Početna procena mase letelica

Konstrukcija i tehnologija proizvodnje letelica

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Miloš Petrašinović

2019/2020.

Deo I

Kratki uvod u MATLAB/Octave

Sadržaj

Uvod

Primer programa/skripta

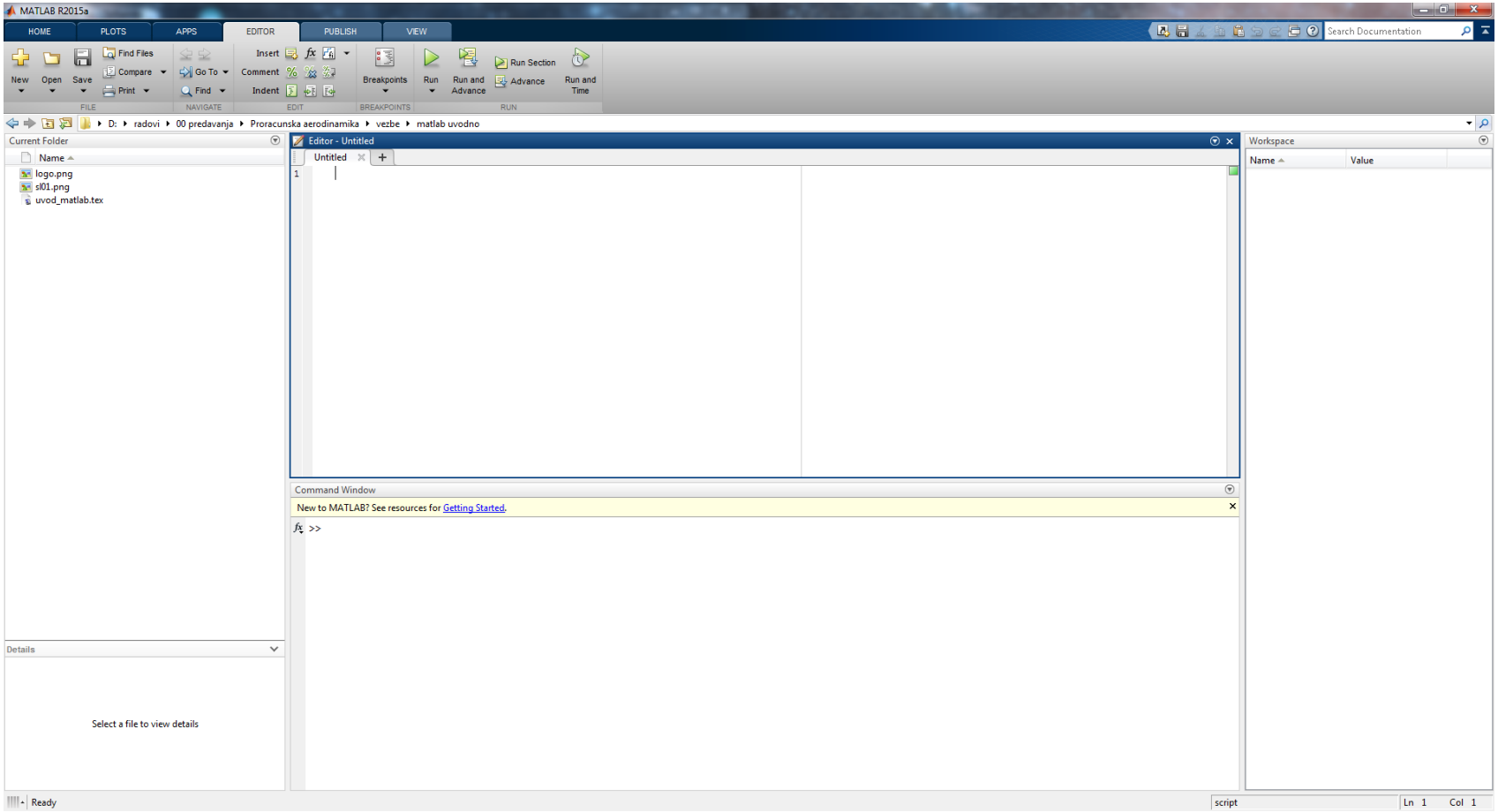
Interaktivna upotreba

Zadaci za vežbu

Korisne informacije

- Inženjerski alati/programski jezici:
  - Python,
  - MATLAB, Octave,
  - FORTRAN,
  - C, C++,
  - Maxima, Maple,
  - Mathematica
  - ...
- Čitati i koristiti zvaničnu dokumentaciju!
- Korisni linkovi:
  - `https://ftp.gnu.org/gnu/octave/windows/`
  - `https://maxima.en.softonic.com`
  - `https://www.maplesoft.com/MapleEducation/`
  - `https://www.wolfram.com/mathematica/`

Radno okruženje MATLAB-a



Primer programa/skripta

```
% vertikalni hitac
clear all   % pocisti sve promenljive
clc         % pocisti komandni prozor

% naredbe dodele
vo = 5;     % pocetna brzina
g = 9.81;   % ubrzanje zemljine teze
t = 0.6;    % vreme
% izracunavanje vertikalnog polozaja/koordinate
% rezultat je skalar koji se ispisuje
y = vo*t - 0.5*g*t^2
```

Primer – vertikalni hitac

Editor - D:\radovi\00 predavanja\Proracunska aerodinamika\vezbe\matlab uvodno\pr01.m

pr01.m

```
1     % vertikalni hitac
2 -   clear all   % pocisti sve promenljive
3 -   clc         % pocisti komandni prozor
4
5     % naredbe dodele
6 -   vo = 5;     % pocetna brzina
7 -   g = 9.81;   % ubrzanje zemljine teze
8 -   t = 0.6;    % vreme
9     % izracunavanje vertikalnog polozaja/koordinate
10    % rezultat je skalar koji se ispisuje
11 -  y = vo*t - 0.5*g*t^2
12
```

Command Window

New to MATLAB? See resources for Getting Started.

```
y =

    1.2342

fx >>
```

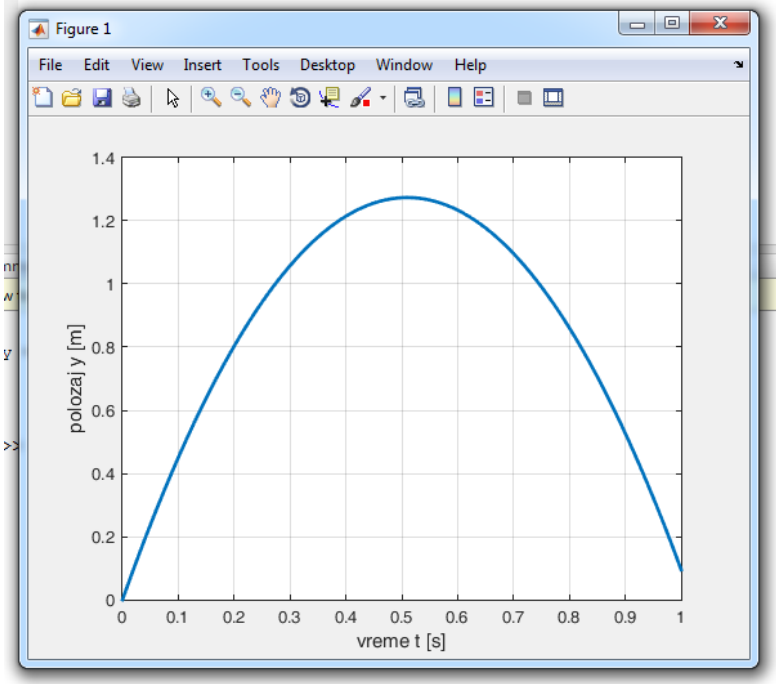
Primer programa/skripta

```
% za vise vremenskih trenutaka
t = 0:0.01:1;   % 1. nacin, definicija niza
% 2. nacin, uniformno rasporedjen niz, fja linspace
t = linspace(0, 1, 101);
% izracunavanje vertikalnog polozaja/koordinate
% rezultat je vektor koji se skicira
y = vo*t - 0.5*g*t.^2;

figure
plot(t, y, 'linewidth', 2)
xlabel('vreme t [s]'), ylabel('polozaj y [m]')
grid on
```

Primer – vertikalni hitac

pr01.m

```
% za vise vremenskih trenutaka
t = 0:0.01:1;   % 1. nacin, definicija niza
t = linspace(0, 1, 101); % 2. nacin, uniformno rasporedjen niz
% izracunavanje vertikalnog polozaja/koordinate
% rezultat je vektor koji se skicira
y = vo*t - 0.5*g*t.^2;

figure
plot(t, y, 'linewidth', 2)
xlabel('vreme t [s]'), ylabel('polozaj y [m]')
grid on
```



Interaktivna upotreba u komandnom prozoru

- `>> 2+2`

  ans = 4
- `>> 2*3`

  ans = 6
- `>> 10/3`

  ans = 3.3333
- `>> 2^3`

  ans = 8
- `>> a = sqrt(5)`

  a = 2.2361
- `>> fprintf('%6.2f %8.3f\n', a, a+3)`

  2.24 5.236
- `>> h = zeros(4,2); h(1,1) = 3; h(1,2) = 2;`
- `>> sin(pi/4)`

  ans = 0.7071

Interaktivna upotreba u komandnom prozoru

Slično, moguće je:

- definisanje i manipulacija promenljivim,
- definisanje funkcija,
- skiciranje fja (1d, 2d),
- rad sa nizovima, matricama,
- množenje matrica,
- nalaženje determinante, inverzne, transponovane matrice,
- rešavanje sistema jednačina,
- nalaženje nula, minimuma, maksimuma funkcija/nizova,
- diferenciranje/integraljenje fja,
- generisanje slučajnih brojeva,
- ...

Zadaci za vežbu

1. Igrati se sa skriptovima i videti šta se dogadja kada:
   - se ukloni znak za komentar %,
   - se ukloni znak = iz naredbe dodele vrednosti,
   - se promeni izraz za izračunavanje

     ```
     y = vo*t - 0.5*g*t.^2
     ```

     u

     ```
     y = vo*t
     ```
   - i sl.
2. Skicirati kubnu fju $f(x) = x^3 - 15x^2 + 2x - 17$ i naći njen min i max na intervalu $x \in [-20, 20]$.
3. Naći sumu (naredba *sum*) i srednju vrednost niza celih brojeva $a = [-5, 1, 3, 7, 18, 25, 35, 98]$. Izvršiti i skicirati transformacije $a + 2$, $3 * a$, $a^2 + 3a + 2$, $\log(a)$. Razmotriti dobijene vrednosti.

Deo II

Početna procena mase lake letelice

Sadržaj

Zahtevi

Analiza izvedenih konstrukcija

Gorivo

Procena mase

Uticaj $(L/D)_{\text{max}}$

Sledeći čas

Zahtevi – 1/4

- Analiza tržišta (potreba),
- Narudžbina,
- Raspisani konkurs,
- Vlastito uverenje da letelica ima veliku budućnost,
- Bilo koji drugi motiv iza kojeg stoje pare . . .

Zahtevi – 2/4

Podaci koji mogu biti zadati u zahtevu:

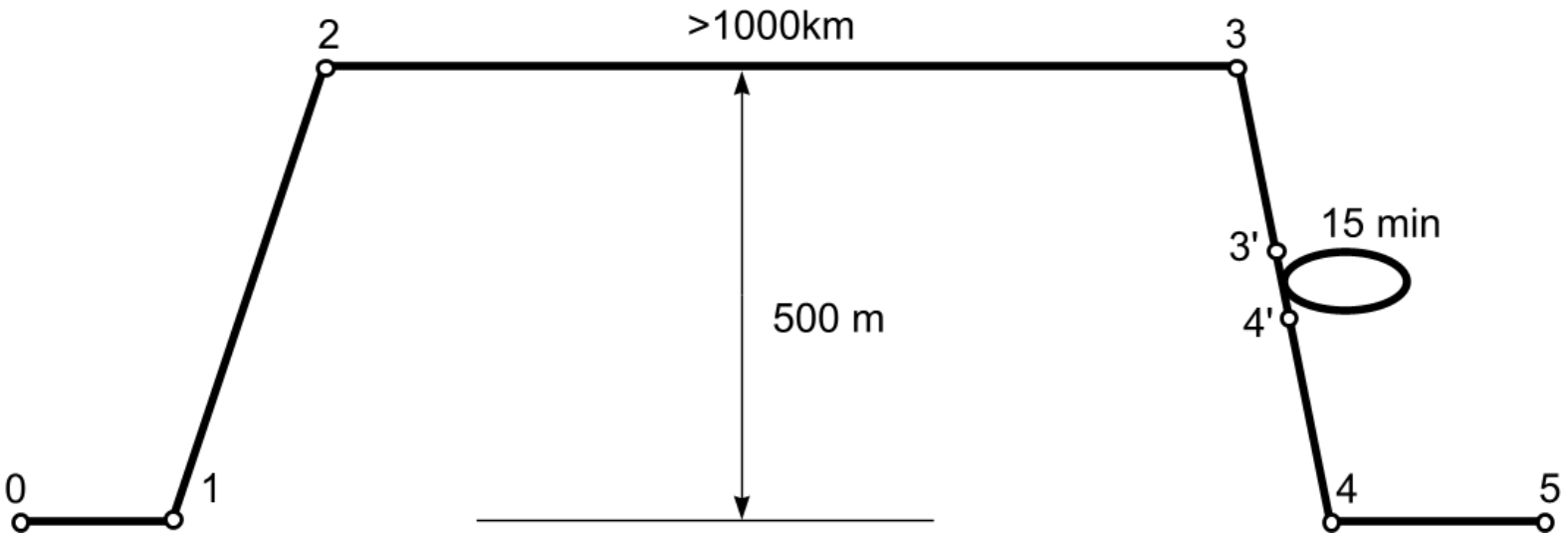
- Kategorija: LSA, ULL - češki, ultralight ili microlight,
- Propisi: ASTM, češki ULL, EASA LSA 1, VLA, ...
- Maksimalna težina: 450 [kg], sa padobranom: 472 [kg],
- Teret: dva putnika i prtljag od 40 – 50 [kg],
- Maksimalna brzina leta: 200 – 240 [km/h],
- Brzina krstarenja: 200 [km/h],
- Dužina poletno-sletne piste: 300 [m], efektivno 150 [m],
- Dolet: veći od 1000 [km],
- Plafon leta: veći od 2000 [m].

