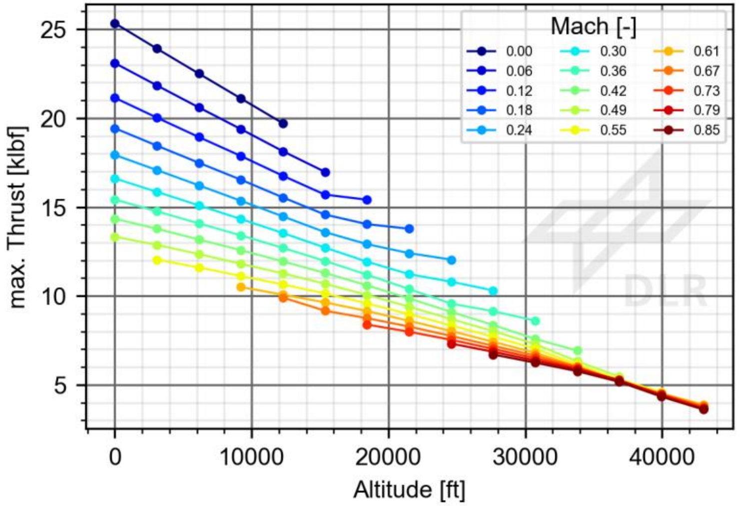
Parameter	Unit	Take-Off	EOF	2nd Seg.	TOC	Mid Cruise
Delta Temp. ISA	K	0.0	0.0	0.0	0.0	0.0
Mach-Number	-	0.0	0.23	0.24	0.76	0.78
Altitude	ft	0.0	35.0	400.0	35000	35000
Engine Rating	-	MTO	RTO	RTO	MCL	MCR
Thrust	N	124534.8	86872.0	77534.0	23026.0	19513.0
Shaft-Power Offtakes	kW	95.0	95.0	95.0	50.0	50.0
Bleed Air Offtakes	kg/s	0.0	0.0	0.0	0.425	0.425

