Helsinki Metropolia University of Applied Sciences
Degree Programme in Environmental Engineering

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Wind Energy Project

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1 Introduction

Helsinki Metropolia University of Applied Sciences has the project of powering the Eco-house, a small office building located on the campus of Myyrmäki, using clean energy sources. A Windside WS-0,30 C wind turbine was installed on the Eco-house roof to provide the building with electricity. Unfortunately, this turbine never works because of a lack of wind resources in this area.

The school purchased a weather station in order to monitor the wind and solar resources on the roof of its highest building, the B building. The weather station includes a Vaisala WXT520 Weather Transmitter, a pyranometer, a pole mast and a foundation for the pole mast. The foundation has already been placed on the roof.

The first objective of our project was to install the Weather Transmitter WXT520 and the pole mast on the roof of B building, and proceed to wind speed measurements. The second objective was to relocate the WS-0,30 C wind turbine from the Eco-house roof to the B building roof, where the wind speed is higher.

2 Theoretical background

2.1 Vaisala Weather Transmitter WXT520

2.1.1 Properties of the WXT520

The Vaisala Weather Transmitter WXT520 is a compact, lightweight and accurate instrument that measures six essential weather parameters : wind speed, wind direction, precipitation, barometric pressure, air temperature and relative humidity. It is equipped with a heating system that is automatically switched on at low temperatures, to prevent snow and ice deposition on the transmitter. It is easy to install, has a low power consumption, and no moving parts, hence little or no maintenance is needed. Figure 1 shows a picture of the WXT520.

Figure 1. Vaisala Weather Transmitter WXT520 (Hellopro)

To measure wind speed and direction, the WXT520 uses Vaisala WINDCAP® sensor technology. The transmitter uses three equally spaced ultrasonic transducers on a horizontal plane to measure the time it takes the ultrasound to travel from each transducer to the two others, and determines the wind speed and direction based on this information.

Rainfall is measured using Vaisala RAINCAP® technology. A piezoelectrical sensor is mounted under the steel cover on the transmitter. A piezoelectrical sensor is made of a small disk, which when deformed by pressure, generates a voltage proportional to the deformation (Wikipedia). The sensor detects the impact of raindrops on the steel cover. ”The signals from the impact are proportional to the volume of the drops. Hence, the signal of each drop can be converted directly to accumulated rainfall” (Vaisala, p. 27).

Pressure, temperature and humidity are measured using respectively BAROCAP®, THERMOCAP® and HUMICAP® sensor technologies. These technologies are based on a RC oscillator and two reference capacitors. The capacitance in these three sensors is continuously measured and a microprocessor “performs compensation for the temperature dependency of the pressure and humidity sensors” (Vaisala, p. 28).

2.1.2 Data collection

The WXT520 is equipped with a USB connector and a 8-pin M12 female connector. It comes with a software named Vaisala Weather Transmitter Configuration Tool. By connecting the WXT520 via USB to a PC and running the Configuration Tool, one can perform measurements of the six weather parameters. The transmitter is powered by the USB bus and does not require any additional power source. The measured data however, can only be read from the PC and cannot be stored nor exported to other systems. For long-time continuous measurements where the measured data needs to be stored in a database and/or exported to other systems, the WXT520 can be connected to an OPC server via the 8-pin M12 connector. In that case, a power supply of 24 Volts is required.

An OPC server is a software that acts as a protocol converter. Connected to a PLC (Programmable Logic Controller), a data source, a database or a user’s interface, an OPC server ”translates the data into a standard-based OPC format. ” (Wikipedia). HMI (Human Machine Interface), spreadsheet and other OPC compliant applications can then connect to the OPC Server to read and write device data.

2.1.3 Grounding

Grounding the weather transmitter is done by running a cable from the fixing screw on the mounting kit to the grounding place inside the ventilation room of the B building, which is just below the location of the foundation on which the transmitter will be installed. A grounding kit was purchased from Vaisala, and includes a longer fixing screw, two nuts and washers and an Abico connector for the grounding kit. Figure 2 shows the grounding of the transmitter using the grounding kit.

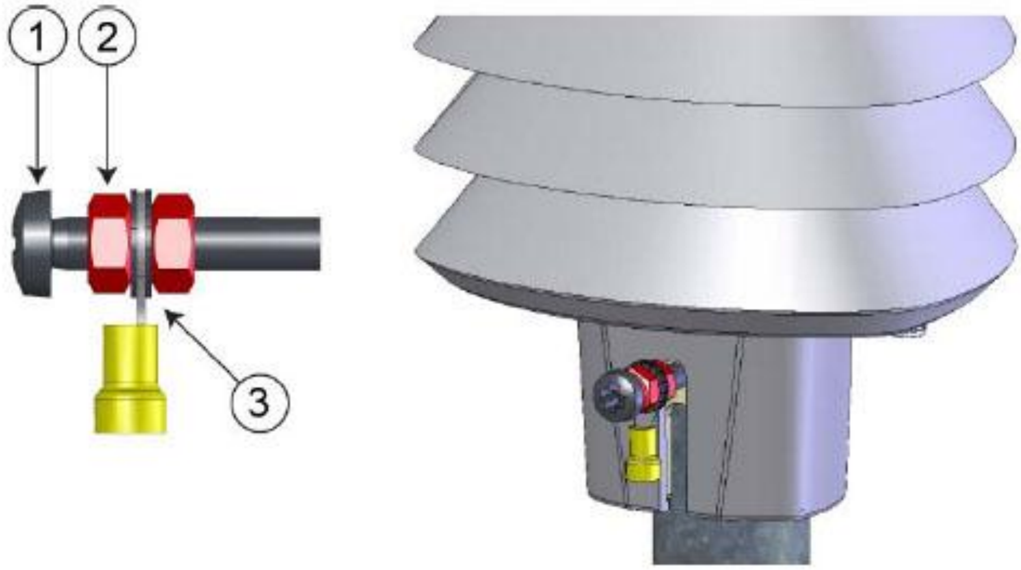

Figure 2. Grounding using the Bushing and Grounding kit (Vaisala, p. 39)

2.1.4 Surge protectors

Vaisala offers two surge protectors, the WSP150 and WSP152, that can be purchased separately from the weather transmitter. The WSP150 is an overvoltage supressor that can be used with all Vaisala wind and weather instruments. The WSP152 can be used with Vaisala WXT transmitters and WMT sensors. It is designed to protect the host PC against surges entering through the USB port. Vaisala recommends the use of surge protectors ”when weather instruments are installed on top of high buildings or masts and in open grounds, that is, anywhere with an elevated risk of lightning strike" (Vaisala, p. 24).

2.2 Windside WS-0,30 C wind turbine

A wind turbine, or windmill, is a device that converts mechanical energy from the wind into electrical energy. "Kinetic energy of the oncoming air strikes the rotor blades, turning them, and hence the axial kinetic energy is turned into mechanical energy of the rotating blades" (Al-Shemmeri, p. 20). The blades are connected to a shaft, in turn connected to a generator that will convert the mechanical energy from the rotating shaft into electrical energy. Some losses are dissipated through the energy conversion process, and only part of the kinetic energy of the incoming wind will end up as electrical energy.

There are windmills of various sizes, to fit the specific power needs and wind ressources available in different areas. The best windmills are described by their capability to give higher power output with lower average wind speeds. During this project, we were to relocate the Windside WS-0,30 C windmill installed on the Eco-house to the newest Metropolia building, B building, for power measurements. Figure 3 shows the design and main dimensions of the WS-0,30 C wind turbine.

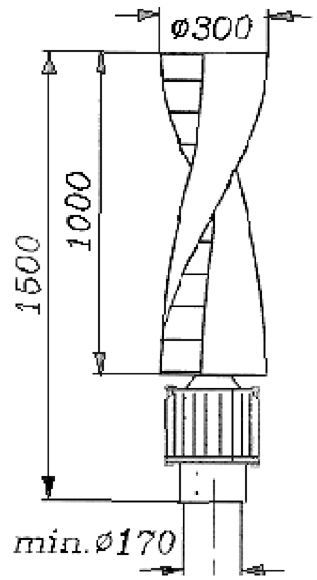

Figure 3. The WS-0,30 C turbine (Windside)

The WS-0,30 C turbine is a vertical windmill based on sailing engineering principles. The turbine rotor is rotated by two spiral-formed vanes, unlike some other types which have 3-star shaped vanes. Windside offers different turbine designs, to suit their use in different applications and in different wind conditions. These differences are indicated by the letters A, B or C at the end of each model number. A indicates a turbine designed for wind speeds up to 60 m/s, B 40 m/s, and C 30 m/s. Table 1 shows some technical properties of the WS-0,30 C.

Table 1. Windside WS-0,30 C wind turbine properties (Windside)

Rated power	9A/12V
Cut-in wind speed	2,0 m/s
Rated wind speed	18 m/s
Cut-out wind speed	none
Swept area	0,30 square meters
Vane weight	2 kg
Total weight of turbine	43 kg
Rotor speed control	electronic
Generator model	windside
Charging controller	Windside WGU-22
Measured sound emission	0 dB
Gear box	without gear
Generator type	12.volts
Main brake system	electronic

Windside turbines are designed to be durable, resisting the harshest environments with a minium maintenance, while providing a maximum power output. Tests on mechanical durability and torques of the WS-0,30 turbine were carried out by the Technical Research Centre in 1981, 1988, and later by Windside itself in the Åland archipelago. Between 1989 and 1991, the Finnish Army also tested the WS-4 turbine in the archipelago of Finland. This test lasted continuously for 450 days. During this time, the output power was recorded using a computer, giving 8 values every second. Figure 4 shows the charging of batteries by WS-0,30 turbines.

