MASTA 2015 (Micro-Satellite Technology) Team Pilot Project Final Poster

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THERMAL CONTROL SUBSYSTEM (TCS)

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PURPOSE OF THERMAL CONTROL

The purpose of the satellite's thermal control is to maintain each equipment within its specified temperature range with required margins during all phases of the mission. The temperature ranges that QY-1 Project's thermal control must maintain during the operating mode are abstracted in table. However, to take into account the modeling assumption errors and uncertainties of the thermal physical properties, a thermal uncertainty margin of 5 C shall be included in all analyses so that the maximum or minimum predicted flight temperatures could be determined.

Component	Operating Temperature		Survival Temperature	
	Minimum (°C)	Maximum (°C)	Minimum (°C)	Maximum (°C)
2U CubeSat Structure	-40	150	-47	155
Solar Panels 2U Side	-55	150	-60	155
Solar Panels 1U Side	-55	150	-60	155
Battery board	0	50	-5	55
EPS board	-40	85	-45	90
Magnetometer	-35	75	-40	80
IMU + GPS	-40	80	-45	85
Magnetorquer board	-40	70	-45	75
Camera	0	60	-5	65
Transceiver board	-20	50	-25	55
Antenna	-30	70	-35	75
OBC board	-25	60	-30	65
Spectrometer	-20	40	-25	45

PASSIVE THERMAL DESIGN

Passive thermal control requires no input power for thermal regulation within a spacecraft. This can be achieved using several methods and is highly advantageous to spacecraft designers, especially for the cubesat form factor, as passive thermal control systems are associated with low cost, volume, weight and risk, and have been shown to be reliable. The integration of Multi-Layer Insulation (MLI), thermal coating, heat pipes, and sunshades are examples of passive methods to achieve thermal balance in a spacecraft.

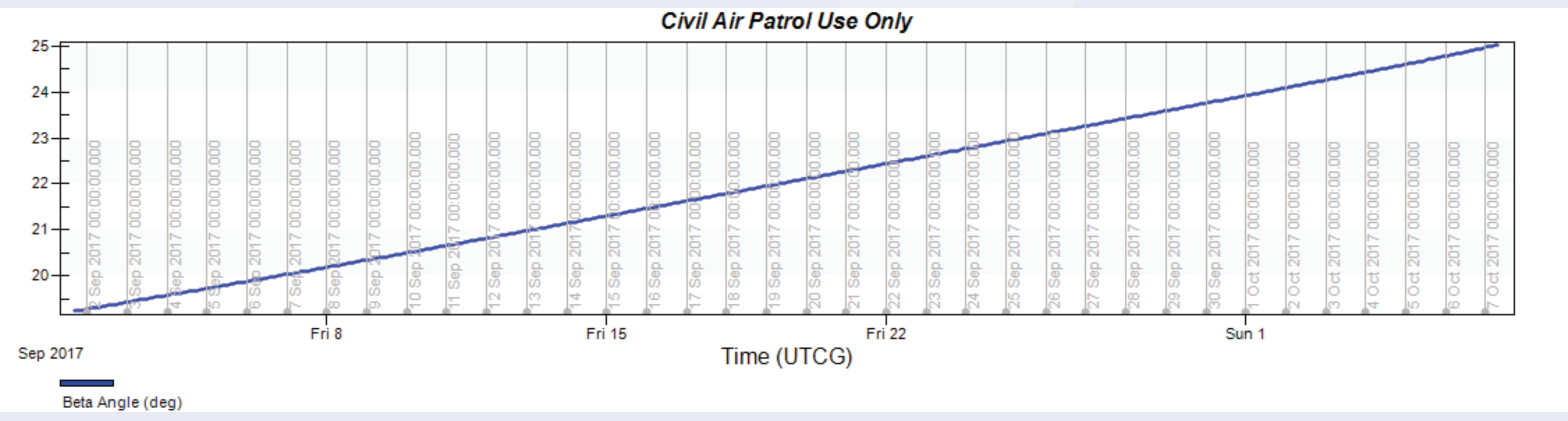
Our CubeSat has approximately 80% solar panels. For the rest, we will use thermal coating.

