Thermal Analysis of a Small Satellite in Post-Mission Phase

Ahmed Elhefnawy
Space Technology Center
Cairo, Egypt
a.7efnawy@gmail.com

Ahmed Elweteedy
Military Technical College
Cairo, Egypt
aelweteedy@mtc.edu.eg

***Abstract*— The objective of satellite thermal control is maintaining all satellite components within their operational temperature range for different missions. Most small satellites are designed to have passive thermal control system. In this paper the thermal analysis of a small satellite in post-mission phase is introduced. The European Student Earth Orbiter (ESEO) satellite was chosen in this study. This phase starts at the end of the operational phase and should last at least 2 years for the chosen satellite. A finite difference thermal model using a commercial software "Thermal Desktop" was described for the selected satellite. Model results verification were performed by varying design variables and seeing whether component temperatures increased or decreased as expected. A sample of one component temperature variation on each panel was chosen and introduced to be compared with upper and lower bounds on temperature predictions. The results concluded that all satellite components operate properly within their specified temperature limits.**

Keywords— Thermal control system; Thermal analysis modeling; Modeling tool.

I. INTRODUCTION

The thermal control system on a satellite generally uses two basic approaches for temperature management: passive and active thermal control. Many satellite thermal control systems use a combination of passive and active control, though the passive control methods make up the majority of the system with supplemental active control methods for equipment with small temperature tolerances [1]. Small satellites most commonly employ passive control methods. Passive thermal control techniques include material property selection, controlling the path of heat transfer, and using insulation systems to ensure that temperatures remain within acceptable limits [1].

Studies in small satellite thermal control analysis have been conducted by several researchers. Czernik [2] discussed the thermal control methods for Compass-1 satellite. It is designed for a circular, sun-synchronous Low Earth Orbit (LEO) with an altitude of 600 km and an inclination of 98°. Its mission duration is six months. passive thermal control was used and ANSYS software has been chosen for modelling this spacecraft.

The thermal control system of OUFTI-1 satellite was presented by Jacques [3]. The satellite orbit has a perigee altitude of 354 km, an apogee altitude of 1447 km and an inclination of 71˚. A passive thermal control system was used, with a small electric heater for the battery. Thermal models were developed within both MATLAB/Simulink and ESATAN/ESARAD environments.

Dinh [4] illustrated the modeling of a nanosatellite using Thermal Desktop software. The satellite has a passive thermal control system. It was designed to operate in LEO with altitude of 400 km.

Bulut et al [5] described the thermal control system of Turksat-3U Nanosatellite [6]. The satellite orbit is sun-synchronous orbit with altitude 600 km and inclination 98˚. The satellite has passive thermal control system. The thermal model was built in Therm-XL.

The passive thermal control system of OSIRIS-3U satellite was discussed by Garzon [7]. The satellite orbit has altitude 400 km and inclination 51.6°. A time-dependent finite-element model of the temperature variations of OSIRIS-3U was created in COMSOL Multiphysics using the heat transfer module.

Poucet [8] presented the thermal control system of ESEO satellite. The mission was based on circular sun-synchronous LEO of 520 km in altitude and 97.48° for inclination. Finite difference modeling was completed using ESATAN software package. The satellite has active thermal control system.

Silva et al [9] introduced the thermal control system of Amazonia-1 satellite. The thermal control design was supported by thermal analysis using Thermal desktop software package. The target orbit was sun-synchronous orbit with altitude 752.4 km and an inclination 98.405°. The satellite active thermal control system was based on heaters regulated by software via thermistors.

Appendix A summarizes the university-class missions for small satellites from 70's up to 2017[10], [11]

This paper describes the analysis of the thermal control system for the "ESEO" satellite [8] in one of its mission phases. It has five main phases: launch and early operations phase, operational phase, extended phase, post-mission phase, and satellite disposal. The analysis is focused on post-mission phase. This phase starts at the end of extended phase (if performed) or at the end of the operational phase. A finite difference thermal model using a commercial software "Thermal Desktop" (TD) was described for the selected satellite. Model results verification were performed by varying design variables and seeing whether component temperatures increased or decreased as expected.

II. Satellite Thermal Analysis

ESEO has a cuboid shape with six structural panels and three solar panels of which two are deployable and one fixed. The main dimensions are within a cuboid of 967 × 750 × 680 mm and the total mass of satellite is less than 100 kg. Satellite systems / components are given in Table 1.

To accurately determine the satellite components temperature distribution, a finite difference model of the spacecraft was created. The model was developed by using TD software package. First, the configuration of the spacecraft as geometry, materials, and placement of equipment must be defined. Then, the boundary conditions are completely described. The boundary conditions are comprised of the spacecraft's orbit, attitude, thermal environment, and internal heat dissipation. The temperature requirements of the spacecraft components should be specified.

ESEO orbit leads to thermal environment with solar flux of 1371 W/m^2, albedo 0.3, and earth infra-red of 237 W/m^2 [8]. The total heat dissipation in post-mission phase for all equipment is 155.28 W. Operating temperature limits are usually determined by manufacturer. The structural panels and the internal equipment have range (-20 to +40) and solar panels range (-100 to +100).

The thermal control system includes material property selection, controlling the path of heat transfer, using insulation systems, and radiators. The conductive paths are controlled by using thermal fillers between the panels with thermal conductivity of 1.3 W/m.K [1]. Most of satellite panels were covered with multi- layer insulation. Panels 2 and 5 are used as radiators which have emissivity of 0.88, 0.6 and absorptivity 0.26, 0.14 respectively.

Once the above-mentioned data are inserted in the model, the simulation is utilized to predict the temperatures that the satellite components will experience. The satellite component temperatures results are then compared to the specified limits. For a component whose temperatures do not comply with its limits, alternatives to rectifying the problem may be examined, such as applying different surface coatings or adding insulation to the satellite model. In the following section the model results are presented.

III. Results and Discussion

Fig. 1 through Fig. 8 show the temperature variation for post-mission phase as predicted by TD. The results show that all equipment normally operate within specified limits. In these figures, the temperature responses are repeated every orbit as a periodic. The maximum temperature occurs when the satellite exposed to all three external heat inputs, solar, albedo and earth emission. After that, the satellite enters the eclipse and the temperatures of the entire satellite begins to decrease due to the loss of heat input from the solar and albedo sources. When the satellite exits the eclipse, the temperature starts to raise again.

