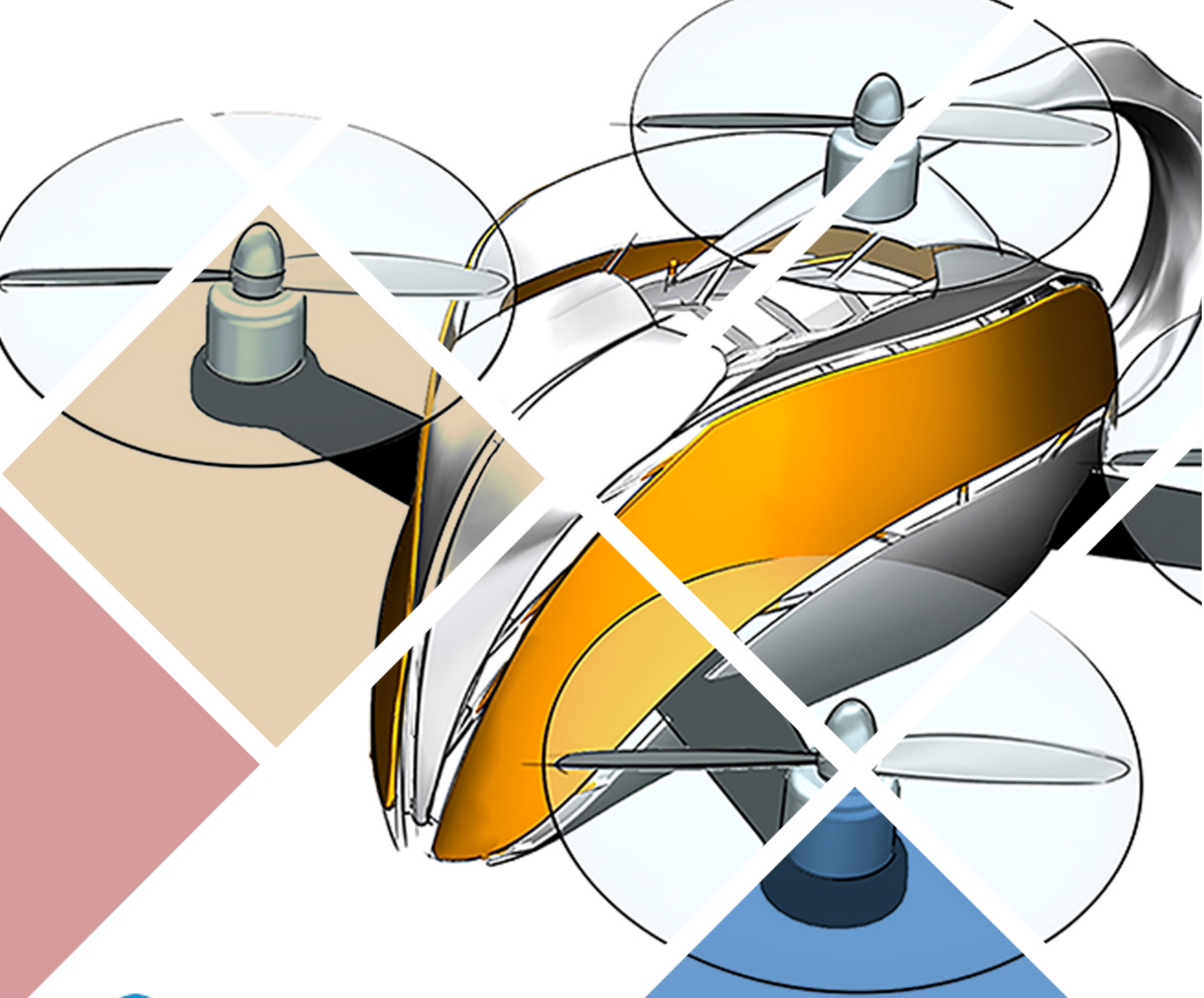


DRONE TEAM

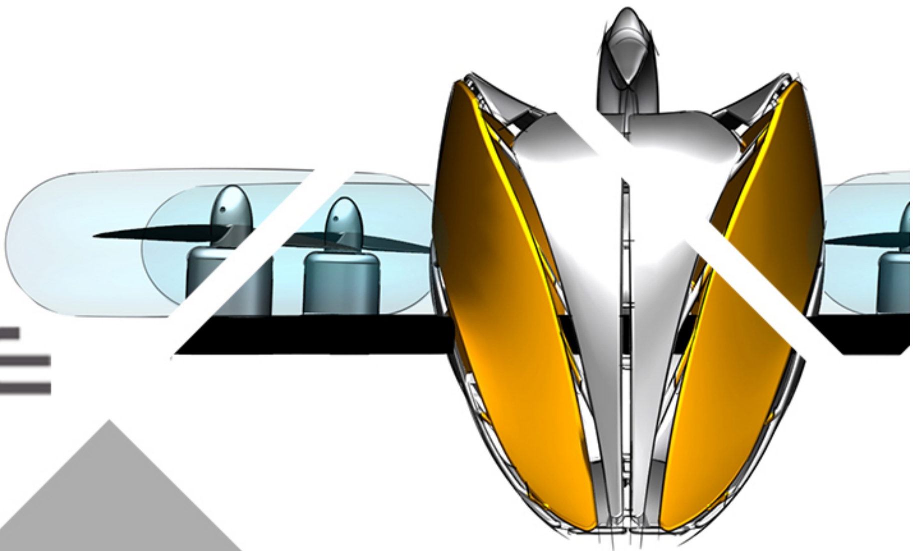
Drone It Yourself!

