Phase A

Antenna Deployment System

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INTRODUCTION

1 PROJECT OBJECTIVES AND REQUIREMENTS

All exchanged information between the satellite and the ground station are effected by radio transmitters on amateur radio frequencies. The used antennas will have a length of up to 2 meters. During the take off, the satellite mustn't exceed a cube with slightly more than 10cm side length and a mass of 1kg. Therefore a system to deploy the antennas is needed.

The first requirement of the deployment system is the high reliability. This has to be achieved with several other constraints like mass, volume and power consumption. The mass for the antenna system is budgeted to 25g. The used volume in the interior of the satellite has to be kept as small as possible and it mustn't exceed the cube more than 6.5mm. In addition to that, the system has to fulfil all the compatibility criteria for space applications.

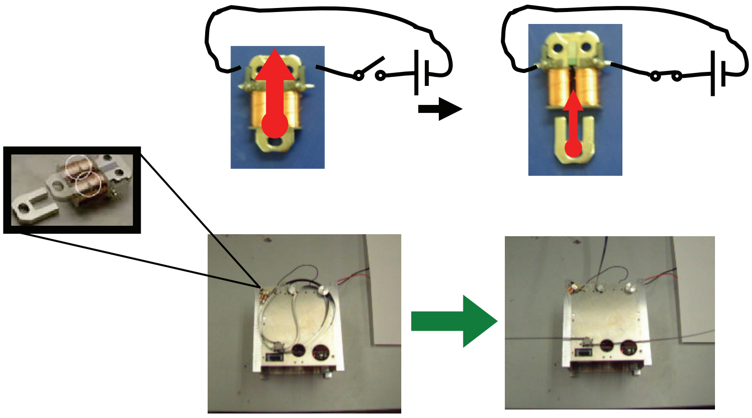
2 DESIGN TRADES/ANALYSES

2.1 Actuator

Around 15 minutes after the launch of our Cubesat the antennas have to deploy autonomously. The most critical part is the activation mechanism to start the deployment. In other Cubesat projects there have mainly 2 different actuators been used. A magnetic actuator and an actuator by melting wire. The system has to guarantee a fixation of the antenna during the 15g accelerations of the rocket launch, vibrations and shocks. All this without any energy consumptions, because the launching conditions specify the complete shutdown of the electrical system.

2.1.1 Magnetic actuator

A permanent magnet is assuring the mechanical connection to a metallic part during the take off. In the moment of the deployment an electrical magnet is switched on, to counteract the permanent magnetic field. Together with the spring effect of the antenna the metallic part will be pulled out of the initial position and the deployment starts. This system was already studied by another Cubesat team. They were showing that in their case a force of 3.5N was sufficient to guarantee the fixation of the antennas during the vibrations and the shocks of the take off [R1]. The counteracting force has to be 2.7N to activate the deployment.



Principle of a magnetic actuator

One of the disadvantages is the handling of the ejected metallic part. The design specifications for Cubesats forbid the lose of hardware in space. So the concerned part would have to deploy together with the antennas. On the other hand, this system would be easily reversible, which is a practical advantage during the tests. Particularly if the antenna system will be tested in a microgravity during a parabolic flight.

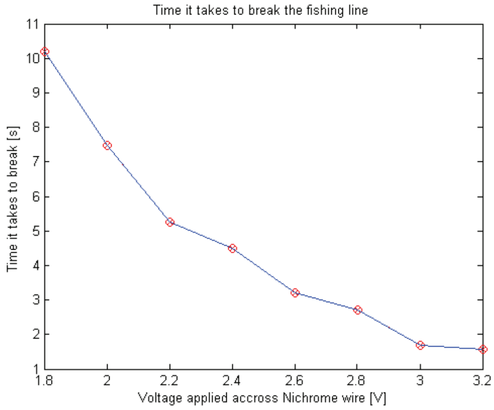
2.1.2 Melting wire actuator

Based on the strict constraint of the space and weight budget the whole deployment system has to be kept as simple as possible. In addition to that, the simple systems are in space applications often more reliable. Therefore the most used actuator in Cubesats is the melting wire. A lightweight 0.15 diameter nylon wire is fixing the antennas in stowed position. After the satellites release of the P-POD a current is applied through a wire, which is coiled around the nylon, to heat it up and finally to melt it. The optimal material for the heating wire is Nichrome. This material is well known in hobby rocket techniques [R2] for low amperage applications.

In the moment of the deployment no other subsystem of the satellite is activated. So we can permit us to use a certain peak power. But of course the challenge is to consume the less energy possible. The heating behaviour of the nylon wire is strongly influenced by the low pressure conditions of space. The heat can only be transmitted by conduction and not by convection. The Norwegian Cubesat team tested their Melting wire actuator in a vacuum chamber and got the following results [R3]:

Nichrome Wire vacuum test:		2cm wire, 3 coils
Voltage (v)	Current (a)	
1	0.2	Plastic melts
1.25	0.25	
2	0.4	
2.6	0.5	Nichrome gluing
3.2	0.6	
3.9	0.7	
4.4	0.8	
4.5	0.9	Nichrome melts

They experienced that the nylon wire brakes in under a second when the voltage is between 3.6V and 4.2V. The corresponding current of around 0,7A leads to the energy consumption of 2.5Ws. The Hawaiian team was studying the breaking time versus the applied voltage in a similar melting wire actuator and they found an exponential relation [R4]. That means there is a critical voltage for witch the consumed energy is minimal.



Plot of the time it takes to break the fishing line at a certain voltage applied across the Nichrome wire. The Nichrome wire coil had a diameter of 2 mm and was 3.75 mm long.

An interesting fact is also that the environmental temperature did not influence the power consumption until the break of the wire (because of the missing heat convection). It is important to coil the Nichrome wire as tight as possible around the nylon to assure the contact. The Norwegian team experienced an optimal number of coils of 3.

2.2 Antenna material and shape

The antenna length in the deployed state is defined by the chosen frequency. To assure a simultaneous transmission and reception we had to clearly operate on two different frequencies. That means that the length of one of our antenna will be up to 600mm. In stowed position the antenna mustn't exceed the 100mm cube. This high length difference between the deployed and the stowed antenna, and the strict mass and volume budget is strongly limiting the possibilities for the antenna shape.

2.2.1 Flat and flexible

The most used antennas in Cubesats are therefore of a flat and flexible shape. They can be rolled up in many different kinds to optimise the used volume, and they deploy with help of their own spring force.

To be able to bend them, the thickness shouldn't be too high. In discussion with our ACDS we realised that the Eigen frequency is a critical point. In order to raise it and to make the antennas more stable we thought about the following, slightly modified solutions:

2.2.2 Flat/flexible, with "v" shape

A "v" shape along the antenna would help to stabilise. It can be compared with the measuring band which is commonly used in commerce. But it is difficult to produce. With the installation we had in the workshops of the EPFL it was not possible to bend a 3 mm thin band along more than 20 cm. Therefore we contacted a German company [R5] which is effecting the necessary tests.

