

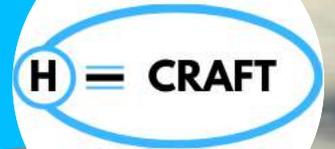


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# Project H-Craft

Aircraft Design Seminar 2020/21



# The Team



Miquel  
Altadill Llasat



Felix  
Brenner



Konstantin  
Brüker



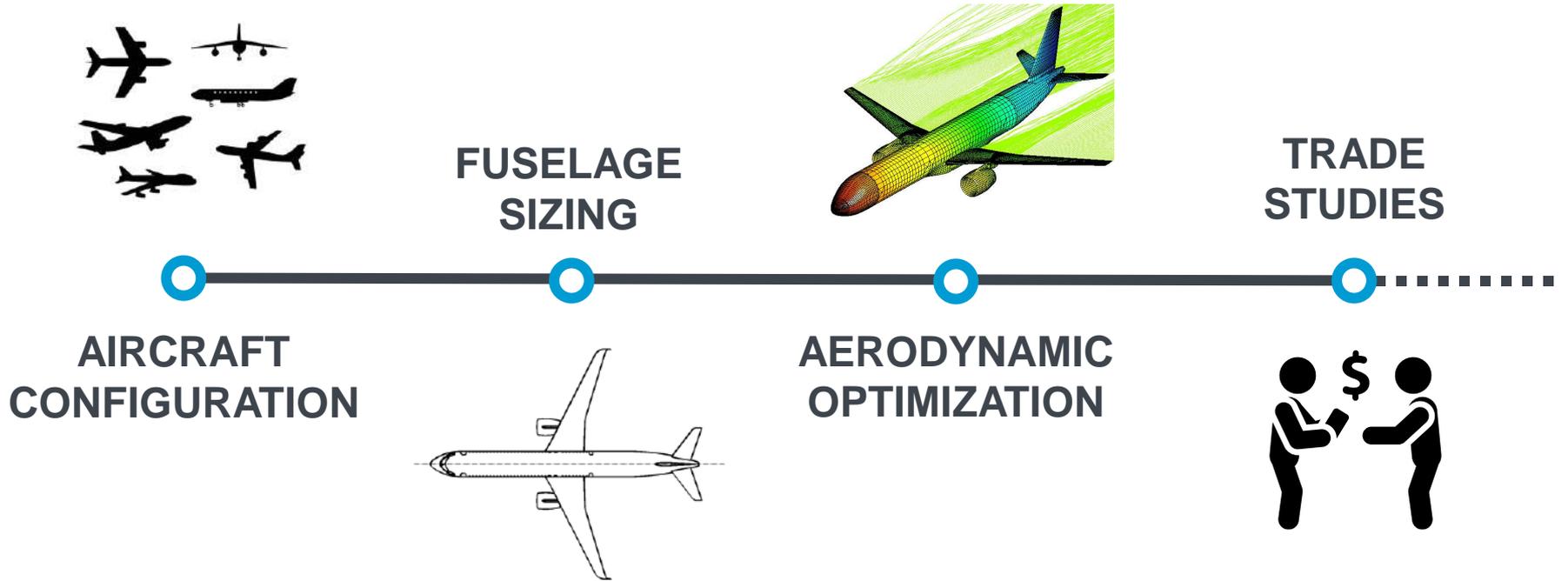
Andreas  
Friedrichs

# Design Goals

1. Achieving Top Level Aircraft Requirements
2. Reducing the overall MTOM
3. Improved aerodynamics
4. Efficient engines

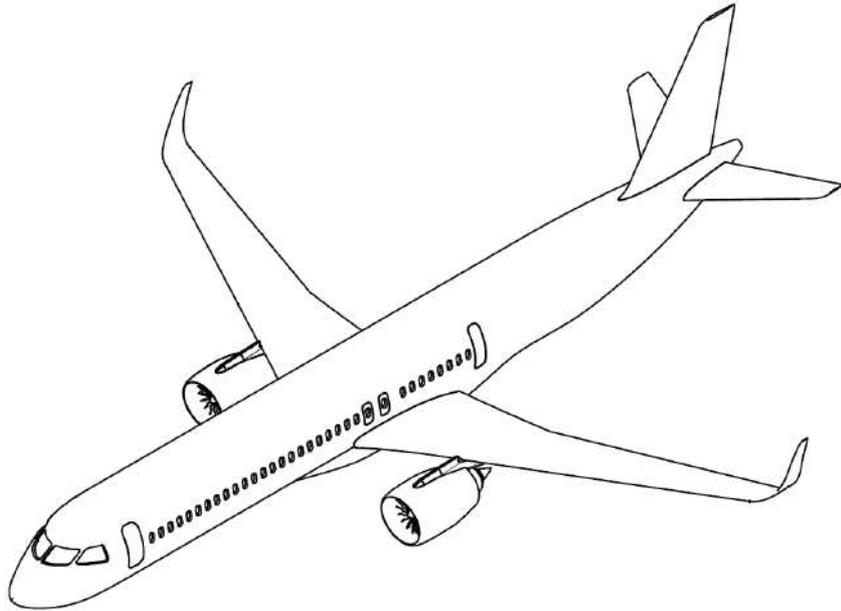


# Design Roadmap





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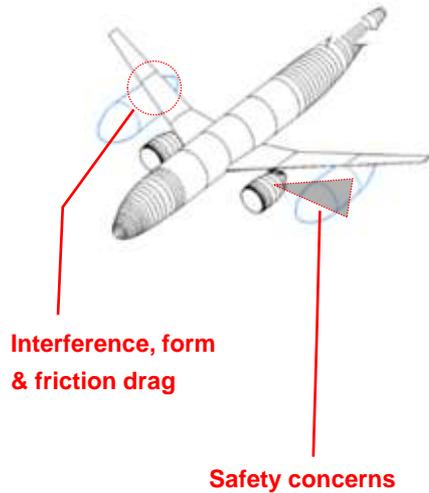
# Aircraft configuration

**H = CRAFT**

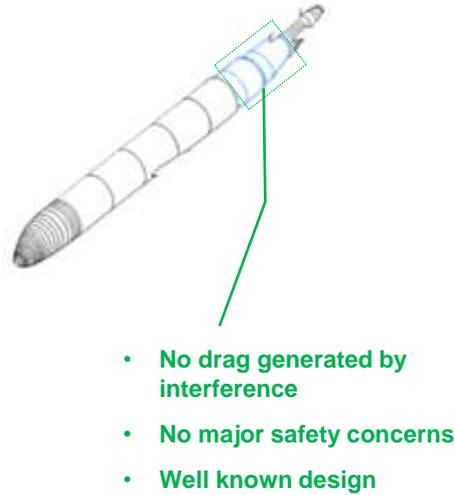
# Aircraft configuration

## Fuel tank positioning

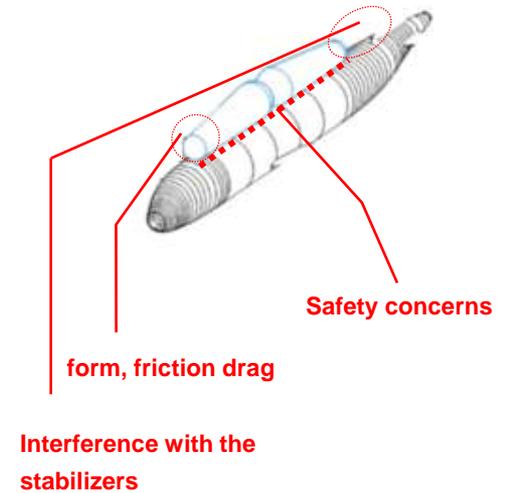
### Under wing pods



### Rear integrated tanks



### On top integrated tanks



# Aircraft configuration

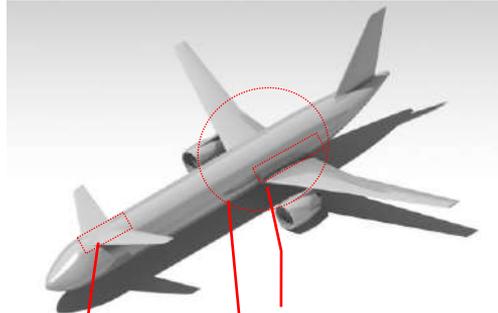
## Basic aircraft configuration

### Standard



- Well known design
- Aerodynamic optimization based on the reference aircraft
- Less space issues