MAKING AND DESIGNING A TOY DRONE
THROUGH MULTIDISCIPLINARY
COLLABORATIVE WORK
Project no. 2015-1-ES01-KA202-015925

Co-funded by the
Erasmus+ Programme
of the European Union

Drone It Yourself! consists of the following modules:

0. INTRODUCTION TO THE DRONETEAM PROJECT
1. BASIC TOY DRONE FRAME
2. MODULE OF FLIGHT CONTROL
3. MODULE OF COMMUNICATION CONTROL
4. MODULE OF ADVANCED FRAME
5. MODULE OF GPS-COMPASS CONTROL
6. MODULE OF PROBLEM MANAGEMENT
7. MODULE OF FLIGHT STABILIZATION SYSTEM
8. MODULE OF FIRST PERSON VIEW
9. DRONETEAM E-LEARNING PLATFORM
10. OTHER DEVELOPMENTS
11. GLOSSARY



DRONE TEAM

This project has been funded with support from the European Commission. This publication reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

MODULE OF FLIGHT STABILIZATION SYSTEM

2015-1-ES01-KA202-015925

Co-funded by the
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1. FLIGHT STABILIZATION SYSTEM

The stabilization system of a drone is offered by the Flight Controller and the sensors that allow to measure the flight parameters that are corrected by the controller. These sensors are the Accelerometer, Magnetometer, Gyroscope and Barometer. These sensors have been specified in section “5. MODULE OF GPS/COMPASS CONTROL”. The advanced Flight Controller used in the DroneTeam Project has been explained in section “4. MODULE OF ADVANCED FRAME”.

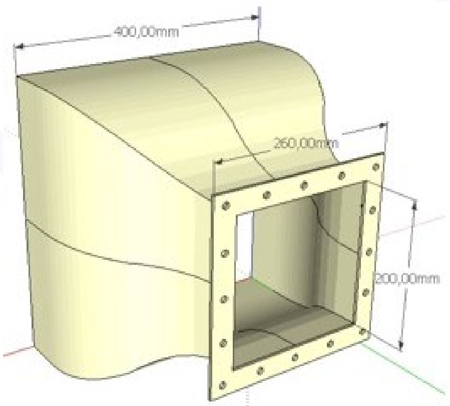
In this section you can see the wind tunnel construction, hypotheses, measurements and results.

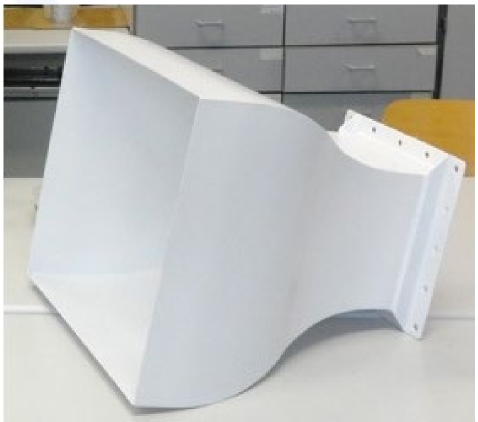
2. USING A WIND TUNNEL

2.1. WIND TUNNEL CONSTRUCTION.

You need a physical laboratory, and sensors to measure some aspects on the drone. You can develop your own wind tunnel as a making workshop in your school with students. Because of the limited space in the tunnel, we had to use a smaller drone.

Design and construction of the main chamber. Production of leading tubes of 4000 slim. We use CAD 3D design and CNC machines.

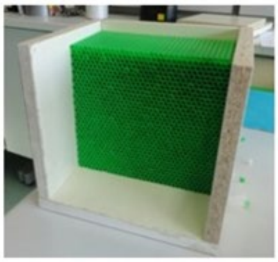
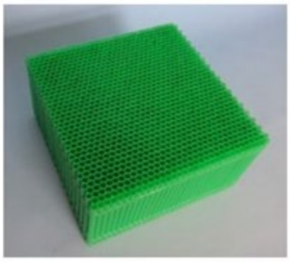




Manufacturing of diffuser system. For this we use straws (green straws)



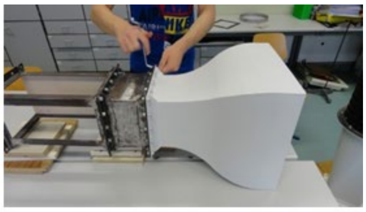


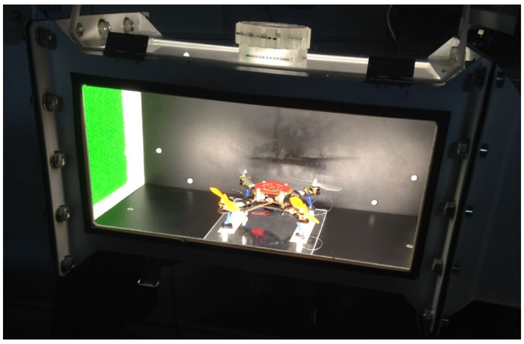




The fan is obtained from old Nissan car.


Measuring equipment for the Wind Tunnel:


Assembling the Wind Tunnel:



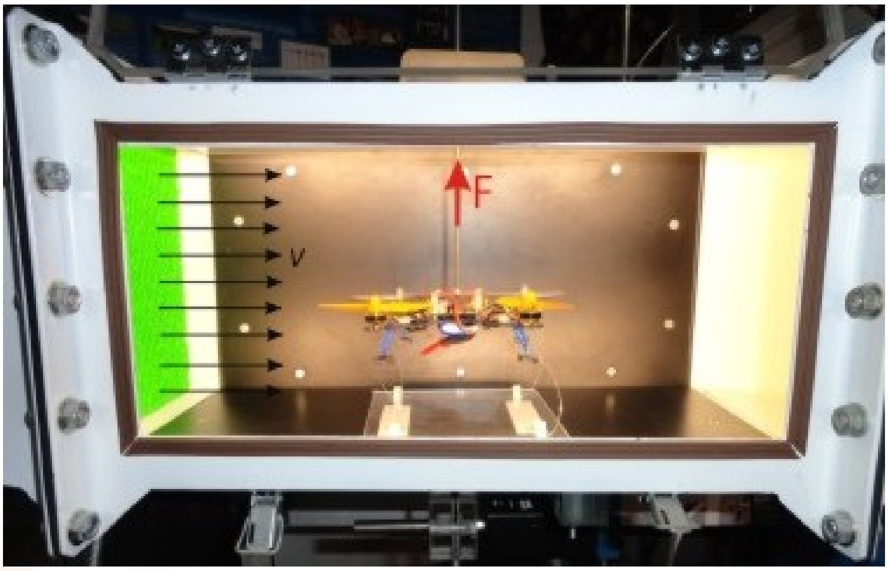


2.2. HYPOTHESES.

We assumed 2 hypotheses which we wanted to confirm or deny with measurements:

> **HYPOTHESIS 1:** Does horizontal velocity of vessel's motion influence the amount of force of air buoyancy during the flight?