2.2.3 Material criteria

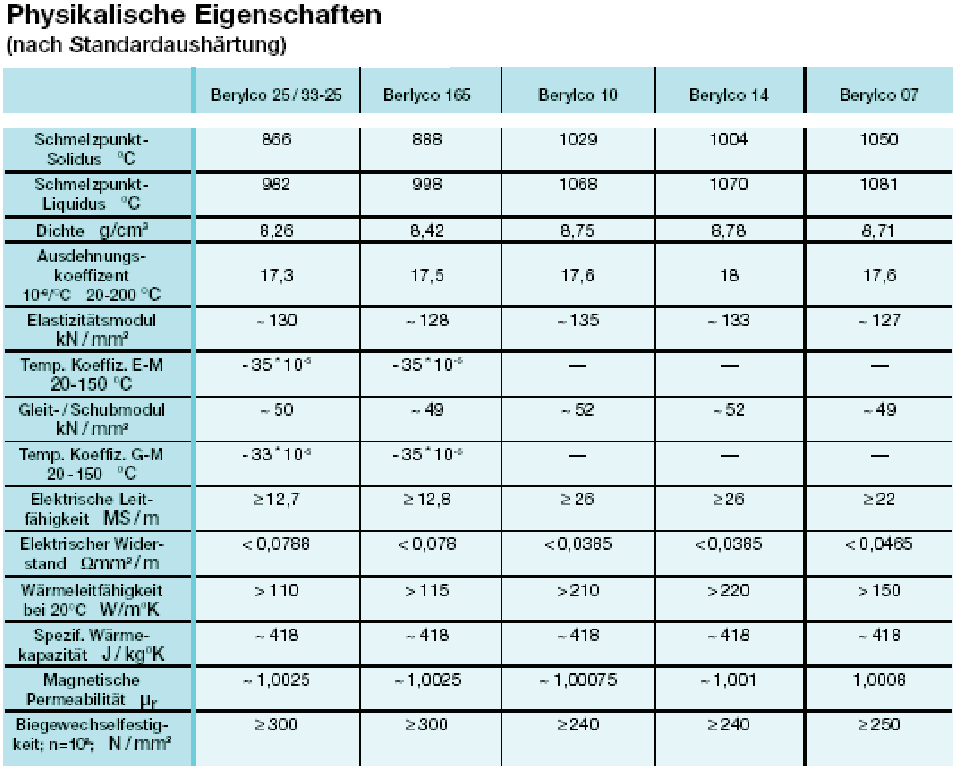
An important point is the choice of the antenna's material. The antenna is over a long period in the stowed position and will be heated up and cooled down. Anyways it has to keep the original shape and to stay flexible.

In other Cubesats the antennas were often electrical and magnetic conductors. But in our case the magnetic conductivity could be a disadvantage. Depending on the orientation and the length of the conductor, the magnetic field of the earth can be locally reoriented. Of course this doesn't get along with an orientation system using magnetic sensors.

These requirements were leading to a specific beryllium copper alloy of the company NGK in Solothurn.

2.2.3.1 Berylco 10

This material is an alloy of high conductivity and high rigidity [R6]. It is mostly used for electrical conducting springs. The material can be hardened after the plastic deformation. For our application the company NGK is recommending us a 1/2 hardening, to guarantee the high flexibility. This alloy resists much higher temperatures than normal copper alloys. In a wide temperature range, there are no losses of the mechanical performances.



Physikalische Eigenschaften
(nach Standardaushärtung)

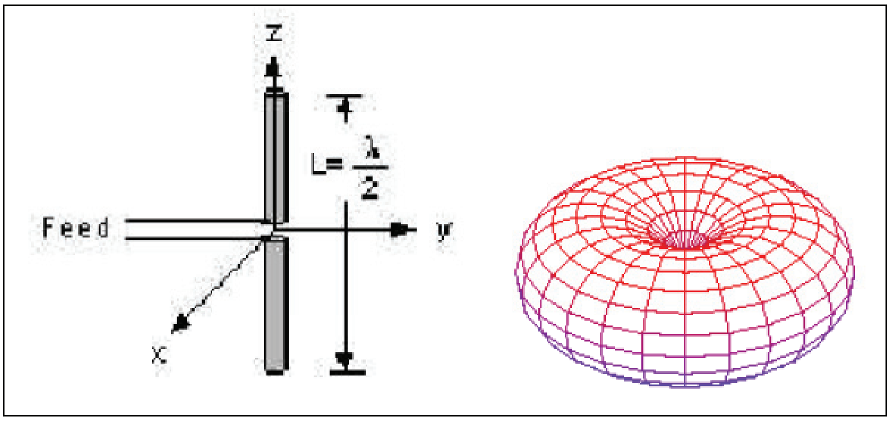
	Berylco 25 / 33-25	Berlyco 165	Berylco 10	Berylco 14	Berylco 07
Schmelzpunkt-Solidus °C	866	888	1029	1004	1050
Schmelzpunkt-Liquidus °C	982	998	1068	1070	1081
Dichte g/cm³	8,26	8,42	8,75	8,78	8,71
Ausdehnungs-koeffizent 10^{-6}/°C 20-200 °C	17,3	17,5	17,6	18	17,6
Elastizitätsmodul kN / mm²	~ 130	~ 128	~ 135	~ 133	~ 127
Temp. Koeffiz. E-M 20-150 °C	$-35*10^{-6}$	$-35*10^{-6}$	—	—	—
Gleit- / Schubmodul kN / mm²	~ 50	~ 49	~ 52	~ 52	~ 49
Temp. Koeffiz. G-M 20 - 150 °C	$-33*10^{-6}$	$-35*10^{-6}$	—	—	—
Elektrische Leit-fähigkeit MS / m	≥ 12,7	≥ 12,8	≥ 26	≥ 26	≥ 22
Elektrischer Wider-stand Ωmm² / m	< 0,0788	< 0,078	< 0,0385	< 0,0385	< 0,0465
Wärmeleitfähigkeit bei 20°C W/m°K	> 110	> 115	> 210	> 220	> 150
Spezif. Wärme-kapazität J / kg°K	~ 418	~ 418	~ 418	~ 418	~ 418
Magnetische Permeabilität μ_r	~ 1,0025	~ 1,0025	~ 1,00075	~ 1,001	1,0008
Biegewechselfestig-keit; $n=10^6$; N / mm²	≥ 300	≥ 300	≥ 240	≥ 240	≥ 250

Mechanical properties of different Beryllium Copper alloys

2.3 Place and orientation

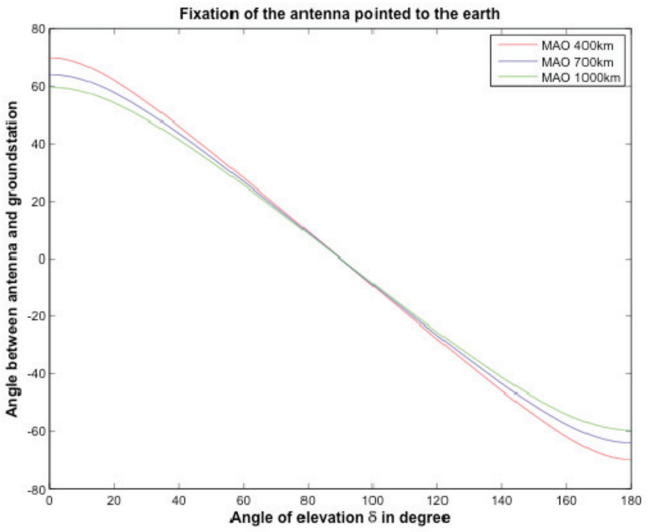
The place and the orientation of the antennas of our satellite is a heavy discussed topic during the design meetings.

A variety of constraints from different subsystems like Structure, ACDS and Communication are influencing the choice. An important parameter is the angle between the antenna and the ground station. The smaller it is, the weaker the transmitted signal. In the following diagram for a standard dipole configuration you see that for an angle of 90° the radiation is optimal, and for the angle 0° there is almost no radiation any more.

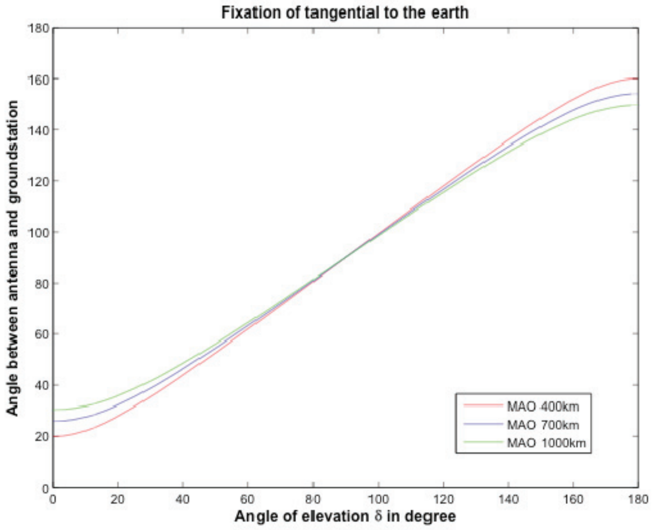


Principle of a half wave dipole antenna with a radiation pattern

With help of the following graphs we try to understand the relation between the antennas orientation on the satellite and the angle between the antenna and the ground station. As we don't know jet the flight height of our satellite we did this calculations for a minimal and a maximal distance. In the first case the antenna is pointing towards the centre of the earth, and in the second case it is tangential to the earth's surface.