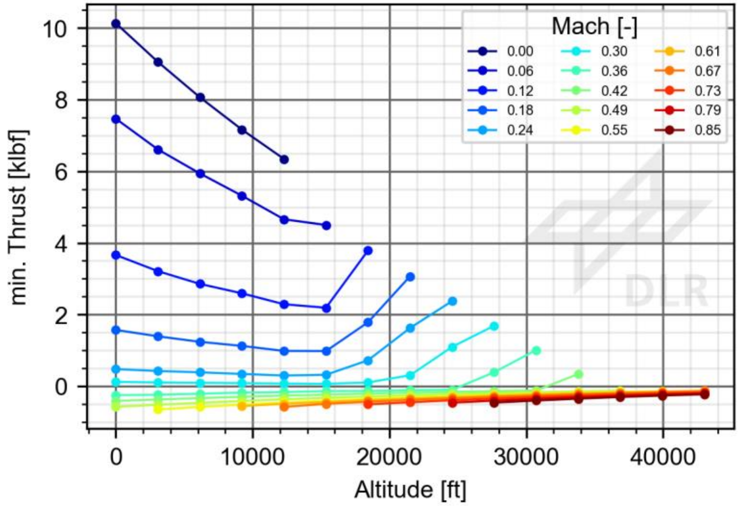


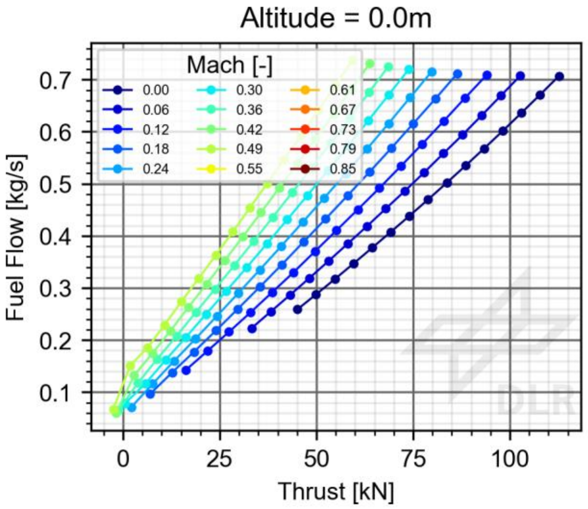
Description

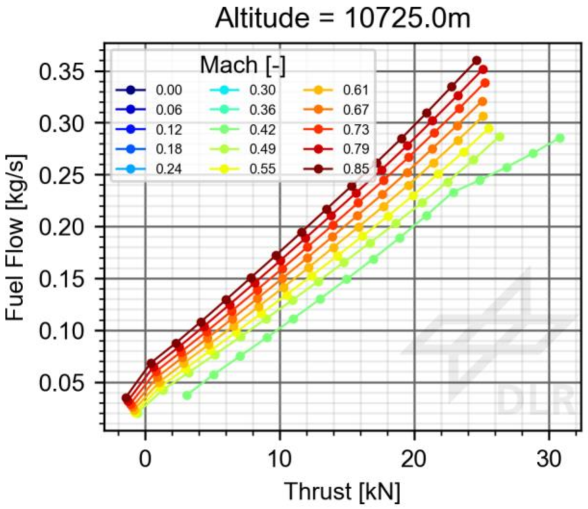
- Take-Off:
  - at MTOM
- EoF (CS25.121a)
  - at approx. MTOM
  - Landing gear extended, Without ground effect
  - Critical engine inoperative
  - Gradient of Climb > 0%
- 2nd Segment (CS25.121b):
  - at approx. MTOM
  - Landing gear retracted , Without ground effect
  - Critical engine inoperative
  - at V2 Speed
  - Gradient of Climb > 2.4%
- TOC:
  - ROC ≥ 300 ft/min
- Cruise:
  - typically not a thrust sizing point but rather a efficiency related point

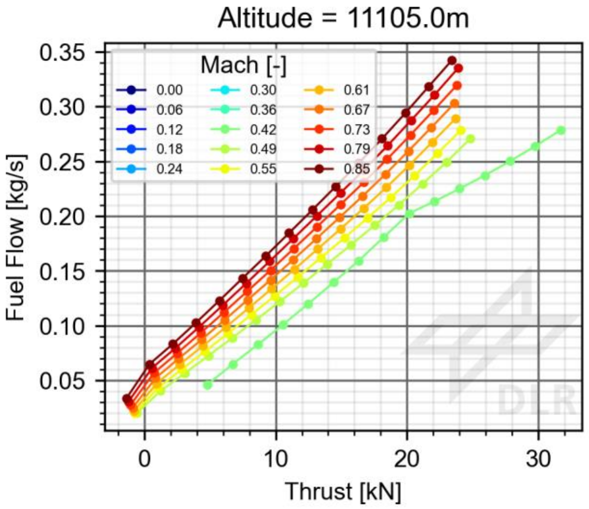
DLR-F25 Research Baseline
Engine Performance

