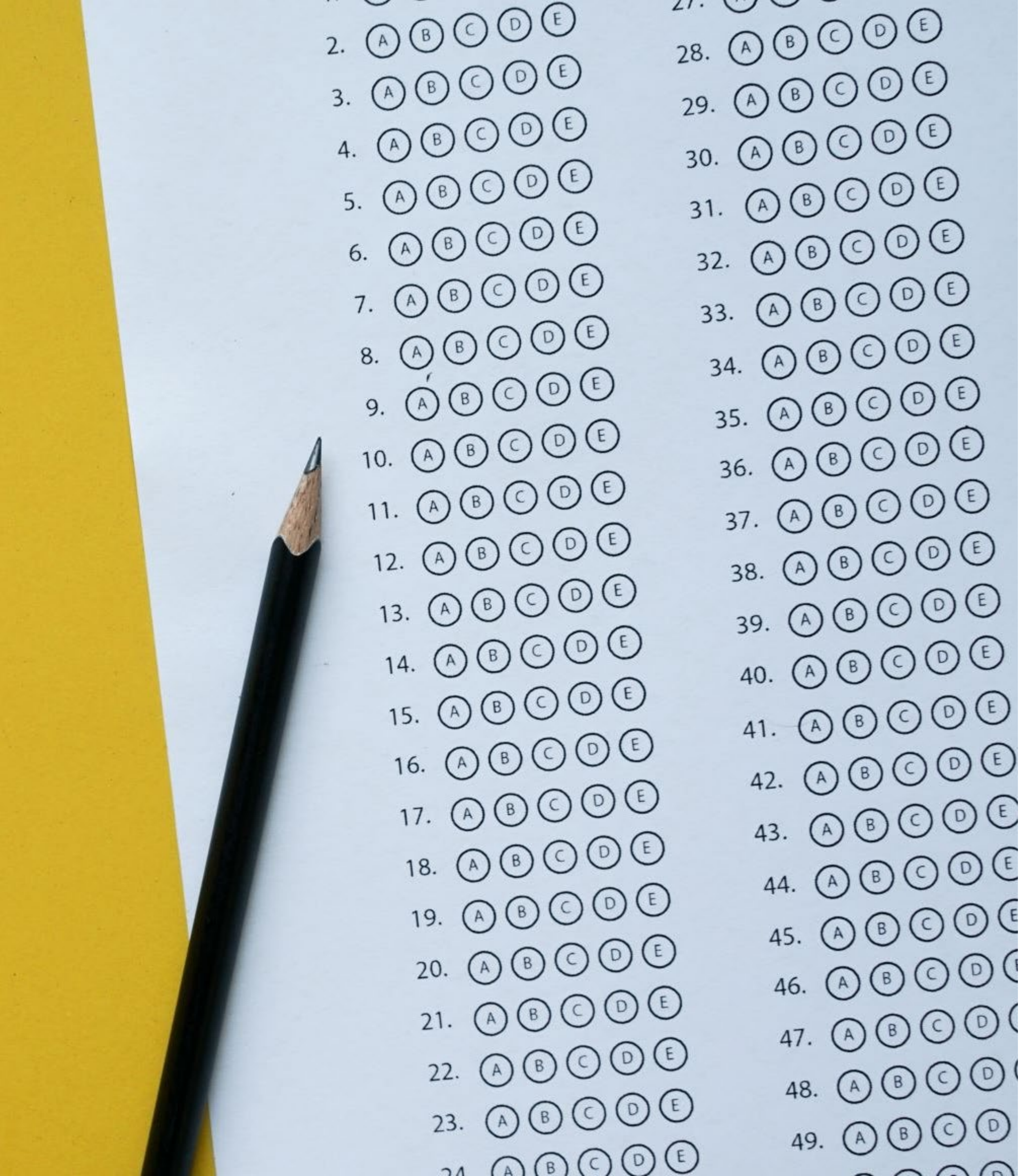


ASSIGNMENT FOR FINAL EXAM: EVTOL AEROELASTIC ASSESSMENT

Course of Aeroelasticity of fixed and rotary wing aircraft

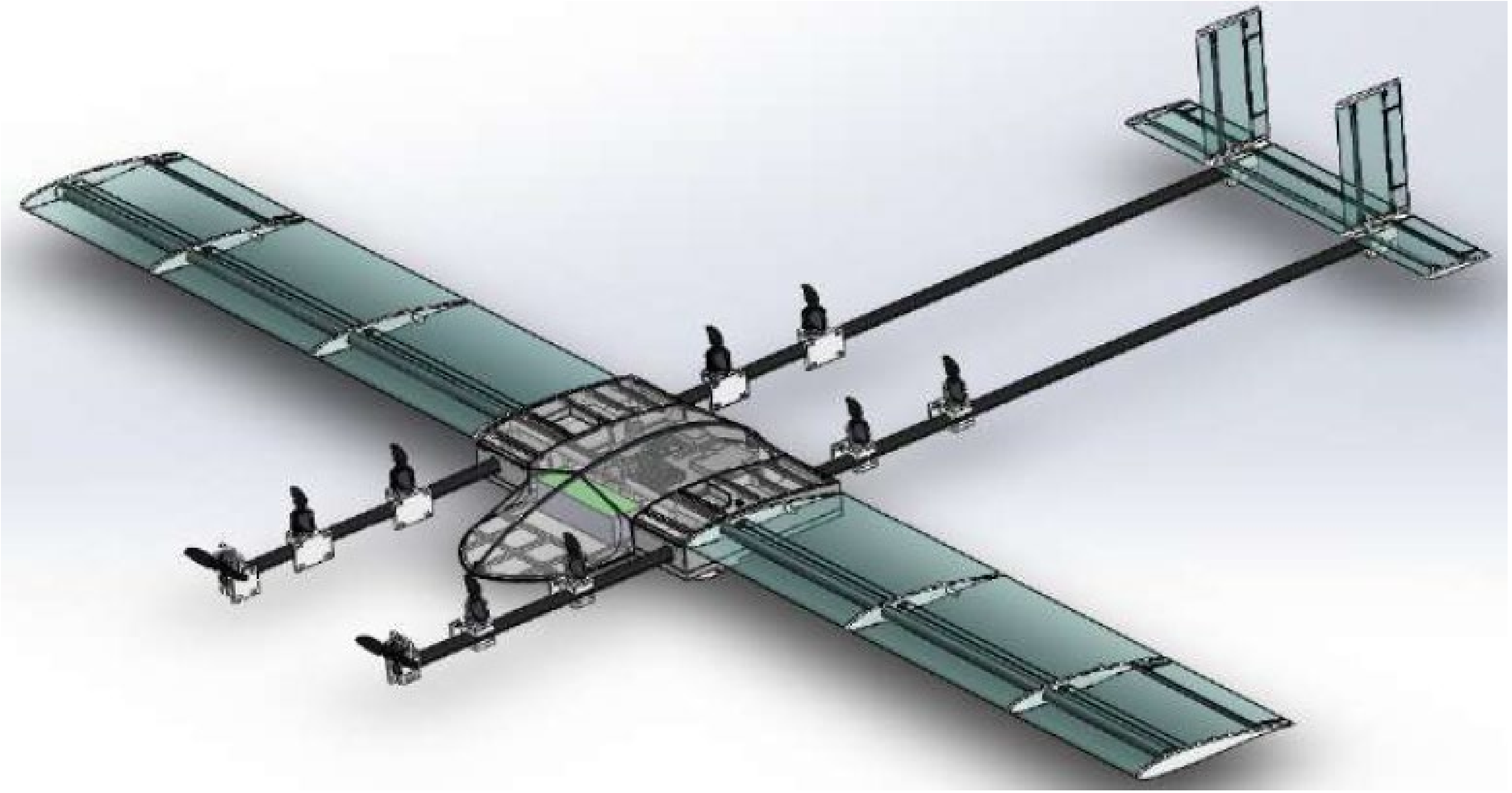