THERMAL DESIGN

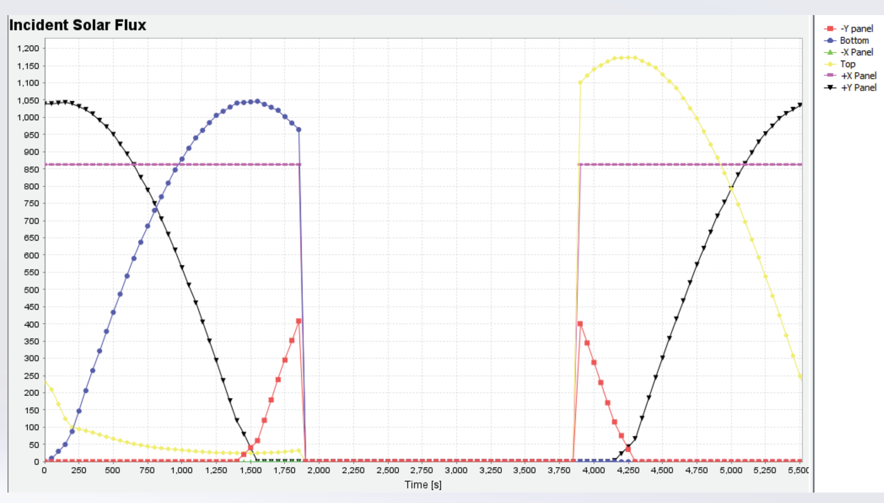
Period	Mean Duration Orbit Using Drag Sail	Mean Duration Orbit without Drag Sail
Sunlight	3366.328 sec	3115.831 sec
Penumbra	8.767 sec	8.708 sec
Umbra	2105.894 sec	2156.962 sec
Total	5489.756 sec	5290.209 sec

This orbit is considered a Low Earth Orbit, so an important thing to take in mind is that IR earth and albedo fluxes will be not negligible and they will produce a relatively influence in BUSAT-1. The duration of the eclipse will be around 38% of the total orbit period.

Our satellite's period (mean) = 5456.498 sec (90.94 min)
Umbra (mean) = 2114.405 sec (35.24 min)

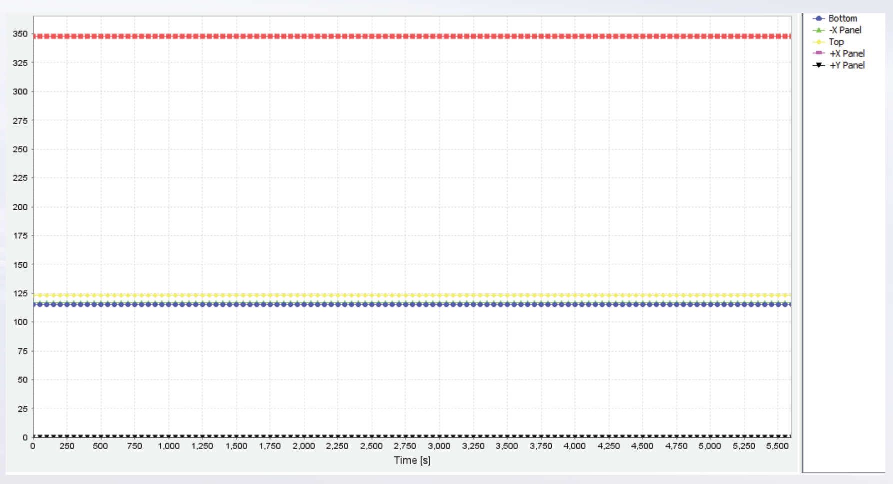


The Beta Angle will change from season to season depending upon orbit parameters, but determining the maximum and minimum Beta Angle is fairly straightforward. Most satellite orbits are fixed with respect to the sun, so during the earth year, the orientation of the orbit with respect to the sunlight on the earth changes.



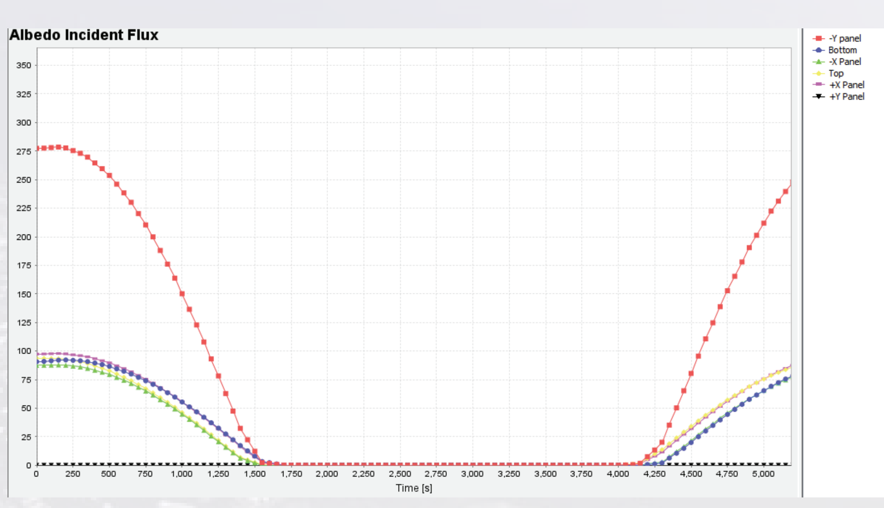
POINTING	
Axis	Pointing
+Z	Velocity
-Z	Anti-velocity
+X	Normal to Orbit
+Y	Normal to Orbit