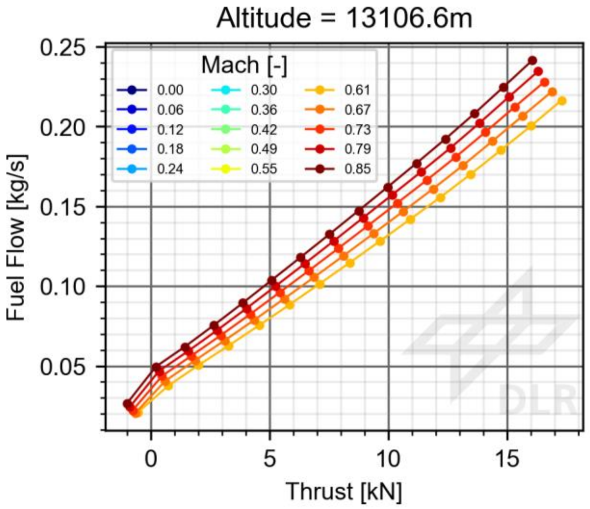








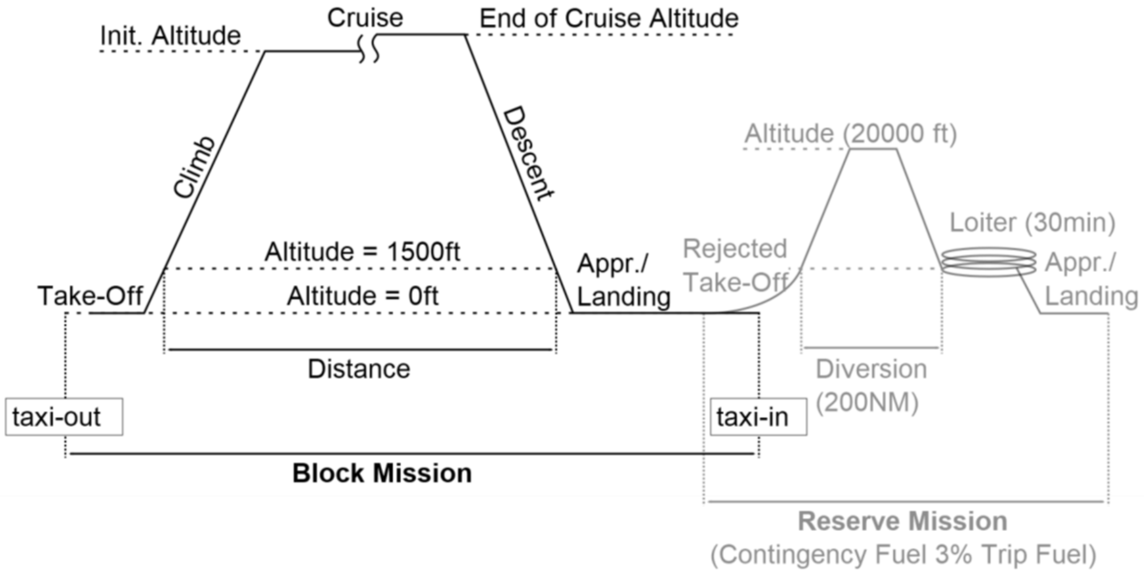




DLR-F25 Research Baseline

Mission Definition and Key Aircraft Characteristics

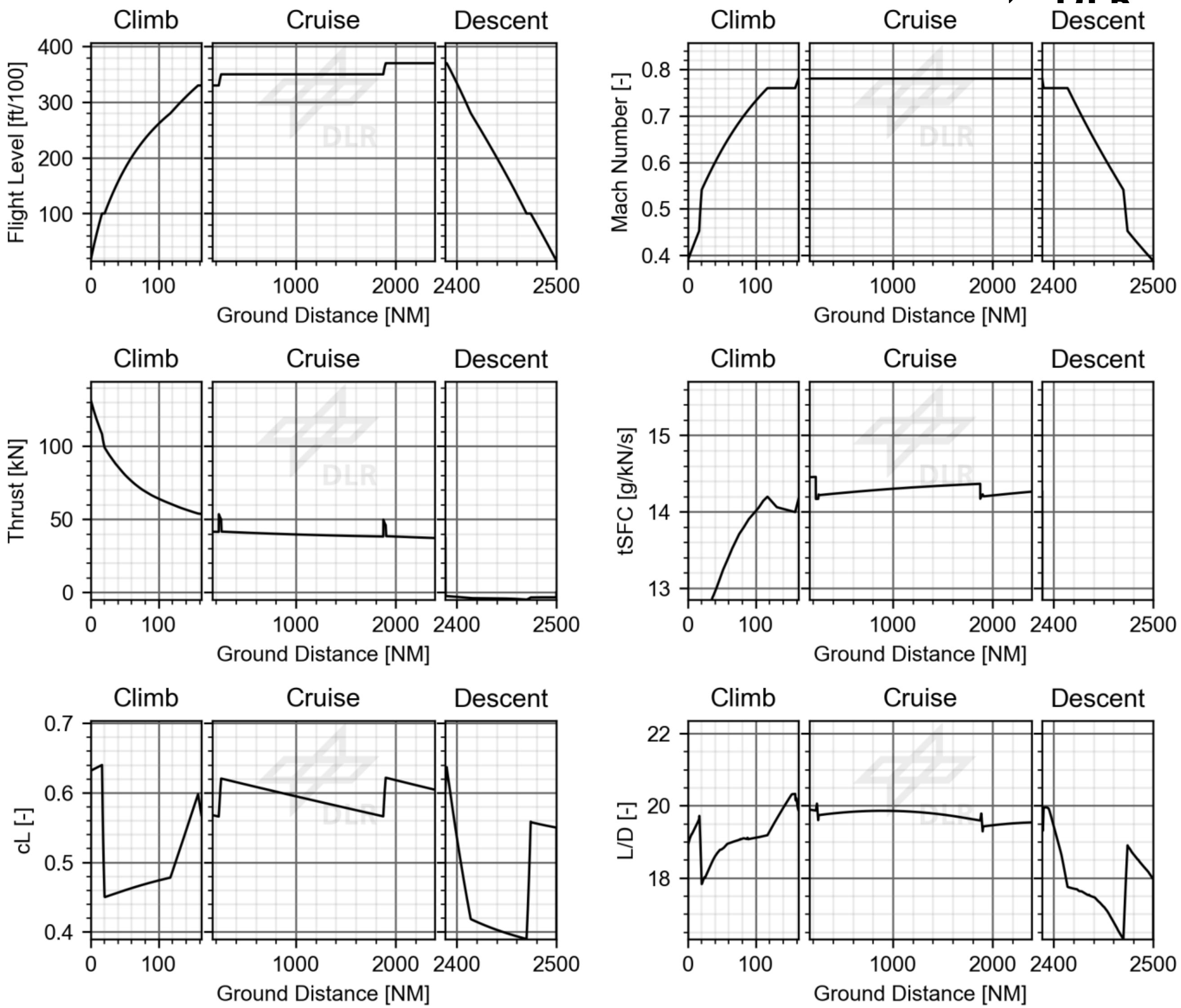
A design mission with a range of 2500NM and a number of passengers of 239PAX at 95 kg/PAX was defined according to DLR-F25_v5 specification. For this design mission, all performance data are calibrated i.e. engine and aerodynamic performances



