

## IAA-CU-13-09-02

### **The Brazilian INPE-UFSM NANOSATC-BR CubeSat Program**

Nelson Jorge Schuch \*, Otávio Cupertino Durão \*\*,  
The NANOSATC-BR Team\*\*\*.

The Brazilian INPE-UFSM NANOSATC-BR CubeSat Program is presented. The Program consists of a Capacity Building Integrated Program on space science, engineering and computer sciences for the development of space technologies using CubeSat satellites, starting with a first Brazilian Scientific Nanosatellite, the NANOSATC-BR1. The INPE-UFSM's cooperation is basically between the Southern Regional Space Research Center (CRS), from the Brazilian INPE/MCTI, with the Santa Maria Space Science Laboratory - LACESM/CT-UFSM; the Santa Maria Design House (SMDH); and the Graduate Program in Microelectronics from the Federal University of Rio Grande do Sul - UFRGS. The Capacity Building Program was conceived at the CRS, where acts the Program's General Coordinator and Manager, having technical collaboration and management of the Mission's General Coordinator for Engineering and Space Technology at INPE's Headquarter (HQ), in São José dos Campos, São Paulo, with the involvement of undergraduate students from the Federal University of Santa Maria – UFSM and graduate students from INPE/MCTI, ITA/DCTA/CA-MD and UFRGS. The Program already consisting of two cubesats, NANOSATC-BR 1 and 2 and with the prospective launch of three other cubesats in the next five years and operate them for at least 6 months each. This paper focuses on the development of the NANOSATC-BR1 Project. The NANOSATC-BR2 Mission payload characteristics are described in specific papers at this 2<sup>o</sup> IAA-2013. The NANOSATC-BR1 Project concept was developed to: i) monitor, in real time, the Geospace, the ionosphere, the energetic particle precipitation and the disturbances at the Earth's magnetosphere over the Brazilian Territory, and ii) the determination of their effects on regions such as the South American Magnetic Anomaly (SAMA) and the Brazilian sector of the Equatorial Electrojet (EEJ). The Program has support from The Brazilian Space Agency (AEB).

---

\* Southern Regional Space Research Center – CRS/CCR/INPE – MCTI, in collaboration with the Santa Maria Space Science Laboratory – LACESM/CT – UFSM, Santa Maria, RS, Brasil, <njschuch@gmail.com>.

\*\*National Institute for Space Research – DGE/CEA/INPE – MCTI, São José dos Campos, SP Brasil, <durao@dir.inpe.br>.

\*\*\* Sixty five persons from National Institute for Space Research - INPE, Federal University of Santa Maria - UFSM, Santa Maria Design House - SMDH, Federal University of Rio Grande do Sul - UFRGS, Aeronautic Institute of Technology - ITA.

## I. The Brazilian NANOSATC-BR Team

1 - Nelson Jorge Schuch, 2 - Otávio Santos Cupertino Durão, 3 - Alexandre Álvares Pimenta, 4 - Geilson Loureiro, 5 - Odim Mendes Jr, 6 - Nalin Babulau Trivedi, 7 - Severino Luiz Guimarães Dutra, 8 - Alisson Dal Lago, 9 - Clezio Marcos Denardini, 10 - Ezequiel Echer, 11 - Natanael Rodrigues Gomes, 12 - Renato Machado, 13 - Andrei Piccinini Legg, 14 - João Baptista dos Santos Martins, 15 - Gelson Lauro Dal Forno, 16 - Damaris Kirsch Pinheiro, 17 - Issamu Muraoka, 18 - Adriano Petry, 19 - Nivaor Rodolfo Rigozo, 20 - Antonio Pereira Jr, 21 - Gustavo Fernando Dessbesell, 22 - Ricardo Reis, 23 - Fernanda Gusão de Lima Kastensmidt, 24 - Antonio Claret Palerosi, 25 - Petrônio Noronha de Souza, 26 - Mario Celso de Almeida, 27 - Pawel Rozenfeld, 28 - Valdemir Carrara, 29 - Ijar Milagre da Fonseca, 30 - Roberto Lopes, 31 - Adalberto Coelho Jr, 32 - Lauro Barbosa Alves, 33 - Udaya Jayanthi, 34 - Ângelo Neri, 35 - Rubens Zolar Gehlen Bohrer, 36 - Claudio Machado Paulo, 37 - Fernando Landerdahl Alves, 38 - Lucas Lourencena Caldas Franke, 39 - Mauricio Ricardo Balestrin, 40 - Guilherme Paul Jaenisch, 41 - Iago Camargo da Silveira, 42 - Dimas Irion Alves, 43 - Tális Piovesan, 44 - Andrei Camponogara, 45 - Felipe Correa dos Santos, 46 - Jose Paulo Marchezi, 47 - Tiago Bremm, 48 - Mauricio Rosa de Souza, 49 - Bruno Knevez Hammerschmitt, 50 - Vinicius Deggeroni, 51 - Cassiano Vasconcelos dos Santos, 52 - Lucas Lopes Costa, 53 - Eduardo Escobar Bürger, 54 - Cassio Espindola Antunes, 55 - Tardelli Ronan Coelho Stekel, 56 - Carlos Roberto Braga, 57 - Juliano Moro, 58 - William do Nascimento Guareschi, 59 - Leonardo Zavareze da Costa, 60 - Pietro Fernando Moro, 61 - Anderson Vestena Bilibio, 62 - Andreos Vestena Bilibio, 63 - Rodrigo Passo Marques, 64 - Miguel Rossatto Bohrz, 65 - José Sergio de Almeida.