### Canard

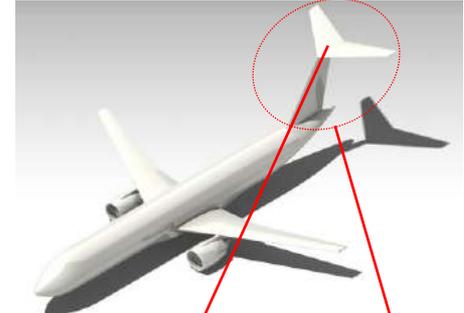


Limited space

Limited space  
(wing box, L/G and tanks)

Interference  
between Canard  
and Wing

### T-Tail



Deep stall  
characteristics

CG Shift

# Aircraft configuration

## Final configuration

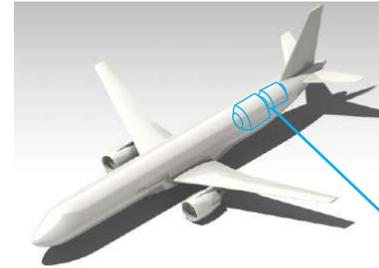
Rear integrated tanks



Standard



Project H-Craft



Final configuration:

- Low additional drag
- No major safety concerns
- Conservative approach

Problems to be solved:

- Increased fuselage weight
- CG shift to the rear

2x LH2 tanks of Kloepper-type shape (redundancy)



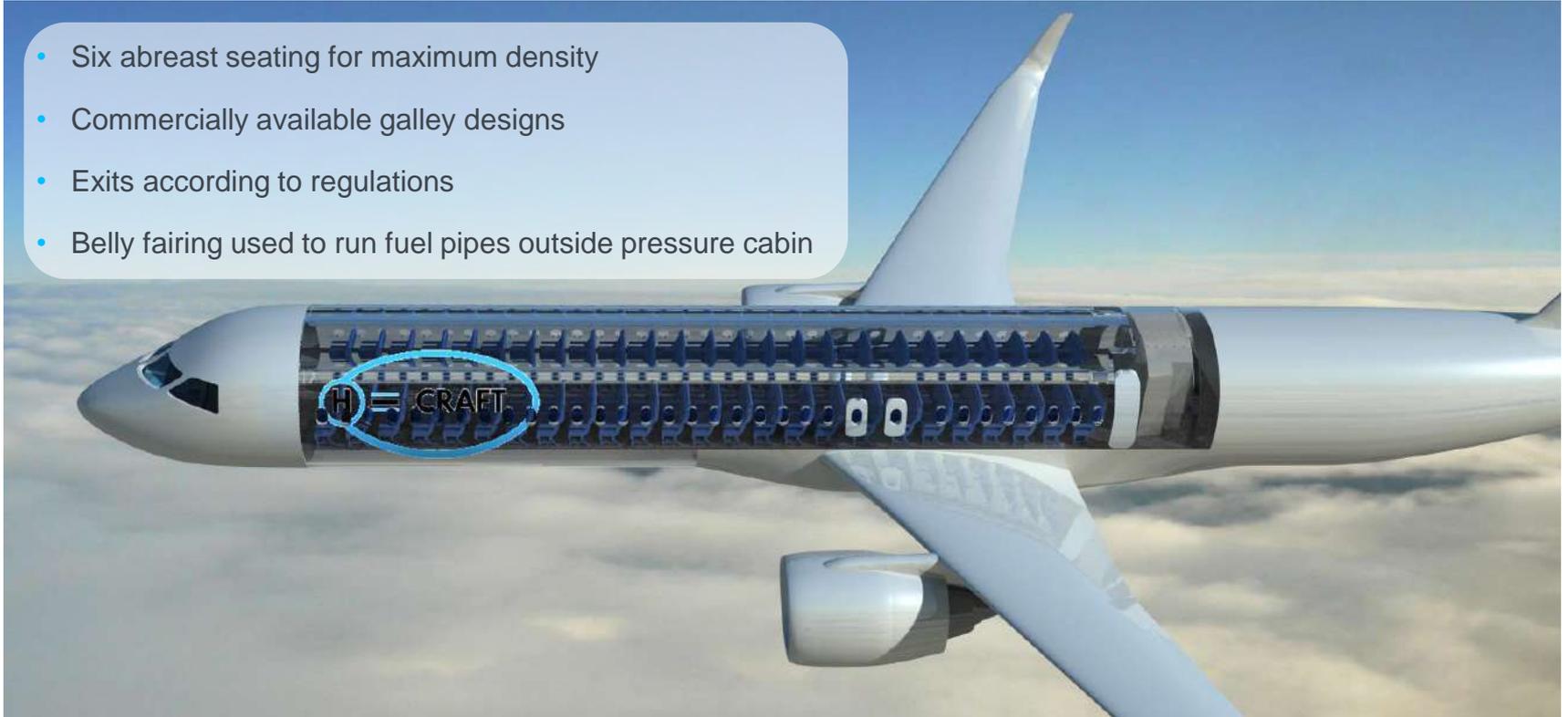
# Fuselage sizing



# Fuselage sizing

## Cabin layout

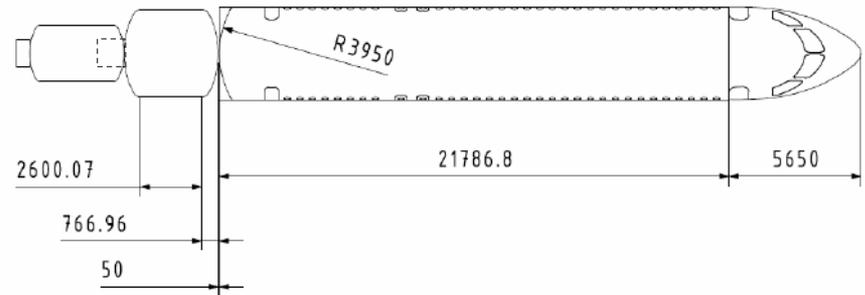
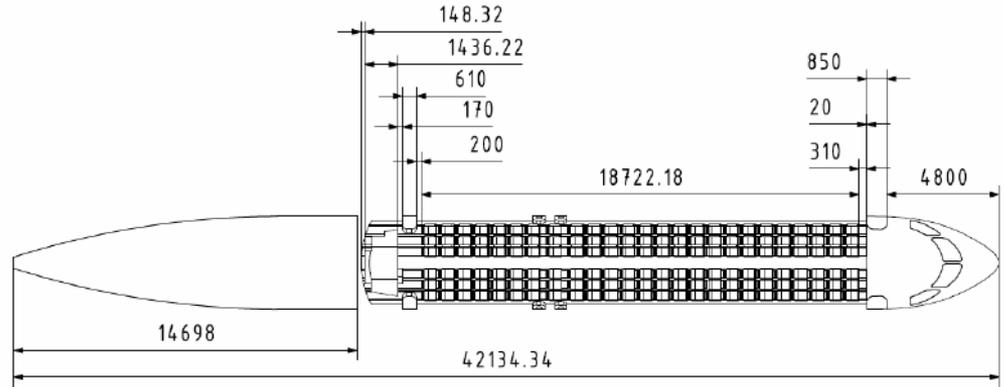
- Six abreast seating for maximum density
- Commercially available galley designs
- Exits according to regulations
- Belly fairing used to run fuel pipes outside pressure cabin