Fig. 1 shows the transient temperature response for the three solar panel in four orbits. The temperature variation (between maximum and minimum temperature levels) of solar panel +X is 75 °C that is smaller than the variation in temperature experienced by solar panels +Z and -Z, 100 °C. This variation for solar panel +X because of its fixation on structural panel 1 (no incident albedo and earth infra-red on its bottom side). All solar panels operate within their margins (-100 to +100 °C)

The temperatures variation for the six structural panels are depicted in Fig. 2. All panels temperature levels at 25 °C as maximum and 16 °C as minimum temperature. As seen, all panels normally operate within their margins (-40 to +85 °C).

TABLE 1 ESEO SYSTEMS / COMPONENTS

No	Equipment	System
1	AMSAT	Payload
2	Tridimensional Telescope dosimeter (Tri-Tel S)	Payload
3	Telemetry and Telecommand system (TMTC)	Communication system
	Telemetry and Telecommand Antenna (TMTC Antenna)	
4	Micro camera (uCAM)	Payload
5	Langmuir plasma diagnostic probe (LMP)	Payload
6	Electric Power System control unit (EPS PEB)	Electric power system
	Battery	
7	Reaction Wheel	Attitude determination and control system
	Magneto Torquer	
	Gyro	
	Magnetometer	
	Star Tracker	
8	On Board data Handling (OBDH)	On Board data Handling system

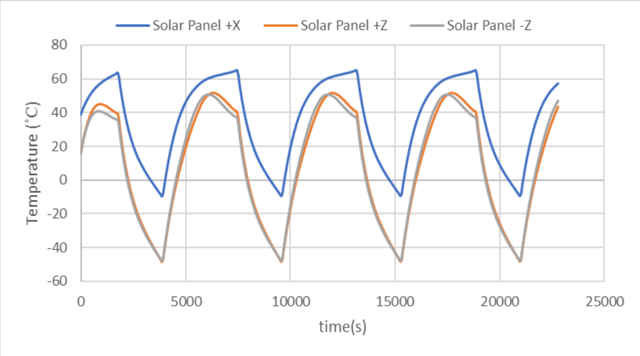

Fig. 1 Solar panels temperature variation for post-mission phase.

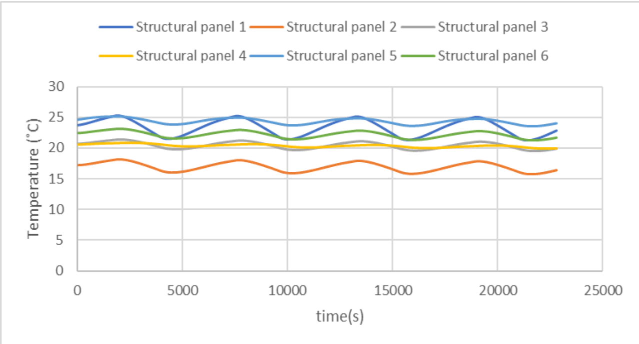

Fig. 2 Structural panels temperature variation for post-mission phase.

Fig. 3 to Fig. 8 present the temperature variation for all satellite components that distributed on the six structural panels. The temperature variation on components agree with their mounted panels.

The battery has the narrowest temperature limits which is considered to be the margin of all internal equipment (-20 to +40 °C). Table 2 summarizes maximum and minimum temperatures results for post-mission phase of all satellite solar panels, structural panels, and internal components compared to the operating temperature limits. As the table shows, the temperature requirements are met, for all the satellite components.

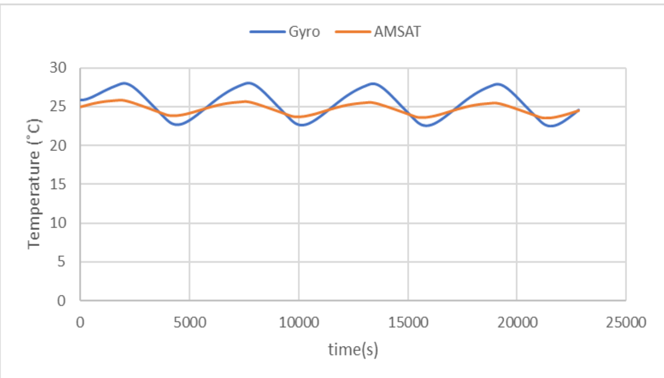

Fig. 3 Temperature variation for equipment on structural panel one in post-mission phase.

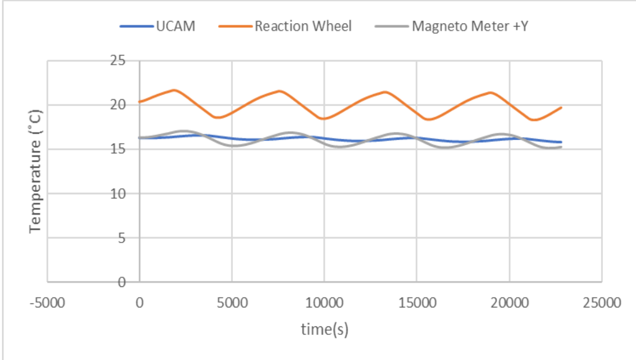

Fig. 4 Temperature variation for equipment on structural panel two in post-mission phase.

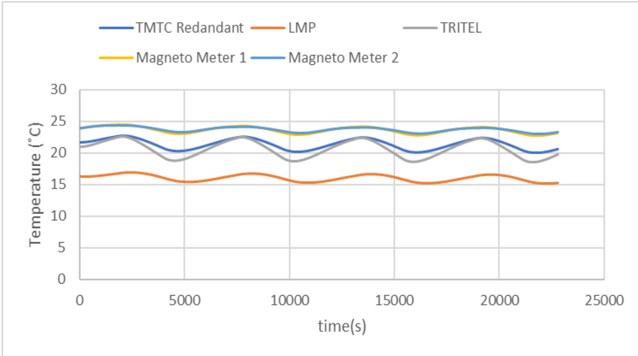

Fig. 5 Temperature variation for equipment on structural panel three in post-mission phase.