## II. Introduction

The Brazilian INPE-UFSM NANOSATC-BR CubeSat Program consists of a Capacity Building Integrated Program on space science, engineering and computer sciences for the development of space technologies using CubeSat satellites, starting with a first Brazilian Scientific Nanosatellite, the NANOSATC-BR1. The INPE-UFSM's cooperation is basically between the Southern Regional Space Research Center (CRS), from the Brazilian INPE/MCTI, with the Santa Maria Space Science Laboratory - LACESM/CT-UFSM; the Santa Maria Design House (SMDH); and the Graduate Program in Microelectronics from the Federal University of Rio Grande do Sul - UFRGS. The Capacity Building Program was conceived at the CRS, where acts the Program's General Coordinator and Manager, having technical collaboration and management of the Mission's General Coordinator for Engineering and Space Technology at INPE's Headquarter (HQ), in São José dos Campos, São Paulo, with the involvement of undergraduate students from the Federal University of Santa Maria – UFSM and graduate students from INPE/MCTI, ITA/DCTA/CA-MD and UFRGS.

This paper is a follow up paper from previous ones that have already been presented at International Workshops. It explains the Program institutional arrangement and the technical characteristics of the satellites and their missions.

The Brazilian INPE-UFSM NANOSATC-BR CubeSat Program has support from The Brazilian Space Agency (AEB).

### III. NANOSATC-BR – Capacity Building

The Brazilian INPE-UFSM NANOSATC-BR Cubesat Program, consists of a National Institute for Space Research – INPE and Federal University of Santa Maria – UFSM, Capacity Building Integrated Program on space science, engineering and computing sciences for the development of space technologies through CubeSat satellites, the first Brazilian University Scientific Nanosatellite.

The Capacity Building Program was conceived at the CRS, where acts the NANOSATC-BR1's Mission General Manager and PI, having technical collaboration and management of the Mission's General Coordinator for Engineering and Space Technology at INPE's Headquarter (HQ), in São José dos Campos, São Paulo, with the involvement of High School and Undergraduate students from the Federal University of Santa Maria – UFSM, Figs. 1 and 2,



Fig. 1: The INPE-UFSM's NANOSATC-BR – CubeSats Development Capacity Building Program involvement of High School and Undergraduate students in training at the Integration and Testing Laboratory - LIT/INPE-MCTI, São José dos Campos, SP. From left to right are: Dr. José Sérgio de Almeida, Eng. Andreia Fatima Sorice Genaro, Mauricio Ricardo Balestrin, Guilherme Paul Jaenisch, Leonardo Zavareze da Costa, Dr. Nelson Jorge Schuch, Pietro Fernando Moro - High School, José Paulo Marchezi, Iago Camargo Silveira and Prof. Dr. Geilson Loureiro.