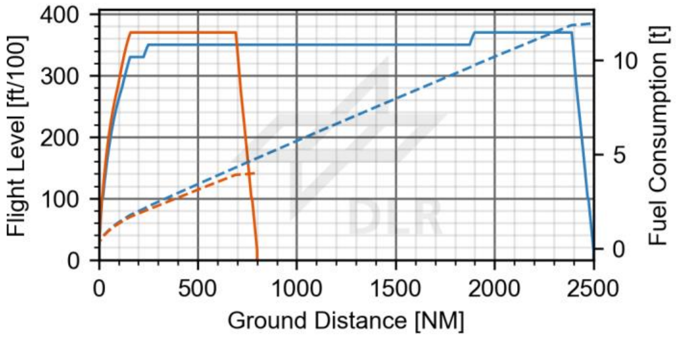
Parameter	Unit	Value
Design Range	NM	2500
Design Passenger Capacity	-	239
Design Cruise Mach Number	-	0.78
Max. Take-Off Mass	t	85.7
Max. Landing Mass	t	74.2
Max. Zero-Fuel Mass	t	71.3
Operating Empty Mass	t	46.3
Max. Fuel Mass	t	16.7
Max. Payload	t	25
Wing Area	m	130.1
Wing Span	m	45.0
Mean Aerodynamic Chord	m	3.5
Wing Loading (@MTOM)	kg/m^2	658.7
Thrust-to-Weight Ratio (@ISA)	-	0.296
Engine Type	-	Turbofan
Thrust (Sea Level Static, ISA)	kN	124.5

DLR-F25 Research Baseline
Design Mission Performance

Mission Phase	Flight Time [min]	Fuel Mass [kg]	Distance [NM]
Block Mission	**133.4**	**4118.5**	**800.0**
Taxi-Out	9.0	94.6	0.0
Take-Off	2.0	191.8	0.0
Climb	25.0	1424.3	166.7
Cruise	70.3	2195.5	524.2
Descent	18.1	100.9	109.2
Approach & Landing	4.0	68.8	0.0
(Taxi-In)	5.0	42.7	0.0
Reserve Mission	**105.8**	**3452.5**	**540.4**
Go-Around	1.6	77.7	0.0
Diversion Climb	28.6	1103.1	174.9
Diversion Cruise	10.4	330.4	67.7
Diversion Descent	31.6	910.6	188.4
Holding	30.0	843.6	109.4
Diversion Approach & Landing	3.6	67.7	0.0
Contingency	0.0	119.4	0.0