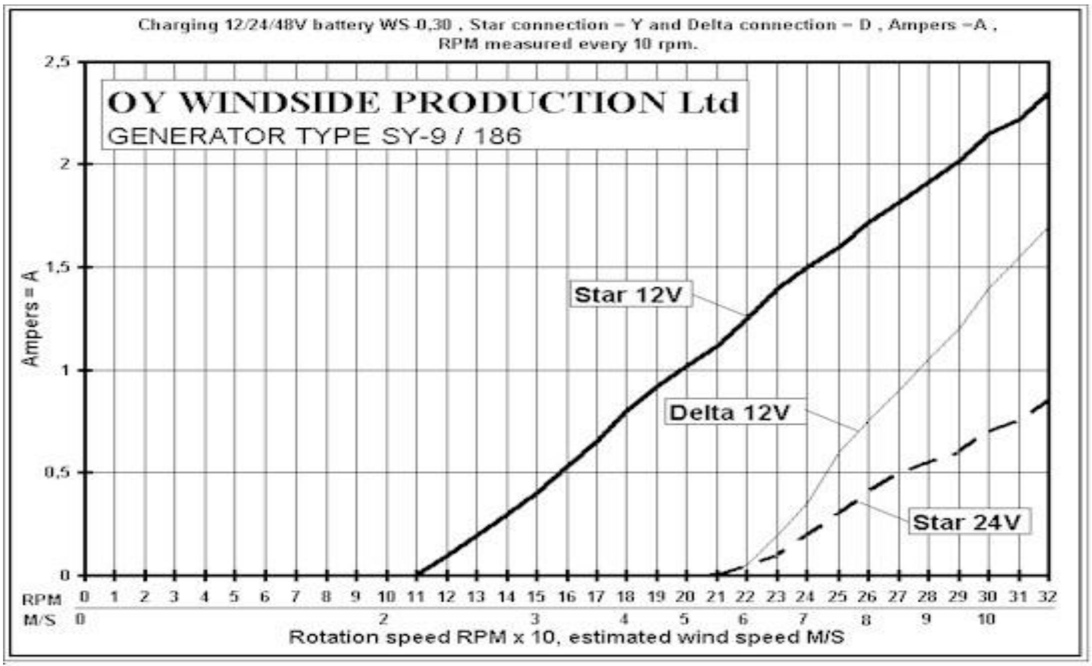

Figure 4. Charging of batteries by WS-0,30 turbine (Windside)

From these tests, Windside concluded that ”In real environment testing in the Archipelago of Finland the Windside Wind Turbine produced up to 50% more electricity in a year than a traditional propeller type turbine of the same swept area”.

In addition to the turbines themselves, Windside offers a wide range of accessories such as generators, charging controllers, phase rectifiers, artificial loads, fastening cylinders and automatic lubrication systems. A charging controller converts the AC-current produced by a turbine into a DC-current, suitable for batteries charging. Once the batteries are charged, the controller will disable the charging action, preventing overcharging. When an additional charging controller is used, or when the electricity is led straight to the batteries, a phase rectifier is needed. An artificial load is used in combination with a charging controller. Once the batteries are full, it converts the extra electrical energy into heat. The number of artificial loads depends on the maximum power of the generator. Finally, Windside recommends the purchase of an automatic lubrication system for remote areas and multi-turbine systems, as ”it lenghtens the interval time between maintenance operations up to 5 years”.

2.3 Other suitable turbines

Suggested future wind turbines from Finland for these kinds of projects could be:

- WinWinD 3
- Mypower

Other wind turbines across Europe include:

- AW-3000 wind turbine (3.0 MW capacity) & AW-1500 wind turbine (1.5 MW capacity) (from Spain). They are produced by ACCIONA ENERGY company.
- DeWind D9, DeWind D8.0 (2000 kW), DeWind D4 600 kW DeWind D8.2 2000 kW DeWind D6 1250 kW (from German manufacturing company called DeWind).

2.3.1 WinWinD 3

One of the leading wind mega wind turbine producers in Finland. Their main wind turbine products are called the WinWinD 3. WinWinD 3 is a completely new 3 MW utility class wind turbine. This type of turbine offers exceptional productivity and reliability in all wind classes. This type of turbine has the following advantages:

- Maximal energy production in all wind speed sites. With the option of three different rotor sizes of 100, 109 and 120 meters, the turbine is optimized for all wind conditions.
- Considerably lighter turbine in weight, including sophisticated loads control, and a high energy yield is achieved in all wind classes.
- Main bearing transfers the rotor loads directly to the main casing of the supporting structure. This keeps the whole drive train free from deformation, providing high reliability. Also integrated power unit, which comprises the main bearing, planetary gearbox and permanent magnet synchronous generator, eliminates the unreliability of high-speed components.

Other advantages include:

- Light nacelle weight – 80 t
- 100, 109 & 120 m rotor diameters

- Exceptional productivity – especially at low wind speeds
- Proven concept with 30 % less moving parts than conventional drive train system
- Designed for high availability
- Maximal grid compliance

General properties:

Rated power	3000 kW
Cut-in	3 – 4 m/s (rotor dependent)
Rated wind speed	11 – 12.5 m/s (rotor dependent)
Cut-out	20 – 25 m/s
Wind class	IEC IA, IIA, IIIA (rotor dependent)
Design lifetime	20 years
Power control	Variable speed, variable pitch control
Turbine concept	Planetary gear with medium speed permanent magnet synchronous generator and full power conversion

About the rotor:

Type	Three-bladed turbine		
Diameter	(1) 100 m	(2) 109 m	(3) 120 m
Swept area	(1) 7867 m2	(2) 9348 m2	(3) 11366 m2
Rotational speed	5 – 16 rpm		

Power unit:

Gear box	Planetary
Generator	Synchronous, permanent magnet
Converter	Full power IGBT conversion
Grid frequency	50 Hz / 60 Hz
Tower Type	Steel, tubular and concrete / steel hybrid
Tower Hub height	90 – 120 m

Brake system:

Aerodynamic	Individual electric pitch with emergency power supply

Mechanical Hydraulic disc brake

Below is a power curve for all the different rotor diameter WinWind 3 turbines.

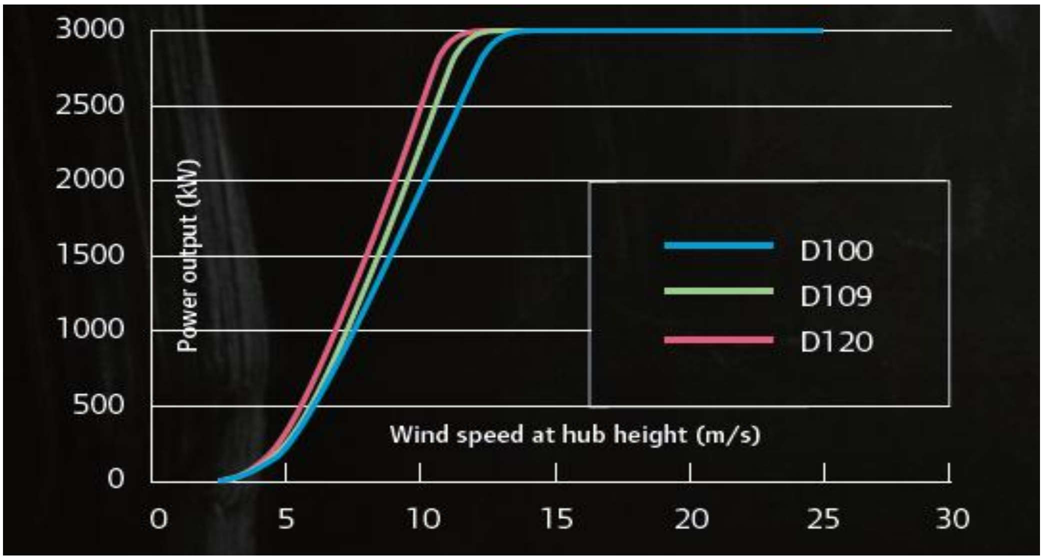

Figure 5. Power curve for different turbine diameters

2.3.2 Mypower

This turbine is manufactured by a Finnish company called Mypower Finland Ltd, but distributed by the Milan-based Blu Mini Power.

The Mypower has a blade diameter of 4.00 metres. This means it has a swept area, or capture area of 12.57 square metres. This is all important when comparing wind turbines, since it directly relates to the amount of passing wind energy the turbine blades can intercept.