We predicted: HORIZONTAL VELOCITY WILL DECREASE AIR BUOYANCY AND THUS DISABLE THE LIFT-OFF OF THE VESSEL.



> **HYPOTHESIS 2:** While moving and flying, drone assumes various positions due to its orientation and inclinations at the changes of course as well as the relative situations such as the impact of wind.

Measurement 2 encompasses the impact of aerodynamic drag in the measuring chamber of the wind tunnel in different positions of the vessel.

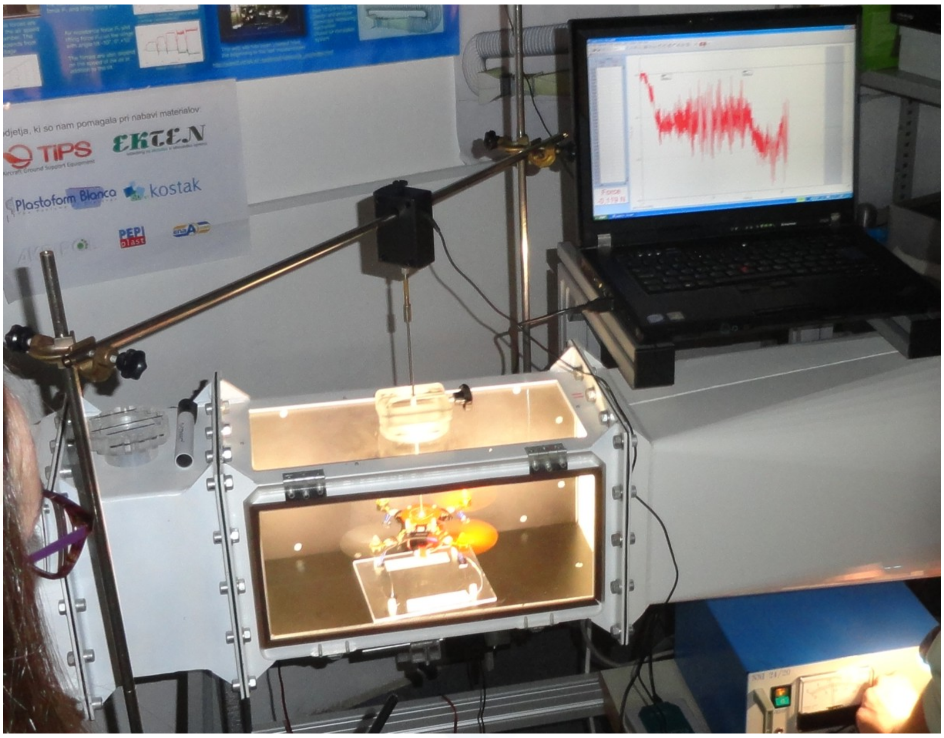
2.3. THE IMPACT OF THE CROSSWIND ACTIVE HORIZONTAL FORCE.

Does horizontal velocity of vessel's motion influence the amount of force of air buoyancy during the flight? We assumed that it does.

We predicted: HORIZONTAL VELOCITY WILL DECREASE AIR BUOYANCY AND THUS DISABLE THE LIFT-OFF OF THE VESSEL.

Direction of the vector defining the velocity of drone's horizontal motion is presented by the relative air velocity through the wind tunnel. We expected results and stated hypotheses.

We constructed brackets and a frame for the fitting of the drone and force gauge Vernier. Gauge was attached vertically to the vessel's air buoyancy.



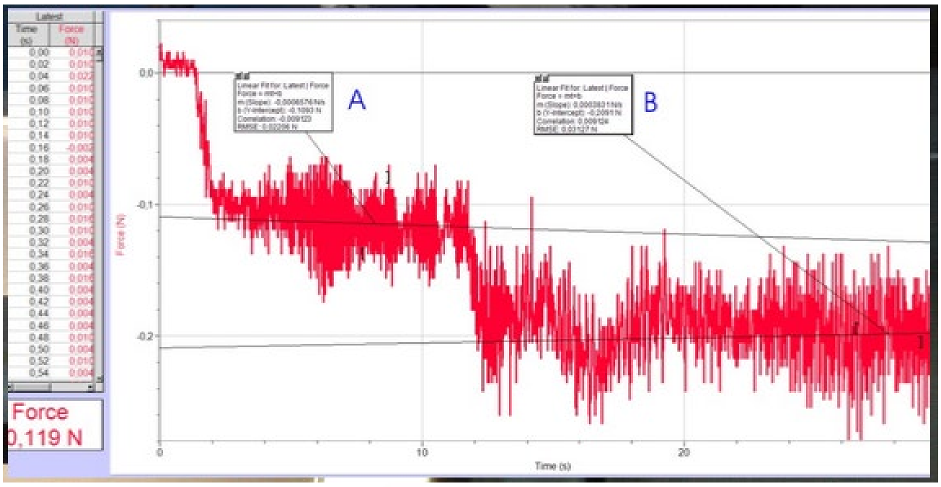
- **PHYSICAL MEASUREMENTS**

Vertical force is measured at the time of the launch of drone's rotors and influences the horizontal components of relative velocity. Force gauge Dual-Range Force Sensor DFS-BTA Vernier is connected via interface to the computer programme Logger Pro. Measurement period is 30 seconds and the measurement frequency 50/s.