Zahtevi – 3/4

Zahtevi (nastavak):

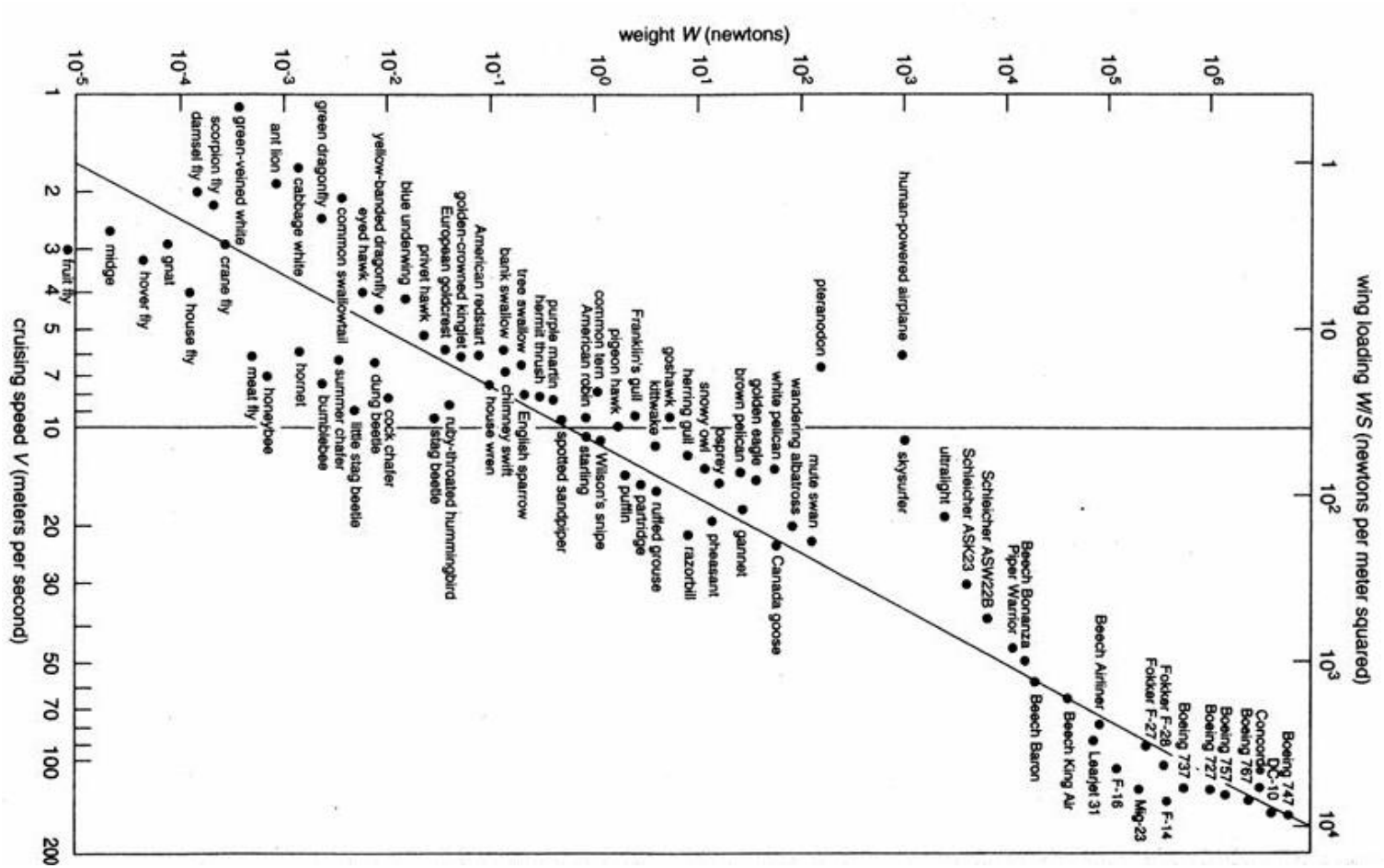
- Motor: 80 [hp] ili 100 [hp],
- Vrata sa obe strane kabine,
- Elisa: podesivog koraka na zemlji,
- Stajni trap: tricikl (nosna noga),
- Krilo: pravougaono, vitopereno,
- Visokokrilac,
- Sletanje i poletanje sa trave,
- Neuvlačivi stajni trap,
- Konstrukcija: metalna, laka za proizvodnju u skromnim uslovima i sa redukovanim alatom.

Zahtevi – 4/4



Slika: Tipična misija leta lakog aviona.

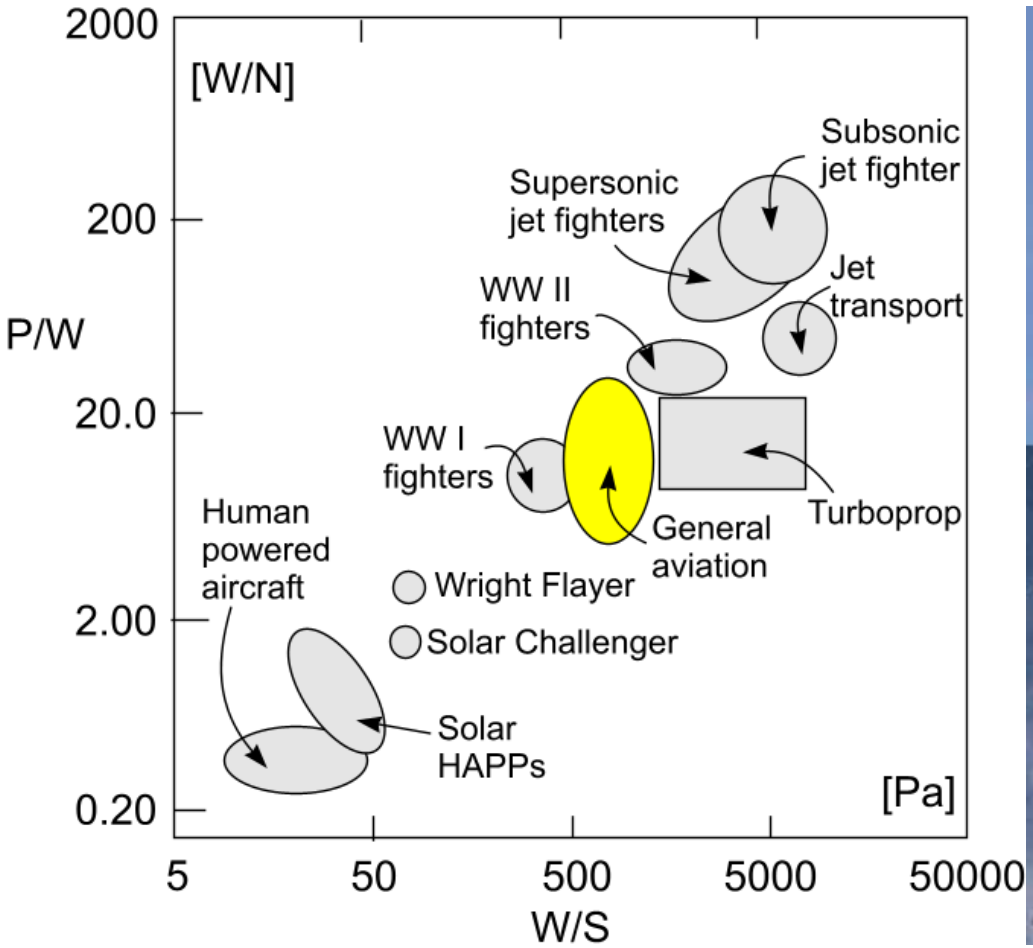
Analiza izvedenih konstrukcija – 1/47



Analiza izvedenih konstrukcija – 2/47

Slika: Najveće odstupanje od trend linije (nestandardne konfiguracije).

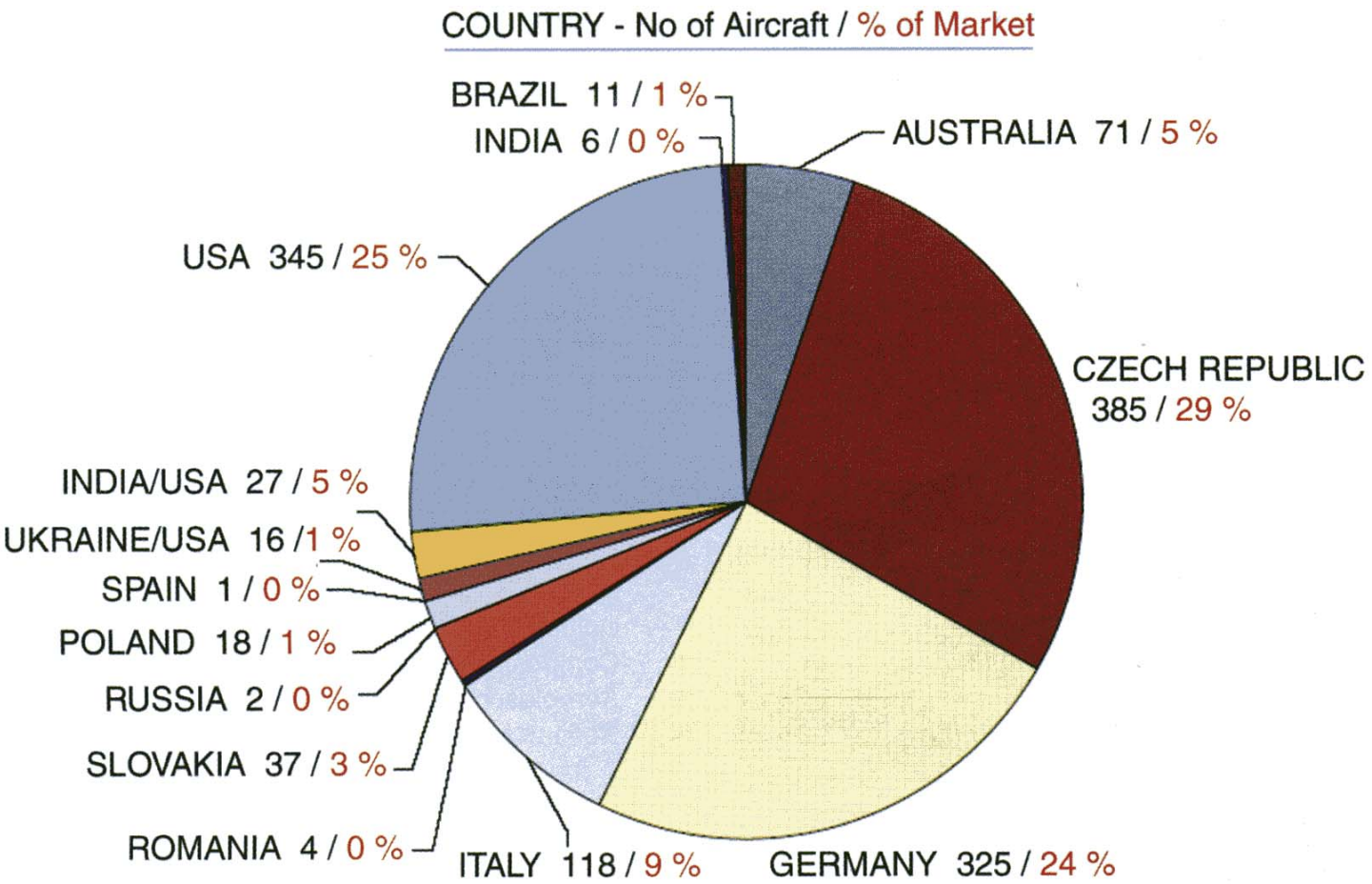
Analiza izvedenih konstrukcija – 3/47



Analiza izvedenih konstrukcija – 4/47

- Za specificirane zahteve neophodno je proceniti masu letelice.
- Uopšte, proces projektovanja letelice započinje procenom mase.
- Kako je naša kategorija limitirana masom potrebno je neke od zahteva prilagoditi propisima.
- Zgodno je ipak videti šta je u okviru te kategorije već napravljeno od letelica.
- Takodje, treba videti šta trendovi kažu za težine (mase) prazne letelice.
- Sledeći slajdovi prikazuju tipične letelice u okviru posmatrane kategorije.

Analiza izvedenih konstrukcija – 5/47



Analiza izvedenih konstrukcija – 6/47

Atec 212 Solo

A single-seat ultralight airplane of composite structure. Fixed tailwheel undercarriage. Stressed for +6/-3 *g*. Powered by Rotax 582UL DCDI or 912UL.
(So far 5 machines built.)

Span 7,50 m, length 5,26 m,
wing area 7,30 m^2,
empty weight 200 kg,
max. level speed (V_h) 245 km/h.

Atec, v.o.s.,
Opolanská 350,
289 07 Libice nad Cidlinou
Czech Republic
www.atecaircraft.eu
e-mail: sales@atecaircraft.eu

Analiza izvedenih konstrukcija – 7/47

Atec 322 Faeta

A two-seat low-wing airplane in LSA category. All carbon structure with wooden wing spar. Fixed tricycle undercarriage. Powered by Rotax 912UL or ULS, with fixed propeller.

Span	9,60 m / 31,50 ft
Length	6,20 m / 20,34 ft
Wing area	10,10 m^2 / 108,72 sq. ft
Empty weight	300 kg / 661 lb
MTOW	550 kg / 1212,5 lb
Max.level speed	222 km/h / 120 kts

Atec, v.o.s.,
Opolanská 350,
289 07 Libice nad Cidlinou
Czech Republic
www.atecaircraft.eu
e-mail: sales@atecaircraft.eu

Analiza izvedenih konstrukcija – 8/47

Atec Zephyr 2000

A two-seat side-by side low-wing ultra light airplane of mixed (composite and wood) structure. Fixed tricycle undercarriage. Powered by Rotax 912UL or ULS, with fixed- or variabl-pitch propellers. The Zephyr 2550 is the LSA version. (190 units of all versions were built so far.)