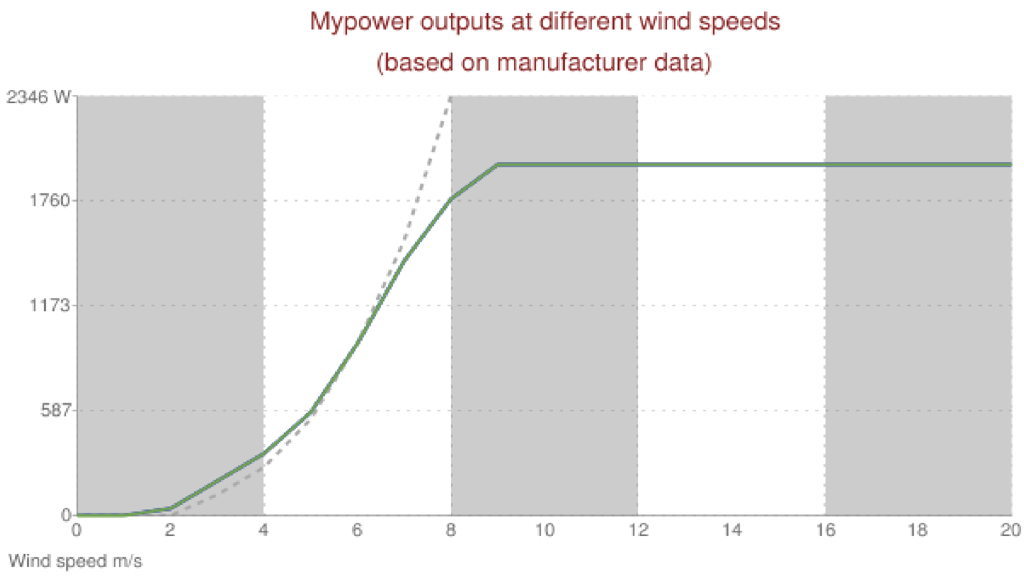

Figure 6. Power curve of Mypower wind turbine

The curve above shows the turbines power output in relation to different wind speeds. The green line shows the actual output that the wind turbine achieves at the given wind speed, and this is according to the manufacturers. The dashed line in the graph shows the theoretical maximum energy that this turbine could extract from the wind, according to Betz's Law (59.3%). At a typical wind speed of 5 m/s, the Mypower is extracting 600 Watts of power from the wind, which is an efficiency of 62.11%.

Also below the graph shows how efficient the turbine behaves across different ranges of wind-speeds.

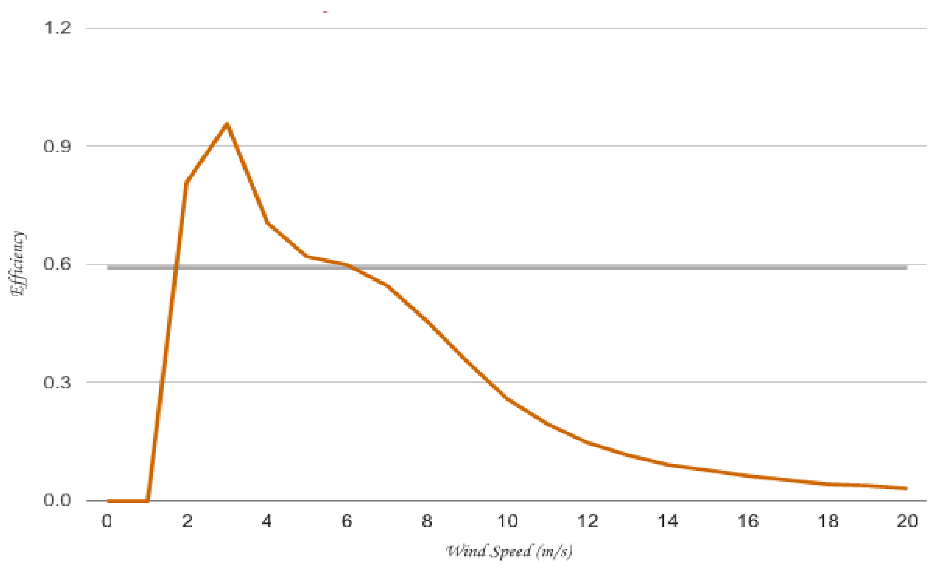

Figure 7. Efficiency of the Mypower turbine plotted against wind speed

2.3.3 Tuulivoima WPE10KW

This type of turbine has the following power out-put potential across the stated wind speeds.

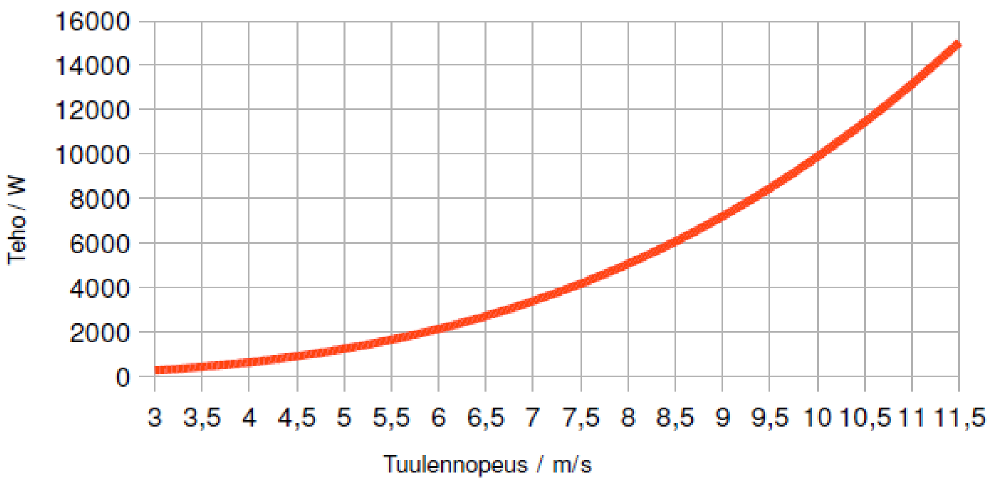

Figure 8. Power produced by the WPE10KW plotted against wind speed

The vertical axis shows the power produce in respect to the wind speed (horizontal axis). Other properties are as listed below:

- Cut-out speed 50 m/s

- Cut-in speed 3 m/s
- Voltage 500 volt output
- Weight 980 kg
- Rated speed 3 > 30 m/s

2.3.4 Tuulivoima WP1000W & WP2000W

Below is the power production curve for the 1 KW type:

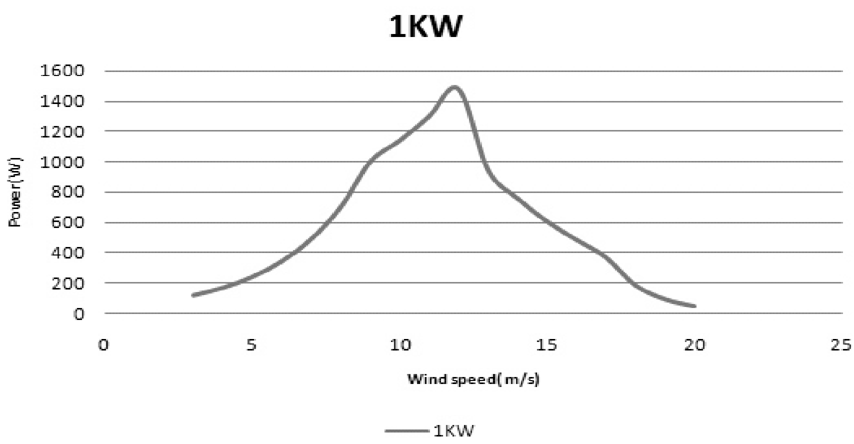

Figure 9. Power produced by WP1000W versus wind speed

Other general properties of the turbine are as follows for both WP type:

	WP1000W	WP2000W
Rotor diameter	2.7 m	3,2 m
Rated wind speed	9 m/s	9 m/s
Max. Power	1300W	2500W
Rotor material	Glass fiber	Glass fiber
Battery type	48V	120V
Generator mass	40 kg	44 kg

As for the 2 KW turbine, it's power versus wind speed potential graph looks like one below. Cut in speeds for both turbines are about 3 m/s.

