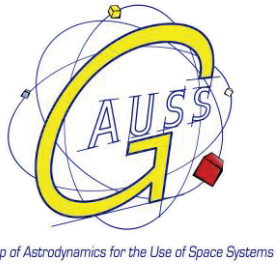
UNIVERSITY SATELLITE MISSIONS AND CUBESAT WORKSHOP 2017

The event is organized by:



Sponsored by:

Front Cover Illustration:

Stylized illustration representing a glimpse of the Ancient Appian Way (*Via Appia Antica*) in Roma, with three CubeSats – main topic of the Conference – heading towards the horizon, symbolizing the future. Copyright © Sarah Luise – GAUSS Srl.

Committees

Scientific Committee

Jean-Michel Contant *(France)*

Mikhail Ovchinnikov *(Russia)*

Filippo Graziani *(Italy)*

Benjamin K. Malphrus *(USA)*

Fernando Aguado Agelet *(Spain)*

Kathleen C. Howell *(USA)*

Piero Galeone *(The Netherlands)*

Anna Guerman *(Portugal)*

Yury Razoumny *(Russia)*

Paolo Teofilatto *(Italy)*

Arun Misra *(Canada)*

David Spencer *(USA)*

Antonio Viviani *(Italy)*

Chantal Cappelletti *(Brazil)*

Local Organizing Committee

Filippo Graziani, *IAA Member, Senior Professor, GAUSS SRL President*

Paolo Teofilatto, *IAA Member, Sapienza University of Rome Professor*

Chantal Cappelletti, *Professor, PhD, IAA Corresponding Member, GAUSS SRL*

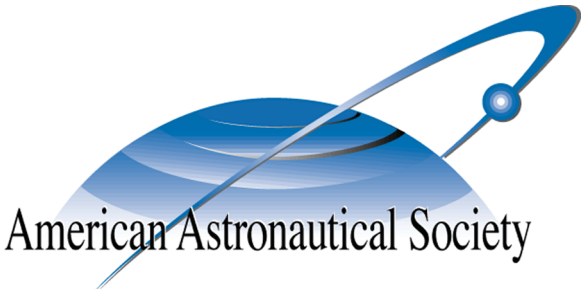
Marta Massimiani, *GAUSS SRL*

Riccardo Di Roberto, *GAUSS SRL*

Sarah Luise, *GAUSS SRL*

Media Coverage

Olga Ovchinnikova



Fourth IAA Conference on UNIVERSITY SATELLITE MISSIONS AND CUBESAT WORKSHOP 2017

Volume 163
ADVANCES IN THE ASTRONAUTICAL SCIENCES

Edited by
Filippo Graziani

Proceedings of the 4th International Academy of Astronautics Conference on University Satellite Missions and CubeSat Workshop held December 4–7, 2017, Rome, Italy.

Published for the American Astronautical Society by
Univelt, Incorporated, P.O. Box 28130, San Diego, California 92198
Web Site: http://www.univelt.com

AAS Publications Office
P.O. Box 28130
San Diego, California 92198

Affiliated with the American Association for the Advancement of Science
Member of the International Astronautical Federation

First Printing 2018

Library of Congress Card No. 57-43769

ISSN 0065-3438

ISBN 978-0-87703-647-0 (Hard Cover Plus CD ROM)
ISBN 978-0-87703-648-7 (Digital Version)

Published for the American Astronautical Society
by Univelt, Incorporated, P.O. Box 28130, San Diego, California 92198
Web Site: http://www.univelt.com

Printed and Bound in the U.S.A.

FOREWORD

I am pleased that the **4th IAA Conference on University Satellite Missions & CubeSat Workshop** (4th–7th December 2017, Roma, Italy) has been a success.

This latest edition has been inspiring for all of us and I believe that it has been a useful experience for the participants, by virtue of the challenging topics and the high level presentations. I hope that all the attendees enjoyed the Conference and the City.

I would like to thank all the entities that supported this event:

First of all, the IAA and Dr. Jean-Michel Contant for his outstanding work as General Secretary of the Academy and for his support to our Conference series.

Thanks to the European Space Agency here represented by Dr. Viyas Gupta and to Dr. Piero Galeone (who was not able to join us).

Thanks to this edition's main sponsors and exhibitors: the European Space Agency, the American Astronautical Society and Univelt Inc., the BCC Bank of Roma, DHV Technology, Astro- und Feinwerktechnik (Adlershof), Surrey Space Centre, Hyperion Technologies, CubeSpace of Stellenbosch University and ISISpace.

Also, I would like to thank all the Lecturers and Speakers who decided to share their works with us: Prof. Guglielmo Aglietti, Prof. Fernando Aguado, Dr. Leon Alkalai, Prof. Mengu Cho, Prof. Anna Guerman, Prof. Benjamin Malphrus, Prof. Arun Misra, Prof. Mikhail Ovchinnikov, Prof. Giuseppe Rega, Prof. Klaus Schilling and Prof. Paolo Teofilatto.

A special thanks to Dr. Vladimir Andreev, Founder of ISC Kosmotras and Dnepr Programme.

This 4th edition of the Conference received over 80 abstracts, coming from about 25 Countries, all to join this durable and international forum. I am proud and honored that so many Nations were represented.

My thanks also to the GAUSS Team, especially to Marta, Sarah and Riccardo for their work as members of the Local Organizing Committee.

The Conference had ten different Sessions, from Launch Opportunities to Space Debris Mitigation, from Missions Overview, Analysis and Design to Payloads, from Subsystems to Attitude Control and New Perspectives.

During the second day we hosted a Special Session in memory of Professor Vladimir Beletsky and then, in the afternoon, we had the first Italian IAA Regional Meeting that included the introduction of the new IAA Academicians and the Gala Dinner. Among the guests: Prof. Amalia Finzi who gave an interesting presentation on Rosetta mission plus the history of astronautics and Prof. Antonio Viviani who chaired the session.

At the end, we had a guided tour at the beautiful *Domus Romane* (ancient Roman houses) of *Palazzo Valentini* in Roma.

I would like to underline the importance of the chosen venue, *Palazzo Pallavicini-Rospigliosi*, built in 1600 by the Cardinal Scipione Borghese and hosting some beautiful frescos, like the Aurora (dawn) by Guido Reni (1614).

In conclusion, my best wishes to all of you to continue profitably studying and working in the fascinating Space field!

We hope to see you at the next edition of the Conference (in a couple of years).

Thank you,

Filippo Graziani
IAA Member,
Senior Professor,
GAUSS Srl President

From the left: Prof. Paolo Teofilatto, Dr. Vladimir Andreev, Dr. Jean-Michel Contant (IAA Secretary General) and Prof. Filippo Graziani.

Group picture at the Conference venue.

CONTENTS

INTRODUCTION
CUBESATS BETWEEN UNIVERSITY AND MARKET

From deforestation of the Amazon river area to space debris, from wildfires in Europe to bacteria on the orbit. These are some of the issues which can be solved with the help of tiny low-cost satellites, the CubeSats. The details of the corresponding projects, as well as the most urgent problems and current trends in CubeSat development were discussed at the 4th IAA Conference on University Satellite Missions held in Rome on December 4–7, 2018.

CubeSats, miniature satellites made of cubic units, were born in the university environment in 1999. In nineteen years they have made quite a voyage, getting visible interest from the industry and governmental organizations. Today over 800 CubeSats are orbiting in LEO and this figure is sure to grow as the CubeSat capability increases and regular launches become available.

As one of the most noticeable trends in space research of the last decade, CubeSats have attracted close attention of the specialists. So, in the 2010s the discussion on the development of miniature spacecrafts has been officially included in the agenda of the International Academy of Astronautics (IAA). Among the key CubeSat-oriented activities sponsored by the IAA there is a series of biannual conferences on university satellite missions organized in Rome by the Group of Astrodynamics for the Use of Space Systems (G.A.U.S.S. Srl), supported by ESA.

Jean-Michel Contant, the IAA's Secretary General, noted that this time the program of the conference reflected the variety of fields which CubeSats are currently involved in: "This is the fourth conference of its series since 2011 and we are witnessing a significant variety of topics covered. CubeSats already have a lot of applications but note the attention towards life science. This is a huge field addressed by the CubeSat community for the first time recently. We are just at the beginning but there is no doubt that CubeSats' low cost and the ability to work in harsh environments will play a great role particularly in this direction."

As the applications are getting more and more diversified, so is the CubeSat community. Filippo Graziani, the founder of the G.A.U.S.S. Company (Sapienza University spin-off specialized in design and realization of microsatellites) commented: "Small satellites bring the big world together. At this conference there are participants from tens of countries, literally from all over the world. For some of them CubeSats are not merely a prominent technology but a real (and sometimes the only) opportunity to have the first national satellite in space. Their own satellite, which will inspire young generations and arise interest in space research and science in general."

Not only CubeSat applications and the professional community are in constant development but also the place of CubeSats in space research. While a few years ago CubeSats were considered mainly as an instrument for 'university science' and merely an educational concept, today they seem to form a young but distinct market. At the conference this could be seen both in the number of spin-offs and other companies which participated in the event along with universities and in the nature of the issues covered. The discussion has become more industry-oriented and the whole process of CubeSat development is gradually getting more conventional and involving the use of COTS components.

CONFERENCE AT A GLANCE

The conference program traditionally revealed the key aspects of CubeSat development, such as spacecraft subsystems and payload design, attitude control problems, as well as PocketQubeSat (ultrasmall CubeSat measuring 2 inches per side) development and general perspectives of CubeSats.

The payload session showed a broad variety of CubeSat applications, from biomedical space research to deep space exploration. Space debris removal appears to be another promising task for the CubeSats. At the same time the problem of disposal of CubeSats itself is becoming more and more pressing, as the LEO environment is getting increasingly cluttered, with some 100 to 150 CubeSats being deployed each year. So this time a specific section of the event was dedicated to space debris mitigation, including post-mission deorbiting of CubeSats.

Whatever the purpose of the flight is, the size of CubeSats forces the developers to deal with a number of technical limitations. So the problems of navigation and subsystem design come into the picture. In addition, the tasks like asteroid missions or debris removal usually require formation flying, and in these kinds of missions guidance and attitude motion become a real challenge. Hence, a separate technical session covered some of the current issues of attitude control.

The sessions were alternated with invited lectures dedicated both to the history and future perspectives of miniature spacecraft development.

During the IAA Regional Meeting, Amalia Finzi, one of the legends of the Italian space research and participant of the Rosetta mission, made a vivid historical overview of comet research and revealed some details of the by now legendary flight to the 67P/Churyumov-Gerasimenko comet.

The plunge in the history of space research continued at the memorial session dedicated to one of the Soviet patriarchs of space flight dynamics research, Vladimir Beletsky. At the session, his colleagues from Russia and Italy shared lively memories on the outstanding researcher. Distinguished for his contribution to the study of celestial body motion about the center of mass which included breakthrough studies on tidal forces, resonant rotation and tether system dynamics, Prof. Beletsky was a pioneer in satellite attitude motion determination with sensor measurement processing. The speakers also commemorated him as a gifted science popularizer and essay writer.

The pace of the conference had been set by an inspiring talk of Leon Alkalai, a NASA Jet Propulsion Laboratory Fellow. He presented an overview of NASA's small satellite

missions and general input of CubeSats and SmallSats in space innovation and the exploration of space beyond LEO.

Special attention of the participants was attracted to the 'CubeSat strategy' of the JPL, one of the key players in breakthrough space research. Dr. Alkalai confessed that while the initial attitude towards CubeSats was quite skeptical, now NASA recognizes CubeSats as a 'disruptive innovation vehicle' which 'also increases the pace of scientific discovery and technology maturation within a constrained budget environment.' CubeSats may also be a stepping stone to more capable small satellite missions in all science areas. In addition, the CubeSats' traditional 'educational' role comes into play: "We see CubeSats as a great opportunity to work with academia, interns, international community, high-schools, public outreach. They also help to train the next generations of explorers," Dr. Alkalai said.

In his overview of the CubeSat missions currently supported by the JPL Dr. Alkalai presented Mars Cube One (MarCO), the first interplanetary CubeSat mission, Firebird (a mission aimed at exploring the physics of relativistic electron microbursts), the ASTERIA (an arcsecond space telescope technology intended for enabling the search for Earth-like planets) and others.

These missions also appeared in the talk given by Benjamin Malphrus, Executive Director of the Space Center at Morehead State University (USA). He introduced a new era of planetary exploration with small satellite platforms and described a number of challenges faced by interplanetary CubeSats today.

As conventional spacecraft design approaches are often not applicable to miniature satellites, the engineers encounter a number of unique issues for development. They are related to a wide range of aspects such as power, telecom, attitude and orbit control, autonomy, lifetime and environment conditions. In particular, CubeSats have constrained resources and because of limited space frame and radiating surface they have difficulties with thermal management. There are also few COTS radiation-tolerant components or subsystems applicable for CubeSats.

In the talk Dr. Malphrus proposed some potential solutions for these problems and his conclusion was quite optimistic: "CubeSats are designed by outstanding teams, using innovative technologies and may offer a new paradigm for Solar system exploration."

According to the organizers, the next IAA Conference on University Satellite Missions is expected in 2019.

By Olga Ovchinnikova

LAUNCH

IAA-AAS-CU-17-01-01
AAS 17-935

AVIONICS AND LAUNCH OPPORTUNITIES FOR AN EUROPEAN MICROLAUNCHER

E. Di Sotto, M. Melara, C. Dominguez, F. Pace, L. Cercos, V. Barrena, G. Novelli, T. Milhano, L. Herrador,[*] R. Torres and R. Verdú[†]

European operational launchers and current launchers under development in Europe (ARIANE 6 and VEGA C) will guarantee independent access to space for the high-end satellite market. These launchers are, however, less focused towards small and micro satellites classes services, especially in terms of offering a dedicated launch service within affordable price. In order to foster the dynamic growth observed since 2013 and up to 2016 in the small satellite domain, the market will need to provide more launch opportunities and increase the portion of launches servicing secondary payloads or to develop Microlaunchers fully dedicated to the small satellites market.

In this view, PLD Space is developing a three stages micro launcher based on liquid propulsion with a reference mission delivering a payload mass of 150 kg into LEO, 400 km circular orbit. Launch operations are going to be carried from southern Spain from an existing missile range.

Since beginning 2017 GMV has decided to back the project of PLD Space and take a stake in this space company. GMV is also developing key technology systems for the Microlaunchers under development.

In particular, GMV is in charge of the complete avionics including all vital subsystems as Power subsystem (from energy storage up to power distribution), Data Handling subsystem (from sensor conditioning and acquisition up to telemetry transmission to ground including bus communication and processing capability), Guidance, Navigation and Control (GNC) subsystem (based on COTS inertial sensors), Onboard Software, and harness for both launchers under development. GMV will is also in charge of the flight segment of the Safety System (Flight Termination System). GMV's team will also be participating jointly with PLD Space in the Microlaunchers integration, qualification and launching-support operations, during the phase of trial flights and commercial flights. These operations are scheduled to start in the first trimester 2019 with the maiden flight of the suborbital launcher ARION 1 from the "El Arenosillo" launch base in Huelva.

[View Full Paper]

[*] GMV, Space Segment and Robotics, Calle Isaac Newton 11, Tres Cantos, Madrid, Spain.
[†] PLD-SPACE, Co-founders, Nicolás Copérnico 7, Elche, Alicante, Spain.

IAA-AAS-CU-17-01-04
AAS 17-936

DNEPR PROGRAM AS A PATH TO SPACE FOR UNIVERSITY SATELLITES

Vladimir Andreev*

In the 1990s, in many universities around the world, space centers were created and actively started to develop and produce micro- and nano-satellites.

The main incentives were:

a) The progress of on-board microelectronics and

b) The desire to include space technology in the student's education process.

The process of creating micro-satellites was and remains relatively inexpensive in financial costs. However, at the same time it took the search of cheap launching into orbit. This issue was originally formed excessive optimism, as the launch operators were not interested for cheap launch services. [View Full Paper]

* Dr. Vladimir Andreev, Founder of Dnepr program and company ISC Kosmotras.

