First IAA/AAS SciTech Forum on SPACE FLIGHT MECHANICS AND SPACE STRUCTURES AND MATERIALS

Front Cover Illustration:

The illustration represents the monument for Yury Gagarin which is located on Gagarin square in Moscow against the background of Earth view from space. Credit: Academy of Engineering, RUDN University.

First IAA/AAS SciTech Forum on SPACE FLIGHT MECHANICS AND SPACE STRUCTURES AND MATERIALS

Volume 170
ADVANCES IN THE ASTRONAUTICAL SCIENCES

Edited by
Yury N. Razoumny
Filippo Graziani
Anna D. Guerman
Jean-Michel Contant

Proceedings of the First IAA/AAS SciTech Forum on Space Flight Mechanics and Space Structures and Materials, 13–15 November 2018, RUDN University, Moscow, Russia

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 2020

Library of Congress Card No. 57-43769

ISSN 0065-3438

ISBN 978-0-87703-663-0 (Hard Cover Plus CD ROM)
ISBN 978-0-87703-664-7 (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.

CONTENTS

IAA/AAS Conference on Space Structures and Materials

FOREWORD

This volume of the Series *Advances in the Astronautical Sciences* is dedicated to the IAA/AAS SciTech Forum on Space Flight Mechanics and Space Structures and Materials (IAA/AAS SciTech Forum) held on November 13-15, 2018 by the International Academy of Astronautics (IAA) and Peoples' Friendship University of Russia (RUDN University) in Moscow with sponsorship of the American Astronautical Society (AAS). It was the first in a series of events organized by the International Academy of Astronautics with the cooperation of the American Astronautical Society that may become a good tradition in the future.

One of the most multinational universities in the world – RUDN University, hosting students from more than 150 countries, was chosen as IAA/AAS SciTech Forum venue. Nowadays RUDN University with its training Space Mission Control Center, Center for Satellite Remote Sensing and multiple laboratory infrastructure is an expanding platform for space education, a place for research and discussion connected with Russian space industry enterprises including Mission Control Center in City of Korolev, Moscow Region used for control of International Space Station together with Mission Control Center at NASA's Johnson Space Center, Houston, Texas.

The IAA/AAS SciTech Forum was attended by leading scientists from the most distinguished universities all over the world: Massachusetts Institute of Technology (USA), Tsinghua University (China), McGill University (Canada), The University of Texas at Austin (USA), Moscow State University (Russia), Pennsylvania State University (USA), China University of Science and Technology (Taiwan), Freie Universitaet Berlin (Germany), University of Colorado Boulder (USA), Texas A&M University (USA), Sapienza University of Rome (Italy), University of Arizona (USA), Bauman Moscow State Technical University (Russia), University at Buffalo SUNY (USA), Dalian University of Technology (India), Ryerson University (Canada) and other institutions.

The Co-Chairs of the International Program Committee were Prof. Yury Razoumny, RUDN University (Russia), Prof. Filippo Graziani, Sapienza University of Rome (Italy), Prof. Anna Guerman, University Beira Interior (Portugal), Dr. Jean-Michel Contant, International Academy of Astronautics (France).

The Members of the International Program Committee:

- Brij Agrawal, USA
- Christophe Bonnal, France
- Fabio Celiani, Italy
- Yi-Wei Chang, Taiwan
- Jeng-Shing Chem Rock, Canada
- Roberto Furfaro, USA
- Eberhard Gill, Nederland
- Pini Gurfil, Technion, Israel
- Kathleen Howell, USA
- Robert Melton, USA
- Arun Misra, Canada
- Daniele Mortari, USA
- Alfred Ng, Canada
- Giovanni Palmerini, Italy
- Antonio B. Prado, Brasilia
- Daniel Scheeres, USA
- David B. Spencer, USA
- Renuganth Varatharajoo, Malaysia
- Tetsuo Yasaka, Japan
- Wang Zhaokui, China

The Members of RUDN University Local Organizing Committee: Yury Razoumny (Chair), Sergei Kupreev, Vera Galishnikova, Irina Tkachenko, Amina Makarova, Elnura Abdurashitova, Aleksandr Marusin, Valery Karnevich.

The IAA/AAS SciTech Forum embraced two Conferences: the IAA/AAS Conference on Space Flight Mechanics and the IAA/AAS Conference on Space Structures and Materials. The Opening Ceremony was held on November 13. It was started with the welcome speeches of the First Vice-Rector of RUDN University Prof. Nur Kirabaev and Secretary General of International Academy of Astronautics Dr. Jean-Michele Contant, and continued with the Regional Meeting of International Academy of Astronautics. During the meeting the award ceremony took place, at which Dr. J.M. Contant presented Academician Diplomas to Newly Elected IAA members and certificates of the International Academy of Astronautics to participants of the International Experiment on Simulating a Manned Mars Flight "Mars-500" conducted by State Corporation "Roscosmos" and the Russian Academy of Sciences with the participation of the European Space Agency and other international partners

The Opening Ceremony was attended by the representatives of Russian space industry First Deputy General Director of State Corporation "Roscosmos" Yury Urlichich, Deputy General Director of State Corporation "Roscosmos" Sergey Savelyev, Deputy General Director of Corporation "Russian Space Systems", Vice-President of International Academy of Astronautics Anatoly Perminov, First Deputy General Director of Rocket and Space Corporation "Energia" Evgeniy Mikrin, and other distinguished guests.

The program of the Forum consisted of 88 presentations that were organized in two parallel conferences with five thematic sessions in each conference. Thematic sessions were dedicated to actual problems of space mission design, space system development, extending the space system lifetime by spacecraft on-orbits servicing, removing elements of space debris, space traffic management, ensuring continuous and sustainable automated control of satellite systems, synthesis of space robotics and intelligent systems and other important issues.

Special time periods in the program were dedicated to Highlight Lectures on the hottest topics of space research presented by world leading scientists in the field of space system development. A total of 13 Highlight Lectures had been presented throughout the three days of the Forum. A short summary of each lecture follows below.

Prof. Kawaguchi Junichiro, Aerospace Exploration Agency (Japan), "*Use of Attitude Motion in Spinning Solar Sails for Orbital Maneuvers*".

This lecture presents an illustrative and instructive space architecture based on 'Deep Space Port', a conceptual space facility that may be constructed at a Sun-Earth libration point, L1/L2. This lecture discusses orbital, attitude motion and their simultaneous stabilization based on a various kind of astrodynamics properties. Especially this lecture focuses its attention on the characteristic maneuver capability for spinning solar sails controlled only by spin control device. Spaceships operated between planets require high efficiency propulsion engines, while they have little thrust. Lift-off and departure from the bottom of gravity well requires high thrust engines, while they are inefficient. So, a single propulsion vehicle NEVER can make a round trip to planets. And cargo and passengers must change ships on the way out side Earth gravity sphere. It is a Deep Space Port, a relay point. It should be, at the same time, nearest and frozen with respect to Earth. So a S-E Libration point fits for it. Infinitesimally small delta-V enables spaceships to depart and return. Setting sail and Returning anchored is practical, even as of today. We live in an era of reusable spaceships. Spin inevitably carries large amount of angular momentum. Steering sail in spin requests therefore controlling and managing of the angular momentum. That is why, so far, spinning solar sail has been not much discussed. Ikaros demonstrated the steering is possible by liquid crystal device. So, steering spinning sail does not require fuel. The liquid crystal device is also usable in spin rate control taking the advantage of diffusive and

absorption, while it is not much efficient. This presentation dares to look into the solar sailing cruise only via spin rate control, excluding pitch and yaw maneuvers, aiming at astrodynamics discussion. Regardless of whether a solar sail is spinning or not, steering it in pitch and yaw axes is required. This is a straightforward conclusion, no discussion. And Ikaros proved that even spinning sail is steered with no fuel. Also regardless of whether it is spinning or not, spin rate control, in other words, roll control capability is essential. An appropriate device must be aboard. What is the most simplified and minimum solar sail configuration to make it voyage? The answer is a spinning soar sail only with a single spin control device, such as a liquid crystal sheet or a single vane aboard.

Prof. Michael Panasyuk, Skobeltsyn Institute of Nuclear Physics, Lomonosov Moscow State University (Russia), "*Radiation Danger and Near-Earth and Deep Space Missions Planning*".

This lecture covers the study of radiation effects on space missions in low orbit and deep space. There are no orbits, regions of space and time intervals that are completely radiation-safe. The problem is how powerful these effects are. The following factors comprise the space radiation impact on spacecraft inside electronics and cosmonauts: galactic cosmic rays, solar energetic particles, radiation belts. Near –Earth's radiation environment becomes more dangerous (atmosphere cooling and RB intensity increasing) in coming years, thus, it is important to predict solar cycles. The South Atlantic Anomaly magnetic field becomes weaker. South Atlantic Anomaly is moving to the west and becomes wider. Radiation conditions at Low Earth Orbit become more dangerous. Considering the electronics, internal electric charge, implemented by energetic particles, creates high electric field potential. Discharge will occur, if potential gradient can exceed a breakdown threshold (the electrical durability of material). Effective internal charging is determined by the structure of the dielectrics, their resistance and the presence of deep energetic traps in their forbidden zones. One possible method of shielding against radiation for long duration missions is magnetic shielding of spacecraft – use of superconducting magnet as cover of spacecraft body. However, time of mission – the most effective "shielding" against radiation. We have to select the most appropriate time both for launch and duration of missions with a goal to minimize radiation risk.

Prof. Daniele Mortari, Texas A&M University (USA), "*From Art to Science: the Flower Constellations*".

In 2018 the Flower Constellations theory celebrated its 16th birthday. Many years were needed to fully develop the current theory as well as to fully understand the implications. This new satellite constellations design tool is today ready to provide solution configurations to many kind of constellation objectives. The theory introduces a new class of space objects characterized by shape preserving configurations where the whole constellation behaves as a "rigid object" in a rotating frame. This rigid object, however, appears with different shapes with respect to different rotating reference frames.

A theory based on a minimal parameterization (Hermite normal form) is the 2D Lattice Flower Constellations which also includes all spatial and temporal symmetric solutions. The 3D Lattice theory extension allows designers to use any inclination when selecting elliptical orbits under J2 perturbation. This has been achieved by replacing the original juggling of satellites with a juggling of orbits whose dynamics is generated by the J2 orbital perturbation. Finally and recently, the Necklace theory applied to 2D and 3D Flower Constellations exponentially increases the space of potential solutions by embedding in the theory the launches and satellites cost constraints.

The evolution of the Flower Constellation theory is presented in this invited talk, by showing some potential configurations to improve existing applications as well as configurations proposing new applications! The number of applications are actually many, including, positioning, communication, radio occultation, interferometric, and surveillance systems, to mention a few. In particular, the Flower Constellations theory allows to design conjunction free constellations with many thousands of satellites and a new class of orbits/constellations, called J2 propelled systems, where the Earth oblateness perturbation (again) is used to generate the dynamics needed to cover spatial volumes around the Earth for measuring or monitoring physical quantities.

Prof. Richard Linares, Massachusetts Institute of Technology (USA), "*Enabling a New Age in Spaceflight and Space Exploration Through Space Traffic Management and Autonomous Space Systems*".

Space flight is entering a period of renaissance, with considerable change in the perception of what humanity's role in space will be. Recently, SpaceX and OneWeb have proposed mega satellite constellations of up to 4,425 satellites in Low Earth Orbit (LEO), which will more than double the number of satellites in LEO. These constellations could revolutionize the telecommunication industry by providing complete global internet coverage. The economic gains of completely connecting rural areas and developing nations cannot be understated, however, the current space infrastructure is not capable of handling such a dramatic increase in the number of active satellites. Therefore, there is a critical need for new solutions to the problem of Space Traffic Management (STM) and Space Situational Awareness (SSA).

Conversely, the technologies that are revolutionizing near-Earth spaceflight will provide new opportunities for deep space exploration. Future science-driven interplanetary missions and/or missions to Lagrangian points and asteroids will require advanced guidance and navigation algorithms that are able to adapt to more demanding mission requirements. For example, future missions to asteroids and comets will require that the spacecraft be able to autonomously navigate in uncertain dynamical environments by executing a precise sequence of maneuvers (e.g. hovering, landing, touch-and-go) based on information collected during the close-proximity operations. These missions will require approaches for landing at selected locations with pinpoint accuracy while autonomously flying fuel-efficient trajectories.

The presentation discussed new methods for enabling STM and autonomous space systems. In particular, this presentation discussed a new method for assessment of confidence in position knowledge through improved satellite drag modeling, which is critical for STM. This presentation also discussed novel methods for accurate upper atmospheric density estimation and uncertainty quantification. Furthermore, swarming satellite and robotic systems can offer new ways of exploring our solar system. Current research with the Jet Propulsion Laboratory on swarming systems was also discussed. Finally, this presentation provided a vision for the basic research that is needed to enable the future of spaceflight and space exploration.

Prof. Maruthi Akella, University of Texas at Austin (USA), "*Dynamic Scaling for High-Performance Adaptive Control of Space Systems*".

Future space missions are expected to take us over large distances from Earth thereby inducing insignificant light-time delays that prevent online mission support from ground. The complex interplay between autonomy and onboard decision support systems introduce new vulnerabilities that are extremely hard to predict with existing mission analysis tools. Sensing, anticipation, adaptation, and learning processes can be generally viewed to characterize autonomy as an overarching system-level property. In this highlight lecture, we review some recent advances in nonlinear stability theory and robust adaptive control that involve immersion and invariance approaches. Specifically, these new state-estimation and control design tools involve the construction of auxiliary filters (dynamic augmentation) for dynamically adjusting the "feedback gains" - ultimately leading to some strong convergence properties and robustness features for the closed-loop system. These technical foundations are strongly motivated by growing numbers of aerospace engineering applications that are currently addressing the critical need for autonomous (and semi-autonomous) control systems with agile maneuvering and robust perception inside dynamic, complex and uncertain environments.

In most nonlinear control problems, designing a satisfactory controller to force system states to track prescribed reference trajectories usually requires model parameters. Closed-loop performance depends largely on how well the mathematical model and the physical plant match. To improve the quality of the controllers, system identification can be performed to improve the plant model before controller design, but it is not always perfect. Adaptive control has been extensively studied as a way of dealing with parameter uncertainties. The philosophy of adaptive control is to control dynamic systems using system parameters estimated online so that robustness to parameter uncertainties automatically follows.

Classical adaptive control design obeys the so-called certainty equivalence (CE) principle. First, a controller is designed with system parameters assumed to be known. Then, the parameters are replaced by estimated values. A parameter update law is determined through the judicious use of a Lyapunov (-like) function such that a tracking objective is fulfilled. The estimate errors remain bounded as the error terms in the time derivative of the Lyapunov (-like) function are canceled by the update law. Departing from the CE philosophy, a new methodology called immersion and invariance (I&I) adaptive control was recently proposed promising better performance and flexibility of parameterization structure. Unlike CE, the estimates do not come directly from the update law. Instead, a function that satisfies a certain partial differential equation (PDE) is combined with the states of the update law to form the estimates. The norm of the estimation error monotonically decreases, and thus the estimated parameters approach the true values as time evolves (a feature not observed in CE-based controllers). Also, the resulting estimate error dynamics allow us to dominate the perturbation term in the Lyapunov (-like) function derivative without the fragile cancellation operation. This new methodology allows nonaffine parameterization for some applications and has been shown to outperform CE-based controllers in transient performance.

When the I&I method was first proposed, applications were limited because designing an I&I adaptive controller typically leads to solving a partial differential equation (PDE). The solution to the PDE always exists for autonomous single-input systems. Existence of solutions to such PDEs is not guaranteed for general multi-input systems, a condition commonly known as the "integrability obstacle." However, by introducing low-pass filters for the state and regressor matrix, this obstacle is shown to be circumvented. Various I&I adaptive controllers have been proposed for linear and nonlinear systems as a result.

Recently, an alternate method to avoid the integrability obstacle was proposed. Aided by a state filter with a dynamic scaling factor appearing in the gain, the PDE becomes solvable. A scaled manifold is proven to be globally stable via a certain choice of the scaling factor dynamics. In other sources, the dynamic scaling method is applied to aircraft flight control systems. In the special case where the system is monotonizable and parameters have known bounds, it is shown that the parameter estimates converge to the true values exponentially fast and the scaling factor returns to unity as the tracking error goes to zero. Compared with the existing method, which requires both state and regressor filters, this approach achieves similar performance as the lower-dimensional dynamic extensions.

It is possible to bring the dynamic gain down to the initial value when the dynamic scaling approach is used taking advantage of the structural properties like observability. However, in most adaptive control design cases, the scaling factor does not have a convergent term in its dynamics and grows monotonically to some unknown constant. This feature can be a drawback because we do not know how large the scaling factor becomes, although it is finite, or whether it can be reset. This could result in "high-gain" control action and cause undesirable transient behavior of the closed-loop system.

In the literature, many model reference adaptive controllers have been developed for the spacecraft attitude control and robot manipulator systems because their dynamic structures admit affine parameterization for the inertia parameters. Unfortunately, ideal I&I adaptive controllers do not exist because no solutions to the PDE of these systems exist. This is due to the nonlinear gyroscopic term in the momentum-level equations of motion. Only the filter approach was applied to the attitude control and robot manipulator systems to overcome the integrability obstacle. In this highlight lecture, we show how to apply the dynamic scaling method to the quaternion-based attitude tracking control problem. Also, we modify the dynamic scaling factor so that it does not increase monotonically but instead converges to the vicinity of the initial value by introducing three scalar dynamics. Moreover, based on the local Lipschitz condition of the regressor matrix, a filter-free controller is proposed that achieves even lower-dimensional dynamic extensions. Because of the structural analogy between the attitude and Euler–Lagrange dynamics, the proposed design scheme is also applied to n-link robot manipulator systems.

Prof. Robert Melton, Pennsylvania State University (USA), "*Time-Optimal Satellite Attitude Maneuvers*".

The problem of reorienting a satellite in minimum time, subject to constraints on the vehicle's motion, presents some interesting challenges. Such a problem arises in the case of an orbiting astronomical observatory such as the Swift satellite, which detects a gamma-ray burst, then must rapidly reorient to point its narrow field-of-view instruments (all fixed in the satellite and pointing in parallel) to observe the fading afterglow. In executing the maneuver, it must avoid pointing the sensitive sensors at bright celestial sources such as the Sun, Earth and Moon.

Initially omitting the path constraints offers some insight to the fundamental motion. For a vehicle with equal principal moments of inertia, and equal maximum control-torque authority about each principal axis, the minimum-time control law is found to be bang-bang; the resulting motion involves some precessional characteristics that reduce the maneuver time compared to that of rotating only about the eigenaxis associated with the new orientation.

Path constraints are established in terms of "keep-out" cones. Each cone axis is centered on the direction of a celestial source that is to be avoided, and the half-angle of the cone is chosen to represent a minimum angular distance that the satellite's sensor axis can point relative to the source direction.

The constrained problem could be formulated as an indirect optimal control problem, with the path constraints adjoined to the Hamiltonian with Lagrange multipliers. This results in a generally intractable form for the solution, and hence, the problem has largely been studied using direct approaches such as pseudospectral and heuristic methods. Pseudospectral methods offer the advantage of greater accuracy in terms of meeting the boundary conditions and satisfying the path constraints; however, they often require an approximate starting solution in order to reduce overall computation time. Heuristic methods, such as swarm-intelligence (Particle Swarm or Fireworks optimization algorithms) provide rapid assessment of the parameterized solution space and yield adequate approximate solutions in short computation times. Such approximations may be sufficient by themselves in certain applications, or could serve as starting points for pseudospectral solutions if greater accuracy is required. None of the studies indicates solutions with boundary points or boundary arcs (i.e., solutions in which the sensor-axis path intersects a constraint cone at a point or along a finite arc).

Recent work has focused on the use of inverse dynamics, in which the kinematics of the maneuver are modelled in terms of Euler parameters or Modified Rodrigues Parameters. Repeated differentiation of the path variables yields the control torques, whose magnitudes must be constrained. This formulation avoids the need for computationally expensive integration of the equations of motion and is found to yield accuracies similar to those in the direct-dynamics formulations.

Future directions for this work include solutions using graphical processing units, which now provide good accuracy as well as significantly faster computation times. The ultimate goal is a solution algorithm and implementation compatible with onboard processors.

Prof. Roberto Furfaro, University of Arizona (USA), "*Deep Learning for Autonomous Space Guidance*".

