The feasibility study aims to assess the practicality of the EPS module. The purpose of this stage is to assess the performance according to the association of the requirements and the state of the art.

==<span style="font-size:18px;">PCC </span>==

As a brief remind, t<span style="text-align:justify;">he PCC module is responsible for the distribution and regulation of electricity through the CubeSat. There is many requirements to fit such as the protection of the modules, the communication with the OBC and the energy distribution from PV cells to battery for the storage and/or to module for the consumption.</span>

<span style="text-align:justify;text-indent:35.4pt;"> The MPPT will have to handle a maximum input voltage of 4V from solar panels and supply power to a 3.7 V battery. Redirecting the current to regulators providing energy to the modules (3.3V and 5V). The modules are both connected to the panels and the battery, that is why regulators will be connected in parallel to the MPPT output and the battery. An additional cell has been integrated because of the large amount of energy needed for the </span>''detumbling''<span style="text-align:justify;text-indent:35.4pt;"> phase, the battery will not be enough to ensure the power supply in this time.</span>

<span style="text-align:justify;text-indent:35.4pt;"> It has been established that a 3.3V regulated bus detumbling could be used to supply ADCS and OBC (which are on the same board), the other 5V converters will be connected to TCS and EDT. These figures are for now only indicative and will have to be changed according to the needs of each module.</span>

<span style="text-align:justify;text-indent:35.4pt;"> The MCU is used for gathering and computing the housekeeping data, taking decisions for connecting/disconnecting users in case of failure and communicating with OBC thanks to an UART bus. The battery level of charge is harvested through an analog-digital converter.</span>

<p class="MsoNormal" style="text-align:justify;text-indent:35.4pt;"><span style="font-family:Calibri;font-size:11pt;">A schematic of the description above, develops the architecture more clearly:</span></p>

[[File:Capture\_d’écran\_2017-03-06\_à\_16.41.54.png|left]]

==Regulators==

<p class="MsoNormal" style="text-align:justify;text-indent:35.4pt;"><span lang="EN-US" style="mso-ansi-language:EN-US">According to the availability on the market, the type of regulators varies as a function of the input and the output. As the battery charge regulator receives a various input from MPPT which can be superior or inferior to 3.7V, it has to work as a step-up and step-down regulator. For increasing the voltage from 3.7V to 5V the second regulator should be a step-up. As the last regulator decreases the voltage to 3.3V, it should be a step-down regulator. But, since the battery's output voltage decrease with its level of charge, the input voltage of regulators could be under 3.3V. Therefore, the last regulator should not be only a step-down regulator, it has to be a step-up/step-down voltage regulator, with a 3.3V output.</span></p>

==Microcontroller==

<p class="MsoNoSpacing" style="text-align:justify"><span lang="EN-US" style="mso-ansi-language:EN-US">The microcontroller has to handle the energy distribution of the entire CubeSat, and has to communicate with the OBC too. Thus, it needs four digital/analog outputs (EDT, ADCS, Telecom, OBC), one BUS with a two-way communication between the microcontroller and the OBC in: UART. And two inputs with a power BUS and one another BUS which is used to send data of the battery level of charge to the microcontroller: SPI.</span></p>

===<span lang="EN-US" style="mso-ansi-language:EN-US">Energy Consumption</span>===

<p class="MsoNoSpacing"><span lang="EN-US" style="mso-ansi-language:EN-US">Generally, microcontrollers consume few energy, around the mirco ampere for the “Active mode” and around the hundreds of nano ampere for the “Off mode”. Others microcontrollers are more economical, they can be used with six different ways.<span style="mso-spacerun:yes"> </span></span></p>

===<span lang="EN-US" style="mso-ansi-language:EN-US"><span style="mso-spacerun:yes">Voltage Range</span></span>===

<p class="MsoNoSpacing">The voltage range of the microcontroller depends of the output voltage of the battery, which is 3.7V.</p>

<p class="MsoNoSpacing"><span lang="EN-US" style="mso-ansi-language:EN-US">Almost microcontrollers have a voltage range of 2-3.6V, except for the ATMEGA1281 which has a voltage range of 2.7-5.5V.</span></p>

===<span lang="EN-US" style="mso-ansi-language:EN-US">Memory</span>===

<p class="MsoNoSpacing"><span lang="EN-US" style="mso-ansi-language:EN-US">In the light of the functions of the microcontrollers the memory didn’t have to be huge. All the microcontrollers are viable.</span></p>