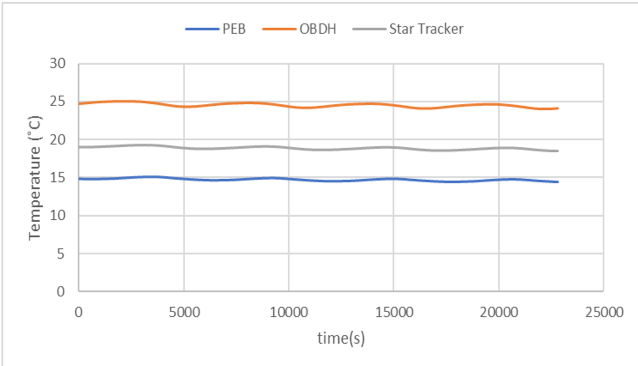

Fig. 6 Temperature variation for equipment on structural panel four in post-mission phase.

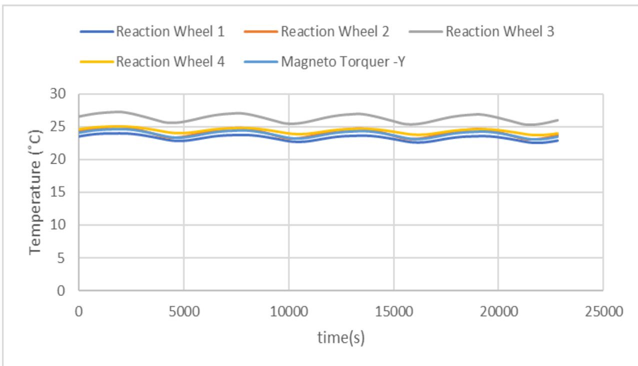

Fig. 7 Temperature variation for equipment on structural panel five in post-mission phase.

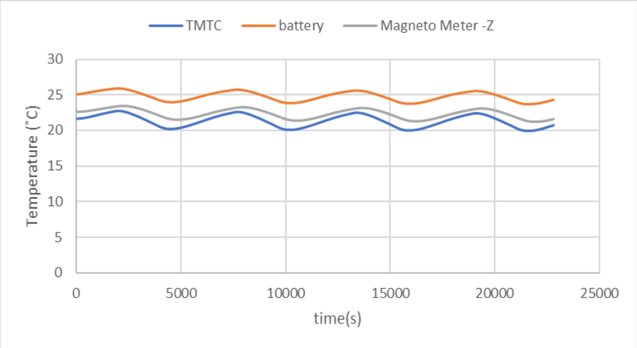

Fig. 8 Temperature variation for equipment on structural panel six in post-mission phase.

TABLE 2 SUMMARY OF RESULTS FOR POST-MISSION PHASE COMPARED TO OPERATING LIMITS.

Component	Maximum Predicted Temperature		Operating Temperature Limit	
	Max	Min	Max	Min
Solar panel +X	65.3	-9.85	-100	+100
Solar Panel +Z	51.55	-48.32	-100	+100
Solar panel -Z	50.84	-47.82	-100	+100
Structural panel 1	25.26	21.21	-40	+85
Structural panel 2	18.18	15.81	-40	+85
Structural panel 3	21.39	19.46	-40	+85
Structural panel 4	20.81	19.96	-40	+85
Structural panel 5	25.23	23.54	-40	+85
Structural panel 6	23.17	21.32	-40	+85
Gyro box	28.04	22.47	-20	+60
AMSAT box	25.79	23.49	-20	+60
uCAM	16.58	15.80	-20	+60
Reaction Wheel +Y	21.67	18.29	-20	+60
Magneto-Torquer +Y	17.06	15.11	-20	+60
TMTC redundant	22.74	20.10	-20	+60
LMP	16.94	15.10	-20	+60
TRITEL S	22.57	18.53	-20	+60
Magnetometer 1	24.47	22.74	-20	+60
Magnetometer 2	24.34	22.93	-20	+60
EPS PEB	15.14	14.41	-20	+60
OBDH	25.04	23.99	-20	+60
Star Tracker	19.33	18.52	-20	+60
Reaction Wheel 1	23.99	22.57	-20	+60
Reaction Wheel 2	25.05	23.00	-20	+60
Reaction Wheel 3	27.22	25.24	-20	+60
Reaction Wheel 4	25.07	23.77	-20	+60
Magneto-Torquer-Y	24.66	23.00	-20	+60
TMTC box	22.73	19.96	-20	+60
EPS Battery	25.93	23.70	-20	+40
Magneto-Torquer -Z	23.39	21.22	-20	+60

IV. RESULTS VERIFICATION

Dealing with mathematical models, verification need to be performed to detect faults. Verification was performed by varying design variables and seeing whether component temperatures increased or decreased as expected [10].

To verify the accuracy of the above results, a sample of one component temperature variation on each panel was chosen to be compared with upper and lower bounds on temperature predictions. In order to define upper and lower bounds on temperature predictions, the parameters used for these cases are chosen such that the resulting thermal loads are as extreme as the satellite will realistically experience during its lifetime. The temperatures reached during post-mission phase on orbit operating conditions should lie between the temperatures reached during these extreme conditions [1].

Fig. 9 to Fig. 14 show the comparative temperature variation for the following components gyro, reaction wheel, Tri-Tel S, OBDH, magneto torquer, and the battery respectively. All of these components' temperatures lie between the temperatures of the extreme operating conditions which verify the TD model.

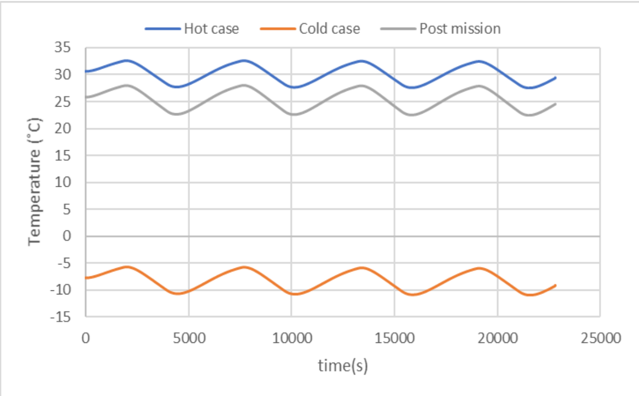

Fig. 9 Temperature variation for gyro in post-mission phase compared with the extreme operating temperatures.