Current trends in real-time space guidance include direct transcription and convexification (as direct transcription yields a non-convex NLP) and Universal Powered Guidance (UPG). Over the past few years, Machine Learning has made enormous advancements, particularly in Deep Learning, Deep Reinforcement Learning, Convolutional Neural Networks, Recurrent Neural Networks. This was enabled by computing speed (e.g. Massive Parallel and GPUs) and data availability. The goal of autonomous self-flying planetary landing via imitation learning is to teach a spacecraft to execute autonomous landing via Deep Learning. The task is approached by training a CNN to optimally map optical images into thrust actions including learning fuel-efficient guidance policies in a closed loop fashion and imitating the optimal guidance policy: use numerically-generated optimal control policies with simulated images from DTMs. The result is a self-landing spacecraft with integrated GNC. The general issue when dealing with training a machine learning

algorithm to learn the functional relationship between state and action is that system trajectories may visited states never seen during the training. However, we do have a teacher as we can numerically generate the optimal solutions via GPOPS (Gauss Pseudospectral Methods) as so-called Dataset Aggregation (DAgger) Algorithm. The network is trained to predict the thrust at particular time, taking the images related to that time and the time before to keep track of velocity. The most relevant numerical results show 99% accuracy. Recurrent networks feature is useful dealing with a guidance problem, with long sequences of data. Raw images have been taken as input and therefore no state estimation is necessary. Deep Neural Networks can solve high-fidelity space guidance and navigation problems. DAgger algorithm can enhance the overall accuracy even if there is no human action/correction.

Prof. Renuganth Varatharajoo, University Putra Malaysia (Malaysia), "*Space System Innovation Towards Spacecraft Synergisms*".

Sputnik 1 was launched on 4 October 1957 by the Soviet Union (Russia). Since then satellite technology has been evolving rapidly for a few decades. However, satellite design approach has been essentially similar. With the demanding space mission requirements, innovative concepts become desirable to anticipate the emerging cost of space missions. Other factors of concern are the in-creasing system complexity and weight as well. The synergistic system design could be an attractive approach for future spacecraft to cope with these issues. Synergism for spacecraft describes the linking or merging of different subsystems in order to achieve a better overall performance, e.g., reliability, mass saving or even for enabling a certain onboard task. Therefore, using the existing subsystems in an integrated fashion to replace not only the conventional system design but also the traditional design approach is a way forward. The earth-orientated satellites need a number of subsystems to accomplish their missions. Spacecraft synergisms could be envisaged by couplings of those conventional subsystems. A wise choice would be to concentrate on one of the most crucial subsystems onboard. Hence, synergisms for the spacecraft attitude control system emerge as the prime topic of interest in this presentation.

Prof. Arun Misra, McGill University (Canada), "*Selected Topics on Dynamics and Control of Space Robots*".

Robotic manipulators have been playing an active role in many space operations for more than three decades. The first-generation space manipulator was the Remote Manipulator System (RMS), also known as the Canadarm, mounted on each Shuttle. It was used extensively from 1981 to 2011 to deploy payloads, retrieve satellites and provide support for extravehicular activities of astronauts. Subsequently, several space manipulators have been built by various space agencies. The Space Station Remote Manipulator System (SSRMS) or Canadarm 2, has been used on the Space Station for the construction of the truss structure as well as manipulation of satellites. Similarly, the Japanese Experiment Module RMS (JEM-RMS) and the Special Purpose Dexterous Manipulator (SPDM) are being used on the Space Station for various activities. The European Robotic Arm (ERA) will be launched in 2019 and will be attached to the Russian segment Nauka on the Space Station. It is expected that robotic activities in space will increase in the future because of their possible role in active space debris removal and on-orbit servicing. This presentation discusses briefly some aspects of the dynamics and control of flexible manipulators and presents briefly the concept behind reactionless manipulation.

A flexible space manipulator is a special case of a large space structure. It is a kinematic chain of interconnected rigid and flexible bodies. This kinematic chain can be simple or complex. A kinematic chain in simple if each body is connected to at most two other bodies. The Shuttle-based Remote Manipulator System (RMS) was a simple, open kinematic chain, while the Special Purpose Dexterous Manipulator (SPDM) on the Space Station is a complex kinematic chain. Space manipulators usually contain one or more long, slender links, the structural flexibility of which may not be negligible. In addition, joint flexibility can be significant for many space manipulators. In fact, for the RMS, joint flexibility was more important than link structural flexibility.

A significant amount of effort has been directed in the last four decades towards the systematic and efficient derivation of the equations of motions of flexible space manipulators. The long links have been modeled usually as Euler-Bernoulli beams to account for their structural flexibility. Discretization of a flexible link can be carried out by using a variety of techniques such as the "assumed modes method", finite element method, lumped parameter approach or by using splines. The joint flexibility on the other hand, is usually modeled by lumped parameters.

The equations of motion of a space manipulator have been derived by using the Newton-Euler method, Lagrange's equations, Kane's method or the natural orthogonal complement approach. The total number of equations for a space manipulator depends on the number of elastic degrees of freedom retained in the dynamical model and the size of this model can be quite large. Although the large size does not pose serious problem for simulation of the dynamical behavior off-line, reduction of the size of the dynamical model is necessary for on-line simulation. Moreover, implementation of a multi-input, multi-output control scheme for a large dynamical model is impractical. Hence, significant amount of effort has been put into developing criteria for reduction of dynamics models. The easiest approach is the retention of modes corresponding to the lowest natural frequencies. However, that may not always be the best method. One of the most logical methods is the modal cost method which considers the natural frequencies and modal damping as well as the observability and controllability of the modes. The modes that have low frequency or low damping, as well as modes that are associated with high excitation should be retained in the dynamical model that is being used for controller design.

Various techniques have been proposed to eliminate structural oscillations. For example, one can use input shaping, i.e., control input can be shaped using the information about the system natural frequencies. The structural oscillations can also be reduced via active damping using piezoelectric devices. A method that has the potential to control both rigid body motion and elastic oscillations is the singular perturbation method, first proposed by Siciliano and Book. In this method, the generalized coordinates are separated into two sets – slow variables (rigid body rotations) and fast variables (elastic oscillations). A fast time variable is also defined. Using the perturbation approach, the system is decomposed into two subsystems. Impedance control can be used for the slow subsystem, while the fast subsystem can be controlled by a linear quadratic regulator.

The dynamics of the service spacecraft carrying the manipulator is strongly coupled to the manipulator dynamics. When the links of a space manipulator rotate during the pre-capture, capture or post-capture phase, the base (service spacecraft) normally undergoes an attitude change. However, for a redundant manipulator, it is possible to devise manipulation schemes to transmit zero disturbance to the base; these are known as reactionless manipulation schemes.

Instead of the joint space, it is also possible to work in the task space and reactionless manipulation can be carried out using an analogous approach. Reactionless capture using two hands has also been demonstrated.

Prof. Giovanni Palmerini, Sapienza University of Rome (Italy), "*GNSS-based Navigation in Lunar Missions*".

Modern space missions increasingly require autonomous operations in order to increase performance, improve versatility, limit ground stations' workload. This is especially true for missions requiring specific ground support, as in the case of lunar missions operated by powerful stations that – in addition to be quite expensive – are also a very limited resource. Current trend towards low-thrust propulsion makes the problem even worst, as the cruise time to the Moon increases up to the order of months. The quest for autonomy suggests applying to these missions the same autonomous navigation techniques successfully adopted for LEO – and increasingly for GEO – spacecraft, which orbit determination is performed by means of relatively inexpensive GNSS receivers accommodated onboard. The advantages would be so relevant that the exploitation of such a possibility is now a relevant research field for several teams all over the world. On the other hand, technological issues are so relevant that this application of the GNSS far above the altitude typically serviced is clearly at – and even beyond – the state of the art.

The power of the GNSS signal, transmitted from source satellites' constellation orbiting at about 20000 km above the Earth, decreases with the square of the distance and will be strongly reduced for a receiver bound to the Moon. Moreover, the signal is primarily irradiated towards the Earth, so that satellites at altitudes higher than the constellation's one should mainly look for the spillover around the Earth sphere of the signals generated from far away sources orbiting above the other side of the globe. Such a borderline availability of the signals leads to consider nonstandard receiver architectures, based on the software approach. In a software receiver the incoming signal is sampled and quickly transformed in a string of bits, to be deeply processed. In fact, reading again and again the input leads to a significant increase in sensitivity, moving the threshold from 20-25 dB-Hz (typical values for hardware receivers) down to at least 10-15 dB-Hz, a level ensuring the availability of the required number of GNSS sources even in proximity of the Moon. However, the acquisition of the signal (successful correlation with a replica in a 3D search volume which axes are the PRNs of the sources, the Doppler shifts and the relative shifts of the replica of the PRN code) cannot be transferred to a consistent tracking. Indeed, no chance to decode the navigation message modulated on top of the signal exists, making the acquisition effort use-less as the lack of the time-of-the-week or Z-count information included in the message prevents the fixing. An approach called "snapshot", where the ambiguity on Z-count could be solved by receiving at least five satellites and exploiting a guess solution within 300km range from the true one has been proposed. Presented, extensive simulations show that such an approach is suitable, as enough sources are visible even in lunar orbit, and that an ex-tended or unscented Kalman filter is capable to ensure the guess solution with the required accuracy.

Prof. Paolo Gasbarri, Sapienza University of Rome (Italy), "*Dynamics Modelling of Large Space Structures in Space Environment: Hybrid FEM-Continuous Approach for GNC Analysis*".

In the last decade a new class of Very Large Space Structures (V-LSS). have been proposed by Space Agencies and developed by Space Industries. V-LSS have broad applications in space including low-stiffness precision shaped antennas for mobile communications satellites, narrow-band broadcast services and remote sensing, low-stiffness planar structures for large solar array etc. A lightweight design responding to the low gravity environment and live loads due to gravity gradients, extreme thermal variations, and solar wind create new and challenging problems in dynamic analysis of V-LSSV-LSS must be designed for minimum weight and they are quite flexible furthermore a significant problem will arise on developing the capability to suppress and control flexible modes of vibration, some of which are closely packed with their frequencies which in turn could be very closed to the ones of the attitude controller. To address the guidance and control laws for large space orbiting structures it is firstly necessary to "correctly" define the space environment in terms also of its perturbing effects. Then orbital dynamics of flexible spacecraft must be developed by considering a suitable choice of kinematic variables and "filtered" equation able to catch the large differences due to the difference in time scales and space scales appearing in the governing equations.

From a structural point of view very accurate model of the V-LSS can be provided only with very detailed Finite Element Model (FEM). FEM drawbacks include: thousands of degree of freedoms, difficulty on defining the center of mass motion (orbital motion), difficulty on defining the motion around the Center of Mass (attitude motion), difficulty on using FEM model for the Guidance and Control Spacecraft laws synthesis, Linearized Analysis.

Some alternatives can be found by developing a Spacecraft Model with few degrees of freedom using classical mathematical approaches (continuous formulation): Lagrangian approach, Newton approach, Galerkin decomposition techniques, non-linear analysis. Drawbacks include: not easy to represent the main characteristics of the flexible structure, very simple structural model (mass and stiffness of the structures are concentrated on few representative elements.

Hybrid FEM-continuous formulation, based on the classical modal reduction, is the best way to model a V-LSS. In this way rigid motion characteristics for GNC are explicitly derived via continuous formulation, furthermore all necessary parameters (flexible eigenmodes and natural frequencies) can be evaluated by a FEM tool and eventually used in an analytical formulation named the continuous model. This in turn

generates a consistent model of the V-LSS where the flexibility is represented by global parameters derived directly by FEM tool.

Prof. Nickolay Smirnov, Lomonosov Moscow State University (Russia) discussed his "*Three-dimensional Study of Combustion and Detonation for Rocket Propulsion Application*".

Self-sustaining waves can propagate in meta-stable media; energy needed to support such waves is released by the wave itself. As a rule, two regimes of propagation exist, subsonic and supersonic; the difference is based on the different mechanisms of medium activation. Processes of transition between those regimes are less studied up to now, in comparison with pure subsonic or supersonic modes. Knowing mechanisms of controlling detonation initiation is important in order to work out effective preventive measures, such as suppressing deflagration to detonation transition in case of combustible mixture ignition, and mitigation of a detonation wave in case it is already developed. On the other hand, the advantages of burning fuel in a detonation regime in comparison with slow burning at constant pressure attract increasing attention to pulse detonation, or rotating detonation, or hybrid rocket burning chambers and to their possible application to new generation engines. Codes for simulation of deflagration, detonation and transition processes in homogeneous turbulized mixtures accounting for hybrid structure of supercomputer were developed. A unique validation and verification basis, incorporating the data of laboratory experiments and exact solutions was developed. Comparison of numerical results with experimental data present in the validation basis was performed. The validation basis could be used for validating different codes including commercial ones for description of unsteady-state processes in chemically reacting mixtures in the domains of complex geometry. The paper presents results of numerical and experimental investigation of mixture ignition and detonation onset in shock wave reflected from inside a wedge. Contrary to existing opinion of shock wave focusing being the mechanism for detonation onset in reflection from a wedge or cone, it was demonstrated that along with the main scenario there exists a transient one, under which focusing causes ignition and successive flame acceleration bringing to detonation onset far behind the reflected shock wave. Several different flow scenarios manifest in reflection of shock waves all being dependent on incident shock wave intensity: reflecting of shock wave with lagging behind combustion zone, formation of detonation wave in reflection and focusing, and intermediate transient regimes. Comparison of numerical and experimental results made it possible to validate the developed 3-D transient mathematical model of chemically reacting gas mixture flows incorporating hydrogen – air mixtures.

Prof. Filippo Graziani, G.A.U.S.S. Srl (Italy) delivered a concluding Highlight Lecture on the topic of "*From San Marco Project to UniSat Satellites and…? – Dreams, Reality, Concerns*".

The Group of Astrodynamics for the Use of Space Systems (G.A.U.S.S. Srl) is an Italian company founded in 2012 as an evolution of GAUSS Laboratory Group of Applied Astrodynamics of the School of Aerospace Engineering ("La Sapienza" University of Rome), active in the Space technology field through research, development and implementation of aerospace projects.

The University of Rome has always been at the forefront of Space research, starting from the Italian golden years (1959-1988) with the creation of the Aerospace Research Center (CRA, 1959) and the beginning of the San Marco Program (agreement between the University and NASA in 1962) that saw the first satellite launched in 1964 from Wallops Island, followed by other nine satellites launched from the mobile platform off the Kenya coast, the San Marco Equatorial Range, in the period 1967-1988.

Subsequently, "La Sapienza" became a flagship University in Europe: as from the nineties the recently created GAUSS Group, with a "hands-on" approach, studied and then developed the first low-cost microsatellite made by students, UNISAT, launched in August 2000. It was followed by UNISAT-2 launched in 2002, UNISAT-3 launched in 2004, UNISAT-4 launched in 2006, EDUSAT launched in 2011 and UNICUBESAT-GG launched in 2012.

Afterwards, GAUSS as a private company has innovated the idea of launch provider, making the UNISAT satellites themselves launcher platforms as well as carriers of fixed payloads. GAUSS Micro Platforms: in 2013 UniSat-5 Platform carrying 7 nanosatellites was launched; in 2014 UniSat-6 Platform

with 4 CubeSats onboard was launched (mission still operative); in 2017 the TUPOD was deployed from ISS and released two TubeSats; in 2020 the new Platform UniSat-7 will be launched with Soyuz-Fregat LV.

Nowadays, GAUSS designs and manufactures: components and subsystems for microsatellites, such as On Board Computers (ABACUS and HERCULES), UHF Radios (2W, 5W and Mini Ground Dongle) and automated Ground Stations; structures and deployers, namely the GPOD (for CubeSats release), the TuPOD (for TubeSats release) and the MRFOD (for PocketQubes).

Microsatellites passed from a didactical dimension to an industrial diffusion. Their significant potential contributed to transform the Space industry towards the ”NewSpace”. The global interest in these small satellites and the launch demand increased exponentially because of their characteristics of more affordability, cost-efficiency and fast-delivery, plus the objective of technological testing.

GAUSS enhanced the microsatellites culture and addressed their utilization in several new applications: innovative materials such as the first 3D-printed deployer (TuPOD), propulsion systems, biomedical experiments in Space, ideas of remote sensing missions as ancillary services of bigger missions and launch solutions.

Within the framework of the IAA/AAS SciTech Forum, three Round Table discussions were organized on the topics in the area of space research international cooperation: “Legal Aspects Ensuring Safety of International Space Activities”, “Moon Village Workshop/The Global Moon Village”, “Next-Generation Space System Development Basing on On-Orbit-Servicing Concept”.

The IAA/AAS SciTech Forum contributed to intensive discussions of the modern research, dissemination of the up-to-date information in the area and better contacts between the members of space scientific community. We are confident that such an event will inspire a stronger cooperation in the space community and will be a research incentive in the Space field panorama.

The success of the Forum became possible due to the great effort of its organizers and active involvement of participants. We express our gratitude to all members of the International Program Committee, the Local Organizing Committee and RUDN University. We appreciated very much the dedication of the participants of the IAA/AAS SciTech Forum (both the authors of papers and the audience in general) that made possible fruitful discussions at the conference sessions and beyond. Finally, we would like to express our gratitude to Mr. Robert Jacobs for his continuous support and to Univelt, Inc., for publishing this volume.

IAA/AAS SciTech Forum 2018 Co-Chairs:
Prof. Yury Razoumny
Prof. Filippo Graziani
Prof. Anna D. Guerman
Dr. Jean-Michel Contant

IAA/AAS CONFERENCE ON SPACE FLIGHT MECHANICS

ORBITAL DYNAMICS AND DETERMINATION

Session Chairs:

Daniele Mortari, *Texas A&M University, USA*
Roberto Furfaro, *University of Arizona, USA*

1. IAA-AAS-SciTech-051
Uniform exponential stability result for the rigid-spacecraft attitude tracking control problem
S. P. Arjun Ram, Maruthi R. Akella, The University of Texas, USA
2. IAA-AAS-SciTech-066
Shape reconstruction of a tumbling unknown orbital target by passive imaging
Renato Volpe, Marco Sabatini, Giovanni Battista Palmerini, Sapienza University of Rome, Italy
3. IAA-AAS-SciTech-022
The joint solution of problem of evasion and keeping in a neighborhood reference orbit
Zay Yar Win, Veniamin Malyshev, Vladimir Bobronnikov, Aleksandr Starkov, Moscow Aviation Institute, Russia
4. IAA-AAS-SciTech-062
High-altitude near-circular orbits for a Lunar orbital station
Anastasia Tselousova, Maksim Shirobokov, Sergey Trofimov, Keldysh Institute of Applied Mathematics, Russia
5. IAA-AAS-SciTech-087
On ultimately the most highly inclined, the most consice solar polar trajectory with practically the shortest period
Junichiro Kawaguchi, JAXA, Japan
6. IAA-AAS-SciTech-049
On the difference in the laws of gyroscopes noises accumulation in platform and strapdown attitude determination inertial systems
Nikolay Krobka, Research Institute for Applied Mechanics named after Academician V.I. Kuznetsov, Russia
7. IAA-AAS-SciTech-050
On critical modes of functioning of attitude determination inertial systems
Nikolay Krobka, Research Institute for Applied Mechanics named after Academician V.I. Kuznetsov, Russia
8. IAA-AAS-SciTech-035
Dust charged particles motion in vicinity of the Lagrange libration points
Tatiana Salnikova, Sergey Stepanov, Lomonosov Moscow State University, Russia
9. IAA-AAS-SciTech-124
Optimal flyby of space debris objects on a geostationary orbit
Andrey Baranov, Nikolay Makarov, Peoples' Friendship University of Russia (RUDN University), Russia
10. IAA-AAS-SciTech-126
Method for determining the moments of trajectory measurements for the correction of the accumulating orbit shift of the spacecraft
Gennadiy Rumyantsev, Vitaly Melnikov, Georgy Polishchuk, Oleg Samusenko, Peoples' Friendship University of Russia (RUDN University), Russia

GUIDANCE, NAVIGATION AND CONTROL

Session Chairs:

Maruthi Akella, *University of Texas at Austin, USA*
Giovanni Palmerini, *Sapienza University of Rome, Italy*