Prof. Giuseppe Quaranta

AA. 2023/24

Agenda

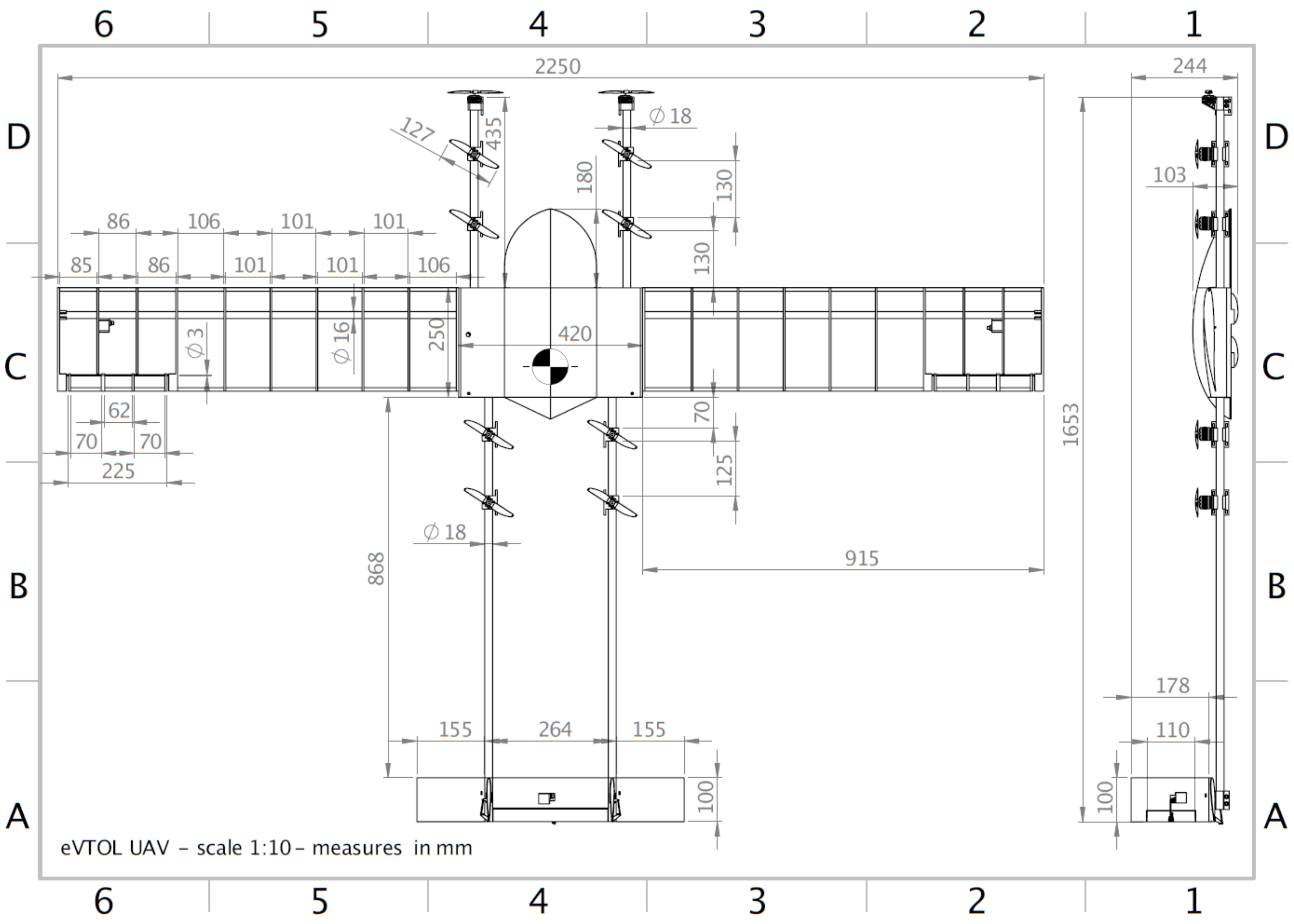
- General Description
- Aiframe Structural characteristics
- Rotors characteristics
- Tasks