- **MEASUREMENT DIAGRAM**

Diagram presents measurement section A, where no impact of air velocity in the wind tunnel is detected. At this time gauge records only the force of drone's rotors rotation (uplift force). Section B presents data related to the wind tunnel launching and the impact of the horizontal air force (relative velocity).

The result is an average force of uplift. The speed of air mass increased the uplift force. Air buoyancy of the vessel increased.

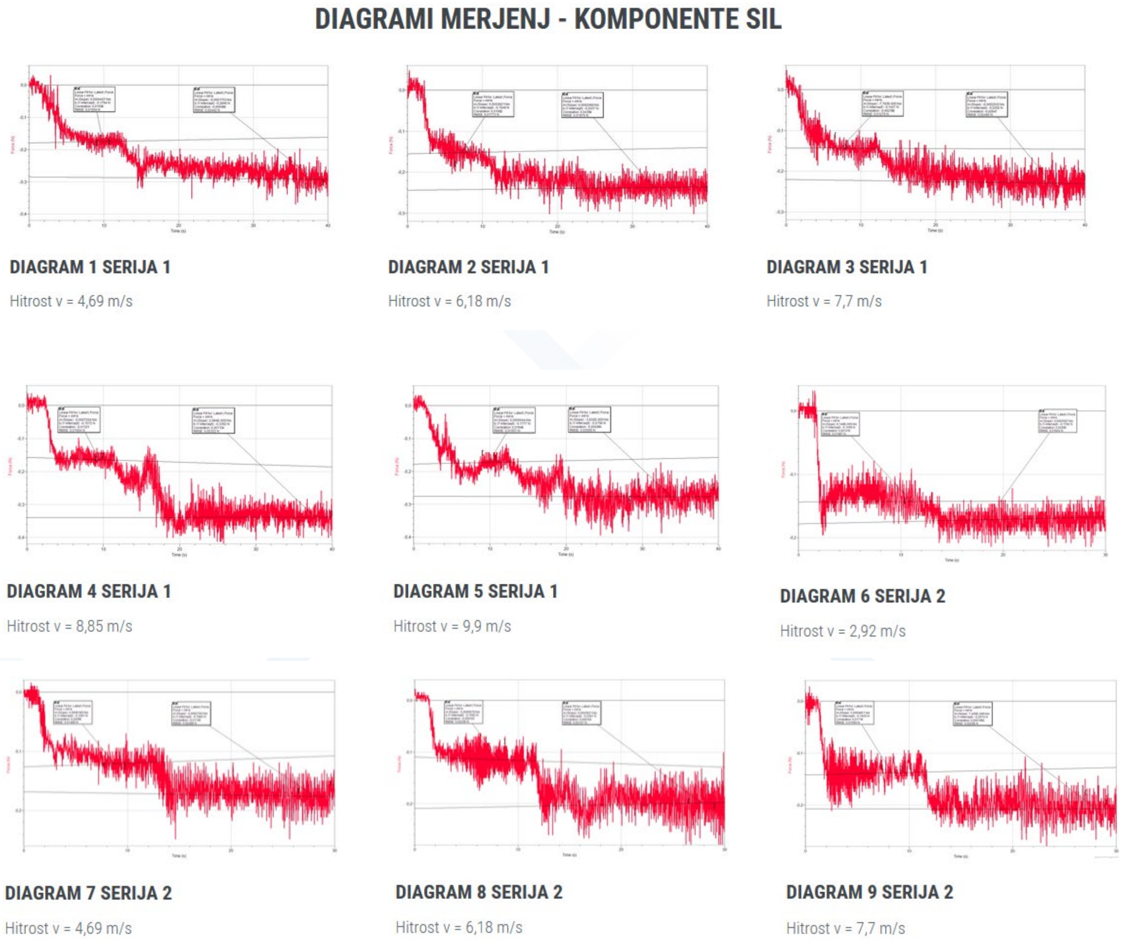


The picture shows air velocity vectors (v), which represent relative movement. The uplift force (F) of a drone is directed vertically at the gauge.

In Series 1 and Series 2 tabs there are two charts from all measurements.

(Hitrost = Speed; Serija=Series)

Measurement Diagrams - Force Components



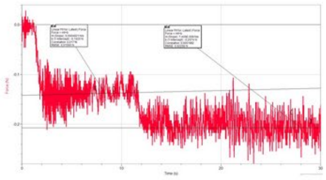


DIAGRAM 9 SERIJA 2

Hitrost v = 7,7 m/s

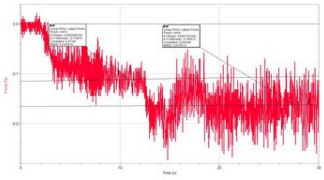


DIAGRAM 10 SERIJA 2

Hitrost v = 8,85 m/s

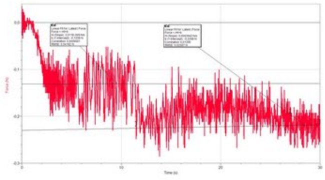


DIAGRAM 11 SERIJA 2

Hitrost v = 9,9 m/s

- **RESULT ANALYSIS**

The gauge accuracy at 0.001 N combined with a high frequency of measurements results in a diagram, which needs to be evaluated according to the average segments of measurements.