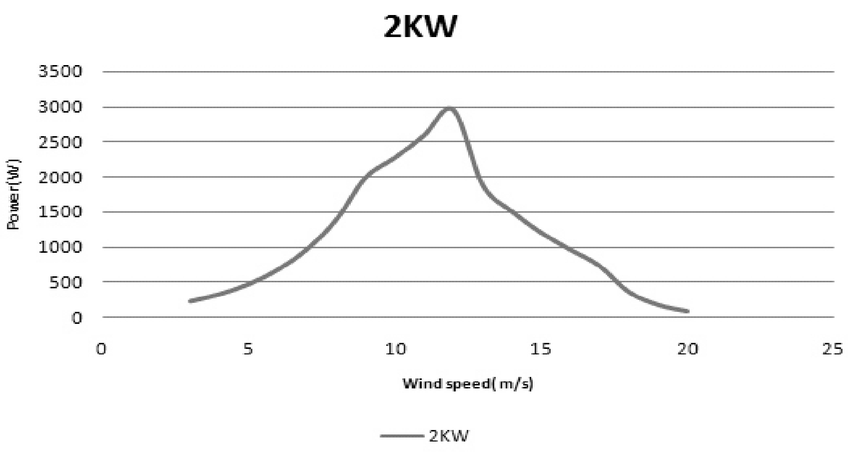

Figure 10. Power produced by WP2000W versus wind speed

2.3.5 Tuulivoima WPE2KW

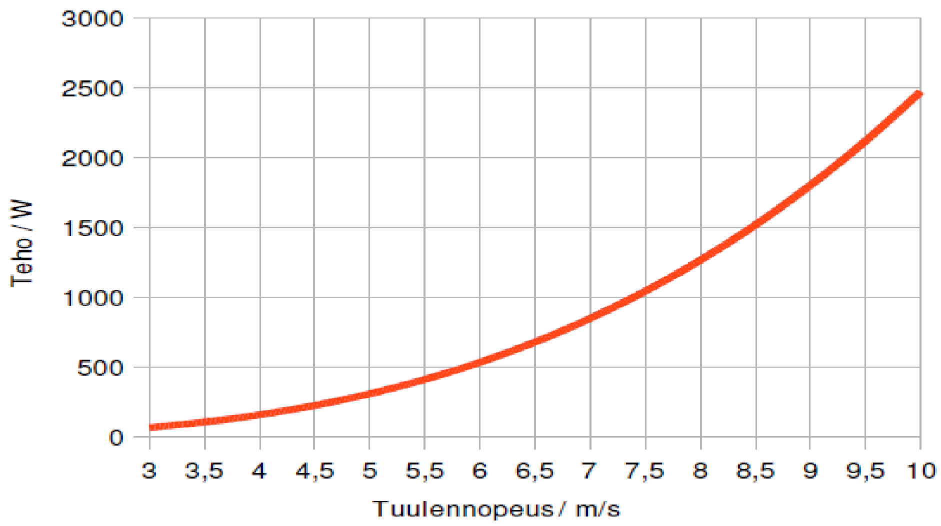

Figure 11. Power produced by the WPE2KW plotted against wind speed

The above curve illustrates the power produced (vertical axis) across different wind speeds (horizontal axis) for this type of turbine WPE2KW.

Other properties of this kind of wind turbine include:

	WPE2KW
Rotor diameter	4,0 m
Rated wind speed	9 m/s
Max. Power	2 kW / 2,8 kW

Rotor material	Glass fiber
Battery type	DC 300 V / 48 V
Turbine mass	123 kg
Cut-in wind speed	3m/s
Cut-out wind speed	50m/s

2.4 Siting

> The economics of wind power depend strongly on wind speed. The actual energy contained in the wind varies with the third power of the wind speed. Double the wind speed, and the energy it carries increases eightfold (Breeze, P & others 2009, p. 436).

Under these circumstances, the selection of a good site for the wind turbine is essential for the project to be economically viable. Each wind turbine has a cut-in speed, a minimal wind speed below which it will not operate, and a rated wind speed, a wind speed at and above which it gives its maximum power output. The turbine model should be carefully chosen so that the rated wind speed matches the average wind speed at the selected location, and vice-versa, if the turbine is selected before the location. The WS-0,30 C windmill that was installed on Eco-house roof never operates, because the wind ressources there are insufficient.

Wind speed increases with height. The higher the turbine will be placed, the better the wind ressources it will find; hence the decision to move the wind turbine from the Eco-house roof to a taller building. Another factor that influences the choice of a site is turbulences. Land relief, unevenness and obstacles such as buildings interfere with the wind flow and cause turbulences. ”Turbulent air creates an additional strain on a wind turbine blade, accelerating the onset of fatigue damage” (Breeze, P & others 2009, p. 437). To limit this damage, the turbine should be placed in a clear spot, with no major obstacle or relief nearby in the direction of prevailing wind.

The Eco-house is surrounded by a high building on one side and by tall trees on the other side. These obstacles considerably reduce the wind speed and create turbulences in this area. A better location for the windmill appears to be A and B buildings roof, as they rise higher than the surrounding trees and buildings. Figure 12 shows the location of the Eco-house and A and B buildings on the campus.

Figure 12. Location of the Eco-house and A and B buildings on Myyrmäki campus (Google)

3 Materials and methods

3.1 Wind speed measurements

When planning a wind energy project, prospective developers will normally conduct wind speed measurements on the potential sites to determine if one of them is suitable for the project. These measurements are usually conducted over at least one full year, longer when possible.

As we had only one weather transmitter and could not measure wind speeds continually before connecting the transmitter to an OPC server and installing it on a mast, we were able to perform only one set of short-time wind speed measurements. Average wind speeds were measured at nine different spots on A building roof for two minutes, by holding the Vaisala Weather Transmitter WXT520 at a height of about two meters above the roof. The transmitter was connected via USB to a laptop and the wind speed values read using the software Vaisala Weather Transmitter Configuration Tool. The measurements were made on a windy day in late October. The wind was coming from the west.

3.2 Connecting the WXT520 to an OPC server

To be able to perform continuous measurements over a long time period and store or export the data measured to other systems (to control a wind turbine for instance), the WXT520 needs to be connected to an OPC server.

We decided to use Advanced OPC Data Logger, a software developed by AGG Software. As we could not afford to buy the licence for this software, we downloaded a trial version, which will run up to two hours daily during two months. Once the trial period has expired, or if we wish to use the software more than two hours daily, we need to buy the licence.

For the WXT520 to communicate with the OPC server, we needed to connect the 8-pin M12 female connector of the transmitter to the DB9 male connector of the RS-232 serial port of the PC on which the OPC server was installed. As the WXT520 will later be placed on B building roof and connected to a PC in the ventilation room of that same building, which is located on the last floor, just under the roof, we purchased a 25 meters long 8-pin cable to make the connection. In addition, we also purchased a 24 Volts DC power supply Type 9320 manufactured by Mascot to power the WXT520. This power supply will be placed next to the computer in the ventilation room.

A 3 meters long 8-pin cable with an M12 male connector on one end and open wires on the other end was included in the WXT520 package. We connected the cable M12 male connector to the WXT520 M12 female connector. We then soldered the wires on the other end of the 3 meters cable to wires of a matching colour on one end of the 25 meters cable we had purchased. We placed insulating tape around each connection made between same colour wires to prevent short circuits.

This way, we obtained a roughly 28 meters long cable connected to the WXT520 on one end, and with open wires on the other end. These open wires will later be soldered to the 24 Volts power supply and to the pins of a DB9 female connector which we will use to make the connection with the RS-232 serial port of a PC.

Before placing the WXT520 on the roof, we decided to test the connection to the OPC server. Table 2 shows the wiring for WXT520 serial interfaces and power supply.

Table 2. Wiring for WXT520 serial interfaces and power supplies (Vaisala, p. 46)

Wire colour	**M12 Pin #**	**RS-232**
Blue	7	Data out (TxD)
Gray	5	-
White	1	Data in (RxD)
Green	3	GND for data
Pink	6	GND for Vh+
Yellow	4	Vh+ (heating)
Red/clear	8	GND for Vin+
Brown	2	Vin+ (operating)

For this test, the heating function of the WXT520 was not needed. We only had to connect the *Vin+* and the *GND for Vin+* pins to power the WXT520, and the *Data in (RxD)*, *Data out (TxD)* and *GND for data* pins to read the measured data on the OPC server. Figure 13 shows the pin assignment on a DB9 male connector, as we had on our computer.

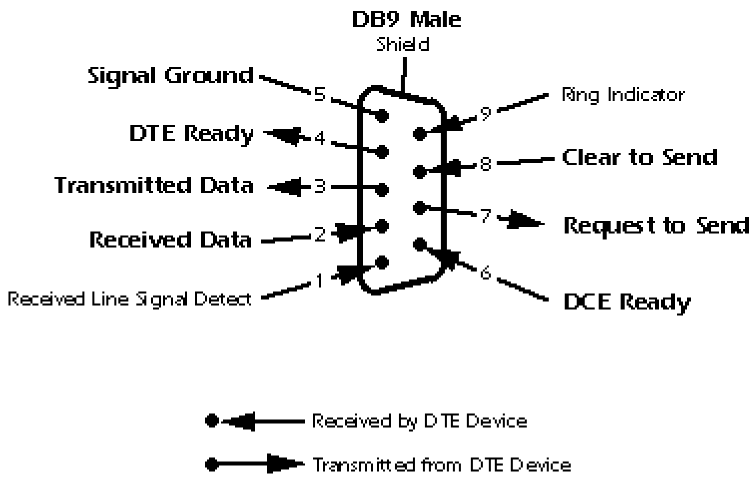

Figure 13. Pin assignment on a DB9 male connector (Camiresearch)

We soldered the blue wire (corresponding to the *Data out (TxD)* pin of the WXT520, as shown in table 2) coming out of our now 28 meters long cable to the pin 2 of a DB9 female connector (corresponding to the *Received Data* pin, as shown in figure 13). Following the same principle, we connected the white wire coming out of our cable to the pin 3 of the DB9 female connector, and the green wire to the pin 5. Finally, we soldered the red wire to the negative wire of the Mascot Type 9320 power supply, and the brown wire to the positive wire. These connections are summarised in table 3.

Table 3. Connections for testing the WXT520 with OPC server

Wire colour	**Connected to ...**
Blue	Pin 2 of DB9 female connector
White	Pin 3 of DB9 female connector
Green	Pin 5 of DB9 female connector
Red	negative wire of the power supply
Brown	Positive wire of the power supply

The weather transmitter was now powered and connected to the PC.