==PV==

<span style="text-align:justify;">The sizing of this module has to be accurate and margins have to be considered to be sure of the capability of production compare to the consumption.</span>

<p class="MsoNormal" style="margin-top:12.0pt;text-align:justify"><span lang="EN-US" style="mso-ansi-language:EN-US">The energy production of the PV mainly depends of two factors which are the efficiency and the surface area of the cells. Other characteristics such as temperature, way to wire or weight have to be taken into account.</span></p>

<h3 class="MsoNormal" style="margin-top:12.0pt;text-align:justify">Temperature</h3>

<p class="MsoNormal" style="margin-top:12.0pt;text-align:justify">The PVs are subject to high electro magnetic radiation that cause huge variation of the temperature over time. (Around 100°C of difference between solar exposition phasis and eclipse). Then PVs shall be sized to undergo the extreme conditions of space environment.</p>

<h3 class="MsoNormal" style="margin-top:12.0pt;text-align:justify">Surface & Efficiency</h3>

<p class="MsoNormal" style="margin-top:12.0pt;text-align:justify">The limited surface area on each side of the nanosatellite implies some restriction on the type of PVs available on the market and in compliance with the need of production. Efficiency and surface being related to each other, finding a compromise between them could imply an increase in the cost.</p>

<p class="MsoNormal" style="margin-top:12.0pt;text-align:justify">As panel's efficiency decreases over time, the capacity of production shall be computed for the beginning and the end of life. According to the allocated power budget, efficiency shall be maximized, Triple Junction solar cells are well indicated for this last condition. Generally, the solar cells designed for 1U CubeSat are between 25% and 30%.</p>

<p class="MsoNormal" style="margin-top:12.0pt;text-align:justify"><span style="text-indent:35.4pt;">Triple junction solar cells are used in space, our CubeSat will integrate this technology too. To save money, a choice of solar cells rather than complete solar panel has been studied.</span></p>

<li class="MsoNormal" style="margin-top:12.0pt;text-align:justify"><span style="text-indent:35.4pt;">The advantages of this solution are the flexibility on architecture, the cheaper cost, and the number of choices between different TJ solar cells.</span></li></li></li></li>

<li class="MsoNormal" style="margin-top:12.0pt;text-align:justify"><span style="text-indent:35.4pt;">The disadvantages of this solution are that the architecture is more complicate than solar panels's architecture (due to the big number of solar cells), the sensors, wire and magnetorquers have to be add by ourselves (inducing more risks on the result), and some solar cells such as TASC cells have not coverglass on it. In this case, there is a need to add encapsulation on cells aftermarket coverglass.</span><p class="MsoNormal" style="margin-top:12.0pt;text-align:justify"><span style="text-indent:35.4pt;">Therefore, the first option will be considered as our solution if the budget enables it. Otherwise, the second option will be considered even if it induce an increase of risk of mission failure.</span></p>

<p class="MsoNormal" style="margin-top:12.0pt;text-align:justify">

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<h2 class="MsoNormal" style="margin-top:12.0pt;text-align:justify">PV Feasibility Study Download</h2>You can find below the study of two kind of PVs Ultra Triple Junction Solar cell from Spectrolab, and ISIS TJ 3G30A<p class="MsoNormal"><span style="text-indent:35.4pt;">The results calculated are the power generated by only one face of the CubeSat. However the CubeSat has 5 sides with solar panels and between one and three sides can be under Sunlight at the same time. The number of sides which receives solar power is related to the orientation of the CubeSat. To estimate the power generated by the entire CubeSat, the calculations have to take in account the inclination of the satellite, in other words, the angles (here in spherical coordinates).</span><span style="text-indent:35.4pt;"> </span></p>

<p class="MsoNormal" style="margin-top:12.0pt;text-align:justify">[[File:PV\_feasibility\_study.pdf]]</p>

<p class="MsoNormal" style="margin-top:12.0pt;text-align:justify">

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<h2 class="MsoNormal" style="margin-top:12.0pt;text-align:justify">Battery</h2><p class="MsoNormal" style="margin-bottom:0cm;margin-bottom:.0001pt;text-align: justify;line-height:normal"><span lang="EN-ZA" style="mso-fareast-font-family: "TimesNewRoman";mso-bidi-font-family:Calibri;mso-bidi-theme-font:minor-latin; color:black;mso-ansi-language:EN-ZA;mso-fareast-language:EN-ZA">To supply the modules in energy, at least one rechargeable battery is needed. There are different types of batteries (Typically Li-Ion and NIMH). The technology, the attitude in a cold and hostile environment and the power consumption have to be considered to size the battery module.</span></p>