Angle between antenna (pointed to earth centre) and ground station



Angle between antenna (tangential to earth) and ground station

We simulated that the connection will brake down for an angle smaller than 25°. That means an antenna which is pointing to the earth centre is loosing the connection to the ground station when the satellite is passing directly over the ground station. It's therefore obvious that the optimal orientation of the antennas is tangential to the earth's surface.

Another constraint is the angle between the two antennas. Because of the simultaneous communication of the two antennas (transmission and reception) we have to minimise their coupling, which means that they have to be orthogonal to each other, and their origins shouldn't be too close together. In order to order to minimise the asymmetric deformation of the connection area, they shouldn't also not be mounted to close to the border of the cube.

A variety of configurations for the antenna placement have already been adopted for Cubesats. In the following paragraphs we try to give an overview of different solutions:

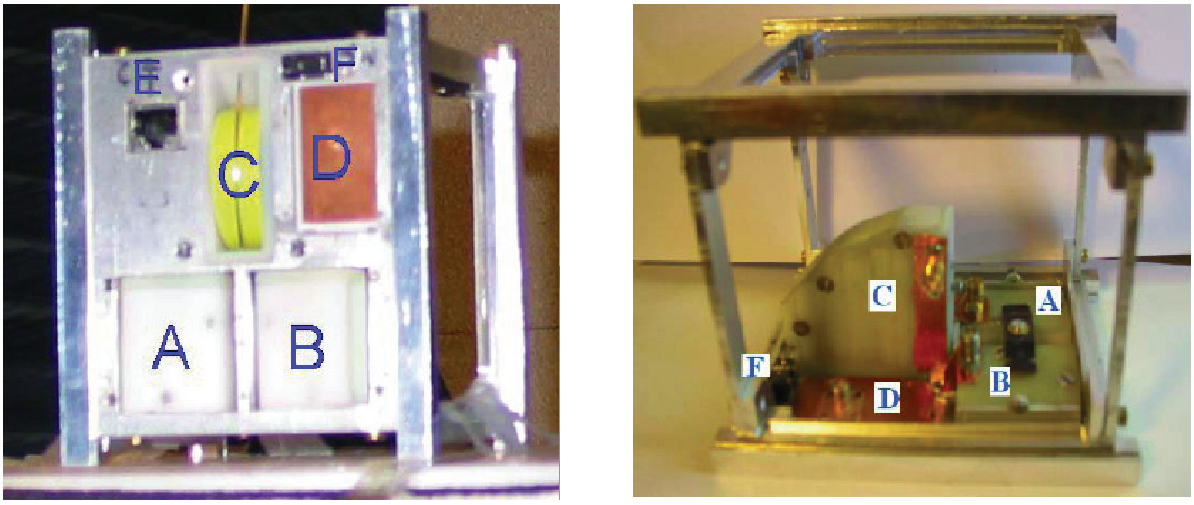
2.3.1 Satellites surface (one side)

From the mechanical point of view it's the simplest solution to role the antenna on one side and to deploy it in the plane. Reasonably it's the same surface which is used to mount the objective of the camera, because this is the only side without solar cells. The solar cells are extremely fragile and it would be difficult to mount the antennas on the same side and assure that the flexible antennas never touch the cells during the deployment. Obviously the side with the camera objective has to be orthogonal to the earth's surface during the recording of the pictures. That means in this constellation at least one of our two orthogonal antennas is pointing towards the earth centre, which isn't optimal (see point 2.3). A rotation of the two antennas of 45° in the plane would not solve the problem, but dead angles would be displaced.

A solution of the problem would be to deploy one of the antennas orthogonal to the satellites surface: this could be realised by a spring system that sets up the antenna as soon as it is deployed. Or by a twist of the antenna, which would be mounted orthogonal to the surface but rolled up in the plane of the surface. Both of these solutions are relatively complicated, which leads to a too low reliability.

2.3.2 Inside the Satellite

A reliable solution for a deployment orthogonal to the surface is to roll up the antenna into the satellite. One of the Norwegian teams used this technique once for a gravity boom. The boom is embedded in a POM box, and prevented from sorting by a melting wire. As seen in picture B, this system takes a lot of place in the interior of the satellite, which we don't have at our disposal. The second disadvantage is the too high weight of the box, which can be used for only one antenna.

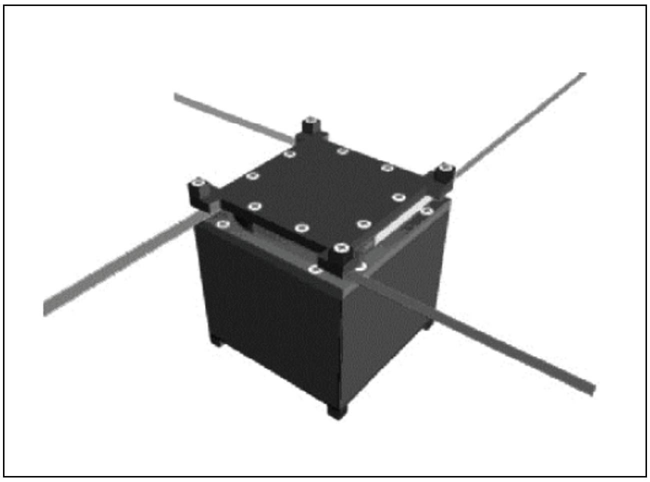


Pictures of the Norwegian gravity boom, rolled up into the satellite

2.3.3 Around the satellite

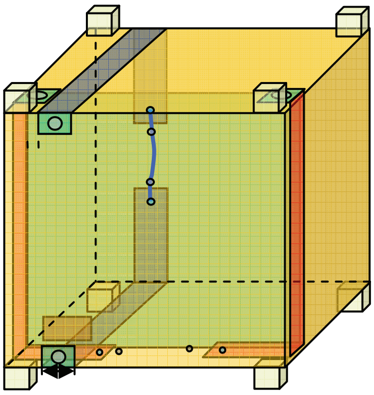
Another possibility to assure an orientation of the two antennas tangential to the earth, is to coil them around the satellite. After the Cubesat design specification this can be done in both directions (crossing or parallel to the rails). As long as the rails have a contact length of at least 75% (85.125mm of possible 113.5mm) with the deployer.

The Calpoly team used a system with 4 equal antennas around the satellite [R7]. The minimal radius to which we can bend the antenna (depending on its material) dictate the needed place in the interior of the cube. In our case the place conditions in the interior of the cube are very limited, and therefore we have to try to place the antennas on the surface.



Antenna deployment system of Calpoly

A Hawaiian Cubesat [R4] was equipped with a deployment system parallel to the rails. In our case this wouldn't be possible, because the used solar cell pairs have the external measurements of 80mm*80mm, which means that the place between the rails is entirely occupied. In addition to that, on 3 of the 5 sides with solar panels we placed the magneto torques.



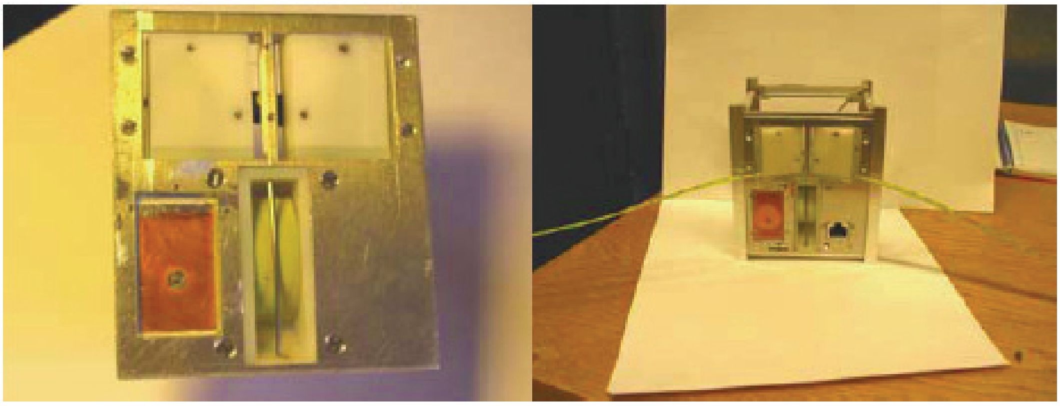
Stowing principle of the Hawaiian antennas

2.4 Packaging

The antennas are exposed to high accelerations (up to 15g) and to high vibrations during the take off. Anyways the flexible lames must never hit the structure or even parts of the P-POD. To keep them in the wanted position there are different solutions:

2.4.1 Slots

The packaging of the antennas in slots is a safe protection against the vibrations of the antennas. On the other hand its obvious that additional mechanisms are necessary, which reduces the reliability. The extra weight and the extra volume of this solution are strongly negative points.