Span 9,60 m, length 6,20 m,
wing area 10,30 m^2,
empty weight 275 kg,
max. level speed (V_h) 245 km/h.

Atec, v.o.s.,
Opolanská 350,
289 07 Libice nad Cidlinou
Czech Republic
www.atecaircraft.eu
e-mail: sales@atecaircraft.eu

Analiza izvedenih konstrukcija – 9/47

Allegro 2007

Side-by-side two-seat ultralight high-wing aircraft of a mixed structure (all-metal wing and horizontal tail, composite fuselage). Tricycle fixed undercarriage. Powered by Rotax 912UL or ULS. Three-bladed Woodcomp or other types of propellers. (Currently over 300 Allegros of various versions flying.)

Span 10,80 m, length 6,10 m,
wing area 11,40 m^2,
empty weight 280 kg,
max.level speed (V_h) 200 km/h.

Fantasy Air, s.r.o.,
Kollarova 511,
397 01 Písek,
Czech Republic
www.fantasyair.com
e-mail: sales@fantasyair.com

Analiza izvedenih konstrukcija – 10/47

Allegro

Side-by-side two-seat ultralight high-wing aircraft of a mixed structure (all-metal wing and horizontal tail, composite fuselage). Tricycle fixed undercarriage. Powered by Rotax 912UL or ULS. Three-bladed Woodcomp or other types of propellers.

Span	10,80 m / 35,43 ft
Length	6,36 m / 20,87 ft
Wing area	11,40 m^2 / 122,71 sq. ft
Empty weight	280 kg / 617 lb
Max.level speed (V_h)	200 km/h / 108 kts

Fantasy Air, s.r.o.,
Kollarova 511,
397 01 Písek,
Czech Republic
www.fantasyair.com
e-mail: sales@fantasyair.com

Analiza izvedenih konstrukcija – 11/47

FM-250 Mystique

FM 250 Mystique is a low wing aerodynamically clean high performance aircraft. It features all-composite sandwich construction utilizing carbon fibers. Comfortable cockpit with side by side seating. The aircraft is powered by powerful and well proven Rotax 912 series engines.

Span	8,56 m / 28,10 ft
Length	6,28 m / 20,6 ft
Wing area	11,10 m^2 / 119 sq. ft
Empty weight	272 kg / 600 lb
Cruising speed	185km/h / 100 kts

Flying Machines, s.r.o.,
Rasošky 33,
55 221 Rasošky,
Czech Republic
www.flyingmachines.cz
e-mail: info@flyingmachines.cz

Analiza izvedenih konstrukcija – 12/47

M1 SpeedCruiser

M1 SpeedCruiser is a side by side all-metal two-seater or three-seater available as an experimental category kit during 2009. The airplane is powered by 260 HP Lycoming 540 engine with three-blade constant speed propeller manufactured by Avia Propeller. First prototype kit has been flown in June 2008.

Span	8,27 m / 27,12 ft
Length	6,60 m / 21,64 ft
Empty Weight	800 kg / 1777 lb
Gross Weight	1170 kg / 2600 lb
Cruise Speed	350 km/h / 195 kts

High Performance Aircraft International, s.r.o.
Lobeček 732
278 01 Kralupy nad Vltavou
www.hpa-international.com
e-mail: hpai@mbox.cz

Analiza izvedenih konstrukcija – 13/47

scheda tecnica
S5 Velocity

Apertura alare m 8,60
Lunghezza m 6,35
Altezza m 2,42
Corda alare m 1,36
Profilo alare NACA 4415
Superficie alare mq 11,69
Larghezza cabina m 1,12
Motore Rotax 912 ULS 100 hp
Peso a vuoto standard kg 284
Peso max al decollo (ATL) kg 550
Fattore di carico +6 -3G
Velocità di stallo flap km/h 48
Velocità di crociera km/h 174
VNE km/h 228
Autonomia km 700

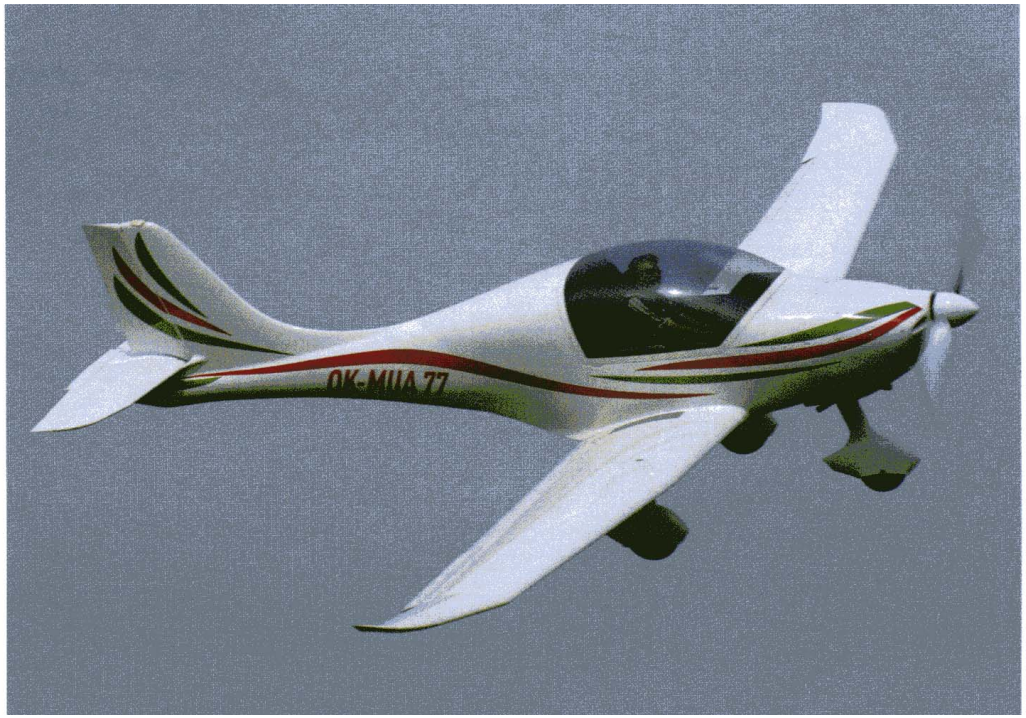
Analiza izvedenih konstrukcija – 14/47

Samba XXL

A side-by-side low-wing light sport aircraft of composite structure. Fixed tricycle undercarriage. Powered by Rotax 912UL or 912ULS engines, with fixed or variable-pitch propeller.

Span	10,00 m / 32,81 ft
Lenght	6,00 m / 19,69 ft
Wing area	8,90 m^2 / 95,80 sq. ft
Empty weight	317,80 kg / 700 lb
Cruising speed	220km/h / 118 kts

Urban Air, s r.o.,
T. G. Masaryka 897
562 01 Ústí nad Orlicí
Czech Republic
e-mail:sales@urbanair.cz



Analiza izvedenih konstrukcija – 15/47

Savage

The Savage is a single-engine, high-wing, two-seater tandem microlight aircraft of classic design.

Span	9,31 m / 30,54 ft
Length	6,39 m / 20,97 ft
Empty weigh	288 kg / 635 lb
Cruising speed	(75%) 170 km/h / 92 kts

Zlin Aviation, s.r.o.,
2. května 685,
Napajedla,
Czech Republic
www.zlinaero.com

Analiza izvedenih konstrukcija – 16/47

Skyleader 500

Side-by-side two-seat low-wing all-metal aircraft suitable for the LSA category. Fixed (or retractable) tricycle undercarriage. Wing with Fowler flaps. Powered by Rotax 912UL, ULS or 914, several types of propellers.

Span	9,90 m / 32,60 ft
Length	7,20 m / 23,62 ft
Wing area	11,85 m^2 / 127,55 sq. ft
Empty weight	315 kg / 695 lb
Cruise speed	200-220 km/h / 108-119 kts

Jihlavan Airplanes, s.r.o.,
Znojemská 826/64,
586 01 Jihlava,
Czech Republic
www.skyleader.aero
e-mail: market@skyleader.aero

Analiza izvedenih konstrukcija – 17/47

Sport Star SL

A side-by-side low-wing LSA -category two-seater of all-metal structure. Fixed tricycle undercarriage. Powered by Rotax 912ULS engine, with fixed or variable-pitch propeller.

Span 8,65 m / 28,38 ft
Length 5,98 / 19,62 ft
Wing area 10,47 m^2 / 112,69 sq. ft
Empty weight 303 kg / 668 lb
Cruising speed 204 km/h / 110 kts

Evektor-Aerotechnik, a.s.,
Letecká 1384,
686 04 Kunovice,
Czech Republic
www.evektor.com
e-mail: marketing@evektor.cz

Analiza izvedenih konstrukcija – 18/47

Sportcruiser

An all-metal two-seat side-by side low-wing LSA airplane. Fixed tricycle undercarriage. Powered by Rotax 912ULS. Woodcomp propellers are two-bladed fixed or three-bladed variable-pitch ones.

Span	8,20 m / 26,90 ft
Length	6,90 m / 22,64 ft
Wing area	12,30 m^2 / 132,40 sq. ft
Empty weight	340 kg / 750 lb
Cruise speed	200 km/h / 108 kts

Czech Aircraft Works, s.r.o.,
Na Záhonech 212,
686 04 Kunovice,
Czech Republic
www.aircraft.cz
e-mail: info@czaw.cz

Analiza izvedenih konstrukcija – 19/47

Sting Sport

A side-by-side composite low-wing ultra light two-seater. Fixed tricycle undercarriage. Powered by Rotax 912UL, 912ULS or 914 or similar engines, turning fixed or variable-pitch propellers. (62 machines have been manufactured so far)

Span 8,44 m, length 5,93 m,
wing area 9,80 m^2,
empty weight 275 kg,
cruising speed 200 - 260 km/h.

TL Ultralight, s.r.o.,
Letiště - budova č. 84,
503 41 Hradec Králové,
Czech Republic
www.tl-ultralight.cz
e-mail: info@tl-ultralight.cz

Analiza izvedenih konstrukcija – 20/47

S-Wing

A braced high-wing composite structure ultra light side-by-side two-seater. Fixed tricycle undercarriage. Powered by Rotax 912UL or 912ULS engines with two-bladed, ground-adjustable composite Woodcomp propellers.

Span	10,20 m / 33,47 ft
Length	6,29 m / 20,64 ft
Wing area	12,68 m^2 / 136,49 sq. ft
Empty weight	296 kg / 653 lb
Cruising speed	160 km/h / 86 kts

Vladimír Rajchl,
L. M. Pařízka 495/8,
370 01 České Budějovice,
Czech Republic
www.s-wing-cz
e-mail: v.rajchl@volny.cz

Analiza izvedenih konstrukcija – 21/47

VL-3

A two-seat side-by side low-wing all-composite structure airplane, approved for both ultralight (450 kg) and up to 600 kg (LSA) category of MTOW. Available with retractable or fixed tricycle undercarriage, respectively. Powered by Rotax 912ULS, with fixed or variable-pitch propellers. The VL-3 holds of the world speed record in the RAL2 category.

Span	8,44 m / 27,69 ft
Length	6,20 m / 20,34 ft
Wing area	9,80 m^2 / 105,49 sq. ft
Empty weight	280-305 kg / 617-673 lb
Max.level speed V_h	280 km/h / 151 kts

Design:

Vanessa air s.r.o.,
Kornická 86,
570 01 Litomyšl,
Czech Republic
www.vanessaair.cz
e-mail: vanessaair@lit.cz

Manufacturer:

Aveko s.r.o.,
Lipová 22,
602 00 Brno,
Czech Republic
www.aveko.com
e-mail: info@aveko.com

Analiza izvedenih konstrukcija – 22/47

KP-2U Rapid 200

Side-by-side two-seat low-wing all-metal ultralight. Retractable tricycle undercarriage. Wing with Fowler flaps. Powered by Rotax 912UL, ULS or 914, several types of propellers. (145 machines have been built.)

Span 9,90 m, length 7,20 m,
wing area 11,85 m2,
empty weight 282 kg,
cruise 200 - 220 km/h.

Jihlavan Airplanes, s.r.o.,
Znojemská 826/64,
586 00 Jihlava,
Czech Republic
www.ultralight.cz
e-mail:info@ultralight.cz

Analiza izvedenih konstrukcija – 23/47

DV-1 Skylark

Two-seat side-by-side, all-metal low-wing ultralight. Fixed tricycle undercarriage. Powered by Rotax 912ULS, eventually BMW or Alpha Prag. Propellers are fixed or variable-pitch. There is also a LSA version. (So far 50 aircraft are flying.)

Span 8,13 m, length 6,62 m,
wing area 9,84 m^2,
empty weight 285 kg,
cruise speed 215 km/h.

Dova Aircraft, s.r.o.,
Kirilovova 115,
739 21 Paskov
Czech Republic
www.dovaaircraft.cz
e-mail: centrum@@dovaas.cz

Analiza izvedenih konstrukcija – 24/47

F-80/F-100 Nemesis

A side-by-side composite low-wing ultra light or LSA two-seater. The UL version has a retractable tricycle undercarriage, the F-100 LSA has a fixed one. Powered by Rotax 912UL, 912ULS or 914 or similar engines, turning two- or three-bladed variable- (the F-100 LSA has a fixed-) pitch propeller.

Span 9,00 m, length 6,65 m,
wing area 10,7 m^2,
weight 284 kg,
cruising speed 247 km/h.

UL Jih, s.r.o.,
Omlenická 742,
382 41 Kaplice,
Czech Republic
www.uljih.cz
e-mail: info@uljih.cz Woodcomp.

