Preliminary Design Review
UltraViolet Imaging Telescope (UVIT)

Thermal Control

UVIT-PDR-008- Version 1.0   17-3-2006.

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Abbreviations used:

Astrosat: An Indian Astronomical satellite.
UVIT: Ultra-Violet Imaging Telescope.
MLI: Multi Layer Insulation.
HC: Honeycomb structure.
FUV: Far Ultra Violet.
NUV: Near-Ultra-Violet.
VIS: Visible.
HV Box: High Voltage Unit/box for the detector.

1. Abstract: The Ultra Violet Imaging Telescope (UVIT), is one of the payloads to be launched on board the Astrosat satellite. This document contains the details of the thermal environment required for the telescope to perform optimally. The parameters governing the thermal environment, the heat sources onboard and the end constraints are enumerated.

2. Introduction: The UVIT has optical components and detectors which have to be held within specified tolerances as detailed elsewhere. Changes in the thermal environment might cause a change in the relative positions of the optical components and detectors. The aim of the thermal design is to ensure that the changes are within the tolerable values.

Limits on the temperature variations allowed for UVIT in orbit:

The nominal temperature during the observations should be 20deg C +/- 2deg C. If the temperature deviation is not uniform over the length of the tube, the gradient over the full tube should be less than +/- 5deg C.

3. Sources of heat: The UVIT payload on Astrosat has the following sources of heat in its structure and associated parts.

a. 3 nos. of filter wheel motor – 3.5W each. This is located inside the telescope structure at the focal plane, below the primary mirror.
b. 3 nos. of detector (camera proximity unit/front end electronics) – 1.67W each. This is located inside the telescope structure at the focal plane, below the primary mirror.
c. High voltage supplies for the detectors – 3W each, 3nos. This is located inside the telescope structure at the focal plane, below the primary mirror.
d. Detector electronics box – 65W. This is located inside the satellite body and has only an electrical connection to the telescope structure and no mechanical or thermal connection. A cable length of 5m is allowed between the detector and this box.
e. 3nos. of power supply for filter wheel motors – 1.5W each. This is located inside the bus of the satellite, outside the telescope structure.

In addition to the above, solar irradiance, earth albedo and earthshine will be considered for the altitude and attitude of Astrosat.

4. Heaters for decontamination: Heaters are used in the structure for de-contamination purposes. The list of heaters for de-contamination with their location and ratings are given below. The surfaces are to be heated to 50deg C.

a. Heater for primary mirrors – 20watts each.
b. Heater for secondary mirror – 6watts each.
c. Heater for filter wheels – 15watts each (Only Far Ultra Violet and Near Ultra Violet bands).

The loads will be thermostatically controlled and their operation will also be controllable by command. The heaters will be controlled with an accuracy of +/-1deg C.

5. Thermal analysis: A thermal analysis of the structure for the above mentioned loads and constraints is being conducted using finite element analysis technique to ascertain the structural integrity in addition to the attainment and gradient of ambient temperature and its distribution inside the structure. The attainment and gradient of ambient temperature and its distribution inside the structure is carried out to maintain the position of optical elements and detectors to the specified tolerance.

The thermal analysis is being done by an external agency, M/s. Cades Digitech Pvt. Ltd., Bangalore. The same vendor is also performing the structural analysis of the UVIT. The idea of having the same vendor for the structural and thermal analysis was suggested by the Astrosat Project Monitoring Committee (APMC) and a vendor for the same was selected by a sub-committee consisting of experts from ISAC and IIA.

The software Thermal Desktop has been used for modeling, RADCAD a subset of Thermal Desktop has been used for calculating radiation view factors and SINDA has been used in the thermal analysis using partial differential equations to arrive at transient and steady state temperatures.

6. Details of thermal analysis:

The following gives the specification for the multi-point thermal analysis of the Ultra-Violet Imaging telescope (UVIT) on board Astrosat.

A detailed thermal analysis of all components of the UVIT will be conducted and also the resulting thermal gradients will be determined.

A number of iterations will be tried out, involving various methods of thermal control to meet the required specifications.