<p class="MsoNormal" style="margin-bottom:0cm;margin-bottom:.0001pt;text-align: justify;line-height:normal"><span>Since the CubeSats have already a huge rate of failure (due to the hostile environment that they have to face with), the battery considered in the ECE³SAT has to be as safe as possible technology designed for space.</span></p>

<p class="MsoNormal" style="margin-bottom:0cm;margin-bottom:.0001pt;text-align: justify;line-height:normal">

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===Energy Needed===

<p class="MsoNormal">There is not a Power Budget for the ECE CubeSat, therefore an average of the precedent CubeSat is used:</p>

<p class="MsoNormal">For improving the battery lifespan, it has to be neither fully charged nor depth discharged. Precisely, the level of charge needs to be maintained between 20% and 90% of the total capacity. According to the amount of energy needed by the system, this should represent 70% of the battery capacity. Then, in consequence the battery should deliver 3.21 Wh.</p>

<p class="MsoNormal" style="margin-bottom:0cm;margin-bottom:.0001pt;text-align: justify;line-height:normal">

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===<span lang="EN-ZA" style="mso-fareast-font-family: "TimesNewRoman";mso-bidi-font-family:Calibri;mso-bidi-theme-font:minor-latin; color:black;mso-ansi-language:EN-ZA;mso-fareast-language:EN-ZA">Energy used</span>===

<p class="MsoNormal" style="margin-bottom:0cm;margin-bottom:.0001pt;text-align: justify;line-height:normal"><span lang="EN-ZA" style="font-size:12.0pt; mso-fareast-font-family:"TimesNewRoman";mso-bidi-font-family:Calibri; mso-bidi-theme-font:minor-latin;mso-ansi-language:EN-ZA;mso-fareast-language: EN-ZA"> </span></p>

<p class="MsoNormal" style="margin-bottom:0cm;margin-bottom:.0001pt;text-align: justify;line-height:normal"><span lang="EN-ZA" style="mso-fareast-font-family: "TimesNewRoman";mso-bidi-font-family:Calibri;mso-bidi-theme-font:minor-latin; color:black;mso-ansi-language:EN-ZA;mso-fareast-language:EN-ZA">To improve the lifespan of the battery, it has to be neither fully charged nor depth discharged. The level of charge needs to be maintained between 20% and 90% of the total capacity.</span><span style="font-size:12pt;"> </span></p>

<p class="MsoNormal" style="margin-bottom:0cm;margin-bottom:.0001pt;text-align: justify;line-height:normal"><span lang="EN-ZA" style="mso-fareast-font-family: "TimesNewRoman";mso-bidi-font-family:Calibri;mso-bidi-theme-font:minor-latin; color:black;mso-ansi-language:EN-ZA;mso-fareast-language:EN-ZA">Moreover, in average, '''2.25Wh''' will be needed during an eclipse according to the power budget part.</span></p>

<p class="MsoNormal" style="margin-bottom:0cm;margin-bottom:.0001pt;text-align: justify;line-height:normal"><span style="color:black;">Thus, a battery will be required with 3.21Wh, or a capacity of </span>'''0.87 Ah'''<span style="color:black;"> with a voltage of 3.7 V.</span></p>

<p class="MsoNormal" style="margin-bottom:0cm;margin-bottom:.0001pt;text-align: justify;line-height:normal"><span lang="EN-ZA" style="mso-fareast-font-family: "TimesNewRoman";mso-bidi-font-family:Calibri;mso-bidi-theme-font:minor-latin; color:black;mso-ansi-language:EN-ZA;mso-fareast-language:EN-ZA">It is in adequacy with the 1 Ah generally used.</span></p>

<p class="MsoNormal" style="margin-bottom:0cm;margin-bottom:.0001pt;text-align: justify;line-height:normal"><span lang="EN-ZA" style="mso-fareast-font-family: "TimesNewRoman";mso-bidi-font-family:Calibri;mso-bidi-theme-font:minor-latin; color:black;mso-ansi-language:EN-ZA;mso-fareast-language:EN-ZA"> </span></p>

