Hochschule für Angewandte Wissenschaften Hamburg
Hamburg University of Applied Sciences

DEPARTMENT FAHRZEUGTECHNIK UND FLUGZEUGBAU

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Flugzeugentwurf / Aircraft Design SS 2011

Date: 04.07.2011

Duration of examination: 180 minutes

Last Name:		First Name:
Matrikelnummer.:		
Points:	of 77	Grade:

1. Part

30 points, 60 minutes, closed books

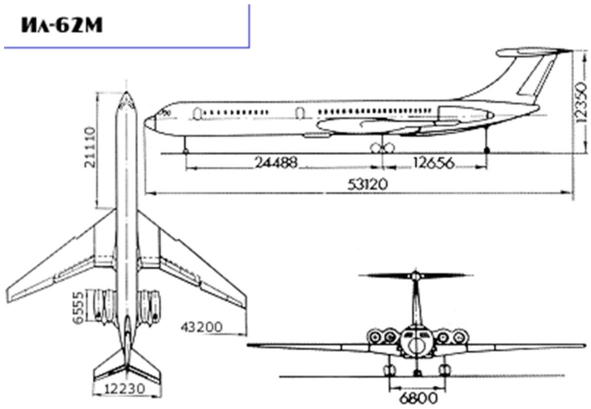
1.1) Please translate to German.
Please write clearly! Unreadable text causes substraction of points!

1. sweep
2. wing root
3. span
4. aisle
5. canard
6. anhedral
7. landing field length
8. trolley
9. landing gear
10. fuselage
11. empennage
12. aileron

1.2) Please translate to English!
Please write clearly! Unreadable text causes substraction of points!

1. Dimensionierung
2. Leitwerk
3. Nutzlast
4. Sitzschiene
5. Maximale Leertankmasse
6. Fracht
7. Reibungswiderstand
8. Triebwerk
9. Küche
10. (Rumpf-)Querschnitt
11. Masseverhältnis
12. Oswald Faktor

1.3) Shown is the Iljuschin Il-62. Please name 4 Pros and Cons (Vor- und Nachteile) or name things that change flight operation!



1.4) An aircraft for 225 passengers is planned. How many seats abreast do you plan for? Explain your reasoning!

1.5) What is Maximum Zero Fuel Weight (Maximale Leertankmasse)? How can you calculate it?

1.6) Please name 5 requirements for a civil passenger aircraft that determine the design point!

1.7) Please name the equation used to calculate m_{MTO} from payload m_{PL}, operating weight empty ratio $\frac{m_{OE}}{m_{MTO}}$ and fuel mass ratio $\frac{m_F}{m_{MTO}}$! An aircraft proposal leads to $\frac{m_{OE}}{m_{MTO}}$ = 0,6 and $\frac{m_F}{m_{MTO}}$ = 0,4. Calculate m_{MTO} of the proposed aircraft! Comment on this aircraft proposal!

1.8) Based on CS-25 what is the required climb gradient (Steiggradient) in a one engine out situation (bei Triebwerksausfall) in the second segment (2. Segment)?

1.9) Please name the standardized aviation container that is mostly in use!

1.10) Given is a part of the certification rules:

CS 25.771 Pilot compartment
(b) The primary controls ... must be located with respect to the propellers so that no member of the minimum flight crew ... or part of the controls, lies in the region between the plane of rotation of any inboard propeller and the surface generated by a line passing through the centre of the propeller hub making an angle of 5º forward or aft of the plane of rotation of the propeller.

If in the event of a blade failure (ein Propeller bricht ab vom Antrieb) of a propeller driven aircraft a passenger is hit (Passagier wird getroffen)- which is certainly fatal (was tötlich sein wird), would this be acceptable according to the part of the paragraph CS 25.771.

1.11) For each sweep angle there is an optimum taper ratio that produces almost an elliptical lift distribution. Which sweep angle requires an optimum taper ratio λ = 1? (Give the order of magnitude and the sign of the sweep angle)

1.12) Airbus and Boeing passenger airplanes experience in cruise a wave drag coefficient of about ... which is equal to ... drag counts.