Analiza izvedenih konstrukcija – 25/47

Jora

A composite-structure braced high-wing side-by-side two-seater ultralight. Fixed tricycle undercarriage. Powered by a choice of engines - Jabiru 2200, Rotax 912UL or Rotax 582. The propeller is a two-bladed, ground-adjustable Woodcomp. (115 aircraft have been built, including the kits.)

Span 9,80 m, length 6,05 m,
wing area 11,40 m^2,
weight 262 - 275 kg,
max. level speed (V_h) 186 km/h.

Jora, spol. s r.o.,
565 42 Vraclav,
Czech Republic,
www.jora.cz
e-mail: joraul@quick.cz

Analiza izvedenih konstrukcija – 26/47

KP-5 Rapid 500

Side-by-side two-seat low-wing all-metal aircraft suitable for the LSA category. Fixed (or retractable) tricycle undercarriage. Wing with Fowler flaps. Powered by Rotax 912UL, ULS or 914, several types of propellers. (12 machines have been built to date.)

Span 9,90 m, length 7,20 m,
wing area 11,85 m^2,
empty weight 315 kg,
cruise 200 - 220 km/h.

Jihlavan Airplanes, s.r.o.,
Znojemská 826/64,
586 00 Jihlava,
Czech Republic
www.ultralight.cz
e-mail:info@ultralight.cz

Analiza izvedenih konstrukcija – 27/47

Parrot

A two-seat side-by side low-wing LSA airplane of all-metal structure. Fixed tricycle undercarriage. Powered by Rotax 912ULS or Jabiru 3200, Woodcomp propellers are two-bladed fixed or three-bladed variable-pitch ones. (Initial production, 4 machines were built so far.)

Span 9.50 m, length 7,60 m,
wing area 12,40 m^2,
empty weight 390 kg,
cruise speed 200 km/h.

Czech Aircraft Works, s.r.o.,
Na Záhonech 212,
686 04 Kunovice,
Czech Republic
www.aircraft.cz
e-mail: info@czaw.cz

Analiza izvedenih konstrukcija – 28/47

Skyboy

Side-by-side high-wing ultralight two-seater of mixed galssfibre and metal structure. Fixed tricycle undercarriage. Powered by Rotax 582 or 912UL, turning a three-bladed Woodcomp or four-bladed Warpdrive propeller. 90 airplanes are flying so far.

Span 9,00 m, length 6,00 m,
wing area 13,50 m^2,
empty weight 285 kg,
max. level speed (V_h) 140 km/h.

Interplane, s.r.o.,
285 21 Zbraslavice,
Czech Republic
www.interplaneaircraft.com
e-mail: interplane@cemail.cz

Analiza izvedenih konstrukcija – 29/47

Skylane UL

A two-seat side by side high-wing ultra-light airplane of mixed structure with dominant composites. Fixed tricycle undercarriage. Powered by Rotax 912UL, Woodcomp fixed two-bladed propeller. (7 pre-series machines fly-ing.)

Span 8,95 m, length 6,65 m,
wing area 10,57 m^2,
empty weight 258 kg,
max. level speed (V_h) 140 km/h.

AirLony,
Nové Náměstí 702,
411 08 Štětí
Czech Republic
www.airlony.cz
e-mail: airlony@airlony.cz

Analiza izvedenih konstrukcija – 30/47

TL-96 Star

A side-by-side low-wing ultralight of composite structure. Fixed tricycle undercarriage. Powered by Rotax 912UL or 914 or similar engines, with fixed or variable-pitch propellers.
(So far 220 aircraft have been produced.)

Span 9,20 m, length 6,50 m,
wing surface 12,20 m^2,
empty weight 275 kg,
cruise speed 180 - 220 km/h.

TL Ultralight, s.r.o.,
Letiště - budova č. 84,
503 41 Hradec Králové,
Czech Republic
www.tl-ultralight.cz
e-mail: info@tl-ultralight.cz

Analiza izvedenih konstrukcija – 31/47

Trener UL

Tandem low-wing ultralight two-seater of mixed structure (metal or wooden wing). Fixed (or retractable), tailwheel undercarriage. Powered by Parma Technik Mikron IIIC. (So far 12 aircrfat built and flown.)

Span 8,68 m, length 6,40 m,
wing area 10,80 m^2,
empty weight 292 kg,
cruise speed 165 km/h.

Tomáš Podešva,
výroba a opravy UL letadel,
Újezd u Uničova 87,
783 96,
Czech Republic
www.podesva-air.com
e-mail:t.podesva@cmail.cz

Analiza izvedenih konstrukcija – 32/47

UFM-13 Lambada

A side-by-side mid-wing ultralight of composite structure. Fixed tricycle or tailwheel undercarriage. Powered by Rotax 912UL, 912ULS or Jabiru 2200 engines, with fixed or variable-pitch propeller. The wing may be fitted with longer wingtip extensions, increasing the span to 15 m. (So far 112 aircraft in the UFM-11 and UFM-13 versions have been produced.)

Span 13,00 m, length 6,60 m,
wing area 12,60 m^2,
empty weight 265 - 280 kg,
cruise speed 150 km/h.

Urban Air, s r.o.,
Dolní Libchavy 83,
561 16 Libchavy
Czech Republic
www.urban air.cz
e-mail:trade@urbanair.cz

Analiza izvedenih konstrukcija – 33/47

VUT-100 Cobra

A a four-seat low-wing touring airplane of all-metal structure. Retractable tricycle undercarriage. A "glass" cockpit with the PFD and MFD displays.
Powered by Lycoming IO-580-B1A of 235 kW/315 hp with a three-bladed constant-speed propeller. Two prototypes are flying.

Span 10,50 m, length 8,00 m,
wing area 12,20 m^2,
empty weight 880 kg, MTOW 1 450 kg,
cruising speed 310 km/h.

Evektor-Aerotechnik, a.s.,
Letecká 1384,
686 04 Kunovice,
Czech Republic
www.evektor.com
e-mail: marketing@evektor.cz

Analiza izvedenih konstrukcija – 34/47

Zlin Z-143L

An all-metal low-wing touring and multi-purpose four-seater. Fixed tricycle undercarriage. Powered by Lycoming O-540J-3A-5, turning a three-bladed Muehlbauer or Hartzell constant-speed propeller. Certified according to FAR 23, 56 machines built so far)

Span 10,14 m, length 7,58 m,
weight empty equipped 850 kg,
MTOW 1350 kg,
cruising speed 232 km/h.

Moravan Aviation, s.r.o.
Letiště 1578,
765 81 Otrokovice,
Czech Republic
www.zlinaircraft.cz
e-mail: m.aeroplane@zlinaircraft.cz

Analiza izvedenih konstrukcija – 35/47

Zlin Z-143LSi

An all-metal low-wing touring and multi-purpose four-seater. Fixed tricycle undercarriage. Powered by Lycoming IO-540C-4D-5, turning a three-bladed Muehlbauer constant-speed propeller. Certified according to FAR 23, 4 machines built so far)

Span 10,14 m, length 7,58 m,
wing area 14,87 m^2 ,
weight empty equipped 850 kg,
MTOW 1350 kg,
cruising speed 243 km/h.

Moravan Aviation, s.r.o.
Letiště 1578,
765 81 Otrokovice,
Czech Republic
www.zlinaircraft.cz

Analiza izvedenih konstrukcija – 36/47

Zlin Z-242L

An all-metal low-wing training and sports side-by-side two-seater. Suitable for aerobatics (+6 and -3,5 *g* in the aerobatic category). Fixed tricycle undercarriage. Powered by Lycoming AEIO-360A-1B-6 turning a three-bladed Muehlbauer or Hartzell constant-speed propeller. Certified according to FAR 23, 135 machines built so far)

Span 9,34 m, length 6,94 m,
weight empty equipped 730 kg,
MTOW 970 kg,
cruising speed 227 km/h.

Moravan Aviation, s.r.o.
Letiště 1578,
765 81 Otrokovice,
Czech Republic
www.zlinaircraft.cz
e-mail: m.aeroplane@zlinaircraft.cz

Analiza izvedenih konstrukcija – 37/47

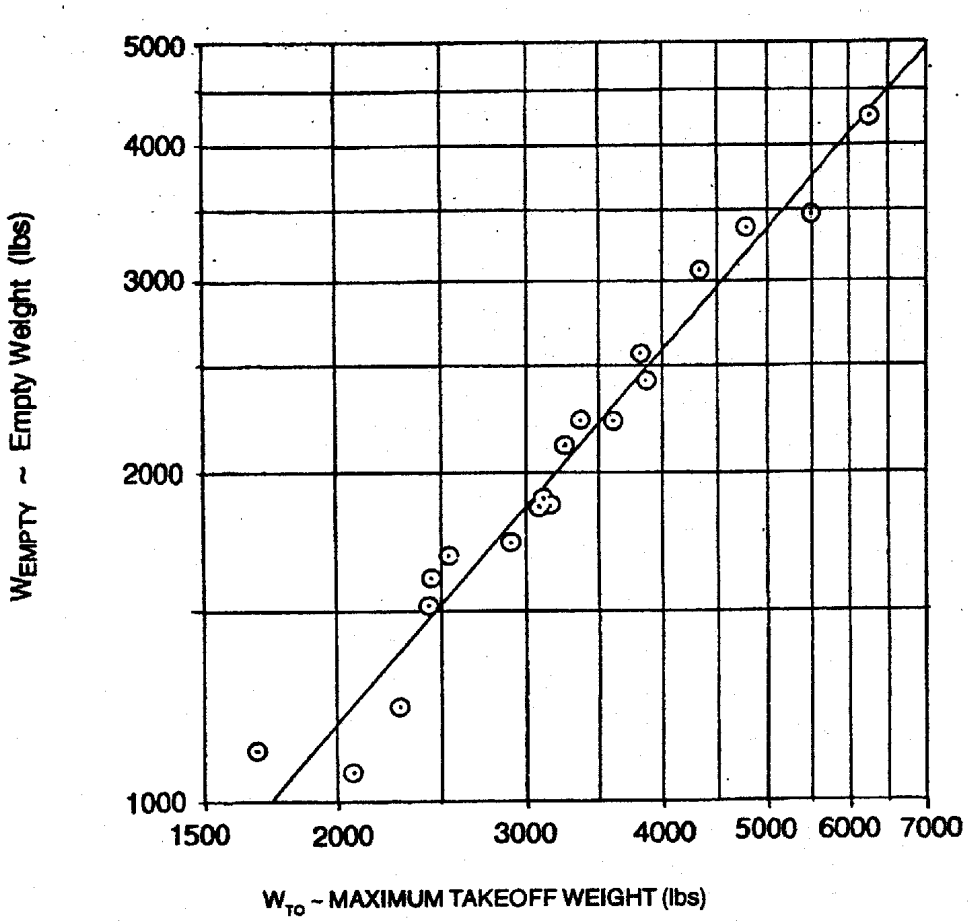
Neki zaključci:

- Klasična aerodinamička šema – simetrična konstrukcija koja se sastoji iz trupa, krila i zadnjih stabilizirajućih površina,
- Položaj krila – najčešće visoko- ili niskokrilac,
- Jedan motor u prednjem delu (moguće i u zadnjem – kao vučna ili potisna elisa, ili kod lakih letelica dva motora na krilima),
- Najčešća klasična konfiguracija repnih površina,
- Stajni trap – tricikl (nosna noga) ili konvencionalni (zadnji točak).

Tabela: Pregled parametara LSA kategorije letelica

Letelica	W_o [kg]	W_e [kg]	b [m]	S [m^2]	L [m]	AR	V_h, V_{max} [km/h]	Motor
Atec 212 Solo	-	200	7.5	7.30	5.26	7.71	245	Rotax 912UL
Atec 322 Faeta	550	300	9.6	10.1	6.2	9.12	222	Rotax 912UL
Atec Zephyr 2000	-	275	9.6	10.3	6.2	8.95	245	Rotax 912ULS
Allegro 2007	-	280	10.8	11.4	6.1	10.23	200	Rotax 912ULS
DV-1 Skylink	-	285	8.13	9.84	6.62	6.72	215	Rotax 912ULS
FM-250 Mystique	-	272	8.56	11.1	6.28	6.60	185	Rotax 912ULS
M1 SpeedCruiser	1170	800	8.27	-	6.6	-	350	Lycoming 540
S5 Velocity	550	284	8.6	11.69	6.35	6.33	174	Rotax 912ULS
Samba XXL	-	318	10	8.9	6.0	11.24	220	Rotax 912ULS
Savage	-	288	9.31	-	6.39	-	170	-
Skyleader 500	-	315	9.9	11.85	7.2	8.27	220	Rotax 912UL
Sport Star SL	-	303	8.65	10.47	5.98	7.15	204	Rotax 912ULS
Sportcruiser	-	340	8.2	12.3	6.9	5.47	200	Rotax 912ULS
Sting Sport	-	275	8.44	9.8	5.93	7.27	200 $\div$ 260	Rotax 912ULS
S-Wing	-	296	10.2	12.68	6.29	8.21	160	Rotax 912ULS
VL-3	600	305	8.44	9.8	6.2	7.27	280	Rotax 912ULS
KP-2U Rapid 200	-	282	9.9	11.85	7.2	8.27	220	Rotax 912ULS
F-80/F-100 Nemesis	-	284	9.0	10.7	6.65	7.57	247	Rotax 912ULS
Jora	-	275	9.8	11.40	6.05	8.42	186	Jabiru 2200
KP-5 Rapid 500	-	220	9.9	11.85	7.2	8.27	220	Rotax 912ULS
Parrot	-	390	9.5	12.4	7.6	7.28	200	Jabiru 3200
Skylane UL	-	258	8.9	10.57	6.65	7.49	140	Rotax 912UL