1. Temperature of different parts of the UVIT assembly for hot and cold orbits as well as for the sunlit and dark sides of the orbits. The temperature should be estimated for the detector housings, filter wheel units and filters, the telescope tubes and the primary and secondary mirrors. In the case of the telescope tubes, there may be a thermal gradient due to its large length along the optic axis. The temperature at the top end of the telescope tube which houses the secondary mirror unit and near the bottom of the telescope tube which houses the primary mirror unit and at a few intermediate points will be determined. Both circumferential and axial temperature distribution in the cylinder will be computed.

2. The heat input required to maintain the payload at the specified temperature by fixing the thermal nodes at this temperature has to be computed. Temperature

distribution is to be recalculated by modifying the node size to match the heater sizes.

3. Steady state analysis starting from an angle of sun vector making 30 deg w.r.t to roll axis and ending with 180 deg, in steps of 15 deg should be made. The solar load should be multiplied by a factor of 0.66 in order to account the eclipse effect. Transient temperature variations of various elements of the UVIT assembly while in orbit are to be estimated. This should be done as co-latitude of sun vector varies from 30degrees to 180degrees and azimuthal angle varies from 0-360degrees range.

4. A film of aluminized material viz. mylar or formvar or polypropylene may have to be provided for the telescope, especially the upper baffle tube and the focal plane unit, in order to ensure that they do not become too cold. A check shall be made to ascertain whether this is required and if necessary, the specifications of this should be estimated. The temperature for the case when the sun shines directly on this film should be estimated.

5. Heaters for baking various parts, of capacities mentioned, will be provided at specified locations. The surfaces are to be heated to 50deg C. The temperature attained by the corresponding parts has to be ascertained. The loads will be thermostatically controlled and the duty cycle for controlling needs to be evaluated. The loads should be controlled with an accuracy of +/-1deg C.

6. The analysis has to be conducted with and without the insulation planned for thermal control.

7. The baking procedure for the payload will be provided. Vendor has to ascertain the integrity of the structure while undergoing this process.

8. Requirements on thermal stability

Of all the requirements for the payload the most difficult to control is the variation in relative alignment of the two telescopes, as a variation of 1" in this over a typical exposure of 1000 s can lead to an additional blurr of ~ 0.3" rms in the image size (due to a less than perfect correlation between aspects of the two telescope during the period of integration).

Relative alignment of axes of the two telescopes should not drift by more than 0.5 arcsec in any fifteen minutes (a typical period of observing a field in UV) of the orbit; but it can change by thirty arcsec on long time scales subject to a drift rate less than one arcsec per fifteen minutes.

A difference of 5 C in temperature across a diagonal of Invar tube (between primary and secondary mirrors), would give:

i) a lateral shift of 15 microns to the secondary mirror, i.e. a shift of two arcsec in position of the images

ii) a tilt of the secondary mirror by 5", i.e. a shift of 4" in the image; these two effects add, and the net shift in position of the image is ~ 6". }

In order to meet the requirement listed in "a)" above, any VARIABLE diagonal temperature gradients in the Invar tube should have a rate < 0.3deg C/1000s, i.e. a very high degree of stabilty in circular symmetry of temperature is required.

In order to keep the separation between the two mirrors constant to 5 microns, the variation on temperature of the invar tube should be less than 13 C as compared to that PREDICTED on ground and used for PRE-LAUNCH setting. (assuming a thermal coeff. of expansion of 1.6 X 10^-6 for Invar36, and ASSUMING that the thermal compensation introduced NEAR the secondary mirror is effective to 80%), FURTHER any temperature gradients along length (axis) of the invar tube should be such that: average temperature of the tube and temperature of the mount of the secondary mirror DO NOT differ by > 1deg C. ELSE, the temperature compensation would not be effective.

The preferred temperature is 20 C, and the limits on temperature are 10deg C and 30deg C.

The above takes into consideration an aluminium temperature compensator. If the aluminium temperature compensator is not used, the orbital temperature should not vary by more than 2deg C than the temperature predicted on ground.

Boundary conditions.