11. IAA-AAS-SciTech-072
The theory of connections: connecting functions
Daniele Mortari, Texas A&M University, USA
12. IAA-AAS-SciTech-081
Weighted least-squares solutions of over-constrained differential equations
Hunter Johnston, Daniele Mortari, Texas A&M University, USA
13. IAA-AAS-SciTech-086
A recurrent deep architecture for quasi-optimal feedback guidance in planetary landing
Roberto Furfaro, University of Arizona, USA
Richard Linares, Massachusetts Institute of Technology, USA
Ilaria Bloise, Marcello Orlandelli, University of Arizona, USA
Pierluigi Di Lizia, Francesco Topputo, Politecnico di Milano, Italy
14. IAA-AAS-SciTech-005
Dynamical aspects of spatial use of gravity assist maneuvers for the solar probes
Alexey Grushevskii, Yury Golubev, Victor Koryanov, Andrey Tuchin, Denis Tuchin, Keldysh Institute of Applied Mathematics, Russia
15. IAA-AAS-SciTech-012
Construction of the Moon-to-Earth trajectory to the Earth entry interface point using multi-impulse transfer
Nadezhda Gavrikova, Lomonosov Moscow State University, Russia
16. IAA-AAS-SciTech-057
Distribution of correction thrusters under Delta-V constraints in local horizontal plane
Anna Okhitina, Yaroslav Mashtakov,Stepan Tkachev, Keldysh Institute of Applied Mathematics, Russia
17. IAA-AAS-SciTech-015
The optimization of interplanetary flight to Phobos with a jet engine of combined low and high limited thrust
Alexander Samokhin, Marina Samokhina, Ilia Grigoriev, Maxim Zapletin, Peoples' Friendship University of Russia (RUDN University), Russia
18. IAA-AAS-SciTech-056
Expansion of the transport capabilities of the space system based on the Proton-M rocket with the use of electric propulsion and a gravitational maneuver near the Earth at the beginning of an interplanetary flight
Mikhail Konstantinov, Research Institute of Applied Mechanics and Electrodynamics, Moscow Aviation Institute, Russia
19. IAA-AAS-SciTech-127
Method for choosing measurement moments of radio altimeter-vertical for orbit parameters correction
Gennadiy Rumyantsev, Vitaly Melnikov, Georgy Polishchuk, Oleg Samusenko, Peoples' Friendship University of Russia (RUDN University), Russia

MISSION DESIGN AND OPTIMIZATION

Session Chairs:

Richard Linares, *Massachusetts Institute of Technology, USA*
Mauro Pontani, *Sapienza University of Rome, Italy*

20. IAA-AAS-SciTech-046
Development and launch of mini-elevator demonstration cubesat STARS-Me
Masahiro Nohmi, Shizuoka University, Japan
Yoji Ishikawa, Obayashi Cooperation, Japan
21. IAA-AAS-SciTech-076
Space trajectory optimization: differential evolution redux
Robert Melton, The Pennsylvania State University, USA
22. IAA-AAS-SciTech-011
Algorithm of the b-plane delivery error estimation for the mission to Venus
Alexander Gammal, Denis Tuchin, Andrew Tuchin, Keldysh Institute of Applied Mathematics, Russia
23. IAA-AAS-SciTech-068
Space navigator: a tool for the optimization of collision avoidance maneuvers
Leonid Gremyachikh, Dmitrii Dubov, Nikita Kazeev, Andrey Ustyuzhanin, National Research University Higher School of Economics, Russia
Anton Tereshkin, Andrey Skuratov, Phygitalism, Russia
Andrey Kulibaba, Sergej Shishkin, Lubov Shiryaeva, JSC Russian Space Systems, Russia
24. IAA-AAS-SciTech-003
Interstellar flights via alcubierre warp drive
Michael Fil'Chenkov, Yuri Laptev, Peoples' Friendship University of Russia (RUDN University), Russia
25. IAA-AAS-SciTech-020
The use of computer-based simulators to train cosmonauts for the fulfillment of the program of scientific-applied research
Andrey Kuritsyn, Maksim Kharlamov, Elena Popova, Yu.A. Gagarin Research and Test Cosmonaut Training Center, Star City, Russia
26. IAA-AAS-SciTech-108
Ecological impact on the environment from laser space solar power plants in the problem of development and development of the Arctic and continental shelf
Vitaly Melnikov, Georgy Polishchuk, Anastasiya Yatsenko, Galina Balandina, Viktoria Novikova, Peoples' Friendship University of Russia (RUDN University), Russia

SATELLITE CONSTELLATIONS AND FORMATION FLYING

Session Chairs:

Robert Melton, *Pennsylvania State University, USA*
Masahiro Nohmi, *Shizuoka University, Japan*

27. IAA-AAS-SciTech-061
Satellite formation control via deep reinforcement learning
Jacob Broida, Richard Linares, Massachusetts Institute of Technology, USA
28. IAA-AAS-SciTech-065
Optimal tether-assisted space debris disposal
Wei Shi Wang, Arun Misra, McGill University, Canada
29. IAA-AAS-SciTech-077
An advanced remote sensing cubesat constellation for multi-spectral EO imaging
Riccardo Di Roberto, Filippo Graziani, GAUSS Srl, Italy
30. IAA-AAS-SciTech-071
Magnetorquers attitude control for differential aerodynamic force application to nanosatellite formation flying construction and maintenance
Uliana Monakhova, Danil Ivanov, Dmitry Roldugin, Keldysh Institute of Applied Mathematics, Russia
31. IAA-AAS-SciTech-078
Relative motion control of two satellites by changing the reflective properties of the solar sails surface
Stepan Tkachev, Tatyana Petrova, Yaroslav Mashtakov, Keldysh Institute of Applied Mathematics, Russia
32. IAA-AAS-SciTech-113
The research method for controlled movement dynamics of tether system
Arun Misra, McGill University, Canada
Sergei Kupreev, Yury Razoumny, Peoples' Friendship University of Russia (RUDN University), Russia
33. IAA-AAS-SciTech-091
The joint solution of problem of evasion and keeping in a neighborhood reference orbit
Veniamin Malyshev, Aleksandr Starkov, Zay Yar Win, Vladimir Bobronnikov, Moscow Aviation Institute, Russia
34. IAA-AAS-SciTech-044
Optimal low-thrust trajectories using nonsingular equinoctial orbit elements
Mauro Pontani, Sapienza University of Rome, Italy
35. IAA-AAS-SciTech-112
The algorithm for solving the problem of choosing the optimal two-tier satellite system structure for continuous scanning of the spherical layer of near-earth space
Daniele Mortari, Texas A&M University, USA
Yury Razoumny, Oleg Samusenko, Viktoria Novikova, Peoples' Friendship University of Russia (RUDN University), Russia
Nguyen Nam Quy, Moscow Aviation Institute, Russia

SPACE MISSIONS AND APPLICATIONS

Session Chairs:

Filippo Graziani, *Sapienza University of Rome, G.A.U.S.S. Srl, Italy*
Renuganth Varatharajoo, *Universiti Putra Malaysia, Malaysia*

36. IAA-AAS-SciTech-090
A historical review and future prospects of space tourism
Jeng-Shing Chern, Ryerson University, Canada
Yi-Wei Chang, China University of Science and Technology, Taiwan
37. IAA-AAS-SciTech-024
Mathematical model of ERS data processing ground segment operation in terms of processing distribution
Andrey Emelianov, Lubov Grishantseva, Ksenia Zubkova, Veniamin Malyshev, Nguyen Viet Hoai Nam, Aleksandr Starkov, Zay Yar Win, Moscow Aviation Institute, Russia
38. IAA-AAS-SciTech-080
Intelligent structuring of the earth remote sensing methods for detecting and identification of radioactive sources of ionizing radiations
Dmitry Panov, Yury Razoumny, Dzhordzh Kovkov, Peoples' Friendship University of Russia (RUDN University), Russia
Alexander Sukhorukov, Plekhanov Russian University of Economics, Russia
Sergey Eroshkin, Russian State Social University, Russia
39. IAA-AAS-SciTech-099
Technique of estimating the volume of storage and transmission of information from synthetic-aperture radar satellite in data centers in digital economic issues
Dzhordzh Kovkov, Yury Razoumny, Peoples' Friendship University of Russia (RUDN University), Russia
Alexander Sukhorukov, Plekhanov Russian University of Economics, Russia
Sergey Eroshkin, Russian State Social University, Russia
Guo Shuhong, Dalian University of Technology, China
40. IAA-AAS-SciTech-088
The program for estimation of the earth remote sensing plans
Maxim Zapletin, Peoples' Friendship University of Russia (RUDN University), Russia
Abylai Zhakypov, JCS NC Kazakhstan Gharysh Sapary, Kazakhstan
41. IAA-AAS-SciTech-111
Space-based Monitoring Capabilities for the Evaluation of Inland Water Resources: Application to Nigeria
Seidu O. Mohammed, National Space Research and Development Agency (NASRDA), Nigeria
Vasily Lobanov, Yury Razoumny, Alexandr Orlovsky, Yaroslav Vasyunin, Peoples' Friendship University of Russia (RUDN University), Russia

IAA/AAS CONFERENCE ON SPACE STRUCTURES AND MATERIALS

SPACECRAFT STRUCTURES AND SENSORS

Session Chairs:

Paolo Gasbarri, *Sapienza University of Rome, Italy*

Vera Galishnikova, *Peoples' Friendship University of Russia (RUDN University), Russia*

42. IAA-AAS-SciTech-037

Calibration of upper atmospheric model based on the precision orbit of a spherical satellite

Junyu Wang, Zhaokui Wang, Tsinghua University, China

43. IAA-AAS-SciTech-101

Fuzzy logic application approach in control of automatic spacecraft

Igor Narozhnyy, Alexander Drozdov, Peoples' Friendship University of Russia (RUDN University), Russia

Nikolay Drozdov, Innovative Oil and Gas Solutions Limited Liability company, Russia

44. IAA-AAS-SciTech-041

The assessment of operational capability of the space-based hyperspectral complex

Sergey Zotov, Igor Polyakov, Anastasia Zotova, Sergey Shibanov, Timofey Kondranin, Egor Dmitriev, Moscow Institute of Physics and Technology, Russia

45. IAA-AAS-SciTech-042

The algorithm of computing the scattering phase function of reflected solar radiation from objects of arbitrary shape

Igor Polyakov, Sergey Zotov, Moscow Institute of Physics and Technology, Russia

46. IAA-AAS-SciTech-030

Nano star tracker AZDK-1

Marat Abubekerov, Andrey Zakharov, Mike Prokhorov, Oleg Stekolshikov, Maksim Tuchin, Nikolay Gostev, Azmerit LLC, Lomonosov Moscow State University, Russia

47. IAA-AAS-SciTech-098

Understanding reliability of the thermoelectric devices for space application

Shehak Sattar, Alexey Osipkov, Peoples' Friendship University of Russia (RUDN University), Russia

48. IAA-AAS-SciTech-069

System of multidimensional attractors of the stress-and-strain behavior in elastic continuous media

Anatoly Speranskiy, Russian Academy of Engineering, Russia

Efim Malitikov, International Association ZNANIE, Russia

ADVANCED SPACE MATERIALS

Session Chairs:

Svetlana Shambina, *Peoples' Friendship University of Russia (RUDN University), Russia*
Kharun Makhmud, *Peoples' Friendship University of Russia (RUDN University), Russia*

49. IAA-AAS-SciTech-009
The analysis of destruction causes and condition diagnostics of hot die forging for space industry
Anna Kornilova, Mohamed Abu Mahadi, Peoples' Friendship University of Russia (RUDN University), Russia
Alexander Selishchev, AO KBAL im. L.N. Koshkina, Russia
Tavkil Ayupov, AO MMZ Avangard, Russia

50. IAA-AAS-SciTech-019
Production nickel composite materials reinforced with ultrafine powders, obtained from aerospace industry waste
Marianna Malkova, Alexander Zadiranov, Peoples' Friendship University of Russia (RUDN University), Russia

51. IAA-AAS-SciTech-027
Development of a universal ultrasonic reactor for processing of rare earth metal ores on the moon
Marianna Malkova, Alexander Zadiranov, Moises Romero, Prashanta Dkhar, Peoples' Friendship University of Russia (RUDN University), Russia

52. IAA-AAS-SciTech-060
Reliability prediction of resonant tunneling diodes and non-linear radio signal converters based on them under influence of temperature factor and ionizing radiations
Mstislav Makeev, Peoples' Friendship University of Russia (RUDN University), Russia
Vladimir Sinyakin, Sergey Meshkov, Bauman Moscow State Technical University, Russia

53. IAA-AAS-SciTech-079
Diamond-like carbon coatings to protect the optical surfaces of orbital telescopes from the outer space factors
Alexey Osipkov, Pavel Mikhalev, Pavel Shiriaev, Konstantin Shishov, Mstislav Makeev, Peoples' Friendship University of Russia (RUDN University), Russia
Vladislav Batshev, Alexander Machikhin, Scientifical and Technological Center of Unique Instrumentation, Russian Academy of Sciences, Russia

54. IAA-AAS-SciTech-083
Research of anisotropy structure of Polyamide 12 parts obtained by selective laser sintering
Pavel Mikhalev, Pavel Shiryaev, Alexander Provatorov, Peoples' Friendship University of Russia (RUDN University), Russia

55. IAA-AAS-SciTech-085
Hybrid mass and radiation sensor based on piezoelectric and thermoelectric effects
Alexander Shupenev, Ivan Korshunov, Alexander Grigoryants, Natalia Pankova, Bauman Moscow State Technical University, Russia
Sergey Yanovich, Peoples' Friendship University of Russia (RUDN University), Russia

56. IAA-AAS-SciTech-097
Analytical technologies for thin coating element material diagnostics with PXWR application
Evgeny Egorov, Peoples' Friendship University of Russia (RUDN University), Russia

57. IAA-AAS-SciTech-034
Increasing the strength of the point mechanical connections of composite parts by constructive-technological method
Fedor Nasonov, Alexandr Zinin, Sergey Bukharov, Moscow Aviation Institute, Russia
Kirill Kharchenko, Georgyi Piskunov, Sukhoi Design Bureau, Russia

STRUCTURAL DESIGN FOR SPACE APPLICATIONS

Session Chairs:
Zhaokui Wang, *National University of Defense Technology, China*
Vladimir Sidorov, *Peoples' Friendship University of Russia (RUDN University), Russia*

58. IAA-AAS-SciTech-067
Uncertainty impact on micro-vibration control of an orbiting large adaptive space structure
Federica Angeletti, Paolo Gasbarri, Sapienza Università di Roma, Italy
59. IAA-AAS-SciTech-036
Microgravity investigation of seepage flows in porous media
Vladislav Dushin, Valeriy Nikitin, Evgeniya Skryleva, Lomonosov Moscow State University, Russia
60. IAA-AAS-SciTech-010
Bending of a thin sheet into a circular cylinder with two free edges for the Moon condition.
Sergey Krivoshapko, Marina Rynkovskaya, Vladimir Jean Paul, Peoples' Friendship University of Russia (RUDN University), Russia
61. IAA-AAS-SciTech-102
Architectural design and structures on the moon
Olga Suslova, Peoples' Friendship University of Russia (RUDN University), Russia
Vera Rogozina, Moscow Architectural Institute, Russia
62. IAA-AAS-SciTech-105
A theory for space frames with warping restraint at nodes
Vera Galishnikova, Peoples' Friendship University of Russia (RUDN University), Russia
63. IAA-AAS-SciTech-103
Lithological study of mars surface by planet orbital stations and rovers
Alexey F. Georgievskiy, Victoriya Bugina, Elena Shaleeva, Alexey A. Georgievskiy, Peoples' Friendship University of Russia (RUDN University), Russia

ENERGY SYSTEMS AND PROPULSION

Session Chairs:

Zhil-ulbe Matje, *Peoples' Friendship University of Russia (RUDN University), Russia*
Vladimir Sidorov, *Peoples' Friendship University of Russia (RUDN University), Russia*

64. IAA-AAS-SciTech-064
Hydrogen energy in the international energy strategy and its relationship with the prospect of the development of transport technologies
Vladimir Konoplev, Zakhar Melnikov, Georgy Belitsky, Andrey Korzin, Peoples' Friendship University of Russia (RUDN University), Russia

65. IAA-AAS-SciTech-100
Study of operating pressure effect on the performance of ejector for liquid-propellant rocket engine testing
Igor Narozhnyy, Alexander Drozdov, Peoples' Friendship University of Russia (RUDN University), Academy of Engineering, Russia
Drozdov N.A., Innovative Oil and Gas Solutions Limited Liability company, Russia

66. IAA-AAS-SciTech-058
The analysis of combustion process of organic fuel for prospective aerospace equipment
Petr Oshchepkov, Ivan Zaev, Sergej Smirnov, Roman Kamyshnikov, Peoples' Friendship University of Russia (RUDN University), Russia
Oleg Kamyshnikov, Universidad Nacional de San Agustín de Arequipa, Peru

67. IAA-AAS-SciTech-094
The ways of effectiveness increase of liquid fuel with organic addition appliance in aerospace equipment
Salim Soo, Khalil Abdel Sater, Alexander Khodyakov, Aleksandr Marusin, Igor Danilov, Sergey Khlopkov, Irina Andryushenko, Peoples' Friendship University of Russia (RUDN University), Russia

68. IAA-AAS-SciTech-016
Investigation of the initial stage of discharge in an ablative pulsed plasma thruster
Alexandr Antipov, Alexandr Bogatyy, Moscow Aviation Institute, Russia

69. IAA-AAS-SciTech-026
Advanced ceramic materials and 3D printing technologies in application to the electrically powered spacecraft propulsion
Victor Balashov, Sergey Khartov, Andrey Mogulkin, Vladislav Nigmatzyanov, Oleg Peysakhovich, Lev Rabinsky, Sergey Sitnikov, Moscow Aviation Institute, Russia

70. IAA-AAS-SciTech-021
Shape optimization of nickel anodes used in the production of galvanic coatings of rocket engine
Marianna Malkova, Alexander Zadiranov, Peoples' Friendship University of Russia (RUDN University), Russia

71. IAA-AAS-SciTech-106
Alternative strategies in astronautics during the energy crisis
Vitaly Melnikov, Georgy Polishchuk, Kseniya Benevolskaya, Oleg Samusenko and Gennadiy Rumyantsev. Peoples' Friendship University of Russia (RUDN University), Russia

72. IAA-AAS-SciTech-107
Transmission and reception of energy from laser space solar power plants
Vitaly Melnikov, Georgy Polishchuk, Oleg Samusenko, Anastasiya Yatsenko, Viktoria Novikova, Peoples' Friendship University of Russia (RUDN University), Russia

INTERNATIONAL SPACE POLICY AND LAW

Session Chairs:

Irina Shatalova, *Peoples' Friendship University of Russia (RUDN University), Russia*
Adu Nikez, *Peoples' Friendship University of Russia (RUDN University), Russia*

73. IAA-AAS-SciTech-114
Current issues of international space law
Aslan Abashidze, Peoples' Friendship University of Russia (RUDN University), Russia
74. IAA-AAS-SciTech-115
Current issues of mining activities on celestial bodies: international law aspects
Albert Khayrutdinov, Peoples' Friendship University of Russia (RUDN University), Russia
75. IAA-AAS-SciTech-116
Guidelines on long-term sustainability of outer space activities: future perspectives
Irina Chernykh, Peoples' Friendship University of Russia (RUDN University), Russia
76. IAA-AAS-SciTech-104
Space technologies to form lexical structure of academic discourse
Svetlana Dmitrichenkova, Elena Dolzhich, Peoples' Friendship University of Russia (RUDN University), Russia
77. IAA-AAS-SciTech-117
System of modern international space law
Alexander Travnikov, Irina Chernykh, Peoples' Friendship University of Russia (RUDN University), Russia
78. IAA-AAS-SciTech-118
Space debris safety and mitigation: some international legal aspects
Alexander Solntsev, Aslan Abashidze, Peoples' Friendship University of Russia (RUDN University), Russia
79. IAA-AAS-SciTech-119
Correlation of international space law and national legislation in the field of space activities
Mira Kulikpaeva, Peoples' Friendship University of Russia (RUDN University), Russia
80. IAA-AAS-SciTech-120
The regional african satellite communications organization (RASCOM): international legal status
Bukuru Jean-Baptist (Burundi), RUDN University, Russia
81. IAA-AAS-SciTech-121
The role of non-binding norms in international space law
Denis Gugunskiy, Peoples' Friendship University of Russia (RUDN University), Russia
82. IAA-AAS-SciTech-122
Disaster risk reduction and international space law
Dmitriy Kruglov, Peoples' Friendship University of Russia (RUDN University), Russia

IAA/AAS CONFERENCE ON SPACE FLIGHT MECHANICS

ORBITAL DYNAMICS AND DETERMINATION

Session Chairs:
Daniele Mortari, *Texas A&M University, USA*
Roberto Furfaro, *University of Arizona, USA*

IAA-AAS-SciTech2018-051
AAS 18-801

UNIFORM EXPONENTIAL STABILITY RESULT FOR THE RIGID-SPACECRAFT ATTITUDE TRACKING CONTROL PROBLEM

S. P. Arjun Ram[*] and Maruthi R. Akella[†]

Uniform exponential stability is proved for the attitude control problem using a PD+ controller which was previously only known to deliver uniform asymptotically stability. The control law retains the classical proportional-derivative (PD) structure plus feedforward terms associated with the desired attitude state. This so called 'PD+' controller has been extensively analyzed in the literature but thus far has only been shown to provide uniform asymptotic stability for the resulting closed-loop system. This paper parameterizes the kinematics through the three-dimensional Modified Rodrigues Parameter (MRP), assumes perfect fullstate measurements, and guarantees a stronger uniform exponential stability (UES) result. It should be emphasized that no additional restrictions on the reference trajectory or high-gain feedback assumptions are placed in achieving this result for the closed loop system. The design of a new Lyapunov function permits this stronger UES result and saliently, this construction naturally extends to the classical Gibbs-Rodrigues parameterization of the attitude kinematics. [View Full Paper]

[*] Graduate Research Assistant, Department of Aerospace Engineering and Engineering Mechanics, The University of Texas at Austin, Austin, Texas 78712, USA. E-mail: arjun.ram@utexas.edu.
[†] E.P. Schoch Professor, Department of Aerospace Engineering and Engineering Mechanics, The University of Texas at Austin, Austin Texas 78712, USA. E-mail: makella@mail.utexas.edu. AAS Fellow.