Analiza izvedenih konstrukcija – 39/47



Analiza izvedenih konstrukcija – 40/47

Tabela: Letelice GA kategorije

Letelica	W_o [lbf]	W_e [lbf]
Katana Xtreme	1698	1201
Piper PA - 18A -150 Super Cub	2070	1060
Piper PA - 25 -150 Pawnee	2300	1220
Piper PA - 28 -161 Warrior HI	2440	1514
Cessna 172 Skyhawk	2450	1600
Piper PA -28 -181 Archer HI	2550	1683
Mooney MSE	2900	1726
Aerospatiale Trinidad TC	3086	1860
Cessna 182 Skylane	3100	1882
Beech 35 Bonanza	3125	1855
Commander 1148	3250	2102
Mooney Ovation	3368	2225
Piper PA - 32 - 235 Cherokee Six	3400	2026
Cessna 206 Stationair	3616	2227
Piper PA - 44 - 180 Seminole	3800	2576
Beech B36TC	3850	2410
Piper PA - 46 - 350P	4300	3080
Piper PA - 34 - 220 Seneca V	4750	3386
Beech 58 Baron	5500	3481
Aero Commander 500A	6250	4255

Analiza izvedenih konstrukcija – 41/47

a) 

b) 

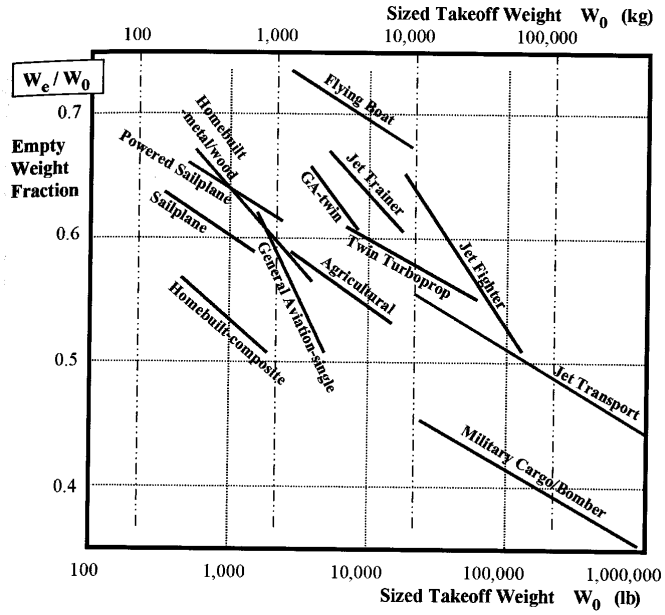
Slika: a) Piper PA 18A 150 Super Cub, b) Diamond Katana Xtreme.

a) 

b) 

Slika: a) Cessna 172 Skyhawk, b) Beech Baron 58.

Analiza izvedenih konstrukcija – 42/47



Slika: Odnos težine prazne letelice prema poletnoj težini.

Za Homebuilt kategoriju od drveta i metala $A = 1.11$, a od kompozita $A = 1.07$.

$$\frac{W_e}{W_o} = A \cdot W_o^{-0.09}$$

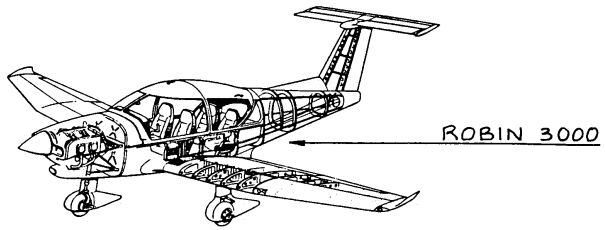
Analiza izvedenih konstrukcija – 43/47

Table 3.1 Empty weight fraction vs W_0

$W_e/W_0 = AW_0^C K_{vs}$	A	{A-metric}	C
Sailplane—unpowered	0.86	{0.83}	−0.05
Sailplane—powered	0.91	{0.88}	−0.05
Homebuilt—metal/wood	1.19	{1.11}	−0.09
Homebuilt—composite	1.15	{1.07}	−0.09
General aviation—single engine	2.36	{2.05}	−0.18
General aviation—twin engine	1.51	{1.4}	−0.10
Agricultural aircraft	0.74	{0.72}	−0.03
Twin turboprop	0.96	{0.92}	−0.05
Flying boat	1.09	{1.05}	−0.05
Jet trainer	1.59	{1.47}	−0.10
Jet fighter	2.34	{2.11}	−0.13
Military cargo/bomber	0.93	{0.88}	−0.07
Jet transport	1.02	{0.97}	−0.06

K_{vs} = variable sweep constant = 1.04 if variable sweep
= 1.00 if fixed sweep

Analiza izvedenih konstrukcija – 44/47



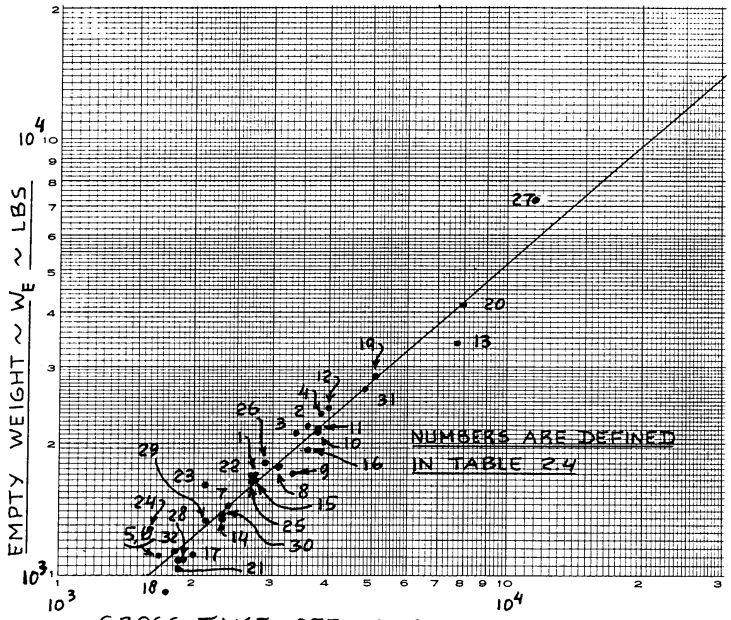


Figure 2.4 Weight Trends for Single Engine Propeller Driven Airplanes

Analiza izvedenih konstrukcija – 45/47

Airplane Type	A	B
1. Homebuilts		
Pers. fun and transportation	0.3411	0.9519
Scaled Fighters	0.5542	0.8654
Composites	0.8222	0.8050
2. Single Engine Propeller Driven	-0.1440	1.1162
3. Twin Engine		
Propeller Driven	0.0966	1.0298
Composites	0.1130	1.0403
4. Agricultural	-0.4398	1.1946
5. Business Jets	0.2678	0.9979
6. Regional TBP	0.3774	0.9647
7. Transport Jets	0.0833	1.0383

Airplane Type	A	B
8. Military Trainers		
Jets	0.6632	0.8640
Turboprops	-1.4041	1.4660
Turboprops without No.2	0.1677	0.9978
Piston/Props	0.5627	0.8761
9. Fighters		
Jets(+ ext.load)	0.5091	0.9505
Jets(clean)	0.1362	1.0116
Turboprops(+ ext.load)	0.2705	0.9830
10. Mil. Patrol, Bomb and Transport		
Jets	-0.2009	1.1037
Turboprops	-0.4179	1.1446
11. Flying Boats, Amphibious and Float Airplanes	0.1703	1.0083
12. Supersonic Cruise	0.4221	0.9876

$$W_e = 10^{(\log_{10} W_o - A)/B}$$

Tabela: Letelice GA kategorije – još podataka

W_o [daN]	W_e [daN]
1200	700
1110	680
760	500
1540	955
1200	740
780	420
1200	700
800	465
1060	620
760	505
1500	1194
999	545
1500	880
1406	784
975	535
1157	641
1043	607
1270	750
1520	770
1635	832
1723	1007
1050	620
1088	726
1730	1002
770	490
1100	570
1230	740
1230	825
1600	1000
3223	1978
1630	1140
1860	1100
1850	1030

Analiza izvedenih konstrukcija – 47/47

Kako bi podaci mogli biti skicirani i analizirani . . .

```
A = 10*[...];   % stvaranje matrice

Wo = A(:,1);    % naredba dodele
We = A(:,2);

figure  % otvaranje grafickog prozora
plot(Wo, We, 'o', 'linewidth', 2)   % skica krive/linije/relacije
% loglog(Wo, We, 'o', 'linewidth', 2)   % u log koordinatama
xlabel('W_o [N]'), ylabel('W_e [N]')    % imena osa
grid on, box on,                    % vidljiva mreza
set(gca, 'fontsize', 14)            % velicina slova

x = Wo;
y = We./Wo;     % rad sa nizovima
```

Nakon toga *Tools – Basic Fitting* . . .
Ili pokretanje podsistema *cftool* . . .

Gorivo – 1/8

Težina aviona na poletanju W_o sastoji se iz:

- Težine praznog aviona – W_e – podleže statistici,
- Težine goriva – W_F – izračunava se na osnovu zahtevanih performansi,
- Težine korisnog tereta (putnici i teret) – W_u – zadaje se zahtevima.

Ukupna težina letelice je zbir težine prazne letelice, težine korisnog tereta i težine goriva:

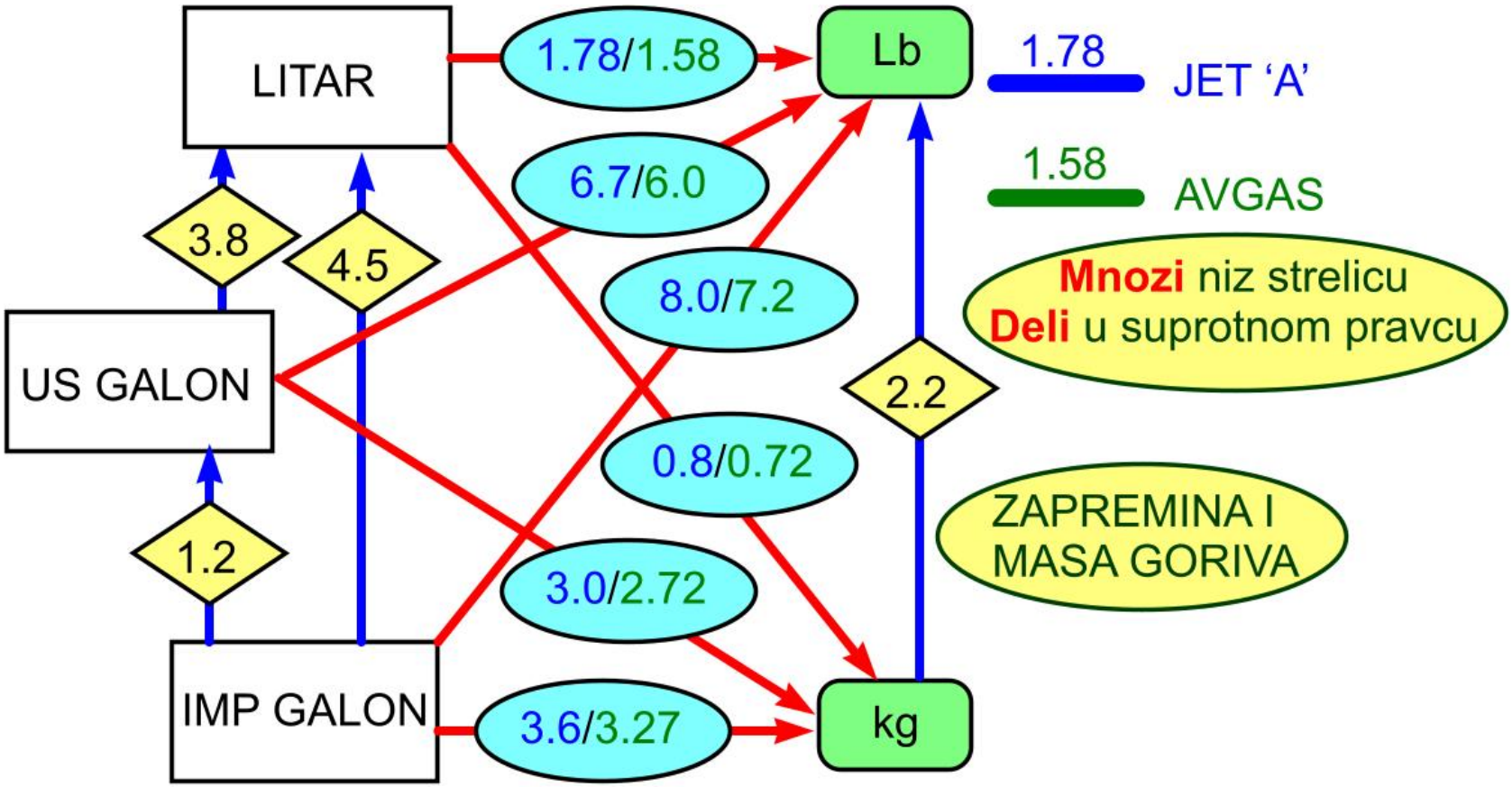
$$W_o = W_e + W_u + W_F$$

ili:

$$W_o - W_e - W_F = W_u \quad \Rightarrow \quad W_o = \frac{W_u}{1 - \frac{W_e}{W_o} - \frac{W_F}{W_o}}$$

Gorivo – 2/8

Konverzija jedinica



Gorivo – 3/8

Neka je težina letelice na kraju izvršenja zadatka (kada je gorivo pri kraju) W_x. Tada je težina potrošenog goriva:

$$W_f = W_o - W_x, \qquad \Rightarrow \qquad \frac{W_f}{W_o} = 1 - \frac{W_x}{W_o}$$

U letelici ima još malo goriva koje se ne može izvući iz rezervoara, kao i neophodna rezerva, što obično iznosi 6%:

$$\frac{W_F}{W_o} = 1.06 \left(1 - \frac{W_x}{W_o}\right) \equiv 1.06 \cdot \frac{W_f}{W_o}$$

gde je W_F ukupna težina goriva u letelici!