3.3 SolidWorks model

Because of important amounts on snow, we were not able to install the weather station on B building roof during this project. To facilitate the installation of the weather station – that is, the WXT520 weather transmitter, pyranometer, pole mast and foundation – we made a three dimensional model of the whole system using SolidWorks (see Appendix 1). The aim was to give a preview of what the weather station should look like once assembled. The exact dimensions of the main components were not always respected, and the smallest ones, such as screws were not represented.

4 Results and analysis

4.1 Wind speed measurements

The wind speed values we measured at nine different spots on A building roof are gathered in table 4.

Table 4. Wind speed measurements on A building roof

Spot	**Measured wind speed [m/s]**
a.	3,3
b.	2,8
c.	2,2
d.	5,1
e.	1,5
f.	2,7
g.	3,3
h.	2,1
i.	1,4

Figure 14 shows the location of the spots were the measurements were taken.

Figure 14. Spots were the measurements were taken (Google)

The wind speeds recorded on A building roof range from 1,4 m/s to 5,1 m/s, the average speed being 2,7 m/s. The large differences observed from one spot to another can be explained by the shielding or channeling effect higher parts of A building and B building have on the wind flow over A building roof.

For safety reasons, we could not access B building roof at the time we did those measurements. Because it is higher than A building, we assume that it offers an exposure to higher wind speeds and less turbulences. We decided it would be best to install the windmill and the weather transmitter on the highest part of the B building. This location is designated by the letter *j.* on figure 14.

4.2 Connecting the WXT520 to an OPC server

Connecting the weather station to the PC via serial port was maybe not so difficult, but due to our lack of knowledge in automation systems, we had to ask automation teachers for help. We managed to successfully connect the WXT520 to the OPC server with his help, but we were not able to reproduce the connection by ourselves later on.

4.3 SolidWorks model

Screen captures of the three dimensional model of the weather station made with SolidWorks can be found in the appendix.

Conclusions and future work

The goal of this project was to install the WXT520 weather transmitter and WS-0,30 C wind turbine on the roof of the B building, on Metropolia campus in Myyrmäki. The installation couldn't be carried out because of significant amounts of snow on the roof of the B building. However, all the preparation for the installation has been done, except for the connection of the weather transmitter to an OPC server during which we still encountered some difficulties. A student from the Automation Degree Programme though, would certainly have the knowledge to do this connection, and the weather station and wind turbine could be installed on the roof as soon as the snow melts. Wind speed tests will be carried out in a chosen spot later this spring.

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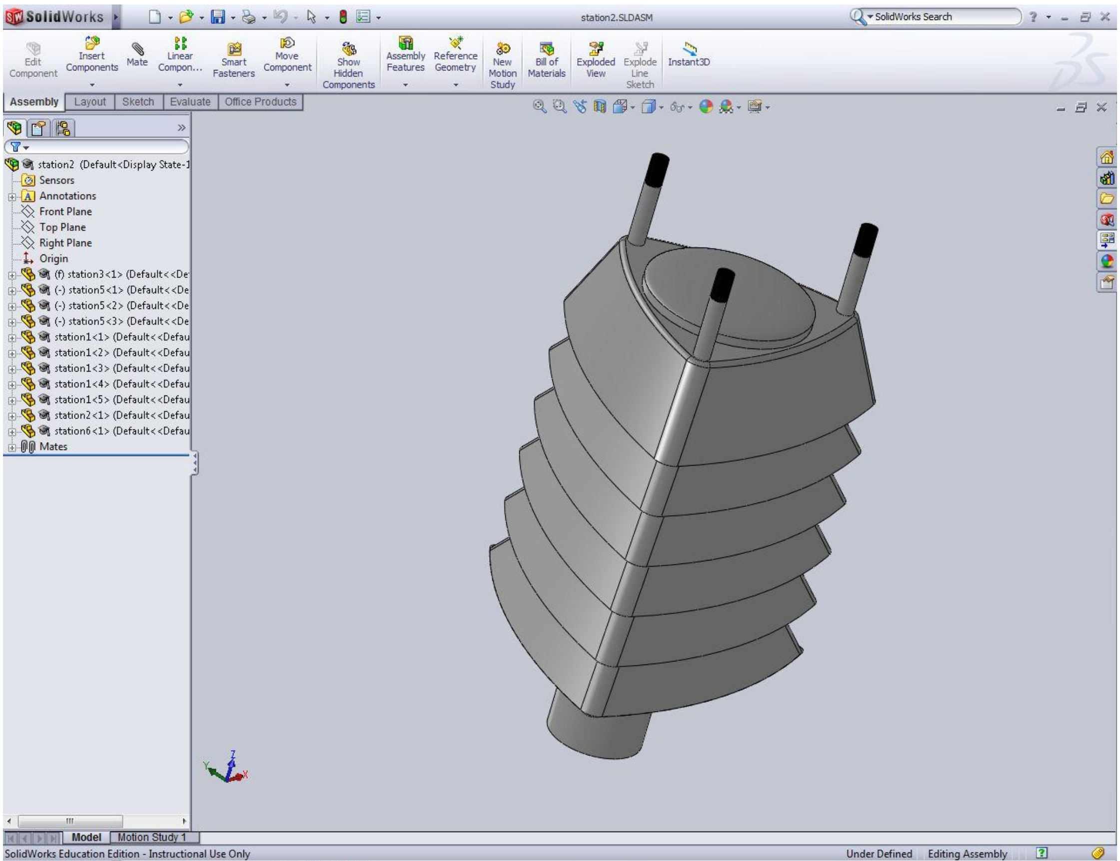
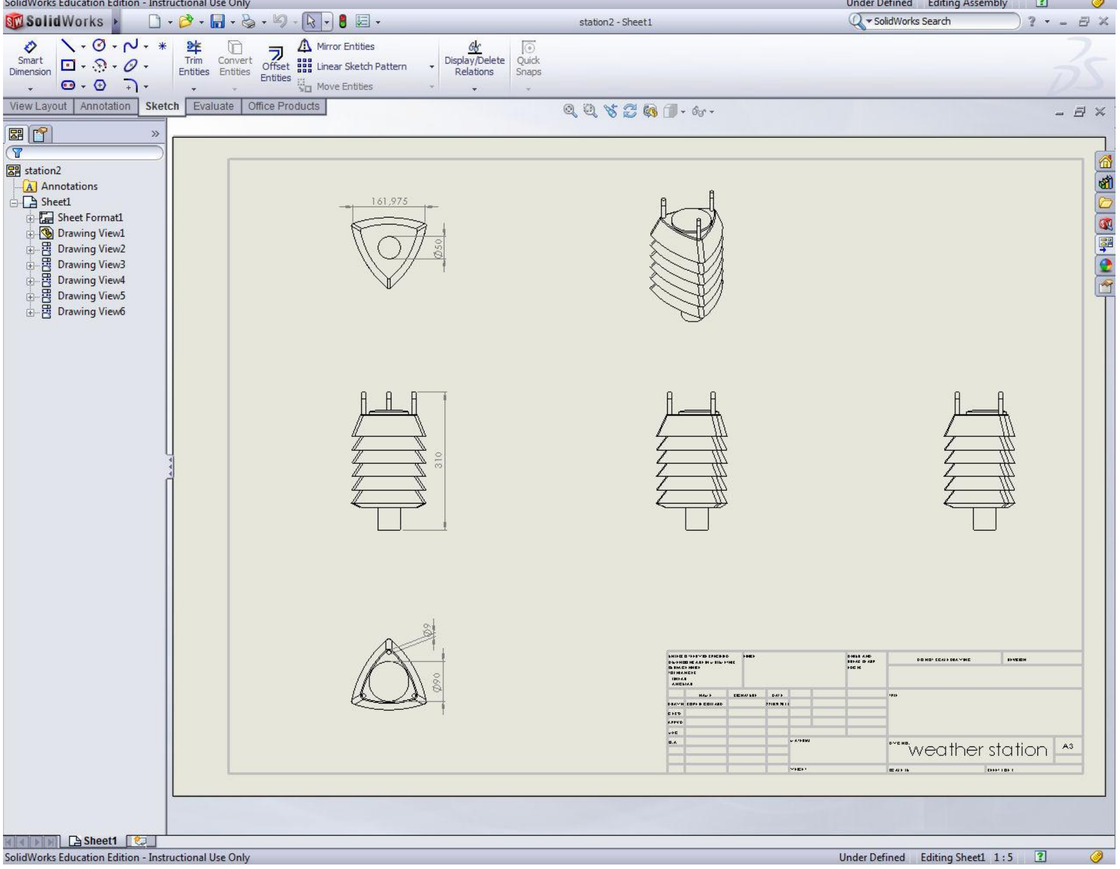
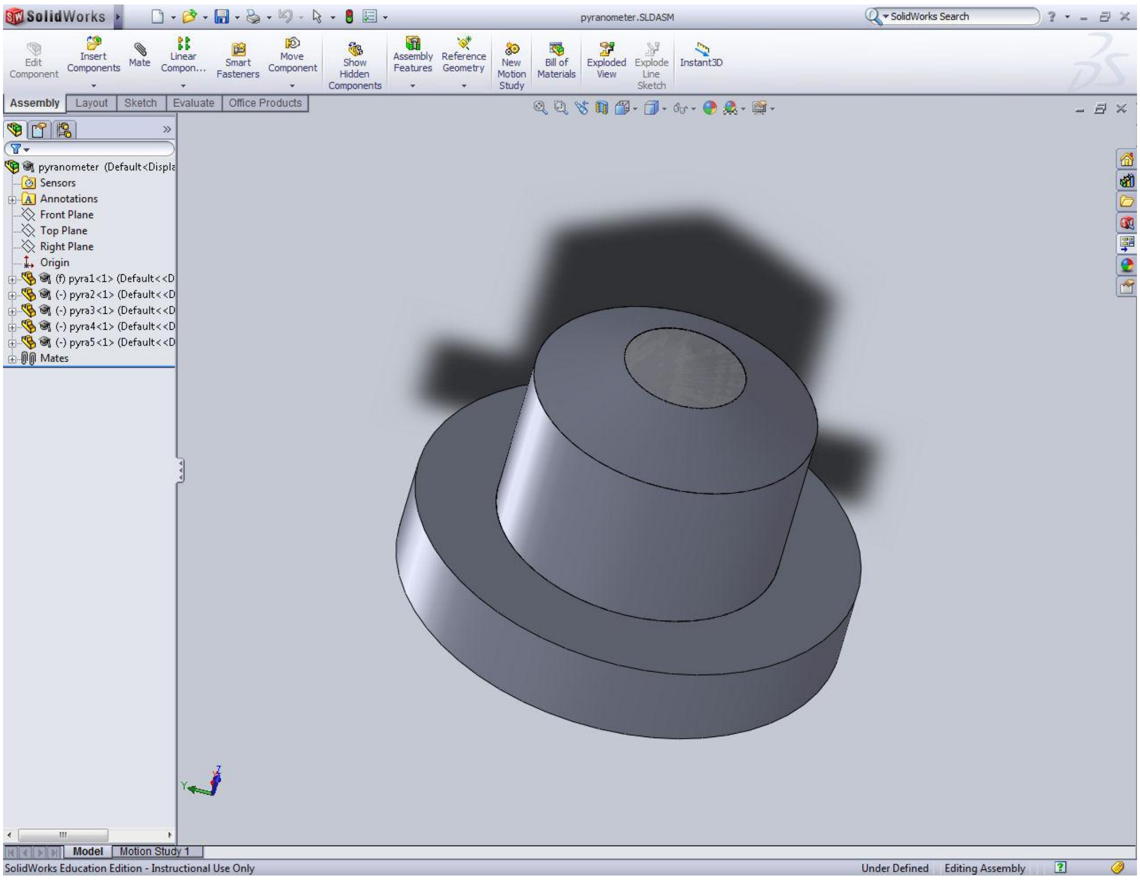
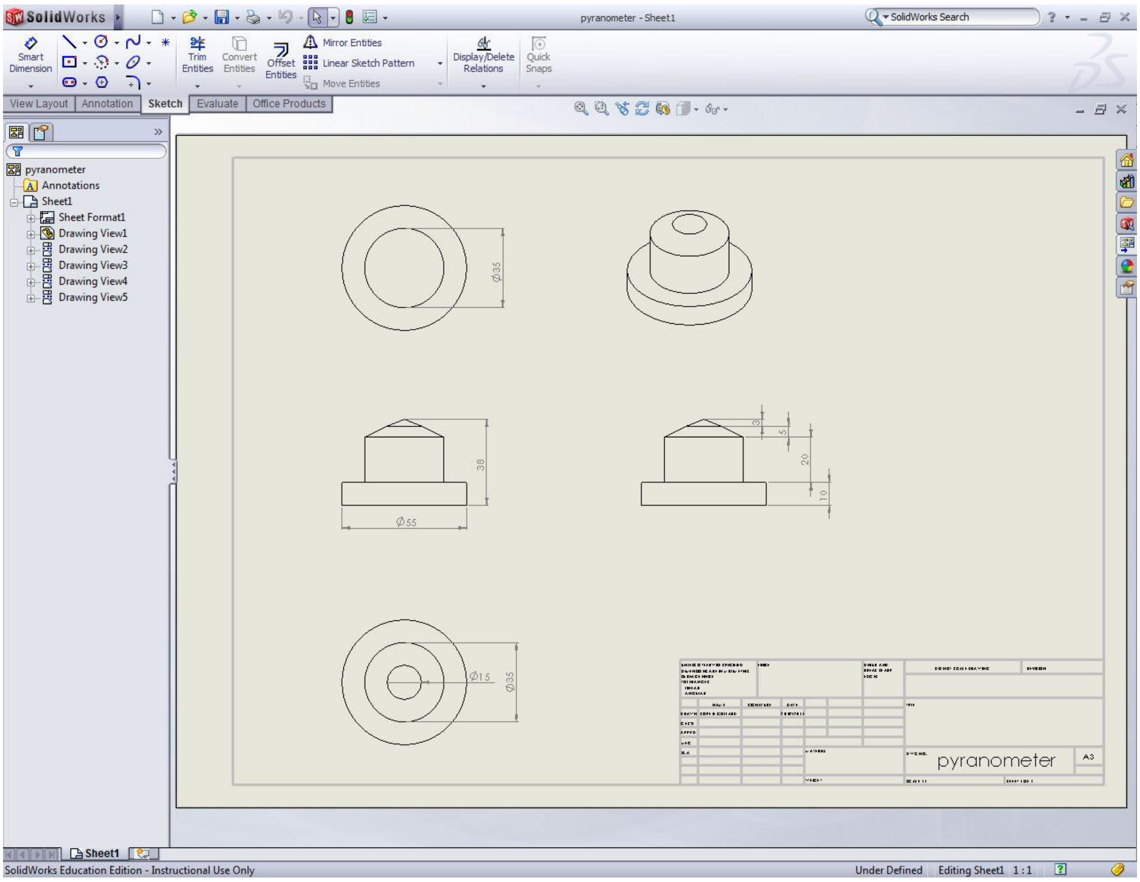
Appendix : screen captures of the SolidWorks model