IAA-AAS-CU-17-01-05
AAS 17-937

NEW LAUNCH OPPORTUNITIES WITH SOYUZ LV

Alexander Serkin[*] and Evgeny Solodovnikov[†]

GK Launch Services is a company established by Glavkosmos (a subsidiary of ROSCOSMOS State Space Corporation) and International Space Company Kosmotras. Its business is focused on setting-up and management of Soyuz-2 commercial launches.

The key targets this joint venture aims at include advancing of commercial launch services, promotion of Russian launch vehicles on the international market, and strengthening the positions of Russia as a competitive launch service provider.

The solid competence of the two companies will facilitate reaching these ambitious goals. Glavkosmos has been participating in global international space projects over 30 years and has already had experience in provision of launch services with Soyuz-2 rocket. Kosmotras has orbit-ed over 100 payloads within 22 commercial launches.

[View Full Paper]

[*] CEO, GK Launch Services, 26/1 Prospekt Mira Ave., Moscow, 129090 Russia.
[†] Sales Director, GK Launch Services, 26/1 Prospekt Mira Ave., Moscow, 129090 Russia.

IAA-AAS-CU-17-01-06
AAS 17-938

THE UNISAT PLATFORM AND GAUSS TECHNOLOGY FOR YOUR CUBESAT

Riccardo Di Roberto*

This work describes all the technology created by GAUSS Srl for nano- and micro-satellite missions. GAUSS has started its operations in early 2000s as a university laboratory. Since then, many launches, satellite platforms and payload technology have been developed by GAUSS engineers. The UNISAT Platform has been used by several satellites as a successful method to reach LEO orbit, and now GAUSS Srl can be either described as a launch broker agent, a launch provider and a space subsystems supplier.

[View Full Paper]

* Aerospace and Astronautical Engineer, RF & Systems, GAUSS Srl. E-mail: riccardo.diroberto@gaussteam.com.

PAYLOAD

IAA-AAS-CU-17-02-01
AAS 17-939

ON-CHIP MICRO-INCUBATOR WITH INTEGRATED SENSORS AND ACTUATORS

Lorenzo Iannascoli,[*] Marco Nardecchia,[*] Francesca Costantini,[*] Simone Pirrotta,[†] Nicola Lovecchio,[‡] Domenico Caputo,[†] Giampiero de Cesare[†] and Augusto Nascetti[*]

Degenerative pathologies are among the greatest long-term risk for astronauts exposed to hazard environment during deep space mission. A breakthrough goal in this area, to improve risk modeling, is to provide biological in-situ analysis of those effects. For this purpose, we developed a scientific payload to study the space environment's effects on cellular cultures. The system is a micro-incubator based on lab-on-chip technology with integrated thin-film sensors and actuators for the active control of the environmental conditions of the cell culture. In further detail, the micro-incubator is composed of a microfluidic network bonded on a glass substrate on which hydrogenated amorphous silicon sensors and thin-film resistive heaters are fabricated. The device implements a thermally-controlled incubation chamber with a reservoir for the nutrients and a network for the distribution of carbon dioxide through a thin gas-permeable membrane. Carbon dioxide is produced on-chip by the pyrolysis of sodium bicarbonate stored in a separate reservoir with a dedicated thin film heater. The proposed payload represents a viable solution for enabling biological experiments aboard CubeSat satellites. [View Full Paper]

[*] School of Aerospace Engineering, Sapienza University of Rome, Via Salaria 851, 00138 Rome, Italy.
[†] Italian Space agency, Via del Politecnico snc, 00133 Rome, Italy.
[‡] Department of Information Engineering, Electronics and Telecommunications, Sapienza University of Rome, Via Eudossiana 18, 00184 Rome, Italy.

IAA-AAS-CU-17-02-02
AAS 17-940

MULTI-SATELLITE PROJECT "UNIVERSAT-SOCRAT" FOR NATURAL AND ARTIFICIAL HAZARDS MONITORING

V. I. Osedlo,[*]* V. A. Sadovnichii,[*] M. I. Panasyuk,[*] V. M. Lipunov[*] and the Universat-SOCRAT project collaboration

D. V. Skobeltsyn Institute of Nuclear Physics of M. V. Lomonosov Moscow State University is developing a project "Universat" of a system of small satellites for monitoring of the space threats: ionizing radiation, potentially dangerous objects of natural (asteroids, meteoroids) and artificial (space debris) origin, and electromagnetic transients of Earth's and space origin.

One of the primary tasks for this satellite system is operational (close to "real time") monitoring of the fluxes of energetic charged particles in the wide range of Earth's radiation belts. For this purpose, one or more satellites with a mass <50–100 kg will be launched to elliptical orbit with height of perigee and apogee ~700 and 8000 km and inclination 63.4°, which crosses wide range of magnetic drift shells at different altitudes. Satellites will be equipped with multidirectional spectrometers of energetic protons and electrons.

Another probably somewhat larger satellite will be launched to Sun-synchronous low Earth orbit. Its main task will be detecting the space debris and asteroids by several wide-angle cameras. Satellite may also carry one or more detectors of different wavelength ranges – from gamma to infrared for detecting electro-magnetic transient events in the Earth's atmosphere and in deep space, and the solar flares.

Currently the first research stage of this project is being carried out, during which the optimal spacecraft orbits, instrument construction and placement are being determined. The project is open for cooperation. [View Full Paper]

[*] M. V. Lomonosov Moscow State University, Russia. E-mail: osedlo@mail.ru.

IAA-AAS-CU-17-02-03
AAS 17-941

STUDY OF TRANSIENT ELECTROMAGNETIC EVENTS AND MAGNETOSPHERE ELECTRON FLUX DYNAMICS ON BOARD SMALL SATELLITE MISSIONS VERNOV AND LOMONOSOV AS EXPERIENCE FOR MULTI SMALL SATELLITE MISSION FOR MONITORING OF NATURAL AND ARTIFICIAL SPACE HAZARDS

M. I. Panasyuk,[*] V. M. Lipunov,[*] V. V. Bogomolov,[*] A. V. Bogomolov,[*] G. K. Garipov,[*] A. F. Iyudin,[*] P. A. Klimov,[*] V. I. Osedlo,[*] V. L. Petrov,[*] S. I. Svertilov[*] and I. V. Yashin[*]

Small satellites are very appropriate for the study of different physical phenomena, which can be dangerous for spacecraft technique and biological objects. The transient electromagnetic events, such as Terrestrial Gamma Ray Flashes (TGF), Transient Luminous Events (TLE) and cosmic Gamma Ray Bursts (GRB) as well as magnetosphere electron flux dynamics are very important factors of natural hazards in the near-Earth space. These phenomena were observed during the space experiment with RELEC (Relativistic Electrons) instruments on board Vernov small satellite from July to December, 2014. The solar-synchronous orbit with small eccentricity (640x830 km), inclination about 98º and period ~98 min provides favourable conditions for the magnetosphere electron precipitation (MEP) study as TGF and TLE observations in different areas of the Atmosphere including Equatorial and Polar Regions.

As the results of observations on Vernov satellite dozens of TGF candidates and thousands of UV and red flashes most likely associated with TLEs and lightning were detected. The MEPs were also observed regularly in different areas of near Earth space. Some of TGF candidates and UV flashes were observed at high latitudes in the regions far away from thunderstorms, but near the MEP areas that could indicate on possible connection between TGF and TLE, i.e. high altitude discharges and MEP.

Such observations were continued on Lomonosov satellite which was launched on April, 28 2016 to the solar-synchronous orbit with 490 km altitude and inclination ~98º. The short-time variations of sub-relativistic and relativistic (0.1 – 3.0 MeV) electron flux variations were detected during Vernov and Lomonosov missions in the different parts of near-Earth space, including Aurora regions. The typical times of such events are in the range from several milliseconds up to dozens of seconds and even minutes. The spatial effects caused by satellite crossing of electron beams or other areas with increased electron density and pure temporal, i.e. burst-like phenomena may be among them.

The experience of Vernov and Lomonosov mission for future project of multi small satellites for Monitoring of Natural and Artificial Space Hazards is also discussed. [View Full Paper]

[*] M. V. Lomonosov Moscow State University, Russia. E-mail: sis@coronas.ru.

IAA-AAS-CU-17-02-04
AAS 17-942

NEMS-TECHNOLOGY BASED NANOGRIPPER FOR MECHANIC MANIPULATION IN SPACE EXPLORATION MISSIONS

Alessio Buzzin,[*] Andrea Veroli,[†] Giampiero de Cesare[‡] and N. P. Belfiore[§]

We present the first prototype of a new concept grasping device whose overall size has been reduced as much as permitted by a new NEMS-based fabrication procedure. The fabrication processes used are compatible with rigid or flexible substrates and the materials employed are biocompatible and chemically inert. The jaws lumen size is adequate to the mechanical manipulation of micro- and sub-microscaled objects and organic matter like bacteria. The proposed device represents a promising solution for pick-transport-place operation and biological experiments for future space exploration missions.

[View Full Paper]

[*] PhD Student, Department of Information Engineering, Electronics and Telecommunications, Sapienza University of Rome, via Eudossiana 18, 00184 Rome, Italy. E-mail: alessio.buzzin@uniroma1.it.
[†] Research Fellow, Department of Information Engineering, Electronics and Telecommunications, Sapienza University of Rome, via Eudossiana 18, 00184, Rome, Italy. E-mail: andrea.veroli@uniroma1.it.
[‡] Professor, Department of Information Engineering, Electronics and Telecommunications, Sapienza University of Rome, via Eudossiana 18, 00184 Rome, Italy. E-mail: giampiero.decesare@uniroma1.it.
[§] Professor, Department of Engineering, Università degli studi di Roma Tre, via della Vasca Navale 79, 00146, Rome, Italy. E-mail: nicolapio.belfiore@uniroma3.it.

IAA-AAS-CU-17-02-05
AAS 17-943

MECSE: A CUBESAT MISSION AIMING TO MEASURE AND MANIPULATE THE IONOSPHERIC PLASMA LAYER

J. B. Monteiro,[*] A. Azevedo,[*] G. Pardal,[*] A. Guerman,[*] J. Páscoa,[*] F. Dias,[*] T. Rebelo,[†] A. João[†] and P. Figueiredo[†]

Radio Frequency (RF) blackout phenomenon is experienced during atmospheric entry due to plasma layer interactions with the spacecraft. During this period, the spacecraft loses all communication with the control center or satellite, including voice, real-time data telemetry, and GNSS navigation. This issue is well known and its mitigation is of high priority with the increase of Earth and Mars entry missions. In fact, continuous communication during atmospheric entry is very important to ensure safety and accomplishment of such missions. One mitigation technique proposed is the use of an electromagnetic field to manipulate the plasma layer surrounding the vehicle. Theoretically, communication will be possible if the radio wave frequencies used are greater than the plasma frequency, and this later is a function of plasma density. Therefore, the use of an electromagnetic field to reduce the plasma density in a localized region can possibly mitigate the RF blackout. In this paper, an innovative CubeSat mission to study the manipulation of the ionospheric plasma is proposed. MECSE (Magneto / Electro hydrodynamics CubeSat Experiment) aims to examine in low Earth orbit whether the electron density of the plasma layer can be reduced through the generation of an internal electromagnetic field. This would create the basis for a more rigorous study on electromagnetic manipulation of plasma and the possible development of technology which will allow, partially or completely, bypass the RF blackout in a future phase. The scientific case is presented, based on a literature review on plasma layer manipulation, and a throughout the preliminary mission and spacecraft design is proposed, including a discussion about the payload and the main challenges. A novel concept of operations for the payloads is suggested, based on the use of short electromagnetic pulses. [View Full Paper]

[*] University of Beira Interior, Portugal. E-mail: jbmonteiro94@gmail.com.
[†] Aerospace and Ocean Engineering, CEiiA - Centre of Engineering and Product Development, Portugal.

IAA-AAS-CU-17-02-06
AAS 17-944

OUFTI-NEXT: THE SECOND CUBESAT OF THE UNIVERSITY OF LIÈGE

Xavier Werner,[*] Serge Habraken,[†] Gaëtan Kerschen[‡] and Jerôme Loicq[§]

In light of this experience, in the fall of 2016, the University of Liège (ULiège) assembled a panel of experts in a unique ideation session aiming at systematically and quickly identifying innovative scientific missions for nanosatellites / CubeSats. Among the many ideas that emerged from this process, the ULiège selected the concept of an earth observation 3U CubeSat and corresponding ground segment to produce images in the mid-wave infrared (MWIR) with a resolution of at least 50 m, dedicated to measure the hydric stress of vegetation. This monitoring would allow farmers to provide optimal irrigation to their crops and thus will lead to spare drinkable water. Performing useful MWIR imaging from a 3U CubeSat would be a World's first. Ultimately, a constellation would be required to provide the necessary daily re-visit rate. In order to prove the concept a demonstrator, called OUFTI-Next, will first be produced. [View Full Paper]

[*] Research Engineer, Aerospace and Mechanical Engineering Department, University of Liège, allée de la Découverte 9, Liège, Belgium.
[†] Professor, Centre Spatial de Liège, University of Liège, avenue du Pré Aily, Liège, Belgium.
[‡] Professor, Aerospace and Mechanical Engineering Department, University of Liège, allée de la Découverte 9, Liège, Belgium.
[§] Professor, Centre Spatial de Liège, University of Liège, avenue du Pré Aily, Liège, Belgium.

MISSION

IAA-AAS-CU-17-03-02
AAS 17-945

NANOSATC-BR STATUS – A JOINT CUBESAT-BASED PROGRAM DEVELOPED BY INPE AND UFSM

Nelson Jorge Schuch,[*] Otávio Santos Cupertino Durão, Marlos Rockenbach da Silva, Fátima Mattiello-Francisco,[†] André Luís da Silva[‡] and the NANOSATC-BR Team[§]

The INPE-UFSM's NANOSATC-BR, CubeSats Development Program started in 2008. Currently, the Program counts with two CubeSats: the NANOSATC-BR1 (1U) launched in 2014 and still in operation & the NANOSATC-BR2 (2U) under development and expected to be launched in 2018. In this paper the finalization of NANOSATC-BR2 development and the scientific and technological results of the NANOSATC-BR1 are presented. Considering the Capacity Building, the major target of the Program, the paper emphasizes the involvement of UFSM undergraduate and graduate students in the conception, development and operation of NANOSATC-BR1 and the participation of INPE graduate students in the OBDH software subsystem development, verification and validation for the NANOSATC-BR2. In addition, the collaborations of other Space Science, Engineering and Computer Science institutions involved in Brazil and abroad are discussed. Concerning NANOSATC-BR1, the paper reports the Capacity Building, the technological and the scientific results of the mission. The Program has received financial support from the Brazilian Space Agency (AEB) and from the Ministry of Science, Technology, Innovation and Communications – MCTIC. [View Full Paper]

[*] Southern Regional Space Center – CRS/COCRE/INPE-MCTIC, in collaboration with the Santa Maria Space Science Laboratory – LACESM/CT-UFSM, Santa Maria – RS, Brazil. E-mail: njschuch@gmail.com.
[†] National Institute for Space Research (INPE/MCTIC), São José dos Campos – SP, Brazil. E-mail: otavio.durao@inpe.br, marlos.silva@inpe.br, fatima.mattiello@inpe.br.
[‡] Federal University of Santa Maria – UFSM, Assistant Professor, Aerospace Engineering, Santa Maria – RS, Brazil. E-mail: andre.silva@ufsm.br.
[§] The NANOSATC-BR Team – Seventy persons from: INPE/MCTIC, UFSM, SMDH, UFRGS, UFABC, UFMG, EMSISTI, ITA/DCTA-MD.

