Critical Design Review (CDR)
Of
ULTRA VIOLET IMAGING TELESCOPE (UVIT)
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Thermal Control

UVIT-CDR-01-006

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Critical Design Review

Ultra-Violet Imaging Telescope (UVIT)

Thermal Control

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1. Introduction:

This report summarises the results obtained from the thermal analysis of the UVIT payload on Astrosat.

2. Specifications:

The thermal control requirements of the Ultra−Violet Imaging Telescope (UVIT) to be launch as a payload on board ASTROSAT are outlined below:

1. The temperature of the telescope tubes is to be in the range of 20±2 °C.
2. The value of 20°C has been estimated from the temperature that can be achieved at the test facility. The value of ±2°C has been derived from the optical tolerances and the corresponding mechanical tolerances.
3. The temperature of components in the focal volume assembly should be 20±5 °C. This has been derived from the optical tolerances and the corresponding mechanical tolerances.
4. The limits of operating temperature allowed for the High Voltage Unit (HVU) is 0 to 30 °C.
5. The limits of operating temperature allowed for the Camera Proximity Unit (CPU or detector) is 0 to 20 °C.
6. Considering the above three requirements, the allowable temperature limits of the focal volume assembly has been fixed as 15 to 20 °C.
7. Circumferential and axial temperature of the telescope tubes should not exceed 5 °C and ±2 °C respectively.
8. Duty cycle requirement should be between 20 % and 65 % for heaters.
9. The temporal change of temperature specified of the telescope tubes is 0.3 °C in 1000 seconds.
10. The filters for the FUV channel has to be maintained at a temperature of ~35 °C to avoid the geo-coronal line.

11. The CPU's have to be maintained at a temperature of 30 ± 5 °C on the launch pad because the launch pad because in view of the behavior of bonded MCP to shock loads in the micro Channel Plate (MCP). This has to be maintained from launch (T) to T+1 hour.

3. Sources of heat.

The UVIT payload on ASTROSAT has the following sources of heat in its structure and associated parts. Heat dissipation is given in Table .

1. 3 nos. of filter wheel motor – 0.5W each. This is located inside the telescope structure at the focal plane, below the primary mirror.
2. 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.
3. High voltage supplies for the detectors – 3.2W each, 3nos. This is located inside the telescope structure at the focal plane, below the primary mirror.
4. Detector electronics box – 65W. This is located inside the satellite body and has only electrical connection to the telescope structure and no mechanical or thermal connection to the payload, but has mechanical and thermal connection to the satellite bus.

In addition to the above, solar irradiance, earth albedo and earthshine has been considered for the altitude and attitude of ASTROSAT.

Table 1. Heat Dissipation of UVIT Components

Sl. no	Component name	Heat dissipation
1.	Filter motor	0.5 W (3 no's)
2.	Detector	1.67 W (3 no's)
3.	High voltage box	3.2 W (3 no's)
Total heat dissipation		16.1 W

Table 2. Comparison of specifications / requirements and results achieved.

Requirements	Achieved values
Temperature of telescope tubes to be between 18deg C and 22deg C	17.5(Minimum) and 22.8(Maximum) in cold invar case
Axial variation of temperature on telescope tubes to be within +/-2deg C	2.3deg C on NUV side in cold focal case and cold invar cases.
Circumferential variation of temperature on telescope tubes to be within 5deg C	2.8deg C in cold focal case.
Temporal variation of temperature at a given point within 1000secs (~15 minutes) (in quasi steady state) to be within 0.3deg C	0.77deg C (TT2 bottom portion in FUV side) in hot focal case (Maximum) and 0.02deg C (TT2 top portion in NUV side) in hot focal case (Minimum)
Temperature of elements in the focal plane volume to be between 15deg C and 20deg C	12.7(Minimum) 20.6(Maximum)
Temperature (during operation) of detectors (CPU's) between 0deg C and 20deg C	16.4(Minimum) 17.9(Maximum)
Temperature (during operation) of High Voltage Units (HVU's) between 0deg C and 30deg C	12.7(Minimum) 18.4(Maximum)
Duty cycle of heaters not to exceed 65%	64% in MB1 in cold invar case.

4. Heater Configuration

Thermal requirement for focal volume assembly is 20±5 °C, and telescope tubes, primary mirror; secondary mirror has to maintain temperature 20±2 °C, detector has to maintain 0 to 20 °C and HV box has to maintain the temperature range 0 to 30 °C. Circumferential and axial temperature of the telescope tubes should not exceed 5 °C and ±2 °C respectively.