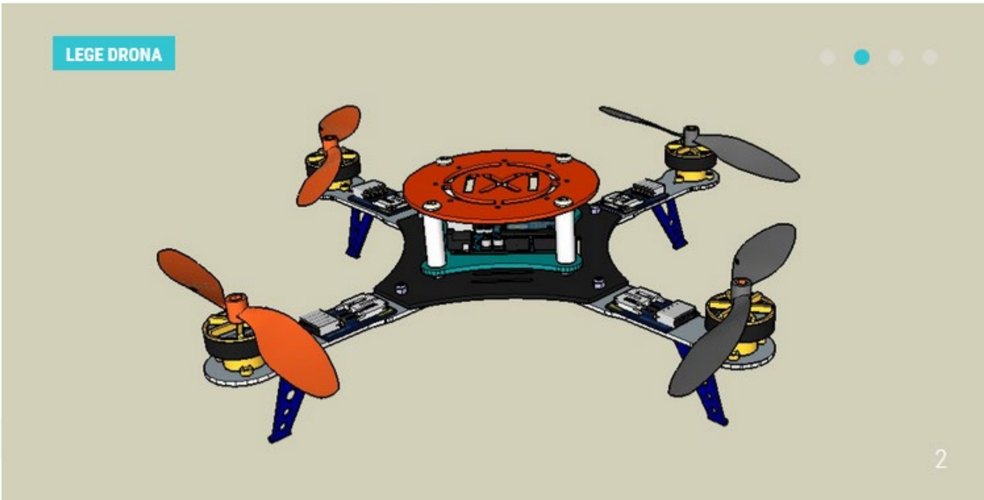
Vessel launching force is therefore increased from -0.1093 N to -0.209 N. It is increased by almost 52 %.

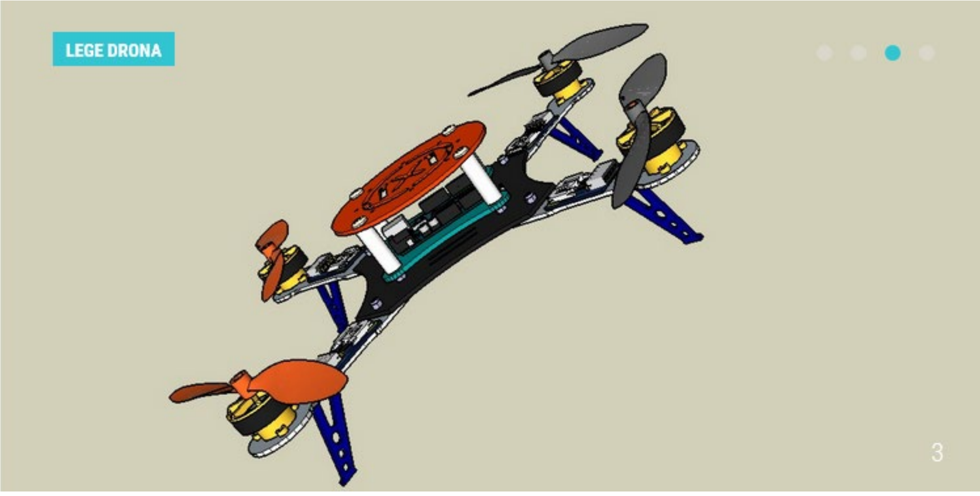
The results of the measurements were surprising. Namely, the measurements showed that side component increases the force of buoyancy, which enables the lifting of the vessel. Our hypothesis was disproved. We found the reason for that in the aerodynamic shape of rotors.

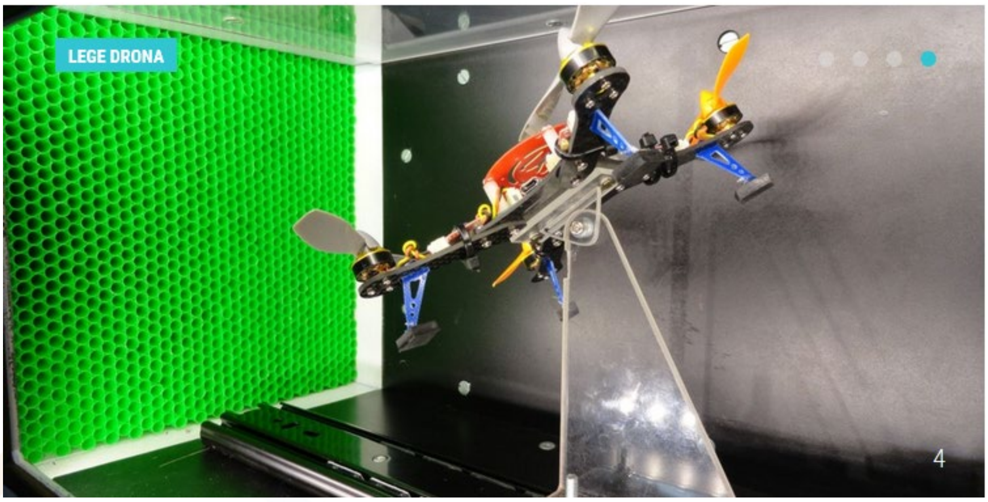
2.4. AERODYNAMIC DRAG FORCE IN DIFFERENT POSSITIONS.

While moving and flying, drone assumes various positions due to its orientation and inclinations at the changes of course as well as the relative situations such as the impact of wind.

Measurement 2 encompasses the impact of aerodynamic drag in the measuring chamber of the wind tunnel in different positions of the vessel.