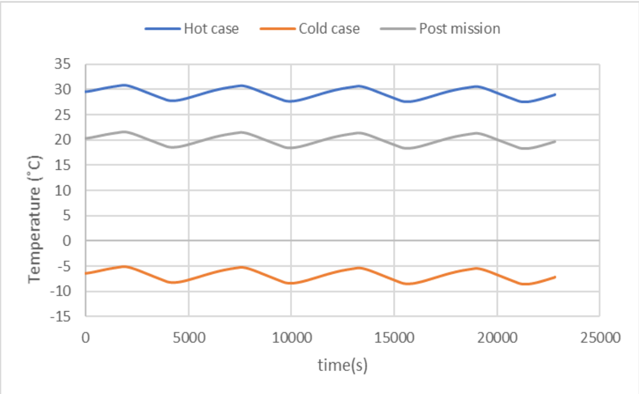

Fig. 10 Temperature variation for reaction wheel in post-mission phase compared with the extreme operating temperature.

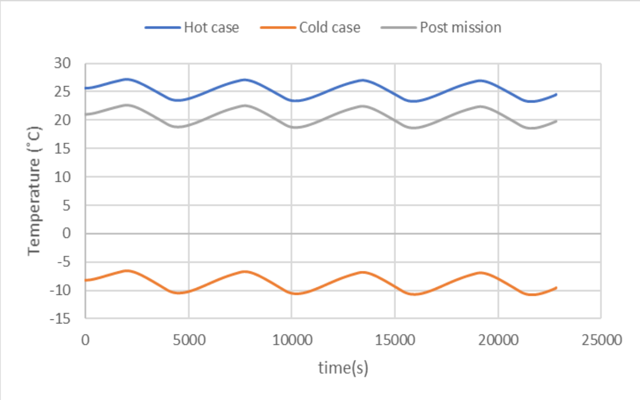

Fig. 11 Temperature variation for Tri-Tel S in post-mission phase compared with the extreme operating temperature.

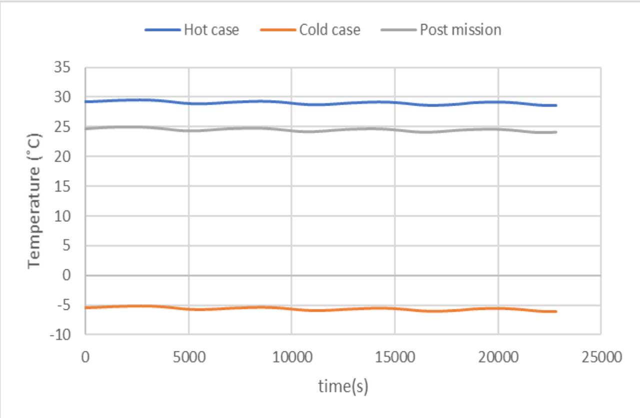

Fig. 12 Temperature variation for OBDH in post-mission phase compared with the extreme operating temperature.

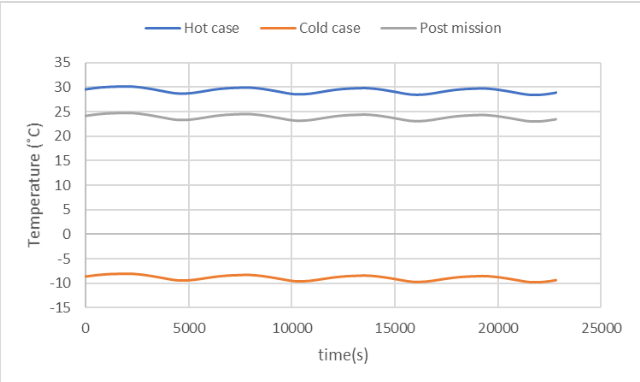

Fig. 13 Temperature variation for Magneto Torquer -Y in post-mission phase compared with the extreme operating temperature.

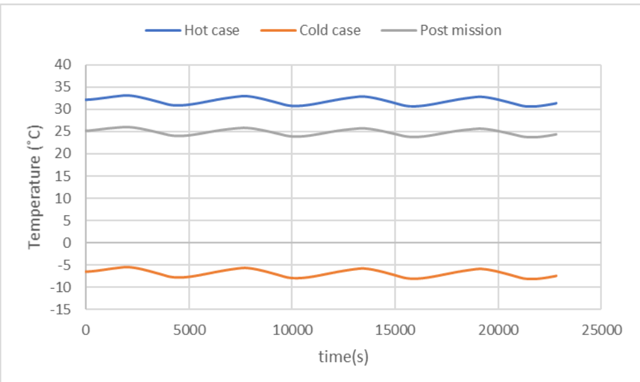

Fig. 14 Temperature variation for battery in post-mission phase compared with the extreme operating temperature.

V. CONCLUSION

The thermal analysis of a small satellite in post-mission phase was presented. A passive thermal control system was used. The satellite internal equipment placement and external radiation exchange were considered to achieve the desired components temperature ranges. The internal conduction and radiation properties were also carefully considered to achieve the temperature limits. Verification was performed by varying design variables and seeing whether component temperatures increased or decreased as expected. The results obtained from simulation show that all satellite components were maintained within their limits.

ACKNOWLEDGMENT

The authors greatly appreciate the assistance of the Space Technology Center and Military Technical College in Egypt for their support.

REFERENCES

[1] K. E. Boushon, “Thermal analysis and control of small satellites in low Earth orbit,” 2018.
[2] S. Czernik, “Design of the Thermal Control System for Compass-1,” University of Applied Sciences Aachen, 2004.
[3] L. Jacques, “Thermal Design of the Oufti-1 nanosatellite,” University of Liège, 2009.
[4] D. Dinh, “Thermal Modeling of Nanosat,” San Jose State University, 2012.
[5] M. Bulut, “Thermal Control of Turksat 3U Nanosatellite,” 2017.
[6] ESA, “TurkSat-3USat.” [Online]. Available: https://directory.eoportal.org/web/eoportal/satellite-missions/t/turksat-3usat.
[7] M. M. Garzon, “Development and Analysis of The Thermal Design For The OSIRIS-3U Cubesat,” The Pennsylvania State University, 2012.
[8] M. J.-L. C. Poucet, “Phase-B Thermal Control Subsytem Design for the ESEO Satellite,” POLITECNICO DI MILANO, 2012.
[9] D. F. da Silva, I. Muraoka, and E. C. Garcia, “Thermal control design conception of the Amazonia-1 satellite,” *J. Aerosp. Technol. Manag.*, vol. 6, no. 2, pp. 169–176, 2014.
[10] M. Swartwout, “Reliving 24 Years in the Next 12 Minutes : A Statistical and Personal History of University-Class Satellites.”
[11] M. Swartwout and C. Jayne, “University-Class Spacecraft by the Numbers : Success , Failure , Debris . (But Mostly Success .).”