# Fuselage sizing

## Tank positioning and dimensions

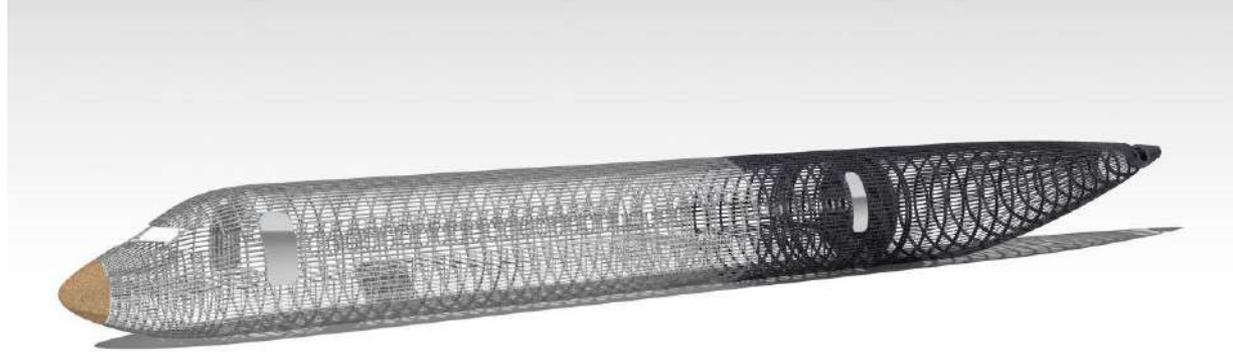
- Rear mounted tanks with minimum space usage
- Tail dimensions according to general guidelines
- Total length of 42.1m at 3.95m diameter



# Fuselage sizing

## Structural design

- Division of material selection to bring C/G forward and reduce weight
- Front half aluminum
- Rear half section CFRP





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# Engines



# IATA Roadmap to 2050

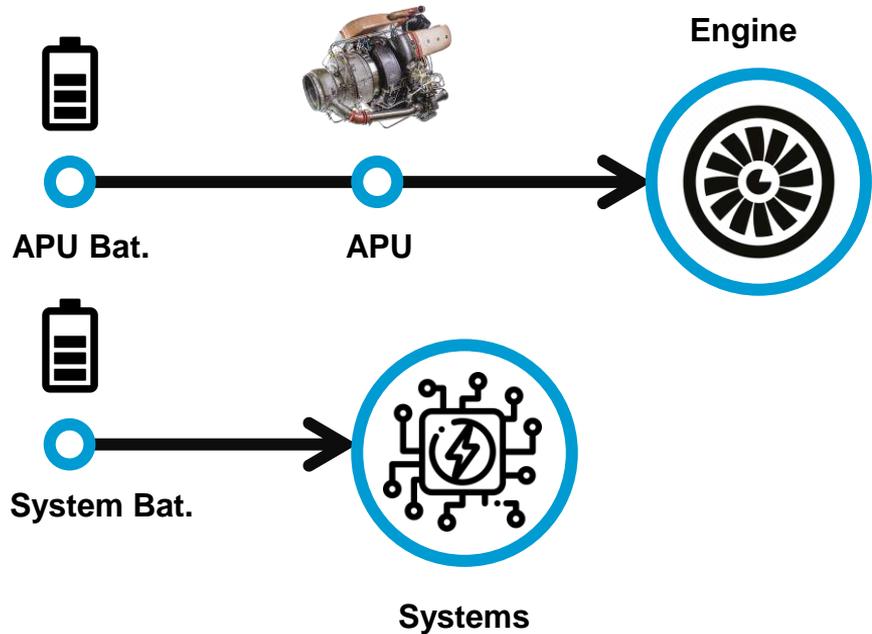
In 2030: new [conventional] engine core concepts

→ Fuel efficiency (FE) up to 30% better

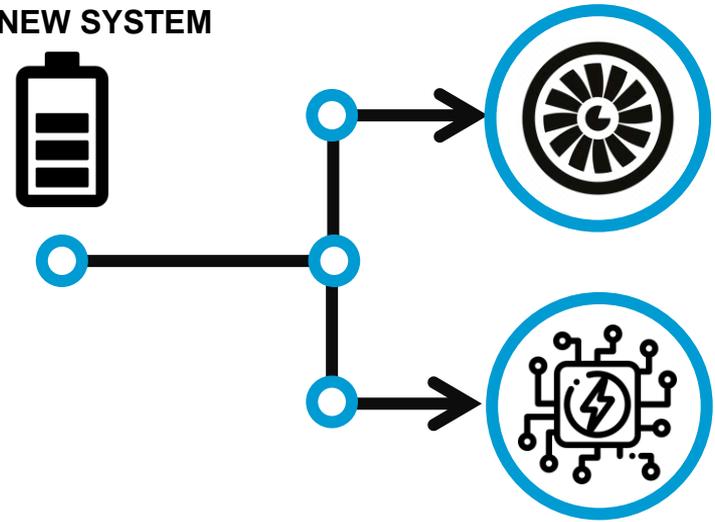
*Assumption: 20% better FE for equivalent LH2 Leap 1A-23 Engine*