IAA-AAS-CU-17-03-03
AAS 17-946

NANOSATC-BR2, 2 UNIT CUBESAT, POWER ANALYSIS, SOLAR FLUX PREDICTION, DESIGN AND 3D PRINTING OF THE FLIGHT MODEL FROM THE UFSM & INPE'S NANOSATC-BR, CUBESAT DEVELOPMENT PROGRAM

Lorenzzo Quevedo Mantovani,[*] Rodrigo Passos Marques,[†] Alex Müller,[‡] Eduardo Xavier Barreto,[§] André Luís da Silva,[**] Otávio dos Santos Cupertino Durão,[††] Fátima Mattielo-Francisco[‡‡] and Nelson Jorge Schuch[§§]

In order to space missions work properly, it is necessary to previously simulate its behavior in space. The main purpose of this work is to predict the orbit behavior of a 2 Unit CubeSat by simulating its flight using a MATLAB code. With this starting point, it is possible to perform a Power Analysis for the satellite and analyze the incident thermal radiation on it for a future Thermal Analysis. In order to help students better understand the CubeSat model and its components, the flight model was designed and 3D printed. The NANOSATC-BR2 is the second nanosatellite from the program NANOSATC-BR, Development of CubeSats Program. [View Full Paper]

[*] Aerospace Engineering Student at the Federal University of Santa Maria (UFSM), Santa Maria – RS, Brazil. E-mail: lorenzzo.mantovani@gmail.com.
[†] Mechanical Engineering Student at the Federal University of Santa Maria (UFSM), Santa Maria – RS, Brazil. E-mail: rodrigo_marques198@hotmail.com.
[‡] Electric Engineering Student at the Federal University of Santa Maria (UFSM), Santa Maria – RS, Brazil. E-mail: alexmuller1997@gmail.com.
[§] Department of Mechanical Engineering at the Federal University of Santa Maria (UFSM), Santa Maria – RS, Brazil. E-mail: eduardo.barreto@gmail.com.
[**] Aerospace Engineering, Federal University of Santa Maria (UFSM), Assistant Professor, Santa Maria – RS, Brazil. E-mail: andre.silva@ufsm.br.
[††] National Institute for Space Research (INPE/MCTIC), São José dos Campos – SP, Brazil. E-mail: otavio.durao@inpe.br.
[‡‡] National Institute for Space Research (INPE/MCTIC), São José dos Campos – SP, Brazil. E-mail: fatima.mattielo@inpe.br.
[§§] Southern Regional Space Research Center – CRS/COCRE/INPE-MCTIC, in collaboration with the Santa Maria Space Science Laboratory – LACESM/CT – UFSM, Santa Maria – RS, Brazil. E-mail: njschuch@gmail.com.

IAA-AAS-CU-17-03-05
AAS 17-947

SMALL SATELLITES, CUBESATS AND UNIVERSITY SATELLITES IN AFRICA AND THEIR MISSIONS

Mohamed B. Argoun[*] and G. Mansour[†]

During 1981-1990 important progress was made in the development of small satellites which can perform similar missions to those performed by much larger commercial satellites. Since middle 1990's several developing countries in Africa, including Algeria, Egypt, Morocco, Nigeria and South Africa and others in Asia and Latin America adopted comprehensive programs for technology transfer of small satellites aiming at building their own satellites for remote sensing. After the advance of the ideas of CubeSats, many more countries were encouraged to enter the space field with objectives ranging from education, to technology acquisition, to developing their own experiments in Space. In this paper we examine various aspects of the CubeSats and University Satellites being developed and used in African countries and their missions. We examine these satellites and programs from the aspect of technology development, technology transfer associated with their development and the educational aspect associated with the University satellites. Also of interest is international cooperation in providing the technology, the country or agency providing that technology the programs and the degree of their participation. International cooperation in terms pf providing launch opportunities for developing countries is an asset for encouraging the trend of developing this type of satellite. The general features and trends of space program development in this specific group of developing countries are extracted. [View Full Paper]

[*] Cairo University, Dept. of Aerospace Engineering, Faculty of Engineering, University Rd, Giza, Egypt. Former Director of Egyptian Space Program at NARSS. Corresponding Author, E-mail: mbargoun@yahoo.com.
[†] Helwan University, Department of Geography, Faculty of Arts.

IAA-AAS-CU-17-03-06
AAS 17-948

THE ALSAT-1N CUBESAT MISSION

Ben Taylor,[*] Chiara Massimiani,[†] Richard Duke,[‡] Brian Stewart,[§] Simon Fellowes,[**] Christopher P. Bridges[††] and Guglielmo S. Aglietti[‡‡]

The AlSat-Nano mission is a joint endeavour by the UK and Algeria to build and operate a 3U CubeSat. The project was designed to provide training to Algerian students, making use of UK engineering and experience. The CubeSat was designed and built by the Surrey Space Centre (SSC) of the University of Surrey and hosts three UK payloads with operations run by the Algerian Space Agency (ASAL). The educational and CubeSat development were funded by the UK Space Agency (UKSA), whilst the UK payloads were self-funded. Launch and operations are funded by ASAL. This paper focuses on the approach taken to testing of the spacecraft and the effect on operations for a successful mission. [View Full Paper]

[*] Project Lead, Surrey Space Centre, University of Surrey, Guildford, UK.
[†] AIT Engineer, Surrey Satellite Technology Ltd., Guildford, UK (formerly with Surrey Space Centre).
[‡] Groundstation Manager, Surrey Space Centre, University of Surrey, Guildford, UK.
[§] Software Engineer, Surrey Space Centre, University of Surrey, Guildford, UK.
[**] Programme Manager, Surrey Space Centre, University of Surrey, Guildford, UK.
[††] Lecturer, Surrey Space Centre, University of Surrey, Guildford, UK.
[‡‡] Director, Surrey Space Centre, University of Surrey, Guildford, UK.

IAA-AAS-CU-17-03-07
AAS 17-949

AN ANALYTICAL APPROACH TO AUTONOMOUS OPTICAL NAVIGATION FOR A CUBESAT MISSION TO A BINARY ASTEROID SYSTEM

Dario Modenini,[*] Marco Zannoni,[*] Riccardo L. Manghi[†] and Paolo Tortora[‡]

We consider the autonomous optical navigation problem for a CubeSat mission to a binary asteroid system. We aimed at providing an approach which limits the computational burden, as to be suitable for real time on-board implementation. To this end, we formulate a theoretical framework which makes use of analytical results for the position determination from imaged ellipsoid targets. To assess the performance of the proposed approach, a simulation environment is developed, taking as a scenario the navigation to a triangular lagrangian point of Didymos system, and having as a target 10m *rms* position accuracy. Alternative formulations of the position fixing are evaluated and compared. Results show the effectiveness of the proposed approach to meet the target position determination accuracy. [View Full Paper]

[*] Research Fellow, Department of Industrial Engineering (DIN), University of Bologna, via Fontanelle 40, 47121, Forlì, Italy.
[†] Ph.D. Candidate, Department of Industrial Engineering (DIN), University of Bologna, via Fontanelle 40, 47121, Forlì, Italy.
[‡] Associate Professor, Department of Industrial Engineering (DIN), University of Bologna, via Fontanelle 40, 47121, Forlì, Italy.

IAA-AAS-CU-17-03-09
AAS 17-950

TECHNICAL KNOWLEDGE GAPS IN NICHE USE CASES OF SMALL SATELLITES

David Earle,[*] Rayan Imam,[†] Olga Mamoutova,[‡] Jorge Monteiro,[*] Siddhesh Naik,[*] Yasith Ramawickrama,[*] Daria Stepanova,[§] Kiran Tikare,[*] Alejandro Lopez[*] [**] and Patricia Randazzo[*] [**]

This review research examined technical papers covering engineering topics related to small satellites. Papers were selected based on the use case or concept of the spacecraft they pertained to. Papers reviewed focused on niche use cases or concepts, defined for the purposes of this research as those use cases or concepts where no spacecraft filling that use case has ever been launched. From these niches, this review research examined the technical aspects of the use cases which have been explored and become understood, and isolated those which had not, especially those indicated in research papers as areas needing development in order to realize a functioning spacecraft. This review focused particularly on trade studies, mission planning analyses, and analyses of obvious required hardware for mission realization. Several major unsolved engineering problems associated with niche use cases were found, and the specifics of their engineering problems were enumerated where possible. [View Full Paper]

[*] Space Generation Advisory Council (SGAC), Small Satellites Project Group (SSPG).
E-mail: sspg@spacegeneration.org.
[†] Space Research Centre, U of K, Sudan.
[‡] Peter the Great St. Petersburg Polytechnic University.
[§] Moscow Institute of Physics and Technology, Moscow, Russia.
[**] SGAC-SSPG Project Admin. Leads.

IAA-AAS-CU-17-03-10
AAS 17-951

AALTO-1 SATELLITE FIRST MONTHS IN ORBIT

P. Niemelä,[*] J. Praks,[†] B. Riwanto, A. Kestilä, A. Näsilä, N. Jovanovic, T. Tikka, N. Silva, H. Leppinen, R. Vainio and P. Janhunen

In this paper we will describe briefly Finnish Aalto-1 CubeSat mission and summarize the mission results achieved during first five months of the mission. The Aalto-1 is the first nanosatellite built in Finland and launched by Finnish consortium. The satellite project started in 2010 as an Aalto University student project, supported by consortium of Universities and institutes. The satellite main mission is education and technology demonstration, as most of the subsystems and payloads are purpose made for this satellite and operated in space for the first time. Main payload of the satellite is a miniature spectral imager AaSI (Aalto-1 Spectral Imager) designed for Earth Observation by VTT Technical Research Centre of Finland. The instrument is based on a Piezo-actuated tunable Fabry-Perot interferometer and is the first such instrument for EO in space. The secondary payload is a radiation monitor, RADMON, which can detect and identify incident particles and their corresponding total energy at 15-second time resolution. The payload is developed by the University of Turku and the University of Helsinki. [4] The third payload is an experimental e-sail technology based deorbiting device, called Plasma Brake, developed and constructed by Finnish Meteorological Institute. Additionally, the satellite has three axis attitude system, on board computer system, several sensor systems and two purpose built-communication systems, tested first time in space. The satellite was finalized and tested for launch in spring 2016 and it was launched to space on 23.6.2017 by Indian PSLV rocket. By now, the satellite has been in space for five months and has already delivered substantial amount of data about its subsystems and achieving many mission goals. The spectral imager AaSI is calibrated in orbit and it has delivered several test images. Also the RADMON instrument has been calibrated in orbit and it has operated over several weeks, providing electron and proton spectrum measurements for several solar storms in autumn 2017. The deorbiting experiment has not been initiated yet. The mission team works currently with attitude stabilization and data collection with two main instruments. [View Full Paper]

[*] Department of Electronics and Nanoengineering, Aalto University, Finland. E-mail: petri.niemela@aalto.fi.
[†] Department of Electronics and Nanoengineering, Aalto University, Finland. E-mail: jaan.praks@aalto.fi.

IAA-AAS-CU-17-03-13
AAS 17-952

MISSION PLANNING WEB APPLICATION FOR EARTH OBSERVATION MISSIONS

W.-T. Loke,[*] R. H.-Y. Ng,[*] J. Z.-Q. Lim,[*] A. N. Nikicio,[*] Z.-N. Ng[*] and C.-H. Goh[†]

Earlier at the 11th IAA Symposium on Small Satellites for Earth Observation, we shared our early work on SpaceCentre, a mission control software application built using progressive web application technologies. The advantages afforded by the web approach were obvious and tremendous – advanced features such as embedded Google Maps and charting libraries can be implemented at the blink of an eye, with readily available libraries available at the developers' fingertips. SpaceCentre has continued to grow in the six months since, and has now been fitted with the ability to perform actuation on the ground equipment – essentially, the ability to carry out satellite operations as it is being planned. This enhancement has demonstrated organic value in having a web-based mission control centre, and has led to SpaceCentre becoming the de facto ground station application for the institute's current and future space programmes.

For the 4th IAA Conference on University Satellite Missions and CubeSat Workshop, we would like to share an update on the current state-of-art of the SpaceCentre mission control application, as well as recent customisations made to support Earth Observation (EO) missions. An intuitive mission tasking module has been designed around the Google Maps widget to evaluate and execute EO missions. This update is tailored towards the on-going Galassia-2 programme, a 3U CubeSat with an optical imaging and high data-rate communications payload designed by students and research staff of the Satellite and Airborne Radar Systems Laboratory, National University of Singapore.

[View Full Paper]

[*] Satellite and Airborne Radar Systems Laboratory, Department of Electrical and Computer Engineering, National University of Singapore, Blk E4A, #04-03, 3 Engineering Drive 3, Singapore 117582.
[†] DSO National Laboratories, 20 Science Park Drive, Singapore 118230.

IAA-AAS-CU-17-03-14
AAS 17-953

FLIGHT RESULTS OF THE NSIGHT-1 QB50 CUBESAT MISSION

L. Visagie,[*] W. H. Steyn,[†] H. Burger[‡] and D. F. Malan[§]

nSight-1 is 2U sized CubeSat that was released from the ISS on 25 May. It was built by SCS-Space in South Africa, in partnership with CubeSpace and Stellenbosch University. The nSight-1 satellite has been in orbit for 6 months at the time of writing, and has already achieved all of the initial project goals. These goals include gathering scientific measurements for the QB50 project, capturing numerous high-quality images from the in-house developed "Gecko" Earth observation camera, and gaining flight heritage on ADCS and camera components. The attitude of the satellite was stabilized within the first two weeks using a single Y-axis momentum wheel and 3-axis magnetorquers. Attitude estimation makes use of a magnetometer only. After in-fight calibration of the magnetometer a pointing accuracy of around 2 to 3 degrees is achieved. A few raw Gecko camera images files have been downloaded to characterize the camera performance. Around 20 high-quality JPG images have also been downloaded, along with numerous thumbnail images, which allows for images to be rejected if they are covered by clouds. The flight software has shown remarkable robustness with only a single unintentional reset of the satellite. Ground operations have been automated to a large degree, allowing optimal use of the constrained UHF 9k6 downlink. nSight- 1 continues to deliver daily science data to QB50, and the remaining operations will be devoted to characterizing the performance of the Gecko camera. [View Full Paper]

[*] Senior Lecturer, Department of Electrical and Electronic Engineering, Stellenbosch University, Private Bag X1, 7602, South Africa.
[†] Professor, Department of Electrical and Electronic Engineering, Stellenbosch University, Private Bag X1, 7602, South Africa.
[‡] CEO, SCS-Space, 3rd Floor, St. Andrews Building, Somerset Links Office Park, Somerset West, 7130, South Africa.
[§] SCS-Space, 3rd Floor St. Andrews Building, Somerset Links Office Park, Somerset West, 7130, South Africa.

IAA-AAS-CU-17-03-15
AAS 17-954

A SMALL PLATFORM APPLICATION FOR CLOSE INSPECTION OF AN OUT OF CONTROL SATELLITE

Renato Volpe,[*] Marco Carpentiero[†] and Angelo Stolfi[*]

The field of space proximity operations such as on-orbit inspection, refueling, repair and debris removal has been recently exploring new innovations for what technology and application scenarios concern. For this scope, small orbiting platforms, despite their limited power and operative capacity, represent a low-cost solution for the majority of proximity missions. Regarding mission architecture, various researches have been carried out to analyze the feasibility of several practical applications in a proximity operation scenario. In this sense, GNC systems, which play a fundamental role for the successfulness of the mission, have undergone relevant improvements. Optical navigation has proved to be a reliable solution for the navigation system, optimal path planning algorithms have been augmented with secure and robust collision avoidance, while control strategies offer satisfying performance in terms of desired position and velocity tracking. The present research shows a possible and feasible application of a small platform (chaser) for the close inspection of an uncontrolled, un-cooperative, Earth-orbiting satellite (target). In an initial phase of the mission, the chaser will follow a closed relative orbit (Parking Orbit) around the target and use measurements acquired from a passive camera and a range sensor in order to estimate target's relative position, velocity, orientation, angular motion and shape. By means of the acquired information, a set of relevant viewpoints for a close and clear inspection of the target is evaluated. As a second step, starting from the Parking Orbit, the chaser will perform a rendezvous maneuver to reach one of the viewpoints, selected as the optimal among all. The Approach Trajectory followed in this phase is computed to be optimal from a propellant consumption point of view and free of collisions with the target. The desired trajectory will be tracked by implementing an impedance control law. Once the viewpoint has been reached, the chaser will maintain the relative position and orientation while performing the inspection by means of a camera mounted on a robotic arm. At the end of this operation, the chaser will transfer to the subsequent viewpoint, following an optimized and safe path. The mission will be achieved once all the viewpoints have been visited. In the paper rigorous analytical formulations of the relative dynamics, estimate process, optimal path planning and control strategy will be presented. Additionally, the feasibility of the proposed architecture will be evaluated through numerical simulations on some test case scenarios. [View Full Paper]

[*] Ph.D. Student, Department of Mechanical and Aerospace Engineering, University of Rome, "La Sapienza", Via Eudossiana 18, 00184 Rome.
[†] Ph.D. Student, Department of Astronautical, Electrical and Energy Engineering, University of Rome, "La Sapienza", Via Eudossiana 18, 00184 Rome.

