First On-Orbit Results from the Tancredo-1 Picosat Mission

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This work describes the launch campaign and the very recent on-orbit results of a space systems re-engineered picosat that uses a tubesat platform named Tancredo 1. This artifact is part of the UbatubaSat project which aims at setting a roadmap for public Brazilian schools. The motivation is to change the reality faced in schools on teaching science which generally achieves moderate results and theirs´ youngsters' low interest to techno-scientific careers. This initiative is being developed since 2010 by the Tancredo de Almeida Neves School in Ubatuba, São Paulo State, Brazil, with technological support from INPE, the National Space Research Institute. Briefly, Tancredo1 is the first picosatellite of the UbatubaSat project and it is compact tube-shaped picosatellite with a mass of less than 0.6 kg based on TubeSat kit from Interorbital Systems (IOS). It was launched in Dec. 9th 2016 towards the Japanese Kibo module of ISS - International Space Station. Once at Kibo, deployment from it was performed in Jan. 16th, 2017 followed final ejection at Jan. 19th, 2017 and ground operations. The picosat carries two payloads: (1) an educational voice recorder and (2) an experimental Langmuir probe from INPE´s Ionosphere research group on Plasma Bubbles. The project has seen encouraging results towards promoting students´ interest in engineering, science and technology, especially in Aerospace Engineering, by the assembly, integration, testing, coding and launch of a picosatellite. This also promotes teamwork among different levels of education because some activities are being developed by basic level, others are planned for secondary technical students and some are even within the scope of INPEs graduate courses. The project has received support for its activities from organizations such as UNESCO, AEB Brazilian Space Agency, GAUSS-Italy, amongst others. The UbatubaSat project team and AMSAT-BR are kindly requesting radio amateurs from around the globe to monitor and report any signals heard from Tancredo-1 which transmits on 437.200 MHz using 1200 bps AFSK AX.25 in submissions preferably on audio, AX.25 KISS files.

***Keywords**: Lightning Detection. Tubesats. Smallsats. Plasma Bubble.*

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1. Introduction

The promotion of STEM (Science, Technology, Engineering and Mathematics) initiatives to foster youngsters' interest towards careers in the techno-scientific fields has been a constant concern for modern societies. In Brazil, efforts for improving the teaching of science in schools have been achieving moderate results according to scores attained in the PISA (Program for International Student Assessment) tests. Therefore, this work presents the Brazilian UbatubaSat Project STEM initiative and the on-orbit results of Tancredo-1, its first picosatellite as well its future steps.

Initiatives like this have been around for almost two decades as pico and nanosatellites were developed in 1999 as cubesats by Bob Twiggs and Jordi Puig-Suari then at Stanford University and California Polytechnic State University - CalPoly respectively [1]. Since then several universities around the world have developed and launched these small satellites for exclusively educational purpose and they worked as educational tools aimed to undergraduates and graduate in the area of space engineering. Microelectronics and its advances have allowed the shipment of an increasing range of scientific payloads and even operational models motivating their proliferation.

This paper summarizes some of the UbatubaSat project and it last achievements being structured as follows. Section 2 presents a short introduction to the UbatubaSat Project. The Tancredo-1 picosat re-engineering and mission description is shown in section 3. The Tancredo-1 launch, first on-orbit results and some failure analysis is discussed in section 4. Finally, the paper concludes itself in section 5.

2. The UbatubaSat Project Summary

In 2010, a group of teachers from the Municipal School Pres. Tancredo de Almeida Neves decided to change the way Science was taught in their school and place the student in contact with real science and technology. Hence they contacted a Mojave CA USA company, named Interorbital (http://www.interorbital.com), which was selling satellite kits and the launch service. Then a cooperation agreement was signed with INPE- Brazilian Institute of Space Research, and the technical support to students began in September 2010.

The Interorbital tubesat kit consists of a descriptive manual, Gerber files for the manufacturing of printed circuit boards. Later on, the kit became unsuitable for the mission requirements and a better version for the Tancredo-1 picosatellite was systems-reengineered by INPE engineer Auro Tikami as part of his Master's case study [2]. The Tancredo-1 project timeline is shown in Figure 2.