Duty cycle requirement should be between 20 % and 65 % for heaters. Heater configuration is finalized based on the thermal requirements of above components and it is given in Table 3. Location of sensor of all UVIT components is given in Table 4.

Table 3. Heater Configurations of UVIT

Sl. No	Component name	Control heaters (W)	Cut−in temperature (°C)	Cut−off temperature (°C)
1.	Main baffle 1	68.75	0	10
2.	Main baffle 2	51.25	18	22
3.	TT1−1	4.5	19	21
4.	TT1−2	5.25	19	21
5.	TT2−1	8.125	19	21
6.	TT2−2	5	19	21
7.	TT3−1	10.5	19	21
8.	TT3−2	2.25	19	21
9.	Primary heater plate	4.5	19	21

Sl. No	Component name	Control heaters (W)	Cut−in temperature (°C)	Cut−off temperature (°C)
10.	Spider ring	7.5	19	21
11.	Bottom ring − Inside	3	19	21
12.	Bottom ring – Outside	4.5	19	21
13.	Focal volume – FUV side	19	16	19
14.	Focal volume – NUV side	11.25	16	19

Total heater power is 205.375 W.

Table 4. Thermistor Location of UVIT Components used in the analysis

Sl. No	Component name	Thermistor location
1.	Main baffle 1 sensor	Middle of cylinder in NUV side
2.	Main baffle 2 sensor	Middle of cylinder in NUV side
3.	TT1−1 sensor	Middle of cylinder in NUV side
4.	TT1−2 sensor	Middle of cylinder in NUV side
5.	TT2−1 sensor	Middle of cylinder in NUV side
6.	TT2−2 sensor	Middle of cylinder in NUV side
7.	TT3−1 sensor	Middle of cylinder in NUV side
8.	TT3−2 sensor	Middle of cylinder in NUV side
9.	Primary heater plate sensor	Top face of primary heater plate in NUV side

Sl. No	Component name	Thermistor location
10.	Spider ring sensor	Inner Ring
11.	Bottom ring sensor – Inside	Inner surface of the ring
12.	Bottom ring sensor – Outside	Outer surface of the ring
13.	Focal volume sensor – FUV side	Near the detector
14.	Focal volume sensor – NUV/VIS side	L bracket

5. Applied Boundary Conditions

The boundary conditions are as follows:

i. Initial temperature of payload components is 20 °C
ii. External space temperature is taken as −269 °C
iii. OSR area is taken as 1600 cm^2, which is placed in the pitch side of thermal cover
iv. Contact conductance is given for all components
v. Defined a radiative enclosure for focal volume assembly, primary and secondary mirror assembly and main baffle assembly
vi. Central cylinder temperature is assumed as 30 °C for hot case and 0 °C for cold cases
vii. Hot orbit is defined as 30deg angle of the sun w.r.t. the '+'ve roll axis.
viii. Cold orbit is defined as 90deg angle of the sun w.r.t. the '+'ve roll axis.

6. De-contamination heaters for the UVIT payload on Astrosat.

The process of de-contamination is carried out during the non-operational mode of the payload. This is to remove any contaminant, which might have been adsorbed by the surface of the components of the payload.

The following components are identified as the crucial surfaces from which contaminants, if any adsorbed, have to be removed.

Primary mirrors.

1. Secondary mirrors
2. Filters in FUV channel
3. Filters in NUV channel.

It is desirable to keep the above surfaces at a temperature of 50deg C for a few days.

After analysis, the following values of heaters are advised for decontamination.

Component	Value of heater
Primary mirrors (Heater fixed on a plate kept below the mirror's non-reflecting face)	-----14 W (Total)
Secondary mirrors (Heater fixed on a plate kept below the mirror's non-reflecting face)	-----14 W (Total)
FUV filters (Heater fixed on the inner portion of the cover of the filter wheel)	-----15 W (Total)
NUV filters (Heater fixed on the inner portion of the cover of the filter wheel)	----15W (Total)

The above heaters may be put in a thermostat loop of 45+/-2 C.

7. Heaters to avoid geocoronal line.

It is required to maintain the filters of the Far Ultra-Violet (FUV) channel at a temperature of 35deg C. This is to avoid the geocoronal line in the spectrum.

Heaters provided on the cover of the FUV filter wheel controlled through a thermostat with settings at 35+/- 2deg C have been modeled and the results obtained are noted below.