Fig. 2: José P. Marchezi, Undergraduate Physics Student, hands-on training with the NANOSATC-BR1 Project's Engineering Model (EM) at LIT/INPE-MCTI.

and Graduate Masters students, Figs. 3 and 4, from INPE/MCTI, ITA/DCTA/CA-MD and UFRGS. Many reports of these students have been published as well as presentations abroad (Bürger E.E, 2009<sup>[1]</sup>, Costa L.L, 2008<sup>[2]</sup>, Guareschi, W. N.<sup>[3]</sup>) about the Program.

The Capacity Building marks can be noted along the past two years, started in 2006 with just with one undergraduate student, actually, 2013, the project counts on 25 students among High School, Engineering and Physics Undergraduate from UFSM, Fig. (3), Master, Fig. (4) and (6), and Doctorate, students from INPE, ITA and UFRGS, involved directly or indirectly on the Project.

The major objective of the INPE-UFSM's NANOSATC-BR – CubeSats Development Capacity Building Program, through the NANOSATC-BR1 & NANOSATC-BR2 CubeSats Projects, is to perform a Specialized Human Resource Capacity Building Program through the training of UFSM's undergraduate and former students in their respective areas, mainly: Engineering, Computer Sciences and Physics, through Science, Technological & Innovation Initiation at INPE/MCTI.



Fig. 3: The INPE-UFSM's NANOSATC-BR – CubeSats Development Capacity Building Program involvement of former UFSM's students, today INPE/MCTI Master's Graduate Engineers at the INPE's Aerospace Engineering & Space Geophysics Graduate Programs, in training with the NANOSATC-BR1 Project's Engineering Model (EM), at LIT/INPE-MCTI. From left to right are: Eng. Lucas L. Costa, Eng. Tardelli R. C. Stekel, Eng. Eduardo E. Bürger, Dr. Fabiano Luis de Sousa, Dr. Otávio S. C. Durão, Dr. Nelson Jorge Schuch, Prof. Dr. Alexandre A. Pimenta.



Fig. 4: Hands-on training with the NANOSATC-BR1 Project's Engineering Model (EM) at LIT/INPE-MCTI. From left to right are: Prof. Dr. Fernanda Lima Kastensmidt from UFRGS and the INPE's Aerospace Engineering Graduate Student, Eng. Eduardo E. Bürger.

Students have an important weight on the Project's technical and scientific branches due their tasks providing subprojects results for each subsystem. The results are consequence of their hard work made in conjunction basically with the UFSM's and INPE's specialists: engineers, technicians and researchers which are the main providers of information.

On the other hand, the Capacity Building Missions aims to Capacity a new generation of scientists, engineers and researches engineering and computing sciences through a CubeSat Program providing hands-on training, Fig. (2), and learning with Aerospace Technologies, Fig. (4).

Through the NANOSATC-BR Program it was possible to approximate the Brazilian Space Program to Universities, such as: UFSM, UFRGS, Federal University of Rio Grande do Norte - UFRGN and University of São Paulo - USP. Therefore, the Program provides hands-on training and learning with Aerospace Engineering & Technologies and Space Weather issues. This participation includes training of the students at INPE and at the Brazilian space industries as well, as at universities and space industries abroad (TU - Berlin, University of Wuerzburg, Innovative Solutions In Space - ISIS - Delft, see Fig. 5, and at The La Sapienza – Università Degli Studi di Roma, TU-Roma), with funding from the Brazilian Space Agency – AEB and from the new Brazilian Program Science without Borders – SwB.