1.13) The chord of a swept wing is measured
O parallel to the x-z-plane (x-z-Ebene)
O in the direction of the undisturbed flow (in Richtung der freien Anströmung)
O perpendicular to the 25%-line (senkrecht zur 25%-Linie)
O perpendicular to the 50%-line (senkrecht zur 50%-Linie)
Mark every statement that is true! (Kennzeichnen Sie jede richtige Aussage)!

1.14) An aircraft shows a pitch attitude on approach (Nicklagewinkel im Landeanflug) with a certain nose down tendency (mit der Flugzeugnase zu weit unter dem Horizont). This could lead to a dangerous touch down with the nose gear first. Make 3 proposals how to change the aircraft design to solve that problem! (Machen Sie 3 Vorschläge um das Problem zu lösen!)

1.15) What are the pros and cons for the fin with the horizontal tail on top of the fin - i.e. in a T-tail configuration? (Nennen Sie die Vor- und Nachteile für das Seitenleitwerk, wenn das Höhenleitwerk sich auf dem Seitenleitwerk befindet!)

1.16) You want to increase the aspect ration of a wing at constant wing mass. Name 3 parameters that you could change (in which way?) or measures to achieve this! (Sie wollen die Flügelstreckung bei konstanter Flügelmasse erhöhen. Nennen Sie 3 Parameter, die Sie [in welcher Weise?] ändern können oder Maßnahmen dies zu erreichen!)

1.17) What is the difference between take-off field length and take-off distance? (Wie unterscheiden sich Sicherheitsstartstrecke und Startstrecke?)

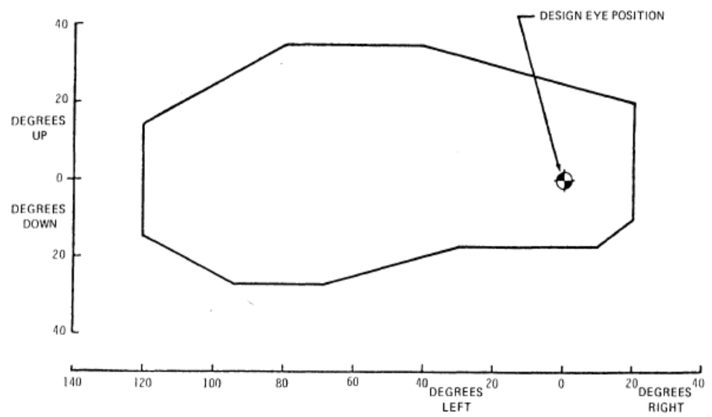
1.18) You know that braking distance increases with the square of the approach speed. Proceeding from here. How do you find an equation including a constant based on statistical data to estimate landing distance from approach speed? (Sie wissen, dass die Bremsstrecke mit dem Quadrat der Anfluggeschwindigkeit steigt. Wie finden Sie daraus ein Gleichung mit einer Konstanten basierend auf statistischen Werten mit der Sie die Landestrecke aus der Anfluggeschwindigkeit abschätzen können?)

1.19) You have to make sure that the flow at the horizontal tail can cope with whatever situation it is faced with - even if the flow at the wing is already in a state where lift can hardly be generated any more. Name 2 parameters and how they have to be selected to achieve this!

1.20) How can you ensure that a vertical tail is still operating at high side slip angles. Name the parameters and the direction of selected values to achieve this! Name measures! (Mit welchem Parameter und welchen Werten oder mit welcher Maßnahme können Sie sicherstellen, dass ein Seitenleitwerk auch bei großen Schiebewinkeln noch wirksam bleibt?)

1.21) Define the tail volume coefficient for the horizontal tail! (Definieren Sie den Höhenleitwerkskoeffizienten!)

1.22) What is this graph used for? (Wofür wird dieses Diagramm genutzt?)



1.23) An aircraft is sized (dimensioniert) with an overall maximum lift coefficient at landing $C_{L,max}$ = 2.4. What is (roughly) the required lift coefficient of the wing?

Questions based on the evening lectures

1.24) Describe why Air-to-Air Refueling (AAR) saves fuel in civil aircraft operations? What is the order of magnitude of its savings?

1.25) Describe why Close Formation Flying (CFF) saves fuel in civil aircraft operations? What is the order of magnitude of its savings?