# Batterie APU

## SYSTEM 1



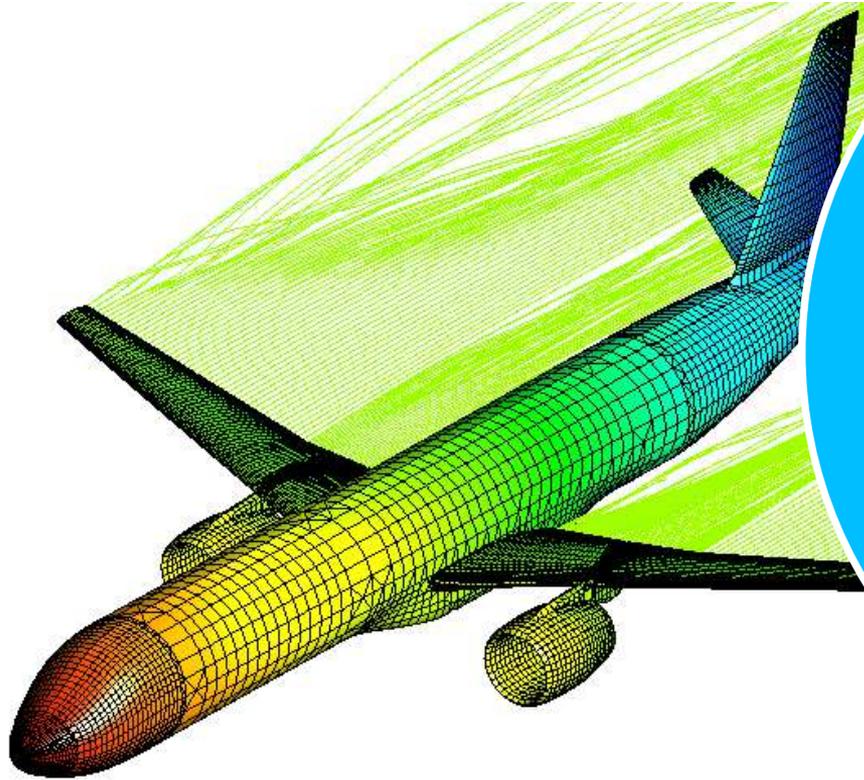
## NEW SYSTEM



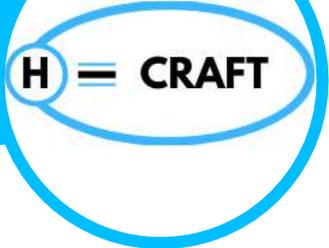
- Integrated Battery System
- Located near the nose gear bay



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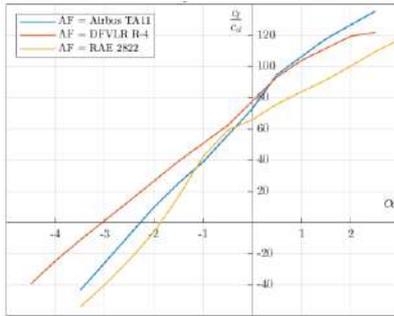


# Aerodynamic optimization



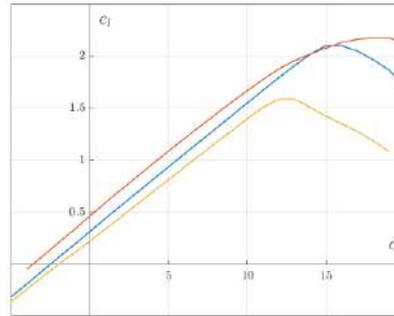
# Aerodynamic optimization

## Airfoil selection process



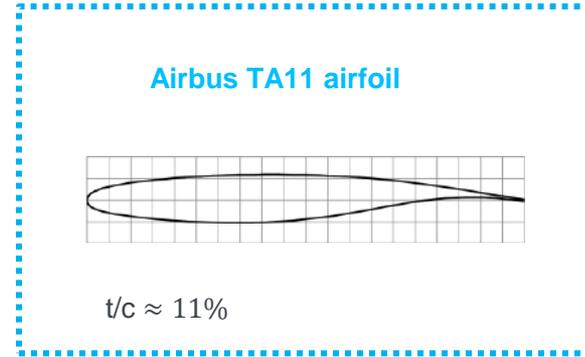
Cruise FL360,  $Re \approx 22 \cdot 10^6$

Best  $\frac{c_l}{c_d}$  ?



Holding 5000ft, 200kts TAS

Stall behaviour ?



# Aerodynamic optimization

## Wing optimization

- Different wings and airfoils analyzed in XFOIL and FlightStream
- Decision to incorporate Winglets
- Final Design:  $L/D_{\text{cruise}} = 18.6$





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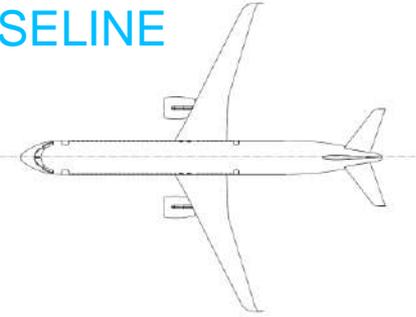
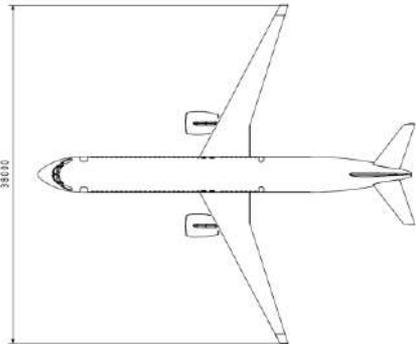
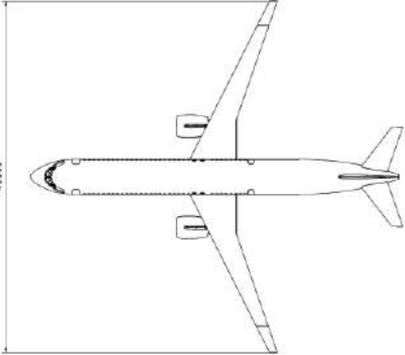


# Trade studies

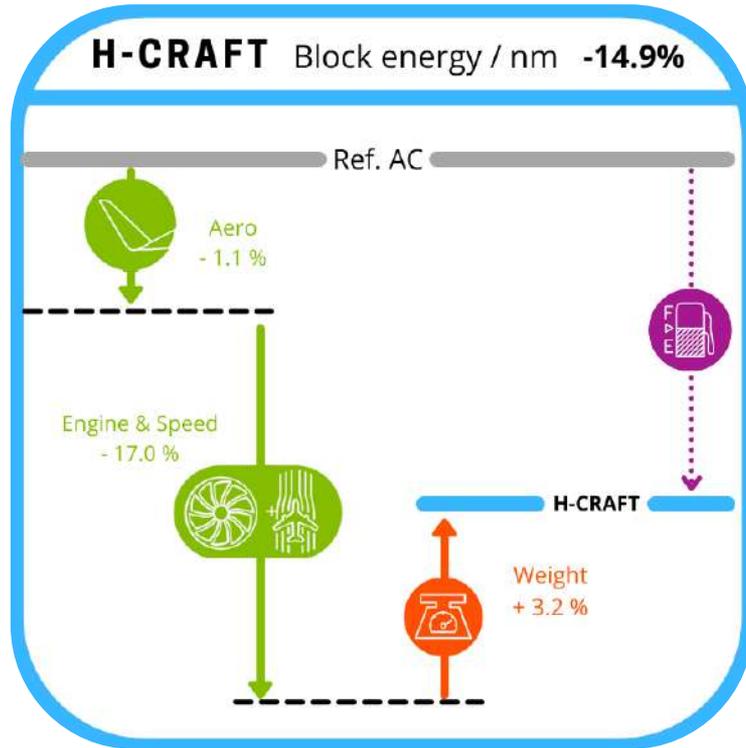


# Trade studies

## Wing aspect ratio - Materials

| $\Lambda = 10.4, b = 36m$  | $\Lambda = 12.0, b = 38m$   | $\Lambda = 12.9, b = 40m$   |
|--|---|---|
| <p><b>BASELINE</b></p>                                  |   |    |
| <ul style="list-style-type: none"><li>• fuselage 50% cfrp</li><li>• <math>DOC_{Fuel}</math>: 21,137,543€ (3.5€ per kg in 2030)</li></ul> | <ul style="list-style-type: none"><li>• foldable wing (1m each)</li><li>• fuselage up to 52% cfrp</li><li>• up to 600,000€ DOC savings (FC -2.9%)</li></ul> | <ul style="list-style-type: none"><li>• foldable wing (2m each)</li><li>• fuselage up to 52.4% cfrp</li><li>• up to 1,000,000€ DOC savings (FC -4.8%)</li></ul> |