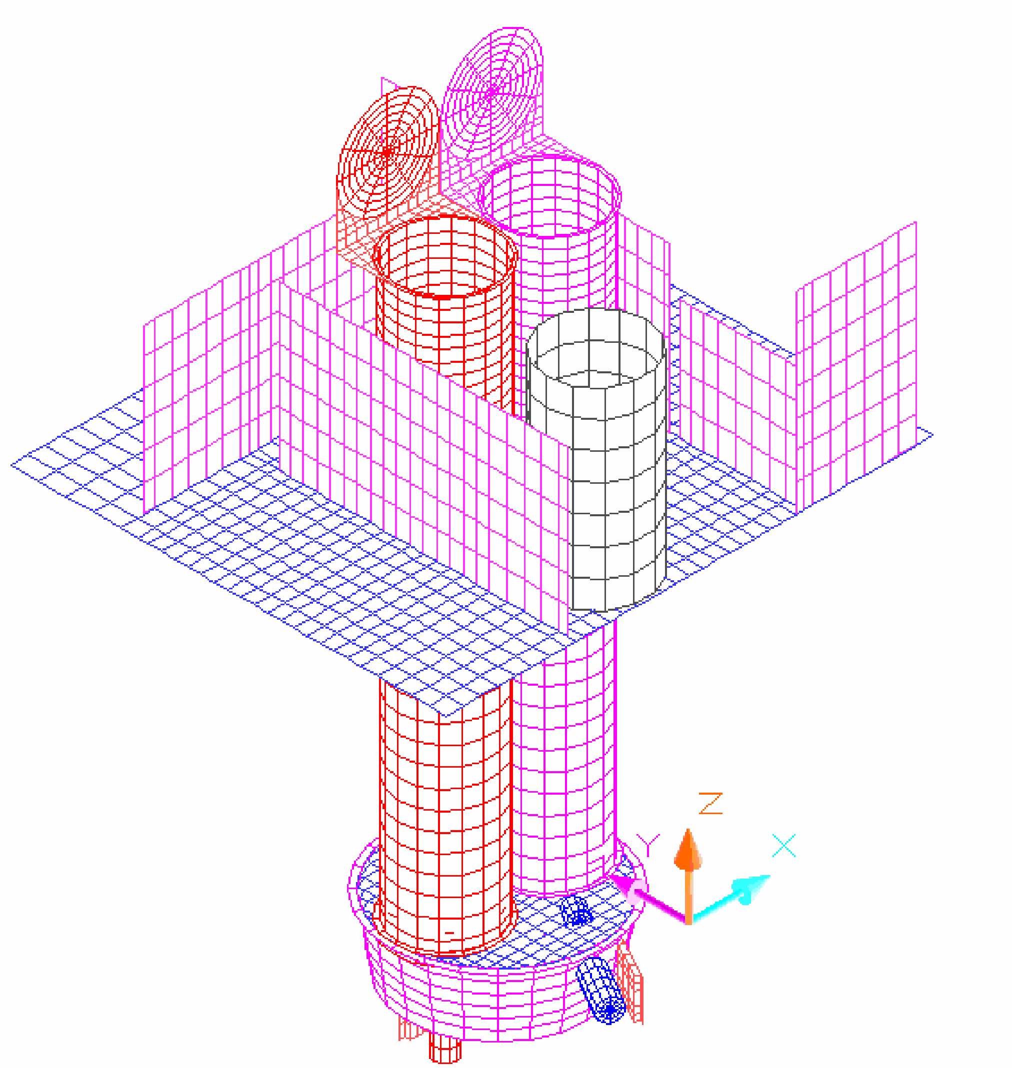
1. Top deck temperature may be assumed as <u>40deg C for hot case and 0 deg C for cold case</u>
2. Cylinder temperature may be assumed as <u>40deg C for hot case and 0 deg C for cold case</u>
3. Hot orbit is defined as 30deg angle of the sun w.r.t. the +ve roll axis.
4. Cold orbit is defined as 90deg angle of the sun w.r.t. the +ve roll axis.
5. Earthshine/albedo loads for the given orbit to be computed.

8. Results and discussion:

Results have been obtained for two sets of analysis conducted.