SolidWorks
pyranometer.SLDASM
Assembly
Layout
Sketch
Evaluate
Office Products
pyranometer
Sensors
Annotations
Front Plane
Top Plane
Right Plane
Origin
Mates
Model
Motion Study 1
SolidWorks Education Edition - Instructional Use Only
Under Defined
Editing Assembly


SolidWorks
pyranometer - Sheet1
View Layout
Annotation
Sketch
Evaluate
Office Products
pyranometer
Annotations
Sheet1
Sheet Format1
Drawing View1
Drawing View2
Drawing View3
Drawing View4
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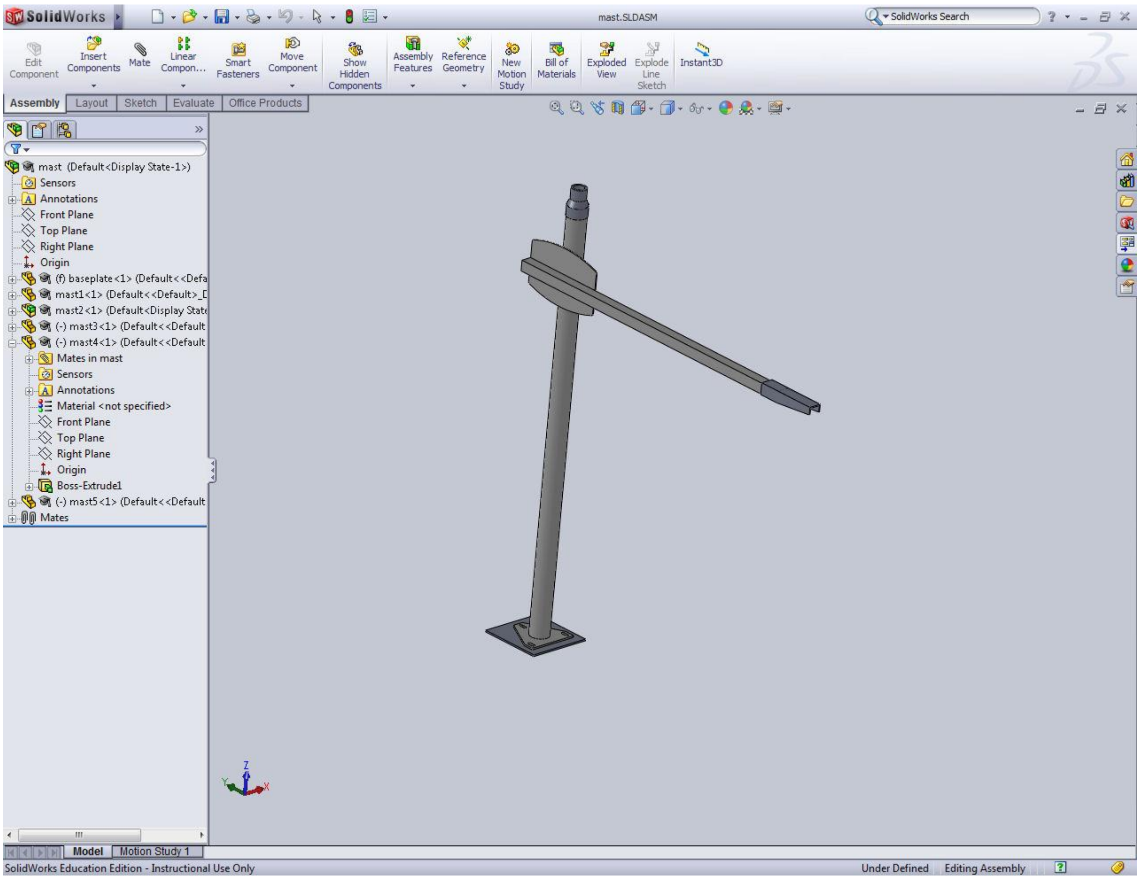
SolidWorks Education Edition - Instructional Use Only
Under Defined
Editing Sheet1 1 : 1