<p class="MsoNormal" style="margin-bottom:0cm;margin-bottom:.0001pt;text-align: justify;line-height:normal"><span lang="EN-ZA" style="mso-fareast-font-family: "TimesNewRoman";mso-bidi-font-family:Calibri;mso-bidi-theme-font:minor-latin; color:black;mso-ansi-language:EN-ZA;mso-fareast-language:EN-ZA">The CubeSat may also consider the use of a non rechargeable battery to execute one time operation. It could be very interesting for some specific operations such as in the detumbling mode in the ECE³Sat case. So, it would a primary battery of 1Wh.</span></p>

<p class="MsoNormal" style="margin-bottom:0cm;margin-bottom:.0001pt;text-align: justify;line-height:normal"><span lang="EN-ZA" style="font-size:12.0pt; mso-fareast-font-family:"TimesNewRoman";mso-bidi-font-family:Calibri; mso-bidi-theme-font:minor-latin;mso-ansi-language:EN-ZA;mso-fareast-language: EN-ZA"> </span></p>

===<span lang="EN-ZA" style="font-size:12.0pt; mso-fareast-font-family:"TimesNewRoman";mso-bidi-font-family:Calibri; mso-bidi-theme-font:minor-latin;mso-ansi-language:EN-ZA;mso-fareast-language: EN-ZA">Vaccum</span>===

<p class="MsoNormal" style="margin-bottom:0cm;margin-bottom:.0001pt;text-align: justify;line-height:normal"><span lang="EN-ZA" style="font-size:12.0pt; mso-fareast-font-family:"TimesNewRoman";mso-bidi-font-family:Calibri; mso-bidi-theme-font:minor-latin;mso-ansi-language:EN-ZA;mso-fareast-language: EN-ZA"> </span></p>

<p class="MsoNormal" style="margin-bottom:0cm;margin-bottom:.0001pt;text-align: justify;line-height:normal"><span lang="EN-ZA" style="mso-fareast-font-family: "TimesNewRoman";mso-bidi-font-family:Calibri;mso-bidi-theme-font:minor-latin; color:black;mso-ansi-language:EN-ZA;mso-fareast-language:EN-ZA">At low earth orbit, the atmosphere influence at really low level the space environment. Therefore, LEO is considered to be in vacuum conditions.</span></p>

<p class="MsoNormal" style="margin-bottom:0cm;margin-bottom:.0001pt;text-align: justify;line-height:normal"><span lang="EN-ZA" style="mso-fareast-font-family: "TimesNewRoman";mso-bidi-font-family:Calibri;mso-bidi-theme-font:minor-latin; color:black;mso-ansi-language:EN-ZA;mso-fareast-language:EN-ZA">The battery designed for the CubeSat has to be able to charge and to furnish electricity to modules in these vacuum conditions. </span></p>

<p class="MsoNormal" style="margin-bottom:0cm;margin-bottom:.0001pt;text-align: justify;line-height:normal"><span lang="EN-ZA" style="font-size:12.0pt; mso-fareast-font-family:"TimesNewRoman";mso-bidi-font-family:Calibri; mso-bidi-theme-font:minor-latin;mso-ansi-language:EN-ZA;mso-fareast-language: EN-ZA"> </span></p>

===<span lang="EN-ZA" style="font-size:12.0pt; mso-fareast-font-family:"TimesNewRoman";mso-bidi-font-family:Calibri; mso-bidi-theme-font:minor-latin;mso-ansi-language:EN-ZA;mso-fareast-language: EN-ZA">Temperature</span>===

<p class="MsoNormal" style="margin-bottom:0cm;margin-bottom:.0001pt;text-align: justify;line-height:normal"><span lang="EN-ZA" style="mso-fareast-font-family: "TimesNewRoman";mso-bidi-font-family:Calibri;mso-bidi-theme-font:minor-latin; color:black;mso-ansi-language:EN-ZA;mso-fareast-language:EN-ZA">The temperature in space is very low and it is important to take into account during the design of the modules. The battery is always confronted to the natural discharge issue, but in a cold environment this problem increases. That means that the battery has to be designed for space, and has to resist to low temperature.</span></p>

<p class="MsoNormal" style="margin-bottom:0cm;margin-bottom:.0001pt;text-align: justify;line-height:normal"><span lang="EN-ZA" style="mso-fareast-font-family: "TimesNewRoman";mso-bidi-font-family:Calibri;mso-bidi-theme-font:minor-latin; color:black;mso-ansi-language:EN-ZA;mso-fareast-language:EN-ZA">The natural discharge of the battery has to be considered according to this extreme temperature. The battery should be able to work well and without too much loss for a temperature of 0 C°. This aims to improve the charge of battery and avoid the depth of discharge.</span></p>

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