# Ladder chart: efficiency





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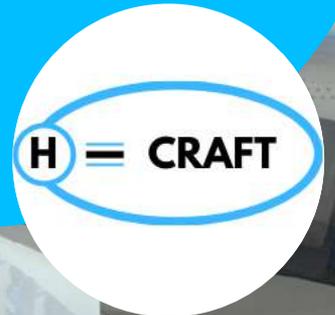
**IFB**  
Institut für Flugzeugbau  
Institute of Aircraft Design





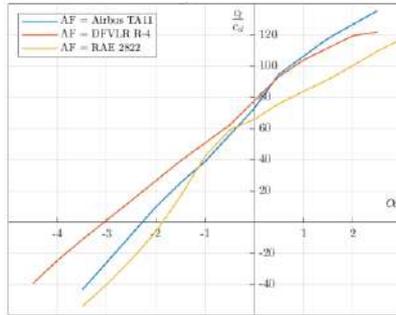
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ANNEX



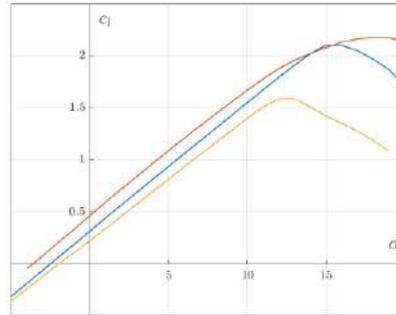
# Aerodynamic optimization, detailed

## Airfoil selection process



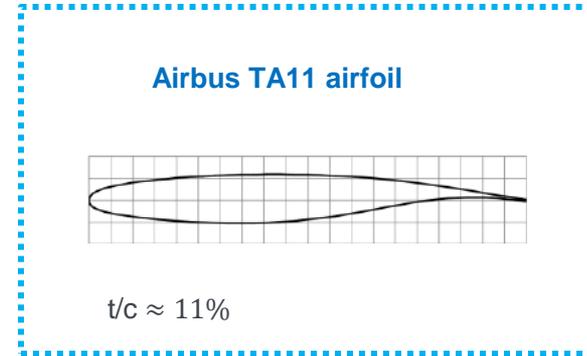
Cruise FL360,  $Re \approx 22 \cdot 10^6$

Best  $\frac{c_l}{c_d}$  at  $\alpha \geq 0$



Holding 5000ft , 200kts TAS

Stall behaviour



DFVLR R-4: flight stream -> too high drag !



Stabilizer airfoil: NACA 0009

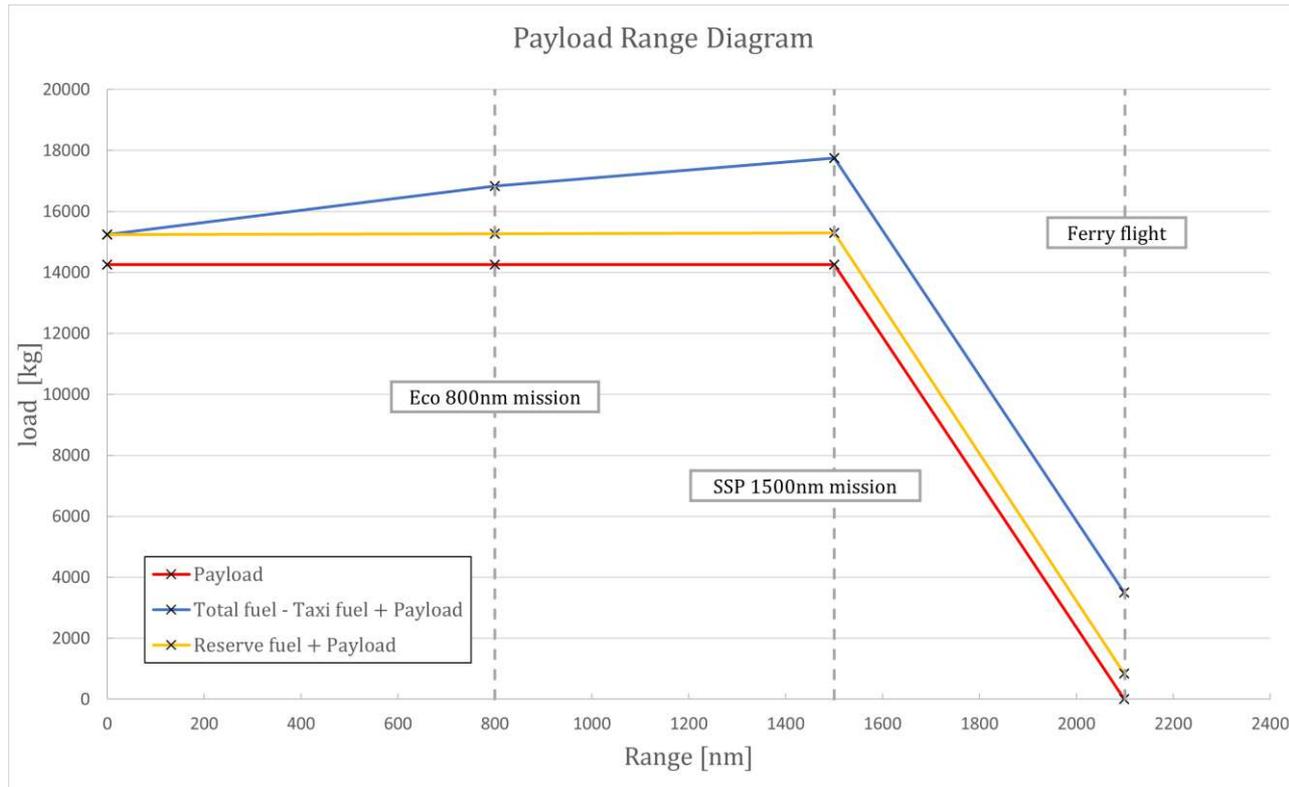
# Trade Study: Wing aspect ratio - Materials