APPENDIX A

SUMMARY OF UNIVERSITY-CLASS MISSIONS FOR SMALL SATELLITES

No	Launch date	Mission	University
1	1/23/70	Australis OSCAR 5	University of Melbourne, Australia
2	10/6/81	OSCAR 9 (UoSAT 1)	University of Surrey, UK
3	3/1/84	OSCAR 11 (UoSAT 2)	University of Surrey, UK
4	4/29/85	NUSAT 1	Weber State, USA
5	1/22/90	OSCAR 18 (WEBERSAT)	Weber State, USA
6	7/17/91	TUBSAT A	Technical University of Berlin
7	8/10/92	OSCAR 23 (KITSAT 1)	Korean Advanced Institute of Science and Technology
8	5/12/93	ARASENE	CNES Amateurs, France
9	9/26/93	KITSAT B	Korean Advanced Institute of Science and Technology
10	1/25/94	TUBSAT B	Technical University of Berlin
11	2/3/94	BREMSAT	University of Bremen, Germany
12	3/28/95	UNAMSAT A	National University of Mexico
13	3/28/95	Techsat 1 (Gurwin 1 Oscar (29))	Technion Institute of Technology,
14	9/5/96	UNAMSAT B	National University of Mexico
15	10/5/97	SPUTNIK JR	Russian high school students
16	10/25/97	Falcon Gold	US Air Force Academy
17	10/30/97	TEAMSAT	ESTEC
18	7/7/98	TUBSAT N	Technical University of Berlin
19	7/7/98	TUBSAT N1	Technical University of Berlin
20	7/10/98	TECHSAT 1B	Technion Institute of Technology
21	10/24/98	SEDSAT 1	University of Alabama-Huntsville
22	10/29/98	PAN SAT	Naval Postgraduate School
23	2/23/99	SUNSAT	University of Stellenbosch
24	5/26/99	KITSAT 3	Korean Advanced Institute of Science and Technology
25	5/26/99	TUBSAT-A	Technical University of Berlin
26	1/27/00	JAWSAT	Weber State
27	1/27/00	OPAL	Stanford University
28	1/27/00	FALCONSAT	US Air Force Academy
29	1/27/00	ASUSAT	Arizona State University
30	2/10/00	PICOSAT 3 (JAK)	Santa Clara University
31	2/12/00	PICOSAT 4 (Thelma)	Santa Clara University
32	2/12/00	PICOSAT 5 (Louise)	Santa Clara University
33	6/28/00	TZINGHUA 1	Tsinghua University
34	9/26/00	SAUDISAT 1A	King Abdelaziz City for Science & Technology
35	9/26/00	UNISAT	University of Rome "La Sapienza"
36	9/26/00	SAUDISAT 1B	King Abdelaziz City for Science & Technology
37	11/21/00	MUNIN	Umea University / Lulea University of Technology
38	9/30/01	PCSAT	US Naval Academy
39	9/30/01	SAPPHIRE	Stanford University
40	12/10/01	MAROC TUBSAT	Technical University of Berlin
41	12/20/02	SAUDISAT 1C	King Abdelaziz City for Science & Technology
42	12/20/02	UNISAT 2	University of Rome "La Sapienza"
43	6/30/03	DTUSAT 1	Technical University of Denmark
44	6/30/03	CUTE-1 (cO-55)	Tokyo Institute of Technology
45	6/30/03	QUAKESAT 1	Stanford University
46	6/30/03	AAU CUBESAT 1	Aalborg University
47	6/30/03	CANX-1	UTIAS (University of Toronto)
48	6/30/03	CUBESAT XI-IV (cO-57)	University of Tokyo
49	8/22/03	UNOSAT 1	Universidad Norte do Parana
50	9/27/03	MOZHAYETS 4	Mizanskey Space Engineering Academy
51	9/27/03	KAISTSAT 4 / STSAT-1	Korean Advanced Institute of Science and Technology
52	6/29/04	SAUDICOMSAT 1	King Abdelaziz City for Science & Technology
53	6/29/04	SAUDICOMSAT 2	King Abdelaziz City for Science & Technology
54	6/29/04	SAUDISAT 2	King Abdelaziz City for Science & Technology
55	6/29/04	UNISAT 3	University of Rome "La Sapienza"
56	12/21/04	3CS: Ralphie	New Mexico State University
57	12/21/04	3CS: Sparkie	Arizona State University
58	8/3/05	PCSat 2	US Naval Academy
59	10/27/05	Mozhayets 5	Mizanskey Space Engineering Academy
60	10/27/05	UWE-1	University of Wurzburg
61	10/27/05	SSETI-EXPRESS	ESTEC
62	10/27/05	CUBESAT XI-V (CO-58)	University of Tokyo
63	10/27/05	Ncube 2	Norwegian Universities
64	2/21/06	CUTE 1.7	Tokyo Institute of Technology
65	3/24/06	FalconSat 2	US Air Force Academy
66	7/26/06	SEEDS	Nihon University
67	7/26/06	SACRED	University of Arizona
68	7/26/06	Rincon 1	University of Arizona
69	7/26/06	Ncube 1	Norwegian Universities
70	7/26/06	MEROPE	Montana State University
71	7/26/06	Mea Huaka'l (Voyager)	University of Hawaii
72	7/26/06	KUTE Sat Pathfinder	University of Kansas
73	7/26/06	ION	University of Illinois
74	7/26/06	ICEcube 2	Cornell University
75	7/26/06	ICEcube 1	Cornell University
76	7/26/06	HAUSAT 1	Hankuk Aviation University
77	7/26/06	CP 2	Cal Poly
78	7/26/06	CP 1 (K7RR-Sat)	Cal Poly
79	7/26/06	PicPot	Politecnico di Torino
80	7/26/06	Unisat 4	University of Rome "La