SPACE DEBRIS MITIGATION

IAA-AAS-CU-17-04-01
AAS 17-955

DRAG DE-ORBIT DEVICE (D3) MISSION FOR VALIDATION OF CONTROLLED SPACECRAFT RE-ENTRY USING AERODYNAMIC DRAG

Sanny Omar,[*] David Guglielmo[†] and Riccardo Bevilacqua[‡]

The miniaturization of technology has led to an increasingly capable body of small satellites such as CubeSats which have fueled a demand for affordable yet reliable miniaturized attitude and orbit control systems. The more relaxed control requirements typically relevant to CubeSats missions open the door for innovative technologies that can replace large and expensive legacy attitude control and propulsion systems. The steadily increasing number of actors in space has also made orbital debris handling and mitigation increasingly important. This includes reducing the amount of debris, minimizing the risk of in-space collisions, and minimizing the hazards to persons and property on the ground from debris re-entry.

The University of Florida Advanced Autonomous Multiple Spacecraft (ADAMUS) lab has developed a Drag De-Orbit Device (D3) for CubeSats consisting of retractable tape-spring booms that provide a drag area of .5 m^2 and can de-orbit a 12U, 15 kg CubeSat from a 700 km circular orbit in 25 years. By modulating the D3 drag area, orbital maneuvering can be performed and the host satellite can be made to de-orbit in a desired location. In addition, the dart configuration of the booms ensures that the host satellite will aerodynamically stabilize in the ram direction with the help of initial rate damping by magnetorquers contained in the D3. By partially retracting two booms opposite each other, the D3 equipped spacecraft will have a clear minimum moment of inertia axis which gravity gradient torques will work to align with the nadir vector. These gravity gradient and aerodynamic torques together can provide passive 3-axis attitude stabilization.

This paper details the design of a 2U CubeSat and mission that will be launched to validate the D3 and the orbital maneuvering, targeted re-entry, collision avoidance, and attitude stabilization algorithms developed by the ADAMUS lab. The targeted re-entry and orbital maneuvering algorithms have been tested extensively through Monte Carlo simulations and collision avoidance algorithms are currently in development. The CubeSat will consist of a standard 1U structure containing a power system, battery, GPS, UHF radio, and D3 control board with the D3 subsystem mounted to the back to achieve a 2U form factor. The search for CubeSat launch opportunities is still in progress, but the team hopes to have the satellite deployed from the International Space Station. Tests of orbital maneuvering and collision avoidance algorithms will commence after de-tumble, boom deployment, and communication with the ground. Approximately two weeks before the expected re-entry, the targeted de-orbit algorithm will steer the satellite to a desired re-entry location visible by a JSpOC radar station. The radar tracking data along with GPS telemetry will be utilized to characterize the performance of the system and algorithms, update re-entry aero-thermodynamic models, and gauge the effectiveness of atmospheric density estimation techniques. [View Full Paper]

[*] PhD Candidate, Mechanical and Aerospace Engineering, University of Florida, 939 Sweetwater Drive, Gainesville, Florida 32611, USA.
[†] Post-Doc, Mechanical and Aerospace Engineering, University of Florida, 939 Sweetwater Drive, Gainesville, Florida 32611, USA.
[‡] Associate Professor, Mechanical and Aerospace Engineering, University of Florida, 939 Sweetwater Drive, Gainesville, Florida 32611, USA.

IAA-AAS-CU-17-04-03
AAS 17-956

PLASMA BRAKE APPROXIMATE TRAJECTORY. PART I: GEOCENTRIC MOTION

Lorenzo Niccolai,[*] Marco Bassetto,[†] Alessandro A. Quarta[‡] and Giovanni Mengali[§]

The problem of space debris is a major concern for spacecraft operating in low Earth orbits. Accordingly, a deorbiting strategy must be currently considered in the preliminary mission design phase, in order to obtain a decay within 25 years after the end of the operative phase. One promising innovation in this field is the plasma brake technology, which exploits the electrostatic interaction between a charged tethers and the ionized particles in the upper stages of the Earth's atmosphere to obtain a drag force. The aim of this paper is to present an approximate model capable of simulating the geocentric trajectory during the deorbiting phase and to provide an estimation of the decay time. The numerical results suggest that a plasma brake-enabled deorbiting of a nanosatellite would comply with the international guidelines. [View Full Paper]

[*] Ph.D. Student, Department of Civil and Industrial Engineering, University of Pisa, Via G. Caruso n.8, I-56122, Pisa, Italy. E-mail: lorenzo.niccolai@ing.unipi.it.
[†] Ph.D. Student, Department of Civil and Industrial Engineering, University of Pisa, Via G. Caruso n.8, I-56122, Pisa, Italy. E-mail: marco.bassetto@ing.unipi.it.
[‡] Associate Professor, Department of Civil and Industrial Engineering, University of Pisa, Via G. Caruso n.8, I-56122, Pisa, Italy. E-mail: a.quarta@ing.unipi.it.
[§] Professor, Department of Civil and Industrial Engineering, University of Pisa, Via G. Caruso n.8, I-56122, Pisa, Italy. E-mail: g.mengali@ing.unipi.it.

IAA-AAS-CU-17-04-04
AAS 17-957

PLASMA BRAKE APPROXIMATE TRAJECTORY. PART II: RELATIVE MOTION

**Marco Bassetto,[*] Lorenzo Niccolai,[†]
Alessandro A. Quarta[‡] and Giovanni Mengali[§]**

Space debris mitigation is a challenge for the immediate future. Its solution represents a necessary step to guarantee a safe operation of satellites in low Earth orbits. Many strategies have been proposed to address this crucial issue, and meet the requirements of the Inter-Agency Space Debris Coordination Committee, according to which an out-of-order satellite should de-orbit within 25 years from its end-of-life. Among all the proposed methods, the plasma brake represents an interesting and innovative option, as it is propellantless and requires a small amount of electric power to work properly. In this paper, the performance of a plasma brake system is analyzed to de-orbit a CubeSat from an initial altitude of 1000 kilometers above the Earth's surface. The total decay time is evaluated using an iterative process, in which the altitude loss is computed starting from the linearized equations of the relative motion with respect to the position that the satellite would occupy on the osculating (nearly circular) orbit. The effectiveness of this procedure is investigated by comparing the results with those obtained through numerical integration of the equations of motion. In particular, the computational time is reduced by four orders of magnitude with an error of 0.1% only. In terms of the decay time, it is shown that the satellite reaches a final altitude of 300 kilometers within a few years when the plasma brake-induced acceleration is about 10^{-3} mm/s^2. [View Full Paper]

[*] Ph.D. Student, Department of Civil and Industrial Engineering, University of Pisa, Via G. Caruso n.8, I-56122, Pisa, Italy. E-mail: marco.bassetto@ing.unipi.it.
[†] Ph.D. Student, Department of Civil and Industrial Engineering, University of Pisa, Via G. Caruso n.8, I-56122, Pisa, Italy. E-mail: lorenzo.niccolai@ing.unipi.it.
[‡] Associate Professor, Department of Civil and Industrial Engineering, University of Pisa, Via G. Caruso n.8, I-56122, Pisa, Italy. E-mail: a.quarta@ing.unipi.it.
[§] Professor, Department of Civil and Industrial Engineering, University of Pisa, Via G. Caruso n.8, I-56122, Pisa, Italy. E-mail: g.mengali@ing.unipi.it.

IAA-AAS-CU-17-04-05
AAS 17-958

THE INFLATESAIL CUBESAT MISSION – THE FIRST EUROPEAN DEMONSTRATION OF DRAG-SAIL DE-ORBITING

Craig Underwood,[*] Andrew Viquerat,[†] Mark Schenk,[‡] Simon Fellowes,[§] Ben Taylor,[**] Chiara Massimiani,[††] Richard Duke,[‡‡] Brian Stewart,[§§] Chris Bridges,[***] Davide Masutti[†††] and Amandine Denis[‡‡‡]

The InflateSail (QB50-UK06) CubeSat, designed and built at the Surrey Space Centre (SSC) at the University of Surrey, UK, for the Von Karman Institute (VKI), Belgium – was one of the technology demonstrators for the QB50 programme. The 3.2 kilogram 3U CubeSat was equipped with a 1 metre long inflatable boom and a $10m^2$ deployable drag sail. InflateSail's primary mission was to demonstrate the effectiveness of using a drag sail in Low Earth Orbit (LEO) to dramatically increase the rate at which satellites lose altitude and re-enter the Earth's atmosphere and it was one of 31 satellites that were launched simultaneously on the PSLV (polar satellite launch vehicle) C-38 from Sri-harikota, India on 23rd June 2017 into a 505km, 97.44º Sun-synchronous orbit (SSO). Shortly after orbital insertion, InflateSail booted-up, and, once safely clear of the other satellites on the launch, it automatically activated its payload – firstly, deploying a 1 metre long inflatable boom comprising a metal-polymer laminate tube, using a cool gas generator (CGG) to provide the inflation gas, and secondly, using a brushless DC motor at the end of the boom to extend four lightweight bistable rigid composite (BRC) booms to draw out the 3.1m x 3.1m square, 12 micron thick polymer drag-sail. As intended, the satellite immediately began to lose altitude, and re-entered the atmosphere just 72 days later – thus demonstrating for the first time the de-orbiting of a spacecraft using European inflatable and drag-sail technologies. The boom/drag-sail technology developed by SSC will next be used on the RemoveDebris mission, due for launch in 2018, which will demonstrate the capturing and de-orbiting of artificial space debris targets using a net and harpoon system. [View Full Paper]

[*] Prof., Surrey Space Centre, University of Surrey, Guildford, Surrey, GU2 7XH, UK.
[†] Dr., Surrey Space Centre, University of Surrey, Guildford, Surrey, GU2 7XH, UK.
[‡] Dr., Faculty of Engineering, University of Bristol, Bristol, Avon, BS8 1TH, UK.
[§] Programme Manager, Surrey Space Centre, University of Surrey, Guildford, Surrey, GU2 7XH, UK.
[**] Project Manager, Surrey Space Centre, University of Surrey, Guildford, Surrey, GU2 7XH, UK.
[††] Research Assistant, Surrey Space Centre, University of Surrey, Guildford, Surrey, GU2 7XH, UK.
[‡‡] Research Officer, Surrey Space Centre, University of Surrey, Guildford, Surrey, GU2 7XH, UK.
[§§] Research Student, Surrey Space Centre, University of Surrey, Guildford, Surrey, GU2 7XH, UK.
[***] Dr., Surrey Space Centre, University of Surrey, Guildford, Surrey, GU2 7XH, UK.
[†††] QB50 Project Manager, Von Karman Institute for Fluid Dynamics, Waterloosesteenweg 72, B-1640 Sint-Genesius-Rode, Belgium.
[‡‡‡] QB50 System Engineer, Von Karman Institute for Fluid Dynamics, Waterloosesteenweg 72, B-1640 Sint-Genesius-Rode, Belgium.

IAA-AAS-CU-17-04-06
AAS 17-959

CUBESAT TECHNOLOGY IN SERVICE TO LARGER ACTIVE DEBRIS REMOVAL MISSIONS

Jason Forshaw,[*] Ben Taylor,[†] Richard Duke,[‡] Simon Fellowes,[§] Brian Stewart[**] and Guglielmo S. Aglietti[††]

The EC FP7 RemoveDebris mission aims to be one of the world's first Active Debris Removal (ADR) missions to demonstrate key technologies in-orbit in a cost-effective ambitious manner, including: net capture, harpoon capture, vision-based navigation, dragsail deorbiting. The mission will utilise two CubeSats as artificial debris targets to demonstrate the technologies.

A core premise of this mission is the ability of CubeSats to be used in service to larger missions, in the case of this mission, active debris removal missions. The use of CubeSats as artificial targets has a range of advantages as opposed to testing technologies on real orbital debris discussed in this paper. [View Full Paper]

[*] Research Fellow, Surrey Space Centre, University of Surrey, Guildford, UK.
[†] Project Engineer, Surrey Space Centre, University of Surrey, Guildford, UK.
[‡] Groundstation Manager, Surrey Space Centre, University of Surrey, Guildford, UK.
[§] Programme Manager, Surrey Space Centre, University of Surrey, Guildford, UK.
[**] Software Engineer, Surrey Space Centre, University of Surrey, Guildford, UK.
[††] Director, Surrey Space Centre, University of Surrey, Guildford, UK.

ATTITUDE CONTROL

IAA-AAS-CU-17-05-02
AAS 17-960

EFFICIENT STAR IDENTIFICATION ALGORITHM FOR NANOSATELLITES IN HARSH ENVIRONMENT

Vincenzo Schiattarella,[*] Dario Spiller[†] and Fabio Curti[‡]

This paper deals with a fast and efficient Lost in Space algorithm for stars pattern recognition in harsh environments using star trackers. Typically, the attitude determination system for CubeSats is based on low accuracy instruments such as sun sensors and magnetometers. However, it is expected that next CubeSat generations will require more accurate attitude estimations provided by stars sensors. False spikes represent the major issue in star identification since star trackers for CubeSat generally have low radiation shielding. The proposed technique is based on the Multi-Poles Algorithm approach. Stars are identified in two phases: 1) the acceptance phase, to yield a set of stars, and 2) the check phase, to avoid erroneous identification. The identification feature is the angular distance between two stars while stars magnitudes are used as a filtering feature to improve the searching strategy. Tests have shown that the algorithm guarantees a reliable identification of stars up to 80 artifacts per image. [View Full Paper]

[*] Post-graduate Student, School of Aerospace Engineering, ARCAlab, University of Rome Sapienza. Italy.
E-mail: vincenzo.schiattarella@uniroma1.it.
[†] PhD Student, School of Aerospace Engineering, ARCAlab, University of Rome Sapienza. Italy.
E-mail: dario.spiller@uniroma1.it.
[‡] Associate Professor, School of Aerospace Engineering, ARCAlab, University of Rome Sapienza. Italy.
E-mail: fabio.curti@uniroma1.it.

IAA-AAS-CU-17-05-03
AAS 17-961

GAIN SELECTION FOR ATTITUDE STABILIZATION OF EARTH-POINTING SPACECRAFT USING MAGNETORQUERS*

Fabio Celani†

This paper considers a feedback control law that achieves attitude stabilization for Earth-pointing spacecraft using only magnetorquers as torque actuators. The control law is proportional derivative (PD)-like with matrix gains, and it guarantees asymptotic stability. The PD gain matrices are determined through the numerical solution of a periodic linear quadric regulator problem. A case study shows the effectiveness of the considered controller gain selection. [View Full Paper]

† Assistant Professor, School of Aerospace Engineering, Sapienza University of Rome, Via Salaria 851, 00138 Roma, Italy. E-mail: fabio.celani@uniroma1.it.

IAA-AAS-CU-17-05-05
AAS 17-962

RESIDUAL MAGNETIC TORQUE ESTIMATION FOR NANO-SATELLITE

Kai Yoshihara,[*] Masahiko Yamazaki[†] and Yasuyuki Miyazaki[‡]

In this research, estimation method of residual magnetic torque is shown by using magnetic observation system of Nano-Satellite. Recently, companies and universities are developing Nano-Satellite of few kilograms in low-cost within short-term for space demonstrations. It is difficult to mount a large size and high accuracy control device on Nano-Satellite. Therefore, only a compact control device can be mounted on Nano-Satellite. 20cm^3 Nano-Satellite, SPROUT developed by Nihon University was launched in 2014. According to the comparison among estimated other disturbances, such as sun pressure, gravity gradient torque, air drug, residual magnetic torque is dominant in such Nano-Satellite. Control torque is determined by estimating the disturbance torque with high accuracy. This is necessary to improve the accuracy of compact and low cost control device of Nano-Satellite. [View Full Paper]

[*] Graduate Student, Department of Aerospace Engineering, 7-24-1, Narashinodai, Funabashi, Chiba, 274-8501, Japan.
[†] Assistant Professor, Department of Aerospace Engineering, 7-24-1, Narashinodai, Funabashi, Chiba, 274-8501, Japan.
[‡] Professor, Department of Aerospace Engineering, 7-24-1, Narashinodai, Funabashi, Chiba, 274-8501, Japan.