SolidWorks
mast.SLDASM
SolidWorks Search
Edit Component
Insert Components
Mate
Linear Compon...
Smart Fasteners
Move Component
Show Hidden Components
Assembly Features
Reference Geometry
New Motion Study
Bill of Materials
Exploded View
Explode Line Sketch
Instant3D
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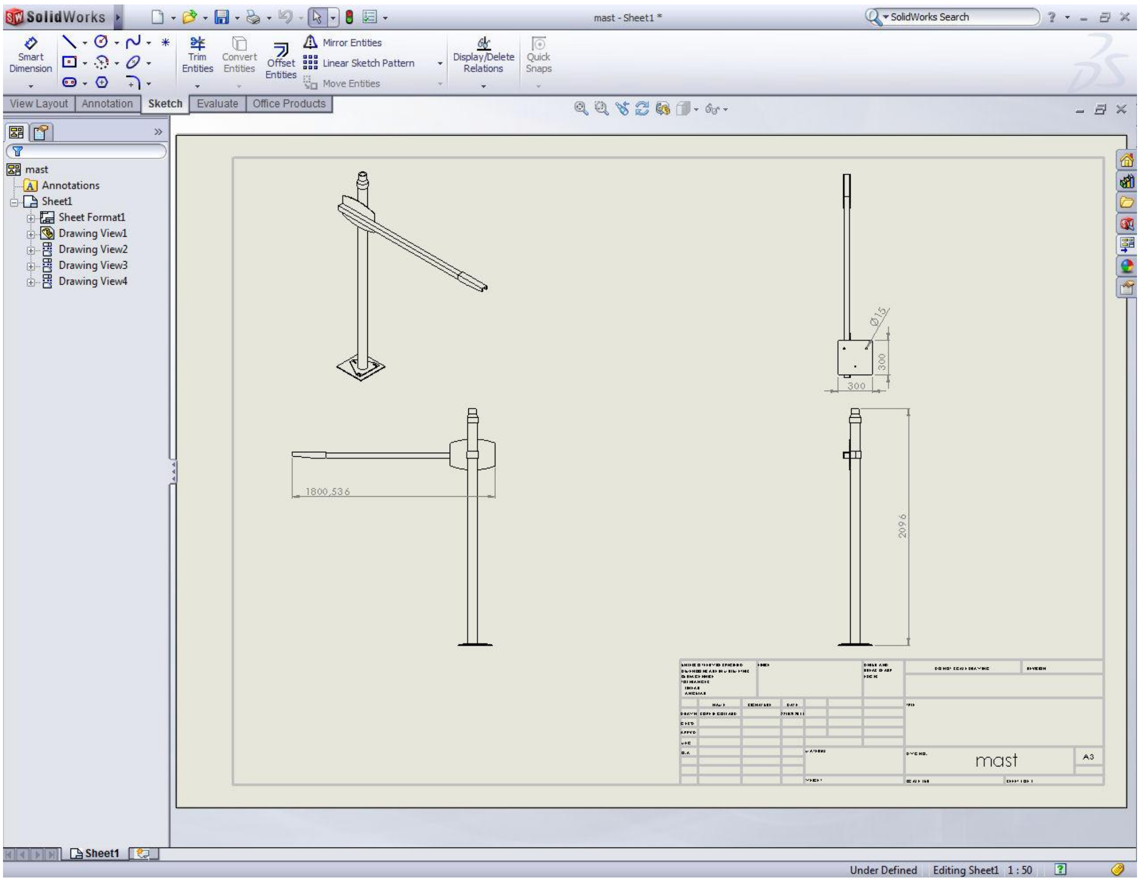
SolidWorks Education Edition - Instructional Use Only
Under Defined
Editing Assembly


SolidWorks
mast - Sheet1 *
SolidWorks Search
Smart Dimension
Trim Entities
Convert Entities
Offset Entities
Mirror Entities
Linear Sketch Pattern
Move Entities
Display/Delete Relations
Quick Snaps
View Layout
Annotation
Sketch
Evaluate
Office Products
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Annotations
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Sheet Format1
Drawing View1
Drawing View2
Drawing View3
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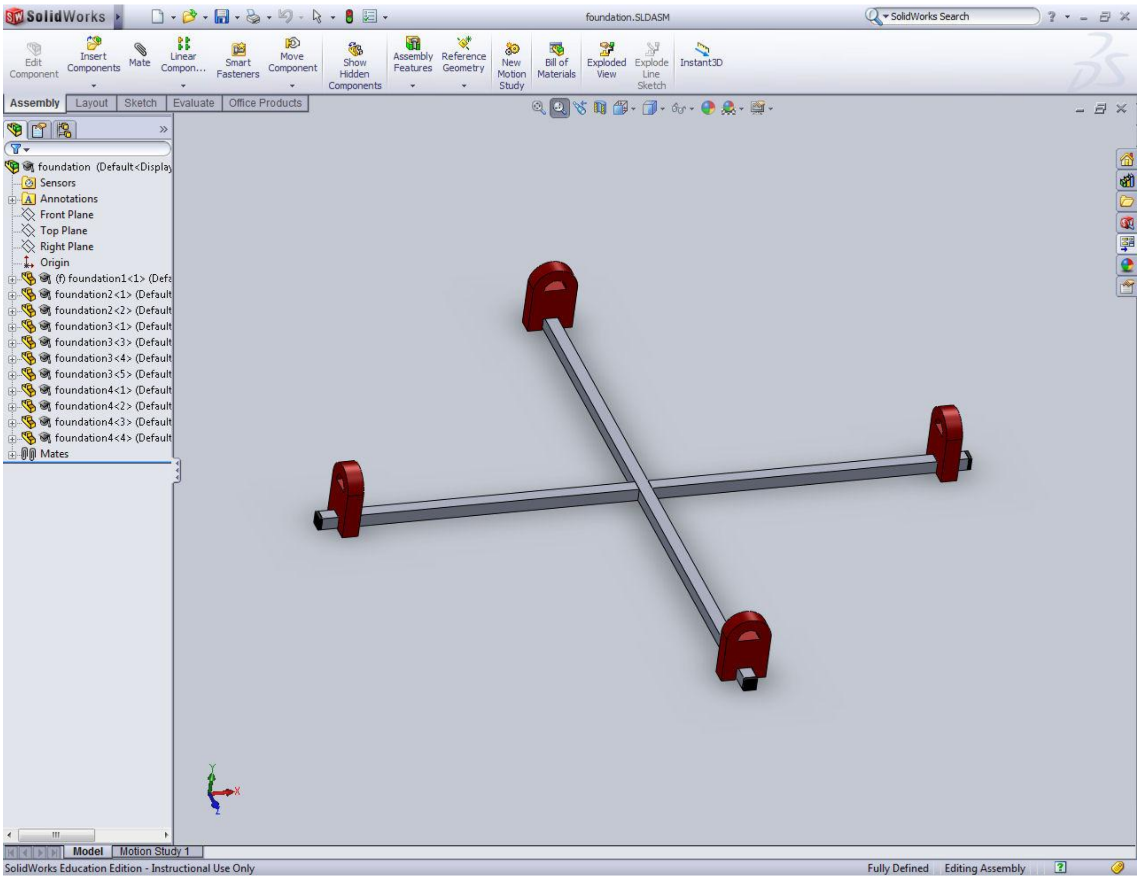
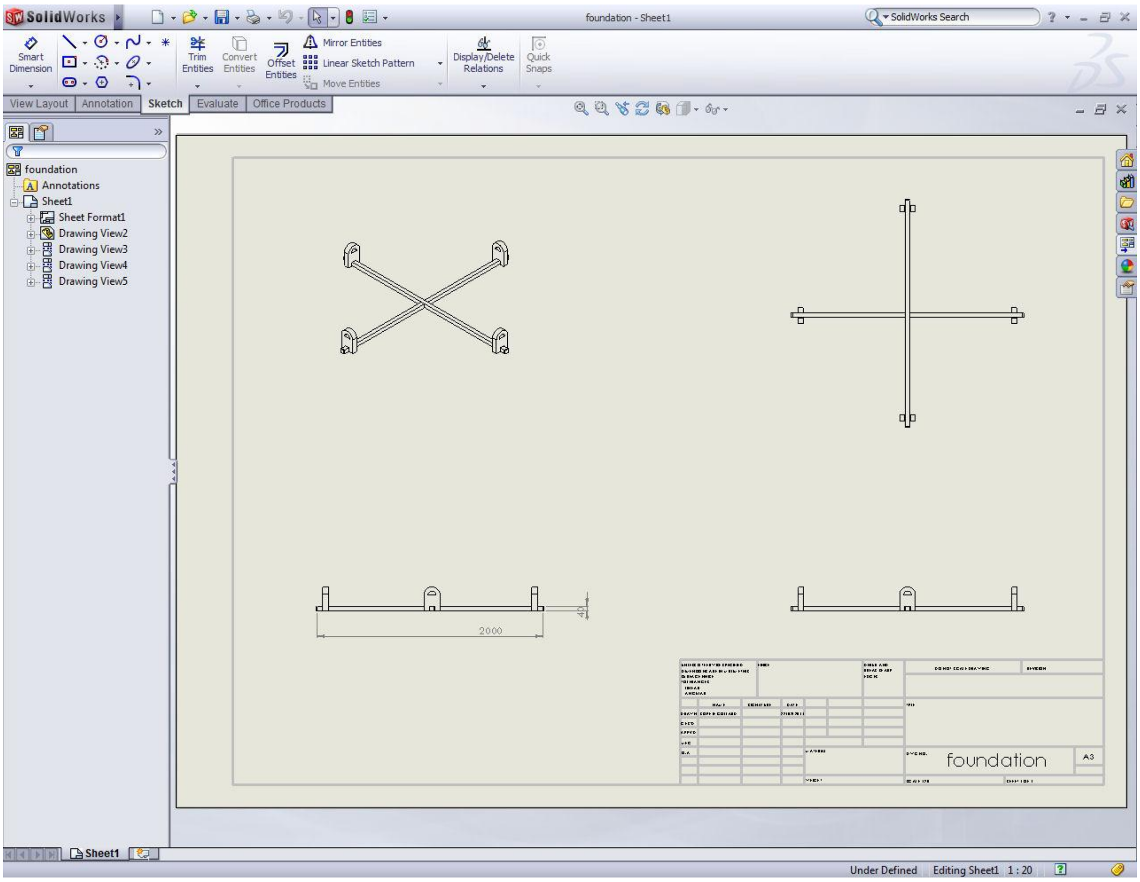
Under Defined
Editing Sheet1
1 : 50