Conditions:

1. Power dissipation in focal volume is ON (HVU's, CPU's and filter motors are ON: telescopes in observing mode)
2. All control heaters ON
3. Temperature band of heater for FUV filters is 33 to 37 C
4. Value of heater for FUV filters is 30W

Results and Discussion:

From the above results, it can be seen that the temperature of the FUV filters achieved is around 30 C. With this configuration, the sensitive elements of the telescope are at the upper limit of their temperature specifications. Therefore, it is advised not to increase the temperature of the FUV filters beyond the value obtained.

The inside portion of the FUV filter cover facing the filter wheel should have a heater of capacity 30 W with a thermostat loop of 35+/-2 C.

8. Heaters to maintain CPU at a higher temperature than ambient before and during launch.

It is required to maintain the temperature of the Micro Channel Plate (MCP) in the Camera Proximity Unit (CPU or detector) from launch T to T+1 hour at 30 +/- 5 deg C in view of the behaviour of bonded MCP to shock loads.

A calculation of heater power required to maintain the CPU's at 30 +/-5 deg C at the launch pad was done and a heater of 15W capacity at each CPU (located on the CPU flange) (Total 3 nos. for the 3 CPU's) may be provided with a control loop of 30+/-2deg C to achieve the desired temperature of the CPU at the launch pad.

9. Results and Discussions

A typical Low earth orbit (LEO) system is considered in the present study. An orbit altitude of 700 km has been chosen for the study.

The results of this analysis are being tabulated in the following manner where the temperatures attained by various components upon attainment of the quasi steady state are tabulated. This quasi steady state was achieved after the 30^{th} orbit.

Note: Temperatures are in °C

i. TT1 is the topmost portion of the telescope tube containing the secondary unit.
ii. TT2 is the middle portion of the telescope tube.
iii. TT3 is the bottommost portion of the telescope tube containing the primary mirror assembly
iv. NUV− Near Ultra-Violet
v. FUV− Far Ultra-Violet

10. Temperatures and Duty Cycles: Results and Observations

10.1 Case: Cold Invar

Table 5 shows the maximum and minimum temperatures in 30th orbit at FUV and NUV sides at particular locations. These values have been obtained from the model after loading the results.

Table 5. Minimum and Maximum Temperatures in 30th orbit

Locations	FUV	NUV
A	−3.3/−13.1	−3.6/−14.6
B	8.2/−2.0	7.6/−3.8
C	16.1/9.0	15.1/7.5
D	22.5/18.0	20.8/16.4
E	24.1/19.7	22.1/18.6
F	21.8/19.8	20.4/19.0
G	21.4/20.0	20.1/19.2
H	21.3/19.4	20.5/19.0
I	20.6/18.6	18.96/18.2
J	20.9/19.0	20.0/18.8
K	19.7/18.3	19.4/18.8
L	23.6/18.0	18.5/18.1

Table 6. Temperature Results for Cold Case – Invar

Sl. No	Name	Minimum temperature in the 30th orbit	Maximum temperature in the 30th orbit	Temperature difference in the 30th orbit
		°C	°C	°C
1.	Doors	−34.9	−16	11.6

Sl. No	Name	Minimum temperature in the 30th orbit	Maximum temperature in the 30th orbit	Temperature difference in the 30th orbit
2.	MB1	−15.7	17.1	25.7
3.	MB2	11.5	25.4	13.2
4.	Spider ring	19.1	23.4	3.8
5.	Invar compensator	19.4	21.3	1.6
6.	Secondary baffle	19.7	21.0	1.1
7.	Secondary Mirror	19.8	20.8	1.0
8.	Secondary heater plate	19.7	20.9	1.1
9.	TT−1	18.7	22.8	3.8
10.	TT−2	17.5	22.2	4.1
11.	TT−3	17.5	21.8	3.9
12.	Invar tubes	17.5	22.8	5.1
13.	Bottom ring	11.6	24.2	11.3
14.	Primary Optical seal	14.2	16.1	1.6
15.	Primary heater plate	18.8	19.2	0.4
16.	Primary Mirror	18.8	19.4	0.5
17.	FUV HV box	13.1	18.4	4.7
18.	FUV Detector	16.4	17.9	1.1
19.	FUV Filter motor	17.6	18.3	0.3
20.	FUV filter wheel	16.4	16.5	0
21.	FUV filter wheel glass	16.1	16.1	0
22.	VIS HV box	12.7	18.1	3.7
23.	VIS Detector	14.9	16.5	0.5
24.	VIS Filter motor	17.1	18.1	0.4