IAA-AAS-CU-17-05-06
AAS 17-963

DESIGN AND DEVELOPMENT OF AN ACTIVE MAGNETIC ACTUATOR FOR ATTITUDE CONTROL SYSTEM OF NANOSATELLITES

Igor Seiiti Kinoshita Ishioka,[*] Simone Battistini,[†] Chantal Cappelletti[‡] and Renato Alves Borges[§]

This work, conducted in the Laboratory of Aerospace Science and Innovation (LAICA) at University of Brasília (UnB) reports the design and development of a triaxial active magnetic actuator for the Attitude Determination and Control System (ADCS) of nanosatellites. The ADCS is necessary for the conduction of space missions, which require stabilization and pointing capabilities. This category of small satellites is characterized by the mass, which stands in the range 1-10kg under NASA's classification. As one of the requisites, the actuator shall be modular and compatible with the CubeSat dimensional standard. The testing campaign, which is part of the work, will be conducted through the ADCS testbed available and developed in the same laboratory. The testbed is equipped with a Helmholtz cage for simulation of Earth's magnetic field in orbital conditions, allowing the verification of the behavior of the triaxial system and therefore its preliminary characterization. [View Full Paper]

[*] University of Brasília, Brazil, 72444-240. E-mail: igorseiiti@gmail.com.
[†] University of Brasília, Brazil, 72444-240. E-mail: simone.battistini@aerospace.unb.br.
[‡] University of Nottingham, United Kingdom, NG7 2RD. E-mail: chantal.cappelletti@nottingham.ac.uk.
[§] University of Brasília, Brazil, 70910-900. E-mail: raborges@aerospace.unb.br.

IAA-AAS-CU-17-05-07
AAS 17-964

MICROSATELLITE MOCK-UP CONTROL USING REINFORCEMENT LEARNING TECHNIQUE

Danil Ivanov,[*] Dmitry Roldugin,[*] Mikhail Ovchinnikov[†] and Mark Shachkov[‡]

The application of the reinforcement learning technique to the microsatellite mock-up position and attitude control is considered in the paper. Classical control approach is compared with the control policy derived from the reinforcement learning framework. The performance of the control algorithm in case of significant uncertainties in the dynamical model is investigated. Real time performance enhancement due to the learning continuing during the ongoing experiment is considered. The experimental study is performed on the facility at the Keldysh Institute of Applied Mathematics. The facility consists of the air-bearing table providing an air cushion, and the microsatellites mock-ups moving on its surface. The problem of relative trajectory tracking in the satellite mock-up formation flying using the reinforcement learning techniques is studied.

[View Full Paper]

[*] PhD, Senior Researcher, Keldysh Institute of Applied Mathematics of RAS, Miusskaya Sq.4, Moscow, Russia.
[†] Professor, Head of Division, Keldysh Institute of Applied Mathematics of RAS, Miusskaya Sq., 4, Moscow, Russia.
[‡] Master Student, Junior Researcher, Keldysh Institute of Applied Mathematics of RAS, Miusskaya Sq., 4, Moscow, Russia.

IAA-AAS-CU-17-05-08
AAS 17-965

LYAPUNOV BASED ATTITUDE CONTROL ALGORITHM FOR SLEW MANEUVERS WITH RESTRICTIONS

**Yaroslav Mashtakov,[*] Mikhail Ovchinnikov,[†]
Stepan Tkachev[‡] and Mark Shachkov[§]**

In this paper the problem of performing the large slew maneuver is considered. There are additional constraints on the spacecraft attitude: body-fixed axis cannot be directed to several given areas in inertial space. Because of this constraints, solving this problem using Pontryagin's maximum principle takes much computational time and can hardly be implemented on-board the satellite. In order to reduce required computational time we suggest to use Lyapunov based attitude control algorithm that ensures asymptotic stability of the required motion and does not violate the restrictions imposed on the attitude.

[View Full Paper]

[*] Junior Researcher, Attitude Control and Guidance Division, Keldysh Institute of Applied Mathematics of RAS, Miusskaya Sq., 4, Moscow, Russia. E-mail: yarmashtakov@gmail.com.
[†] Head of Division, Attitude Control and Guidance Division, Keldysh Institute of Applied Mathematics of RAS, Miusskaya Sq., 4, Moscow, Russia. E-mail: ovchinni@keldysh.ru.
[‡] Senior Researcher, Attitude Control and Guidance Division, Keldysh Institute of Applied Mathematics of RAS, Miusskaya Sq., 4, Moscow, Russia. E-mail: stevens_L@mail.ru.
[§] Junior Researcher, Attitude Control and Guidance Division, Keldysh Institute of Applied Mathematics of RAS, Miusskaya Sq., 4, Moscow, Russia. E-mail: markshachkov@gmail.com.

IAA-AAS-CU-17-05-09
AAS 17-966

DEVELOPMENT OF A HARDWARE-IN-THE-LOOP TEST PLATFORM FOR NANOSATELLITES ADCS INTEGRATED WITH AN UKF

João Victor Lopes de Loiola,[*] Lucas Meneses Bandeira da Silva,[†] Simone Battistini,[‡] Renato Alves Borges[§] and Chantal Cappelletti[**]

In this work, we present the development of a Hardware-in-the-loop test platform used to emulate space conditions on earth. This paper deals with the issue of developing strategies to test nanosatellite's actuation system on earth. In order to address this problem, the Laboratory of Application and Innovation in Aerospace Science (LAICA) at University of Brasília designed an attitude and determination control system (ADCS) using an Unscented Kalman Filter (UKF) and a PD controller aiming to control a reference angle around the platform's Z axis. In this research, it was utilized the SGP4 perturbation model and reaction wheels as actuators. The results obtained provided an effective strategy to improve attitude control of a test platform affected by sensor noise. [View Full Paper]

[*] University of Brasília, Brazil. E-mail: victor@lara.unb.br.
[†] University of Brasília, Brazil. E-mail: silva.ngc7293@gmail.com.
[‡] University of Brasília, Brazil. E-mail: simone.battistini@aerospace.unb.br.
[§] University of Brasília, Brazil. E-mail: raborges@aerospace.unb.br.
[**] University of Nottingham, United Kingdom, NG7 2RD. E-mail chantal.cappelletti@nottingham.ac.uk.

MISSION DESIGN

IAA-AAS-CU-17-06-01
AAS 17-967

SAVING MISSION YET TO BE LAUNCHED: TIGHT SCHEDULE FOR AN UNEXPECTED PROJECT

D. S. Roldugin,[*] M. Yu. Ovchinnikov,[†] D. S. Ivanov,[‡] M. O. Shachkov,[§] M. D. Koptev,[**] O. A. Pantsyrnyi[††] and I. O. Fedorov[‡‡]

CubeSats are often designed and manufactured in a very tight time schedule. However, no one expects to have only one month for the preparation of a mission long before abandoned by another team. This contribution focuses on the rapid attitude control decisions necessary to ensure the CubeSat satellite communication via Iridium constellation. Having magnetorquers, magnetometer and very limited power budget, the only available addition to the system becomes a constant magnet. This forces the satellite to track the geomagnetic induction vector. The satellite acquires promising Iridium orbits visibility while easing burden on the magnetorquers in an energy saving endeavor. Some relevant analysis spotlights, experiments and reasoning are provided. [View Full Paper]

[*] Keldysh Institute of Applied Mathematics of RAS, Moscow, Russia. E-mail: rolduginds@gmail.com.
[†] Keldysh Institute of Applied Mathematics of RAS, Moscow, Russia. E-mail: ovchinni@keldysh.ru.
[‡] Keldysh Institute of Applied Mathematics of RAS, Moscow, Russia. E-mail: danilivanovs@gmail.com.
[§] Keldysh Institute of Applied Mathematics of RAS, Moscow, Russia. E-mail: markshachkov@gmail.com.
[**] Keldysh Institute of Applied Mathematics of RAS, Moscow, Russia. E-mail: inflex95@mail.ru.
[††] Russian Space Systems, Moscow, Russia. E-mail: pantsyrnyi@mail.ru.
[‡‡] Russian Space Systems, Moscow, Russia. E-mail: goshafedorof@mail.ru.

IAA-AAS-CU-17-06-02
AAS 17-968

BUILDING LOW COST CUBESAT: GUIDELINES AND DESIGN APPROACH*

Ibtissam Latachi,† Tajjeeddine Rachidi,‡ Mohammed Karim§ and Ahmed Hanafi**

Educational Cubesat programs are able to provide low cost launch opportunities to developing countries, previously unable to afford access to space. However, designing and building small low cost satellites as simple as 1U Cubesat, and the associated control ground station requires a sophisticated engineering endeavor, especially for organizations with no aerospace engineering programs. This is further exacerbated by the lack of simple guidelines provided in the aerospace literature to guide the execution of a space mission project. Therefore, it is paramount for generalized access to space that simplified methodologies and guidelines be readily available. In this paper, we shall bridge this gap and present a guide to the workflow of the various engineering tasks that need to be accomplished and the interactions between them drawn from our own experience for mission MASAT1, which is mainly characterized by software integration over Cubesat COTS parts. We shall describe the various engineering, management and administrative tasks that need to be undertaken, as well as the design and implementation options that are available to both engineers and project managers, right from the mission definition to the launch and exploitation of Cubesat-based nanosatellites. [View Full Paper]

* This project is supported by the CNRST under grand PPR/2015/12.
† PhD Student at University Sidi Mohammed Ben Abdellah, Morocco. E-mail: latachi.ibtissam@gmail.com.
‡ Full Professor at AlAkhawayn University in Ifrane, Morocco. E-mail: T.Rachidi@aui.ma.
§ Full Professor at University Sidi Mohammed Ben Abdellah, Morocco. E-mail: karim_lessi@yahoo.fr.
** Assistant Professor at University Sidi Mohammed Ben Abdellah, Morocco. E-mail: ahmed.hanafi72@gmail.com.

IAA-AAS-CU-17-06-03
AAS 17-969

CUBESAT CONSTELLATION DEPLOYMENT STRATEGIES

Christophe Vakaet[*] and Alessandra Menicucci[†]

CubeSat based constellations are limited by launch opportunities, manoeuvring, and reliability. In this paper, an approach is proposed to determine the performance of a constellation, using different deployment strategies. Due to low maneuverability and limited launch options, CubeSats require deployment strategies that determine the optimal launch method and maneuvers to ensure rapid deployment, and replacement in case of failure. To do so, a model is developed that applies a Monte Carlo method through repeated sampling of the satellite lifetimes. By simulating discrete realizations of the constellation, over the mission lifetime, the probability distribution of the strategies performance is derived. By comparing deployment strategies, the model can be used to design for the optimal deployment strategy. [View Full Paper]

[*] MSE Student, Department of Control and Simulation, Aerospace Engineering Faculty, Delft University of Technology, Kluyverweg 1, 2629 HS Delft, The Netherlands.
[†] Assistant Professor, Department of Space Engineering, Aerospace Engineering Faculty, Delft University of Technology, Kluyverweg 1, 2629 HS Delft, The Netherlands.

IAA-AAS-CU-17-06-04
AAS 17-970

DEVELOPMENT OF MODULAR 3U CUBESAT STANDARD PLATFORM AND ITS APPLICATION TO KAUSAT-5

Sua Song,[*] Hongrae Kim[*] and Young-Keun Chang[†]

This paper describes the development of a standard platform of 3U Cube Satellite, those function and performance were verified through the development of KAUSAT-5 CubeSat. The design of a universal standard platform is based on the CDS (CubeSat Design Specification) and implements the existing CubeSat technology and some latest technology. The standard platform is built in 1.5U size and developed as a modular concept to add and expand payloads and attitude control actuators to meet the user's needs. In the case of the power system, the solar panel, the battery, and the deployment mechanism are designed to be configured by the user. Mechanical system designs maximize the electrical capability to accommodate various payloads and to integrate and miniaturize tiny parts and subsystem functions/performance into tiny PCBs. The developed 3U standard platform was applied to the KAUSAT-5 satellite, and the function of the standard platform was verified by mounting the VSCMG (Variable Speed Control Moment Gyro), which is a payload for technical demonstration, at the bottom of the platform and the infrared(IR) camera, which is the payload for science mission, on the top. The 3U CubeSat equipped with the electronic optical camera under development is adopting the same platform to reduce development cost and schedule by reducing additional functional verification. [View Full Paper]

[*] Ph.D. Student, Department of Aerospace & Mechanical Engineering, Korea Aerospace University, 76, Hanggongdaehak-ro, Deogyang-gu, Goyang-si, Gyeonggi-do, 10540, Republic of Korea.
[†] Professor, Department of Aerospace & Mechanical Engineering, Korea Aerospace University, 76, Hanggongdaehak-ro, Deogyang-gu, Goyang-si, Gyeonggi-do, 10540, Republic of Korea.

IAA-AAS-CU-17-06-05
AAS 17-971

MOVE-II THE MUNICH ORBITAL VERIFICATION EXPERIMENT II

Martin Langer,[*] Florian Schummer,[*] Nicolas Appel,[*] Thomas Gruebler,[*] Katja Janzer,[*] Jonis Kiesbye,[*] Lucas Krempel,[*] Alexander Lill,[*] David Messmann,[*] Sebastian Rueckerl[*] and Michael Weisgerber[*]

MOVE-II (Munich Orbital Verification Experiment II) is a 1 Unit CubeSat currently under development at the Technical University of Munich (TUM). This paper reports on the technical as well as the organizational advancements of the project. With overall more than 130 students involved so far, the project is currently in Phase D, with the launch of the satellite scheduled for early 2018. For communication purposes, MOVE-II will utilize a novel robust and efficient radio protocol for small satellite radio links, called Nanolink, both on an UHF / VHF transceiver and an S-Band transceiver. The usual power restrictions of the 1U envelope are overcome by four deployable solar panels, which are held down and released by a reusable shape memory mechanism. This allows repeated tests of the mechanism and true test-as-your-fly philosophy. As its scientific goal, the MOVE-II CubeSat will be used for the verification of novel 4-junction solar cells. With a footprint of 10x10 cm, the payload consists of one full size solar cell (8x4 cm) and five positions (each 2x2 cm) for the corresponding isotype solar cells. As opposed to its predecessor mission, MOVE-II will be the first CubeSat of TUM utilizing a magnetorquer based, active attitude determination and control system (ADCS). The system consists of five Printed-Circuit-Boards with directly integrated magnetic coils, forming the outer shell of the spacecraft, and one so-called ADCS Mainboard, located in the board stack of the satellite. Each Sidepanel has its own microcontroller and is connected to the ADCS Mainboard with one of two redundant SPI buses. From an organizational point of view, we tried to increase the reliability of MOVE-II by fast prototyping and releases as well as enhanced hardware-in-the loop tests. We will present the application of agile software development in the project as well as methods that we applied to assure reliability on system level. For that purpose, a Reliability Growth Model, based on our CubeSat Failure Database, was adapted for the project.

[View Full Paper]

[*] Institute of Astronautics, Technical University of Munich, Boltzmannstrasse 15, 85748 Garching, Germany.
E-mail: martin.langer@tum.de.