eVTOL



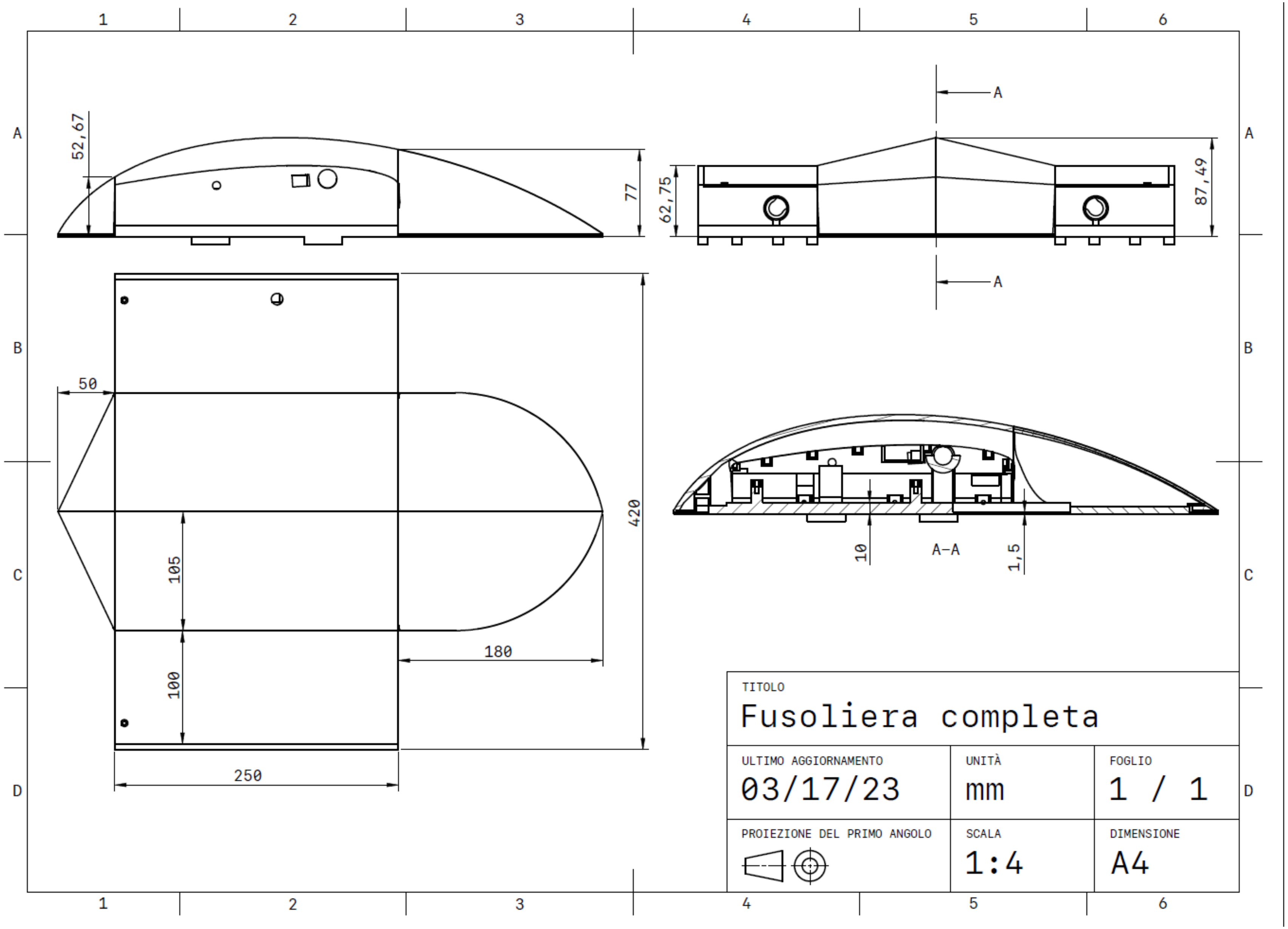
eVTOL

Type	Parameter	Value
Performance requirements	Stall speed	11 m/s
	Cruise speed	15 m/s
	Maximum speed	22 m/s
	Rate of climb	2 m/s
	Cruise altitude	120 m AGL
	Hover time	5 min
	Cruise endurance	85 min
	Payload mass	200 g
Design parameters	Take off mass	4.8 kg
	Wing span	2.25 m
	Wing surface	0.56 m^2