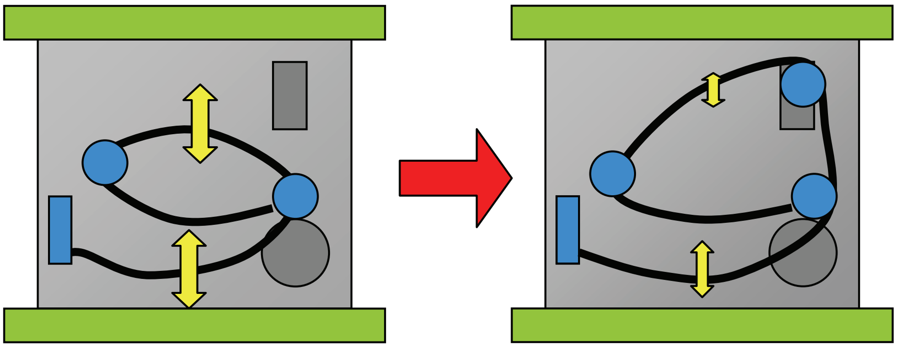


Protection of the antennas by polymer slots

2.4.2 Guide

In order to reduce weight and volume but to maintain the stability the use of contact points is common:

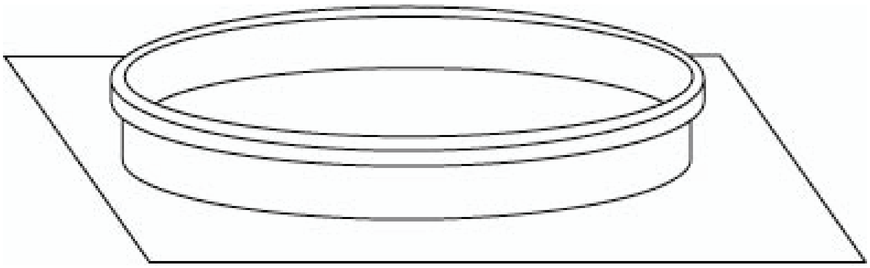
2.4.2.1 contact points



The more contact points we use, the smaller are the vibrations of the antennas. With 3 contact points they are not prevented from vibrations, but they don't hit each other, because of the high distance. In the direction perpendicular to the surface the antennas are stiff and they will stay stable.

2.4.2.2 Entire guide

By increasing the number of contact points of the previous paragraph to an infinite number, we're approaching an entire guide. Of course this would solve the vibration problems. But unfortunately we can't accept the additional weight. And we also don't have enough place for this kind of guide. On the used surface we also have to mount the objective of our camera.

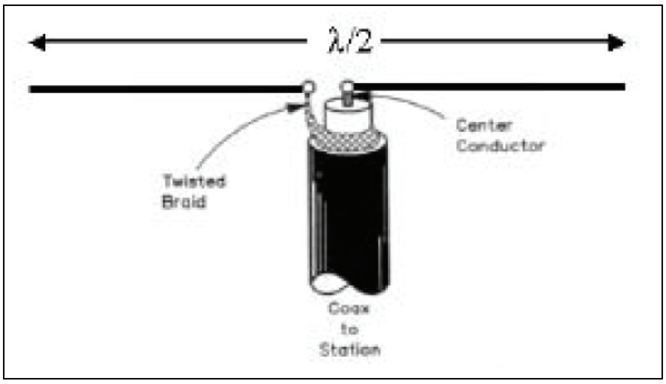


Principle of en entire guide for the antennas

2.5 Electrical isolation

The antennas have to be mounted electrically isolated on the structure. For this reason we use a dialectical polymer element. They have a high temperature range in which they can operate and they are easily machinable. The transmission of the signal is assured by coaxial cables. In the case of the

Dipole antenna it has to be connected as illustrated. One side of the antenna is connected to the outer and one side to the inner conductor.

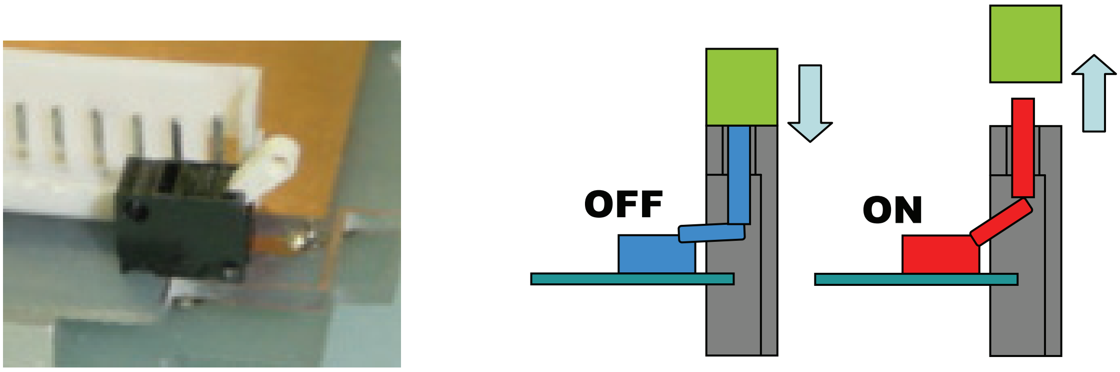


Connection scheme of a dipole antenna

This "direct" connection can lead to an asymmetric deformation of the radiation pattern of our dipole, which could be prevented with the help of an electronic device. In the case of our monopole antenna the outer conductor is connected to the structure of the satellite.

2.6 Power switch and timer

The satellite must be powered off during the take off to prevent any electrical or RF interferences with the launch vehicle and primary payloads. In the moment of the launch, the double KILL switch (placed in two rails), switch on the power of our satellite and with that the onboard processor. This last one is equipped with a timer, which we can use to wait 15 minutes until to starting the deployment.