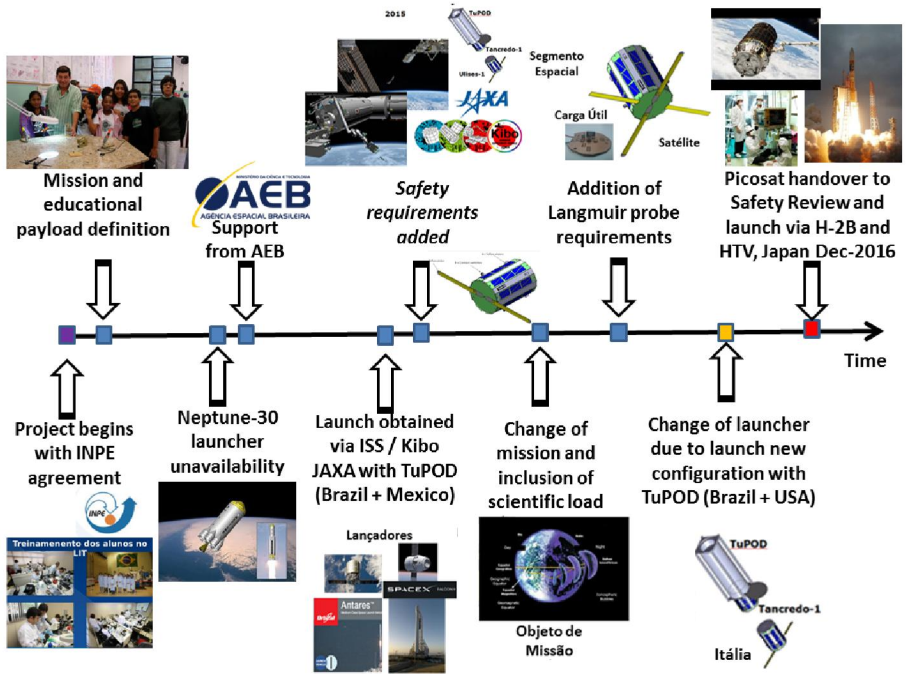

Figure 2 - A timeline of the Tancredo-1 design - Source: Auro Tikami

3. The Picosatellite Launch and On-Orbit Results

Prior to the launch campaign picosat was submitted to the acceptance level tests for workmanship and design/launch verifications and performed environmental stress screening, bake out (outgassing), random and sine vibration and burn-in. The picosat´s battery was also submitted to qualification tests. No radiation test was performed and to mitigate this constraint the picosat was internally coated with kapton, as shown in Figure 3, as well as between solar panels.

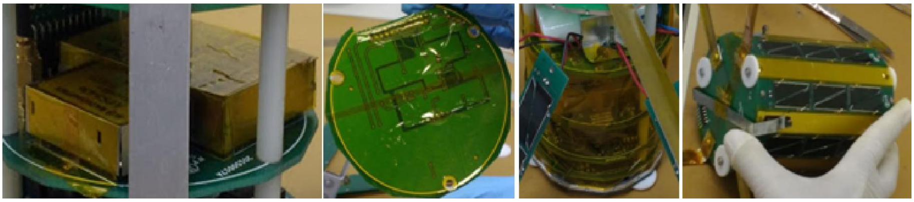

Figure 3 - Tancredo-1 radiation mitigation via kapton.

The TubeSats Tancredo-1 and OSNSat (USA) were both integrated into the TuPOD by October 2016 by GAUSS personnel in Rome, Italy (https://www.gausssteam.com/). The TuPOD is a 3U CubeSat deployer and has the capability to board and release two TubeSats. It was then brought to JAXA (Japan Aerospace Exploration Agency) to be integrated inside the J-SSOD (JEM Small Satellite Orbital Deployer). Then the J_SSOD was installed in the H-IIB Transfer Vehicle (HTV-6). Tancredo-1 inside the TuPOD reached the ISS on-board the HTV-6 cargo ship on December 13th, 2016. The TuPOD was deployed from Kibo on January 16th, 2017 and it released on turn its two TubeSats on January 19th at around 23:30 UTC. Tancredo-1´s (NORAD ID: 41931) first signals (voice and data) were received while flying over Europe by Gauss personnel at around 00:50 UTC on Jan. 20th, see Figure 4.