	Wing airfoil	Selig 2046
	Number of FWD flight motors	2
	Number of VTOL motors	8
	Battery capacity	8500 mAh



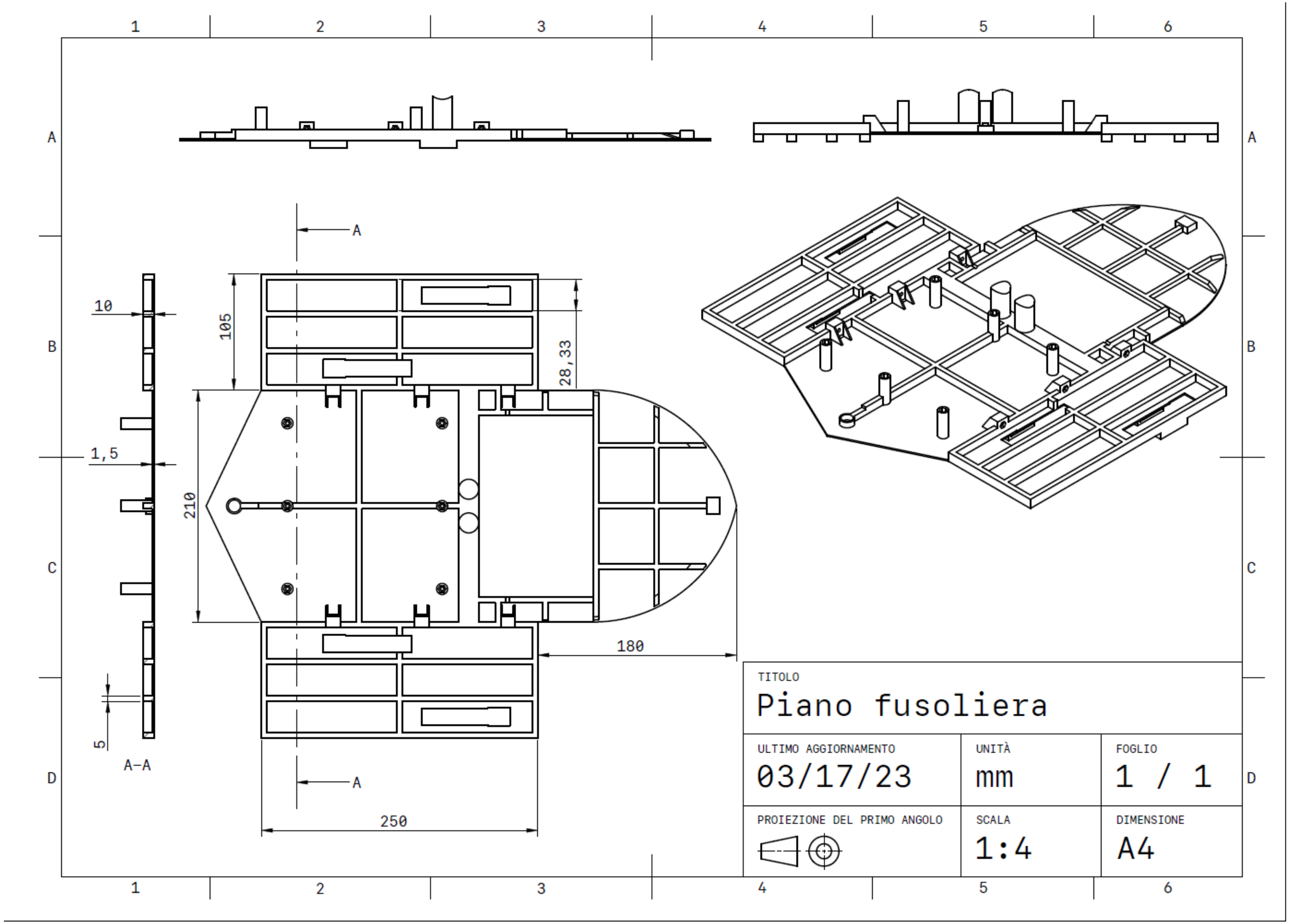
6
5
4
3
2
1
D
C
B
A
2250
244
127
435
Ø 18
180
130
130
103
86
106
101
101
85
86
101
101
106
Ø 3
Ø 16
250
420
62
70
70
225
70
125
1653
Ø 18
915
868
178
155
264
155
110
100
100
eVTOL UAV - scale 1:10 - measures in mm