The panels that receive more indicent solar flux are the panels located at +Z and –Z, respectively, Bottom panel. As in this analysis, spin has not been considered some lateral panels may be never illuminated by the Sun. It is the case of –X panel. Time of eclipse is approximately 38% of the total orbit period.



The panel that receives more IR Earth Power is –Y Panel, as for the attitude proposed, is facing to Nadir. The rest of the panels, are receiving the same flux quantity, around 100W/m2, except +Y panel
that is facing to Zenith. Earth flux is constant along the orbit, as the relative position between satellite and Earth does not change.

i = Orbit Inclination
δ_s = Inclination of Earth's axis to the sun = 23.5°
$$\beta_{max} = |\, i \pm \delta_s \,|$$



Orbit altitude also plays a large role in determining the thermal environment, such as the eclipse period in the shadow of the earth, and direct thermal effects from the earth.

r = planet radius (earth average: 6367 km)
a = orbit altitude
$$\rho = arcsin\left(\frac{r}{r+a}\right) = \text{Angular radius of earth as observed from spacecraft.}$$
$$cos(\Phi/2) = \frac{cos\ \rho}{cos\ \beta}\ ; \Phi = \text{rotation angle of eclipse}$$
$$\mathcal{F}_s = 1 - \frac{\Phi}{360^\circ} = \text{Fraction of time in Sunlight}$$

Solar Cell Surface: 80%
Black Coating surface: 20%
With this value, the equivalent thermo-optical properties can be calculates as:
Side Panel = 0.80 x Solar Cell + 0.20 x Black Coating

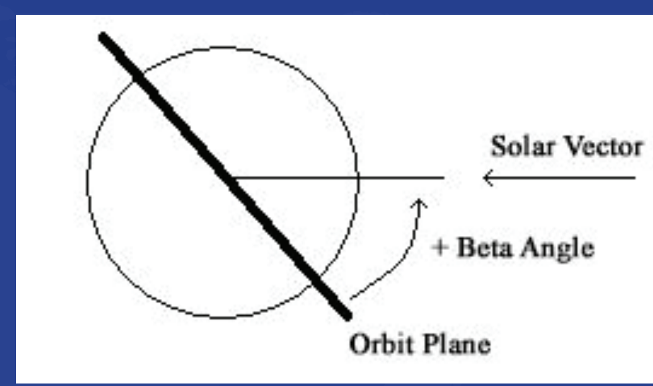
External Geometrical Thermal Nodes

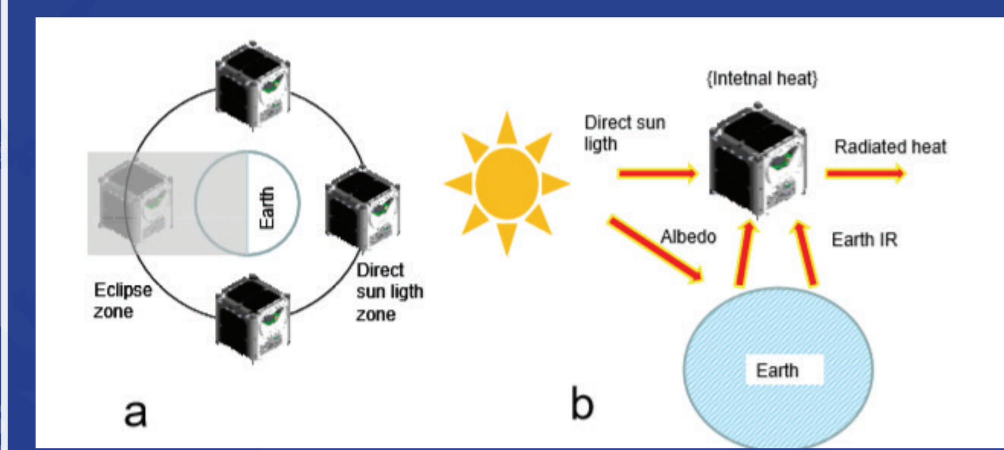
Panel	Solar Cell (%)	Black Coating (%)	Thermo-Optical Properties		Thermal Nodes
	Alpha			Epsilon	
External +X	80	20	0.72	0.81	100
External -X	80	20	0.72	0.81	100
External +Y	80	20	0.72	0.81	100
External -Y	80	20	0.72	0.81	100
External -Z	80	20	0.72	0.81	100

ENVIRONMENT

Table 1. Reference values for the thermal environment.