IAA-AAS-SciTech2018-066
AAS 18-802

SHAPE RECONSTRUCTION OF A TUMBLING UNKNOWN ORBITAL TARGET BY PASSIVE IMAGING

Renato Volpe,[*] Marco Sabatini[†] and Giovanni B. Palmerini[‡]

The capability to approach and service non-cooperative targets is becoming an important asset in space operations. The determination of target's relative kinematic state as observed by the chaser is required, starting from the limited number of images captured only from attained points of view. Due to the extremely large range of possible poses and light conditions, an extensive test campaign based on numerical simulations is required to validate candidate algorithms. A tool simulating in-orbit acquisition of the target image, and a process successful in identifying and matching the features, managing their appearance and disappearance during the approach, are presented. [View Full Paper]

[*] Associate Professor, Department of Mechanical and Aerospace Engineering, Sapienza University of Rome, Via Eudossiana 18, 00184, Italy.
[†] Associate Professor, Department of Astronautical, Electrical and Energetic Engineering, Sapienza University of Rome, Via Salaria 851, 00138, Italy.
[‡] Professor, Scuola di Ingegneria Aerospaziale (SIA), Sapienza University of Rome, Via Salaria 851, 00138, Italy.

IAA-AAS-SciTech2018-022
AAS 18-803

THE JOINT SOLUTION OF PROBLEM OF EVASION AND KEEPING IN A NEIGHBORHOOD REFERENCE ORBIT

Zay Yar Win,[*] Veniamin V. Malyshev,[†] Vladimir T. Bobronnikov[‡] and Aleksandr V. Starkov[§]

The problem of synthesis of optimal control of a linear stochastic system in the presence of additive non-random disturbances is solved, the solution is then applied to the control of a stationary artificial earth satellite in the performance of dynamic operations in the vicinity of a given hovering longitude. Stochastic and mini-max approaches to the problem solution are considered. The application of the developed algorithms is illustrated by the example of modeling the dynamic operation of deviation in the vicinity of the unstable equilibrium point. [View Full Paper]

[*] Postgraduate Student, Moscow Aviation Institute, 4 Volokolamskoe shosse, Moscow, 125993, Russia.
[†] Professor, Moscow Aviation Institute, 4 Volokolamskoe shosse, Moscow, 125993, Russia.
[‡] Professor, Moscow Aviation Institute, 4 Volokolamskoe shosse, Moscow, 125993, Russia.
[§] Associate Professor, Moscow Aviation Institute, 4 Volokolamskoe shosse, Moscow, 125993, Russia.

IAA-AAS-SciTech2018-062
AAS 18-804

HIGH-ALTITUDE NEAR-CIRCULAR ORBITS FOR A LUNAR ORBITAL STATION

Anastasia A. Tselousova,[*] Maksim G. Shirobokov[†] and Sergey P. Trofimov[‡]

High-altitude almost polar circular orbits around the Moon (10-15 thousand km above the surface) are currently proposed as a potential location of a prospective lunar orbital station. These orbits can be considered as an alternative to near-rectilinear halo orbits. The goal of this work is to compare geometrical and dynamical properties of various high-altitude circular obits and the resonant near-rectilinear halo orbits L2 9:2 and L2 4:1. To make a comparison, we investigate stability properties of the proposed orbits, eclipse conditions, and radio visibility of the lunar surface and station radio visibility from the Earth ground stations, including the Deep Space Network and stations located in Russia.
[View Full Paper]

[*] Engineer, Keldysh Institute of Applied Mathematics, 4 Miusskaya sq., Moscow, 125047, Russia.
[†] Researcher, Keldysh Institute of Applied Mathematics, 4 Miusskaya sq., Moscow, 125047, Russia.
[‡] Researcher, Keldysh Institute of Applied Mathematics, 4 Miusskaya sq., Moscow, 125047, Russia.

IAA-AAS-SciTech2018-087
AAS 18-805

ON ULTIMATELY THE MOST HIGHLY INCLINED, THE MOST CONCISE SOLAR POLAR TRAJECTORY WITH PRACTICALLY THE SHORTEST PERIOD

Junichiro Kawaguchi*

This paper presents the extended orbital synthesis results from the author's work in 2009 to achieve ballistic and short period out-of-ecliptic trajectories which possess ultimately the most highly and most concise solar polar properties. Those are realized through almost ballistic flight instead of using electric propulsion or solar sail acceleration. The strategy developed utilizes a Jovian gravity assist first, followed by very high speed synchronized multiple polar gravity assists by Earth or Venus. While the author's work in 2009 presented the trajectories down to almost one year period, this paper will present the further sequences that make the semi-major axis lower than one AU and lower the perihelion distance closer to the Sun for close-up observation of the Sun. [View Full Paper]

* JAXA, Japan.

IAA-AAS-SciTech2018-049
AAS 18-806

ON THE DIFFERENCE IN THE LAWS OF GYROSCOPES NOISES ACCUMULATION IN PLATFORM AND STRAPDOWN ATTITUDE DETERMINATION INERTIAL SYSTEMS

Nikolay I. Krobka*

This paper discusses the difference in the accumulation of attitude determination errors by platform and strapdown INS, built on the same gyroscopes based on any physical principle with arbitrary errors. The difference in the accuracy of platform and strapdown INS may differ by the orders of magnitude (in 10, 100, and more times), depending on the structure of noise and the type of rotation. This effect explains the need to correctly identify the structure of noise of gyroscopes. For gyroscopes intended for strapdown INS, the precise identification of the noise structure is more critical than for platform INS.

[View Full Paper]

* Chief Scientist, Department of Promising Development, Scientific Research Institute for Applied Mechanics named after Academician V. I. Kuznetsov (Branch of the Federal State Unitary Enterprise "Center for Operation of Space Ground Based Infrastructure"), 12A Prud Klychiki str., Moscow, 111123, Russia.

IAA-AAS-SciTech2018-050
AAS 18-807

ON CRITICAL MODES OF FUNCTIONING OF ATTITUDE DETERMINATION INERTIAL SYSTEMS

Nikolay I. Krobka*

This paper presents the critical modes of functioning of strapdown inertial orientation systems in which the attitude error increases with the unchanged accuracy of the gyroscopes and the unchanged attitude determination algorithm. The Euler's geometrical theorem is well known: "A rigid body with a fixed point can be turned to any angle position around some axis by some angle". A new kinematical theorem is proved: "A rigid body with a fixed point can be turned to any angular position so that the angular velocity vector projections contain only harmonic components at one frequency". Three consequences of this theorem are following: 1. The algorithms of integration of kinematic equations with a fixed frequency "don't see" some rotations by 100%. 2. Conventional algorithms for filtering the angular vibrations can filter out not only real angular vibrations but also the turns of the object to unlimited angles. 3. In order to avoid critical operating modes, a transition from attitude determination inertial systems based on unchanged algorithms to the intelligent attitude determination inertial systems based on a strategy with the choice of various algorithms depending on the current conditions of rotation or adaptive algorithms is proposed. [View Full Paper]

* Chief Scientist, Department of Promising Development, Scientific Research Institute for Applied Mechanics named after Academician V. I. Kuznetsov, Federal State Unitary Enterprise "Center for Operation of Space Ground Based Infrastructure", 12A Prud Klychiki str., Moscow, 111123, Russia.

IAA-AAS-SciTech2018-035
AAS 18-808

DUST CHARGED PARTICLES MOTION IN VICINITY OF THE LAGRANGE LIBRATION POINTS

Tatiana Salnikova[*] and Sergey Stepanov[†]

We consider the motion of the particles with small masses and individual electric charges. They produce a self-consistent force field, consisting of gravitational and electrostatic parts. We study a behavior of these charged dust particles in the small vicinity of the Lagrange libration points of the Earth-Moon system. Their evolution is described by the Vlasov-Poisson equations. To analyze the possibility of existence of stable configuration, we use the equations of characteristics for the Vlasov equation. It turned out that for some values of the parameters our initial cloud of the dust charged particles has periodically changing stable configuration. [View Full Paper]

[*] Associate Professor, Lomonosov Moscow State University, 1 Leninskiye Gory, GSP-1, Moscow, 119991, Russia; Associate Professor, Academy of Engineering, Peoples' Friendship University of Russia (RUDN University), 6 Miklukho-Maklaya str., Moscow, 117198, Russia.
[†] Professor, Lomonosov Moscow State University, 1 Leninskiye Gory, GSP-1, Moscow, 119991, Russia; Professor, Dorodnicyn Computing Centre, Russian Academy of Sciences, 40 Vavilov str., Moscow, 1193336 Russia.

IAA-AAS-SciTech2018-124
AAS 18-809

OPTIMAL FLYBY OF SPACE DEBRIS OBJECTS ON A GEOSTATIONARY ORBIT

Andrey A. Baranov[*] and Nikolay Y. Makarov[†]

This work presents the results of numerical forecast for the movement of 92 space debris objects in a geostationary orbit. According to the calculation results, there were compiled the time variation graphs of: inclination, longitude of the ascending node, semi-major axis and eccentricity. Based on the obtained data we elaborated two flyby strategies of space debris objects and made an estimation of fuel costs as part of implementation of active debris removal schemes. The graphs of the change in inclination and the longitude of the ascending node represent the greatest interest, since the rotation of orbit plane by several degrees requires significant expenditures of the total characteristic velocity. The obtained results may be used for further elaboration of active debris removal schemes.

[View Full Paper]

[*] Professor, Academy of Engineering, Peoples' Friendship University of Russia (RUDN University), 6 Miklukho-Maklaya str., Moscow, 117198, Russia.
[†] Postgraduate Student, Academy of Engineering, Peoples' Friendship University of Russia (RUDN University), 6 Miklukho-Maklaya str., Moscow, 117198, Russia.

IAA-AAS-SciTech2018-126
AAS 18-810

METHOD FOR DETERMINING THE MOMENTS OF TRAJECTORY MEASUREMENTS FOR THE CORRECTION OF THE ACCUMULATING ORBIT SHIFT OF THE SPACECRAFT

Gennadiy N. Rumyantsev,[*] Vitaly M. Melnikov,[†] Georgy M. Polishchuk[‡] and Oleg E. Samusenko[§]

The paper proposes an autonomous self-sustainable method for solving the problem of correction of measurement moments to eliminate the accumulating shift along the orbit. The method is based on the independence of the true anomaly at the point of measurement from the shift along the orbit. Various modifications of the method, differing in complexity, computational costs and methodological errors, are proposed.

Keywords: spacecraft, probing technologies, navigational sensing.

[View Full Paper]

[*] Professor, Academy of Engineering, Peoples' Friendship University of Russia (RUDN University), 6 Miklukho-Maklaya str., Moscow, 117198, Russia.
[†] Professor, Academy of Engineering, Peoples' Friendship University of Russia (RUDN University), 6 Miklukho-Maklaya str., Moscow, 117198, Russia.
[‡] Professor, Academy of Engineering, Peoples' Friendship University of Russia (RUDN University), 6 Miklukho-Maklaya str., Moscow, 117198, Russia.
[§] Associate Professor, Academy of Engineering, Peoples' Friendship University of Russia (RUDN University), 6 Miklukho-Maklaya str., Moscow, 117198, Russia.

GUIDANCE, NAVIGATION AND CONTROL

Session Chairs:
Maruthi Akella, *University of Texas at Austin, USA*
Giovanni Palmerini, *Texas A&M University, USA*

IAA-AAS-SciTech2018-072
AAS 18-811

THE THEORY OF CONNECTIONS: CONNECTING FUNCTIONS

Daniele Mortari*

This paper extends to two-dimensions the one-dimensional Theory of Connections, introduced in Ref. [1]. In particular, it generalizes the Coons surface [2] by providing expressions, called *constrained expressions*, representing all possible surfaces having assigned boundary constraints in terms of functions and/or derivatives. These expressions, which contain a new function g(x, y), free to choose, they satisfy all constraints no matter what the g(x, y) is. The boundary constraints considered here are: pure functions constraints (Dirichlet boundaries), pure first derivative constraints (von Neumann boundaries), and mixed constraints. The main purpose of this paper is to provide analytical *constrained expressions*, that can be used to solve two-dimensional constrained optimization problems as, for instance, to solve partial differential equations. [View Full Paper]

* Professor, Aerospace Engineering, Texas A&M University, 3141 - TAMU, College Station, Texas 77843-3141, USA. E-mail: mortari@tamu.edu.

IAA-AAS-SciTech2018-081
AAS 18-812

WEIGHTED LEAST-SQUARES SOLUTIONS OF OVER-CONSTRAINED DIFFERENTIAL EQUATIONS

Hunter Johnston[*] and Daniele Mortari[†]

This study extends the general interpolation method provided by the Theory of Connections (ToC) to obtain solutions for over-constrained ordinary differential equations (ODEs). While it is impossible to perfectly satisfy more constraints than the order of the differential equation, this approach applies the constraints through a weight least-squares technique. Therefore, the constraints are satisfied relative to the specified weights and not exactly. First, this paper derives constrained expressions (an expression with embedded constraint conditions), for two constraints in one degree of freedom (one unknown parameter). These equations are analyzed for major implications of using the weighted least-squares technique on the constraints. Next, the constrained expression for three constraints in two degrees of freedom is derived and applied to the solution of ODEs. To validate this method, two unique tests are presented. The first test considers a second order differential equation subject to three "observed" points affected by noise. The proposed method allows to accommodate all three "observations" into the solution of the differential equation through weighted least-squares. Lastly, a differential equation is solved such that an initial-value problem is transformed into to a boundary-value problem. In all cases, the differential equations are solved at machine error accuracy. [View Full Paper]

[*] PhD Student, Aerospace Engineering, Texas A&M University, 3141 - TAMU, College Station, Texas 77843-3141, USA. E-mail: hunterjohnston@tamu.edu.
[†] Professor, Aerospace Engineering, Texas A&M University, 3141 - TAMU, College Station, Texas 77843-3141, USA. E-mail: mortari@tamu.edu. IEEE and AAS Fellow. IAA Corresponding member.

IAA-AAS-SciTech2018-086
AAS 18-813

A RECURRENT DEEP ARCHITECTURE FOR QUASI-OPTIMAL FEEDBACK GUIDANCE IN PLANETARY LANDING

Roberto Furfaro,[*] Ilaria Bloise,[†] Marcello Orlandelli,[‡] Pierluigi Di Lizia,[§] Francesco Topputo[**] and Richard Linares[††]

Precision landing on large planetary bodies is an important technology that enables future human and robotic exploration of the solar system. For example, over the past decade, landing systems for robotic missions have been developed with the specific goal of deploying robotic agents (e.g. rovers, landers) on the planetary surface (e.g. Mars, Moon). Considering the strong interest for sending humans back to the Moon within the next decade, the landing system technology will continue to progress to keep up with the demand for more stringent requirements. Indeed, more demanding planetary exploration requirements implies a technology development program that calls for more precise guidance systems capable of delivering rovers and/or landers with higher and higher degree of precision. In this paper we design, test and validate a deep Recurrent Neural Network (RNN) architecture capable of predicting the fuel-optimal thrust from sequence of states during a powered planetary descent. Here, the principle behind imitation learning (supervised learning) are applied. A set of propellant-optimal open loop landing trajectories are computed using direct transcription methods (e.g. Gauss Pseudo Spectral methods). Such sequences comprise the training set (i.e. the teacher) employed during the learning phase. A Long-Short Term Memory (LSTM) architecture is employed to keep track of what has entered the network before and use such information to better predict the output. The RNN-LSTM architecture is trained validated and tested to evaluate the performance predictive performance. Finally, the results of a Monte Carlo simulations in Moon landing scenarios are provided to show the effectiveness of the proposed methodology.

[View Full Paper]

[*] Professor, Department of Systems and Industrial Engineering, Department of Aerospace and Mechanical Engineering, University of Arizona, Tucson, Arizona 85721, USA. E-mail: robertof@email.arizona.edu.
[†] Visiting Graduate Student, Department of Systems and Industrial Engineering, University of Arizona, Tucson, Arizona 86721, USA.
[‡] Visiting Graduate Student, Department of Systems and Industrial Engineering, University of Arizona, Tucson, Arizona 86721, USA.
[§] Assistant Professor, Dipartimento di Scienze e Tecnologie Aerospaziali, Politecnico di Milano, via La Masa 34, 20156 Milano, Italy.
[**] Assistant Professor, Dipartimento di Scienze e Tecnologie Aerospaziali, Politecnico di Milano, via La Masa 34, 20156 Milano, Italy.
[††] Charles Stark Draper Assistant Professor, Department of Aeronautics and Astronautics, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139, USA.

IAA-AAS-SciTech2018-005
AAS 18-814

DYNAMICAL ASPECTS OF SPATIAL USE OF GRAVITY ASSIST MANEUVERS FOR THE SOLAR PROBES

Alexey Grushevskii,[*] Yury F. Golubev,[†] Victor Koryanov,[‡] Andrey Tuchin[§] and Denis Tuchin[**]

Low-cost interplanetary tours with the high inclined orbit's formation in the Solar system with use of gravitational maneuvers near its planets (Earth and Venus) and with the accurate ephemeris using are considered. Limited dynamic opportunities of their use require multiple passes near them. Topicality of the regular creation of optimum scenarios – sequences of cranking passing of celestial bodies and the solution of conditions of their execution is obvious. This work is devoted to the description of required features of trajectory's beams for the creation of such chains. Previously a comparative analysis of various modern astrodynamics studies of the 3D implementation of GAMs taking into account accurate ephemerides was performed. Improved analytical formulas for the change of inclination of an SC orbit as a result of 3D GAMs were obtained and realistic results of the computation of parameters of the SC orbit inclination changes at the planets of the Solar system and their moons were presented. In this paper, we describe algorithms for designing multi-pass chains of GAMs that result in an energy-efficient increase of the inclination of the SC orbit to the ecliptic plane. Simultaneously, a generalization of the analytical formulas for the general case of elliptic orbits of the SC and the partner planet for the GAM is obtained. Applications of its using for the study of concrete options of mission "InterhelioZond" are given. [View Full Paper]

[*] Chief Scientific Officer, Keldysh Institute of Applied Mathematics, 4 Miusskaya sq., Moscow, 125047, Russia.
[†] Head of Department, Keldysh Institute of Applied Mathematics, 4 Miusskaya sq., Moscow, 125047, Russia.
[‡] Senior Researcher, Keldysh Institute of Applied Mathematics, 4 Miusskaya sq., Moscow, 125047, Russia.
[§] Head of Sector, Keldysh Institute of Applied Mathematics, 4 Miusskaya sq., Moscow, 125047, Russia.
[**] Leading Researcher, Keldysh Institute of Applied Mathematics, 4 Miusskaya sq., Moscow, 125047, Russia.