Fuselage



52,67
77
62,75
87,49
A
A-A
50
105
100
250
180
420
10
1,5
TITOLO
Fusoliera completa
ULTIMO AGGIORNAMENTO
03/17/23
UNITÀ
mm
FOGLIO
1 / 1
PROIEZIONE DEL PRIMO ANGOLO
SCALA
1:4
DIMENSIONE
A4

Fuselage (Cont.)

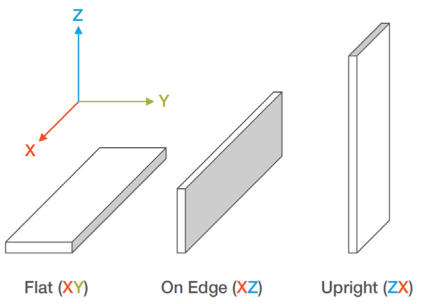


Fuselage

ASA Black samples were printed with a 0.010 in. (0.254 mm) layer height on the F900. For the full test procedure please see [Stratasys Materials Test Procedure](#) (immediate download upon clicking the link).

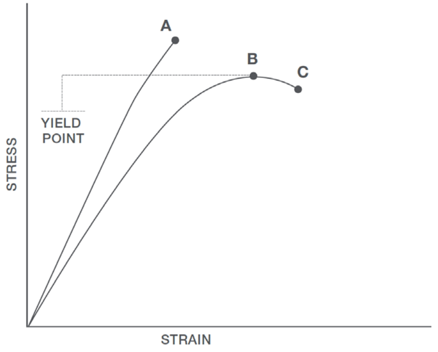
Print Orientation

Parts created using FDM are anisotropic as a result of the printing process. Below is a reference of the different orientations used to characterize the material.



Tensile Curves

Due to the anisotropic nature of FDM, tensile curves look different depending on orientation. Below is a guide of the two types of curves seen when printing tensile samples and what reported values mean.



A = Tensile at break, elongation at break (no yield point)
B = Tensile at yield, elongation at yield
C = Tensile at break, elongation at break

		XZ Orientation[1]	ZX Orientation[1]
Tensile Properties: ASTM D638			
Yield Strength	MPa	33 (1)	No yield
	psi	4750 (150)	No yield
Elongation @ Yield	%	2.52 (0.08)	No yield
Strength @ Break	MPa	30 (1)	28 (2)
	psi	4630 (140)	4110 (310)
Elongation @ Break	%	5.9 (0.8)	1.8 (0.3)
Modulus (Elastic)	GPa	2.14 (0.07)	2.0 (0.2)
	ksi	310 (10)	300 (30)
Flexural Properties: ASTM D790, Procedure A			
Strength @ Break	MPa	No break	50 (1)
	psi	No break	7395 (200)
Strength @ 5% Strain	MPa	60 (1)	-
	psi	8925 (150)	-
Strain @ Break	%	No break	3.9 (0.2)
Modulus	GPa	1.97 (0.05)	1.75 (0.03)
	ksi	285 (6)	255 (5)
Compression Properties: ASTM D695			
Yield Strength	MPa	75 (4)	190 (30)
	psi	10940 (545)	27200 (4075)
Modulus	GPa	2.04 (0.06)	2.4 (0.3)
	ksi	295 (8)	350 (40)

Mass component

Mass Component	[g]	Notes
Front Right Motor Tube	255	Tube Weight with Cables Inserted
Front Left Motor Tube	223	Tube Weight with Cables Inserted
Right Rear Motor Tube	192	Tube Weight with Cables Inserted
Left Rear Motor Tube	203	Tube Weight with Cables Inserted
Vertical Motor	164	Motor, ESC, Stand, Propeller
Horizontal Motor	87	Motor, ESC, Mount, Propeller
Vertical Tail	39	Tail, Rudder, Servo Motor
Horizontal tail	89	Tail, BCD, servo motor

Mass Component	[g]	Notes
Horizontal tail	89	Tail, BCD, servo motor
Servo Motor	15	
Rib wing	11	
Spar	26	A spar for each half-wing
Electronics	340	On-board electronics, excluding battery
Battery	484	Weight of each battery
Fuselage	1156.574	Weight of the entire fuselage
Fuselage Covers	350.028	Fuselage Cover Weight (Center & Sides)

Structural components

Carbon fiber composite material for tubes

Name	Inner diameter [mm]	Outer Diameter [mm]
Anterior Motor	16	18
Posterior Motor	16	18
Wing Spar	14	16

Material type		Density ρ (kg/m^3)	Tensile Strength σ_u (GPa)	Elastic Modulus E (GPa)	Breaking Length $\sigma_u/(\rho g)$ (km)
Carbon fiber	Standard	1760	3.53	230	205
	High strength	1820	7.06	294	396
	High modulus	1870	3.45	441	188
Steel	S355	7850	0.50	210	6
	Wire	7850	1.77	210	23

Tail Balsa wood

Density of 150 kg/m3, Elastic Modulus of 3710 MPa, and a Poisson's Ratio of 0.26.