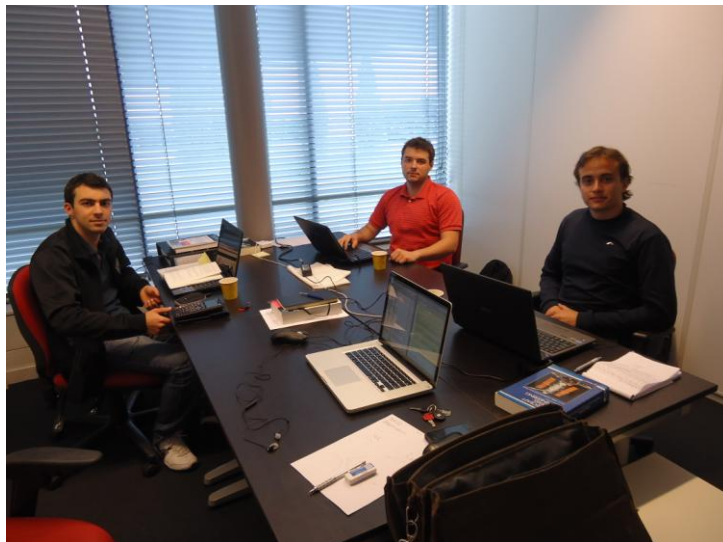


Fig. 5: The INPE-UFSM's NANOSATC-BR – CubeSats Development Capacity Building Program training of undergraduate students at space industry abroad from Brazil. From left to right are: Tális Piovesan, Lucas Lourencena Caldas Franke and Fernando Landerdahl Alves at ISIS-Delft, in The Netherlands, supported with funding from the Brazilian Program Science without Borders – SwB and from ISIS.



## IV. NANOSATC-BR Missions

The Program already consisting of two CubeSats, the NANOSATC-BR1 and NANOSATC-BR2 and of the possibility of launch of three other CubeSats in the next five years and operate them for at least 6 months each. These new missions aim to study and monitor the Geospace and space weather and its relationship with the solar cycle and the Earth's atmosphere. The paper focuses on the development of the NANOSATC-BR1 Project.

The NANOSATC-BR1 Scientific Mission is to monitor, in real time, the Geospace over the Brazilian Territory. In order to accomplish this aim, the payload instruments will be a fluxgate magnetometer, XEN-1210, from Xensor Integration Company, to measure the intensity of the Earth Magnetic Field over the SAMA and the EEJ over the Brazilian sector.

The NANOSATC-BR1 concept was developed to: i) monitor, in real time, the Geospace, the energetic particle precipitation and the disturbances at the Earth's Magnetosphere over the Brazilian Territory, and ii) the determination of their effects on regions such as the SAMA, Fig. (6), and the Brazilian sector of the EEJ, Fig. (7).

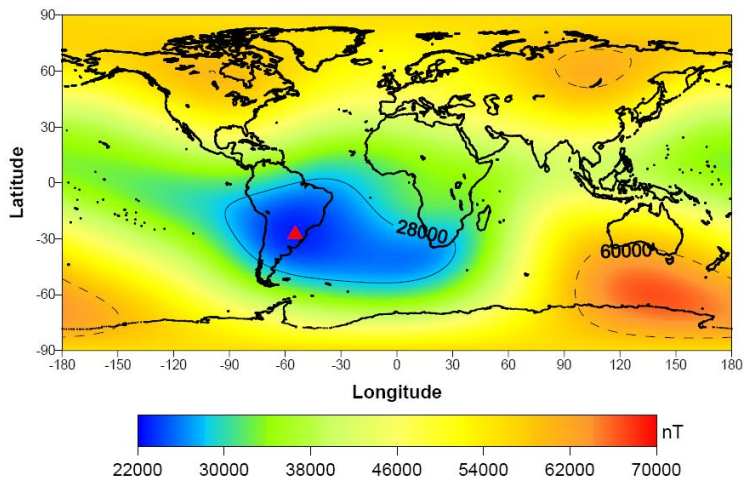


Fig. 6: Magnetic field intensity, year 2000, where the 28000nT isopleths shows the South American Magnetic Anomaly (SAMA) region<sup>[4]</sup>.

The NANOSATC-BR1 Technological Mission is to carry a FPGA and two integrated circuits (IC's) designed by the Santa Maria Design House (SMDH) and the Graduate Program in Microelectronics from the Federal University of Rio Grande do Sul - UFRGS, that were developed for space use due to their radiation resistance that were using different techniques: design and fault tolerance (software).

These are the first circuits designed in Brazil for space applications that will fly in a satellite.

