

## Project 3 – Weight analysis

This project consists of two parts. First part includes fuselage interior (cockpit) conceptual design. Second part includes mentioned weight analysis – computing the position of centre of gravity.

### Cockpit (fuselage interior) project

Cockpit (fuselage interior) project should be done in form of a drawing, that shows arrangement of the aircraft equipment, taking ergonomic rules into account. In order to do that, one can use [Sizing guide for cockpits](#) placed on the website. Below, there are three examples of cockpit (fuselage) projects from previous years. These drawings are only an example and should not be used as a sample or template.

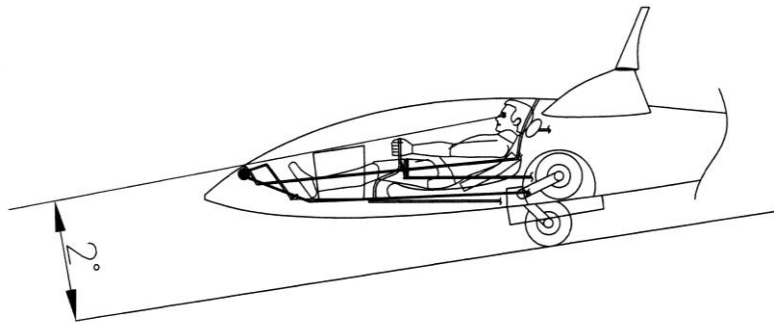


Fig. 1 – Project of glider's cockpit [1]

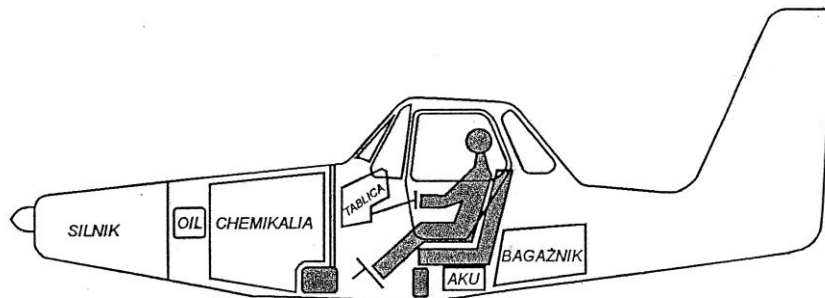


Fig. 2 – Project of agricultural aircraft's cockpit [2]

## Rozmieszczenie pasażerów (z podziałem na klasę biznes i ekonomiczną)

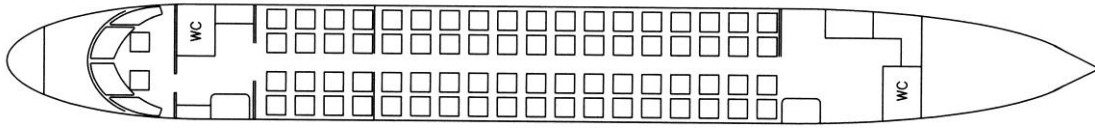


Fig. 3 – Project of a passenger aircraft’s cabin – top view [3]

## Rozmieszczenie bagażu (dwa luki w dolnej części kadłuba i skrytki nad głowami pasażerów)

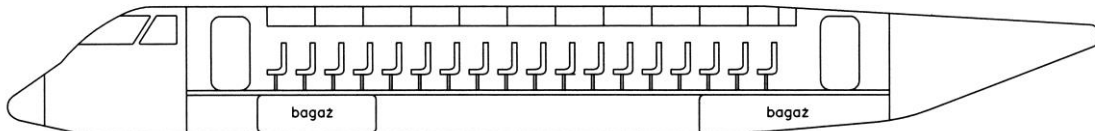


Fig. 4 – Project of a passenger aircraft’s cabin – side view [3]

## Aircraft’s weight analysis

The weight analysis starts with dividing the aircraft’s body into the components (structure, equipment, payload etc.), and estimating the weight of these components, as well as positions of their centres of gravity. In order to do that, one should make a drawing called a weight breakdown (Fig. 5). Next, using relations (1-2) the position of centre of gravity can be determined and its position can be computed to a scheme related to the mean aerodynamic chord. Component mass data should be presented in a table, and calculations should be done e.g. according to the scheme shown below. Example shown in Tab.1 shows only a method of presenting results. Number of aircraft’s components taken into consideration should be usually higher.