IAA-AAS-CU-17-06-06
AAS 17-972

SPUTNIX EDUCATION: FROM SATELLITE MOCKUP TO CUBESAT LAUNCH

Zaynulla S. Zhumaev,[*] Anton L. Vlaskin,[†] Anton S. Sivkov[‡] and Roman N. Zharkikh[§]

In 2019 international WorldSkills competition will be held in Russia, Kazan. A new discipline "Space systems design" will move to international level. At the moment competition format was tested in various competitions inside Russia. Children under 18 years old competing in assembling and programming satellite mockup, meanwhile university students are assembling and coding ADCS and flight control algorithms on a real satellite by using industrial laboratory facility. [View Full Paper]

[*] Head of Department, Educational Department, SPUTNIX, Kauchkovaya str., 4, Skolkovo, Moscow Region, 143005, Russia.
[†] Chief Designer, R&D, SPUTNIX, Kauchkovaya str., 4, Skolkovo, Moscow Region, 143005, Russia.
[‡] CTO, R&D, SPUTNIX, Kauchkovaya str., 4, Skolkovo, Moscow Region, 143005, Russia.
[§] Project Manager, R&D, SPUTNIX, Kauchkovaya str., 4, Skolkovo, Moscow Region, 143005, Russia.

IAA-AAS-CU-17-06-07
AAS 17-973

DEVELOPMENT OF A FLEXIBLE NANOSATLLITE MISSION CONTROL SYSTEM USING AGILE DEVELOPMENT METHODOLOGY#

Richard Duke,[*] Brian Stewart,[†] Ben Taylor,[‡] Christopher P. Bridges,[§] Simon Fellowes[**] and Guglielmo S. Aglietti[††]

A key requirement for the Surrey Space Centre is to be able to support multiple missions at any one time in a low-cost environment with missions developed in short time scales. In this paper we describe the development of our in-house Mission Control System (MCS). The utilisation of an agile development methodology allows an early support capability, resulting in system availability during the build and test phase. This allows standard user interfaces for the full project lifecycle, resulting in lower familiarisation time. Testing time between ground and space segments is maximised resulting in a more robust system.

Reliability comes from placing an industry standard relational database at the core. User software and external interfaces are separated from mission-critical modules allowing rapid development with low risk. Automated code generation ensures compatibility between the mission control system and spacecraft on-board software, whilst streamlining implementation. The system has a flexible design allowing custom requirements for each mission, whilst keeping a clean standard interface to the user. Recent operational examples are discussed. [View Full Paper]

[*] Groundstation Manager, Surrey Space Centre, University of Surrey, Guildford, UK.
[†] Software Engineer, Surrey Space Centre, University of Surrey, Guildford, UK.
[‡] Project Engineer, Surrey Space Centre, University of Surrey, Guildford, UK.
[§] Lecturer, Surrey Space Centre, University of Surrey, Guildford, UK.
[**] Programme Manager, Surrey Space Centre, University of Surrey, Guildford, UK.
[††] Director, Surrey Space Centre, University of Surrey, Guildford, UK.

IAA-AAS-CU-17-06-09
AAS 17-974

LUNISAT ORBIT MAINTENANCE AND LOW-THRUST MANEUVERS*

Mauro Pontani,† Riccardo Di Roberto,‡ Paolo Teofilatto§ and Filippo Graziani**

Lunisat represents a next-generation microsatellite aimed at orbiting the Moon, and equipped with dispensers for the release of nanosatellites. This research is focused on orbital dynamics of the main microsatellite, and specifically addresses orbit maintenance and low-thrust maneuvers. Nonsingular equinoctial orbit elements are employed for orbit propagations, in conjunction with numerical averaging. This is a powerful technique for the numerical integration of the mean elements, and allows substantial computational improvements. Due to the masconian character of the lunar mass distribution, low altitude, near-circular lunar orbits are affected by a considerable number of harmonics of the Moon gravitational field. Thus, in the dynamical modeling a large number of harmonics are included, as well as the Earth and Sun perturbing influence as third bodies. Low-altitude lunar satellites turn out to impact the Moon surface after a few weeks or months. In case of unsatisfactory lifetime, two simple orbit maintenance strategies are evaluated, together with the related propellant budget. Moreover, minimum-time low-thrust transfers for reducing the orbit altitude are investigated, either for nanosatellite release or for the conclusive phase of the Lunisat mission, which finally terminates with the impact on the Moon surface. [View Full Paper]

† Assistant Professor, Department of Astronautical, Electrical, and Energy Engineering, Sapienza – University of Rome, Via Salaria 851, 00138 Rome, Italy.
‡ Astronautical Engineer, GAUSS S.r.l., Via Sambuca Pistoiese 70, 00138 Rome, Italy.
§ Professor, School of Aerospace Engineering, Sapienza – University of Rome, Via Salaria 851, 00138 Rome, Italy.
** Senior Professor and GAUSS S.r.l. President, GAUSS S.r.l., Via Sambuca Pistoiese 70, 00138 Rome, Italy.

POCKETQUBE

IAA-AAS-CU-17-07-01
AAS 17-975

FEMTO, PICO, NANO: OVERVIEW OF NEW SATELLITE STANDARDS AND APPLICATIONS

Chantal Cappelletti*

With the beginning of the "CubeSat Era" at the end of the 1990s, a revolution started in the field of satellites. When Prof. Twiggs and Prof. Puig Suari introduced the CubeSat specifications, nanosatellites were considered only as toys, unable to accomplish interesting mission goals. In the last two decades, CubeSats have become attractive not only for the academic world but also for small companies, industries and governmental institutions, showing that is possible to perform ambitious mission tasks using modern and easy-to-access solutions. The introduction of the CubeSat standard allowed also establishing a new market and the birth of small-sat companies that, starting from successful university projects based on CubeSat, have based their business on the design and manufacturing of CubeSat components. Without the introduction of the CubeSat standard this would have been impossible because there would not have been a market ready to receive these technologies. Furthermore, CubeSats allowed access to space to emerging countries and young generations, such as medium and high school students. The success of this platform encouraged other players to introduce and try to divulgate their own platforms, always trying to reduce weight and costs. Recently, new standards based on nano, pico and femto satellite platforms are becoming more popular and are showing their potentialities for future missions and applications. This paper gives an overview of CubeSats and other small satellites platforms, showing details of some recent missions. Limitations and benefits of every platform will be introduced and discussed. [View Full Paper]

* Assistant Professor, University of Nottingham, United Kingdom. E-mail: chantal.cappelletti@nottingham.ac.uk.

IAA-AAS-CU-17-07-03
AAS 17-976

A NEW ELECTRICAL POWER SYSTEM ARCHITECTURE FOR DELFI-PQ

M. S. Uludag,[*] S. Speretta,[†] J. Bouwmeester,[‡] E. Gill[§] and T. PerezSoriano[**]

Due to strict constraint regarding the volume of a PocketQube (50x50x50 mm) it is crucial to reduce the space that is consumed by the satellite bus subsystems. This paper focuses on a new architecture for the electrical subsystem in order to reduce its volume and increase the usage of empty surfaces inside the satellite. This increment in volume efficiency is going to be achieved by splitting the electrical power system on different surfaces and reducing the number of required voltage regulators. This modular approach is going to be realized by two main steps. First, removing the regulated bus from the satellite and delivering an unregulated bus to the subsystems. This will also give flexibility to other subsystems to use a voltage level which are more suitable for their requirements. Secondly, the internal side of the solar panels are going to be used for MPPT (maximum power point tracking) circuits, actually achieving a distributed power generation system, similar to ground-based solar power generation systems. The battery board is going to be a separate board with its dedicated communication lines and will also act as an interface between the solar panels and power distribution board via simple spring loaded connectors. This latter solution helps reducing dramatically the number of cables in the satellite, thus simplifying integration. The main objective of this work is turning the EPS(electrical power system) into a more flexible, scalable and volume-efficient system by a physical relocation of its components and a lean approach. The new EPS will be functionally and environmentally tested in a flight representative satellite model with the aim to verify its simplification in integration, assess its true performance as well as its reliability during launch vibration which especially includes spring-loaded connectors. [View Full Paper]

[*] Electronics Engineer, Faculty of Aerospace Engineering, Delft University of Technology, Delft, The Netherlands.
E-mail: m.s.uludag@tudelft.nl.
[†] Researcher Dr., Faculty of Aerospace Engineering, Delft University of Technology, Delft, The Netherlands.
E-mail: s.speretta@tudelft.nl.
[‡] Researcher, Faculty of Aerospace Engineering, Delft University of Technology, Delft, The Netherlands.
E-mail: jasper.bouwmeester@tudelft.nl.
[§] Prof., Faculty of Aerospace Engineering, Delft University of Technology, Delft, The Netherlands.
E-mail: E.K.A.Gill@tudelft.nl.
[**] Electronics Engineer, Faculty of Aerospace Engineering, Delft University of Technology Delft, The Netherlands.

MISSION ANALYSIS

IAA-AAS-CU-17-08-01
AAS 17-977

SGP4 PROPAGATION ERROR REDUCTION USING BIAS CORRECTION TECHNIQUES FOR CUBESATS

Volkan Ç. Özcan[*] and A. Rüstem Aslan[†]

This paper examines a bias correction method to decrease inaccuracies of SGP4 propagation for cubesats. Using only historical TLE data and TLE differencing methods, residuals of SGP4 propagation are fit into first and second order polynomials and exponential equations for various coordinate components from TEME, RSW, NTW, PQW coordinate systems as well as classical orbital, equinoctial and flight elements. A total of 36 different elements are used. The most appropriate type of fit equation for each test case is selected by comparing root mean squared errors. A bias detection concept based on confidence intervals is developed to programmatically understand if error behaviour is systematic (biased) in a certain coordinate element. It is shown that certain coordinate elements suffer systematic errors most of the time while error growth on others are seemingly random, although complete behaviour is different for each satellite. Estimations of error growth equations for coordinate elements that suffer systematic errors are used to modify SGP4 results to reduce propagation errors. Success, bias detection and error reduction rates of this bias correction operation are investigated with respect to propagation duration, fit span and goodness of fit. It has been found that drastically increasing the accuracy of SGP4 propagation (for both position and velocity predictions) is possible with efficient selection of coordinate elements and statistical properties. As a result, it is shown that for certain coordinate elements, if a systematic error growth is detected, results of SGP4 can be modified and modifications lead to improvements for more than 99% of the biased cases. It is shown that improvements can be small (less than 1%) or very large (up to 99%) with a mean of 52% error reduction for all coordinate elements.

[View Full Paper]

[*] MSc, Astronautical Engineering, Istanbul Technical University, 34469 Maslak, Istanbul, Turkey.
[†] Prof. Dr., Astronautical Engineering, Istanbul Technical University, 34469 Maslak, Istanbul, Turkey.

IAA-AAS-CU-17-08-02
AAS 17-978

TOM: A FORMATION FOR PHOTOGRAMMETRIC EARTH OBSERVATION BY THREE CUBESATS

Klaus Schilling,[*] Tristan Tzschichholz,[†] Iurii Motroniuk,[†] Anna Aumann,[†] Ilham Mammadov,[†] Oliver Ruf,[†] Christopher Schmidt,[‡] Nicolas Appel,[§] Alexander Kleinschrodt,[*] Sergio Montenegro[*] and Andreas Nüchter[*]

A formation of cooperating pico-satellites enables observation of target areas on the Earth's surface from different perspectives. Three-dimensional surface maps can this way be generated by photogrammetric methods and application of sensor data fusion approaches. This offers interesting application potential to characterize in Earth observation specific aspects, like ash clouds from volcano eruptions, damages after earthquakes, growth of city limits, ships on sea, …

This contribution addresses the preliminary pico-satellite system and the payload design, as well as formation flying technologies for coordination of the three TOM satellites to perform joint observations. The technology base focusses on networked control algorithms, using inter-satellite links and relative navigation approaches. Challenges address in particular the attitude and orbit control system at the size of a 3U-CubeSat in order to realize an appropriate pointing accuracy. For this purpose, miniature reaction wheels have been developed with specific high rotation speed as essential element of the attitude control system. The input precision for fine pointing of the control systems is achieved by using feature extraction from observation data.

Additionally, one of the TOM satellites houses an optical link to the ground, demonstrating the capability of a high-bandwidth downlink for future missions. The concepts for testing the formation's performance on ground by employing high precision turntables are addressed. Thus, TOM realizes in a limited budget frame an innovative pico-satellite formation mission for Earth observation applications. [View Full Paper]

[*] University Würzburg, Institute of Informatics, Am Hubland, 97074 Würzburg, Germany.
E-mail: schi@informatik.uni-wuerzburg.de.
[†] Zentrum für Telematik, Magdalene-Schoch-Str. 5, 97074 Würzburg, Germany.
[‡] DLR, Institute of Communications and Navigation, Münchner Straße 20, 82234 Weßling, Germany.
[§] Chair of Astronautics, Technical University of Munich, Boltzmannstr. 15, 85748 Garching, Germany.

SUBSYSTEMS

IAA-AAS-CU-17-09-02
AAS 17-979

CHANGING OF THE REQUIREMENTS AND BUSINESS MODELS FOR CUBESAT DEPLOYER

Stephan Roemer[*] and Thomas Hellwig[†]

The Cubesat community is changing fast during the last years. Not only on the technical side (e.g. size of the Cubesats) but also in the customer behavior and business activities. These changes have drastic effects on the requirements to the deployers as well as for the business models of the Cubesat deployer manufacturers. The paper shows how Astro- und Feinwerktechnik Adlershof GmbH is dealing with these challenges.

[View Full Paper]

[*] Astro- und Feinwerktechnik Adlershof GmbH, Albert Einstein Strasse 12, 12489 Berlin, Germany.
E-mail: s.roemer@astrofein.com.
[†] Dr., Astro- und Feinwerktechnik Adlershof GmbH, Albert Einstein Strasse 12, 12489 Berlin, Germany.
E-mail: t.hellwig@astrofein.com.

IAA-AAS-CU-17-09-03
AAS 17-980

SPOOQY-1, A CUBESAT TO DEMONSTRATE AN ENTANGLED PHOTON LIGHT SOURCE

Xueliang Bai,[*] Md. Tanvirul Islam,[†] Karthik Ilangovan,[†] Hong Nhung Nguyen,[†] Rakhitha Chandrasekara,[†] Zhongkan Tang,[†] Zongsheng Tang,[†] Simon Barraclough,[‡] Douglas Griffin,[‡] Russell Boyce,[‡] and Alexander Ling[†,§]

Quantum Key Distribution (QKD) is a technology that can distribute private encryption keys between two parties with strong security assurances underpinned by quantum mechanics. Entanglement-based QKD is one of the strongest forms of QKD. Performing QKD using satellites can overcome the range constraints of ground-based QKD systems imposed by atmospheric losses or attenuation in optical fibres. Recently, satellite-based QKD has been demonstrated by the Chinese Academy of Sciences' 630kg Micius satellite. We are developing similar, but highly-miniaturised QKD, technologies targeted at CubeSats. Our first technology demonstration, the first generation of our quantum light source is currently in-orbit on board of the Galassia 2U CubeSat. Meanwhile, SpooQy-1 is a 3U CubeSat currently being built at CQT that aims to validate the space-worthiness of our next generation entangled photon light source and demonstrate a radio beacon of quantum random numbers. In future missions our miniaturised entangled photon light sources can be combined with high precision Pointing, Acquisition and Tracking System (PATS) and optical communication links to enable a global QKD network with small satellites. In this paper, we will discuss the details and challenges of the SpooQy-1 design as well as future prospects for CubeSat-based Quantum Key Distribution. [View Full Paper]

[*] Corresponding Author, Centre for Quantum Technologies, National University of Singapore, Block S 15, 3 Science Drive 2, Singapore, 117543. E-mail: cqtbx@nus.edu.sg.
[†] Centre for Quantum Technologies, National University of Singapore, Block S 15, 3 Science Drive 2, Singapore, 117543.
[‡] University of New South Wales Canberra, School of Engineering and Information Technology, PO Box 7916, Canberra, ACT 2610, Australia.
[§] Department of Physics, National University of Singapore, 2 Science Drive 3 Blk S12, Level 2, Singapore 117551, Singapore.