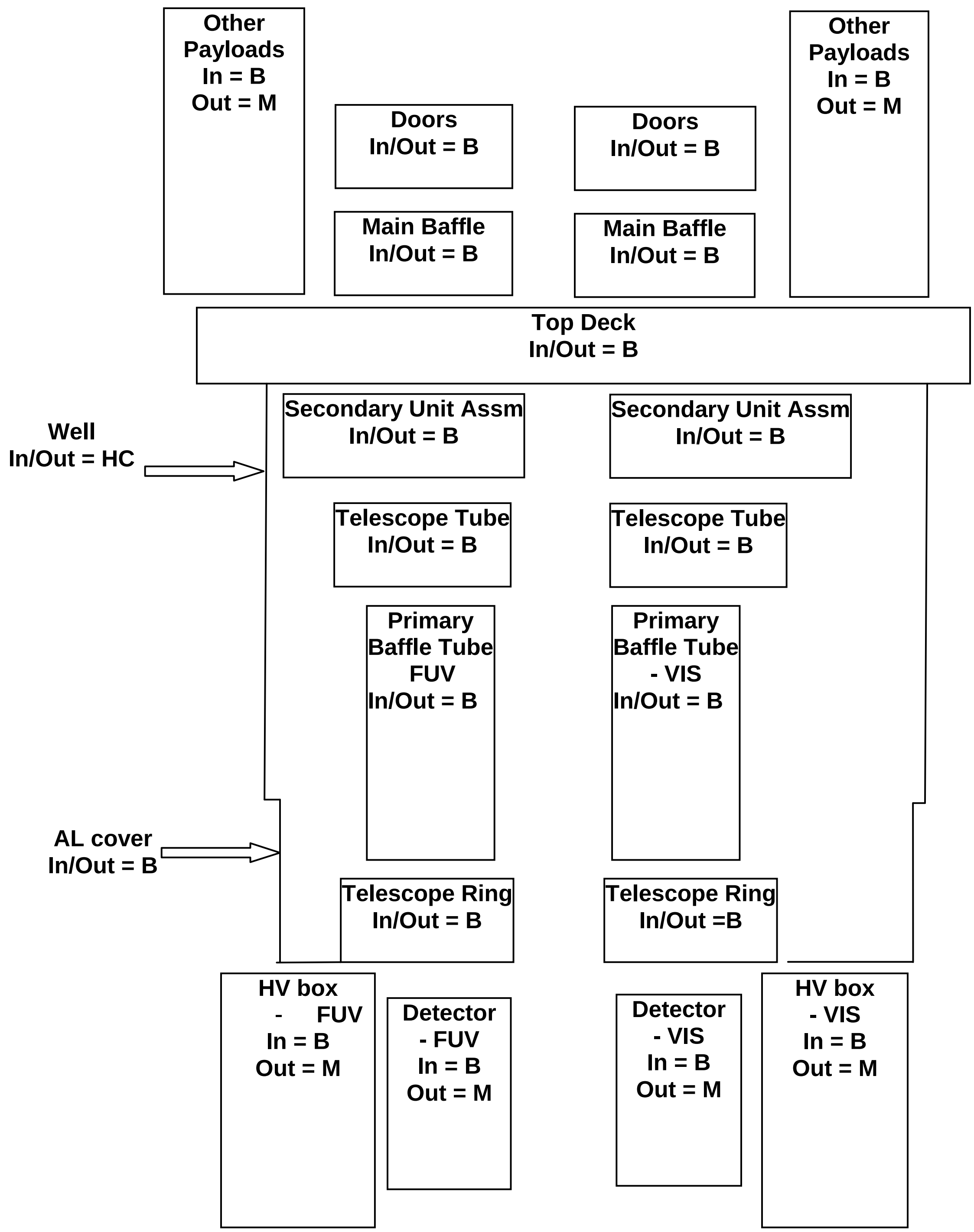
The analysis was conducted as per the guidelines given by Thermal Systems Division, ISAC, Bangalore.

The finite difference model made for the payload is given below.



The details of the surfaces are given in the sketches below.

Sketch showing the details of the surfaces (black anodized etc) of various components.
Black coated components: (both inside and outside)



Note:

1. Primary and Secondary Mirror is made up of Zerodur.
2. Detector – NUV and HV box – NUV is not shown, but both the components are black coated
3. Inside and Outside of the Aluminum compensator is coated with Black Anodized
4. Three Filter motors are coated with Black anodized (both Inside and Outside)

Notations used:
Inside :In
Outside :Out
Black coated :B
MLI :M
Honey-comb : HC

The first set of results of analysis has been done without any insulation. The analysis has been conducted for the winter solistice referred to as the hot case. The satellite temperature has been considered as 40deg C and the angle made to the sun vector by the +ve roll axis of the satellite has been considered as 30degrees.