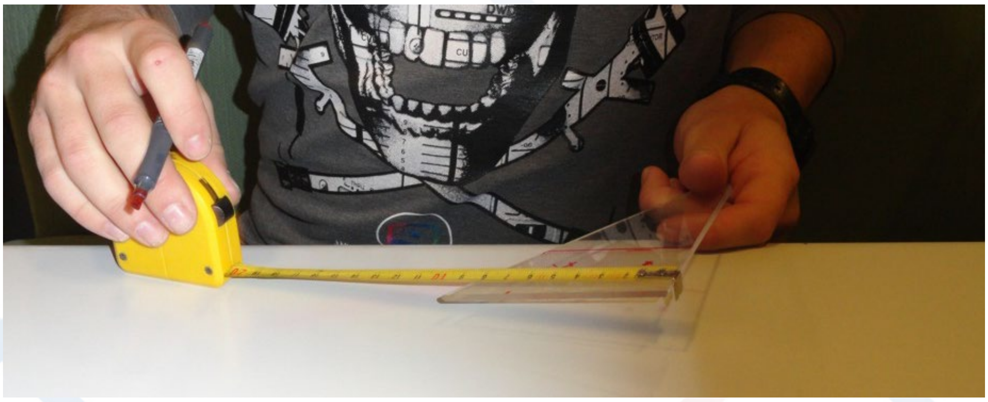


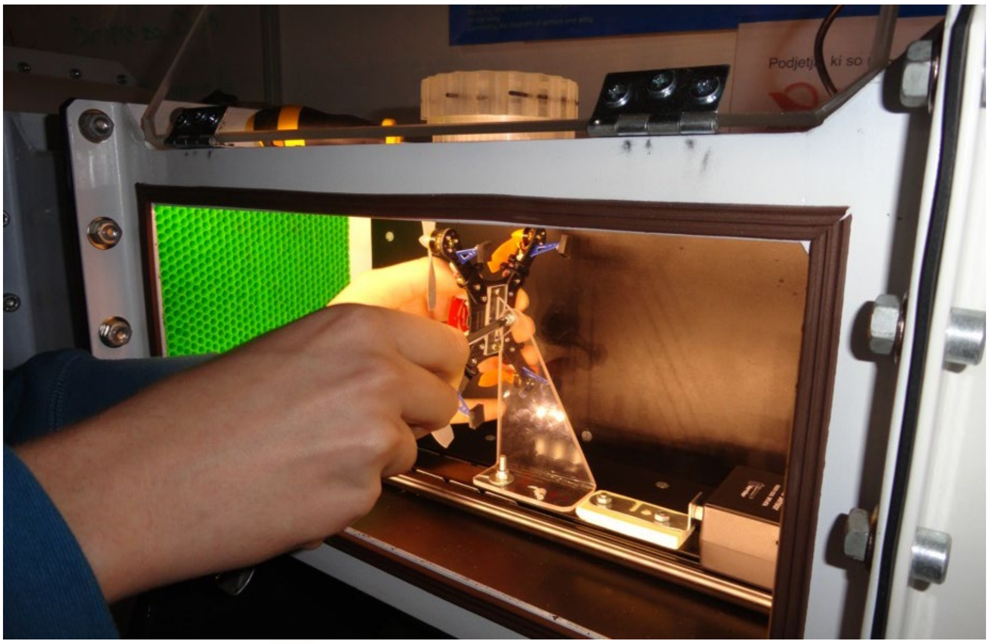




A SLIDING BUS - A BRACKET

A supporting mechanism enabling various inclinations in different drone positions needs to be constructed.



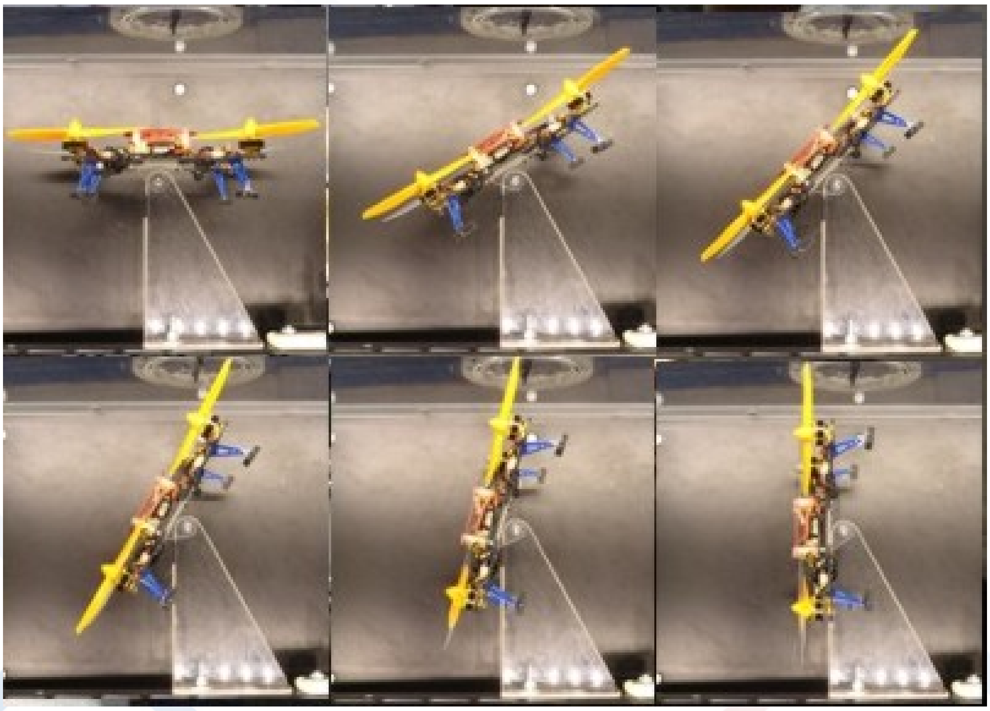


2.5. AERODYNAMIC DRAG MEASUREMENTS AND RESULTS.

2.5.1. AIR RESISTANCE MEASUREMENT SERIES

X-shaped drones are the most common. Our model has four symmetrically positioned rotors as well. With such shapes we can expect relatively high aerodynamic drag.

We wanted to prove how important drone position during the flight is. Series of measurements show the correlation between the aerodynamic drag force and the angle - inclination of a vessel as well as the relative velocity of motion.



Series 1

The first series shows three main positions of flying. Horizontal position is mostly theoretic as this kind of movement results in additional force components, which move the drone in a vertical way. Angle 45° is common but not permanent. Angle 90° means vertical movement. At this angle the measured air drag force is at its highest value.