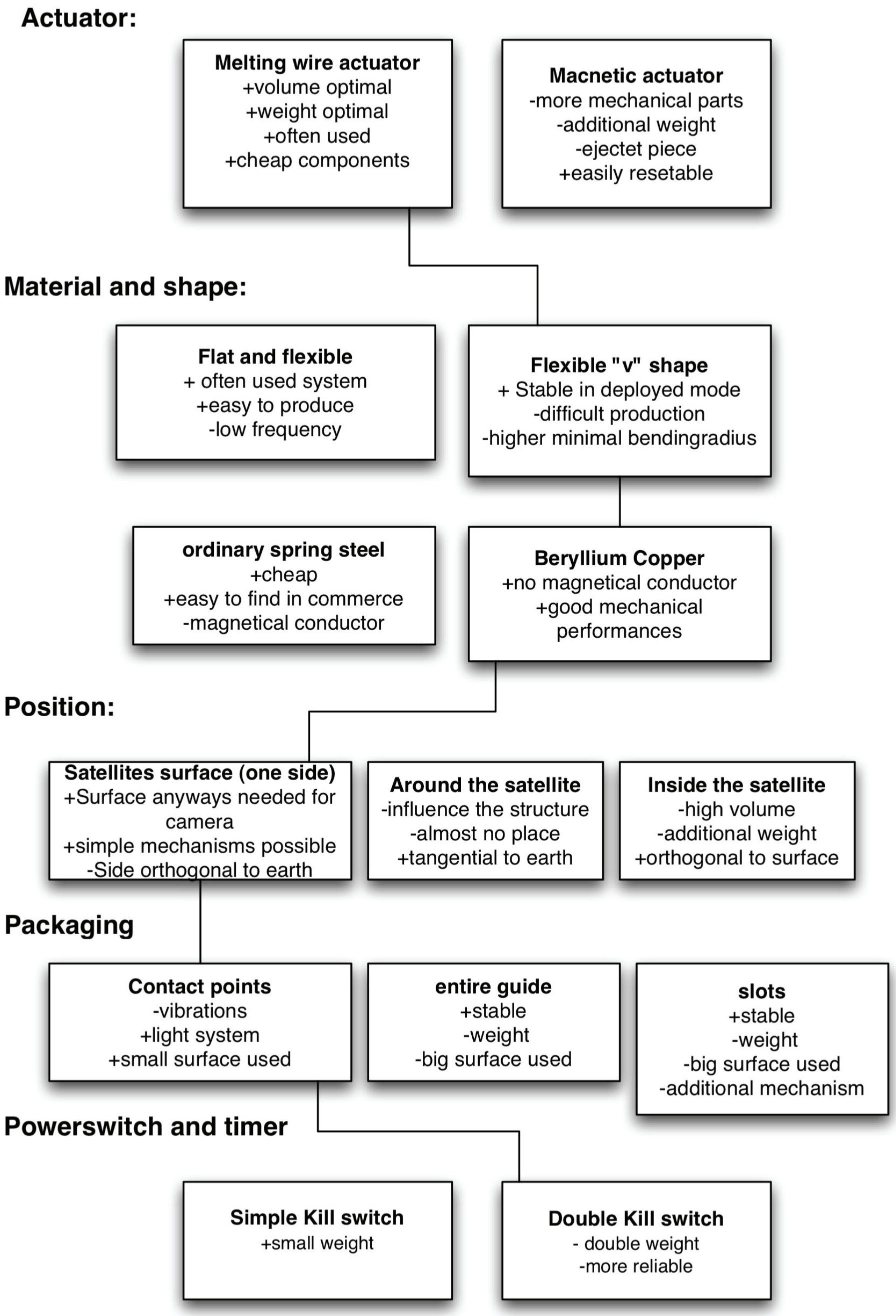
Double Kill switch to assure the activation of the satellite

We use 2 Kill switches in parallel for redundancy. If only one of the switches in ON, the system can get power.

3 BASELINE DESIGN RECOMMENDATIONS

In order to get a first baseline design we had to take a choice for each point listed above. But I tend to say that this choice does not have to be considered as a final version. All the subsystems are strongly related, and a change in one of them could provoke changes in the other ones. Anyways its important to go further and building a first prototype to experience the real behaviour of the system and to get knowledge's that will be helpful for another, modified final solution.

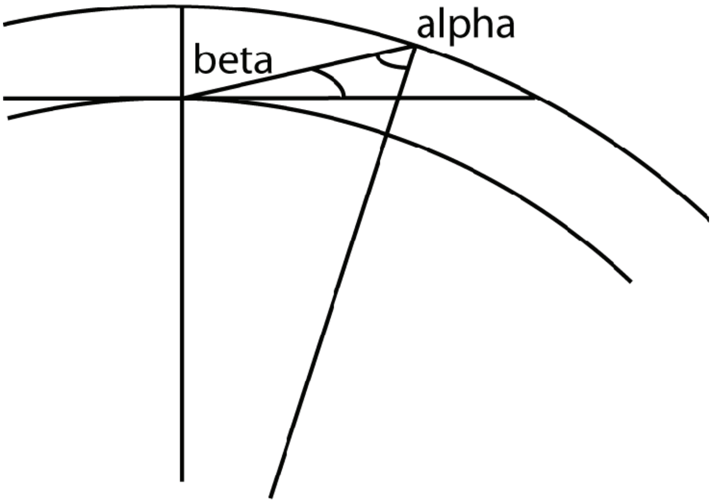
3.1 Solutions summary and preliminary choice



3.2 Discussion of base line recommendation

3.2.1 Connection time

We chose the placement of the antennas on one side (same as camera), by knowing that a critical point will be that one antenna is pointing the earth centre: To estimate the consequence of this, we tried to get the mean connection time with a worst case configuration.



Dependence of the elevation angle (beta) and the angle between the antenna and the ground station

Because the simulation of the antennas is not jet implemented in the orbit simulation, we had to do some approximations. In paragraph 2.3 we saw that for an elevation angle of more than 65° the angle between the ground station and the antenna starts to get critical.

With this assumption we can evaluate the daily mean connection time of an antenna pointing the earth centre, and compare it with the optimal case (connection to satellite as soon as he passed the elevation angle (beta) of 10°, until he disappears on the other side at the elevated angle of 10°.

Altitude 400km:	Mean time in s:
connection between beta=10° and 90°	296.564
connection between beta=10° and 75°	273.471
connection between beta=10° and 65°	256.455

Altitude 1000km:	Mean time in s:
connection between beta=10° and 90°	587.51
connection between beta=10° and 75°	528.302
connection between beta=10° and 65°	498.38

Depending on the altitude the mean loss of communication time for a dead angle of 50° is only 13.5% in 400km high (resp. 15.1% in 1000km high).

3.2.1.1 Second Ground Station

It would be possible to correct this loss by a collaboration with a second ground station. In that case we would even rise the connection time to 512.9s for 400km altitude and 996.76s for 1000km altitude. At that point it has to be said that we considered at the beginning of our project a communication mean-time of 600s. That means with only one ground station this could be hard to achieve, and we have to do further investigations on this topic.

Even if we could accept a loss of 15% communication time, we would loose the connection exactly over the ground station, where the distance to the satellite is relatively small. After the second of Akins lows, how to design a spacecraft, you should always consider the cases that something goes wrong. Therefore this short communication time directly over the ground station should be accounted more important than only 15% of the communication time. For this reason we figured out some additional scenarios.

3.2.1.2 Rotation of antennas

A rotation of the antennas on the satellites surface would not solve the problem of the dead angle, the zone with no connectivity would even the larger because of the geometric distortion. But it would not be anymore directly above the ground station, which is a big advantage.

3.2.1.3 Turning satellite of 90°

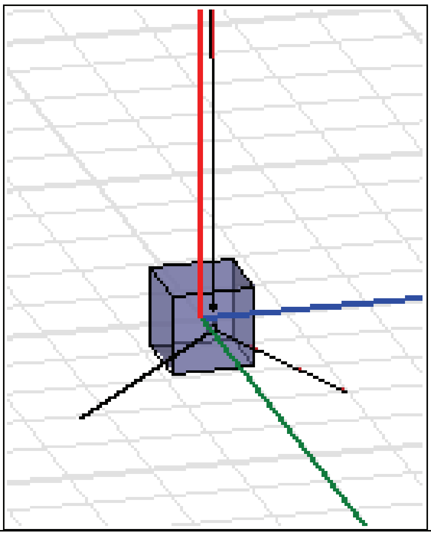
During the conception phase of the actual solution we thought that it would be possible to turn the satellite during daytime of 90° (face with antennas and camera towards the earth), to assure the optimal connection of the antennas while we don't take any pictures. We considered it also as an advantage to have the long monopole antenna in the direction of the earth gravity during the recording of the pictures, to stabilise the satellite. But finally, the latest calculations of our ACDS showed us that the effect of the monopole antenna as a gravity boom is not significant, and the effort to turn the satellite is much too high.

3.2.1.4 Reduce decoupling angle

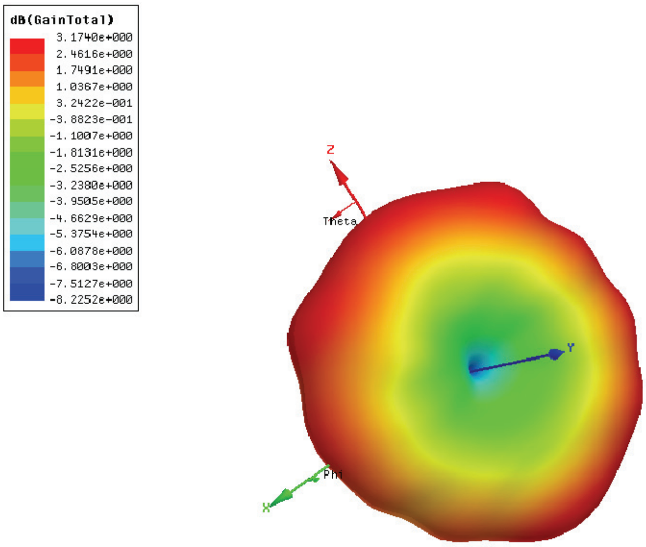
To decouple the two antennas, an angle of 90° between them is recommended. With the effect that always one of the antennas is in unfavourable orientation. Therefore we tried to decrease this angle, with the result that the individual orientation gets better, but the radiation diagram gets more and more distorted.