IAA-AAS-SciTech2018-012
AAS 18-815

CONSTRUCTION OF THE MOON-TO-EARTH TRAJECTORY TO THE EARTH ENTRY INTERFACE POINT USING MULTI-IMPULSE TRANSFER

Nadezhda M. Gavrikova*

The problem of the lunar trans-Earth injection trajectory's calculation has been studied for a long time. In this work the accent is made on the calculation of the full trajectory to the Earth entry interface (EEI) point (not only part of trajectory before the return hyperbola injection). Such problems as the calculation of the EEI point's parameters, the selection of the maneuvering scheme and the choice of numerical methods are resolved. The results of the numerical simulation for the three-body problem (the Earth, the Moon, the spacecraft) considering noncentral gravity models are presented. Calculations were made for the "Vostochny" landing site. [View Full Paper]

* Postgraduate Student, Faculty of Mechanics and Mathematics, Department of Theoretical Mechanics and Mechatronics, Lomonosov Moscow State University, 1 Leninskiye Gory, GSP-1, Moscow, 119991, Russia.

IAA-AAS-SciTech2018-057
AAS 18-816

DISTRIBUTION OF CORRECTION THRUSTERS UNDER DELTA-V CONSTRAINTS IN LOCAL HORIZONTAL PLANE

Anna Okhitina,[*] Yaroslav Mashtakov[†] and Stepan Tkachev[‡]

This paper is devoted to the problem of orbit correction thrusters distribution on-board the geostationary satellite. It is necessary to simultaneously correct orbital elements and provide reaction wheels desaturation. This problem is complicated by the fact that one of the thrusters might fail but in spite of this the system must maintain its efficiency. Besides, Delta-V Constraints in Local Horizontal Plane should be considered. In this work necessary and sufficient conditions for ensuring the desaturation of the reaction wheels are found. In addition, numerical solution of the optimization problem of the thrusters' location is given. [View Full Paper]

[*] Engineer, Space Systems Dynamics Department, Keldysh Institute of Applied Mathematics, 4 Miusskaya sq., Moscow, 125047, Russia.
[†] Junior Researcher, Space Systems Dynamics Department, Keldysh Institute of Applied Mathematics, 14 Miusskaya sq., Moscow, 125047, Russia.
[‡] Senior Researcher, Space Systems Dynamics Department, Keldysh Institute of Applied Mathematics, 4 Miusskaya sq., Moscow, 125047, Russia.

IAA-AAS-SciTech2018-015
AAS 18-817

THE OPTIMIZATION OF INTERPLANETARY FLIGHT TO PHOBOS WITH A JET ENGINE OF COMBINED LOW AND HIGH LIMITED THRUST

Alexander S. Samokhin,[*] Marina A. Samokhina,[†] Ilia S. Grigoriev[‡] and Maxim P. Zapletin[§]

The optimization problem of space transfer of the spacecraft to Phobos is considered. On the one hand this problem is coincided to real mission to Phobos, which Russian Federation is going to realize in the next few years. On the other hand, the method development of the spacecraft interplanetary trajectory optimization is a question of present interest. The authors of researches usually neglect the planetocentric legs of trajectory in such problems, and there is no through optimization of the whole mission. In this paper the method of Pontryagin's extremals design in such problems with the taking into account these features by the example of flight to Phobos. The coordinates and velocity vectors of the Earth, Mars and Phobos correspond to ephemeris DE424 and MAR097. Gravitational fields of the Sun, the Earth and Mars are considered to be Newtonian. The spacecraft is equipped with High- and Low-thrust engines. The problem of cosmodynamics is formalized as an optimal control task and then is solved numerically by shooting method. In this paper certain trajectories are designed, and the possible gain due to using of combined propulsion in comparison with using only High-thrust engines is considered.

[View Full Paper]

[*] Assistant, Lomonosov Moscow State University, 1 Leninskiye Gory, GSP-1, Moscow, 119991, Russia; Senior Lecturer, Academy of Engineering, Peoples' Friendship University of Russia (RUDN University), 6 Miklukho-Maklaya str., Moscow, 117198, Russia; Researcher, V. A. Trapeznikov Institute of Control Sciences of Russian Academy of Sciences, 65 Profsoyuznaya str., Moscow 117997, Russia.
[†] Researcher, V. A. Trapeznikov Institute of Control Sciences of Russian Academy of Sciences, 65 Profsoyuznaya str., Moscow 117997, Russia; Assistant, Lomonosov Moscow State University, 1 Leninskiye Gory, GSP-1, Moscow, 119991, Russia; Senior Lecturer, Academy of Engineering, Peoples' Friendship University of Russia (RUDN University), 6 Miklukho-Maklaya str., Moscow, 117198, Russia.
[‡] Associate Professor, Lomonosov Moscow State University, 1 Leninskiye Gory, GSP-1, Moscow, 119991, Russia; Professor, Academy of Engineering, Peoples' Friendship University of Russia (RUDN University), 6 Miklukho-Maklaya str., Moscow, 117198, Russia.
[§] Associate Professor, Department of Mechanics and Mathematics, Lomonosov Moscow State University, 1 Leninskiye Gory, GSP-1, Moscow, 119991, Russia.

IAA-AAS-SciTech2018-056
AAS 18-818

EXPANSION OF THE TRANSPORT CAPABILITIES OF THE SPACE SYSTEM BASED ON THE PROTON-M ROCKET WITH THE USE OF ELECTRIC PROPULSION AND A GRAVITATIONAL MANEUVER NEAR THE EARTH AT THE BEGINNING OF AN INTERPLANETARY FLIGHT

Mikhail S. Konstantinov*

An analysis is made of the increase in the transport capabilities of the space system based on the “Proton-M” launcher in the implementation of interplanetary flights due to the use of the heliocentric Earth-Earth flight (on which electric propulsion (EP) is working) and the gravitational maneuver (swingby) near the Earth. It is assumed that the chemical upper stage "Breeze-M" provides for the space vehicle to leave the vicinity of the Earth with a relatively small hyperbolic excess of velocity. Then the chemical upper stage separates from the spacecraft. Heliocentric flight Earth - Earth is realized using EP. The possibility of using EP based on one and two stationary plasma thrusters SPT-140 is analyzed. Due to the work of the EP, the spacecraft is approaching to the Earth (for Earth swingby) with a large hyperbolic excess of velocity (for example, up to 12 km/s). Thus, the introduction into the scheme of interplanetary flight of the heliocentric Earth-Earth flight and the use of the Earth swingby makes it possible to insert spacecraft of large mass into a hyperbolic trajectory of departing from the Earth (with a large hyperbolic excess of velocity). The mass of the spacecraft on the hyperbolic trajectory of departing from the Earth (after the swingby near it) as a function of the magnitude of the hyperbolic excess of velocity is analyzed. [View Full Paper]

* Professor, Research Institute of Applied Mechanics and Electrodynamics, Moscow Aviation Institute, 4 Volokolamskoe shosse, Moscow, 125993, Russia.

IAA-AAS-SciTech2018-127
AAS 18-819

METHOD FOR CHOOSING MEASUREMENT MOMENTS OF RADIO ALTIMETER-VERTICAL FOR ORBIT PARAMETERS CORRECTION

Gennadiy N. Rumyantsev,[*] Vitaly M. Melnikov,[†] Georgy M. Polishchuk[‡] and Oleg E. Samusenko[§]

The paper proposes a method for choosing the measurements moments of a radio altimeter-vertical, based on the obtained analytical dependences of the covariance matrix elements on the measurements moments. The method is used for autonomous correction of orbit parameters.

Keywords: autonomous navigation system, measurement tools, radio-altimeter-vertical

[View Full Paper]

[*] Professor, Academy of Engineering, Peoples' Friendship University of Russia (RUDN University), 6 Miklukho-Maklaya str., Moscow, 117198, Russia.
[†] Professor, Academy of Engineering, Peoples' Friendship University of Russia (RUDN University), 6 Miklukho-Maklaya str., Moscow, 117198, Russia.
[‡] Professor, Academy of Engineering, Peoples' Friendship University of Russia (RUDN University), 6 Miklukho-Maklaya str., Moscow, 117198, Russia.
[§] Associate Professor, Academy of Engineering, Peoples' Friendship University of Russia (RUDN University), 6 Miklukho-Maklaya str., Moscow, 117198, Russia.

MISSION DESIGN AND OPTIMIZATION

Session Chairs:
Richard Linares, *Massachusetts Institute of Technology, USA*
Mauro Pontani, *Sapienza University of Rome, Italy*

IAA-AAS-SciTech2018-046
AAS 18-820

DEVELOPMENT AND LAUNCH OF MINI-ELEVATOR DEMONSTRATION CUBESAT STARS-ME

Masahiro Nohmi[*] and Yoji Ishikawa[†]

A space elevator demonstration satellite named "STARS-Me" is launched in 2018. It consists of two CubeSats, those are connected by a rigid tape tether. One has a climber, and the other has the tether deployment mechanism consisting of approximately 11m tether. The mission sequences are divided into three. (i) Initial operation mode: it is operated under the docking condition. (ii) STARS-Me separation mode: By the command from the ground station, two satellites will deploy the tether using motors. (iii) Climber traverse mode: The climber will traverse on the tether after being unlocked. STARS-Me was put on the orbit on October 6, and currently is being operated. [View Full Paper]

[*] Professor, Faculty of Engineering, Shizuoka University, 3-5-1 Johoku, Naka-ku, Hamamatsu, Japan 432-8561.
[†] Doctor, Obayashi Corporation, 2-15-2 Konan, Minato-ku, Tokyo, Japan 108-8502.

IAA-AAS-SciTech2018-076
AAS 18-821

SPACE TRAJECTORY OPTIMIZATION: DIFFERENTIAL EVOLUTION REDUX

Robert G. Melton*

A modified version of the differential evolution (DE) algorithm, using a hypertorus for the solution space and an additive component for some of the trial solutions, is applied to two trajectory optimization problems (determining initial conditions for Lyapunov orbits in the circular-restricted three-body problem, and determining optimal steering strategies for a two-arc low-thrust orbital transfer). The results are compared with those using particle swarm optimization (PSO), with DE showing significantly less likelihood of stagnation than PSO, while requiring a modest increase in computation time. [View Full Paper]

* Professor, Department of Aerospace Engineering, The Pennsylvania State University, 229 Hammond Bldg., University Park, Pennsylvania 16802, USA.

IAA-AAS-SciTech2018-011
AAS 18-822

ALGORITHM OF THE B-PLANE DELIVERY ERROR ESTIMATION FOR THE MISSION TO VENUS

Alexander S. Gammal,[*] Andrew G. Tuchin[†] and Denis A. Tuchin[‡]

Modern missions dedicated to solar and heliospheric physics require out-of-ecliptic orbits of a spacecraft (SC). The effective implementation of the missions such as ESA's Solar Orbiter or Russian Interheliozond project is impossible without using gravity assist maneuvers (GAMs). Knowledge of the SC's delivery error estimations is crucial for the missions using GAMs. Such estimations are required not only at during the mission development stage, but also at the mission execution stage. Errors estimations of the SC delivery to planets for GAMs were made for the mission Interheliozond, intended to study the Sun from the close distance. Some results of calculations are presented.

[View Full Paper]

[*] Postgraduate Student, Keldysh Institute of Applied Mathematics, 4 Miusskaya sq., Moscow, 125047, Russia.
[†] Chief Scientist, Keldysh Institute of Applied Mathematics, 4 Miusskaya sq., Moscow, 125047, Russia.
[‡] Lead Researcher, Keldysh Institute of Applied Mathematics, 4 Miusskaya sq., Moscow, 125047, Russia.

IAA-AAS-SciTech2018-068
AAS 18-823

SPACE NAVIGATOR: A TOOL FOR THE OPTIMIZATION OF COLLISION AVOIDANCE MANEUVERS

Leonid Gremyachikh,[*] Dmitrii Dubov,[†] Nikita Kazeev,[‡] Andrey Kulibaba,[§] Andrey Skuratov,[**] Anton Tereshkin,[††] Andrey Ustyuzhanin,[‡‡] Lubov Shiryaeva[§§] and Sergej Shishkin[***]

The number of space objects will grow several times in a few years due to the planned launches of constellations of thousands microsatellites. It leads to a significant increase in the threat of satellite collisions. Spacecraft must undertake collision avoidance maneuvers to mitigate the risk. According to publicly available information, conjunction events are now manually handled by operators on the Earth. The manual maneuver planning requires qualified personnel and will be impractical for constellations of thousands satellites. In this paper we propose a new modular autonomous collision avoidance system called "Space Navigator". It is based on a novel maneuver optimization approach that combines domain knowledge with Reinforcement Learning methods. [View Full Paper]

[*] Research Assistant, Laboratory of Methods for Big Data Analysis, Faculty of Computer Science, National Research University Higher School of Economics, 3 Kochnovsky Proezd, Moscow, 125319, Russia.
[†] Graduate Student, Laboratory of Methods for Big Data Analysis, Faculty of Computer Science, National Research University Higher School of Economics, 3 Kochnovsky Proezd, Moscow, 125319, Russia.
[‡] Postgraduate Student, Laboratory of Methods for Big Data Analysis, Faculty of Computer Science, National Research University Higher School of Economics, 3 Kochnovsky Proezd, Moscow, 125319, Russia.
[§] Department Head, Certification Center for Elements and Equipment, JSC Russian Space Systems, 53 Aviamotornaya str., Moscow, 111024, Russia.
[**] Unity Developer, Phygitalism, 27/8 Presnensky Val str., Moscow, 123557, Russia.
[††] 3D Artist, Phygitalism, 27/8 Presnensky Val str., Moscow, 123557, Russia.
[‡‡] Laboratory Head, Laboratory of Methods for Big Data Analysis, Faculty of Computer Science, National Research University Higher School of Economics, 3 Kochnovsky Proezd, Moscow, 125319, Russia.
[§§] Department Head, Design and Technology Center, JSC Russian Space Systems, 53 Aviamotornaya str., Moscow, 111024, Russia.
[***] Bureau Chief, Quality Management System Center, JSC Russian Space Systems, 53 Aviamotornaya str., Moscow, 111024, Russia.

IAA-AAS-SciTech2018-003
AAS 18-824

INTERSTELLAR FLIGHTS VIA ALCUBIERRE WARP DRIVE

Michael Fil'chenkov[*] and Yuri Laptev[†]

The possibilities of interstellar flights for extraterrestrial civilizations have been considered. A superluminal motion (hypermotion) via Alcubierre warp drive is analyzed. Parameters of the warp drive have been estimated. The equations of starship geodesics have been solved. The starship velocity has been shown to exceed the speed of light, with the local velocity relative to deformed space-time being subluminal. The warp drive creation by a supercivilization requires a galactic energy consumption. Hawking radiation does not prove to affect the ship interior considerably, Difficulties related to a practical realization of the hypermotion are indicated. [View Full Paper]

[*] Deputy Director, Institute of Gravitation and Cosmology, Peoples' Friendship University of Russia (RUDN University), 6 Miklukho-Maklaya str., Moscow, 117198, Russia.
[†] Assistant, Institute of Gravitation and Cosmology, Peoples' Friendship University of Russia (RUDN University), 6 Miklukho-Maklaya str., Moscow, 117198, Russia.

IAA-AAS-SciTech2018-020
AAS 18-825

THE USE OF COMPUTER-BASED SIMULATORS TO TRAIN COSMONAUTS FOR THE FULFILLMENT OF THE PROGRAM OF SCIENTIFIC-APPLIED RESEARCH

Andrey A. Kuritsyn,[*] Elena V. Popova[†] and Maksim M. Kharlamov[‡]

The progressive development of the ISS RS and putting the multi-functional laboratory module into operation on the Russian Segment lead both to an increase in the number of scientific-applied research and experiments (SAR), carried out by cosmonauts aboard the ISS, and to the actualization of ensuring the high quality of cosmonaut training for performing them. One of the ways of solving the problem is to upgrade technical facilities for cosmonaut training using digital information technologies.

Theoretical studies of the problem of improving the efficiency of cosmonaut training for carrying out SAR aboard the ISS on the basis of computer technology are being conducted at the Gagarin R&T CTC since 2006. The unique simulator complex, developed in 2013, is now actively used and upgraded. It comprises the dedicated stand to train cosmonauts for geophysical exploration and monitoring of the Earth, automated workplaces for conducting aerial visual instrumental observations (VIOs), complex of functional-simulation stands on the basis of computer-assisted virtual simulators of space experiments and scientific equipment using interactive 3D models (the "Nauka" complex).

The said complex allows training cosmonauts for research on the space station, verifying flight data files and, also, improving techniques of performing space experiments.

[View Full Paper]

[*] Head Office, Yu.A. Gagarin Research and Test Cosmonaut Training Center, Star City, Moscow Region, 141160, Russia.
[†] Deputy Chief, Yu.A. Gagarin Research and Test Cosmonaut Training Center, Star City, Moscow Region, 141160, Russia.
[‡] Chief of Unit, Yu.A. Gagarin Research and Test Cosmonaut Training Center, Star City, Moscow Region, 141160, Russia.

IAA-AAS-SciTech2018-108
AAS 18-826

ECOLOGICAL IMPACT ON THE ENVIRONMENT FROM LASER SPACE SOLAR POWER PLANTS IN THE PROBLEM OF DEVELOPMENT AND DEVELOPMENT OF THE ARCTIC AND CONTINENTAL SHELF

Vitaly M. Melnikov,[*] Georgy M. Polishchuk,[†] Anastasiya N. Yatsenko,[‡] Galina I. Balandina[§] and Viktoria D. Novikova[**]

Space technology is capable of solving the problem of the climate stabilization and the substitution of oil by creating a space solar power plants (SSPP) that redistributes the energy to the Earth. The environmental impact of nuclear, thermal, hydroelectric and laser space solar power plants on the environment is compared. Comparing different methods for transmission of energy (ultrahigh frequency (UHF), laser), and the effectiveness or efficiency of the various stages of transformation. The conclusion is made about the advantages of using laser SSP in comparison with analogues in the problem of development and development of the Arctic and the continental shelf, since environmentally friendly (without chemical toxicity and radiation), cheap energy (at 6 times cheaper than its production on Earth) of any scale is transmitted directly to the area of its consumption and does not require deforestation and non-use of agricultural areas, and other costs associated with the creation of long power lines in the Far North. [View Full Paper]

[*] Professor, Academy of Engineering, Peoples' Friendship University of Russia (RUDN University), 6 Miklukho-Maklaya str., Moscow, 117198, Russia.
[†] Professor, Academy of Engineering, Peoples' Friendship University of Russia (RUDN University), 6 Miklukho-Maklaya str., Moscow, 117198, Russia.
[‡] Assistant, Academy of Engineering, Peoples' Friendship University of Russia (RUDN University), 6 Miklukho-Maklaya str., Moscow, 117198, Russia.
[§] Lecturer, Academy of Engineering, Peoples' Friendship University of Russia (RUDN University), 6 Miklukho- Maklaya str., Moscow, 117198, Russia.
[**] Student, Academy of Engineering, Peoples' Friendship University of Russia (RUDN University), 6 Miklukho- Maklaya str., Moscow, 117198, Russia.

SATELLITE CONSTELLATIONS AND FORMATION FLYING

Session Chairs:
Robert Melton, *The Pennsylvania State University, USA*
Masahiro Nohmi, *Shizuoka University, Japan*

IAA-AAS-SciTech2018-061
AAS 18-827

SATELLITE FORMATION CONTROL VIA DEEP REINFORCEMENT LEARNING

Jacob Broida[*] and Richard Linares[†]

This work uses the Multi-Agent Deep Deterministic Policy Gradient (MADDPG) method, which is a state-of-the-art and efficient multi-agent Reinforcement Learning (RL) approach, for developing closed-loop formation control polices. RL offers a promising solution for the satellite formation control problem since it can handle complex constraints and nonlinear dynamics. This work develops policies for controlling satellite formations in perturbed orbital environments. Deep neural networks are used to represent the closed-loop policies which are trained in simulation. Once trained the neural network policies can be executed in real-time. Furthermore, simulation results will be shown for deployment, collision avoidance, and formation station-keeping functions. [View Full Paper]

[*] Graduate Student, Department of Aeronautics and Astronautics, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139, USA.
[†] Charles Stark Draper Assistant Professor, Department of Aeronautics and Astronautics, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139, USA. E-mail: linaresr@mit.edu.