No	Launch date	Mission	University
			Sapienza"
81	7/26/06	Baumanets 1	Bauman Moscow State Technical University
82	9/22/06	HITSAT (HO-59)	Hokkaido Institute of Technology
83	12/10/06	ANDE FCAL SPHERE 2	US Naval Academy
84	12/20/06	RAFT (NO 60)	US Naval Academy
85	12/20/06	MARSCOM	US Naval Academy
86	1/10/07	PEHUENSAT 1	National University of Comahue
87	3/9/07	MIDSTAR 1	US Naval Academy
88	3/9/07	FALCONSAT 3	US Air Force Academy
89	4/17/07	SAUDICOMSAT 7	King Abdulaziz City for Science & Technology
90	4/17/07	SAUDICOMSAT 6	King Abdulaziz City for Science & Technology
91	4/17/07	SAUDICOMSAT 5	King Abdulaziz City for Science & Technology
92	4/17/07	SAUDICOMSAT 3	King Abdulaziz City for Science & Technology
93	4/17/07	SAUDICOMSAT 4	King Abdulaziz City for Science & Technology
94	4/17/07	LIBERTAD 1	University of Sergio Arboleda
95	4/17/07	CP3	Cal Poly
96	4/17/07	CAPE 1	University of Louisiana
97	4/17/07	CP4	Cal Poly
98	9/25/07	YES2/FOTINO	ESTEC
99	9/25/07	YES2/FLOYD	ESTEC
100	4/28/08	CUTE-1.7+APd II	Tokyo Institute of Technology
101	4/28/08	COMPASS 1	Fachhochschule Aachen
102	4/28/08	AAUSAT 2	Aalborg University
103	4/28/08	DELFI C3 (DO-64)	Technical University of Delft
104	4/28/08	CANX 2	UTIAS (University of Toronto)
105	4/28/08	SEEDS 2 (CO-66)	Nihon University
106	1/23/09	PRISM (HITOMI)	University of Tokyo
107	1/23/09	SPRITE-SAT (RISING)	Tohoku University
108	1/23/09	STARS (KUKAI)	Kagawa University
109	1/23/09	KKS-1 (KISEKI)	Tokyo Metropolitan college of Industrial Technology
110	4/20/09	ANUSAT	Anna University
111	5/19/09	CP 6	Cal Poly
112	7/15/09	BEVO 1	University of Texas
113	7/15/09	DRAGONSAT 2 (AggieSat 2)	Texas A&M University
114	9/17/09	UGATUSAT	Ufa State Aviation Technical University
115	9/17/09	SUMBANDILA	University of Stellenbosch
116	9/23/09	SWISSCUBE (Swisscube 1)	Ecole Polytechnique Federale de Lausanne
117	9/23/09	BEESAT	Technical University of Berlin
118	9/23/09	UWE-2	University of Wurzburg
119	9/23/09	ITU-PSAT 1	Istanbul Technical University
120	5/20/10	HAYATO (K-SAT)	Kagoshima University
121	5/20/10	WASEdA-SAT2	Waseda University
122	5/20/10	NEGAI-STAR	Soka University

No	Launch date	Mission	University
		(Negai-Boshi)	
123	5/20/10	UNITEc-1	University Space Engineering consortium
124	7/12/10	STUDSAT	Indian university consortium
125	7/12/10	TISAT 1	Scuola universitaria Della Svizzera italiana
126	11/20/10	RAX 1 (USA 218)	University of Michigan
127	11/20/10	FALCONSAT 5 (USA 221)	US Air Force Academy
128	11/20/10	FAST 1 (USA 222)	University of Texas
129	11/20/10	FAST 2 (USA 228)	University of Texas
130	12/8/10	Mayflower-Caerus	University of Southern California
131	3/4/11	Hermes	Colorado Space Grant consortium
132	3/4/11	KySat 1	Kentucky Space
133	3/4/11	E1P (Explorer 1 Prime)	Montana State University
134	4/20/11	YOUTHSAT	M.V. Lomonosov Moscow state university
135	4/20/11	XSAT	Nanyang Technological University
136	8/17/11	EDUSAT	University of Rome "La Sapienza"
137	10/12/11	JUGNU	Indian Institute of Technology Kanpur
138	10/28/11	DICE 1 (DICE X)	Utah State University
139	10/28/11	DICE 2 (DICE Y)	Utah State University
140	10/28/11	RAX 2	University of Michigan
141	10/28/11	AubieSat1 (AO-71)	Auburn University
142	10/28/11	M-cubed (W/HRBE)	Montana State University
143	10/28/11	HRBE (Explorer-1 PRIME)	University of Michigan
144	11/9/11	TX 1	Nanjing University
145	2/13/12	ALMASAT-1	University of Bologna
146	2/13/12	e-st@r	Politecnico di Torino
147	2/13/12	Goliat	University of Bucharest
148	2/13/12	MaSat 1 (MO-72)	Budapest University of Technology and Economics
149	2/13/12	XaTcobeo	University of Vigo
150	2/13/12	PW-Sat 1	Warsaw University of Technology
151	2/13/12	ROBUSTA	University of Montpellier II
152	2/13/12	Unicubesat-GGS	University of Rome "La Sapienza"
153	5/17/12	HORYU 2	Kyushu Institute of Technology (KIT)
154	9/13/12	CSSWE	University of Colorado LASP
155	9/13/12	CXBN	Kentucky Space
156	9/13/12	CP5	Cal Poly
157	10/4/12	RAIKO	Tohoku University
158	10/4/12	FITSAT-1 (NIWAKA)	Fukuoka Institute of Technology
159	10/4/12	TechEd Sat	San Jose State University
160	10/4/12	F1	FPT Technology Research Institute
161	2/25/13	AAUSAT 3	Aalborg University