1. Serija meritev sile upora

	Vir (V)	Hitrost (m/s)	Vodoravno 0°	Kot 45°	Kot 90°
1	4	2,92	-0,00286	-0,00188	-0,0027
2	6	4,69	-0,00481	-0,01209	-0,0690
3	8	6,18	-0,01385	-0,1423	-0,1589
4	10	7,7	-0,04626	-0,1931	-0,2909
5	12	8,85	-0,09457	-0,2304	-0,4466

DIAGRAMI MERJENJ - SILE ZRAČNEGA UPORA NA DRON

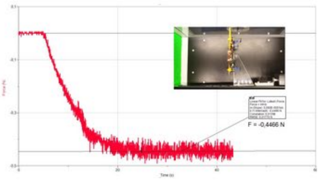


DIAGRAM 1 SERIJA 1/90°

Hitrost v = 8,85 m/s

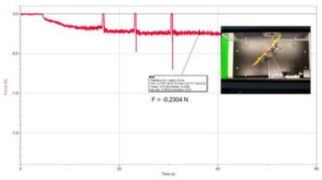


DIAGRAM 2 SERIJA 1/45°

Hitrost v = 8,85 m/s

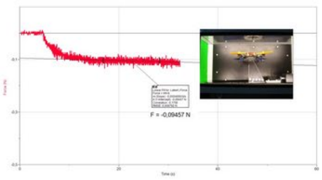


DIAGRAM 3 SERIJA 1/0°

Hitrost v = 8,85 m/s

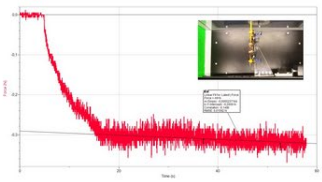


DIAGRAM 4 SERIJA 1/90°

Hitrost v = 7,7 m/s

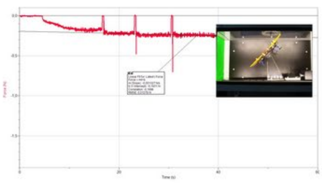


DIAGRAM 5 SERIJA 1/45°

Hitrost v = 7,7 m/s

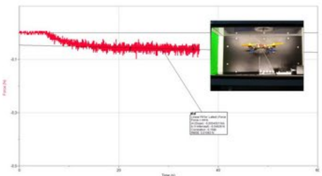


DIAGRAM 6 SERIJA 1/0°<

Hitrost v = 7,7 m/s

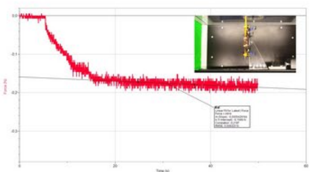


DIAGRAM 7 SERIJA 1/90°

Hitrost v = 6,18 m/s

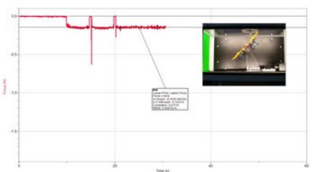


DIAGRAM 8 SERIJA 1/45°

Hitrost v = 6,18 m/s

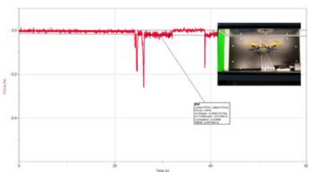


DIAGRAM 9 SERIJA 1/0°

Hitrost v = 6,18 m/s

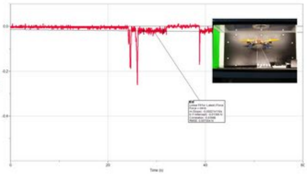


DIAGRAM 9 SERIJA 1/0°

Hitrost v = 6,18 m/s

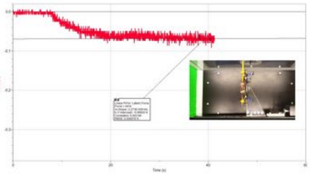


DIAGRAM 10 SERIJA 1/90°

Hitrost v = 4,69 m/s

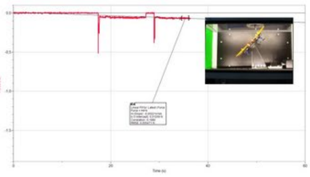


DIAGRAM 11 SERIJA 1/45°

Hitrost v = 4,69 m/s

Series 2

The frame of the drone used in this measurement allowed us to measure random drone inclinations. We selected several values and observed the changes in the resistance dependent on the angles presented in the chart.

2. Serija meritev sile upora

	Vir (V)	Hitrost (m/s)	Kot 15°	Kot 30°	Kot 60°	Kot 75°
1	4	2,92				
2	6	4,69	-0,0198	-0,04505	-0,03158	-0,05515
3	8	6,18	-0,0492	-0,08441	-0,1415	-0,2007
4	10	7,7	-0,1027	-0,1483	-0,2945	-0,3288
5	12	8,85	-0,1606	-0,1961	-0,534	-0,4365