Engine - Propellers

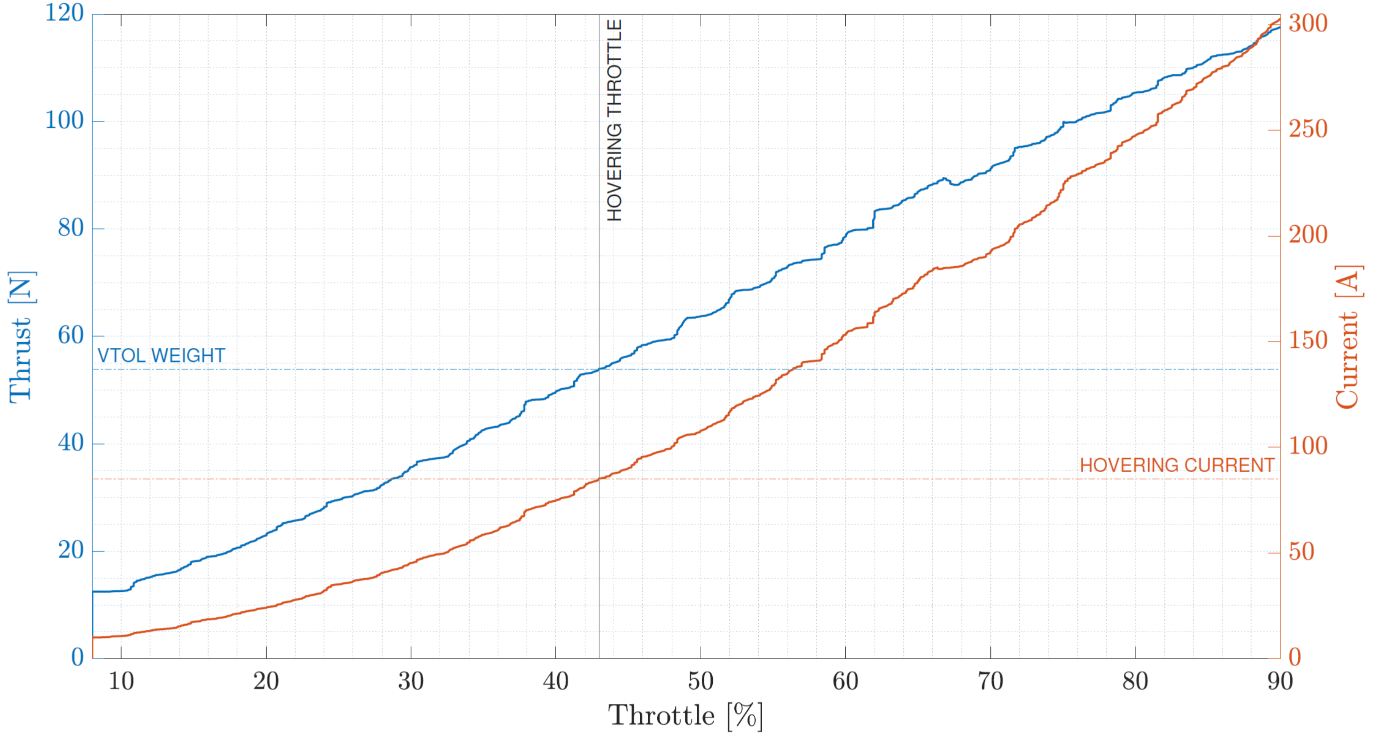


Figure 2.7: Thrust against throttle and current against throttle (for the entire propulsive system): motor for vertical flight $KDE\,2315\,XF - 2050$, 7x4.2 propeller, powered with standard battery.