Detailed for Annex

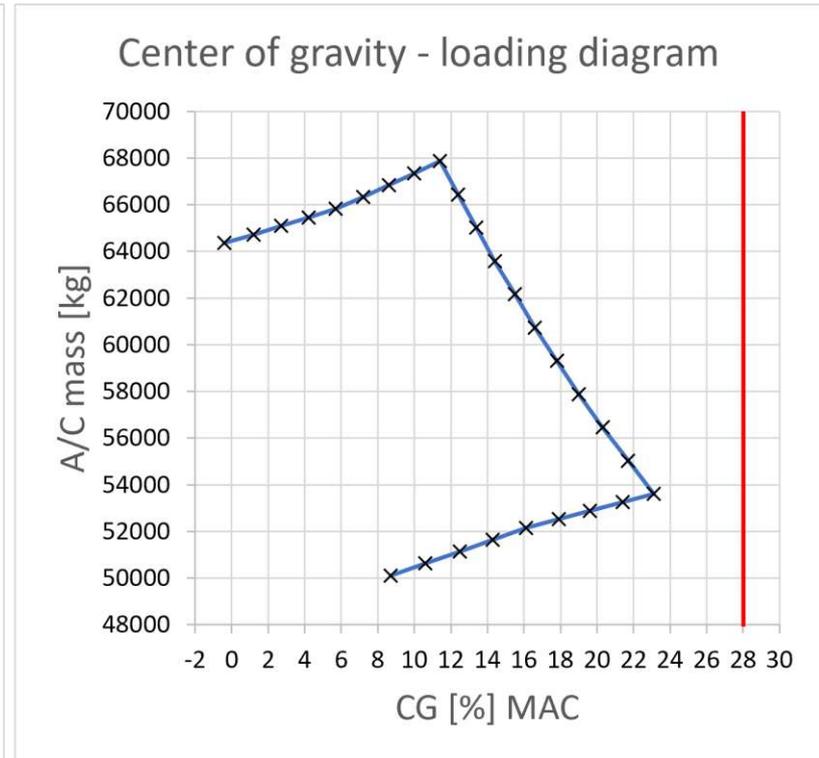
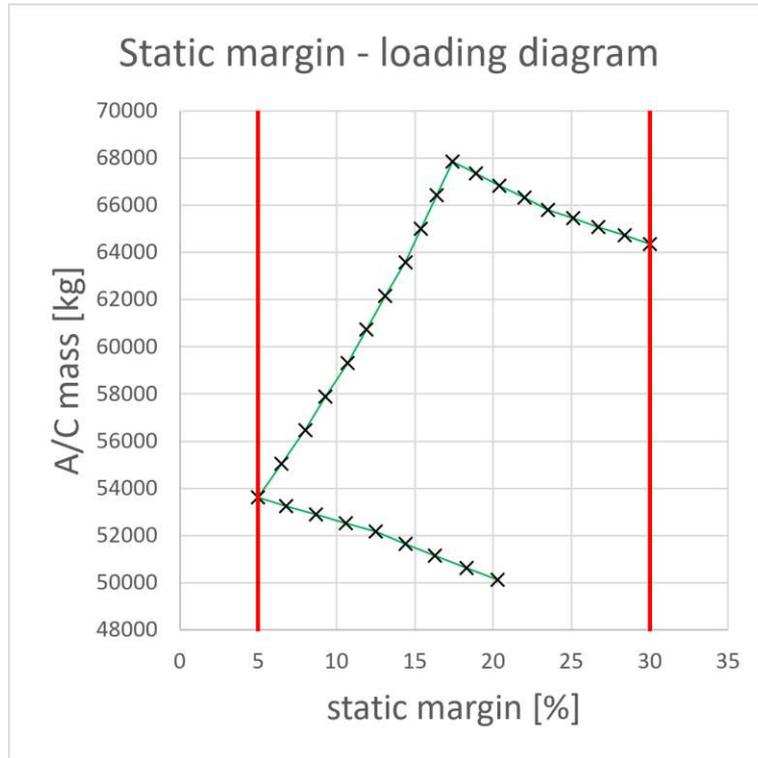
## 2-parameter analysis

|                        | Wing aspect ratio 10.41   | Wing aspect ratio 11.59   | Wing aspect ratio 12.85   |
|------------------------|---|---|---|
| Fuselage<br>52.4% cfrp | $MTOM = 67770\text{kg}$<br>$C_{D,i} = 0.0113$<br>$f_{C_{SPP,\%}} = 99.9\%$<br>$DOC_{fuel} = 21,137,543\text{€}$   | $MTOM = 67980\text{kg}$<br>$C_{D,i} = 0.0113$<br>$f_{C_{SPP,\%}} = 97.2\%$<br>$DOC_{fuel} = 20,545,692\text{€}$ | $MTOM = 68086\text{kg}$<br>$C_{D,i} = 0.0113$<br>$f_{C_{SPP,\%}} = 95.2\%$<br>$DOC_{fuel} = 20,122,841\text{€}$ |
| Fuselage<br>52% cfrp   | $MTOM = 67788\text{kg}$<br>$C_{D,i} = 0.0122$<br>$f_{C_{SPP,\%}} = 99.9\%$<br>$DOC_{fuel} = 21,137,543\text{€}$   | $MTOM = 67945\text{kg}$<br>$C_{D,i} = 0.0122$<br>$f_{C_{SPP,\%}} = 97.1\%$<br>$DOC_{fuel} = 20,524,554\text{€}$ | $MTOM = 68105\text{kg}$<br>$C_{D,i} = 0.0122$<br>$f_{C_{SPP,\%}} = 95.2\%$<br>$DOC_{fuel} = 20,122,841\text{€}$ |
| Fuselage<br>50% cfrp   | <p style="text-align: center;"><b>BASELINE</b></p> $MTOM = 67862\text{kg}$<br>$C_{D,i} = 0.0137$<br>$f_{C_{SPP,\%}} = 100\%$<br>$DOC_{fuel} = 21,137,543\text{€}$ | $MTOM = 68073\text{kg}$<br>$C_{D,i} = 0.0137$<br>$f_{C_{SPP,\%}} = 97.3\%$<br>$DOC_{fuel} = 20,566,829\text{€}$ | $MTOM = 68179\text{kg}$<br>$C_{D,i} = 0.0137$<br>$f_{C_{SPP,\%}} = 95.3\%$<br>$DOC_{fuel} = 20,144,078\text{€}$ |