IAA-AAS-SciTech2018-065
AAS 18-828

OPTIMAL TETHER-ASSISTED SPACE DEBRIS DISPOSAL

Wei Shi Wang[*] and Arun K. Misra[†]

Optimal transfer of space debris from its original orbit to a lower orbit using a space tug and a tether is considered. The magnitude of the low thrust applied to the tug is assumed to be constant, but the thrust angle is varied to achieve fuel-optimal orbital transfer. The optimization formulation leads to a two-point boundary value problem which is solved to give the optimal variation of the thrust angle as well as the system response. It is noted that a maximum tether angle constraint must be added to the optimization scheme to eliminate large tether librations. [View Full Paper]

[*] Research Assistant, Department of Mechanical Engineering, McGill University, Montreal, QC, Canada, H3A 0C3.
[†] Thomas Workman Professor, Department of Mechanical Engineering, McGill University, Montreal, QC, Canada, H3A 0C3.

IAA-AAS-SciTech2018-077
AAS 18-829

AN ADVANCED REMOTE SENSING CUBESAT CONSTELLATION FOR MULTI-SPECTRAL EO IMAGING

Riccardo Di Roberto[*] and Filippo Graziani[†]

The use of CubeSat missions for Earth Observation has greatly increased in the last 5 years, thanks to the miniaturization of components, optical payloads, the boost in power efficiency of critical systems and the resulting reduction in overall costs for the mission. GAUSS is proposing the creation of a hybrid constellation of 3U and 6U Cubesats, designed using lean-satellite methodology for the reduction in the costs of the single platform's development and manufacturing. The constellation under study will be competitively positioned in the Earth Observation scenario, generally dominated by institutional missions, in terms of data quality and fast response. The mission will make use of an advanced optical payload with sensing capabilities in the VNIR range, with seven spectral bands, some of which will be chosen from the 10m resolution bands currently in use by Sentinel-2. In particular, the proposed constellation will feature a min GSD of 5m for all the selected spectral bands, with a 20km swath at 500km of altitude, thanks to a TDI (Time Delay and Integration) CCD detector technology notably employed in low-light settings, as well as for fast-moving objects. This inclusion will increase radiometric performances, as well as multi-band enhancements and cross-sensor consistency, which are generally referred as the principal limitations of current CubeSat EO (*Earth Observation*) missions in orbit. The use of spectral bands currently employed by Sentinel missions will allow such observations to be integrated with publicly available Sentinel data, providing meaningful insights regarding the cooperation of existing and new EO constellations, as well as to conduct several studies on inter-calibration techniques of the space platforms. The constellation will be composed of both 3U and 6U CubeSat platforms, in SSO orbits selected and spaced as to allow interlink communications among the neighbouring CubeSats, for improved data download even when the satellites are not in visibility of a groundstation. The proposed constellation, compared to traditional missions, will have the advantage of being easily scalable, with faster access time to space, as well as reduced costs for the production of the single platform and its launch, particularly with the employment of the 3U CubeSat form factor. The constellation will make use of a hybrid approach also for the ADCS, with a custom-developed system composed of both reaction wheels and magnetorquers for the active control of the platforms. In this paper the main characteristics relative to this CubeSat constellation for multi-spectral imaging will be discussed. [View Full Paper]

[*] Aerospace and Astronautical Engineer, RF & Systems, GAUSS Srl, Rome, Italy.
E-mail: riccardo.diroberto@gaussteam.com.
[†] Professor of Astrodynamics, President of GAUSS Srl, Rome, Italy. E-mail: filippo.graziani@gaussteam.com.

IAA-AAS-SciTech2018-071
AAS 18-830

MAGNETORQUERS ATTITUDE CONTROL FOR DIFFERENTIAL AERODYNAMIC FORCE APPLICATION TO NANOSATELLITE FORMATION FLYING CONSTRUCTION AND MAINTENANCE

Uliana Monakhova,[*] Danil Ivanov[†] and Dmitry Roldugin[‡]

The paper considers a problem of satellites formation flying construction immediately after their launch. During the separation from the launcher some error in the ejection velocity is inevitable. It results in a slightly different orbital period of the satellites, so they will gradually move apart along the orbit and the relative trajectories become unbounded. The differential drag-based control is considered. The attitude control of the satellite is implemented by magnetorquers. [View Full Paper]

[*] Master Student, Keldysh Institute of Applied Mathematics, 4 Miusskaya sq., Moscow, 125047, Russia.
[†] Professor, Keldysh Institute of Applied Mathematics, 4 Miusskaya sq., Moscow, 125047, Russia.
[‡] Professor, Keldysh Institute of Applied Mathematics, 4 Miusskaya sq., Moscow, 125047, Russia.

IAA-AAS-SciTech2018-078
AAS 18-831

RELATIVE MOTION CONTROL OF TWO SATELLITES BY CHANGING THE REFLECTIVE PROPERTIES OF THE SOLAR SAILS SURFACE

Yaroslav V. Mashtakov,[*] Tatyana Yu. Petrova[†] and Stepan S. Tkachev[‡]

Satellite formations flying are becoming popular nowadays. They are more fail-safety. If one of satellites fails, the group of others will be able to continue the mission. The main problem of using formations is keeping them closely. Due to the presence of different external perturbations satellites are flying apart. The variety of possibilities of the relative motion control is divided into thrusters, which require propellant and propellantless. This work considers the usage of the solar radiation pressure. Control is based on rotation of sail normal which is provided by the variation of the sail surface optical properties.

[View Full Paper]

[*] Junior Researcher, Space Systems Dynamics Department, Keldysh Institute of Applied Mathematics, 4 Miusskaya sq., Moscow, 125047, Russia.
[†] Junior Researcher, Space Systems Dynamics Department, Keldysh Institute of Applied Mathematics, 4 Miusskaya sq., Moscow, 125047, Russia.
[‡] Senior Researcher, Space Systems Dynamics Department, Keldysh Institute of Applied Mathematics, 4 Miusskaya sq., Moscow, 125047, Russia.

IAA-AAS-SciTech2018-113
AAS 18-832

THE RESEARCH METHOD OF CONTROLLED MOVEMENT DYNAMICS OF TETHER SYSTEM

Yury N. Razoumny,[*] Sergei A. Kupreev[†] and Arun K. Misra[‡]

During the study the dynamics of controlled movement of tether systems, it is proposed to use topological structures of the exponential law of the length control of the connecting tether. Using the example of a flat circular motion of the mass center of the tether system proved the application of the exponential law, which allows us to obtain a finite number of topological structures. At each time point the control parameter of the exponential control law and, consequently, the corresponding topological structure can be determined for any control law of the length of the connecting tether. The comparison of the control law under consideration and the range of changes in the control parameter of the exponential law makes it possible to identify all the "slippery" parts of the relative motion of connected objects in a "kaleidoscope" of topological structures and explain the source of stochastic movements. [View Full Paper]

[*] Director, Professor, Academy of Engineering, Peoples' Friendship University of Russia (RUDN University), 6 Miklukho-Maklaya str., Moscow, 117198, Russia.
[†] Professor, Academy of Engineering, Peoples' Friendship University of Russia (RUDN University), 6 Miklukho-Maklaya str., Moscow, 117198, Russia.
[‡] Thomas Workman Professor, Department of Mechanical Engineering, McGill University, Montreal, QC, H3A 0C3, Canada.

IAA-AAS-SciTech2018-091
AAS 18-833

THE JOINT SOLUTION OF PROBLEM OF EVASION AND KEEPING IN A NEIGHBORHOOD REFERENCE ORBIT

Zay Yar Win,[*] Veniamin V. Malyshev,[†]
Vladimir T. Bobronnikov[‡] and Aleksandr V. Starkov[§]

The problem of synthesis of optimal control of a linear stochastic system in the presence of additive non-random disturbances is solved, the solution is then applied to the control of a stationary artificial earth satellite in the performance of dynamic operations in the vicinity of a given hovering longitude. Stochastic and mini-max approaches to the problem solution are considered. The application of the developed algorithms is illustrated by the example of modeling the dynamic operation of deviation in the vicinity of the unstable equilibrium point. [View Full Paper]

[*] Postgraduate Student, Moscow Aviation Institute, 4 Volokolamskoe shosse, Moscow, 125993, Russia.
[†] Professor, Moscow Aviation Institute, 4 Volokolamskoe shosse, Moscow, 125993, Russia.
[‡] Professor, Moscow Aviation Institute, 4 Volokolamskoe shosse, Moscow, 125993, Russia.
[§] Associate Professor, Moscow Aviation Institute, 4 Volokolamskoe shosse, Moscow, 125993, Russia.

IAA-AAS-SciTech2018-044
AAS 18-834

OPTIMAL LOW-THRUST TRAJECTORIES USING NONSINGULAR EQUINOCTIAL ORBIT ELEMENTS*

Mauro Pontani†

Low-thrust propulsion was proven to allow substantial propellant savings with respect to high-thrust systems, at the price of increasing the time of flight. This work addresses low-thrust orbit transfer optimization, which consists in finding the thrust direction time history that minimizes the time of flight. The indirect heuristic method is outlined and employed. It is based on the joint use of a heuristic technique and the necessary conditions associated with the optimization problem. If this is formulated using the polar coordinates for position and velocity, a major drawback resides in hypersensitivity on the initial values of the adjoint variables associated with the dynamics equations. This research proves that the use of nonsingular equinoctial elements allows overcoming this serious difficulty, by mitigating hypersensitivity. Two interesting low-thrust orbit transfer problems are considered, i.e. (a) from a circular, equatorial low Earth orbit to a geostationary orbit, and (b) between a circular, low Earth orbit and a hyperbolic trajectory. In both cases, the minimum-time transfer path is found with great accuracy. [View Full Paper]

† Assistant Professor, Department of Astronautical, Electrical, and Energy Engineering, Sapienza University of Rome, via Salaria 851, 00138 Rome, Italy.

IAA-AAS-SciTech2018-112
AAS 18-835

THE ALGORITHM FOR SOLVING THE PROBLEM OF CHOOSING THE OPTIMAL TWO-TIER SATELLITE SYSTEM STRUCTURE FOR CONTINUOUS SCANNING OF THE SPHERICAL LAYER OF NEAR-EARTH SPACE

Daniele Mortari,[*] Yury N. Razoumny,[†] Oleg E. Samusenko,[‡] Viktoria D. Novikova[§] and Nguyen Nam Quy[**]

The article deals with the task of optimization of orbital construction two-tier satellite constellation for continuous scanning of spherical layer of near-earth space. The satellites of the upper and the lower tiers satellites are supplied with multidirectional on-board equipment, and the spherical layer is divided into two zones of responsibility: the lower part of the layer is in the zone of responsibility (observation) of the upper tier, and the upper part of the layer is in the zone of responsibility (observation) of the lower tier. Each layer has the structure of J. Walker's delta-system. We use the minimum loss of the overall characteristic velocity as the optimization criterion, which necessary for the launch of satellites into orbit and the formation of the orbital structure. We also present the method for calculating the optimal orbital parameters of satellites of the lower and upper tiers at a fixed height of the spherical layer division into zones of responsibility and provide the algorithm for choosing the optimal height division of spherical layer into zones of responsibility for optimal satellite constellation of continuous scanning of spherical layer of near-Earth space. [View Full Paper]

[*] Professor, Aerospace Engineering, Texas A&M University, 746C H.R. Bright Building Ross Street - 3141 TAMU, College Station, Texas 77843-3141, USA.
[†] Professor, PhD, Director of Academy of Engineering, Peoples' Friendship University of Russia (RUDN University), 6 Miklukho-Maklaya str., Moscow, 117198, Russia.
[‡] PhD, Director of Institute of Space Technologies of Academy of Engineering, Peoples' Friendship University of Russia (RUDN University), 6 Miklukho-Maklaya str., Moscow, 117198, Russia.
[§] Student, Department of Mechanics and Mechatronic of Institute of Space Technologies of Academy of Engineering, Peoples' Friendship University of Russia (RUDN University), 6 Miklukho-Maklaya str., Moscow, 117198, Russia.
[**] PhD, Teacher at Le Quy Don Technical University, 236 Hoang Quoc Viet Street, Bac Tu Liem, Hanoi, Vietnam.

SPACE MISSIONS AND APPLICATIONS

Session Chairs:
Filippo Graziani, *Sapienza University of Rome, G.A.U.S.S. Srl, Italy*
Renuganth Varatharajoo, *Universiti Putra Malaysia, Malaysia*

IAA-AAS-SciTech2018-090
AAS 18-836

A HISTORICAL REVIEW AND FUTURE PROSPECTS OF SPACE TOURISM

Yi-Wei (Eva) Chang[*] and Jeng-Shing (Rock) Chern[†]

Ever since the first appearance of the term "space tourism" in 1960s, it has been developed for about 60 years from conceiving to realization. However, it is not until the 21st century the commercial space tourism is really operated. During the first decade from 2001 to 2010, 7 millionaires paid tens of million USD each trip privately and travelled to the International Space Station (ISS) 8 times by taking Russia's Soyuz rockets and Soyuz-TMA spacecraft. On the other hands, the dawn of true private human access to space (PHAS) took place in 2004. The privately founded traffic tools SpaceShipOne/White Knight One reached 112 km suborbital altitude on 4 October 2004, much higher than the internationally recognized space regime of 100 km. During the past months in 2018, the second SpaceShipTwo completed the third powered test flight to reach 55 km altitude, and the Blue Origin's New Shepard System completed mission 9 (M9) test flight. Blue Origin planned to sell suborbital flight ticket in 2018, and Virgin Galactic Spaceline Company already has several hundred tickets in reservation planned to start commercial suborbital travel operations in 2019. Space tourism could be divided into two categories: orbital space tourism (OST) and suborbital space tourism (SST). Major differences are high vs. low in the prices, high vs. low in the physiological thresholds, long vs. short in the training and travelling time, and more vs. less in the experiences. This paper presents a historical review on the developments of space tourism concepts, space hotels concepts and market models in USA, Europe and Japan, and then predicts its future prospects. It is expected that OST could grow slowly but steadily, and SST could be prosperous with more rapid growth in the near future. [View Full Paper]

[*] Assistant Professor, Department of Tourism and Hospitality, China University of Science and Technology, 200 Chunghwa Street, Henshan Village, Hsinchu County, Taiwan 31241. E-mail: managing-editor@iaamail.org & eva77tw@cc.hc.cust.edu.tw.
[†] Adjunct Professor, Department of Aerospace Engineering, Ryerson University, 350 Victoria Street, Toronto, Ontario, Canada M5B 2K3. E-mail: editor-in-chief@iaamail.org.

IAA-AAS-SciTech2018-024
AAS 18-837

MATHEMATICAL MODEL OF ERS DATA PROCESSING GROUND SEGMENT OPERATION IN TERMS OF PROCESSING DISTRIBUTION

Andrey A. Emelianov,[*] Lubov A. Grishantseva,[†] Ksenia I. Zubkova,[‡] Veniamin V. Malyshev,[§] Nguyen Viet Hoai Nam,[**] Aleksandr V. Starkov[††] and Zay Yar Win[‡‡]

We have proposed mathematical models of the Earth's remote sensing (ERS) data processing ground segment operation, which can be a basis under the design of custom-made software. We have formulated the problem of distribution of purpose data from various type ERS spacecraft among ground infrastructure segments. We have executed decomposition, compiled a list, and formulated models that, when merged, will allow to build a centered mathematical model of the ground segment operation in terms of purpose data distribution. [View Full Paper]

[*] Postgraduate Student, Moscow Aviation Institute, 4 Volokolamskoe shosse, Moscow, 125993, Russia.
[†] Associate Professor, Moscow Aviation Institute, 4 Volokolamskoe shosse, Moscow, 125993, Russia.
[‡] Postgraduate Student, Moscow Aviation Institute, 4 Volokolamskoe shosse, Moscow, 125993, Russia.
[§] Professor, Moscow Aviation Institute, 4 Volokolamskoe shosse, Moscow, 125993, Russia.
[**] Postgraduate Student, Moscow Aviation Institute, 4 Volokolamskoe shosse, Moscow, 125993, Russia.
[††] Associate Professor, Moscow Aviation Institute, 4 Volokolamskoe shosse, Moscow, 125993, Russia.
[‡‡] Postgraduate Student, Moscow Aviation Institute, 4 Volokolamskoe shosse, Moscow, 125993, Russia.

IAA-AAS-SciTech2018-080
AAS 18-838

INTELLIGENT STRUCTURING OF THE EARTH REMOTE SENSING METHODS FOR DETECTING AND IDENTIFICATION OF RADIOACTIVE SOURCES OF IONIZING RADIATIONS

Dmitry Panov,[*] Alexander Sukhorukov,[†] Yury N. Razoumny,[‡] Dzhordzh Kovkov[§] and Sergey Eroshkin[**]

The article presents a system structuring of the Earth remote sensing methods for detection and identification radioactive sources of ionizing radiation (ERS SIR), on the basis of the existing physical phenomena. The structuring is formed according to consolidation of all existing and advanced ERS SIR methods with its attributes in two-dimensional sequence of structural-logical relations, where principle physical properties of ionizing disturbances in environment, and different methods of their detection are determined. A two-dimensional schema is presented in the snowflake structure can be easily formalized to build multi-dimensional databases (multi-dimensional "cube") for Data Mining. Subsequently, such formalization can be implemented into the artificial intelligence systems, which can help the researchers and developers of new ERS SIR multi-channel systems to take into account opportunities and features of existing methods in an integrated manner and add there new advanced methods. [View Full Paper]

[*] Professor, Academy of Engineering, Peoples' Friendship University of Russia (RUDN University), 6 Miklukho-Maklaya str., Moscow, 117198, Russia.
[†] Professor, Department of Management of Projects and Programs, Plekhanov Russian University of Economics, 36 Stremyanny lane, Moscow, 117997, Russia.
[‡] Director, Professor, Academy of Engineering, Peoples' Friendship University of Russia (RUDN University), 6 Miklukho-Maklaya str., Moscow, 117198, Russia.
[§] Associate Professor, Academy of Engineering, Peoples' Friendship University of Russia (RUDN University), Miklukho-Maklaya str., Moscow, 117198, Russia.
[**] Associate Professor, Department of management and administrative management, Russian State Social University, 4/1 Wilhelm Pieck str., Moscow, 129226, Russia.

IAA-AAS-SciTech2018-099
AAS 18-839

TECHNIQUE OF ESTIMATING THE VOLUME OF STORAGE AND TRANSMISSION OF INFORMATION FROM SYNTHETIC-APERTURE RADAR SATELLITE IN DATA CENTERS IN DIGITAL ECONOMIC ISSUES

Yury N. Razoumny,[*] Guo Shuhong,[†] Alexander Sukhorukov,[‡] Dzhordzh Kovkov[§] and Sergey Eroshkin[**]

Technique for estimating the volume of storage and transmission of information from satellite synthetic-aperture radar (SAR) in data centers (DCs) in the digital economy problems is proposed. This technique takes into account the full statistical harmonization of the analog messages generation source with digital storage, processing and transmission systems. The proposed technique is detailed on the example of the statistical model of the process of generating analog SAR information in digital control systems for effective land-use management. The practical importance of this technique involves the possibility of statistical estimation of the storage and transmission of information from satellite SAR in the data centers, while allowing modeling and constructing specific data bases that are optimal in terms of the information volume. [View Full Paper]

[*] Director, Professor, Academy of Engineering, Peoples' Friendship University of Russia (RUDN University), 6 Miklukho-Maklaya str., Moscow, 117198, Russia.
[†] Associate, DUT-BSU Joint institute, Dalian University of Technology, No.2 Linggong Road, Ganjingzi District, Dalian, 116024, China.
[‡] Professor, Department of Management of Projects and Programs, Plekhanov Russian University of Economics, 36 Stremyanny lane, Moscow, 117997, Russia.
[§] Associate Professor, Academy of Engineering, Peoples' Friendship University of Russia (RUDN University),6 Miklukho-Maklaya str., Moscow, 117198, Russia.
[**] Associate Professor, Department of management and administrative management, Russian State Social University, 4/1Wilhelm Pieck str., Moscow, 129226, Russia.