IAA-AAS-CU-17-09-04
AAS 17-981

NEW THREE DIMENSIONAL PHASED ARRAY ANTENNA FOR SPACE COMMUNICATIONS

Nobuyuki Kaya*

An Indian Polar Satellite Launch Vehicle lifted off on Feb. 14, 2017, carrying 104 satellites on a single rocket. All the 104 satellites must be communicated with the ground stations for the control and data acquisition. The ground stations are required to communicate simultaneously with so many satellites. We are newly developing a ground receiving station using an active phased array antenna. The purpose of this study is to build them around the world in order to realize a worldwide receiving antenna network to communicate simultaneously with several satellites and to get information in real-time through the internet anytime and anywhere. We have already built the first pilot model of the receiving antenna at the frequency of X-band and succeeded in receiving the signal from the satellites. We will explain the newly developed pilot receiving antenna and the receiving data from the satellites. [View Full Paper]

* Professor Emeritus, Kobe University, 1-1 Rokkodaicho, Nada, Kobe 657-8501, Japan.
CEO, WaveArrays, Inc.

IAA-AAS-CU-17-09-06
AAS 17-982

A SPACE-RATED SOFT IP-CORE COMPATIBLE WITH THE PIC® HARDWARE ARCHITECTURE AND INSTRUCTION SET

Luigi Blasi, Antonio Mastrandrea, Francesco Menichelli and Mauro Olivieri*

Radiation hardening for coping with cosmic-ray-induced faults in electronic equipment has always been a central topic of hardware/software development for aerospace missions. This work presents the design, verification and validation of an 8-bit space-rated RISC MCU FPGA soft-core, featuring hardware architecture and instruction set architecture full compliance with Microchip® PICmicro Midrange MCU. The MCU is code compatible with programs compiled with standard Microchip® tools and has been validated on a custom breadboard to qualify the design for the utilization in harsh space environment.

The MCU features an 8-bit fault-tolerant processing core, two 8-bit GPIOs ports, an 8-bit SPI module, an 8-bit UART, a hard-coded non-maskable custom Watch-dog Timer (WDT), and an 8-bit Timer Module. Moreover, it provides two interrupt sources detecting faults inside the MCU Core. The development is compliant with standards ECSS-Q-ST-60-02C "Space product assurance: ASIC and FPGA development" and ECSS-Q-HB-60-02A "Space product assurance: Techniques for radiation effects mitigation in ASICs and FPGAs handbook".

The design features a selection of Radiation-Hardening-By-Design techniques to implement intrinsic and cost effective hardware fault-tolerance, namely Local Triple Modular Redundancy at register/gate level, Error Detection And Correction SEC-DED Hamming codes in memory cells, and Monostable WDT to reset the whole system after a detection of a Functional Interrupt. To emphasize application-tailored hardware cost, the program memory has been implemented in the FPGA LUT cells. The MCU has been synthesized on an Intel-Altera Cyclone IV FPGA device and a Microsemi RTAX-S 1000 rad-hard FPGA device. In both cases the maximum clock frequency is over 20 MHz, i.e. the original PICmicro frequency. An experimental test in artificially radiated operating environment is under development. The target applications for the MCU are low-cost program space missions based on CubeSat deployment. In particular, the on-board primary or secondary payload tasks, that are usually control and signal processing applications (e.g. technology demonstrator and university programs), can be implemented by the proposed fault-tolerant soft-IP core. [View Full Paper]

* Department of Information Engineering, Electronics and Telecommunications, Sapienza University of Rome, Italy.

IAA-AAS-CU-17-09-08
AAS 17-983

CENTER OF MASS COMPENSATION OF A NANOSATELLITE TESTBED BASED ON THE EXTENDED KALMAN FILTER

Rodrigo Cardoso da Silva,[*] Renato Alves Borges,[†] Simone Battistini[‡] and Chantal Cappelletti[§]

Before sending nanosatellites to the space, various tests must be taken to ensure that all of its systems are fail-proof. With this purpose, testbeds are developed to simulate the peculiarities of the space environment. The Laboratory of Aerospace Science and Innovation (LAICA) of the University of Brasília, aiming to have a platform capable of testing nanosatellites, is developing a testbed whose purpose is to simulate some of these peculiarities, such as absence of gravitational torque. This is accomplished by submitting the testbed to algorithms that makes the distance between its center of rotation (CR) and its center of mass (CM) as close as possible to zero. This balancing procedure, often called CM offset compensation, may be implemented in various manners. This work presents the insights of one of such techniques, which is based on the Extended Kalman Filter (EKF). For this, the dynamic modeling, the algorithm principles and simulation results are presented. [View Full Paper]

[*] University of Brasília, Brazil. E-mail: rcsilva@lara.unb.br.
[†] University of Brasília, Brazil. E-mail: raborges@aerospace.unb.br.
[‡] University of Brasília, Brazil. E-mail: simone.battistini@aerospace.unb.br.
[§] University of Nottingham, United Kingdom, NG7 2RD, chantal.cappelletti@nottingham.ac.uk

IAA-AAS-CU-17-09-10
AAS 17-984

GAUSS T&C RADIOS FOR MICROSATELLITES

Aitor Conde Rodríguez,[*] Marco Truglio,[†] Filippo Graziani,[‡] Salvatore Paiano[§] and Augusto Nascetti[**]

During the last years, GAUSS Srl has operated several satellites using commercially available radios on the satellite platforms and on ground stations. GAUSS has designed T&C radios to better meet its own needs, taking into account the best characteristics of the used radios and solving or minimizing the problems found on those radios.

From this experience, GAUSS designed and built two new UHF radios (a Low Power and a High Power version) together with a set of accessories to command and operate them. These two radios have efficiencies over 50% and allow great flexibility and reconfigurability in flight, always keeping in mind reliability from the hardware and software points of view.

Alongside the radios also a fully functional PC software has been developed in order to use it as a frontend to configure and command the radio.

Currently both the UHF radios are available on the market, while GAUSS is testing the VHF version of the radio and designing a new S-Band transmitter for CubeSats.

[View Full Paper]

[*] G.A.U.S.S. Srl, Italy. E-mail: aitor.conde@gaussteam.com.
[†] G.A.U.S.S. Srl, Italy. E-mail: marco.truglio@gaussteam.com.
[‡] G.A.U.S.S. Srl, Italy. E-mail: filippo.graziani@gaussteam.com.
[§] G.A.U.S.S. Srl, Italy. E-mail: salvatore.paiano@gaussteam.com.
[**] "Sapienza" University of Rome, Italy. E-mail: augusto.nascetti@uniroma1.it.

IAA-AAS-CU-17-09-11
AAS 17-985

HERCULES:
A RELIABLE OBC SAVING SPACE ON YOUR CUBESAT

Marco Truglio,[*] Aitor Conde Rodriguez[†] and Filippo Graziani[‡]

Based on the experience gained with the GAUSS "ABACUS" on board computer (OBC), which has currently reached three-and-a-half years of continuous in orbit operations, GAUSS is now presenting a new OBC named "Hercules". Hercules has been designed to be a hi-reliable, fault-tolerant on board computer using advanced COTS components such as a Lockstep ARM processor intrinsically designed to be used in safety and critical applications. The CPU is part of the Texas Instruments Hercules family processors from which this OBC takes its name. The Lockstep CPU architecture used consists in a dual ARM Cortex-R4F laying on the same chip and processing the same tasks. A CPU embedded core-compare-module compares cycle by cycle the results of the two cores, detecting fault events and entering the CPU in a defined safe mode to avoid risks and allowing to adopt countermeasures to resume the system functionality. The OBC Hercules has several fault tolerant features such as redundant IMU sensors and an intrinsically radiation tolerant FRAM memory. Another feature of Hercules is the possibility to add, on its own board, a customer daughter-board interconnected with analog channels, general purposes I/Os and serial communication ports, making it suitable to be used also as a payload computer. One of the daughter-board connectors is directly compatible with the GAUSS Satellite Radio which can be placed on the same board of the OBC allowing to save space inside the satellite and providing a powerful and multifunctional system with a high integration ratio. [View Full Paper]

[*] G.A.U.S.S. Srl, Italy. E-mail: marco.truglio@gaussteam.com.
[†] G.A.U.S.S. Srl, Italy. E-mail: aitor.conde@gaussteam.com.
[‡] G.A.U.S.S. Srl, Italy. E-mail: filippo.graziani@gaussteam.com.

NEW PERSPECTIVES

IAA-AAS-CU-17-10-01
AAS 17-986

THE CONSTELLATION FOR MARS POSITION ACQUISITION USING SMALL SATELLITES: CUBESAT DESIGN FEASIBILITY AND CHALLENGES

Patrick Kelly[*] and Riccardo Bevilacqua[†]

A satellite constellation concept called the Constellation for Mars Position Acquisition using Small Satellites (COMPASS) is introduced as a communications and navigation network for Mars. The constellation will bolster user operation and capability for future Mars missions. This paper outlines the constellation and examines top level feasibility and design challenges for the satellite hardware. Using existing satellite components made commercially available, such a satellite may be realizable but the requirements of the proposed design will challenge the capabilities of the contemporary CubeSat.

[View Full Paper]

[*] Graduate Student, Mechanical and Aerospace Engineering, University of Florida, 939 Sweetwater Drive, MAE-A 211, Gainesville, Florida 32611, USA.
[†] Associate Professor, Mechanical and Aerospace Engineering, University of Florida, 939 Sweetwater Drive, MAE-A 308, Gainesville, Florida 32611, USA.

IAA-AAS-CU-17-10-02
AAS 17-987

OPTIMAL FORMATION INSPECTION USING SMALL SPACECRAFT

Andrea Caruso,[*] Giovanni Mengali[†] and Alessandro A. Quarta[‡]

This paper presents an optimization method capable of determining the optimal relative trajectory of a CubeSat used to perform on-orbit inspections of each member of a spacecraft formation. The trajectory of the CubeSat relative to the formation is obtained by solving the linearized Hill's equations. The inspector spacecraft is assumed able to perform a set of impulsive manoeuvres, and the objective function to minimize is the total velocity change required to carry out a rendezvous manoeuvre with all of the spacecraft in the formation. Different global optimization algorithms are used to find the optimal relative trajectory and the results are then refined using local optimization methods. This approach can find a solution that is close to the global minimum of the cost function. The method developed in this work is applied to different mission scenarios, including two-dimensional and three-dimensional formation structures. [View Full Paper]

[*] Ph.D. Student, Department of Civil and Industrial Engineering, Via G. Caruso n.8, I-56122, Pisa, Italy.
E-mail: andrea.caruso@ing.unipi.it.
[†] Professor, Department of Civil and Industrial Engineering, Via G. Caruso n.8, I-56122, Pisa, Italy.
E-mail: g.mengali@ing.unipi.it.
[‡] Associate Professor, Department of Civil and Industrial Engineering, Via G. Caruso n.8, I-56122, Pisa, Italy.
E-mail: a.quarta@ing.unipi.it.

IAA-AAS-CU-17-10-03
AAS 17-988

PROJECT OF THE TECHNOLOGY TESTING OF THE FORMATION FLIGHT OF LOW-ORBIT NANOSATELLITES

Igor Belokonov[*] and Denis Avariaskin[†]

Space Research Department of Samara University is currently working on the design of the nanosatellite SamSat-M containing propulsion system. Nanosatellite is aimed to test the maneuvering technology on orbit and to test the technology of small space debris inspection. It is supposed that the formation will contain only two nanosatellites. The first one (SamSat-M with the propulsion system) will test inspectoral movement and the technology of keeping of the certain distance to the second one and de-orbiting. The second nanosatellite will be a target for the first one and, at the same time, it will have its own scientific experiment. It is supposed that these nanosatellites will be launched at low orbit of 300-400 km. It is also planned to use existing low-orbit communication satellite systems like Iridium and Globalstar to provide the intersatellite link. [View Full Paper]

[*] Professor, Space Research Department, Samara National Research University, Moskovskoe shosse 34, Samara 443086, Russian Federation.
[†] Senior Lecturer, Space Research Department, Samara National Research University, Moskovskoe shosse 34, Samara 443086, Russian Federation.

IAA-AAS-CU-17-10-05
AAS 17-989

SPUTNIX ORBICRAFT PRO – COMPLETE CUBESAT KIT BASED ON RASPBERRY-PI

Zaynulla Zhumaev,[*] Roman Zharkikh,[†] Alexander Purikov,[‡] Veronica Shteyngardt[§] and Anton Sivkov[**]

This article describes a new CubeSat platform kit from Russian company SPUTNIX, including the reasons urged the development, general description, features and technical parameters of the platform subsystems. The kit could be interesting for those educational and scientific groups which are involved in space science and elaboration, especially using CubeSat technologies. Besides kit overview, the article could be helpful in choosing appropriate technical solutions for future developments. Also it provides possible purposes of usage and some real implementation cases in educational satellite activities of MSU and MIEM universities. [View Full Paper]

[*] Head of Educational Department, SPUTNIX, Russia. E-mail: zaynulla.zhumaev@sputnix.ru.
[†] Lead Engineer, R&D, SPUTNIX, Russia. E-mail: roman.zharkikh@sputnix.ru.
[‡] Lead Engineer, R&D, SPUTNIX, Russia. E-mail: aleksandr.purikov@sputnix.ru.
[§] Engineer, SPUTNIX, Russia. E-mail: veronika.shteyngardt@sputnix.ru.
[**] Acting Technical Director, SPUTNIX, Russia. E-mail: anton.sivkov@sputnix.ru.

IAA-AAS-CU-17-10-06
AAS 17-990

WILL CUBESATS INTRODUCE A MOORE'S LAW TO SPACE SCIENCE MISSIONS?

René W. Fléron*

The advent of the CubeSat standard has changed the way space engineering is taught throughout the world. Engineering students are introduced to hands on space projects at unprecedented scales. This in terms has led to the production of vast numbers of small spacecrafts which are ultimately launched into low earth orbit. By necessity these spacecrafts are built primarily using of the shelf components. This mechanism thus tests COTS components, miniaturized systems and new designs in large numbers and gives flight heritage to the successful ones. Parallel to teaching there's a growing industry of small space companies likewise eager to develop, test and fly new space technology. This also increases the pool of space hardware with flight heritage.

Historically the space business has been very conservative in terms of technology renewal preferring well proven technology and systems. Thus spacecraft sizes – though with a large spread – have remained constant. For many scientific missions size directly impacts the science returns, however lighter probes could potentially fly faster and thus go closer. Likewise, smaller unit mass allows for swarms potentially allowing for new science.

Review of space missions indicates that some CubeSat technology adaptation is taking place, introducing a variety of Moore's law to space science. Moore's law presents a single parameter; the doubling time of transistor density on IC's. The work presented here shows that size reduction cannot by described by a single parameter but must also take into account the mission scenario. [View Full Paper]

* M.Sc.E., DTU Space, Technical University of Denmark, Elektrovej Building 327, DK-2800 Kgs. Lyngby, Denmark.

IAA-AAS-CU-17-10-08
AAS 17-991

A CONSTELLATION OF CUBESATS FOR AMAZON RAINFOREST DEFORESTATION MONITORING

Lucas M. B. da Silva,[*] Fernanda P. Cyrne,[*] Iohana G. G. de Siqueira,[*] Pedro Henrique Beghelli[*] and Rafael da S. Rodrigues[*]

This article presents the results of a pre-phase A study conducted by undergraduate students from Aerospace Engineering at University of Brasilia. The mission consists on use a constellation of CubeSats to make observations of the deforestation areas in the Brazilian Legal Amazon. The main characteristics of this mission is to have good spatial resolution and revisit time using a sun-synchronous orbit, which is suitable for the Earth observation. To accomplish the design of this mission, the subsystems of the satellite, such as the payload and the bus were designed/chosen to fit all the requirements. The orbit was also designed, i.e. all the main characteristics of the orbit were calculated analytically and simulated by software. [View Full Paper]

[*] Student, University of Brasilia, Area especial de indstria. Projeo A, UnB - DF - 480 Gama Leste, Braslia, Distrito Federal, Brazil, zip code: 72444-240.

LECTURES

IAA-AAS-CU-17-11-03
AAS 17-992

FROM CLASSICAL THEORY TO INNOVATION PRACTICE. IN MEMORY OF PROFESSOR VLADIMIR BELETSKY

Mikhail Ovchinnikov*

The paper is devoted to memories of Professor Vladimir Beletsky (1930-2017) and it surveys the main results of his studies in area of spaceflight dynamics starting from pioneering works in attitude and orbital dynamics been used in the beginning of space exploration era and continues in demand of nowadays pro-jects. [View Full Paper]

* Professor, Dr. of Sci., IAA (M2), Attitude Control & Guidance Division, Keldysh Institute of Applied Mathematics RAS, Miusskaya Sq., 4, Moscow 125047, Russia.