No	Launch date	Mission	University
162	2/25/13	STRANd-1	University of Surrey
163	4/19/13	AIST 2	Samara Aerospace University
164	4/19/13	BeeSat 3	Technical University of Berlin
165	4/19/13	SOMP	Technical University of Dresden
166	4/19/13	BeeSat 2	Technical University of Berlin
167	4/26/13	TURKSAT 3USAT	Istanbul Technical University
168	5/7/13	ESTcube-1	University of Tartu
169	9/29/13	CUSat	Cornell University
170	9/29/13	Dande	Colorado Space Grant consortium
171	11/20/13	CAPE 2	University of Louisiana
172	11/20/13	DragonSat	Drexel University
173	11/20/13	KYSat II	Kentucky Space
174	11/20/13	TJSat	Thomas Jefferson High School
175	11/20/13	NPS-SCAT	Naval Postgraduate School
176	11/20/13	COPPER	Saint Louis University
177	11/20/13	Black Knight	US Military Academy
178	11/20/13	SPA-1 Trailblazer	COSMIAC
179	11/20/13	SwampSat	University of Florida
180	11/20/13	Ho'oponopono-2	University of Hawaii
181	11/20/13	ChargerSat	University of Alabama-Huntsville
182	11/20/13	Vermont Lunar	Vermont Technical college
183	11/20/13	TechEdSat-3	San Jose State University
184	11/21/13	ZACUBE 1	Cape Peninsula University of Technology
185	11/21/13	UniSat 5	University of Rome "La Sapienza"
186	11/21/13	delfi-n3Xt	Technical University of Delft
187	11/21/13	Icube 1	Institute of Space Technology Islamabad
188	11/21/13	HumSat-d	University of Vigo
189	11/21/13	$50SAT / BeakerSat 2 / Eagle 2	Kentucky Space
190	11/21/13	BeakerSat 1 / Eagle 1	Kentucky Space
191	11/21/13	VELOX-P 2	Nanyang Technological University
192	11/21/13	First-MOVE	Technical University of Munich
193	11/21/13	PUCP-SAT 1	Pontifical catholic University of Peru
194	11/21/13	QubeScout	University of Maryland Baltimore county
195	11/21/13	HiNcube	Narvik University College
196	11/21/13	UWE 3	University of Wurzburg
197	12/6/13	Pocket-PUCP	Pontifical Catholic University of Peru
198	12/6/13	FIREBIRD 1	Montana State University
199	12/6/13	FIREBIRD 2	Montana State University
200	12/6/13	M-cubed-2	University of Michigan
201	12/6/13	CUNYSat-1	City University of New York
202	12/28/13	AIST 1 (RS-41)	Samara Aerospace University
203	2/27/14	ShindaiSat	Shinsu University
204	2/27/14	IFT 1 (Yui)	University of Tsukuba
205	2/27/14	OPUSAT	Osaka Prefecture University

No	Launch date	Mission	University
		(CosMoz)	
206	2/27/14	TeikyoSat 3	Tokyo University
207	2/27/14	INVADER (CO-77)	Tama Art University
208	2/27/14	KSAT 2 (Hayato 2)	Kagoshima University
209	2/27/14	STARS 2 (Gennai)	Kagawa University
210	2/28/14	UAPSat	Pontifical Catholic University of Peru
211	2/28/14	LitSat 1	Kaunas University of Technology
212	2/28/14	LituanicaSAT 1	Kaunas University of Technology
213	4/18/14	TSAT (TestSat-Lite)	Taylor University
214	4/18/14	ALL-STAR/THEIA	Colorado Space Grant consortium
215	4/18/14	KickSat 1	Cornell University
216	5/24/14	UNIFORM 1	Wakayama University
217	5/24/14	Rising 2	Tohoku University
218	5/24/14	SPROUT	Nihon University
219	6/19/14	Hodoyoshi 4	University of Tokyo
220	6/19/14	UniSat 6	University of Rome "La Sapienza"
221	6/19/14	Hodoyoshi 3	University of Tokyo
222	6/19/14	PACE	National Cheng Kung University
223	6/19/14	DTUSat 2	Technical University of Denmark
224	6/19/14	ANTELSAT	University of the Republic (Uruguay)
225	6/19/14	PolyITAN 1	National Technical University of Ukraine
226	6/19/14	Tigrisat	University of Rome "La Sapienza"
227	6/19/14	BRITE-CA 2 (BRITE-Montreal CanX 3F)	UTIAS (University of Toronto)
228	6/30/14	VELOX PIII	Nanyang Technological University
229	6/30/14	VELOX I-NSAT	Nanyang Technological University
230	8/19/14	Chasqui 1	National University of Engineering
231	10/28/14	RACE	University of Texas
232	11/6/14	ChubuSat 1	Nagoya University Daido University
233	11/6/14	QSAT-EOS	Kyushu University
234	11/6/14	Tsubame	Tokyo Institute of Technology
235	1/31/15	FIREBIRD-IIA	Montana State University
236	1/31/15	FIREBIRD-IIB	Montana State University
237	1/31/15	EXOCUBE (CP10)	Cal Poly
238	3/4/15	TechEdSat 4 (TES 4)	San Jose State University
239	3/4/15	MicroMAS	MIT
240	3/4/15	Lambdasat	Greek Silicon Valley folks
241	5/20/15	USS Langley	US Naval Academy
242	5/20/15	Opticube 1	Cal Poly
243	5/20/15	Opticube 2	Cal Poly
244	5/20/15	Opticube 3	Cal Poly

No	Launch date	Mission	University
245	9/17/15	SERPENS	SERPENS
246	9/17/15	S-CUBE	Tohoku University
247	9/19/15	Zheda Pixing 2A	Zhejiang University
248	9/19/15	Zheda Pixing 2B	Zhejiang University
249	9/19/15	ZJ 2 (Kongjian Shiyan 1) NORAD UNCERTAIN	Tsinghua University
250	9/19/15	Naxing 2	Tsinghua University
251	9/19/15	LilacSat 2 (CAS 3H)	Harbin Institute of Technology
252	9/19/15	Zijing 1 (NORAD UNCERTAIN)	Tsinghua University
253	9/25/15	NJUST 2 (TW 1B)	Nanjing University
254	10/5/15	AAUSAT-5	Aalborg University
255	10/8/15	BisonSat	Salish Kootenai college
256	10/8/15	ARC-1	University of Alaska Fairbanks
257	10/8/15	Propcube Merryweather	Naval Postgraduate School
258	10/8/15	Propcube Flora	Naval Postgraduate School
259	11/3/15	PrintSat	Montana State University
260	11/3/15	Argus	Saint Louis University
261	11/3/15	HiakaSat	University of Hawaii
262	12/6/15	AggieSat 4	Texas A&M University
263	12/6/15	Bevo 2	University of Texas
264	12/6/15	MinXSS	University of Colorado LASP
265	12/6/15	CADRE	University of Michigan
266	12/6/15	STMSat 1	St. Thomas More Cathedral School
267	2/17/16	ChubuSat 2 (Kinshachi 2)	Nagoya University Daido University
268	2/17/16	ChubuSat 3 (Kinshachi 3)	Nagoya University Daido University
269	2/17/16	Horyu 4 (AEGIS)	Kyusyu Institute of Technology (KIT)
270	3/31/16	Tomsk-TPU 120	Tomsk Polytechnic University
271	4/25/16	OUFTI 1	University de Liege
272	4/25/16	e-st@r 2	Politecnico di Torino
273	4/25/16	AAUSAT-4	Aalborg University
274	4/28/16	Aist 2d	Samara Aerospace University
275	4/28/16	SamSat-218/d (Kontakt-Nanosputnik)	Samara Aerospace University
276	6/22/16	SathyabamaSat	Sathyabama University
277	6/22/16	Swayam	College of Engineering Pune
278	6/22/16	BeeSat-4	Technical University of Berlin
279	6/25/16	Aoxiang zhixing	Shaanxi Engineering Laboratory
280	8/15/16	3CAT-2	Universidad Politcnica de Catalunya
281	9/26/16	Pratham	IIT Bombay
282	9/26/16	CanX-7	UTIAS (University of Toronto)
283	11/11/16	Opticube 4	Cal Poly
284	12/9/16	TechEdSat 5	San Jose State University
285	12/9/16	AOBA-VELOX 3	University of Tokyo
286	12/9/16	AOBA-VELOX 3	Nanyang Technological University