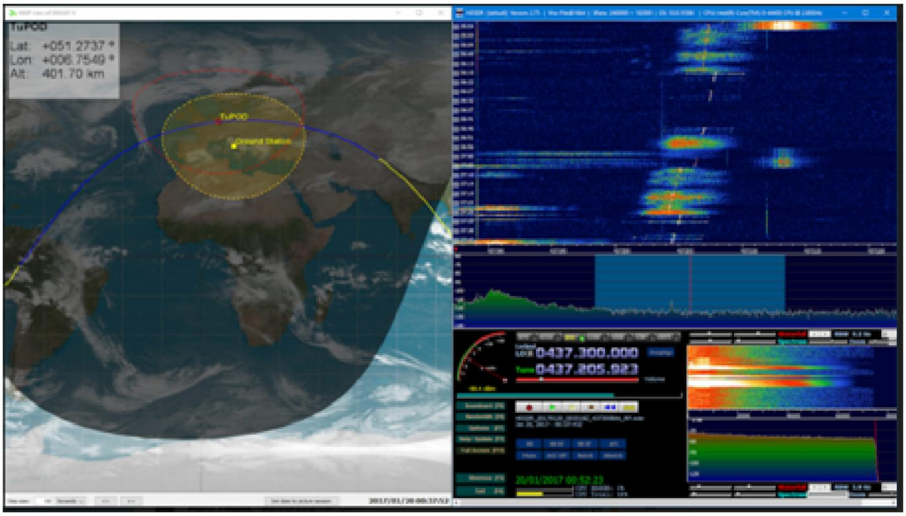

Figure 4 - Tancredo-1 first signal reception over Italy. - Source: Gauss Srl

The radio amateurs around the world also received the Tancredo-1 signals as shown from Figures 5 and 6 sent by the USA and Germany.

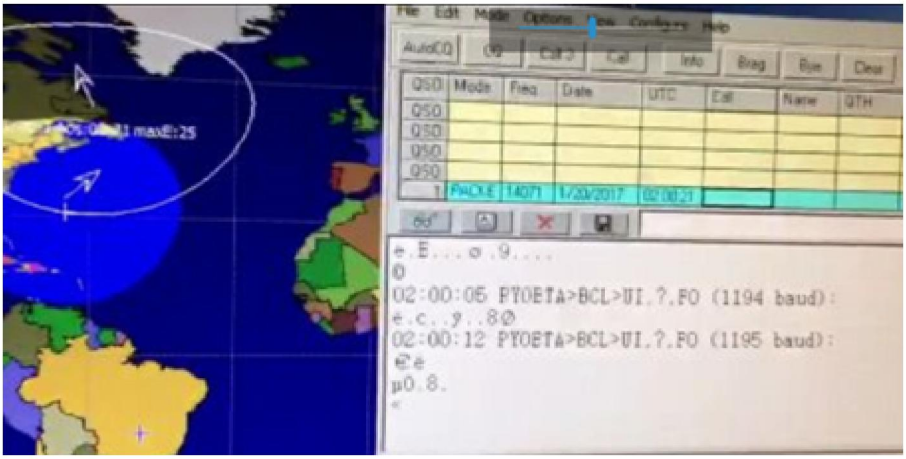

Figure 5 - Tancredo-1 (PY0ETA) copied in USA - Source: Drew Glasbrenner (KO4MA)