Source/Skin	Reference value	Description
Sun (solar constant)	1367 W/m^2	From [14].
Albedo	479 W/m^2	Fraction of solar constant, function of the view factor.
Earth IR	221 W/m^2	Function of Earth temperature and view factor.
Internal heat	20 W/m^2	Heat generated by the internal equipment.
Radiated heat	To be computed depending on the design.	





THE SUN

The Earth's orbit is slightly eccentric, the solar heat flux, Is ,varies from 1322 W/m2 to 1414 W/m2. This variation should be kept in mind when analyzing the hot and cold cases. The orbital parameter of largest effect on the thermal environment is the Beta Angle.

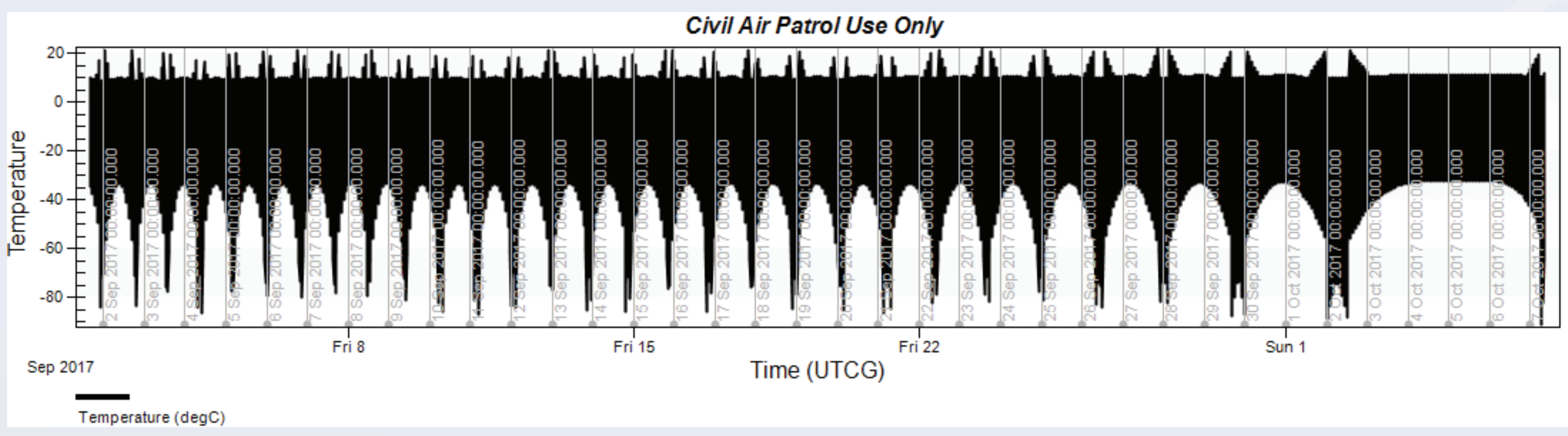
EARTH ALBEDO

Earth albedo is sunlight that is reflected off of the clouds, land, ice and water. Typical earth albedo is 30%-50%, but it can be very different depending on where the spacecraft is over the earth, since it is strongly affected by the local environment.
This reflection factor can be looked up in tables, but a conservative (high) estimate is palbedo=0.5 for a hot case. At high Beta Angles, albedo is small, and at low Beta Angles albedo is high, so it has a moderating effect on spacecraft average temperature.

EARTH RADIATION

This parameter is also very dependent on the local conditions directly below the spacecraft. A hot desert will radiate far more heat to the spacecraft than a cool glacier or icecap.
Typical earth radiation is between 218 W/m2 and 244 W/m2, with equatorial orbits generally having higher heat fluxes and polar orbits having lower ones. The database linked above for albedo data also has a data set for earth IR. Using this database you may be able to create a more accurate model for the earth IR. Since Earth IR is higher at the equator than the poles, a high earth IR flux is not found with high Beta orbits.