Gorivo – 4/8

Odnos W_x/W_o se može napisati u obliku:

$$\frac{W_x}{W_o} = \frac{W_1}{W_o} \cdot \frac{W_2}{W_1} \cdot \frac{W_3}{W_2} \cdots \frac{W_{x-1}}{W_{x-2}} \cdot \frac{W_x}{W_{x-1}}$$

Odnosi W_n/W_{n-1} predstavljaju odnose težina letelice na kraju i na početku segmenta misije! Izraz za dolet (R) i istrajnost leta (E):

$$R = \frac{\eta_e}{c} \cdot \frac{L}{D} \cdot \ln \frac{W_{n-1}}{W_n}, \qquad E = \frac{\eta_e}{c} \cdot \frac{1}{V_\infty} \cdot \frac{L}{D} \cdot \ln \frac{W_{n-1}}{W_n}$$

Odakle sledi:

$$\frac{W_n}{W_{n-1}} = e^{-R \cdot c/(\eta_e \cdot L/D)} \qquad \frac{W_n}{W_{n-1}} = e^{-E \cdot c \cdot V_\infty/(\eta_e \cdot L/D)}$$

Gorivo – 5/8

- Ostali segmenti W_n/W_{n-1} znatno kraće traju tako da se njihova procena zasniva na statističkoj analizi segmenata.
- Jedini segment koji ima smisla prikazivati preko formule je penjanje:

$$\frac{W_n}{W_{n-1}} = 1 - 0.04 \cdot \mathrm{M}_\infty$$

  gde je M_∞ Mahov broj penjanja letelice.
- Optimalni odnos L/D u kruženju iznosi $0.866 \cdot (L/D)_{\max}$

Tabela: Izbor optimalne finese

	Krstarenje	Istrajnost
Mlazni	$0.866 \cdot (L/D)_{\max}$	$(L/D)_{\max}$
Elisni	$(L/D)_{\max}$	$0.866 \cdot (L/D)_{\max}$

Gorivo – 6/8

Neki tipični maseni odnosi

Tabela: Težinski (maseni) odnosi za tipične segmente misije

Segment misije	W_i/W_{i-1}
Zagrevanje i poletanje	0.970
Penjanje	0.985
Sletanje	0.995

Neki od segmenata su definisani propisima za različite kategorije letelica!

Gorivo – 7/8

Težina letelice na poletanju:

$$W_o = W_e + W_F + W_u \qquad \Rightarrow \qquad W_o \left(1 - \frac{W_e}{W_o} - \frac{W_F}{W_o}\right) = W_u$$

W_o – težina letelice na poletanju; W_e – težina prazne letelice sa svim potrebnim fluidima osim goriva; W_F – težina goriva; W_u – korisan teret (putnici + prtljag);
Jednačina za odredjivanje poletne težine letelice:

$$W_o = \frac{W_u}{1 - \frac{W_e}{W_o} - \frac{W_F}{W_o}}$$

Gorivo – 8/8

Pregled jednačina

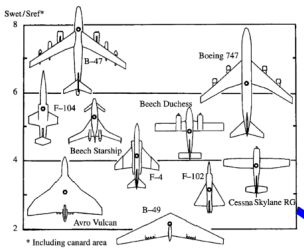
$$\frac{W_x}{W_o} = \frac{W_1}{W_o} \cdot \frac{W_2}{W_1} \cdot \frac{W_3}{W_2} \cdots \frac{W_{x-1}}{W_{x-2}} \cdot \frac{W_x}{W_{x-1}}$$

$$\frac{W_F}{W_o} = 1.06 \left(1 - \frac{W_x}{W_o}\right)$$

$$W_o = \frac{W_u}{1 - \frac{W_e}{W_o} - \frac{W_F}{W_o}}$$

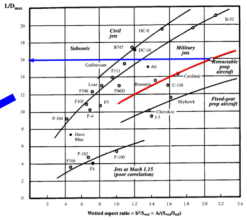
$$\frac{W_e}{W_o} = A \cdot W_o^C$$

Procena mase – 1/20



KONSTRUKTIVNI ZAHTEVI

IZRADA KONSTRUKTIVNE SKICE



IZBOR VITKOSTI KRILA

Sw/Sref, L/Dmax, L/Dkrstarenja

L/Dmax ~ AR+10

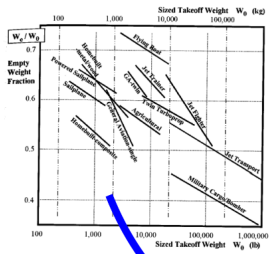
Ckrs=6.63e-7,Ckru=8.3e-7 [1/m]

SPECIFICNA POTROSNJA MOTORA

PROCENA UDELA GORIVA Wf/Wo

$$\frac{W_f}{W_o} = 1.06\left(1 - \frac{W_x}{W_o}\right)$$

$$\frac{W_x}{W_o} = \frac{W_1}{W_o}\cdot\frac{W_2}{W_1}\cdots\frac{W_{x-1}}{W_{x-2}}\cdot\frac{W_x}{W_{x-1}}$$



$$W_o = \frac{W_{crew} + W_{payload}}{1 - \frac{W_f}{W_o} - \frac{W_e}{W_o}}$$

PROCENA Wo

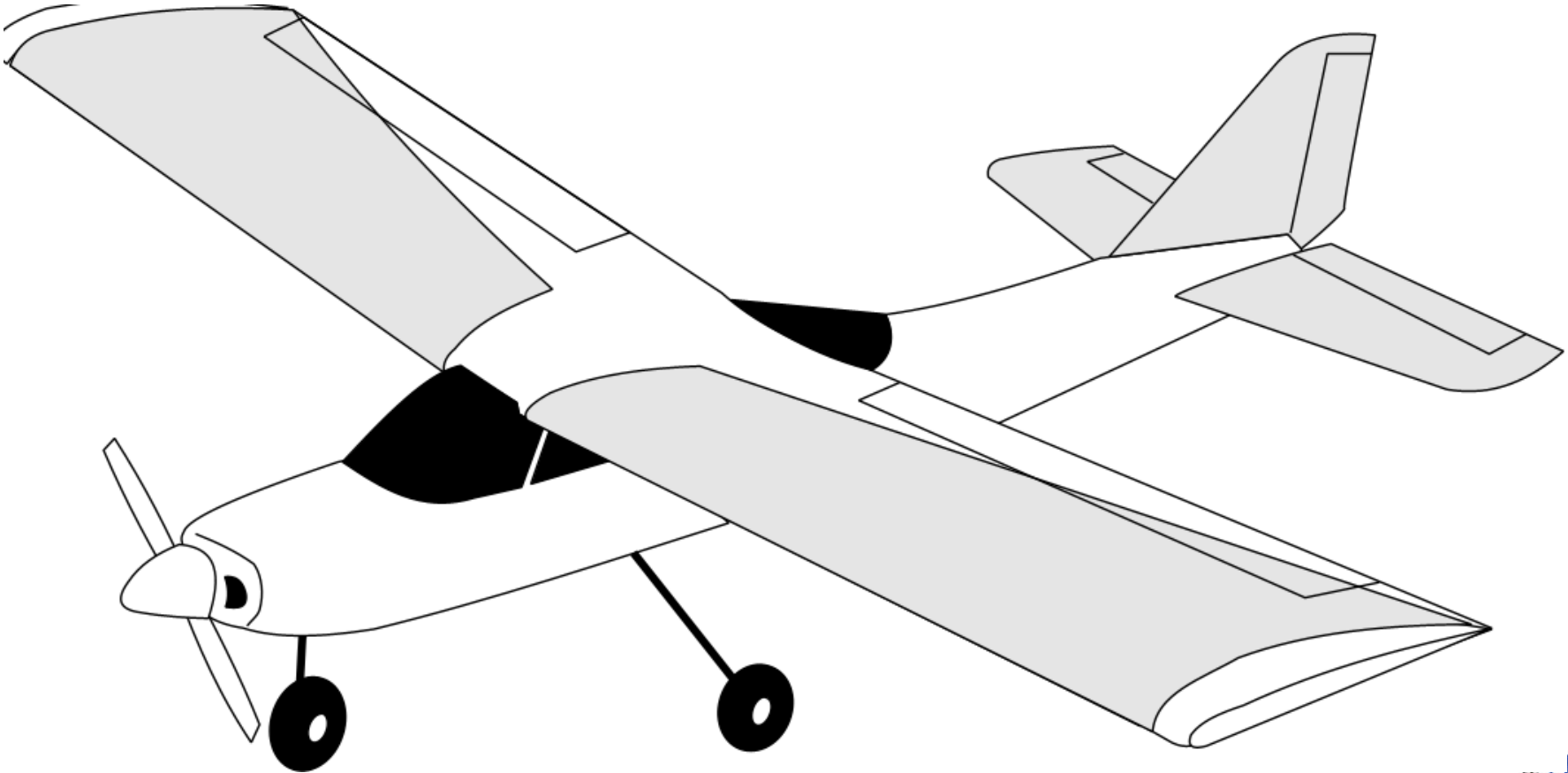
We/Wo TREND

Wo NA OSNOVU JEDNACINE

$$\frac{W_e}{W_o} = AW_o^C K_{vs},$$

IZRACUNATO Wo

Procena mase – 2/20

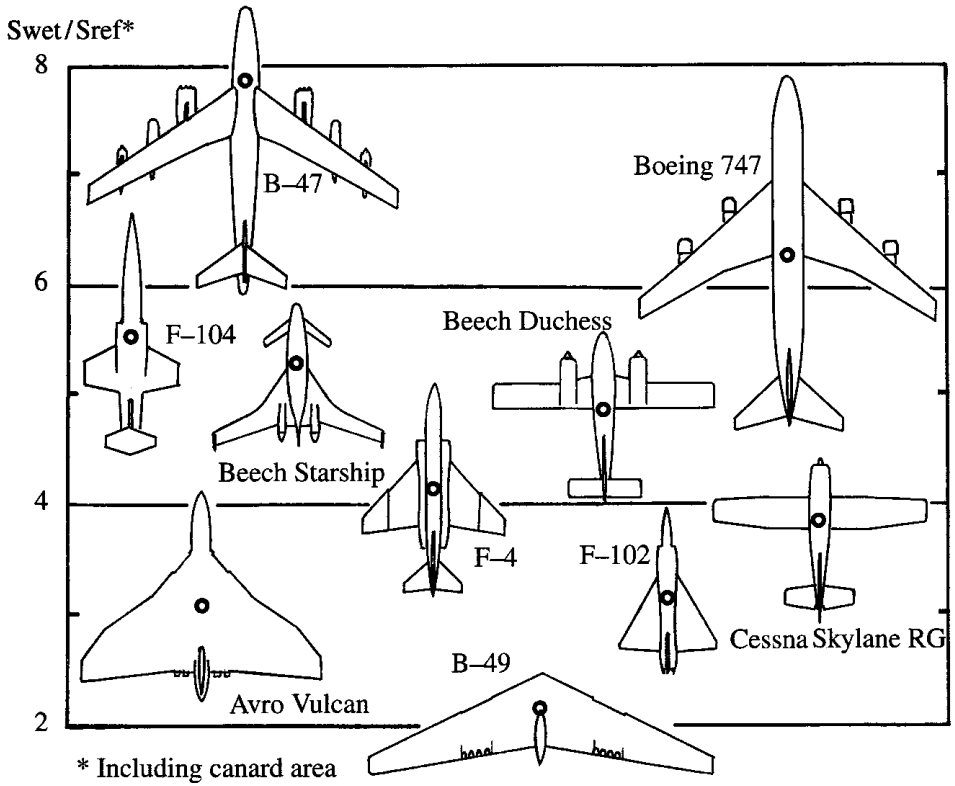


Slika: Skica koja prikazuje koncept aviona.

Procena mase – 3/20

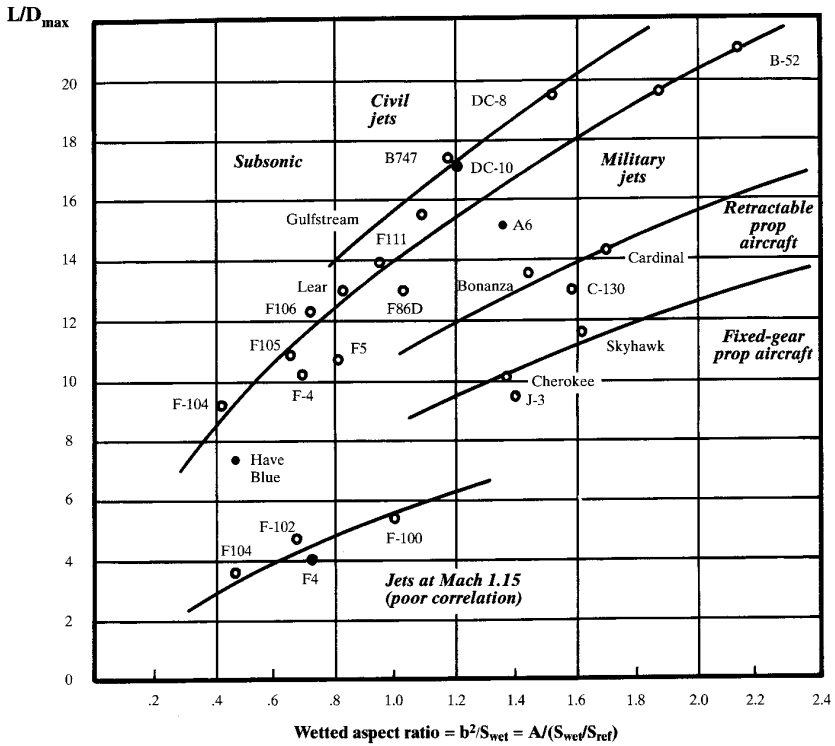
- Za prvu procenu težina izabraćemo srednju vitkost analiziranih konstrukcija: $AR = 7.89$
- Specifična potrošnja motora u krstarenju $c = 6.63 \cdot 10^{-7}$ [1/m]
- Specifična potrošnja motora u kruženju $c = 8.3 \cdot 10^{-7}$ [1/m]