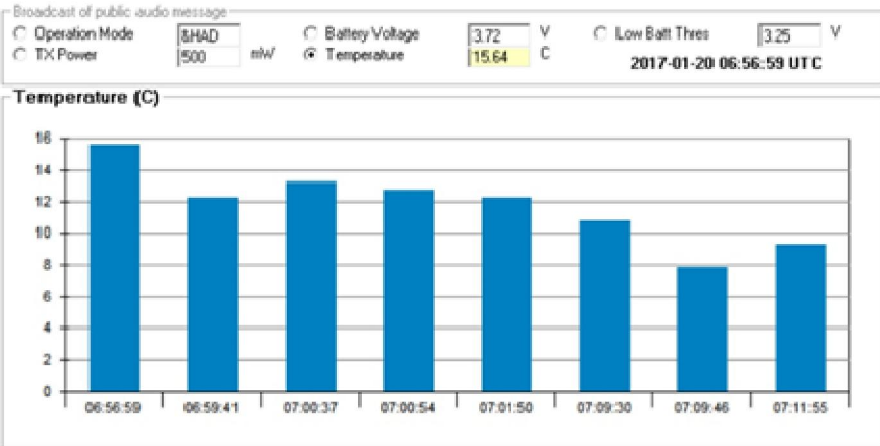

Figure 6 - Tancredo-1 telemetry copied in Germany. **Source**: Mike Rupprecht - DK3WN

All received Tancredo-1 housekeeping and payload data were in the expected normal limits with no problem identification. Samples of telemetry are summarized in Figures 7-9.

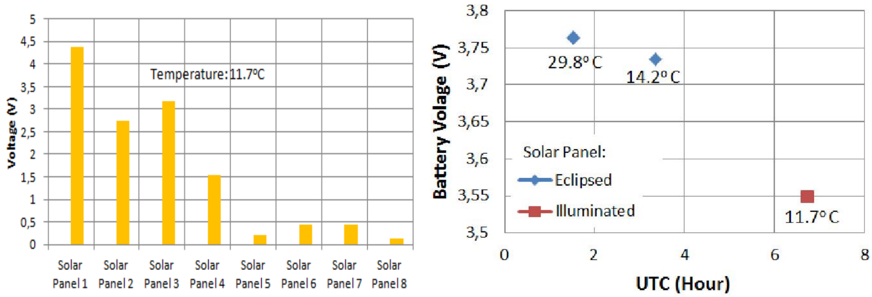

Figure 7 - Solar Panel and Battery Voltage - Source: Drew Glasbrenner (KO4MA)

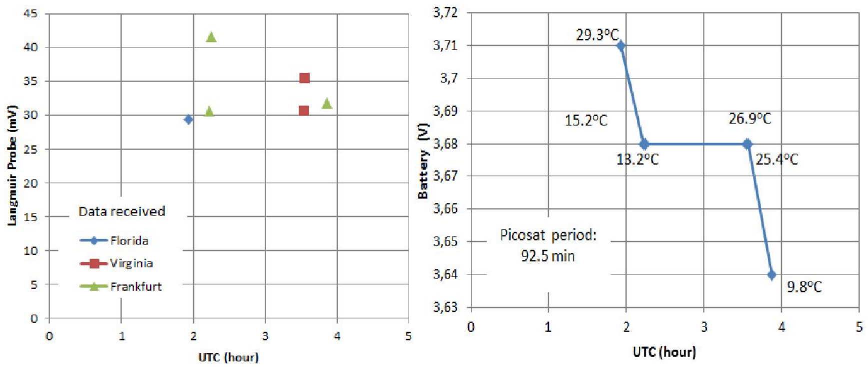

Figure 8 - Langmuir Probe data and Battery Voltage - Source: Drew (FL,USA), Mike (DE), Scott (VA, USA).

The following Tancredo-1 telemetries show it was running in normal mode operation (ARF_CFG=ff and REC_CFG=2) with alternating power transmission every 73s-operation cycle. After some days unfortunately the picosat went silent as shows its failure analysis.

Seq	Hex	Description		
1	eb	header		
2	90	header		
3	0b	frame lenght		
4	63	TC_Window		
5	2	battery lsb	Battery:	3.76 V
6	3	battery msb		
7	ff	ARF_CFG	Operation:	Standard
8	2	REC_CFG		
9	1	cycle_dly	1 s	
10	38	temperature	27.4 °C	
11	d8	check sum		
Sum	0	frame validated		