The results of these analysis are being tabulated in the following table where the temperatures attained by various components upon attainment of the quasi static state are tabulated. This quasi static state was achieved after the fifth orbit. The details of the analysis is given in the report attached in the annexures.

Table 1: Results for Transient State analysis – Winter solstice

Sl. No	***Components***	***Maximum Temperature (deg C)***	***Minimum Temperature (deg C)***
1.	Main Baffle	108.83	8.42
2.	Main Baffle Flange	42.79	20.25
3.	Doors	60.99	11.09
4.	Main Baffle Top Flange	67.0762	6.77
5.	Top Deck	100.952	10.62
6.	Other Payloads	113.895	-64.65
7.	Central Cylinder	79.7608	19.71
8.	Secondary Unit Assembly	29.2456	24.08
9.	Aluminum Compensator	20.2596	--
10.	Telescope Tube/ Ring	20.6517/20.3909	20.53/20.29
11.	Primary Baffle Tube – FUV	24.4445	--

Sl. No	*Components*	*Maximum Temperature (deg C)*	*Minimum Temperature (deg C)*
12.	Primary Baffle Tube – NUV	18.0534	18.00
13.	Primary Baffle Tube – VIS	26.2513	--
14.	Detector – FUV	35.8366	4.87
15.	Detector – NUV	45.778	9.77
16.	Detector – VIS	35.4485	3.57
17.	Filter Motor – FUV	84.9121	--
18.	Filter Motor – NUV	62.8956	--
19.	Filter Motor – VIS	97.1103	--
20.	HV Box – FUV	56.3567	7.42
21.	HV Box – NUV	56.301	5.75
22.	HV Box – VIS	43.1505	0.10
23.	Aluminum Cover	24.0114	-20.63

*A blank in the table (in the minimum temperature column) indicates that there is no change in temperature.

As can be seen, the temperatures attained by some components are out of the acceptable range.

The second report has been conducted with insulations at places suggested by Thermal Systems Division, ISAC, Bangalore.

The results of these analysis are being tabulated in the following table where the temperatures attained by various components upon attainment of the quasi static state are tabulated. This quasi static state was achieved after the twenty first orbit.