Engine - Propellers

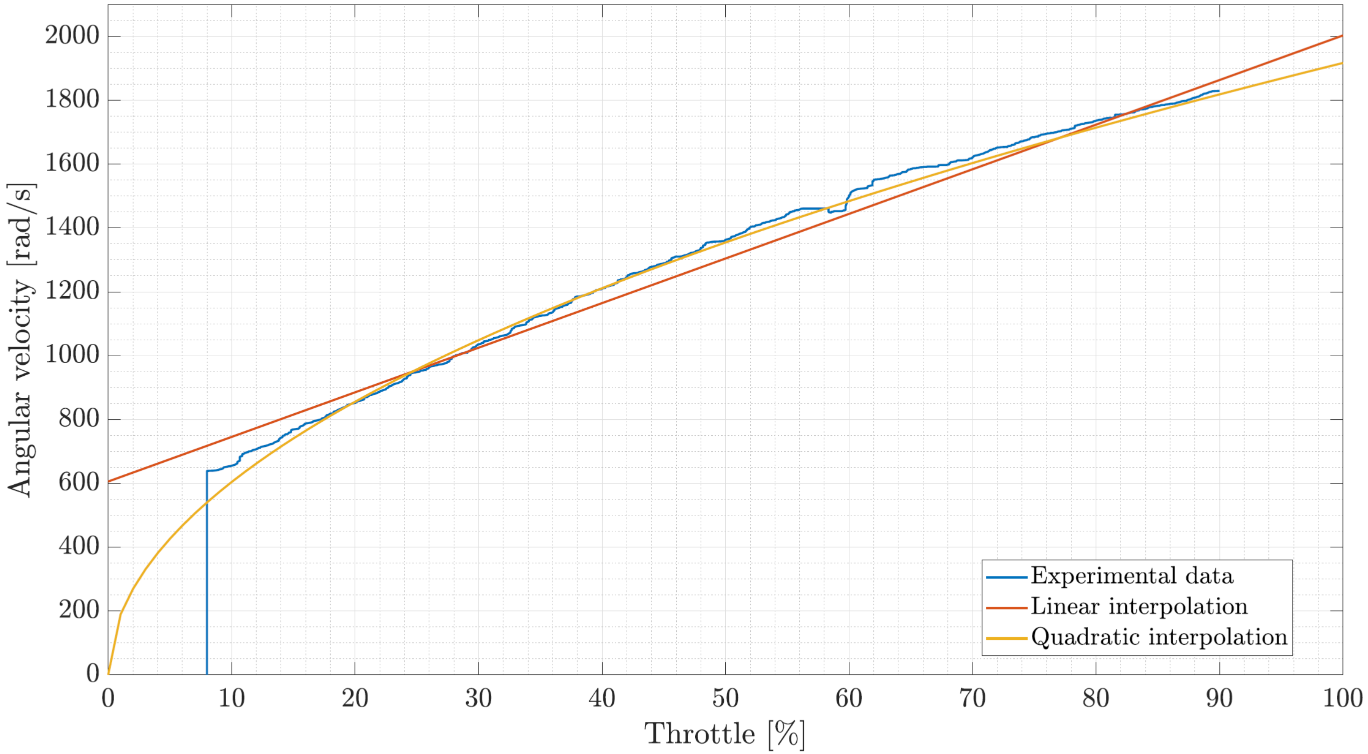


Figure 2.8: Angular velocity against throttle: motor for vertical flight $KDE\,2315\,XF-2050$, 7x4.2 propeller, powered with standard battery.

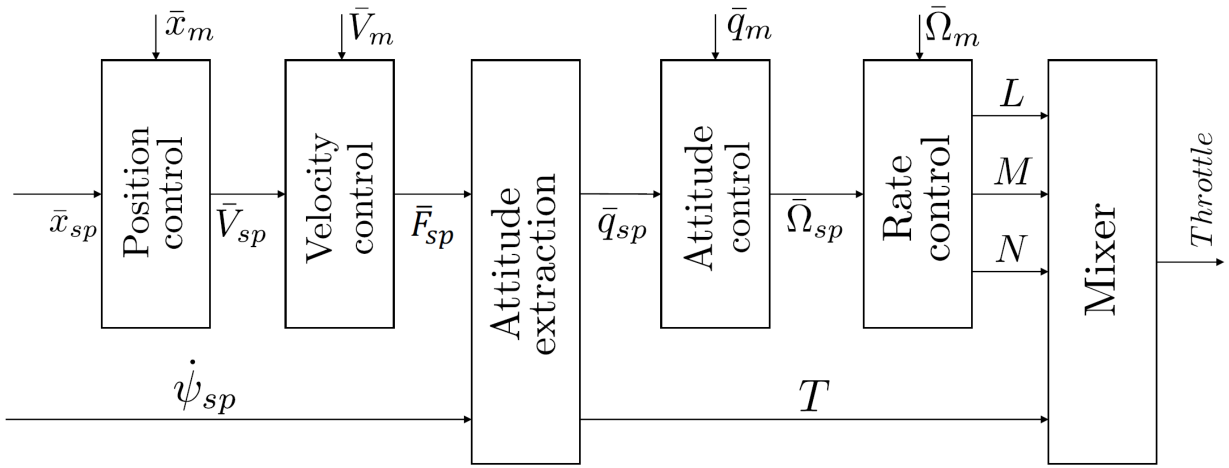
Propellers

- CAD Model provided PropellerAssy
- Propeller model Gemfan Flash 7042-2
- Blade section geometry provided in «blade1_data.mat"
- Generate_DUST_input.m generates all blade data in format compatible with DUST. All airfoil coordinate are expressed starting from the leading edge

Mechanical Properties of ABS

Elongation at Break	10 - 50 %
Elongation at Yield	1.7 - 6 %
Flexibility (Flexural Modulus)	1.6 - 2.4 GPa
Hardness Shore D	100
Stiffness (Flexural Modulus)	1.6 - 2.4 GPa
Strength at Break (Tensile)	29.8 - 43 MPa
Strength at Yield (Tensile)	29.6 - 48 MPa
Toughness (Notched Izod Impact at Room Temperature)	200 - 215 J/m
Toughness at Low Temperature (Notched Izod Impact at Low Temperature)	20 - 160 J/m
Young Modulus	1.79 - 3.2 GPa