MEASUREMENT DIAGRAMS - AERODYNAMIC DRAG

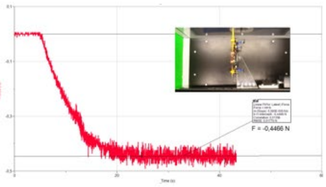


DIAGRAM 1 SERIES 1/90°

Velocity v = 8,85 m/s

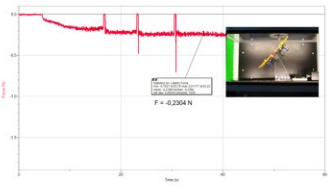


DIAGRAM 2 SERIES 1/45°

Velocity v = 8,85 m/s

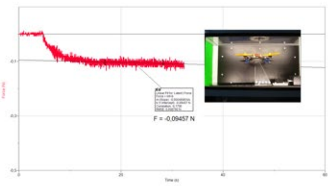


DIAGRAM 3 SERIES 1/0°

Velocity v = 8,85 m/s

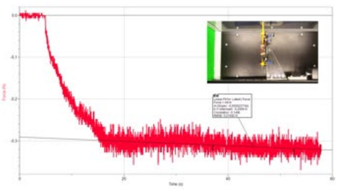


DIAGRAM 4 SERIES 1/90°

Velocity v = 7,7 m/s

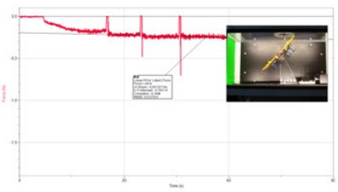


DIAGRAM 5 SERIES 1/45°

Velocity v = 7,7 m/s

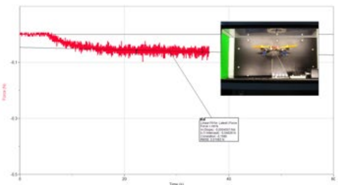


DIAGRAM 6 SERIES 1/0°<

Velocity v = 7,7 m/s

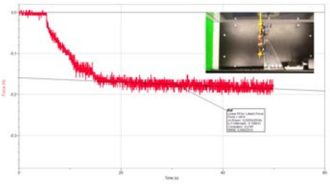


DIAGRAM 7 SERIES 1/90°

Velocity v = 6,18 m/s

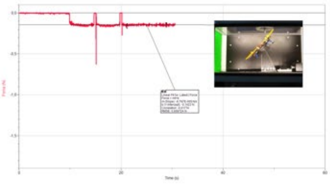


DIAGRAM 8 SERIES 1/45°

Velocity v = 6,18 m/s

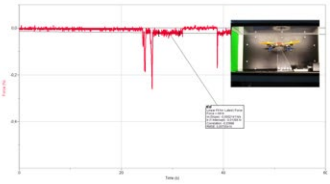


DIAGRAM 9 SERIES 1/0°

Velocity v = 6,18 m/s

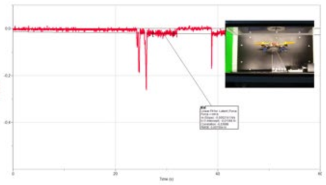


DIAGRAM 9 SERIES 1/0°

Velocity v = 6,18 m/s

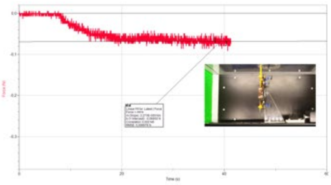


DIAGRAM 10 SERIES 1/90°

Velocity v = 4,69 m/s

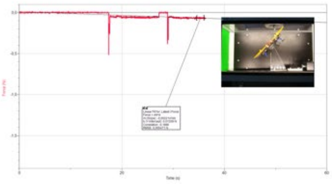
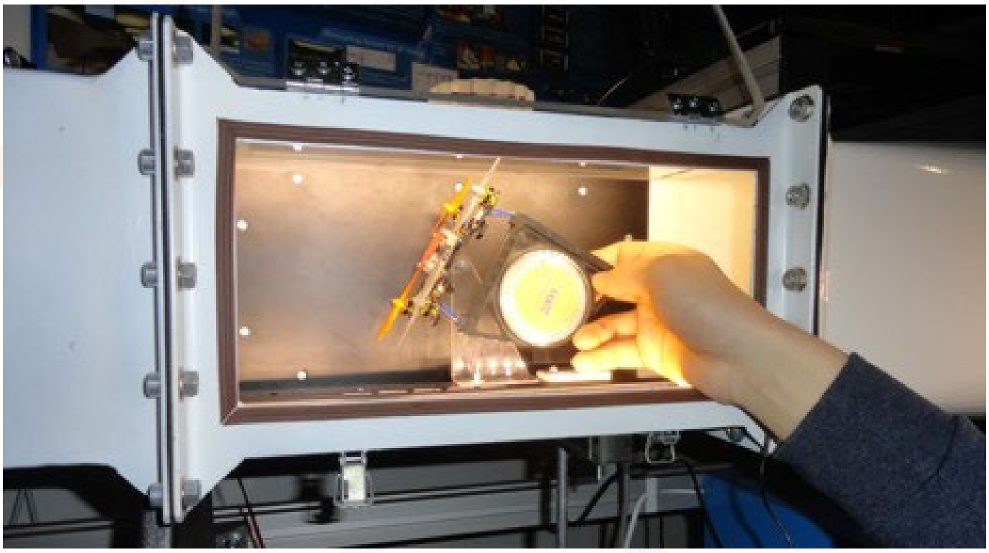


DIAGRAM 11 SERIES 1/45°

Velocity v = 4,69 m/s

2.5.2. INCLINATIONS

Each series of measurements at different speed was adjusted manually with a barycentric protractor.



2.5.3. THE TOUCH OF A GAUGE

The accuracy of aerodynamic drag force measurements depends on the transfer of a body's area (intersection) directly upon the gauge. In order to nullify the impact of the force gauge itself upon the measurements, the measurement was conducted in the section between a bracket over the angle bus to the connection with the gauge Dual-Range Force Sensor DFS - BTA Vernier. The obstruction of a drag and static friction force in the bus were prevented by respective separation of the measured part from a sensor. Separation X in picture A enables the movement of measurement system to the force gauge (picture B) merely due to the impact of the aerodynamic drag caused by air mass in the wind tunnel.

2.5.4. PROBLEMS AT MEASUREMENTS.

The greatest problem with all measurements was the continuity of drone's power supply. Battery providing supply for the drive and the steering of a vessel has a very small capacity. Drone as a machine consumes too much electricity in comparison with the power supply capacity. The voltage in batteries rapidly dropped to the minimum thus enabling only short-term relevant measurements. Charged battery's maximum voltage was 4.2V. As the voltage dropped to merely 3.8V, there were problems with the remote signal reception and the constancy of rotor frequency.

The picture shows air velocity vectors (v), which represent relative movement. The uplift force (F) of a drone is directed vertically at the gauge.

In Series 1 and Series 2 tabs there are two charts from all measurements.