foundation.SLDASM
SolidWorks Education Edition - Instructional Use Only
Fully Defined
Editing Assembly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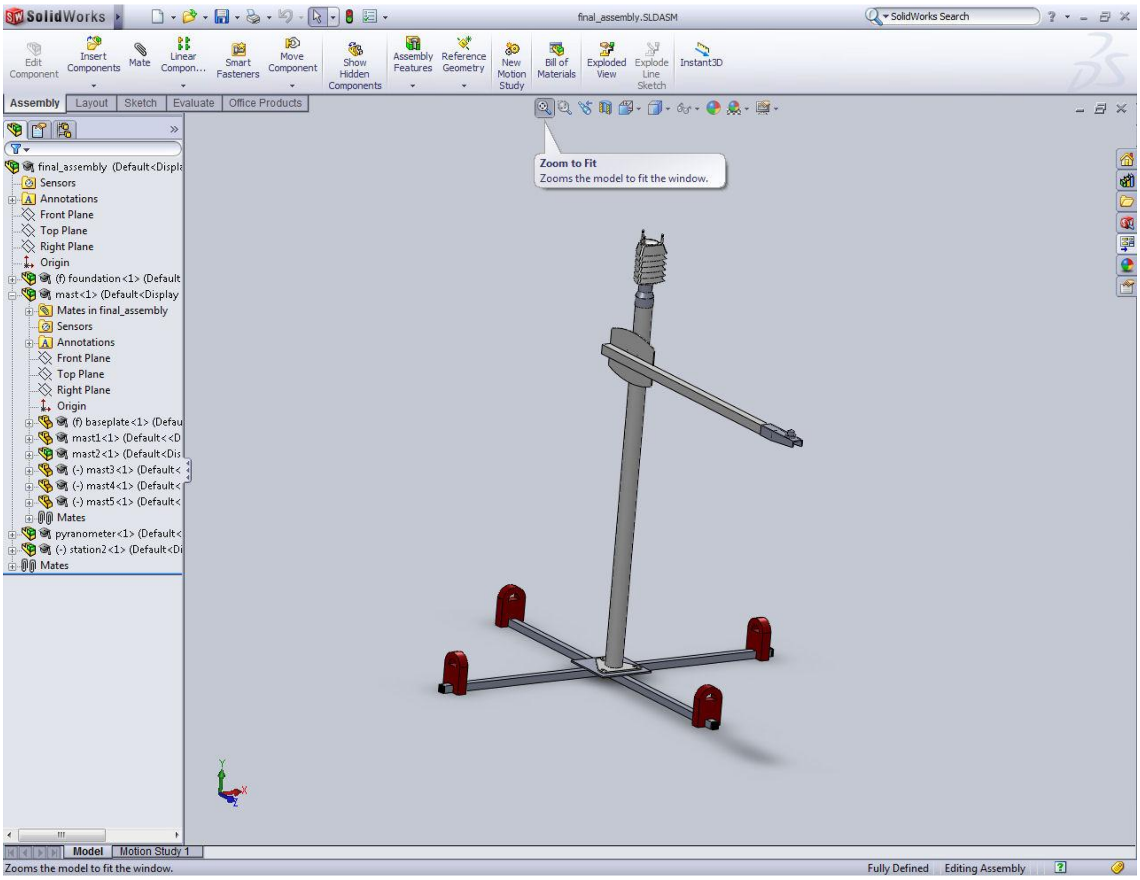
Under Defined
Editing Sheet1 1 : 20


SolidWorks
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SolidWorks Search
Edit Component
Insert Components
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Smart Fasteners
Move Component
Show Hidden Components
Assembly Features
Reference Geometry
New Motion Study
Bill of Materials
Exploded View
Explode Line Sketch
Instant3D
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Layout
Sketch
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Zooms the model to fit the window.
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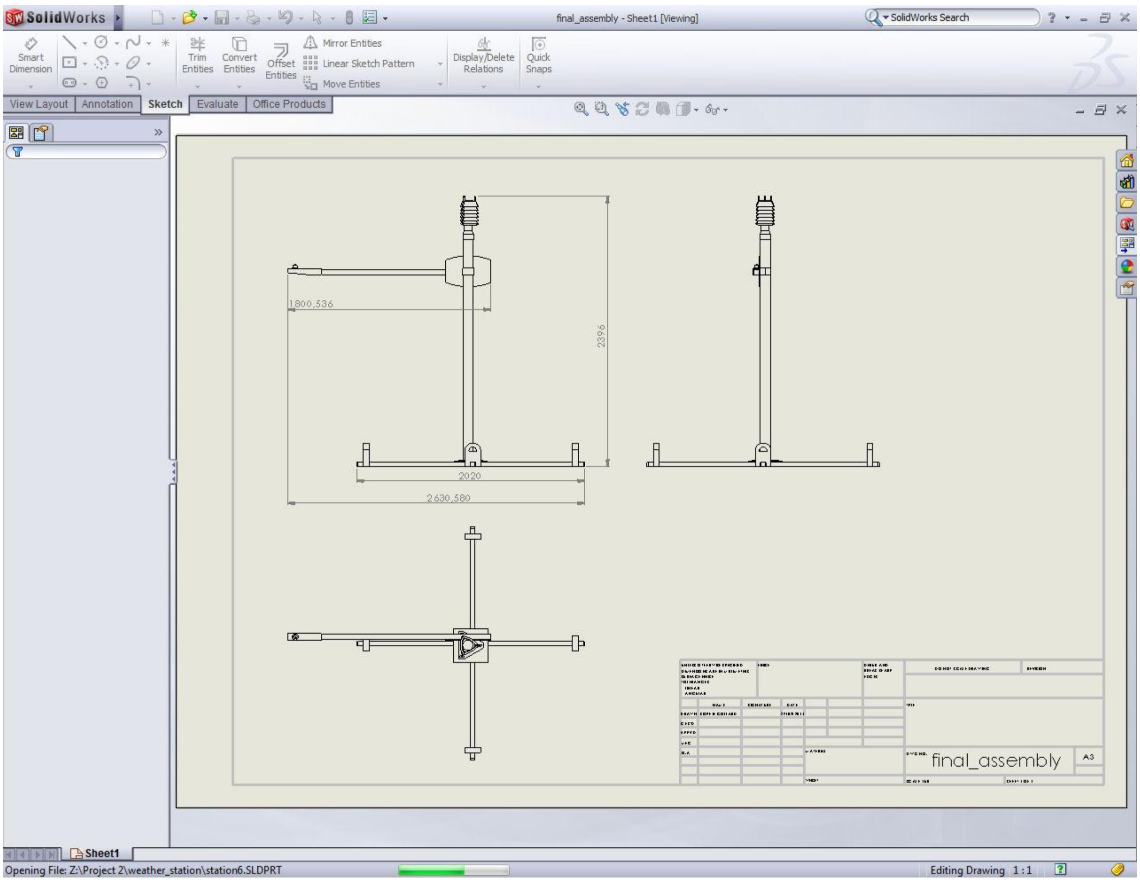
Fully Defined
Editing Assembly


SolidWorks
final_assembly - Sheet1 [Viewing]
SolidWorks Search
Smart Dimension
Trim Entities
Convert Entities
Offset Entities
Mirror Entities
Linear Sketch Pattern
Move Entities
Display/Delete Relations
Quick Snaps
View Layout
Annotation
Sketch
Evaluate
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final_assembly
A3
Sheet1
Opening File: Z:\Project 2\weather_station\station6.SLDPRT
Editing Drawing 1 : 1