Controls


$\bar{x}_m$
$\bar{V}_m$
$\bar{q}_m$
$\bar{\Omega}_m$
Position control
Velocity control
Attitude extraction
Attitude control
Rate control
Mixer
$\bar{x}_{sp}$
$\bar{V}_{sp}$
$\bar{F}_{sp}$
$\bar{q}_{sp}$
$\bar{\Omega}_{sp}$
L
M
N
$Throttle$
$\dot{\psi}_{sp}$
T

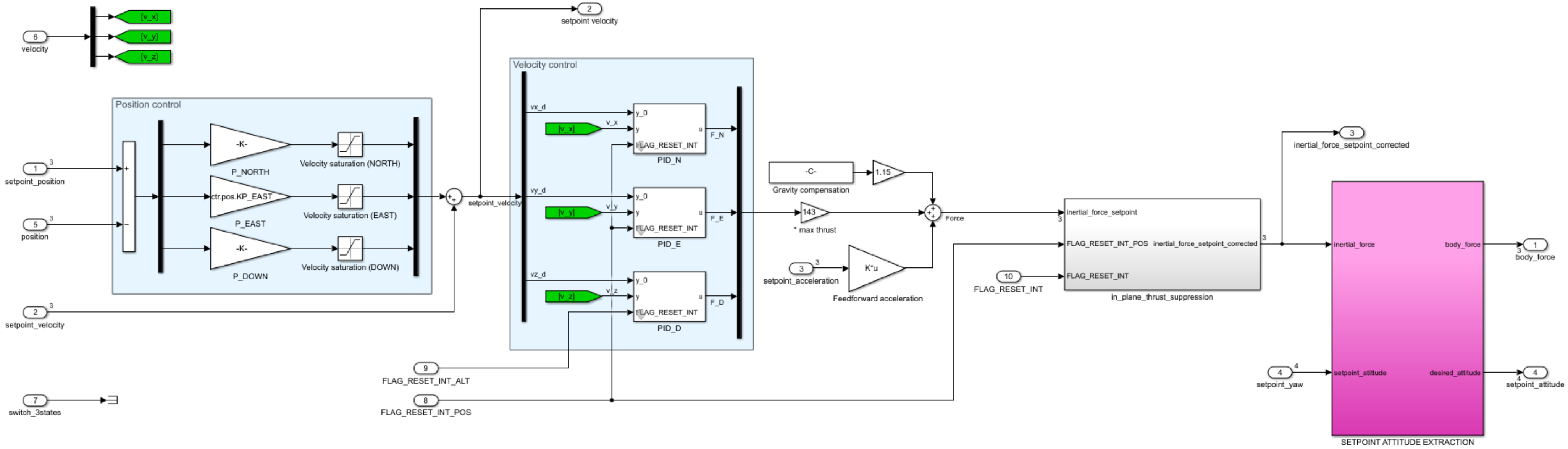


Figure 3.5: *Simulink* position control block.

Controller Gains

There has been a necessity to notch the frequency 91.98 rad/s
For flight at low speed

Controller	Proportional	Integral	Derivative
Roll rate	$K_P = 4.05$	$K_I = 0.05$	$K_D = 0$
Pitch rate	$K_P = 8.00$	$K_I = 1.40$	$K_D = 0$
Yaw rate	$K_P = 2.20$	$K_I = 0.25$	$K_D = 0$
Roll angle	$K_P = 3.55$		
Pitch angle	$K_P = 3.00$		
Yaw angle	$K_P = 1.20$		
V_{North}	$K_P = 0.10$	$K_I = 0.01$	$K_D = 0$
V_{East}	$K_P = 0.10$	$K_I = 0.01$	$K_D = 0$
V_{Down}	$K_P = 0.90$	$K_I = 0.15$	$K_D = 0$
Pos_{North}	$K_P = 0.60$		
Pos_{East}	$K_P = 0.60$		
Pos_{Down}	$K_P = 0.60$		

$$N(s) = \frac{s^2 + 2 \cdot g \cdot d \cdot f \cdot s + f^2}{s^2 + 2 \cdot d \cdot f \cdot s + f^2},$$

f	g	d
91.98	0.0001	0.2

Possible themes

Basic problems

- Perform an aeroelastic assessment of the airframe part (NASTRAN, Flutter speed)
- Assess the rigid and aeroelastic stability derivatives and the impact on the flight dynamic model (NASTRAN + Matlab)
- Perform an aeroelastic assessment of the propellers (MBDyn)
- Assess the aeroservoelastic structural coupling problems at low speed, and high speed of the airframe (NASTRAN + Matlab)

Composite team problems

- Aero(servo)elastic structural coupling problems of the Full system (NASTRAN + Mbdyn)
- Whirl flutter (NASTRAN + Mbdyn)