Sl. No	Name	Minimum temperature in the 30th orbit	Maximum temperature in the 30th orbit	Temperature difference in the 30th orbit
25.	VIS filter wheel	15.5	15.8	0
26.	VIS filter wheel glass	15.1	15.2	0
27.	NUV HV box	13.2	17.1	3.3
28.	NUV Detector	16.3	17.8	0.8
29.	NUV Filter motor	17.3	18.1	0.4
30.	NUV filter wheel	15.6	15.9	0
31.	NUV filter wheel glass	15.2	15.3	0
32.	All brackets	14.8	20.6	5.7
33.	All filter motors	17.1	18.3	0.4
34.	All detectors	16.4	17.9	1.1
35.	All HV box	12.7	18.4	4.7
36.	All filter wheel covers	13.6	18.2	3.1
37.	Primary baffle tubes	12.9	20.0	6.9
38.	Thermal cover	−12.6	13.0	24.8
39.	OSR Elements	−12.7	6.3	17.1
40.	Focal volume assembly	12.7	20.6	7.8

Observation

From the above results, it can be seen that temperatures obtained from the analysis are within the specified limits.

10.2 Case: Hot Focal

Table 6 shows the maximum and minimum temperatures in 30th orbit at FUV and NUV sides at particular locations. These values have been obtained from the model after loading the results.

Table 6. Minimum and Maximum Temperatures in 30th orbit

Locations	FUV	NUV
A	−4.9/−12.2	−4.2/−12.6
B	6.3/−2.6	7.0/−2.6
C	14.9/7.9	15.3/8.3
D	20.5/16.6	20.8/17.2
E	21.9/18.4	22.3/18.9
F	20.1/18.7	20.5/19.1
G	20.0/18.9	20.4/19.3
H	19.5/18.8	19.8/19.2
I	20.6/18.6	19.6/18.8
J	19.6/19.3	20.0/19.7
K	19.0/18.4	20.1/19.5
L	21.4/17.2	19.8/18.8

Table 7. Temperature Results for Hot Case

Sl. No	Name	Minimum temperature in the 30th orbit	Maximum temperature in the 30th orbit	Temperature difference in the 30th orbit
		°C	°C	°C
1.	Doors	−37.5	−16.8	11.4
2.	MB1	−15.0	16.4	25.9
3.	MB2	11.7	22.8	11.1

Sl. No	Name	Minimum temperature in the 30th orbit	Maximum temperature in the 30th orbit	Temperature difference in the 30th orbit
4.	Spider ring	18.6	21.5	2.0
5.	Invar compensator	18.6	20.3	1.0
6.	Secondary baffle	18.7	20.1	0.6
7.	Secondary Mirror	19.0	19.6	0.5
8.	Secondary heater plate	18.9	19.8	0.6
9.	TT−1	18.2	21.1	2.5
10.	TT−2	17.6	21.4	3.8
11.	TT−3	18.0	20.2	2.0
12.	Invar tubes	17.6	21.4	3.8
13.	Bottom ring	14.3	23.1	8.6
14.	Primary Optical seal	16.5	18.4	1.6
15.	Primary heater plate	18.7	19.5	0.8
16.	Primary Mirror	18.7	19.5	0.8
17.	FUV HV box	15.0	20.0	3.3
18.	FUV Detector	16.7	19.2	0.7
19.	FUV Filter motor	19.3	20.5	0.4
20.	FUV filter wheel	17.3	17.8	0
21.	FUV filter wheel glass	16.8	17.0	0
22.	VIS HV box	16.1	22.2	3.5
23.	VIS Detector	17.6	19.8	0.8
24.	VIS Filter motor	20.2	21.3	0.4
25.	VIS filter wheel	18.4	18.8	0
26.	VIS filter wheel glass	18.0	18.1	0

Sl. No	Name	Minimum temperature in the 30th orbit	Maximum temperature in the 30th orbit	Temperature difference in the 30th orbit
27.	NUV HV box	17.1	20.8	2.4
28.	NUV Detector	19.4	21.8	1.0
29.	NUV Filter motor	21.1	22.2	0.4
30.	NUV filter wheel	19.2	19.6	0
31.	NUV filter wheel glass	18.8	18.9	0
32.	All brackets	15.9	20.6	4.0
33.	All filter motors	19.3	22.2	0.4
34.	All detectors	16.7	21.8	1.0
35.	All HV box	15.0	22.2	3.5
36.	All filter wheel covers	15.3	18.9	2.4
37.	Primary baffle tubes	15.0	19.7	4.0
38.	Thermal cover	−8.8	17.8	23.2
39.	OSR Elements	−8.9	16.7	16.3
40.	Focal volume assembly	15.0	22.2	6.7

Observation

From the above results, it can be seen that temperatures obtained from the analysis are within the specified limits.