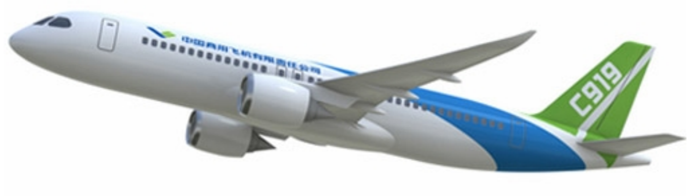
2. Part

Name:___________________________________

47 points, 120 minutes, open books and laptop

Task 2.1 (21 points)

The task is to make a preliminary redesign of the short and medium range Comac C919. This should be done with help of the spread sheet from the lecture.



These are the requirements for the aircraft:

- Range 3000 NM (long range type)
  (with reserves as given in FAR Part 121 international with 5% fuel reserves on flight distance, distance to alternate: 200 NM)
  at payload for maximum passenger range: 168 passengers with baggage each at 102 kg
- Take-off field length $s_{TOFL} \leq$ 2200 m (ISA, MSL)
- Approach speed: 135 kt
- Furthermore the requirements from FAR Part 25 §121(b) (2. Segment) and FAR Part 25 §121(d) (missed approach) shall be met
- Mach number in cruise: 0.785

For your calculation:

- Maximum lift coefficient of the aircraft in landing configuration $C_{L,max,L}$ = 2.9
- The ratio of maximum landing mass and maximum take-off mass m_{ML} / m_{MTO} = 0.8616
- Maximum lift coefficient of the aircraft in take-off configuration $C_{L,max,TO}$ = 2.32
- Correlation factor for landing k_L and take-off k_{TO} according to the lecture
- Find: Glide ratio E in take-off configuration and glide ratio E in landing configuration
  With: Aspect ratio A = 9.5 , $C_{D,0}$ = 0.02 and Oswald factor e = 0.7
- The maximum glide ratio E_{max} in cruise is calculated with e = 0.78; C_f = 0.003; S_{wet} / S_W = 6.2
- Oswald factor in cruise: e = 0.78
- The by-pass ratio (BPR) of the two CFM International LEAP-X engines is μ = 11; their thrust specific fuel consumption for cruise and loiter <u>is improved by 15%</u> compared to the standard value of c = 16 mg/(Ns)
- The ratio of cruise speed and speed for minimum drag V_{CR}/V_{md} has to be determined so that a favorable matching chart results!
- The operating empty weight ratio m_{OE} / m_{MTO} is assumed to be 54,5 %
- Use these values as Mission-Segment Fuel Fractions: Engine Start: 0.999; Taxi: 0.997; Take-Off: 0.996; Climb: 0.996; Descent: 0.995; Landing: 0.995

Calculate <u>and answer</u>:

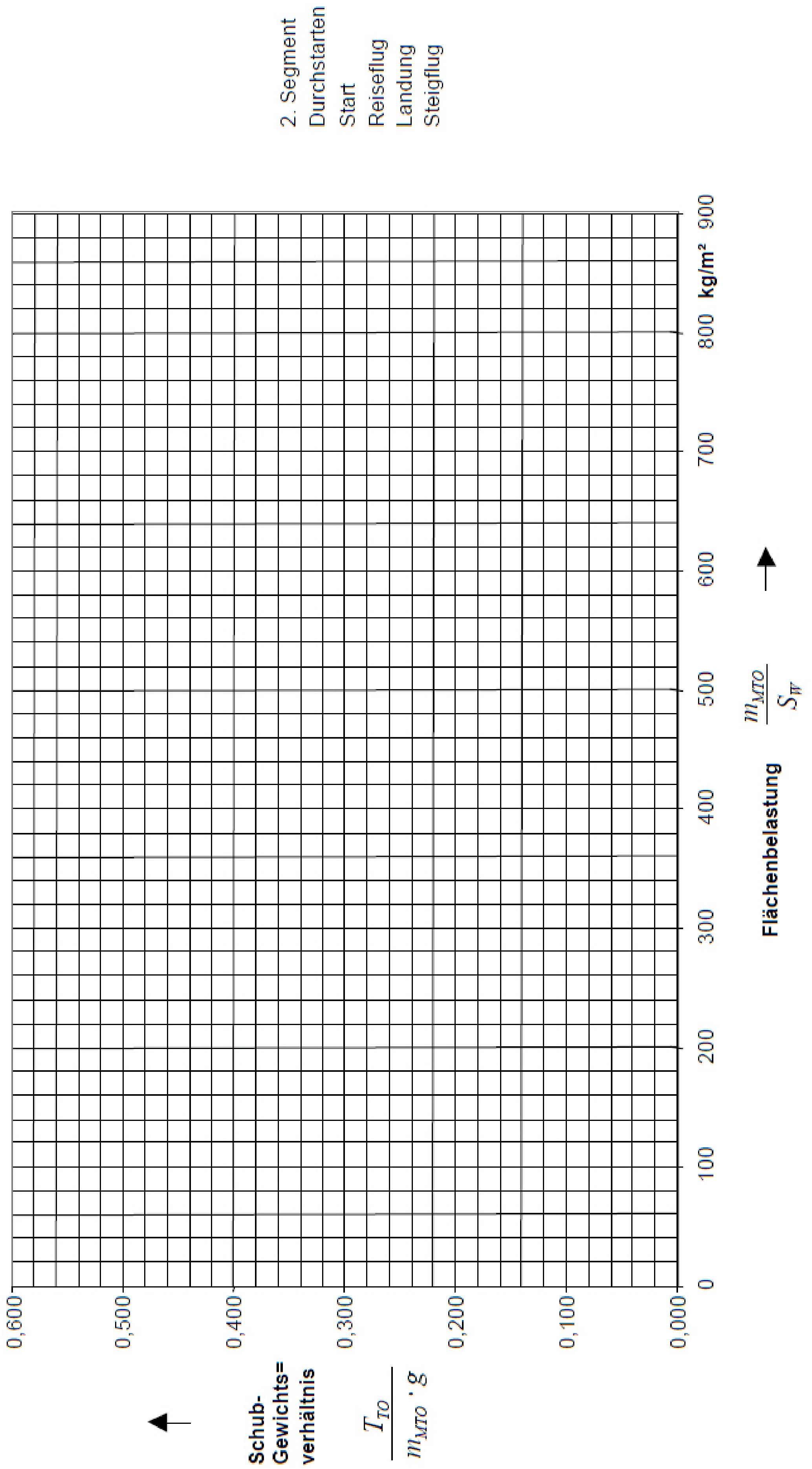
- <u>All parameters as requested in the form attached</u> (including all intermediate results that are asked for in the form)! Plot the matching chart!
- COMAC states a maximum payload of 20500 kg. Can this be achieved if

  $m_{ML} > m_{MZF} + m_{F,res}$? If not, what can be achieved ?
- Calculate the cargo mass that can be transported in addition to 168 passengers with baggage at 102 kg at maximum payload.

Results to task 2.1

Please insert your results here! Do not forget the units!

- Wing loading from landing field length:
- Thrust to weight ratio from take-off field length (at wing loading from landing):
- Glide Ratio in 2. Segment:
- Glide Ratio during missed approach maneuver:
- Thrust to weight ratio from climb requirement in 2. Segment:
- Thrust to weight ratio from climb requirement during missed approach maneuver:
- V_{CR}/V_{md} :
- Design point
    - Thrust to weight ratio :
    - Wing loading:
- Cruise altitude:
- maximum take-off mass:
- maximum landing mass:
- wing area:
- span (NEW, NEW, NEW!):
- thrust of one engine **in N**:
- required tank volume **in m^3**:


2. Segment
Durchstarten
Start
Reiseflug
Landung
Steigflug
0
100
200
300
400
500
600
700
800
900
kg/m²
Flächenbelastung
$\frac{m_{MTO}}{S_W}$
0,000
0,100
0,200
0,300
0,400
0,500
0,600
Schub-
Gewichts=
verhältnis
$\frac{T_{TO}}{m_{MTO} \cdot g}$

Task 2.2 (3 points)

A jet with four engines has a glide ratio on approach of 11. The ratio of maximum landing mass to maximum take-off mass is 0.8. Calculate the required thrust-to-weight ratio based on CS-25 or FAR Part 25 for a missed approach procedure with one engine inoperative!