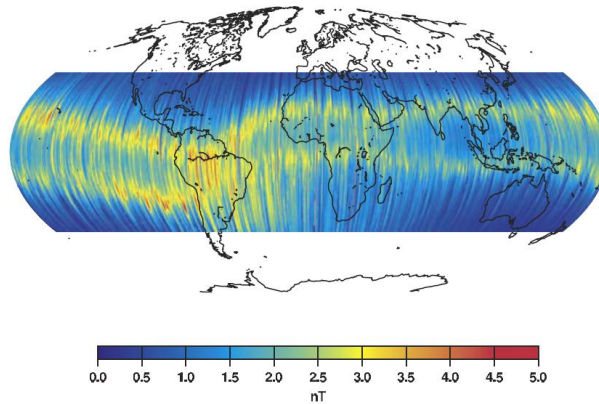


Fig. 7: Ionosphere Equatorial Electrojet (EEJ) representation<sup>[5]</sup>.

## V. NANOSATC-BR1 - Current Situation

The first Brazilian CubeSat satellite, the NANOSATC-BR1, is a 10x10x11.3 cm. cube weighing less than 1.33 kg. It has name and up and down frequencies link determined by The International Amateur Radio Union – IARU, in 2011.

The NANOSATC-BR1's Engineering Model Platform (EM), the Flight Model Platform (FM), the Ground Support Equipment and the Ground Station for the INPE-UFSM's NANOSATC-BR1 mission and equipment were provided, integrated and tested by ISIS.

The NANOSATC-BR1 Project's Engineering Model (EM), Fig. (8), and Flight Model (FM) platforms, to provide the project requirements and support the payload, have already been delivered by ISIS at LIT/INPE-MCTI, in São José dos Campos, SP.

The accommodation of the payloads in the circuit board: Magnetometer, ICs and FPGA, has been solved in cooperation between INPE, ISIS, UFRGS and SMDH-UFSM.

The NANOSATC-BR1's Ground Station (GS) is already installed and in operations at CRS/CCR/INPE-MCTI, Santa Maria, RS, Brazil, Fig. (9).



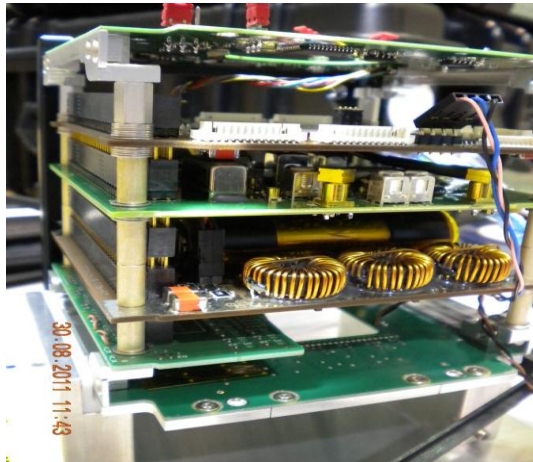


Fig. 8. The CubeSat NANOSATC-BR1 Engineering Model at LIT/INPE-MCTI.

The NANOSATC-BR1 was planned to be launched in the first semester of 2013, probably in April, with the Chinese Long March space vehicle. However, because of the very high Brazilian bureaucracy INPE/MCTI could not conclude and published, in 2012 fiscal year, the international bid to select and contract an international Launcher Company. As consequence, all the official Brazilian bureaucracy should be redone in the first semester of 2013, with a probably launch in the second semester of 2013. Likewise other CubeSat projects, the NANOSATC-BR1 will be launched as a tertiary payload. The launch opportunities as well as the Launch Vehicle are still under discussion.



Fig. 9: The NANOSATC-BR's Ground Station (GS) with VHF/UHF band and S-band antennas at CRS/CCR/INPE-MCTI, in Santa Maria, RS.

## **VI. NANOSATC-BR2 - CURRENT SITUATION**

Through the NANOSATC-BR Program a second nanosat is already being developed by the Partnership INPE-UFSM, it is named NANOSATC-BR2, which is a 2U CubeSat, (10x10x22.6 cm), permitting a more ambitious mission than the NANOSATC-BR1, with three major objectives: academic/capacity building, scientific and technological. The scientific mission is to monitor the Earth's Ionosphere and Magnetic Field. The Ionosphere composition disturbances in the SAMA region over Brazil have severe effects on satellite telecommunications and in the precise location with services such as GPS. The payload equipments for the scientific mission will be a Langmuir probe and a fluxgate magnetometer, XEN-1210. This equipment is available in a larger size and is being miniaturized for CubeSats. The NANOSATC-BR2 platform is being developed to satisfy the payload equipment's requirements.