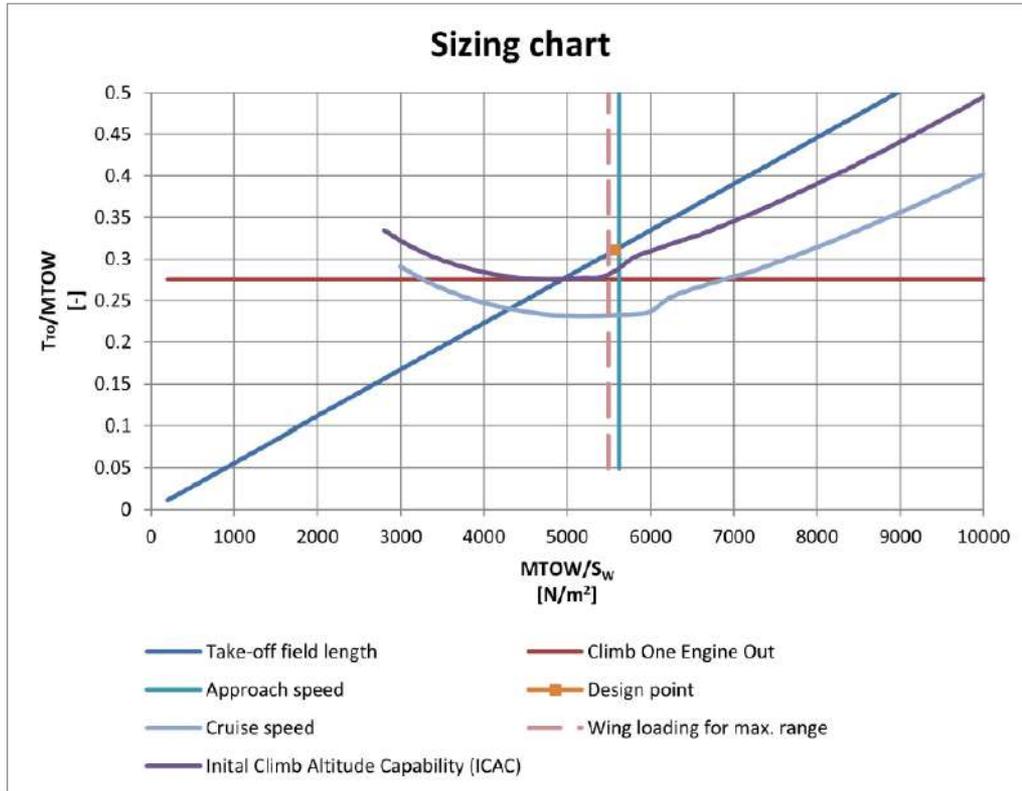
# Payload Range Diagram



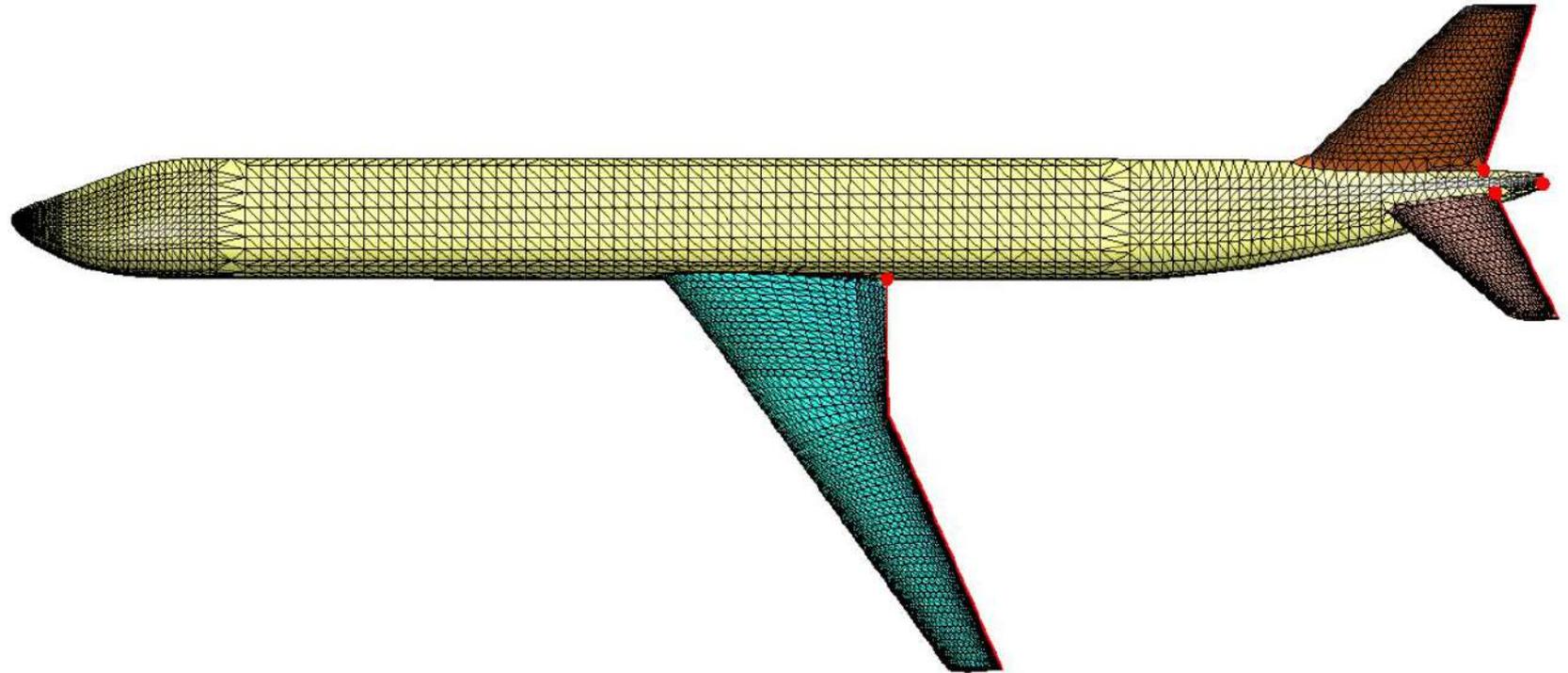
# Center of Gravity – Static margin



# Sizing chart



# Mesh for Flight Steam Analysis



# Drag Polar, L/D Polar for cruise flight

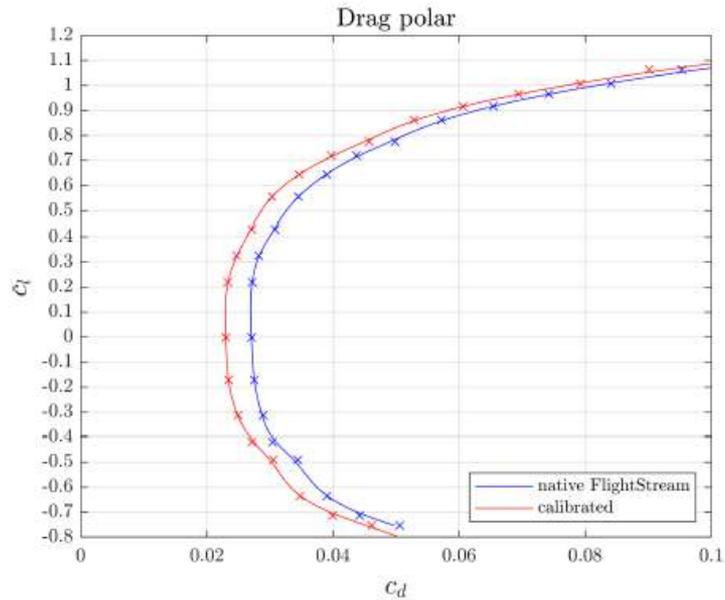


Figure 4.14: Drag polar cruise flight

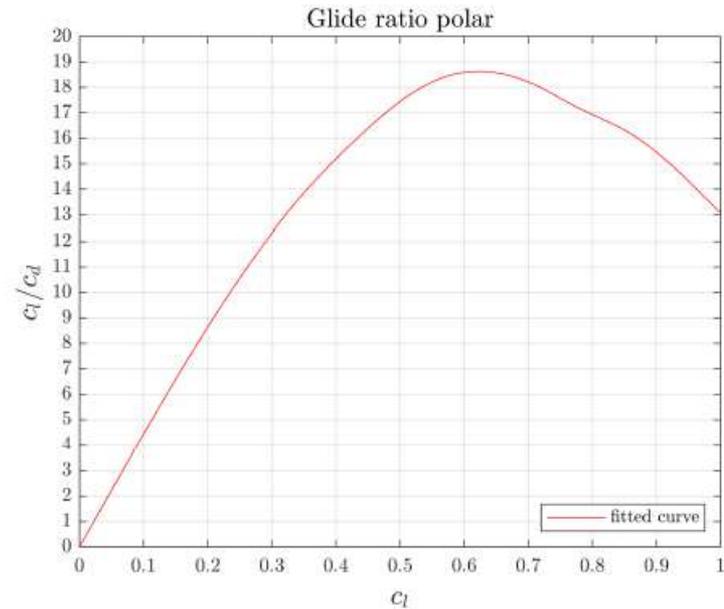
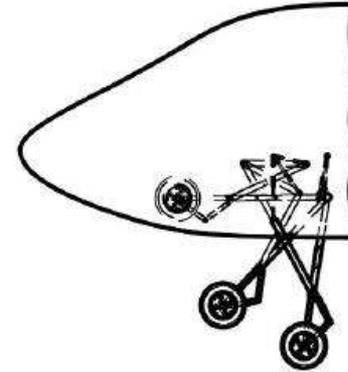
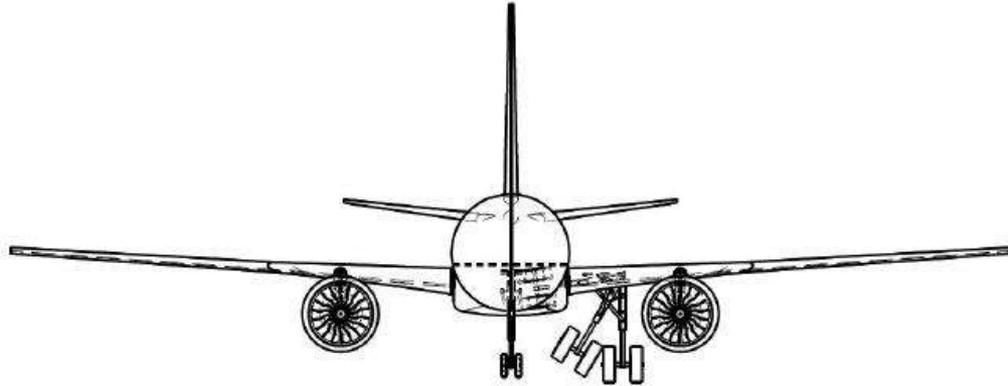