3.2.1.5 Dipole shift of 30°

The fact that it does not help anything to keep the long monopole in the direction of the gravity, leads us to another solution. We let the dipole point into the direction of the earth but reduce its angle to 120° instead of 180°. The radiation pattern will be deformed but the radiation in the direction of the antenna will increase from -14dB to -8dB. In this case the distance to the satellite is small and the communications should be guaranteed for every elevation angle.

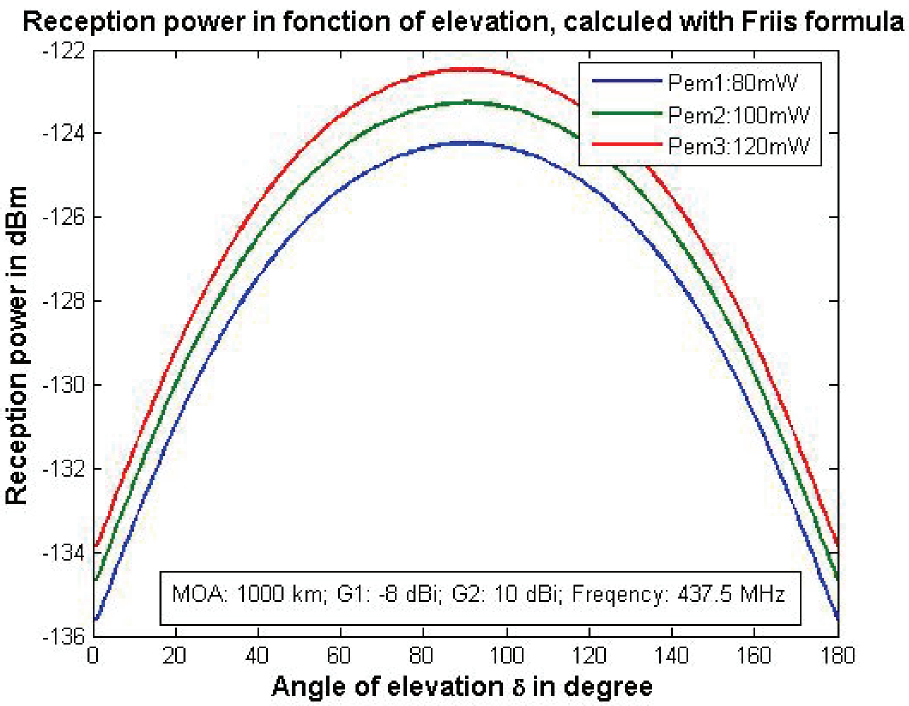


Antenna configuration with the two dipole antennas in an angle of 120°



Radiation diagram of the shifted dipole.

With help of a small Matlab simulation (made by our communication subsystem) we calculated the received power from the antenna with a constant gain of -8dB, which corresponds to the worst possible case (angle 0° between antenna and ground station). We see that in the region of the elevation angle between 60° and 120° (critical zone) the received power is still higher than -126dBm, which is enough to assure the communication



With this constellation (shifted dipole with angle of 120°) we found a solution to get the full communication mean-time. On the other hand the solution is not perfect. There is still directly above the ground station the zone with the lowest radiation for one of the antennas. It has to be further investigated if in combination with 5.2.1.2 and 5.2.1.4 the system can be got more reliable. On one hand the low radiation would not be above the ground station anymore, but on the other hand the distance gets higher and therefore the received energy smaller.

3.2.2 Mass-, Volume- and Power budget

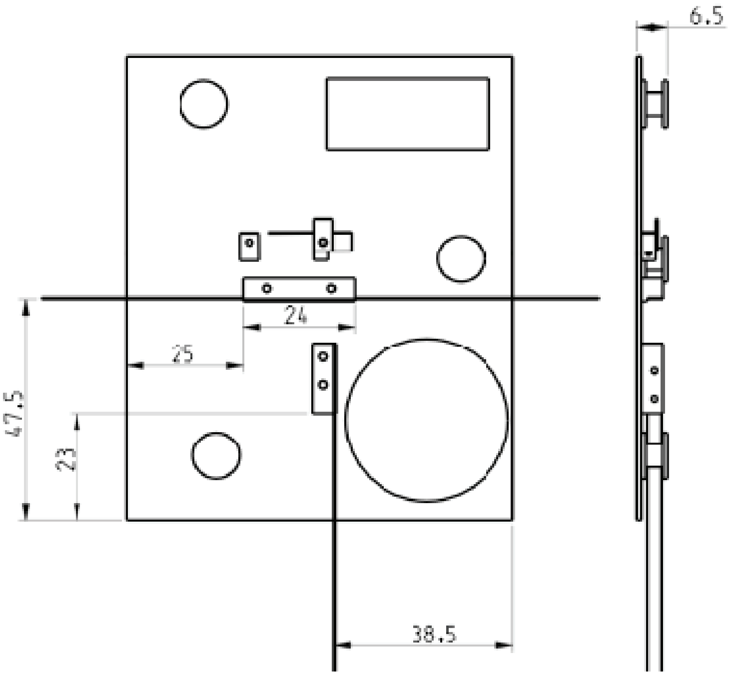
3.2.2.1 Mass budget

For the moment, a critical element in our Cubesat is the mass limitation. The budgeted mass for the antenna deployment was 25 grams, which is very hard to achieve. Only with the actual baseline (particularly melting wire actuator and winding of a flat antenna around 3 contact points) we could get along with this minimal weight.

Mass budget:	(in g)	
•Mono&Dipole	7.0875	
•2 connectors	3	estimation
•Cables	3	estimation
•3 Polymer fixations	1.225	
•3 points of contacts (Aluminium)	1.14453	
•10 screws	2	estimation
•Melting wire fix	1.5	estimation
Total:	18.95703	
Additional weight (not our subsystem)		
•2 Kill switches	10	literature
•1 Aluminium panel for prototype mounting	27	
Total:	37	

3.2.2.2 Volume

After the Cubesat specification, the cube of 10cm side length mustn't be exceeded of more than 6.5mm on each side. We placed our antenna system outside the cube, within these 6.5mm. The prototype is mounted on a 1mm Aluminium plate and glued on the structure. The highest elements (the 3 contact points to guide the antennas) are 5.5mm high, which means that we didn't exceed the allowed volume.