Seq	Hex	Description		
1	eb	header		
2	90	header		
3	14	frame length		
4	4a	LP24	LP data	
5	17	hour	**OBC Time**	**23:49:56**
6	31	min		
7	38	sec		
8	f2	bat lsb	Bat	3.68 V
9	2	bat msb		
10	37	temperature	Temp	26.9 °C
11	0e	LP1 lsb	LP1	68.4 mV
12	0	LP1 msb		
13	4	LP2 lsb	LP2	19.5 mV
14	0	LP2 msb		
15	2	LP3 lsb	LP3	9.8 mV
16	0	LP3 msb		
17	5	LP4 lsb	LP4	24.4 mV
18	0	LP4 msb		
19	32	power	**Power**	**500 mW**
20	31	check sum		
Sum	0			Frame validated

seq	hex	Description		
1	eb	header		
2	90	header		
3	14	frame length		
4	4a	LP24	LP data	
5	17	hour	**OBC Time**	**23:51:09**
6	33	min		
7	9	sec		
8	f2	bat lsb	Bat	3.68 V
9	2	bat msb		
10	34	temperature	Temp	25.4 °C
11	0f	LP1 lsb	LP1	73.3 mV
12	0	LP1 msb		
13	7	LP2 lsb	LP2	34.2 mV
14	0	LP2 msb		
15	2	LP3 lsb	LP3	9.8 mV
16	0	LP3 msb		
17	5	LP4 lsb	LP4	24.4 mV
18	0	LP4 msb		
19	a	power	**Power**	**100 mW**
20	85	check sum		
Sum	0			Frame validated

Figure 9 - Tancredo-1 telemetries indicating normal mode operation

4. Tancredo-1 Preliminary Failure Analysis

The electronics components in the space are subject to very harsh environmental conditions as very high temperature variations, vacuum, radiation and others. After several passes mainly over South Atlantic Anomaly region (SAA), Tancredo-1 have become inactive and possible root causes are investigated.

The picosat lifetime is expected to last up to 3 months. As all its telemetry and payload signals received show normal operation without details, possible hypotheses for its inactivity shall be further investigated.

Tancredo-1´s power distribution has the following subsystems and payloads: Electrical Power (EPS), Communications (COM), On-Board Computer (OBC), Educational Payload and Scientific Payload. Circuit analysis shows that the DC-DC converter is critical for both subsystems EPS and OBC. Some main characteristics of these subsystems are: COM is controlled by the OBC processor which in high impedance causes the COM to be in reception mode. OBC's DC-DC converter has current surge protection circuit by cutting its output voltage when this occurs.

Considering that EPS is more exposed to the environment there is a high failure probability for the picosat silence in the early operation phase by radiation by Single Event Effect (SEE). Other assumption is the DC-DC converter may have been damaged or data acquisition CMOS integrated circuit may have short circuited and thus cutting off the OBC processor´s power. It's also possible that only Communication subsystem may have been damaged despite of kapton shielding mitigation.

No component qualifies as radiation tolerant. Other less likely assumptions for platform failure such as payloads and power switches damaged by SEE. The lack of more telemetry makes this task challenging. INPE´s formal tracking to this picosat stopped after 3 weeks after orbital ejection which makes it harder to infer true status.

5. Conclusions

This work reported the first on-orbit results from the first UbatubaSat picosatellite named Tancredo-1. The project, since the beginning, was not only aimed at correcting the distortions of science teaching, but going beyond putting the student to develop a real technological scientific project, working with professional researchers.

A group of youngsters took part in the complete picosatellite project life span (assembly, integration, testing, coding, launch and, tracking). The project also got support from various organizations such as UNESCO, AEB Brazilian Space Agency, GAUSS-Italy JAXA-JAMSS and AMSAT. The picosat worked successfully in orbit but went silent after 4 days and its formal monitoring ceased 3 weeks after launch. Results and a preliminary failure analysis were presented

Tracking Tancredo-1 is still available through the N2YO link: http://www.n2yo.com/satellite/?s=41931 and the two-line elements from http://celestrak.com/NORAD/elements/tle-new.txt.

The authors believe in this project the most import asset is what it left on Earth and not so much the picosat that reenters in 90 days or so. This materializes on what it may inspire on other initiatives to improve the quality of the Brazilian educational system in the areas of science, technology and innovation. Furthermore, it may even reach the other end of the Brazilian educational system which covers students in universities and research institutes.

References

[1] Heidt, Hank, et al., *CubeSat: A new Generation of Picosatellite for Education and Industry Low-Cost Space Experimentation*, 14th Annual/USU Conference on Small Satellites, 2000.

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