Figure 4.15: Glide ratio polar cruise flight

# Landing gear kinematics



# Ground operations

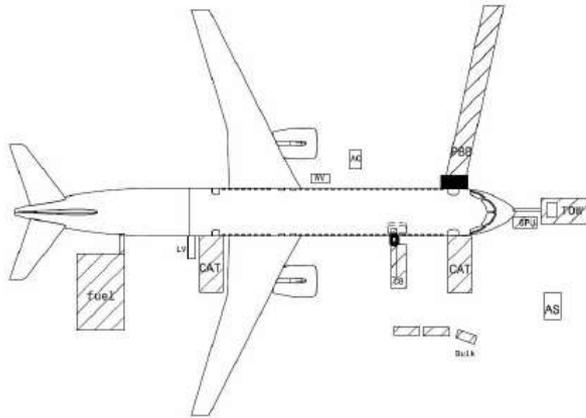


Figure 8.2: Airport Ops PBB

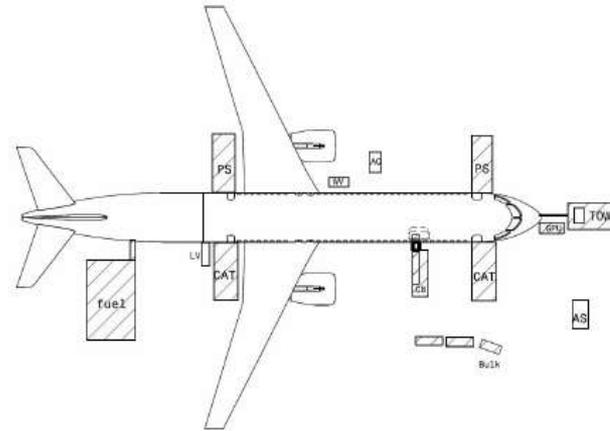
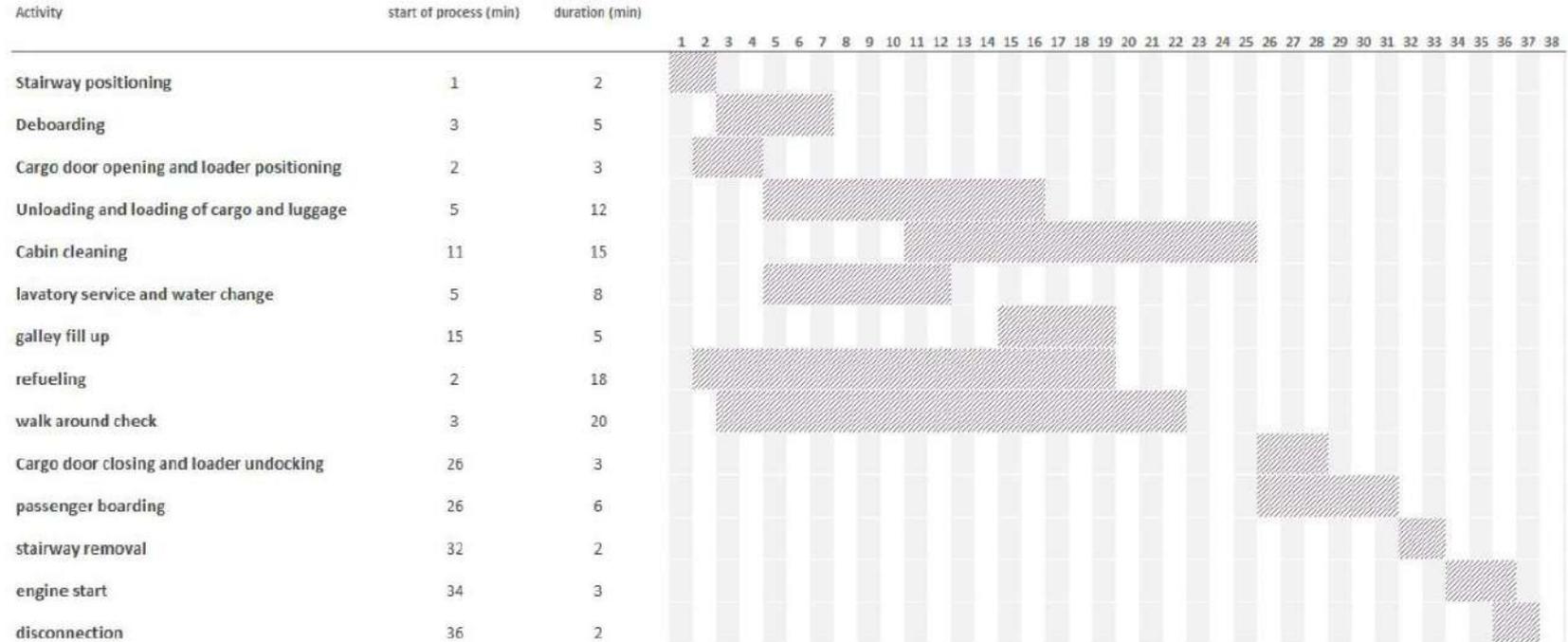


Figure 8.1: Airport Ops PS

# Turn around



## Two parameter study detailed

| $\Lambda$ | cfrp [%] | $\Delta$ wing [kg] | $\Delta$ fuel [kg] | OME [kg] | MTOW [kg] | $L/D$ | $c_{Di,cruise}$ |
|-----------|----------|--------------------|--------------------|----------|-----------|-------|-----------------|
| 10.41     | 50       | 0                  | -4                 | 50111    | 67862     | 18.60 | 0.0137          |
| 10.41     | 52       | 0                  | -4                 | 50076    | 67788     | 18.60 | 0.0137          |
| 10.41     | 52.4     | 0                  | -5                 | 50067    | 67770     | 18.60 | 0.0137          |
| 11.59     | 50       | 100                | -65                | 50211    | 68073     | 19.48 | 0.0122          |
| 11.59     | 52       | 100                | -70                | 50176    | 67945     | 19.48 | 0.0122          |
| 11.59     | 52.4     | 100                | -69                | 50167    | 67980     | 19.48 | 0.0122          |
| 12.85     | 50       | 150                | -115               | 50261    | 68179     | 20.04 | 0.0113          |
| 12.85     | 52       | 150                | -118               | 50226    | 68105     | 20.04 | 0.0113          |
| 12.85     | 52.4     | 150                | -118               | 50217    | 68086     | 20.04 | 0.0113          |

Table A.5: Two-Parameter Study detailed results