Task 2.3 (3 points)

It can be assumed that the C919 has a maximum lift coefficient of the whole aircraft of 2.9.

a) According to the lecture, the high lift design for the wing should produce a maximum lift coefficient of ... ! Calculate this missing number!

b) The clean wing may produce a maximum lift coefficient of 1.7, the leading edge high lift devices may achieve 40 % of the required high lift. Estimate the required $\Delta C_{L,max,f}$ of the trailing edge high lift devices! Take into account the simplified approach from the lecture.

Task 2.4 (4 points)

Page 11 shows a box wing aircraft. The CG is assumed to be located right in the middle between the two wings.

a) Determine the scale (Maßstab) of the drawing!

b) Determine the distance from the CG to the aerodynamic center on the vertical tail!

c) Based on the tail volume coefficient for conventional aircraft, estimate the required fin area of the box wing.

Task 2.5 (3 points)

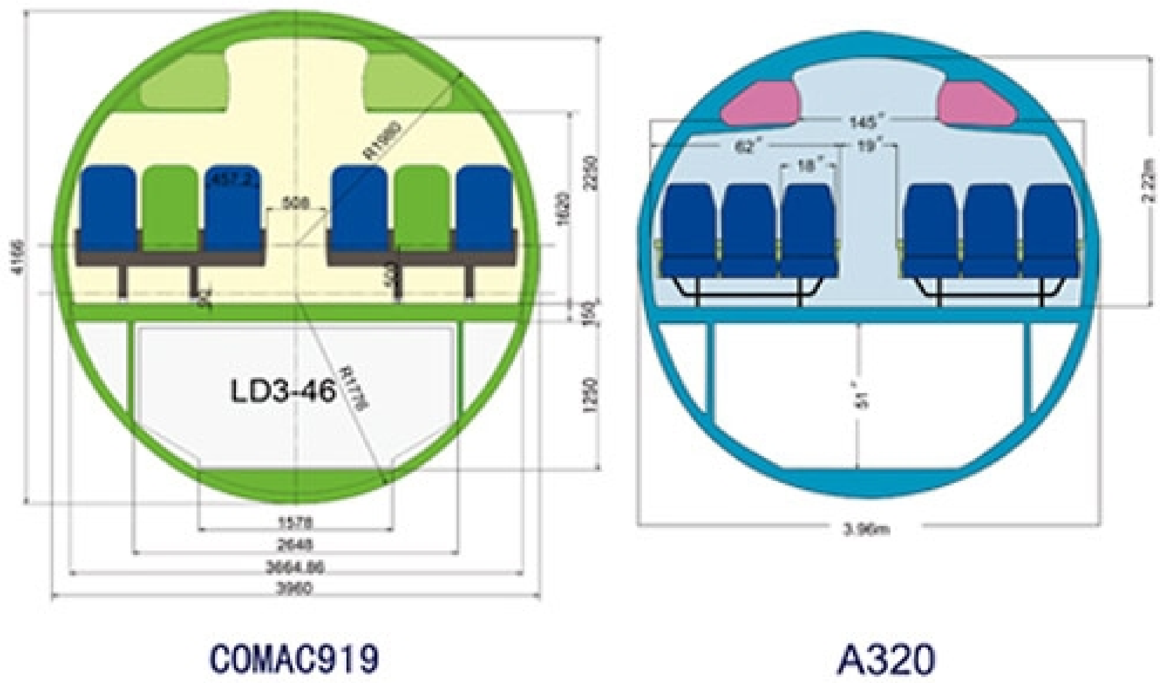
Apply the equation given in the lecture for wave drag estimation. An aircraft shows a critical Mach number of 0.5. Given are the coefficients $a = 0.09$ and $b = 5.5$ to represent the rise of the wave drag coefficient. Calculate the wave drag coefficient for $M = 0.75$. How is this Mach number called? What else can you report about this Mach number if the aircraft follows common layout principles applied at Airbus or Boeing?

Task 2.6 (5 points)

Estimate the total sales price of the COMAC C919 based on the lecture notes and more specific on the AEA method for short and medium range aircraft (**AEA 1989a**)! Use the number of seats for your estimates and further data given in Task 2.1.

Task 2.7 (8 points)
Comment on the differences between parameters of the cross sections of
i) the C919 (see below),
ii) the A320 (see below and lecture notes)
iii) and minimum parameters from the lecture notes (especially from RAYMER)
with respect to
a) Fuselage width and height
b) Aisle width, height
c) Seat width
d) Cargo hold height and cargo hold floor width.
Present you results systematically in a table! Comment on COMAC's strategy in the competitions!