TEMPERATURE MODEL



- Temperature Model for QY-1_Sail
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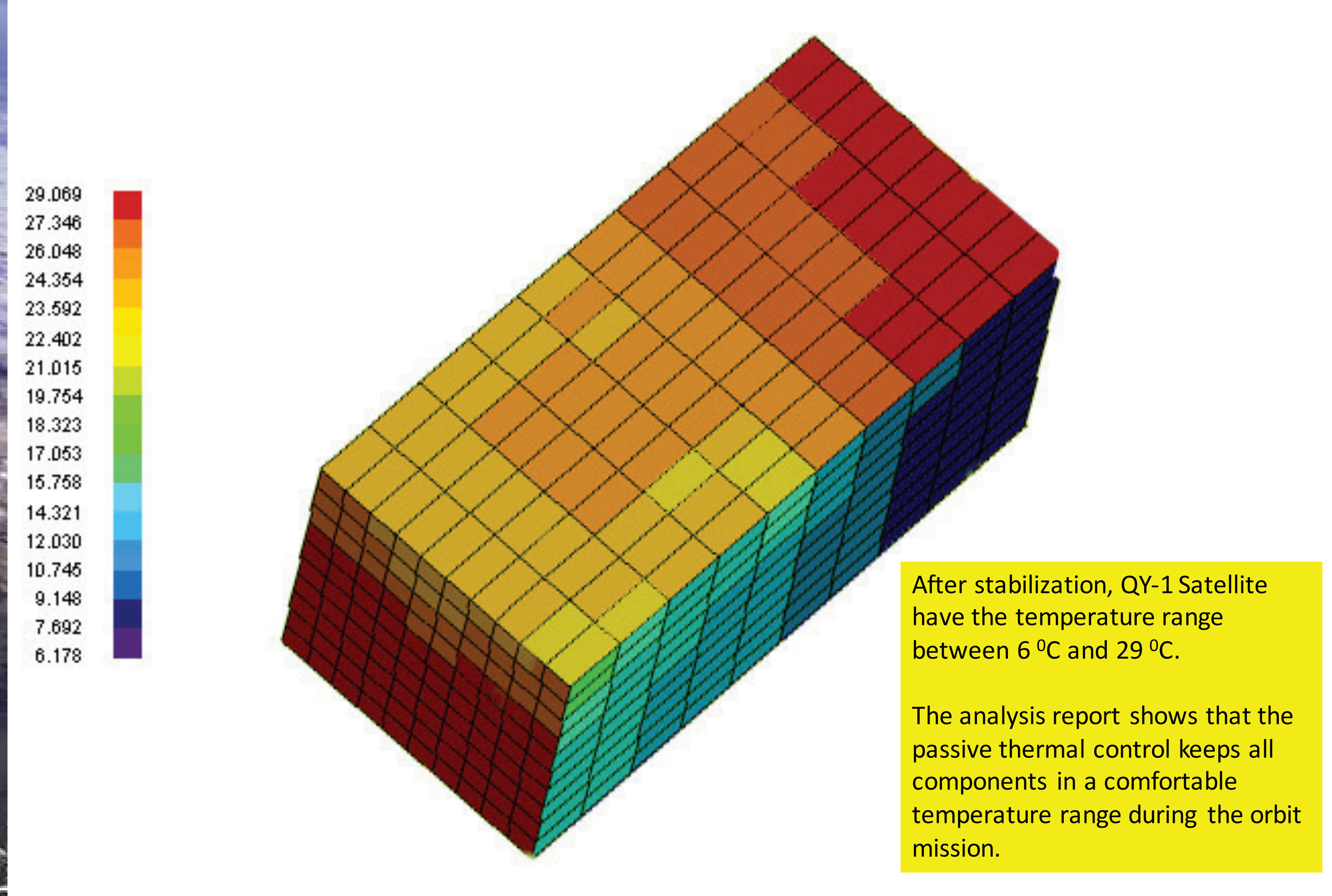
- Solar Flux at 1 AU = 1365.078 W/m^2
- Earth Albedo = 0.340
- Cross sectional Area = 0.100 m^2
- Material Emissivity = 0.924
- Material Absorptivity = 0.248
- Plate Normal Vector = Sun (based on Satellite/QY-1_Sail)
- Temperature range = -80 C to +22 C



After stabilization, QY-1 Satellite have the temperature range between 6 °C and 29 °C.

The analysis report shows that the passive thermal control keeps all components in a comfortable temperature range during the orbit mission.