Table 2: Results for Transient State analysis – Winter solstice

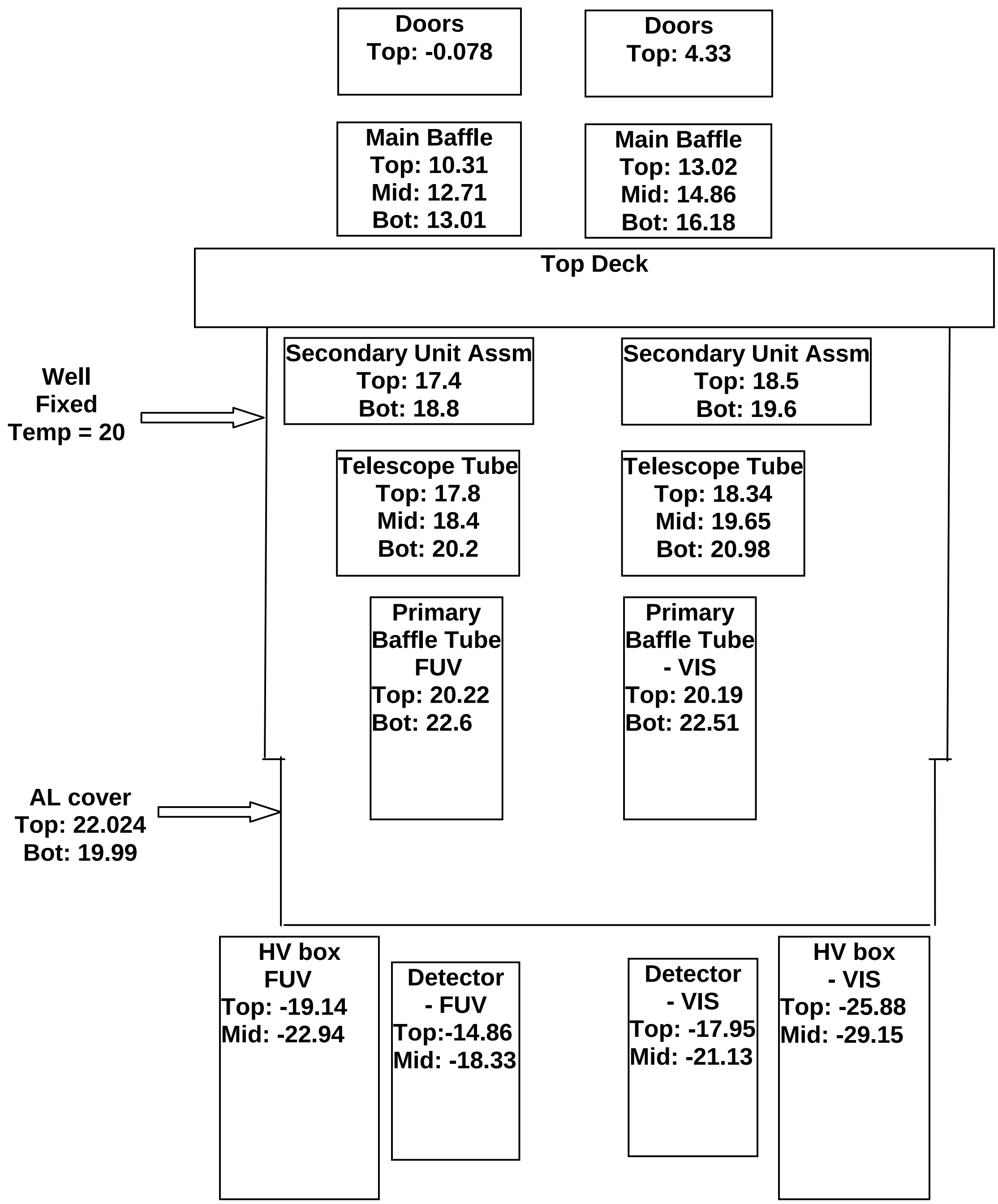
Sl. No	*Components*	*Maximum Temperature (deg C)*	*Minimum Temperature (deg C)*
1.0	Main Baffle	20.81	16.56
2.0	Main Baffle Flange -	19.55	9.48
3.0	Doors	21.84	11.81
4.0	Main Baffle Top Flange	23.93	--

Sl. No	Components	Maximum Temperature (deg C)	Minimum Temperature (deg C)
5.0	Top Deck	58.41	10.38
6.0	Other Payloads	140.82	-46.91
7.0	Central Cylinder	49.80	5.48
8.0	Secondary Unit Assembly	19.93	--
9.0	Aluminum Compensator	19.94	--
10.0	Telescope Tube	21.88	--
11.0	Telescope Ring	21.95	--
12.0	Primary Mirror	20.13	--
13.0	Primary Baffle Tube – FUV	22.88	--
14.0	Primary Baffle Tube – NUV	20.59	--
15.0	Primary Baffle Tube – VIS	23.51	--
16.0	Detector – FUV	3.04	-20.70
17.0	Detector – NUV	38.11	1.14
18.0	Detector – VIS	5.42	-16.63
19.0	Filter Motor – FUV	42.87	--
20.0	Filter Motor – NUV	45.84	--
21.0	Filter Motor – VIS	47.49	--
22.0	HV Box – FUV	48.18	48.00
23.0	HV Box – NUV	11.78	-2.50
24.0	HV Box – VIS	54.03	49.31
25.0	Aluminum Cover	24.00	--

*A blank in the table (in the minimum temperature column) indicates that there is no change in temperature.

As can be seen here also many components are having a temperature outside the acceptable limit.

The following table gives the temperature readings for few components.



Note:
1. Aluminum Compensator 1 and 2 is 19.634 and 19.357
2. Primary Baffle Tube – NUV: Top : 19.93; Bot: 20.01
3. Detector – NUV: Top: -17.30 and HV box – NUV: Top: -24.40
4. All temperatures are in deg C

9. Conclusions and further work:

Some of the details of the joints and configurations at the focal plane volume are not finalized.

It has been planned to run the analysis after working out the details of various joints and interfaces. Various configurations of thermal control materials like multi layer insulation (MLI) and optical solar reflectors (OSR) will be tried out to meet the required specifications.