10.3 Case: Cold Focal

Table shows the maximum and minimum temperatures in 30th orbit at FUV and NUV sides at particular locations, which is described in the **Error! Reference source not found.**. These values have been obtained from the model after loading the results.

Table 8. Minimum and Maximum Temperatures in 30th orbit

Locations	FUV	NUV
A	−4.1/−13.8	−5.4/−13.3
B	8.1/−3.3	7.4/−3.3
C	16.6/7.0	15.5/6.0
D	22.0/17.7	20.7/16.3
E	23.4/20.0	22.1/19.0
F	21.6/19.8	20.4/19.0
G	21.0/19.5	21.2/19.0
H	20.8/19.2	20.5/19.0
I	19.1/18.4	20.5/18.5
J	20.9/18.9	20.0/18.7
K	20.2/18.5	19.6/18.8
L	20.8/17.0	18.5/17.0

Table 9. Temperature results for Cold Case – Focal

Sl. No	Name	Minimum temperature in the 30th orbit	Maximum temperature in the 30th orbit	Temperature difference in the 30th orbit
		°C	°C	°C

Sl. No	Name	Minimum temperature in the 30th orbit	Maximum temperature in the 30th orbit	Temperature difference in the 30th orbit
1.	Doors	−33.3	−12.1	10.4
2.	MB1	−15.0	16.9	24.7
3.	MB2	9.7	24.6	12.3
4.	Spider ring	18.9	22.7	3.1
5.	Invar compensator	19.2	20.9	1.3
6.	Secondary baffle	19.7	20.7	0.9
7.	Secondary Mirror	19.8	20.6	0.8
8.	Secondary heater plate	19.7	20.6	0.9
9.	TT−1	18.7	22.5	3.6
10.	TT−2	17.5	22.2	4.0
11.	TT−3	17.4	21.7	3.8
12.	Invar tubes	17.4	22.5	4.9
13.	Bottom ring	11.4	23.6	11.5
14.	Primary Optical seal	13.9	15.7	1.7
15.	Primary heater plate	18.8	19.2	0.5
16.	Primary Mirror	18.8	19.4	0.6
17.	FUV HV box	13.0	18.2	4.8
18.	FUV Detector	16.4	17.8	1.1
19.	FUV Filter motor	17.4	18.0	0.3
20.	FUV filter wheel	16.4	16.4	0
21.	FUV filter wheel glass	16.0	16.0	0
22.	VIS HV box	12.9	17.1	3.8
23.	VIS Detector	15.1	16.0	0.4

Sl. No	Name	Minimum temperature in the 30th orbit	Maximum temperature in the 30th orbit	Temperature difference in the 30th orbit
24.	VIS Filter motor	17.0	17.5	0.3
25.	VIS filter wheel	15.4	15.5	0
26.	VIS filter wheel glass	14.9	15.0	0
27.	NUV HV box	13.3	16.8	3.1
28.	NUV Detector	16.3	17.4	0.7
29.	NUV Filter motor	17.1	17.7	0.3
30.	NUV filter wheel	15.4	15.5	0
31.	NUV filter wheel glass	14.9	15.0	0
32.	All brackets	14.8	21.0	5.7
33.	All filter motors	17.0	18.0	0.3
34.	All detectors	15.1	17.8	1.1
35.	All HV box	12.9	18.2	4.8
36.	All filter wheel covers	14.1	18.0	3.1
37.	Primary baffle tubes	12.8	19.9	7.2
38.	Thermal cover	−14.0	11.5	24.7
39.	OSR Elements	−14.1	3.4	17.3
40.	Focal volume assembly	12.9	21.0	7.6

Observation

From the above results, it can be seen that temperatures obtained from the analysis are within the specified limits.

11. Conclusion

1. Heater configuration, which satisfies thermal requirements, is finalized.
2. From the above results, it can be seen that temperatures are within the thermal requirements.
3. Duty cycle is acceptable for hot and cold case.