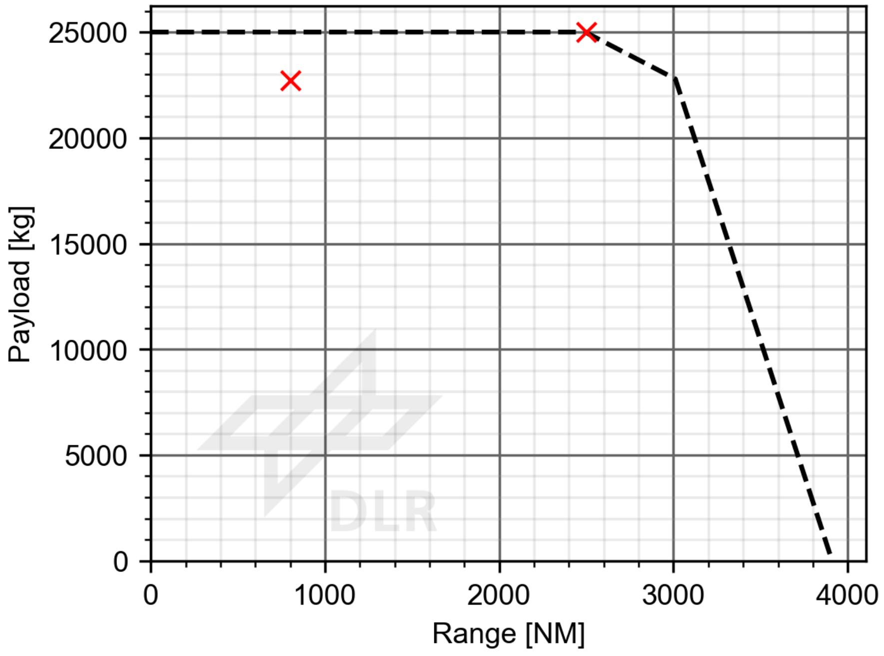
DLR-F25 Research Baseline
Cruise Performance Comparison



Parameter	DLR-F25 v5 Design Mission	DLR-F25 v5 Evaluation Mission
Range [NM]	2500.0	800.0
Payload [t]	25.0	22.7
Mach Number (Cruise) [-]	0.78	0.78
Block Fuel [kg]	12061.2	4118.49
Init. Cruise Altitude [FL]	330.0	370.0
Mid Cruise Altitude [FL]	350.0	370.0
End of Cruise Altitude [FL]	370.0	370.0
No. of Cruise Steps [-]	2.0	0.0

Parameter	DLR-F25 v5 Design Mission	DLR-F25 v5 Evaluation Mission
Mid Cruise Performance		
Lift Coefficient [-]	0.592	0.598
Drag Coefficient [-]	0.03	0.031
L/D Ratio [-]	19.85	19.54
CAS [m/s]	136.0	129.9
TAS [m/s]	231.3	230.2
Angle of Attack [deg]	-0.0	0.0
Thrust [kN]	39.4	36.8
Thrust max. [kN]	49.9	45.9
tsfc [g/kN/s]	14.31	14.28
Avg. Cruise Performance		
Lift Coefficient [-]	0.597	0.592
Drag Coefficient [-]	0.0303	0.0303
L/D Ratio [-]	19.7	19.54
CAS [m/s]	134.8	129.9
TAS [m/s]	231.1	230.2
Thrust [kN]	39.4	36.4
tsfc [g/kN/s]	14.29	14.3

Payload-Range Characteristics



General Information:

- Max. Payload: 25000 kg
- Design No. PAX: 239 @ 95 per PAX
- Design Mission: 2500NM @ 25000 kg Payload

Mission Profile:

- Climb: 300kts
- Cruise: Mach 0.78
- Descent: 300kts

Reserve:

- No wind, ISA condition
- 200NM Alternate Airport
- 30min Holding @1500 ft
- Contingency Fuel: 3.0% Trip Fuel

Evaluation Mission:

- Typical short-medium range mission of 800nm
- Payload without cargo as 239 Pax at 95kg

DLR-F25 Research Baseline
Aircraft sensitivities

Sensitivities on design mission (2500nm):