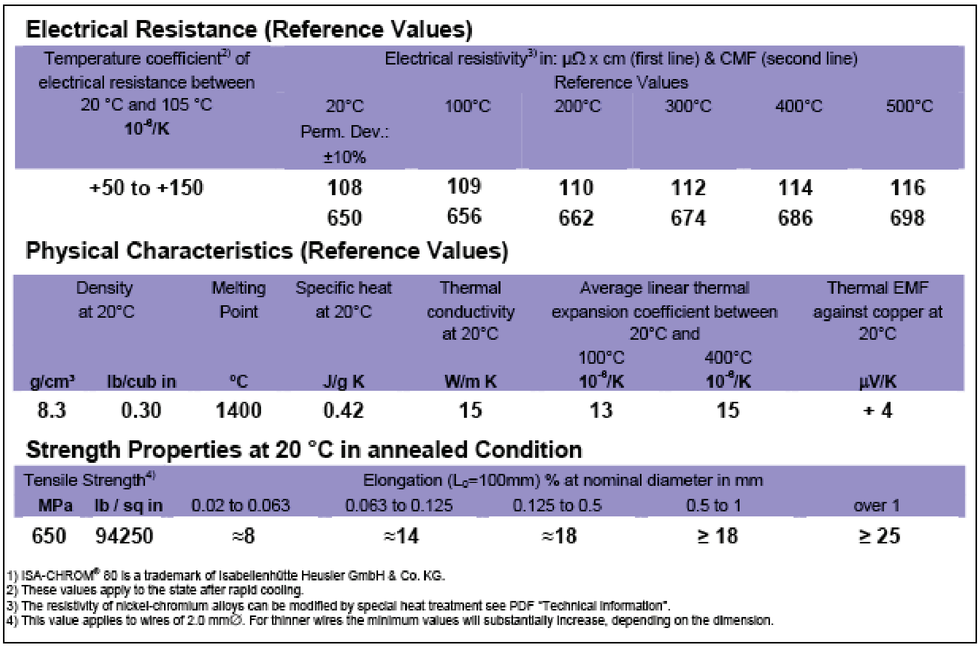


Drawing of a prototype version in 2 views

3.2.2.3 Power

As discussed already in paragraph 2.1.2, the power consumption is influenced by the low-pressure environment in the space. The missing heat convection will provoke the heating wire to get faster to a certain temperature. In case of a good contact between the Nichrome wire and the nylon, the nylon melts faster (with a lower power consumption) than in normal conditions. On the other hand we have to pay attention that the Nichrome is not overheating and melting itself. In the following paragraph we try to optimise the choice of the Nichrome wire to get a temperature of 600° with the lowest power consumption.

Choice of the material: Beside the mechanical properties, the wire should have a high resistivity, and of course a melting Temperature of at least 3 times the melting temperature of nylon (250°). In all of these points the best performance are presented by an ISA-CHROM 80 (NiCr8020) wire of the German company Isabellenhütte [R8], which is a distributor of the Swedish company Kanthal [R9]. The wire has an operating temperature of 1200°C and is characterised as "corrosion resistant". Its high resistivity is 109uOhm*cm at 100°C, with a low temperature coefficient of 10E-6/K.



Electrical Resistance (Reference Values)

Temperature coefficient[2] of electrical resistance between 20 °C and 105 °C 10^{-6}/K	Electrical resistivity[3] in: µΩ x cm (first line) & CMF (second line) Reference Values					
	20°C Perm. Dev.: ±10%	100°C	200°C	300°C	400°C	500°C
+50 to +150	108	109	110	112	114	116
	650	656	662	674	686	698

Physical Characteristics (Reference Values)

Density at 20°C		Melting Point	Specific heat at 20°C	Thermal conductivity at 20°C	Average linear thermal expansion coefficient between 20°C and		Thermal EMF against copper at 20°C
					100°C	400°C	
g/cm³	lb/cub in	°C	J/g K	W/m K	10^{-6}/K	10^{-6}/K	µV/K
8.3	0.30	1400	0.42	15	13	15	+ 4

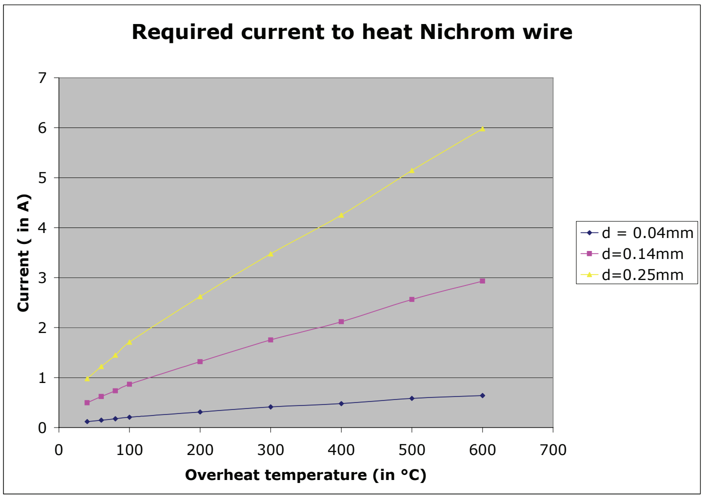
Strength Properties at 20 °C in annealed Condition

Tensile Strength[4]		Elongation (L_0=100mm) % at nominal diameter in mm				
MPa	lb / sq in	0.02 to 0.063	0.063 to 0.125	0.125 to 0.5	0.5 to 1	over 1
650	94250	≈8	≈14	≈18	≥ 18	≥ 25

1) ISA-CHROM® 80 is a trademark of Isabellenhütte Heusler GmbH & Co. KG.
2) These values apply to the state after rapid cooling.
3) The resistivity of nickel-chromium alloys can be modified by special heat treatment see PDF "Technical information".
4) This value applies to wires of 2.0 mm∅. For thinner wires the minimum values will substantially increase, depending on the dimension.

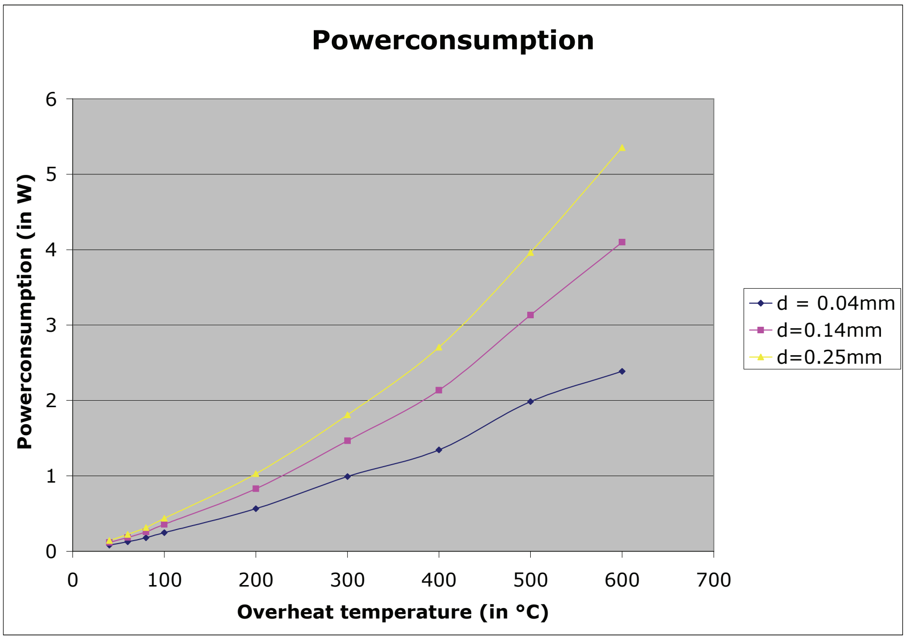
Technical specification of ISA-CHROM 80 (NiCr8020)

For this given material we calculated the required current to overheat the Nichrome wire to a given temperature in normal environment.



Dependence of wire temperature and current for a Nichrome wire

With the assumption of a constant wire resistance during the heating, we transformed this diagram to the power consumption. The length of the wire is estimated at 15mm.



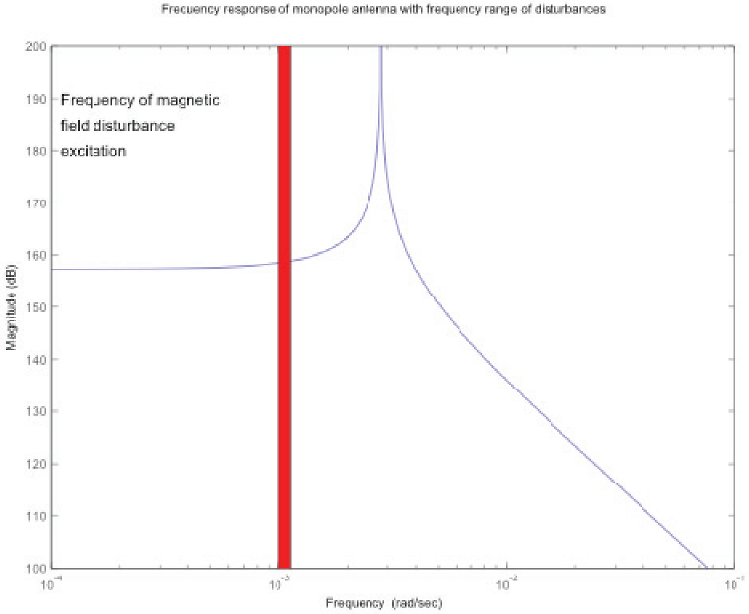
Power consumption for a given temperature with a 15mm wire

For an overheat of 600°C we see that a dominant factor is the wire diameter. The melting behaviour (particularly melting time) of the nylon is very hard to calculate. Therefore detailed tests are essential.