Procena mase – 4/20



Slika: Iznalazimo na osnovu izgleda letelice $S_w/S_{ref} \approx 4.5$

Procena mase – 5/20

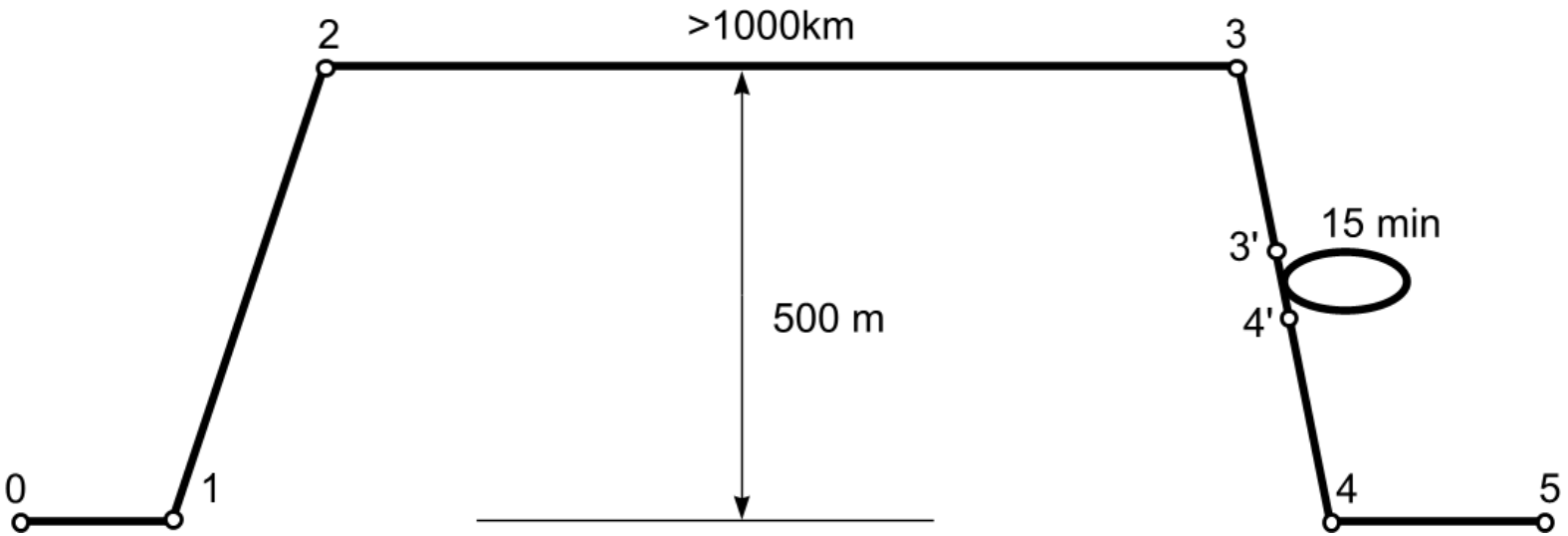


Slika: Na osnovu $AR/(S_w/S_{ref}) = 7.89/4.5 \approx 1.75$ očitavamo $L/D_{\max} = 11.5$

Procena mase – 6/20

- Za odabranu kategoriju letelica mi već iz statističkih podataka znamo:
  - Maksimalna masa na poletanju: 472 [kg]
  - Dva putnika: $2 \cdot 77 = 154$ [kg]
  - Masa padobrana i elemenata za povezivanje: 22 [kg]
  - Masa prazne letelice: $265 \div 285$ [kg]
- Tako da proračun koji sledi neće imati mnogo smisla, ali vam je neophodan za proračun vaše letelice.
- Količina goriva će nadopunjavati dobijenu masu do 472 [kg], s tim što ćemo napraviti rezervoare sa većim kapacitetom.
- Propisi zahtevaju da u masi letelice od 472 kg bude goriva za 30 min leta!

Procena mase – 7/20



Procena mase – 8/20

Težine u karakterističnim tačkama misije

- Početna težina – W_o.
- Težina na kraju poletanja – W_1.
- Težina na kraju penjanja – W_2.
- Težina na kraju doleta od 1000 km – W_3.
- Težina na kraju 15 min kruženja – W_4.
- Težina na kraju leta – W_5.

Procena mase – 9/20

Na osnovu tabele sa statističkim podacima o utrošku goriva:

- Na kraju zagrevanja i poletanja: $W_1/W_o = 0.970$. Usvojićemo $W_1/W_o = 0.985$ jer nema dugog čekanja na poletanje na malim aerodromima (poljanama).
- Na kraju penjanja:

$$\frac{W_2}{W_1} = 1 - 0.04\mathrm{M}_\infty, \qquad \mathrm{M}_\infty = \frac{200/3.6}{340} \approx 0.16, \qquad \frac{W_2}{W_1} = 0.994$$

- Na kraju sletanja: $W_5/W_4 = 0.995$
- Letelica tokom leta menja finesu jer joj težina opada, tako da ne leti stalno sa $(L/D)_{\max}$!

Procena mase – 10/20

Na kraju doleta $L/D = 0.94(L/D)_{\max} = 0.94 \cdot 11.5 \approx 10.8$:

$$\frac{W_3}{W_2} = e^{-R \cdot c/(\eta_e \cdot L/D)} = e^{-10^6 \cdot 6.63 \cdot 10^{-7}/(0.8 \cdot 10.8)} \approx 0.926$$

Za 15 [min] = 900 [s] kruženja ($L/D = 0.866 \cdot 11.5 \approx 9.96$):

$$\frac{W_4}{W_3} = e^{-E \cdot c \cdot V_\infty/(\eta_e \cdot L/D)} = e^{900 \cdot 8.3 \cdot 10^{-7} \cdot 200/(3.6 \cdot 0.8 \cdot 9.96)} \approx 0.995$$

Sada možemo izračunati W_5/W_o:

$$\begin{aligned} \frac{W_5}{W_o} &= \frac{W_1}{W_o} \cdot \frac{W_2}{W_1} \cdot \frac{W_3}{W_2} \cdot \frac{W_4}{W_3} \cdot \frac{W_5}{W_4} \\ &= 0.985 \cdot 0.994 \cdot 0.926 \cdot 0.995 \cdot 0.995 \\ &\approx 0.898 \end{aligned}$$

Procena mase – 11/20

Količina goriva u rezervoarima:

$$\frac{W_F}{W_o} = 1.06 \cdot \left(1 - \frac{W_5}{W_o}\right) = 1.06 \cdot (1 - 0.898) \approx 0.108$$

Započećemo sa težinom od $W_o = 472 \cdot 9.80655 \approx 4629\ [N]$.
Procenićemo na osnovu trenda težina praznih letelica:

$$\frac{W_e}{W_o} = A \cdot W_o^C = 1.11 \cdot 4629^{-0.09} \approx 0.519$$

Ovaj trend je napravljen za generalnu avijaciju (nešto teže letelice).
Iskustvo pokazuje da je za LSA letelice realnija
procena $W_e/W_o = 0.6$.

Procena mase – 12/20

Ostaje nam još da izračunamo novu poletnu težinu:

$$W_o = \frac{W_u}{1 - \frac{W_e}{W_o} - \frac{W_F}{W_o}} = \frac{(154 + 22 + 30) \cdot 9.81}{1 - 0.519 - 0.108} \approx 5418$$

Ovo je nova početna težina sa kojom odredjujemo novo W_e/W_o:

$$\frac{W_e}{W_o} = 1.11 \cdot 5418^{-0.09} \approx 0.512$$

Ponovo procenjujemo W_o:

$$W_o = \frac{W_u}{1 - \frac{W_e}{W_o} - \frac{W_F}{W_o}} = \frac{(154 + 22 + 30) \cdot 9.81}{1 - 0.512 - 0.108} \approx 5318$$

Procena mase – 13/20

Procena W_e/W_o za $W_o = 5318\ [N]$:

$$\frac{W_e}{W_o} = 1.11 \cdot 5318^{-0.09} \approx 0.513$$

Ponovo W_o:

$$W_o = \frac{W_u}{1 - \frac{W_e}{W_o} - \frac{W_F}{W_o}} = \frac{(154 + 22 + 30) \cdot 9.81}{1 - 0.513 - 0.108} \approx 5332$$

Napravićemo još jedan krug:

$$\frac{W_e}{W_o} = 1.11 \cdot 5332^{-0.09} \approx 0.513,\ W_o = \frac{(154 + 22 + 30) \cdot 9.81}{1 - 0.513 - 0.108} \approx 5332$$

Primer programa/skripta

```
% ultralaka letelica, korisni teret Wfix = 2*77 + 22 (+ 30)
clear all, clc

% pretpostavka, za ovu kategoriju, elisni pogon
L_Dmax = 11.5;          % max finesa
L_Dkrs = 0.94*L_Dmax;   % finesa krstarenje
L_Dkrz = 0.866*L_Dmax;  % finesa kruzenje

Ckrs = 6.63e-7;         % potrosnja goriva u krstarenju, [1/m]
Ckru = 8.3e-7;          % potrosnja goriva u kruzenju, [1/m]
eta = 0.8;

V = 200/3.6;            % brzina krstarenja, [m/s]
M = V/340;              % Mahov broj
R = 1000000;            % dolet, [m]
E = 15*60;              % istrajnost leta (kruzenje), [s]

W1Wo = 0.985;           % zagrevanje i poletanje, mala letelica
W2W1 = 1 - 0.04*M;      % penjanje
W3W2 = exp(-R*Ckrs/(eta*L_Dkrs));   % krstarenje na daljinu R
W4W3 = exp(-E*Ckru*V/(eta*L_Dkrz)); % kruzenje od 3h
W5W4 = 0.995;           % sletanje i taksiranje

% skupno
W5Wo = W1Wo*W2W1*W3W2*W4W3*W5W4;
```

Primer programa/skripta – nastavak

```
WfWo = 1.06*(1-W5Wo);   % udeo goriva u letelici, +6% rezerve
Wfix = (2*77+22+30)*9.81;  % korisni teret, [N]

% pocetno resenje, [N]
Wo = 472*9.81;

n = 10;
A = zeros(n,1); B = zeros(n,1);
for i=1:n
    A(i) = Wo;
    WeWo = 1.11*Wo^(-0.09);     % udeo prazne letelice, preporuka
%     WeWo = (0.6367*Wo - 382.7)/Wo; % linearna zavisnost
%     WeWo = 0.3955*Wo^(0.045);       % stepena zavisnost
    B(i) = WeWo;
    Wo = Wfix/(1 - WfWo - WeWo);
end
disp('Maseni odnosi'), disp(B')
disp('Ukupna tezina [N]'), disp(A')
We = WeWo*Wo;
Wf = WfWo*Wo;
disp('Konacna ukupna masa [kg]'), disp(Wo/9.81)
```

Procena mase – 14/20

- Izračunali smo konačnu težinu na poletanju $W_o = 5332\ [N]$, što je oko 70 [kg] više od dozvoljenog maksimuma za LSA kategoriju.
- Po svojoj težini letelica spada u VLA kategoriju, što znači stroži propisi.
- Zbog toga ćemo umesto pronalaženja mase letelice usvojiti maksimum $W_o = 472 \cdot 9.81 \approx 4630$ [N].
- Usvojićemo češki prosek za $W_e/W_o = 0.6$, skinućemo prtljag od 30 [kg] i videti koliko nam ostaje goriva i kojem to doletu odgovara!

Procena mase – 15/20

Na osnovu:

$$W_o = \frac{W_u}{1 - \frac{W_e}{W_o} - \frac{W_F}{W_o}}$$

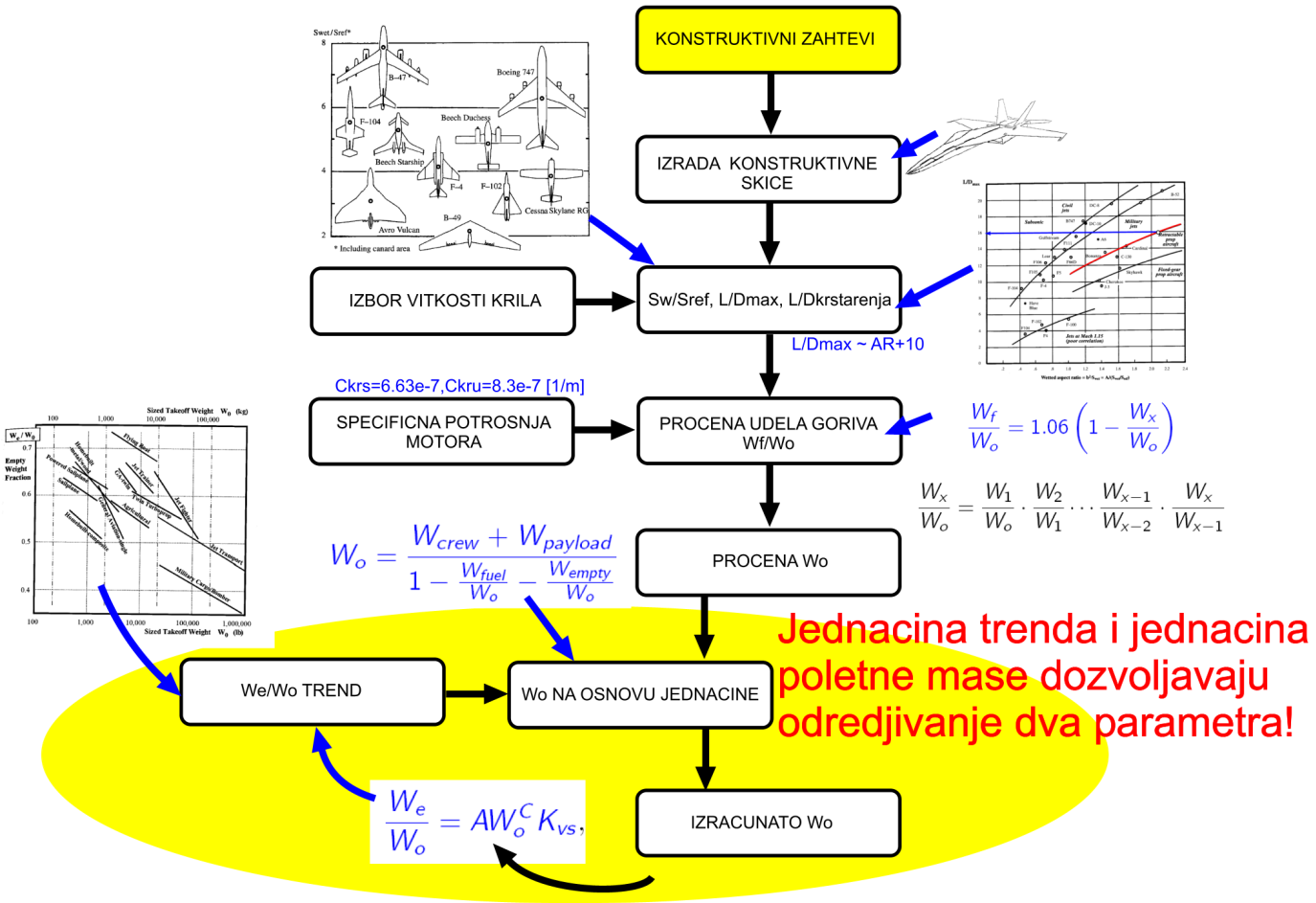
gde se koristan teret sada sastoji samo iz težine putnika i padobrana $W_u = (154 + 22) \cdot 9.81 \approx 1727$ [N].
Zamenom u gornju jednačinu:

$$4630 = \frac{1727}{1 - 0.6 - \frac{W_F}{W_o}}, \qquad \frac{W_F}{W_o} \approx 0.027, \qquad W_F = 125 \text{ [N]}$$