IAA-AAS-CU-17-11-05
AAS 17-993

DYNAMICS AND CONTROL OF SPACE TETHERS

A. A. Burov,[*] A. D. Guerman,[†] I. I. Kosenko[‡] and V. I. Nikonov[§]

We study attitude dynamics of a slender spacecraft with variable mass distribution in an elliptic orbit. Equations of motion are derived. Steady motions are investigated within appropriate assumptions related to the mass redistribution control. Chaotic behaviour and stable periodic motions are studied via numerical experiments. [View Full Paper]

[*] Federal Research Center "Computer Science and Control", Vavilova St. 40, Moscow 119333, Russia; National Research University "Higher School of Economics", Myasnitskaya St. 20, Moscow 101000, Russia.
[†] Centre for Mechanical and Aerospace Science and Technologies, University of Beira Interior, Convento de Sto. Antonio, 6201-001 Covilhã, Portugal.
[‡] Moscow Aviation Institute (National Research University) Volokolamskoe chaussée 4, Moscow 125993, Russia; Federal Research Center "Computer Science and Control", Vavilova St. 40, Moscow 119333, Russia.
[§] Centre for Mechanical and Aerospace Science and Technologies, University of Beira Interior, Convento de Sto. Antonio, 6201-001 Covilhã, Portugal. (On leave from FRC "Computer Science and Control" of Russian Academy of Sciences).

IAA-AAS-CU-17-11-06
AAS 17-994

ON THE BELETSKY EQUATION

Paolo Teofilatto*

This paper was presented at the Beletsky Session of the 4th IAA Conference on University Satellite Missions and CubeSat Workshop held in Rome and dedicated to the memory of the great Russian mathematician and pioneer scientist of Astrodynamics. The paper is concentrated to the so called Beletsky equation, concerning the attitude motion of a satellite under gravity gradient torque. In fact Professor Beletsky dealt with many aspects of astrodynamics giving deep and useful contributions and establishing some theoretical basis for the development of the space activity in USSR, then it looks like disappointing that his name is so strictly linked to a simple equation such as

$$(1 + e \cos \theta)\phi'' - 2e \sin \theta \, \phi' + \alpha \sin \phi = 4e \sin \theta$$

describing the planar attitude motion of a satellite in elliptic orbit: The reason of the enormous success of the Beletsky equation is just in its simplicity and in the interesting characteristics of its phase space, where regular and periodic solutions are merged together with unstable and chaotic solutions. This is not unusual for a non linear differential equation, but in the Beletsky equation these characteristics can be understood in deep and the transition to chaos can be checked by various indices, so many researchers were attracted by the results that can be achieved from the abstract point of view of dynamical system theory while obtaining output of concrete interest in space applications. Most of the content presented in this paper is derived from my PhD thesis "Chaos in Astrodymanics" presented at the School of Aerospace Engineering of Rome in 1991 and developed under the supervision of Professor Filippo Graziani. [View Full Paper]

* Dean of the School of Aerospace Engineering, Sapienza University of Rome, Via Salaria 851, 00138 Rome, Italy.

INDEX

NUMERICAL INDEX*

VOLUME 163 ADVANCES IN THE ASTRONAUTICAL SCIENCES, FOURTH IAA CONFERENCE ON UNIVERSITY SATELLITE MISSIONS AND CUBESAT WORKSHOP (2017)

(Fourth IAA Conference on University Satellite Missions and CubeSat Workshop Dynamics and Control of Space Systems, 4–7 December 2017, Rome, Italy)

* Unless otherwise indicated all papers appear in Volume 163, *Advances in the Astronautical Sciences*.

AAS 17-946 NANOSATC-BR2, 2 Unit CubeSat, Power Analysis, Solar Flux Prediction, Design and 3D Printing of the Flight Model from the UFSM & INPE's NANOSATC-BR, CubeSat Development Program, Lorenzzo Quevedo Mantovani, Rodrigo Passos Marques, Alex Müller, Eduardo Xavier Barreto, André Luís da Silva, Otávio dos Santos Cupertino Durão, Fátima Mattielo Francisco and Nelson Jorge Schuch (IAA-AAS-CU-17-03-03)

AAS 17-947 Small Satellites, CubeSats and University Satellites in Africa and Their Missions, Mohamed B. Argoun and G. Mansour (IAA-AAS-CU-17-03-05)

AAS 17-948 The AlSat-1N CubeSat Mission, Ben Taylor, Chiara Massimiani, Richard Duke, Brian Stewart, Simon Fellowes, Christopher P. Bridges and Guglielmo S. Aglietti (IAA-AAS-CU-17-03-06)

AAS 17-949 An Analytical Approach to Autonomous Optical Navigation for a CubeSat Mission to a Binary Asteroid System, Dario Modenini, Marco Zannoni, Riccardo L. Manghi and Paolo Tortora (IAA-AAS-CU-17-03-07)

AAS 17-950 Technical Knowledge Gaps in Niche Use Cases of Small Satellites, David Earle, Rayan Imam, Olga Mamoutova, Jorge Monteiro, Siddhesh Naik, Yasith Ramawickrama, Daria Stepanova, Kiran Tikare, Alejandro Lopez and Patricia Randazzo (IAA-AAS-CU-17-03-09)

AAS 17-951 Aalto-1 Satellite First Months in Orbit, P. Niemelä, J. Praks, B. Riwanto, A. Kestilä, A. Näsilä, N. Jovanovic, T. Tikka, N. Silva, H. Leppinen, R. Vainio and P. Janhunen (IAA-AAS-CU-17-03-10)

AAS 17-952 Mission Planning Web Application for Earth Observation Missions, W.-T. Loke, R. H.-Y. Ng, J. Z.-Q. Lim, A. N. Nikicio, Z.-N. Ng and C.-H. Goh (IAA-AAS-CU-17-03-13)

AAS 17-953 Flight Results of the nSight-1 QB50 CubeSat Mission, L. Visagie, W. H. Steyn, H. Burger and D. F. Malan (IAA-AAS-CU-17-03-14)

AAS 17-954 A Small Platform Application for Close Inspection of an Out of Control Satellite, Renato Volpe, Marco Carpentiero and Angelo Stolfi (IAA-AAS-CU-17-03-15)

AAS 17-955 Drag De-Orbit Device (D3) Mission for Validation of Controlled Spacecraft Re-Entry Using Aerodynamic Drag, Sanny Omar, David Guglielmo and Riccardo Bevilacqua (IAA-AAS-CU-17-04-01)

AAS 17-956 Plasma Brake Approximate Trajectory. Part I: Geocentric Motion, Lorenzo Niccolai, Marco Bassetto, Alessandro A. Quarta and Giovanni Mengali (IAA-AAS-CU-17-04-03)

AAS 17-957 Plasma Brake Approximate Trajectory. Part II: Relative Motion, Marco Bassetto, Lorenzo Niccolai, Alessandro A. Quarta and Giovanni Mengali (IAA-AAS-CU-17-04-04)

AAS 17-958 The InflateSail CubeSat Mission – The First European Demonstration of Drag-Sail De-Orbiting, Craig Underwood, Andrew Viquerat, Mark Schenk, Simon Fellowes, Ben Taylor, Chiara Massimiani, Richard Duke, Brian Stewart, Chris Bridges, Davide Masutti and Amandine Denis (IAA-AAS-CU-17-04-05)

AAS 17-959 CubeSat Technology in Service to Larger Active Debris Removal Missions, Jason Forshaw, Ben Taylor, Richard Duke, Simon Fellowes, Brian Stewart and Guglielmo S. Aglietti (IAA-AAS-CU-17-04-06)

AAS 17-960 Efficient Star Identification Algorithm for Nanosatellites in Harsh Environment, Vincenzo Schiattarella, Dario Spiller and Fabio Curti (IAA-AAS-CU-17-05-02)

AAS 17-961 Gain Selection for Attitude Stabilization of Earth-Pointing Spacecraft Using Magnetorquers, Fabio Celani (IAA-AAS-CU-17-05-03)

AAS 17-962 Residual Magnetic Torque Estimation for Nano-Satellite, Kai Yoshihara, Masahiko Yamazaki and Yasuyuki Miyazaki (IAA-AAS-CU-17-05-05)

AAS 17-963 Design and Development of an Active Magnetic Actuator for Attitude Control System of Nanosatellites, Igor Seiiti Kinoshita Ishioka, Simone Battistini, Chantal Cappelletti and Renato Alves Borges (IAA-AAS-CU-17-05-06)

AAS 17-964 Microsatellite Mock-Up Control Using Reinforcement Learning Technique, Danil Ivanov, Dmitry Roldugin, Mikhail Ovchinnikov and Mark Shachkov (IAA-AAS-CU-17-05-07)

AAS 17-965 Lyapunov Based Attitude Control Algorithm for Slew Maneuvers with Restrictions, Yaroslav Mashtakov, Mikhail Ovchinnikov, Stepan Tkachev and Mark Shachkov (IAA-AAS-CU-17-05-08)

AAS 17-966 Development of a Hardware-in-the-Loop Test Platform for Nanosatellites ADCS Integrated with an UKF, João Victor Lopes de Loiola, Lucas Meneses Bandeira da Silva, Simone Battistini, Chantal Cappelletti and Renato Alves Borges (IAA-AAS-CU-17-05-09)

AAS 17-967 Saving Mission Yet to be Launched: Tight Schedule for an Unexpected Project, D. S. Roldugin, M. Yu. Ovchinnikov, D. S. Ivanov, M. O. Shachkov, M. D. Koptev, O. A. Pantsyrnyi and I. O. Fedorov (IAA-AAS-CU-17-06-01)

AAS 17-968 Building Low Cost CubeSat: Guidelines and Design Approach, Ibtissam Latachi, Tajjeeddine Rachidi, Mohammed Karim and Ahmed Hanafi (IAA-AAS-CU-17-06-02)

AAS 17-969 CubeSat Constellation Deployment Strategies, Christophe Vakaet and Alessandra Menicucci (IAA-AAS-CU-17-06-03)

AAS 17-970 Development of Modular 3U CubeSat Standard Platform and its Application to KAUSAT-5, Sua Song, Hongrae Kim and Young-Keun Chang (IAA-AAS-CU-17-06-04)

AAS 17-971 MOVE-II The Munich Orbital Verification Experiment II, Martin Langer, Florian Schummer, Nicolas Appel, Thomas Gruebler, Katja Janzer, Jonis Kiesbye, Lucas Krempel, Alexander Lill, David Messmann, Sebastian Rueckerl and Michael Weisgerber (IAA-AAS-CU-17-06-05)

AAS 17-972 SPUTNIX Education: From Satellite Mockup to CubeSat Launch, Zaynulla S. Zhumaev, Anton L. Vlaskin, Anton S. Sivkov and Roman N. Zharkikh (IAA-AAS-CU-17-06-06)

AAS 17-973 Development of a Flexible Nanosatllite Mission Control System Using Agile Development Methodology#, Richard Duke, Brian Stewart, Ben Taylor, Christopher P. Bridges, Simon Fellowes and Guglielmo S. Aglietti (IAA-AAS-CU-17-06-07)

AAS 17-974 Lunisat Orbit Maintenance and Low-Thrust Maneuvers, Mauro Pontani, Riccardo Di Roberto, Paolo Teofilatto and Filippo Graziani (IAA-AAS-CU-17-06-09)

AAS 17-975 Femto, Pico, Nano: Overview of New Satellite Standards and Applications, Chantal Cappelletti (IAA-AAS-CU-17-07-01)

AAS 17-976 A New Electrical Power System Architecture for Delfi-PQ, M. S. Uludag, S. Speretta, J. Bouwmeester, E. Gill and T. PerezSoriano (IAA-AAS-CU-17-07-03)

AAS 17-977 SGP4 Propagation Error Reduction Using Bias Correction Techniques for CubeSats, Volkan Ç. Özcan and A. Rüstem Aslan (IAA-AAS-CU-17-08-01)

AAS 17-978 TOM: A Formation for Photogrammetric Earth Observation by Three CubeSats, Klaus Schilling, Tristan Tzschichholz, Iurii Motroniuk, Anna Aumann, Ilham Mammadov, Oliver Ruf, Christopher Schmidt, Nicolas Appel, Alexander Kleinschrodt, Sergio Montenegro and Andreas Nüchter (IAA-AAS-CU-17-08-02)

AAS 17-979 Changing of the Requirements and Business Models for CubeSat Deployer, Stephan Roemer and Thomas Hellwig (IAA-AAS-CU-17-09-02)

AAS 17-980 SpooQy-1, A CubeSat to Demonstrate an Entangled Photon Light Source, Xueliang Bai, Md. Tanvirul Islam, Karthik Ilangovan, Hong Nhung Nguyen, Rakhitha Chandrasekara, Zhongkan Tang, Zongsheng Tang, Simon Barraclough, Douglas Griffin, Russell Boyce and Alexander Ling (IAA-AAS-CU-17-09-03)

AAS 17-981 New Three Dimensional Phased Array Antenna for Space Communications, Nobuyuki Kaya (IAA-AAS-CU-17-09-04)

AAS 17-982 A Space-Rated Soft IP-Core Compatible with the PIC® Hardware Architecture and Instruction Set, Luigi Blasi, Antonio Mastrandrea, Francesco Menichelli and Mauro Olivieri (IAA-AAS-CU-17-09-06)

AAS 17-983 Center of Mass Compensation of a Nanosatellite Testbed Based on the Extended Kalman Filter, Rodrigo Cardoso da Silva, Renato Alves Borges, Simone Battistini and Chantal Cappelletti (IAA-AAS-CU-17-09-08)

AAS 17-984 GAUSS T&C Radios for Microsatellites, Aitor Conde Rodríguez, Marco Truglio, Filippo Graziani, Salvatore Paiano and Augusto Nascetti (IAA-AAS-CU-17-09-10)

AAS 17-985 Hercules: A Reliable OBC Saving Space on Your CubeSat, Marco Truglio, Aitor Conde Rodriguez and Filippo Graziani (IAA-AAS-CU-17-09-11)

AAS 17-986 The Constellation for Mars Position Acquisition Using Small Satellites: CubeSat Design Feasibility and Challenges, Patrick Kelly and Riccardo Bevilacqua (IAA-AAS-CU-17-10-01)

AAS 17-987 Optimal Formation Inspection Using Small Spacecraft, Andrea Caruso, Giovanni Mengali and Alessandro A. Quarta (IAA-AAS-CU-17-10-02)

AAS 17-988 Project of the Technology Testing of the formation Flight of Low-Orbit Nanosatellites, Igor Belokonov and Denis Avariaskin (IAA-AAS-CU-17-10-03)

AAS 17-989 SPUTNIX OrbiCraft Pro – Complete CubeSat Kit Based on Raspberry-Pi, Zaynulla Zhumaev, Roman Zharkikh, Alexander Purikov, Veronica Shteyngardt and Anton Sivkov (IAA-AAS-CU-17-10-05)

AAS 17-990 Will CubeSats Introduce a Moore's Law to Space Science Missions?, René W. Fléron (IAA-AAS-CU-17-10-06)

AAS 17-991 A Constellation of CubeSats for Amazon Rainforest Deforestation Monitoring, Lucas M. B. da Silva, Fernanda P. Cyrne, Iohana G. G. de Siqueira, Pedro Henrique Beghelli and Rafael da S. Rodrigues (IAA-AAS-CU-17-10-08)

AAS 17-992 From Classical Theory to Innovation Practice. In Memory of Professor Vladimir Beletsky, Mikhail Ovchinnikov (IAA-AAS-CU-17-11-03)

AAS 17-993 Dynamics and Control of Space Tethers, A. A. Burov, A. D. Guerman, I. I. Kosenko and V. I. Nikonov (IAA-AAS-CU-17-11-05)

AAS 17-994 On the Beletsky Equation, Paolo Teofilatto (IAA-AAS-CU-17-11-06)

AUTHOR INDEX