IAA-AAS-SciTech2018-088
AAS 18-840

THE PROGRAM FOR ESTIMATION OF THE EARTH REMOTE SENSING PLANS

Maxim P. Zapletin[*] and Abylai T. Zhakypov[†]

The web application described here has been designed for evaluating the orbit of a remote sensing (RS) satellite and for planning the survey of the specified area on the Earth's surface. It is essential for RS to select an appropriate satellite, taking into account such criteria as optical characteristics and frequency of surveys. The developed program offers a user-friendly interface and efficient calculation of the satellite position. Using this application, the customer will be able to see the trajectory of any available commercial ERS spacecraft for a specified time interval, estimate all the possibilities that meet the customer's requirements for shooting a point or a polygon on the Earth's surface and schedule a survey of the area of interest taking into account all the required limitations. The algorithm is based on the SGP4 model, which uses public TLE data for Earth remote sensing satellites, formulas of celestial mechanics, analytical geometry, and heuristic methods for reducing computations. The program code is written in JavaScript and PHP programming languages with using the Bootstrap, JQuery, and Cesiumjs libraries. The article contains screenshots of the program itself and the results of speed tests of calculations performance are presented in the article. [View Full Paper]

[*] Associate Professor, Academy of Engineering, Peoples' Friendship University of Russia (RUDN University), 6 Miklukho-Maklaya str., Moscow, 117198, Russia.
[†] Engineer, JCS NC Kazakhstan Gharysh Sapary, Astana, 010000, Kazakhstan.

IAA-AAS-SciTech2018-111
AAS 18-841

SPACE-BASED MONITORING CAPABILITIES FOR THE EVALUATION OF INLAND WATER RESOURCES: APPLICATION TO NIGERIA

Seidu O. Mohammed,[*] Yury N. Razoumny,[†] Alexandr Orlovskiy,[‡] Vasily Lobanov[§] and Yaroslav Vasyunin[**]

This work presents the results of satellite imagery analysis to evaluate the quantity of inland water bodies in Nigeria. The current experience of space monitoring of the surface water is also discussed — the complex environmental situation in the Lake Chad region is acknowledged. Google Earth Engine platform was selected as the main tool for water monitoring at national scale, as it provides web-based access to an extensive catalog of imagery in a ready-to-analyze format. This theme is proposed to become the subject of an International Academy of Astronautics study group to investigate and recommend actions against the degradation of Lake Chad and more generally to make recommendations about paths towards better protection of our planet water land and all ecosystems attached.

Keywords: geospatial analysis, water monitoring, NDWI, big data, Google Earth Engine

[View Full Paper]

[*] Director General, National Space Research and Development Agency, Umaru Musa Yaradua Express Way PMB 437, Lugbe, Abuja, Nigeria.
[†] Director, Professor, Academy of Engineering, Peoples' Friendship University of Russia (RUDN University), 6 Miklukho-Maklaya str., Moscow, 117198, Russia.
[‡] Assistant Professor, Academy of Engineering, Peoples' Friendship University of Russia (RUDN University), 6 Miklukho-Maklaya str., Moscow, 117198, Russia.
[§] Assistant Professor, Academy of Engineering, Peoples' Friendship University of Russia (RUDN University), 6 Miklukho-Maklaya str., Moscow, 117198, Russia.
[**] Assistant Professor, Academy of Engineering, Peoples' Friendship University of Russia (RUDN University), 6 Miklukho-Maklaya str., Moscow, 117198, Russia.

IAA/AAS CONFERENCE ON SPACE STRUCTURES AND MATERIALS

SPACECRAFT STRUCTURES AND SENSORS

Session Chairs:
Paolo Gasbarri, *Sapienza University of Rome, Italy*
Vera Galishnikova, *Peoples' Friendship University of Russia (RUDN University) Russia*

IAA-AAS-SciTech2018-037
AAS 18-842

CALIBRATION OF UPPER ATMOSPHERIC MODEL BASED ON THE PRECISION ORBIT OF A SPHERICAL SATELLITE

Wang Junyu[*] and Wang Zhaokui[†]

The atmospheric drag force is the dominant non-conservative perturbation force acting on LEO satellites. Therefore, the determination and prediction of the atmospheric density is crucial for the orbit prediction and reentry analysis of LEO satellites. The existing semi-empirical models of atmospheric density has error of 15~30% order, which could not meet the accuracy demand of many tasks. In this paper, a novel method based on the precision orbit of a spherical satellite is proposed to improve accuracy of the density model, and the method is verified using simulated data. The result shows that the accuracy of atmospheric density prediction is increased to about 1%. [View Full Paper]

[*] Master Student, School of Aerospace Engineering, Tsinghua University, Beijing, 100084, China.
[†] Associate Professor, School of Aerospace Engineering, Tsinghua University, Beijing, 100084, China.

IAA-AAS-SciTech2018-101
AAS 18-843

FUZZY LOGIC APPLICATION APPROACH IN CONTROL OF AUTOMATIC SPACECRAFT

Alexander N. Drozdov,[*] Nikolay A. Drozdov[†] and Igor M. Narozhnyy[‡]

The increasing complexity and variety of tasks, the solution of which is placed on automatic systems, have recently determined an increased need for control systems with as much as possible universal properties. However, none of the currently existing approaches to building control systems — neither the theory of automatic control, nor artificial neural networks, nor other technologies, possess the necessary universality. On the other hand, there is confidence in the possibility of constructing systems with the desired properties, which is based on fuzzy controllers. The main method of which is fuzzy logic and soft measurement.

The use of soft measurement approaches implies the replacement of hard deterministic methods for determining the parameters and characteristics of a system or object by their tracking probability estimate. To obtain the most reliable results, it is necessary to conduct long-term monitoring, taking into account the state of not only the object itself, but also the external environment. Fuzzy modeling provides effective methods and tools for studying systems in the event of insufficient or uncertainty of knowledge about the system under study, when obtaining the required information is a difficult, time-consuming, expensive or impossible task.

Fuzzy neural networks or hybrid networks are designed to combine the advantages of neural networks and fuzzy inference systems. On the one hand, they allow developing and presenting system models in the form of fuzzy production rules, which have clarity and simplicity of meaningful interpretation, on the other hand, the capabilities of neural networks are used to construct fuzzy production rules. \ Such systems not only use a priori information, but can acquire new knowledge and are logically transparent to the user.

This paper presents an overview possibility of fuzzy logic and soft measurement in control of automatic spacecraft. [View Full Paper]

[*] Professor, Academy of Engineering, Peoples' Friendship University of Russia (RUDN University), 6 Miklukho-Maklaya str., Moscow, 117198, Russia.
[†] General Director, Innovative Oil and Gas Solutions Limited Liability company, 64/1 Shipilovskaya Street, Moscow, 115682, Russia.
[‡] Senior Lecturer, Academy of Engineering, Peoples' Friendship University of Russia (RUDN University), 6 Miklukho-Maklaya str., Moscow, 117198, Russia.

IAA-AAS-SciTech2018-041
AAS 18-844

THE ASSESSMENT OF OPERATIONAL CAPABILITY OF THE SPACE-BASED HYPERSPECTRAL COMPLEX

Sergey A. Zotov,[*] Y. V. Dmitriev,[†] Sergey Y. Shibanov,[‡] Timofey V. Kondranin,[§] Igor N. Polyakov[**] and Anastasia G. Zotova[††]

The goal of the work is to develop method for the assessment of operational capability of the space-based hyperspectral complex (HSC). Representation of the operational capability of remote sensing instrument during the problem of thematic processing solution let us make a conclusion about the advisability of its inclusion in space mission. It is expected to assess operational capability using the statistic data received with the help of imitational method. In this work the results of the method's usage at the example of developed HSC are given. The HSC is going to be based on the International Space Station (ISS). [View Full Paper]

[*] Engineer, Phystech School of Aerospace Technology, Moscow Institute of Physics and Technology (MIPT), 9 Institutskiy per., Dolgoprudny, Moscow Region, 141701, Russia.
[†] Senior Researcher, Phystech School of Aerospace Technology, Moscow Institute of Physics and Technology (MIPT), 9 Institutskiy per., Dolgoprudny, Moscow Region, 141701, Russia.
[‡] Senior Researcher, Phystech School of Aerospace Technology, Moscow Institute of Physics and Technology (MIPT), 9 Institutskiy per., Dolgoprudny, Moscow Region, 141701, Russia.
[§] Senior Researcher, Phystech School of Aerospace Technology, Moscow Institute of Physics and Technology (MIPT), 9 Institutskiy per., Dolgoprudny, Moscow Region, 141701, Russia.
[**] First rank engineer, Phystech School of Aerospace Technology, Moscow Institute of Physics and Technology (MIPT), 9 Institutskiy per., Dolgoprudny, Moscow Region, 141701, Russia.
[††] Engineer, Phystech School of Aerospace Technology, Moscow Institute of Physics and Technology (MIPT), 9 Institutskiy per., Dolgoprudny, Moscow Region, 141701, Russia.

IAA-AAS-SciTech2018-042
AAS 18-845

THE ALGORITHM OF COMPUTING THE SCATTERING PHASE FUNCTION OF REFLECTED SOLAR RADIATION FROM OBJECTS OF ARBITRARY SHAPE

Igor Polyakov[*] and Sergey Zotov[†]

It is described in current article the algorithm of computing the scattering phase function of the reflected solar radiation from a space of arbitrary object, which is observed by the other spacecraft using optoelectronic device of the visible range in terms of remote outer space. The algorithm is based on the computing the illumination of the observed object surface caused by solar radiation and determining its brightness. The scientific and technical solution proposed in the methodology allows to generate the data required for determine the state vector of the target spacecraft in the space rendezvous problem.

[View Full Paper]

[*] First Rank Engineer, Phystech School of Aerospace Technology, Moscow Institute of Physics and Technology, 9 Institutskiy per., Dolgoprudny, Moscow Region, 141701, Russia.
[†] Engineer, Phystech School of Aerospace Technology, Moscow Institute of Physics and Technology, 9 Institutskiy per., Dolgoprudny, Moscow Region, 141701, Russia.

IAA-AAS-SciTech2018-030
AAS 18-846

NANO STAR TRACKER AZDK-1

Marat K. Abubekerov,[*] Andrey I. Zakharov,[†] Mike E. Prokhorov,[‡] Oleg Yu. Stekolchshikov,[§] Maksim S. Tuchin[**] and Nikolay Yu. Gostev[††]

Nano Star Tracker AZDK-1 is under development by Azmerit LLC. This star tracker is designed first of all for nano and micro satellites, but can also be used on larger spacecrafts. Its dimensions, which are 56×60×93 mm, its weight is 193 g, and its average power consumption of 0.3W (1,25 W peak) enable to use it in a CubeSat satellites. AZDK-1 has a high attitude accuracy, which is achieved through a more complicated image processing, allowing of taking into account the systematic errors. It is expected that the use of CMOS photo sensor with effective size of 512×512 pixels and with an update rate of 5 Hz gives the attitude error $\sigma_{XY} \approx 5''$. Attitude accuracy improvement technique was taken from the processing of astronomical images. In the article present the results of functional, vibrodynamic, thermal vacuum tests. [View Full Paper]

[*] Deputy General Director, Azmerit LLC, 1/75G, Leninskie Gory, Moscow, 119991, Russia; Senior Researcher, Sternberg Astronomical Institute, Lomonosov Moscow State University, 1 Leninskiye Gory, GSP-1, Moscow, 119991, Russia.
[†] Scientific Supervisor, Azmerit LLC, 1/75G, Leninskie Gory, Moscow, 119991, Russia; Researcher, Sternberg Astronomical Institute, Lomonosov Moscow State University, 1 Leninskiye Gory, GSP-1, Moscow, 119991, Russia.
[‡] Technical Director, Azmerit LLC, 1/75G, Leninskie Gory, Moscow, 119991, Russia; Head of Space Projects Laboratory, Sternberg Astronomical Institute, Lomonosov Moscow State University, 1 Leninskiye Gory, GSP-1, Moscow, 119991, Russia.
[§] Chief Constructor, Azmerit LLC, 1/75G, Leninskie Gory, Moscow, 119991, Russia; Senior Researcher, Sternberg Astronomical Institute, Lomonosov Moscow State University, 1 Leninskiye Gory, GSP-1, Moscow, 119991, Russia.
[**] Programmer, Azmerit LLC, Resident of the Skolkovo Foundation; Junior Researcher, Sternberg Astronomical Institute, Lomonosov Moscow State University, 1 Leninskiye Gory, GSP-1, Moscow, 119991, Russia.
[††] Researcher, Sternberg Astronomical Institute, Lomonosov Moscow State University, 1 Leninskiye Gory, GSP-1, Moscow, 119991, Russia.

IAA-AAS-SciTech2018-098
AAS 18-847

UNDERSTANDING RELIABILITY OF THE THERMOELECTRIC DEVICES FOR SPACE APPLICATION

Shehak Sattar[*] and Alexey Osipkov[†]

Energy harvesting in space is the fundamental requirement in almost all space exploring systems and applications. Environmental radiation, such as solar and Albedo radiation, in space and generation of thermal load during operation tends the flow of heat inside the satellite structure. Thermal load is driven by subsystems and electronics. For this purpose, we use thermoelectric module to produce energy from waste heat as well as control temperature of the system. Thermoelectric devices are widely used in different space applications and Radioisotopic thermoelectric generator are widely used different space missions. In this paper comprehensive discussion has been done on recently proposed alternative designs, material competency and life-scaling models for improving longevity of the thermoelectric modules for space applications. A precise discussion has been drawn on space devices and their obstacles. As part of deep space mission, to ensure the longevity of device, work is being done on mechanical stability and suppression of sublimation. [View Full Paper]

[*] Postgraduate Student, Academy of Engineering, Peoples' Friendship University of Russia (RUDN University), 6 Miklukho-Maklaya str., Moscow, 117198, Russia.
[†] Associate Professor, Academy of Engineering, Peoples' Friendship University of Russia (RUDN University), 6 Miklukho-Maklaya str., Moscow, 117198, Russia.

IAA-AAS-SciTech2018-069
AAS 18-848

SYSTEM OF MULTIDIMENSIONAL ATTRACTORS OF THE STRESS-AND-STRAIN BEHAVIOR IN ELASTIC CONTINUOUS MEDIA

Anatoly A. Speranskiy[*] and Yefim M. Malitikov[†]

«…throughout the history of mankind our fate has been defined by observation tools»
Michio Kaku. Physics of the Future

Abstract. On the basis of scientific fundamentals of mechanics in continuous elastic media, there has been proposed a new creative method of observation, assessment and forecast of the stress-and-strain behaviour of mechanical objects. Phase elliptical hodographs of the spectrum of harmonic oscillations in an elastic medium have up to 50 measured diagnostic and calculated analytical parameters for estimating the energy states in the pace of real time, providing an intelligent translation process from BigData to DeepData with reference to dynamic models for assessing the current resource and the forecast, designed to ensure the safety of long-term space expeditions.

Keywords: elastic continuous media, stress-and-strain behavior, vector-phase measurement, trajectory energy reconstruction, forecast of resource state, Wave Health Monitoring, maintenance, diagnostics, homeostasis, attractor, trend, prognostics.

[View Full Paper]

[*] Vice President, Russian Academy of Engineering, 9/4 Gazetny per., Moscow, 125009, Russia.
[†] President, International Association ZNANIE, 50 Gilyarovskogo str., Moscow, 129110, Russia.

ADVANCED SPACE MATERIALS

Session Chairs:
Svetlana Shambina, *Peoples' Friendship University of Russia (RUDN University) Russia*
Kharun Makhmud, *Peoples' Friendship University of Russia (RUDN University) Russia*

IAA-AAS-SciTech2018-009
AAS 18-849

THE ANALYSIS OF DESTRUCTION CAUSES AND CONDITION DIAGNOSTICS OF HOT DIE FORGING FOR SPACE INDUSTRY

Anna V. Kornilova,[*] Mohamed I. Abu Mahadi,[†] Alexander I. Selishchev[‡] and Tavkil H. Ayupov[§]

The article causes of die forging breakdown are analysed and influenced on them factors are systematized, the results of researches of coercive force changes in material of milled stamp during production and exploitation are reported, possibilities of controlling the coercive force for die forging are stated. The publication was prepared with the support of the "RUDN University Program 5-100". [View Full Paper]

[*] Professor, Academy of Engineering, Peoples' Friendship University of Russia (RUDN University), 6 Miklukho-Maklaya str., Moscow, 117198, Russia.
[†] Associate Professor, Academy of Engineering, Peoples' Friendship University of Russia (RUDN University),6 Miklukho-Maklaya str., Moscow, 117198, Russia.
[‡] Engineer, AO KBAL im. L.N. Koshkina, 21A 50-years of October pr.kt., Klimovsk md., Podolsk, Moscow region,142180, Russia.
[§] Foreman, AO MMZ Avangard, 33 Klary Tsetkin str., Moscow, 125130, Russia.

IAA-AAS-SciTech2018-019
AAS 18-850

PRODUCTION NICKEL COMPOSITE MATERIALS REINFORCED WITH ULTRAFINE POWDERS, OBTAINED FROM AEROSPACE INDUSTRY WASTE

Marianna Yu. Malkova[*] and Alexander N. Zadiranov[†]

First developed and studied composite materials on a metal substrate (matrix) obtained by the electrodeposition of aerospace industry nickel waste of the electrolytes-suspensions based sulfate, chloride, acetate and methanesulfonateon containing ultrafine powders kaolin and bentonite clays. It was established that by using ultrafine powders on electrolyte suspensions, metal matrix composites (MMCs) reinforced by ultrafine uniform-sized elements are produced. New MMCs from electrolyte suspensions with addition of nanosize powders of kaolin and bentonite were obtained as a result of the conducted experiments and had been thoroughly studied. The effect of kaolin and bentonite nanosize powder additive concentration on substrate porosity and its electrochemical properties (corrosion resistance, electrochemical activity) had been established. It was shown that porosity, corrosion resistance and electrochemical activity of MMC are determined by the grain size of ultrafine elements and their concentration in the electrolyte suspension. Consumption of organic additives for the electrolytes that provide the required surface quality of MMC was determined and optimized. [View Full Paper]

[*] Professor, Academy of Engineering, Peoples' Friendship University of Russia (RUDN University), 6 Miklukho-Maklaya str., Moscow, 117198, Russia.
[†] Professor, Academy of Engineering, Peoples' Friendship University of Russia (RUDN University), 6 Miklukho-Maklaya str., Moscow, 117198, Russia.

IAA-AAS-SciTech2018-027
AAS 18-851

DEVELOPMENT OF A UNIVERSAL ULTRASONIC REACTOR FOR PROCESSING OF RARE EARTH METAL ORES ON THE MOON

Marianna Yu. Malkova,[*] Alexander N. Zadiranov,[†] Moises Romero[‡] and Prashanta Dkhar[§]

In the last ten to fifteen years, the demand of the aerospace industry for rare earth metals, whose reserves are limited, has increased dramatically. It is known that the lunar soil contains high concentrations of rare earth elements, which can be used in the production of alloys for space technology. The aim of this work is to study the efficiency of processing ore concentrates containing REE by leaching with the application of the multipurpose ultrasonic reactor. The device for ultrasonic flow processing of the ore raw material which contains rare-earth elements is developed and tested. The optimum regimes of the device operation which ensure its stable performance for leaching of rare-earth elements from different media are established. High efficiency of utilizing the device for leaching various concentrates has been experimentally established. It is shown that the degree of extraction of uranium, P_2O_5 and Al_2O_3 into the solution during leaching of these concentrates is at least 93.0-98.3%. [View Full Paper]

[*] Professor, Academy of Engineering, Peoples' Friendship University of Russia (RUDN University), 6 Miklukho-Maklaya str., Moscow, 117198, Russia.
[†] Professor, Academy of Engineering, Peoples' Friendship University of Russia (RUDN University), 6 Miklukho-Maklaya str., Moscow, 117198, Russia.
[‡] Senior Lecturer, Academy of Engineering, Peoples' Friendship University of Russia (RUDN University), 6 Miklukho-Maklaya str., Moscow, 117198, Russia.
[§] Senior Lecturer, Academy of Engineering, Peoples' Friendship University of Russia (RUDN University), 6 Miklukho-Maklaya str., Moscow, 117198, Russia.