Što odgovara doletu:

$$R = \frac{\eta}{c} \cdot \frac{L}{D} \ln\left(\frac{1}{1 - \frac{W_F}{W_o}}\right) = \frac{0.8}{6.63 \cdot 10^{-7}} \cdot 10.8 \cdot \ln\left(\frac{1}{1 - 0.027}\right) \approx 357 \text{ [km]}$$

Procena mase – 16/20



Procena mase – 17/20

- Proverimo da li se uklapamo u propise da za težinu od 4630 [N] imamo goriva za 0.5 h leta.
- Istrajnost leta treba da bude $E = 0.5\ \text{h} = 1800\ \text{s}$, pri $V_\infty = 160\ \text{km/h} = 44.44\ \text{m/s}$:

$$\frac{W_F}{W_o} = 1 - e^{-EcV_\infty/(\eta_e L/D)} = 1 - e^{-1800 \cdot 6.63 \cdot 10^{-7} \cdot 44.44/(0.8 \cdot 11.5)} \approx 0.0057$$

- Kako je 0.0057 manje od prethodno izračunatog 0.027 to znači da nam po propisima preostaje nešto i za prtljag:

$$W_o = \frac{W_u}{1 - 0.6 - W_F/W_o}, \quad \Rightarrow \quad W_u = 4630 \cdot (0.4 - 0.0057) \approx 1825\ [\text{N}]$$

$$W_{prtljag} = 1825 - 1727 \approx 98\ [\text{N}]$$

Procena mase – 18/20

Količina prtljaga je: 98 [N], odnosno oko 10 [kg].

Izračunaćemo sada potrebnu količinu goriva za dolet od 1000 [km].
Masa prazne letelice sa korisnim teretom je:

$$W_{oo} = W_o \cdot (1 - 0.0057) = 4630 \cdot (1 - 0.0057) \approx 4604 \text{ [N]}$$

Za dolet od 1000 [km] potreban je odnos:

$$\frac{W_F}{W_{oo} + W_F} = 0.108, \quad \Rightarrow \quad W_F = 557 \text{ [N]}$$

Procena mase – 19/20

- Potrebna količina goriva za dolet od 1000 [km] je 57 [kg] ili $V_G = 57/0.72 \approx 80$ [ℓ].
- Konačna poletna težina letelice sa 10 [kg] prtljaga je $W_o = 5161$ [N].
- Maksimalni faktor opterećenja sa maksimalnom masom letelice je: $n = 4 \cdot 4630/5161 \approx 3.59$.
- Po propisima za težinu letelice od 472 kg maksimalni faktor opterećenja (G) je 4.
- Ugao naginjanja u horizontalnom zaokretu koji generiše faktor opterećenja $n = 3.59$ je:

$$\phi = \arccos\left(\frac{1}{n}\right) = \arccos\left(\frac{1}{3.59}\right) \approx 74^\circ$$

Procena mase – 20/20

Uticaj $(L/D)_{\max}$ – 1/4

- Do sada smo od aerodinamike pozajmili samo procenu $(L/D)_{\max}$.
- Svi ostali statistički podaci su manje osetljivi od izbora finese letelice.
- Kako je promena mase nakon doleta R:

$$\frac{W_n}{W_{n-1}} = e^{-R\cdot c/(\eta_e \cdot L/D)} = e^{\frac{R}{L/D}\cdot\frac{c}{\eta_e}}$$

to se isti odnos težina može ostvariti održavanjem odnosa:

$$\frac{R}{L/D} = \text{const.}$$

Uticaj $(L/D)_{\max}$ – 2/4

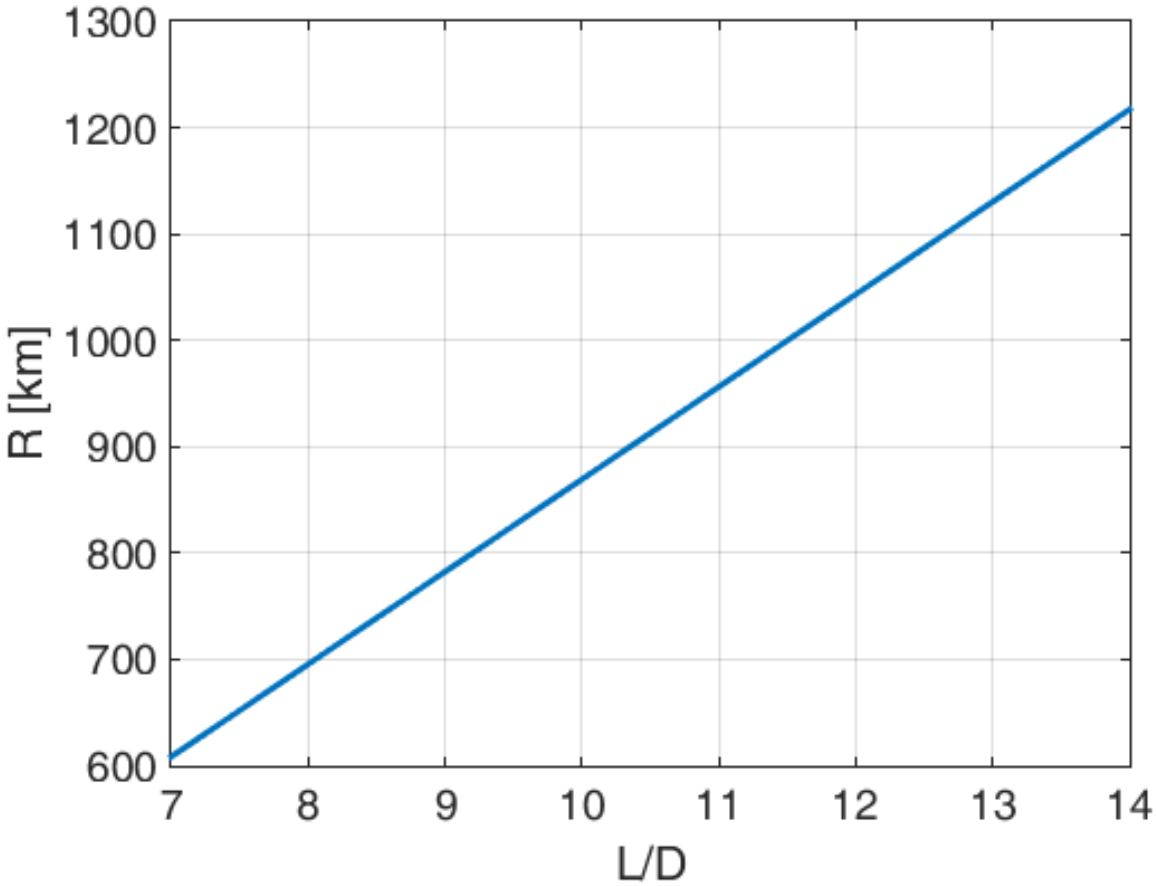
Isti odnos $R/(L/D)$ se mora održavati jer je za LSA kategoriju:

- Propisana maksimalna težina sa padobranom.
- Korisan teret W_u se ne može znatnije smanjivati.
- Relativni udeo prazne letelice iznosi $W_e/W_o = 0.55 \div 0.62$.
- Potrebna zapremina rezervoara:

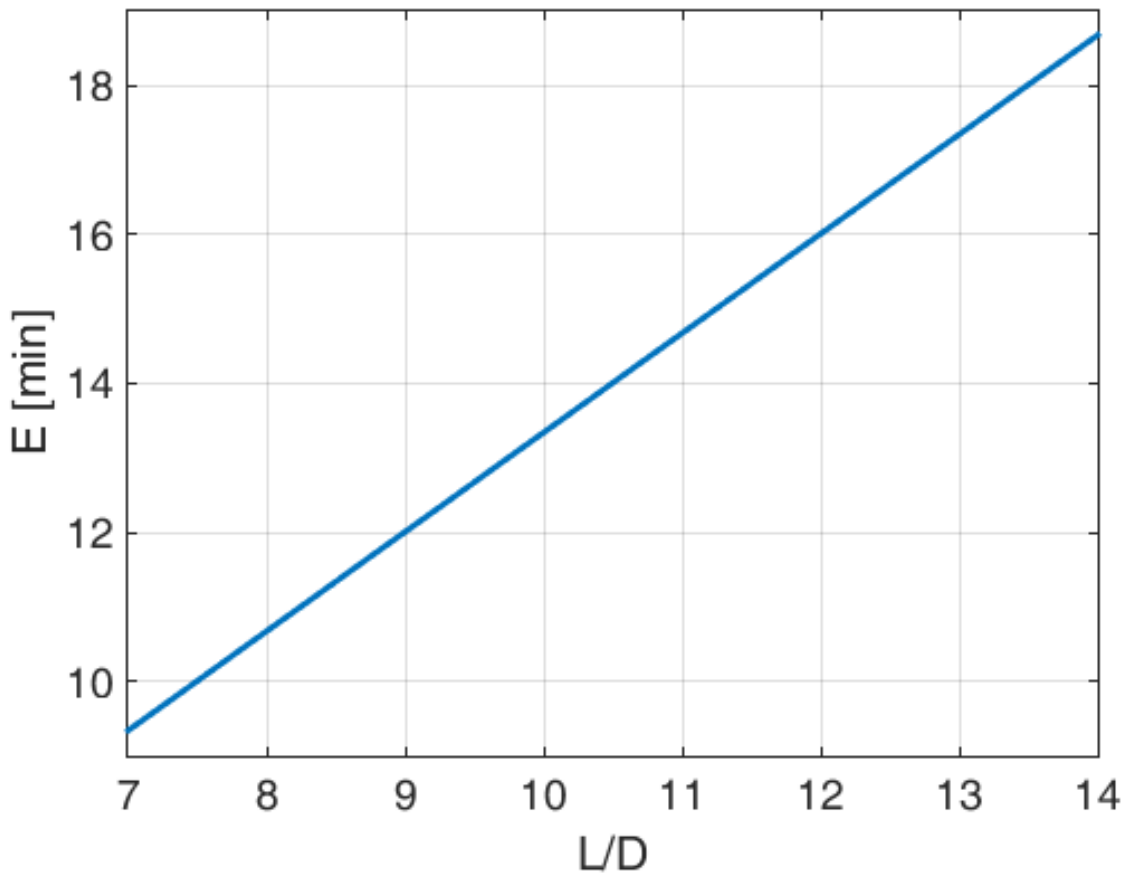
$$V_F = \frac{W_F}{\varrho_F} = \frac{W_o \cdot \frac{W_F}{W_o}}{\varrho_F} = \frac{472 \cdot 0.108}{720} \approx 71\ [\ell]$$

- Razmotrimo promenu doleta R kada se finesa menja u rasponu $L/D = 7 \div 14$.
- Slično se može izvršiti za istrajnost leta E.

Uticaj $(L/D)_{max}$ – 3/4



Uticaj $(L/D)_{max}$ – 4/4



Nastavak skripta – uticaj finese

```
% ...
% zavisnost doleta od finese
L_D = linspace(7, 14, 101);
Range = eta/Ckrs*0.94*L_D*log(1/W3W2);
figure
plot(L_D, Range/1e3, 'linewidth', 2)
xlabel('L/D'), ylabel('R [km]')
grid on, box on, axis([7 14 600 1300])
set(gca, 'fontsize', 14)

% zavisnost istrajnosti od finese
End = eta/Ckru/V*0.886*L_D*log(1/W4W3);
figure
plot(L_D, End/60, 'linewidth', 2)
xlabel('L/D'), ylabel('E [min]')
grid on, box on, axis([7 14 9 19])
set(gca, 'fontsize', 14)
```

Sledeći čas – 1/1

Optimizacija W/S i P/W (T/W) parametara:

- S obzirom na dolet,
- Dužinu poletne staze,
- Brzinu pri otcepljenju strujanja na krilu,
- Istrajnost u letu,
- Maksimalnu brzinu,
- Brzinu penjanja,
- Maksimalnu ugaonu brzinu kruženja (minimalni radijus),
- Maksimalni faktor opterećenja,
- Plafon penjanja,
- Cenu izrade, korišćenja i smeštanja letelice.