The NANOSATC-BR2 Project's Engineering Model (EM), and Flight Model (FM) platforms, to provide the project requirements and support the payload, was delivered by ISIS, last month – January 2013, and are at LIT/INPE-MCTI, in São José dos Campos, SP.

The accommodation of the payloads for the CubeSat 2U, in the circuit board of NANOSATC-BR2: Magnetometer, ICs and FPGA, has been solved in cooperation between INPE, ISIS, UFRGS and SMDH-UFSM.

The NANOSATC-BR2's Ground Station (GS) will be installed and operated at Aeronautic Institute of Technology - ITA/DCTA/CA-MD, São José dos Campos, SP, Brazil, in agreement/cooperation signed between INPE/MCTI and ITA/DCTA/CA-MD.

The launch of NANOSATC-BR2 is planned to be launched in the first semester of 2015. Likewise NANOSATC-BR1 and other CubeSat projects, the NANOSATC-BR2 will be launched as a tertiary payload. The launch opportunities as well as the Launch Vehicle are under discussion.

## **VII. Conclusions**

The Brazilian INPE-UFSM NANOSATC-BR Cubesat Program with small satellites, already proved to be an excellent tool for developing a new generation of scientists, engineers and researches engineering and computing sciences with Aerospace Technologies in Brazil, since it is been provided to young Brazilian people contact with low cost and fast developments on Space Technology.

The NANOSATC-BR1 & NANOSATC-BR2 Projects are already contributing in order to aggregate human resource, technology and scientific capability to the

Brazilian institutions, such as UFSM, UFRGS, ITA, USP, SMDH, INPE, involving them directly to the Brazilian Space Program - PNAE.

Additionally, it is also expected an increase in the Brazilian Space Agency support and more investments from the Brazilian Government for the development of Space Technology and for new universities initiatives, in Brazil, such as the Brazilian INPE-UFSM NANOSATC-BR Cubesat Program, with its CubeSats the NANOSATC-BR1 & NANOSATC-BR2 Projects.

## VIII. Acknowledgements

The authors thank to the Brazilian Space Agency - AEB and to USP's LSI-Tec Association for the support, opportunity and grants. Also thank to Dr. Carlos Alberto Gurgel Veras, the AEB's Director of Satellites, Applications and Development and to Dr. Nilton Morimoto, the LSITEC/USP's Administrative Director, for important contribution for the Brazilian INPE-UFSM NANOSATC-BR Cubesat Program, with its CubeSats the NANOSATC-BR1 & NANOSATC-BR2 Projects. The authors thank to Santa Maria Design House - SMDH, to Professors Dr. Ricardo Reis and Dr. Fernanda G. L. Kastensmidt from the Graduate Program in Microelectronics, Informatics Institute from Federal University of Rio Grande do Sul - UFRGS and to the MCTI-CNPq/INPE/PCI-PIBIC-PIBIT and FAPERGS Programs for fellowships. N. J. Schuch acknowledges to Eng. Abe Bonnema and the ISIS's Board of Directors for the grant, tutorial and logistics support at Delft for the students of the Program and to the Brazilian CNPq for grant 313865/2009-4.

## References

- [1] Bürger, E.E et al, "The Launch of the Brazilian INPE/UFSM's Cubesat – The NanosatC-Br Space Weather Mission", Small Satellites Programmes for Sustainable Development Symposium, UN/Austria/ESA, 2009.
- [2] Costa, L. L. et al, "NanosatC-Br – The First Brazilian Cubesat", 59th. IAC, Intl. Astronautical Federation, 2008.
- [3] Guareschi, W. N. et al, "Analysis of Field Programmable Gate Array Alternatives for Use In Nanosatellites", 61th. IAC, Intl. Astronautical Federation, 2010.
- [4] Heirtzler, J. R., "The Future of the South Atlantic Anomaly and implications for radiation damage in space". *Journal of Atmospheric and Solar-Terrestrial Physics*, pp.1701-1708. 2002.
- [5] Lühr, H., S. Maus, & M. Rother, "Noon-time equatorial electrojet: Its spatial features as determined by the CHAMP satellite", *J. Geophys. Res.*, 109, A01306, doi:10.1029/2002JA009656. 2004.