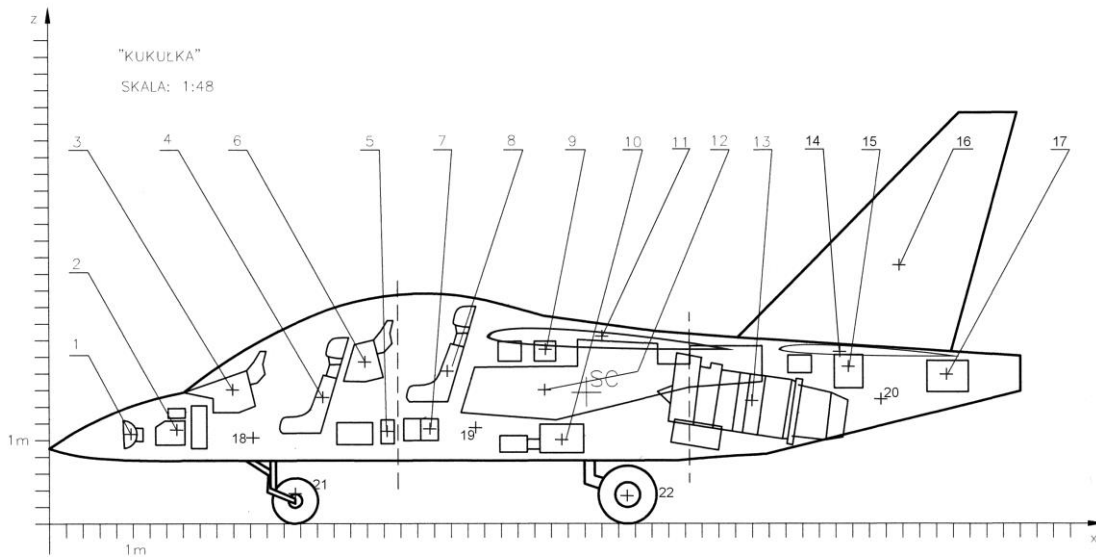


Fig. 5 – Jet trainer’s weight breakdown example (student project [4])

Calculations scheme:

1. Estimation of aircraft’s components weight – calculations and estimations are done based on statistic data and statistic formulas from [5,6],
2. Loading variants definition,
3. Computing the Mean Aerodynamic Chord and it’s position,
4. Computing CG (centre of gravity) according to formulas::

$$X_{CG} = \frac{\sum_{i=1}^n m_i x_i}{\sum_{i=1}^n m_i}, \quad Y_{CG} = \frac{\sum_{i=1}^n m_i y_i}{\sum_{i=1}^n m_i}, \quad Z_{CG} = \frac{\sum_{i=1}^n m_i z_i}{\sum_{i=1}^n m_i} \quad (1)$$

5. Computing CG position in percent of MAC:

$$x_{CG}[\%] = 100(X_{CG} - (X_A - 0.25Ca)) / Ca \quad (2)$$

where:

$Ca$  – mean aerodynamic chord (MAC),  
 $X_A$  – position of  $\frac{1}{4}$  of MAC

No.	Component	$m_i$	$x_i$	$z_i$	$m_i \times x_i$	$m_i \times z_i$
1	Radar	25	0.96	1.08	24.0	27.0
2	Electronic equipment #1	40	1.60	1.09	64.0	43.6
3	Avionics #1	35	2.30	1.62	80.5	56.7
4	Ejection seat #1	110	3.17	1.42	348.7	156.2
5	Electronic equipment #2	40	3.84	1.08	153.6	43.2
6	Avionics #2	35	3.88	2.00	135.8	70.0
7	Battery	40	4.37	1.11	174.8	44.4
8	Ejection seat #2	110	4.72	1.77	519.2	194.7
9	Electronic equipment #3	40	5.72	2.05	228.8	82.0
10	Air conditioning	60	5.94	1.02	356.4	61.2
11	Wings	810	6.51	1.58	5273.1	1279.8
12	Fuel tank	130	5.71	1.76	742.3	228.8
13	Engines	1000	8.29	1.46	8290.0	1460.0
14	Horizontal tail	180	9.15	1.66	1647.0	298.8
15	APU	250	9.30	1.86	2325.0	465.0
16	Vertical tail	95	10.05	2.76	954.8	262.2
17	Electronic equipment	30	10.73	1.77	321.9	53.1
18	Fuselage section #1	750	2.54	1.52	1905.0	1140.0
19	Fuselage section #2	1050	4.90	1.61	5145.0	1690.5
20	Fuselage section #3	450	9.29	1.46	4180.5	657.0
21	Nose landing gear	40	2.85	0.50	114.0	20.0
22	Main landing gear	100	6.70	0.50	670.0	50.0
Sum		5420			33654.4	8384.2

Tab. 1 – Weight breakdown – geometry and weight data (example [4])

Final results should be shown in a following form:

$$X_{CG} = 6.209 \text{ m}$$

$$Z_{CG} = 1.547 \text{ m}$$

$$\text{Mean aerodynamic chord } 1.7 \text{ m}$$

$$\text{X of MAC nose } 5.7 \text{ m}$$

$$X_{CG} = 30\%$$

One should check, if CG in extreme positions meets the conditions related to its position in relation to the [wheelbase of landing gear](#). If these conditions aren't met, changes to a project, leading to meeting these conditions, should be suggested.

## References:

1. Maciej Kalwara, Łukasz Pruszyński, Szybowiec klasy otwartej – student project – Politechnika Warszawska 2006
2. Piotr Araszkievicz, Adam Toczek, Dawid Wróbel, Piotr Busz, Lekki samolot wsparcia ekologicznego – student project – Politechnika Warszawska 2005
3. Marcin Chrust, Andrzej Gajda, Piotr Nowacki, Łukasz Skonecki, Wiktor Stołowski – „Bening” regional jet – student project – Politechnika Warszawska 2006
4. Tomasz Bąk, Łukasz Mężyk, Kamil Stępień, Piotr Wodyński, Odrzutowy samolot szkolno-bojowy “Kukułka” – student project – Politechnika Warszawska 2006
5. St. Danilecki „Projektowanie samolotów”, Oficyna Wydawnicza Politechniki Warszawskiej, Warszawa 2000
6. D.P. Raymer „Aircraft Design, a Conceptual Approach”, AIAA Education Series, 2012