COMAC Cross Section Comparison:



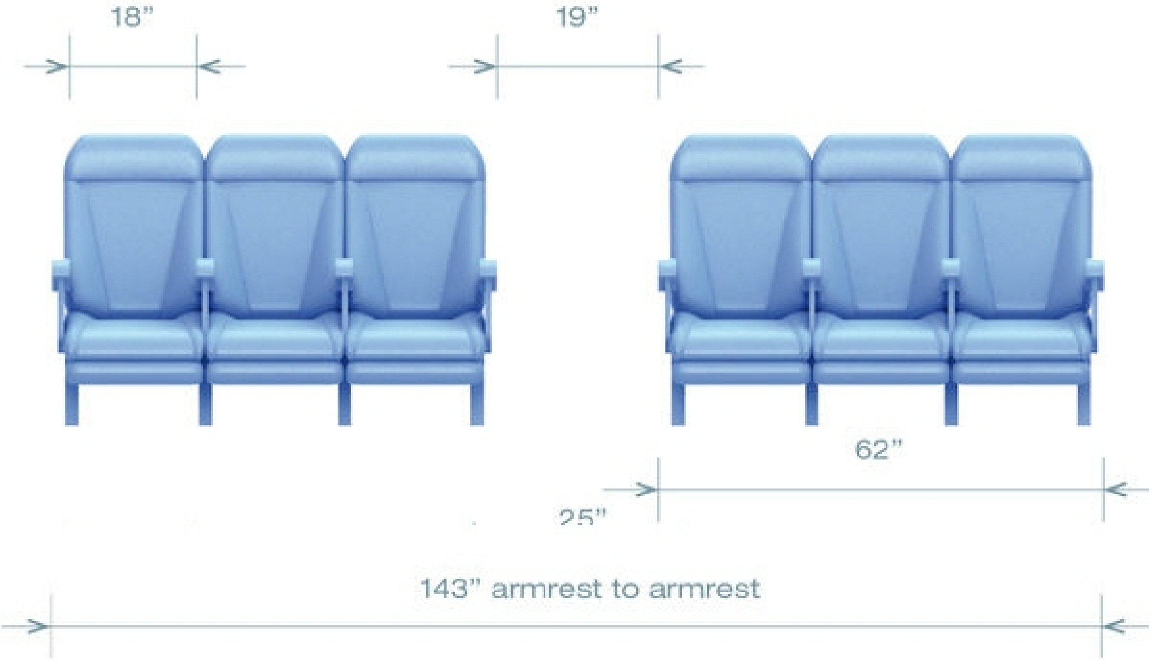
COMAC C919 Measurements (if not readable from the graph):

Height:	4166 mm	**Below:**	1578 mm	**Floor:**	150 mm
Seat:	457.2 mm		2640 mm	**Cargo:**	1250 mm
Aisle:	500 mm		3664 mm		
Cabin:	R1980 mm		3960 mm		
	1620 mm		R1778 mm		
	2250 mm				

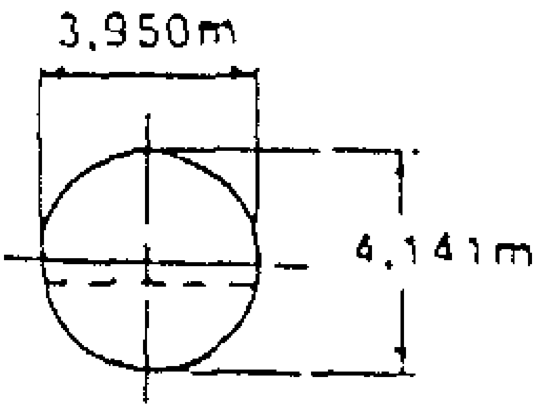
Aibus A320 Measurements (if not readable from the graph):