No	Launch date	Mission	University
287	12/9/16	STARS C	Kagawa University
288	12/9/16	Yui-2 (ITF-2)	University of Tsukuba
289	12/9/16	Waseda-SAT 3	Waseda University
290	12/9/16	Tancredo 1	Escola Municipal Presidente Tancredo de Almeida Neves
291	12/28/16	BY70-1	CAST
292	1/9/17	Xingyun Shiyan 1	Northwestern Polytechnical University
293	1/9/17	Kaidun 1	Nanjing University of Technology
294	2/15/17	Al-Farabi	Al-Farabi Kazakh National University
295	4/18/17	SOMP-2 (QB50 DE02)	Technical University of Dresden
296	4/18/17	HAVELSAT (QB50 TR02)	Istanbul Technical University
297	4/18/17	QBUS 4 (QB50 US04 Columbia)	Universidad del Turabo
298	4/18/17	KySat 3 (SGSat)	Kentucky Space
299	4/18/17	CXBN 2	Kentucky Space
300	4/18/17	Phoenix (QB50 TW01)	National Cheng Kung University
301	4/18/17	X-Cubesat (QB50 FR01)	Vacuole Polytechnique
302	4/18/17	CSUNSat 1	Cal State Northridge
303	4/18/17	UPSat (QB50 GR02)	University of Patras
304	4/18/17	SpaceCube (QB50 FR05)	Vacuole de Mines
305	4/18/17	Hoopoe (QB50 IL01)	Space Lab Herzliya Science Center
306	4/18/17	UNSW-ECO (QB50 AU02)	University of New South Wales
307	4/18/17	NJUST 1 (QB50 CN03)	Nanjing University of Science and Technology
308	4/18/17	QBUS 1 (QB50 US01 Challenger)	University of Colorado
309	4/18/17	DUTHSat (QB50 GR01)	Democritus University of Thrace
310	4/18/17	LilacSat 1 (QB50 CN02)	Harbin Institute of Technology
311	4/18/17	SNUSAT 1b (QB50 KR03)	Seoul National University
312	4/18/17	QBITO (QB50 ES01)	Universidad Polytechnical de Madrid
313	4/18/17	Aalto 2 (QB50 FI01)	Aalto University
314	4/18/17	SUSat (QB50 AU01)	University of Adelaide
315	4/18/17	I-INSPIRE 2 (QB50 AU03)	University of Sydney
316	4/18/17	SNUSAT 1 (QB50 KR02)	Seoul National University
317	4/18/17	PolyITAN-2-SAU (QB50 UA01)	National Technical University of Ukraine
318	4/18/17	Ex-Alta 1 (QB50 CA03)	University of Alberta
319	4/18/17	Aoxiang 1 (QB50 CN04)	Northwestern Polytechnical University
320	4/18/17	BeEagleSat (QB50 TR01)	Istanbul Technical University
321	4/18/17	QBUS 2 (QB50 U202 Atlantis)	University of Michigan
322	6/23/17	UCLSat (QB50	University College London

No	Launch date	Mission	University
		GB03)	
323	6/23/17	NIUSAT (Keralshree)	Noorul Islam University
324	6/23/17	InflateSail (QB50 GB06)	University of Surrey
325	6/23/17	Aalto 1	Aalto University
326	6/23/17	COMPASS 2	Fachhochschule Aachen
327	6/23/17	Pegasus (QB50 AT03)	Fachhochschule Wiener Neustadt
328	6/23/17	SUCHAI	Universidad de Chile
329	6/23/17	SKCUBE	Slovak Organization for Space Activities
330	6/23/17	Venta 1	Ventspils University
331	6/23/17	ROBUSTA 1B	University of Montpellier II
332	6/23/17	URSA MAIOR (QB50 IT02	University of Rome "La Sapienza"
333	7/14/17	Flying Laptop	University of Stuttgart
334	7/14/17	TechnoSat	Technical University of Berlin
335	7/14/17	Mayak	CosmoMayak
336	7/14/17	Iskra-MAI-85	Moscow Aviation Institute
337	7/14/17	Ecuador-UTE-YuZGU	Southwestern State University
338	6/3/17	Bird B (BRAC Onnesha)	Kyushu Institute of Technology
339	6/3/17	Bird G (GhanaSat 1)	Kyushu Institute of Technology
340	6/3/17	Bird J (Toki)	Kyushu Institute of Technology
341	6/3/17	Bird M (Mazaalai NUMSA	Kyushu Institute of Technology
342	6/3/17	Bird N (EduSat 1)	Kyushu Institute of Technology
343	6/14/17	Tanyusha-YuZGU 1	Southwestern State University
344	6/14/17	Tanyusha-YuZGU 2	Southwestern State University
345	8/14/17	ASTERIA	MIT/SSL
346	8/14/17	OSIRIS-3U	Penn State University
347	11/12/17	TechEdSat-6	San Jose State University
348	11/18/17	Buccaneer-RRM	University of New South Wales
349	11/18/17	EagleSat	Embry-Riddle
350	11/18/17	MakerSat 0	Northwest Nazarene University
351	11/28/17	Baumanets 2	Bauman Moscow State Technical University