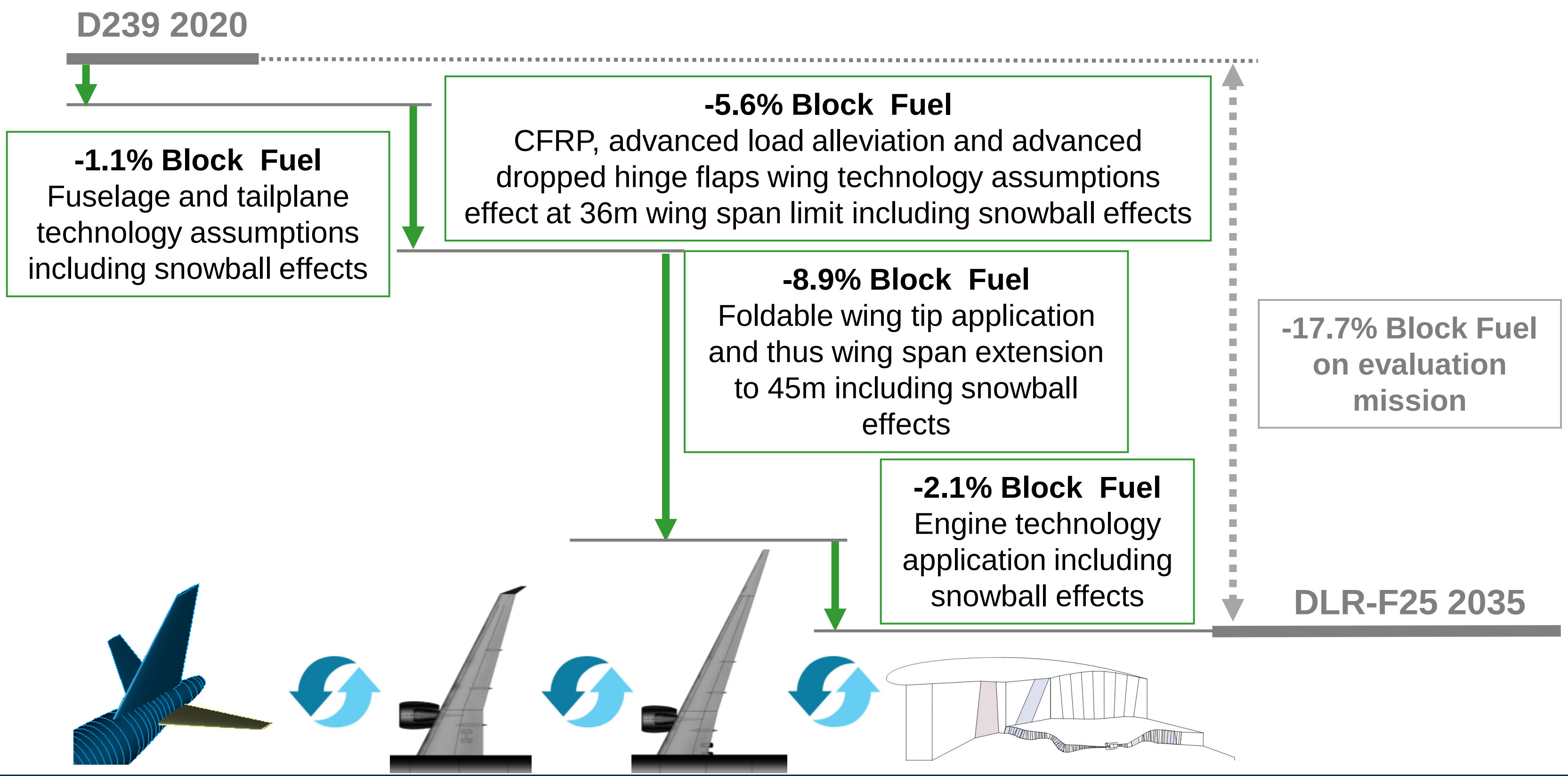
$$\frac{\partial FB}{\partial TSFC} = 1.33 \left[\frac{\%}{\%}\right] \qquad \frac{\partial FB}{\partial M} = 2.04 \left[\frac{\%}{t}\right] \qquad \frac{\partial FB}{\partial dc} = 3.31 \left[\frac{\%}{10dc}\right]$$

Sensitivities on evaluation mission (800nm):

$$\frac{\partial FB}{\partial TSFC} = 1.16 \left[\frac{\%}{\%}\right] \qquad \frac{\partial FB}{\partial M} = 1.90 \left[\frac{\%}{t}\right] \qquad \frac{\partial FB}{\partial dc} = 3.15 \left[\frac{\%}{10dc}\right]$$

FB	Fuel Burn
TSFC	Thrust Specific Fuel Consumption
W	Bare Engine Weight
DC	Drag Count for ref area of 130m²

DLR-F25 Research Baseline
Technology Assessment on Aircraft Level



- Stepwise application of technology assumptions
- Snowball effects include resizing of the aircraft based on mass savings and performance improvements
- Engine is redesigned/rescaled at each step for updated thrust requirements
- Wing area is adapted at each step based on fuel volume, take-off performance and approach speed requirements