As already mentioned we expect a lower power consumption in vacuum. The experienced Power of the Norwegian team (2.5W), for a similar 0.15mm Nichrome wire corresponds to our results. Due to the short consummation time (estimated around 1 second) and the fact that no other subsystem is using power at that time, this is a value that has been accepted by our EPS. With the 0.04mm Nichrome wire we could reduce it more, but the risk to melt the Nichrome itself gets higher. Anyways we will continue the tests with both of the diameters (0.04mm and 0.16mm).

3.2.3 Antenna Eigen frequency

A simulation of our ACDS subsystem shows the Eigen frequency of the antenna system.



Eigen frequency of the antennas vs the one of the satellite (red stripe)

Concerning these results the first mode is close to the vibration mode of the structure. That means that we risk getting them in resonance, which would be very hard to control.

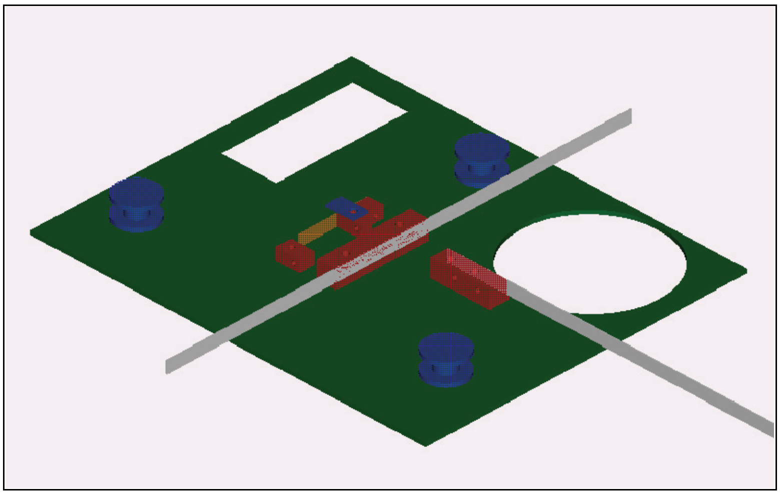
The calculations have been done with a rectangular cross section. We hope that the particular "v"shape (see paragraph 2.2.2) will raise the frequency. An other idea is to change the width along the antenna, to make it stiffer in the origin and lighter at the ends. But for the moment we can only say that we recognised the critical point and we will do further tests and investigations. We took also into consideration to measure the precise Eigen frequency and its impact on the satellite in a microgravity environment.

3.3 Prototyping

For building a prototype, the main criteria's were the following:

- Reliable!
- Volume and weight reduction.
- Flexible to adapt for other configurations.
- Easy access to reset the deployment mechanism for tests.
- Guaranteed contact between Nichrome and Nylon wire.

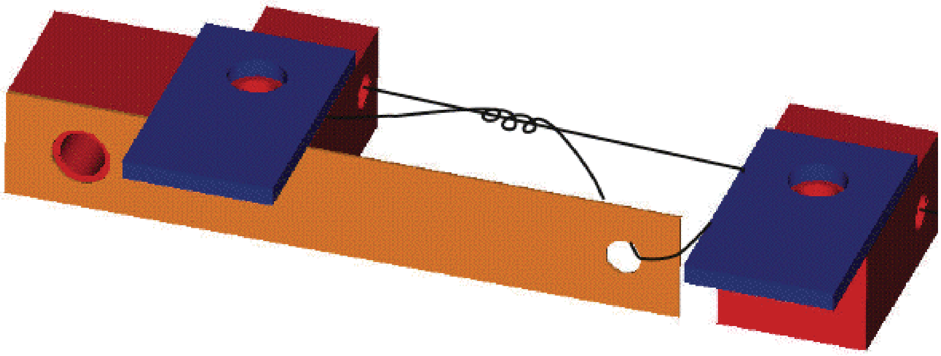
To assure the reliability we designed the system as simple as possible, which has also a positive effect on the volume and the weight. One of the problems is that the precise antenna length can't be determined theoretically. For the design that means that we don't know exactly the place of the fixation and it has to be adaptable.



3D scheme of one prototype version

3.3.1 Nichrome wire fixation

Because of the small diameters of the two considered Nichrome wires, we have to guarantee that there are no mechanical forces. Anyways the Nichrome should be in direct contact with the nylon wire, to assure a fast melting. These two points were leading us to a flexible spring structure.



Nichrome wire fixation with spring to assure the contact

The nylon is guided through two holes, for not transmitting the shocks on the Nichrome wire. In addition to that, the Nichrome wire is mounted on one side on a laminated spring. The spring assures an optimal contact of the Nichrome around the Nylon. Of course this spring starts to vibrate during the take off, but the mass of the spring is so small that created dynamic forces are sufficient small for the Nichrome wire. This has to be further investigated during tests.

In case that the spring system is not adequate, we can use the same structure, but instead of passing the Nichrome wire trough the spring, we fix it directly on the second Polymer part. In that case the contact of the two wires have to be regulated manually, by pulling the Nichrome wire before fixing.

3.3.2 Material choice

The choice of the Nichrome wire and the beryllium copper has preliminary been discussed. The third critical choice is the material for the electrical isolation between the antennas and the structure panel. The volume for these fixations is very limited (total high of 5.5mm), which leads to a high demand of mechanical properties and a good machinability. The most critical parameter in our case is the large temperature domain (-100°C to -150°C). Usually polymers get brittle for low temperatures.

- POM (polyacid-copolymer)

Temperature range: -50°C to 115°C

Characteristics: Good mechanical properties, high stiffness and hardness. Dimensional stability and high shock resistance. Very good machinability.

- VESPEL (Polyamide)

Temperature range: -250°C to +240°C (peak resistance up to +450°C)

Characteristics: Very high dimensional stability, high stiffness and hardness. Good mechanical properties, shock resistance. Good dielectrically properties.

We decided to use POM for our first prototype, because of the very high price of VESPEL. But keeping in mind that for later versions VESPEL is the optimal material.

3.4 Tests

During the end of phase A and during phase B, various test on the deployment system are planed:

- Melting behaviour of Nylon in normal conditions
- Reliability of deployment
- Melting behaviour of Nylon in vacuum chamber
- Vibration analyse
- Analyse of the Eigen frequency of the antennas and its influence on the position control (ev. tests in microgravity)

The first two points are planed until the review of phase A and the others in phase B.

CONCLUSIONS, FUTURE WORK

The placement and the orientation of the antennas is the most critical point, which is influenced by many subsystems. The optimal orientation of the antennas is tangential to the earth, and therefore the optimal place would be the satellites side tangential to the earth too. These sides are not accessible in our case because of the solar panels and the magneto torques. With our solution (Shifted dipole, 3.2.1.5) we found a way to place the antennas on the side of the objective (perpendicular to the earth) and anyways having the full communication time. On the other hand the radiation pattern has the weakest values in the region close to the ground station. In our opinion the only possibility to evite that, is to deploy the antenna perpendicular to the surface. This would be possible by rolling up the antenna into the interior of the Cubesat. During the decisions for a baseline of phase A the place in the interior was very limited and this solution was not possible. If the place conditions are changing, this solution should be taken into consideration.

REFERENCES

[R1] University of Tokyo, Critical Design Review, April 2001

[R2] http://www.aeroconsystems.com/electronics/nichrome.htm

[R3] Norges Teknisk Naturvitenskapellige Universitetet, Hovedoppgave, Jan Otterstad, January 2003

[R4] University of Hawaii, Departement of Electrical Engineering, Spring 2002

[R5] http://www.ngkdbg.de/

[R6] http://www.glucymet.ch/?Rpage=berylliumkupfer.html

[R7] http://cubesat.calpoly.edu/_new/index.html

[R8] http://www.isabellenhuette.de/INDEX.HTM

[R9] http://www.kanthal.com/