Hi Michel,

My name is Ruiqi and currently I am working to carry out the thermal analysis of Bluesat when operating in stratosphere (around 40km in altitude), where the satellite is attached to a weather balloon, and when operating in space.

In my simplified model, the satellite is a 240mm by 240mm by 240mm aluminium cube covered with silicon based solar panel on all 6 faces.

Assume the emissivityand absorptance of the solar panel are,



(Ok classical value use in thales alénia space for Si cell 0,85)



(Ok classical value use in thales alénia space for Si cell 0,89)



These values are just estimation based other cube satellite’s publications but the actual values of Bluesat solar panel would be similar.

When mounted on Weather Balloon, heat exchange between Bluesat and surroundings would be,

1. Radiation from Sun
2. Radiation between Bluesat and surroundings
3. Convection
4. Conduction

My first assumption is due to low air density, convection and conduction would be omitted in the analysis but would you please advise, based on your expertise, whether convection and conduction should be brought into consideration?

Usually convection and conduction are neglected in space for thermal analysis because of very low pressure. But in your case there is some atmosphere . If the relative speed to the air is low the hypothesis may be verify. The best way to proceed is to compute your thermal analysis without those term and after verify the hypothesis by computing the convection power with the temperature obtain in the previous analysis. By comparison with the internal power dissipation you will be able to verify the hypothesis

Example 

A vertical surface of bluesat and  coefficient of natural convection



Nu Nussel number





 thermal conductivity of the air

H height of the surface

Radiation from the Sun, in my analysis was calculated as following.

Heat Flux of the sun is taken as



The flux change depending of the date of the year may be other value has to be chosen (best case, worst case, value of the date of launch,….) depending on the mission specification



Because where close to the Earth there is also radiation coming from Earth albedo in visible and in infrared Check the value

When satellite is fully exposed under sunlight, the maximum and minimum projection area would be,

|  |  |  |
| --- | --- | --- |
| Projection Angle |  |  |
| Projection Area and |  |  |

Assuming the satellite keeps rotating and projection area is varying from minimum to maximum, the average projection area is assumed to be,

This hypothesis seems to be very strong. It means you have some mechanism that perform the rotation during the flight. The blue sat is not very big and its thermal inertia not big also. Assuming an average temperature may not represent the reality with enough precision. The difference of temperature at solar cell level and at internal part( electronic board) can in the range of tenth of degree (part of the solar power is convert in electricity and dissipated internally creating an temperature gradient)



the exact average for an uniform rotation is compute by an integral over a rotation of 2\*pi. I ‘m not sure to be equal to



Thus the radiation energy from sun, can be calculated,



Radiation between satellite and surroundings would be,



Where

is the emissivity of the solar panel.



is the Stefan’s constant is equal to



is the total surface area of the satellite,



are solar panel temperature and surrounding temperature respectively in Kelvin.



For Stratosphere application, at 40km in altitude, surrounding temperature is about



Without taking internal heat emission, due to conservation of energy, following equation must remain valid:



Thus,



However, this calculation does not include the internal heat emission which is estimated to be around 10W. Where is coming this (average?) power? From the solar cell? From battery? The difference of power from Psolar cell –P battery should be added in the equilibrium

Solar Panel Temperature would be much lower when in space where is around 0 Degrees.



In this case,



Apparently, without any heat insulation, electrical components are likely to fail due to lower temperature.

First of all, would you please suggest any wrong or unrealistic assumptions in my analysis, or what considerations can be added to make the analysis more realistic?

Secondly, if any insulations required, would you please explain how insulation layer would prevent satellite from losing heat to surroundings?

Thanks for your help and any help would be highly appreciated.

RuiqiKe

Over all recommendation

The computation should be done in worst-case the hypothesis of averaging is very strong.

A recommendation is to set up a more realistic model by putting at least 1 thermal node per external surface and 1 thermal node inside the cube (need to evaluate the thermal conduction to the surface)

This type of model can be done with Excel

Verify the hypothesis on the convection because convection will decrease the temperature…

Take into account the net internal power it should help if any

Internal insulation may not be need or not needed we need to have a thermal model in which you compute the internal temperature and then decide how to insulate

Take into account the earth albedo it will help

Qi

**Node i**

**Ti**

**MCi, i, i**

**Node j**

**Tj**

**Node k**

**Tk**



# Earth Albedo

# Earth IR

Solar Flow

Radiation to Space

**Deep Space Node**

**T=2.7K**

**Conduction**

**GLij(Tj-Ti)**

**Radiation**

**GRij(Tj4-Ti4)**

**Conduction**

**GLik(Ti-Tk)**

**Radiation**

**GRik(Tk4-Ti4)**

Verify that the balloon will not modify the environment in term of surface field of view and radiating temperature