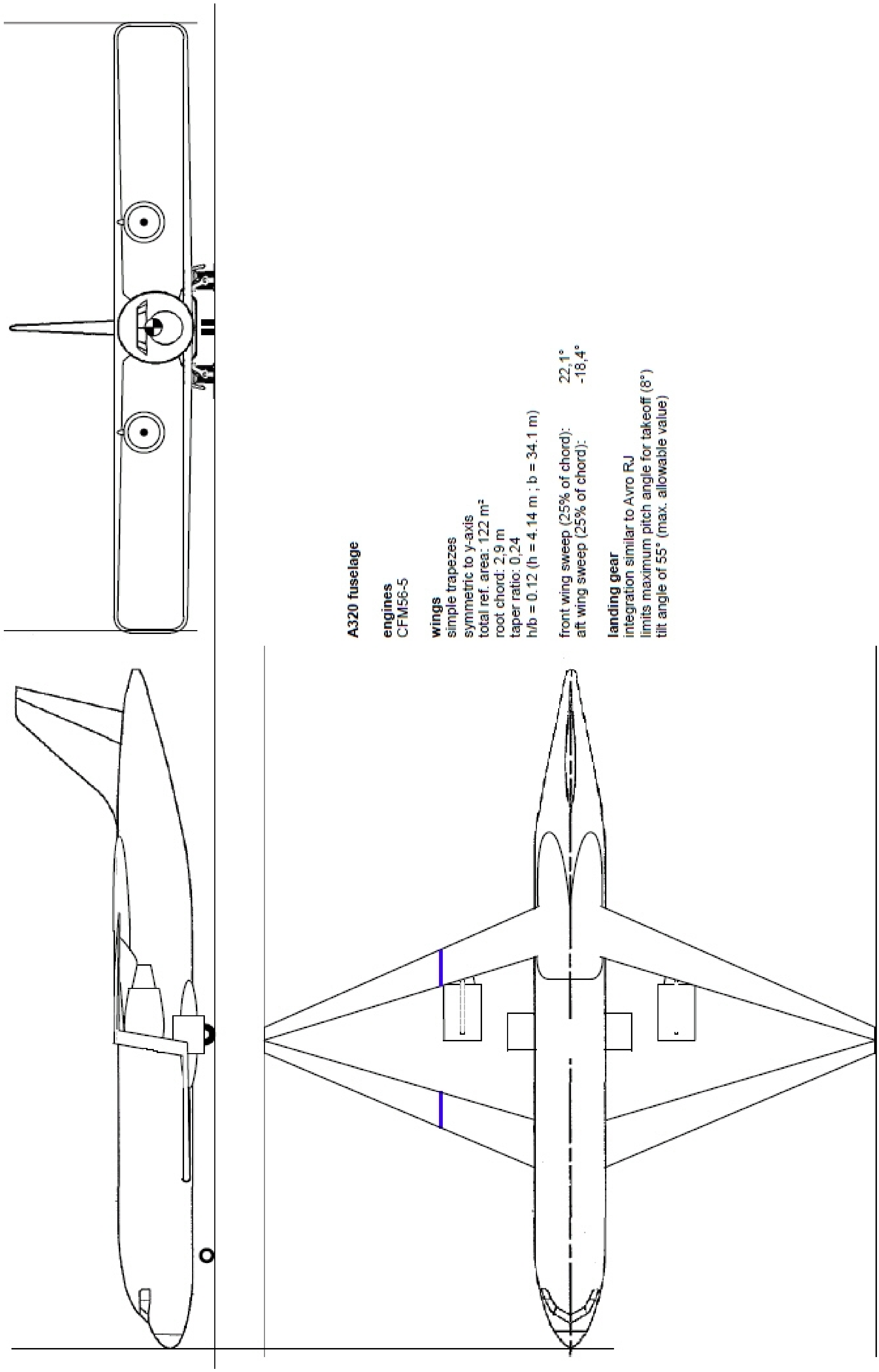
Height: 2.22 m

A320 Seating:



A320 Cross Section:




A320 fuselage
engines
CFM56-5
wings
simple trapezes
symmetric to y-axis
total ref. area: 122 m²
root chord: 2,9 m
taper ratio: 0,24
h/b = 0.12 (h = 4.14 m ; b = 34.1 m)
front wing sweep (25% of chord): 22,1°
aft wing sweep (25% of chord): -18,4°
landing gear
integration similar to Avro RJ
limits maximum pitch angle for takeoff (8°)
tilt angle of 55° (max. allowable value)