IAA-AAS-SciTech2018-060
AAS 18-852

RELIABILITY PREDICTION OF RESONANT TUNNELING DIODES AND NON-LINEAR RADIO SIGNAL CONVERTERS BASED ON THEM UNDER INFLUENCE OF TEMPERATURE FACTOR AND IONIZING RADIATIONS

Mstislav O. Makeev,[*] Vladimir Yu. Sinyakin[†] and Sergey A. Meshkov[‡]

The methodology of predicting reliability of resonant tunneling diodes (RTD) and non-linear radio signal converters based on them is developed. Reliability of non-linear converters of radio signals is considered on the example of radio frequency identification (RFID) systems with passive tags, the reliability of which is estimated in terms of a parametric failure associated with the I-V characteristics drift of RTDs that are part of the tag rectifier under the influence of external factors beyond the tolerance limits. The methodology of the time to failure of the RFID passive tag power supply system calculation by the criterion of the minimum permissible range is presented. The developed methodology can be used in the design of RFID systems with passive UHF and SHF tags and other non-linear radio signal converters to predict their reliability under specified operating conditions. [View Full Paper]

[*] Associate Professor, Academy of Engineering, Peoples' Friendship University of Russia (RUDN University), 6 Miklukho-Maklaya str., Moscow, 117198, Russia; Senior Scientist, R&E Center Functional Micro/Nanosystems, Bauman Moscow State Technical University, 5/1 Baumanskaya 2-ya str., Moscow, 105005, Russia.
[†] R&D Center Radioelectronics and Laser Technology, Bauman Moscow State Technical University, 5/1 Baumanskaya 2-ya str., Moscow, 105005, Russia.
[‡] Associate Professor, R&D Center Radioelectronics and Laser Technology, Bauman Moscow State Technical University, 5/1 Baumanskaya 2-ya str., Moscow, 105005, Russia.

IAA-AAS-SciTech2018-079
AAS 18-853

DIAMOND-LIKE CARBON COATINGS TO PROTECT THE OPTICAL SURFACES OF ORBITAL TELESCOPES FROM THE OUTER SPACE FACTORS

Alexey Osipkov,[*] Mstislav Makeev,[†] Pavel Mikhalev,[‡] Alexander Machikhin,[§] Vladislav Batshev,[**] Pavel Shiriaev[††] and Konstantin Shishov[‡‡]

The paper presents the results of experimental studies on the hardening of reflecting surfaces of telescopes mirrors for space applications by applying diamond like coatings (DLC) to their surface with an electric arc method with laser burning of a carbon plasma and separation of the cloud of plasma. Describes the features of the technological process. Determines the relationship of the structure and composition of the DLC layers to the physical and mechanical properties of optical surfaces shows the promise of this technology for solving the problem of the effect of cosmic factors on the data surface.

[View Full Paper]

[*] Assistant, Academy of Engineering, Peoples' Friendship University of Russia (RUDN University), 6 Miklukho- Maklaya str., Moscow, 117198, Russia.
[†] Assistant, Academy of Engineering, Peoples' Friendship University of Russia (RUDN University), 6 Miklukho- Maklaya str., Moscow, 117198, Russia.
[‡] Postgraduate Student, Assistant professor, Academy of Engineering, Peoples' Friendship University of Russia (RUDN University), 6 Miklukho-Maklaya str., Moscow, 117198, Russia.
[§] Scientific Researcher, Scientific and Technological Center of Unique Instrumentation, Russian Academy of Sciences, 15 Butlerova str., Moscow, 117342, Russia.
[**] Scientific Researcher, Scientific and Technological Center of Unique Instrumentation, Russian Academy of Sciences, 15 Butlerova str., Moscow, 117342, Russia.
[††] Postgraduate Student, Assistant professor, Academy of Engineering, Peoples' Friendship University of Russia (RUDN University), 6 Miklukho-Maklaya str., Moscow, 117198, Russia.
[‡‡] Postgraduate Student, Assistant professor, Academy of Engineering, Peoples' Friendship University of Russia (RUDN University), 6 Miklukho-Maklaya str., Moscow, 117198, Russia.

IAA-AAS-SciTech2018-083
AAS 18-854

RESEARCH OF ANISOTROPY STRUCTURE OF POLYAMIDE 12 PARTS OBTAINED BY SELECTIVE LASER SINTERING

Pavel Mikhalev,[*] Pavel Shiriaev[†] and Alexander Provatorov[‡]

Additive manufacturing in space is supposed to solve a problem of independently creating parts for repair, modifying scientific equipment and designing new devices by astronauts without support from the Earth. However, 3D printing in space is a challenging task, which requires a detailed study of machines, technologies and materials. This article considers the prospects of using objects from Polyamide 12, which are obtained by 3D technology - selective laser sintering (SLS), in orbits during space explorations.

The major research purpose is the investigation of the anisotropy structure of the Polyamide 12 samples. The paper presents theoretical studies of SLS powder materials permeability for gases due to their high porosity. The proposed mathematical model allows calculating material permeability for gases, depending on its structure. This work describes the developed technique of the parts manufacturing from EOSPA 2200 material by 3D printer EOS Formiga P 1000. The experimental results are compared to the simulation data and discussed. [View Full Paper]

[*] Postgraduate Student, Academy of Engineering, Peoples' Friendship University of Russia (RUDN University), 6 Miklukho-Maklaya str., Moscow, 117198, Russia.
[†] Postgraduate Student, Academy of Engineering, Peoples' Friendship University of Russia (RUDN University), 6 Miklukho-Maklaya str., Moscow, 117198, Russia.
[‡] Postgraduate Student, Academy of Engineering, Peoples' Friendship University of Russia (RUDN University), 6 Miklukho-Maklaya str., Moscow, 117198, Russia.

IAA-AAS-SciTech2018-085
AAS 18-855

HYBRID MASS AND RADIATION SENSOR BASED ON PIEZOELECTRIC AND THERMOELECTRIC EFFECTS

Alexander E. Shupenev,[*] Sergey V. Yanovich,[†] Ivan S. Korshunov,[‡] Natalia S. Pankova[§] and Alexander G. Grigoryants[**]

The deposition of contaminants onto spacecraft surfaces may have a negative impact and deposition rate is related to insolation cycles. The present work is focused on the development of a hybrid sensor of the deposited mass based on the piezoelectric effect and the energy parameters of radiation using thermoelectric principles. The design calculation of the thermoelectric part showed the possibility of providing the required responsivity with a diameter of the absorption area of 10 mm and 35 thermopiles using the combination of p-$Bi_{0.5}Sb_{1.5}Te_3$ and n-$Bi_2Te_{2.7}Se_{0.3}$ thin films prepared by pulsed laser deposition method.

[View Full Paper]

[*] Postgraduate Student, Department of Laser Technology in Engineering, Bauman Moscow State Technical University, 5/1 Baumanskaya 2-ya str., 105005, Moscow, Russia.
[†] Postgraduate Student, Academy of Engineering, Peoples' Friendship University of Russia (RUDN University), 6 Miklukho-Maklaya str., Moscow, 117198, Russia.
[‡] Postgraduate Student, Department of Laser Technology in Engineering, Bauman Moscow State Technical University, 5/1 Baumanskaya 2-ya str., 105005, Moscow, Russia.
[§] Postgraduate Student, Department of Laser Technology in Engineering, Bauman Moscow State Technical University, 5/1 Baumanskaya 2-ya str., 105005, Moscow, Russia.
[**] Professor, Department of Laser Technology in Engineering, Bauman Moscow State Technical University, 5/1 Baumanskaya 2-ya str., 105005, Moscow, Russia.

IAA-AAS-SciTech2018-097
AAS 18-856

ANALYTICAL TECHNOLOGIES FOR THIN COATING ELEMENT MATERIAL DIAGNOSTICS WITH PXWR APPLICATION

Evgeny Egorov*

The work presents short characteristics of methods for nondestructive analysis of the material element composition in the bulk and thin surface layer of studied objects. Rutherford backscattering spectrometry was chosen as the basic analytical method owing to absoluteness of it experimental data. This method can be used for the element diagnostics both bulk and thin film coating, successfully. The trace element concentration in target surface layers with thickness 3-5 nm was determinated by TXRF spectrometry application. The work characterizes in the details the Proton Induced X-ray Emission (PIXE) spectrometry, which is very effective for the light element diagnostics in materials. There is presented in the short summary a description of the X-ray nanophotonics new device – the planar X-ray waveguide-resonator (PXWR). Experimental investigations showed that the device application for TXRF method modification decreases pollution detection limits on two orders and creates on PIXE spectrometry base new effective method for the target surface element diagnostics. [View Full Paper]

* Assistant, Academy of Engineering, Peoples' Friendship University of Russia (RUDN University), 6 Miklukho-Maklaya str., Moscow, 117198, Russia.

IAA-AAS-SciTech2018-034
AAS 18-857

INCREASING THE STRENGTH OF THE POINT MECHANICAL CONNECTIONS OF COMPOSITE PARTS BY CONSTRUCTIVE-TECHNOLOGICAL METHOD

Fedor Nasonov,[*] Alexandr Zinin,[†] Sergey Bukharov,[‡] Kirill Kharchenko[§] and Georgyi Piskunov[**]

The method of increasing of load-carrying ability of point joints of composite structures of holes for mechanical fasteners by installing fiberglass liners by thermal expansion resin transfer molding is proposed. The efficiency of the proposed solution in the aspect of restoring the strength and reliability of the compound is estimated. [View Full Paper]

[*] Assistant, Moscow Aviation Institute, 4 Volokolamskoe shosse, Moscow, 125993, Russia; Technical Engineer, Sukhoi Design Bereau, 23B Polikarpov str., Moscow, 125284, Russia.
[†] Professor, Moscow Aviation Institute, 4 Volokolamskoe shosse, Moscow, 125993, Russia.
[‡] Professor, Moscow Aviation Institute, 4 Volokolamskoe shosse, Moscow, 125993, Russia.
[§] Engineer, Sukhoi Design Bereau, 23B Polikarpov str., Moscow, 125284, Russia.
[**] Engineer, Sukhoi Design Bereau, 23B Polikarpov str., Moscow, 125284, Russia.

STRUCTURAL DESIGN FOR SPACE APPLICATIONS

Session Chairs:
Zhaokui Wang, *National University of Defense Technology, China*
Vladimir Sidorov, *Peoples' Friendship University of Russia (RUDN University) Russia*

IAA-AAS-SciTech2018-067
AAS 18-858

UNCERTAINTY IMPACT ON MICRO-VIBRATION CONTROL OF AN ORBITING LARGE ADAPTIVE SPACE STRUCTURE

Federica Angeletti[*] and Paolo Gasbarri[†]

Large deployable structures are required for the advancement of modern space activities. A wide variety of EO (Earth Observation) satellites are actually using and will profit by large antenna systems supported by truss-like structures with low mass and stiffness. A net of smart actuators can be embedded in the supporting frame elements to make the structure adaptive itself and to limit undesired elastic vibrations. In the present paper, the supporting structure of a very large mesh reflector is investigated. An optimization procedure has been carried out to evaluate the damping efficacy of the actuators. After having assessed the best authority of the devices belonging to the active net, a control strategy has been implemented to coordinate their simultaneous action. One of the most relevant issue to ensure a good performance of a spacecraft integrated control strategy is related to its robustness when some uncertainty parameters are considered at design stage. In addition, the properties of space modules may be affected by slight changes due to launch loads. The effects of the attitude control authority and its robustness to uncertainties on mechanical and elastic parameters of both passive structure and actuators have been analysed and discussed. [View Full Paper]

[*] Postgraduate Student, Mechanical and Aerospace Engineering, Dept., Sapienza University of Rome, Via Eudossiana 18, 00184 Rome RM, Italy.
[†] Associate Professor, Mechanical and Aerospace Engineering, Dept., Sapienza University of Rome, Via Eudossiana 18, 00184 Roma RM, Italy.

IAA-AAS-SciTech2018-036
AAS 18-859

MICROGRAVITY INVESTIGATION OF SEEPAGE FLOWS IN POROUS MEDIA

Evgeniya I. Skryleva,[*] Valeriy F. Nikitin[†] and Vladislav R. Dushin[‡]

The capillary driven filtration in porous media under microgravity conditions is investigated. Experiments on the flow of a liquid in an inhomogeneous artificial porous medium are presented. A non-stationary mathematical model of the flow of a multiphase fluid in a sample of a porous medium is described. The experimental data are compared with the results of a three-dimensional numerical simulation of the multiphase seepage process. The behavior of the imbibition front when passing through a boundary of medias with different permeabilities was investigated. [View Full Paper]

[*] Researcher, Scientific Research Institute for System Analysis, Russian Academy of Sciences, 36-1 Nakhimovskiy pr., Moscow, 117218, Russia; Postgraduate Student, Lomonosov Moscow State University, 1 Leninskiye Gory, GSP-1, Moscow, 119991, Russia.
[†] Researcher, Scientific Research Institute for System Analysis, Russian Academy of Sciences, 36-1 Nakhimovskiy pr., Moscow, 117218, Russia; Postgraduate Student, Lomonosov Moscow State University, 1 Leninskiye Gory, GSP-1, Moscow, 119991, Russia.
[‡] Associate Professor, Lomonosov Moscow State University, 1 Leninskiye Gory, GSP-1, Moscow, 119991, Russia.

IAA-AAS-SciTech2018-010
AAS 18-860

BENDING OF A THIN SHEET INTO A CIRCULAR CYLINDER WITH TWO FREE EDGES FOR THE MOON CONDITIONS

Sergey N. Krivoshapko,[*] Marina Rynkovskaya[†] and Vladimir Jean Paul[‡]

Thin-walled shell structures are widely used in various branches of the machinery industry. The durability and reliability of chemical engineering machines, pipelines, and elements of aircrafts, ships, and other types of shell structures considerably depend on the accuracy in determining their stress–strain behavior. The thin-walled metal products in the form of developable surfaces are usually manufactured by a parabolic bending of a thin flat preform into the desired product, and the bending is conducted without occurring of tears and folds and that is very important if it is made on the moon surface. Parabolic bending takes place with the conservation of rectilinear generators of developable middle surface, and shell thickness remains constant. But in real shell structures due to the Poisson's ratio, inner bending moments appear in two directions, so the rectilinear generators of developable middle surface will be bent. This situation can be corrected if to make boundary bending moments at both opposite edges not coinciding with the rectilinear generators. The process of parabolic bending of a thin plane slab or a shell with the middle developable surface provokes the appearance of internal normal stresses which can mount to yield strength. The results of the research can be used in marine design, civil engineering, air-space industry, and other manufacturing processes. [View Full Paper]

[*] Professor, Academy of Engineering, Peoples' Friendship University of Russia (RUDN University), 6 Miklukho-Maklaya str., Moscow, 117198, Russia.
[†] Associate Professor, Academy of Engineering, Peoples' Friendship University of Russia (RUDN University), 6 Miklukho-Maklaya str., Moscow, 117198, Russia.
[‡] Assistant, Academy of Engineering, Peoples' Friendship University of Russia (RUDN University), 6 Miklukho- Maklaya str., Moscow, 117198, Russia.

IAA-AAS-SciTech2018-102
AAS 18-861

ARCHITECTURAL DESIGN AND STRUCTURES ON THE MOON

Olga Yu. Suslova[*] and Vera M. Rogozina[†]

The hypothesis of a sequence of architectural mastering of the moon suggests several stages of settlement. At the first stage, it is necessary to deliver and build light structures for the cosmonauts of the “pioneers”. The requirements for a constructive, technological and planning solution of such first lunar "tents" are revealed. Issues of spatial rigidity and stability of forms under conditions of lunar gravity are investigated. The analysis of lightweight and pre-fabricated systems led to the choice of two options, having a very compact form in the assembled state and quickly unfolding at the construction site. The authors of these designs are Russian engineers and architects. The first lunar buildings should use the lunar soil as a thermal insulation and anti-radiation protection. According to the hypothesis, the second stage of the architectural and constructive exploration of the moon is assumed. At this stage modular buildings will be erected for living, research and production. They can be stationary and mobile. Different design solutions of such buildings are analyzed. Conclusions about the feasibility of the use of certain structures.

[View Full Paper]

[*] Associate Professor, Academy of Engineering, Peoples’ Friendship University of Russia (RUDN University), 6 Miklukho-Maklaya str., Moscow, 117198, Russia.
[†] Associate Professor, Moscow Architectural Institute, 11/4 Rozhdestvenka str., Moscow, 107031, Russia.

IAA-AAS-SciTech2018-105
AAS 18-862

A THEORY FOR SPACE FRAMES WITH WARPING RESTRAINT AT NODES

Vera Galishnikova*

Large-span bar structures are used extensively in different areas of engineering. In civil construction their potential for freedom of form over long spans makes them architecturally attractive. From the engineering point of view, they have such properties as lightness, high rigidity and rapid erection. This makes them highly advantageous for various space applications – complex orbital structures, large-span roofs for missions on the Moon and planets of the Solar system, as well as for building of terrestrial infrastructure. The analysis of single structural members for combined stretching, flexure and torsion shows that warping restraint at nodes can lead to torsional moments exceeding the moments due to uniform torsion. Conventional design of space frames with symmetrical closed sections and flexible nodes does not account for warping restraint at the nodes. It is, however, not evident that warping effects can be ignored in novel space frame designs with unsymmetrical thin-walled sections and stiff nodes. Conventional frame analysis using the displacement and rotation coordinates as nodal variables does not account for warping stiffness. The kinematical coordinate axes of the members, using the shear center as origin and the principal axes for bending, do not pass through the nodes of the frame. This impedes corrections of the computed results to account for warping effects. A space frame theory is presented, which can be used as the basis for the implementation of an analysis platform for the first order linear analysis of space frames with significant warping restraint at their nodes. [View Full Paper]

* Professor, Academy of Engineering, Peoples' Friendship University of Russia (RUDN University), 6 Miklukho-Maklaya str., Moscow, 117198, Russia.

IAA-AAS-SciTech2018-103
AAS 18-863

LITHOLOGICAL STUDY OF MARS SURFACE BY PLANET ORBITAL STATIONS AND ROVERS

Alexey F. Georgievskiy,[*] Victoriya M. Bugina,[†] Elena F. Shaleeva[‡] and Alexey A. Georgievskiy[§]

NASA rovers such as Viking 1.2; Pathfinder; Spirit; Opportunity; Phoenix; Curiosity collected and transmitted photo documents and data of the mineralogical and material composition of Martian sedimentary rocks. Analysis of the accumulated factual basis gives grounds for concluding that sedimentary rock formation on Mars, as on Earth, proceeded under the influence of gravitational, cryogenic, aeolian and fluvial factors, the interrelation between which was determined by the activity of physical and chemical weathering processes. Also meteorite and volcanic material participated in the formation of sedimentary rocks. It is possible to discover deposits of Fe, Mn, U, rare earth elements, noble metals, Cu, Pb, Zn, B, Ba, Sr, P, various salts and water on Mars. [View Full Paper]

[*] Associate Professor, Academy of Engineering, Peoples' Friendship University of Russia (RUDN University), 6 Miklukho-Maklaya str., Moscow, 117198, Russia.
[†] Associate Professor, Academy of Engineering, Peoples' Friendship University of Russia (RUDN University), 6 Miklukho-Maklaya str., Moscow, 117198, Russia.
[‡] Senior Lecturer, Academy of Engineering, Peoples' Friendship University of Russia (RUDN University), 6 Miklukho-Maklaya str., Moscow, 117198, Russia.
[§] Senior Lecturer, Academy of Engineering, Peoples' Friendship University of Russia (RUDN University),6 Miklukho-Maklaya str., Moscow, 117198, Russia.

ENERGY SYSTEMS AND PROPULSION

Session Chairs:
Zhil-ulbe Matje, *Peoples' Friendship University of Russia (RUDN University) Russia*
Vladimir Sidorov, *Peoples' Friendship University of Russia (RUDN University) Russia*

IAA-AAS-SciTech2018-064
AAS 18-864

HYDROGEN ENERGY IN THE INTERNATIONAL ENERGY STRATEGY AND ITS RELATIONSHIP WITH THE PROSPECT OF THE DEVELOPMENT OF TRANSPORT TECHNOLOGIES

Vladimir N. Konoplev,[*] Andrey S. Korzin,[†] Zakhar G. Melnikov[‡] and Georgy V. Belitsky[§]

The article shows the strategy of international energy consumption and its relationship with the prospect of the development of transport technologies using hydrogen. The results were analyzed and the advantages of using hydrogen in cargo and passenger transport as the main fuel and mixtures: with gasoline and methane “hitan” were shown. The features of a new method of hydrogen storage based on a microporous structure – which allows to create hydrogen batteries with an unprecedented high hydrogen content and provide a sufficiently high explosion- safe operation – are revealed. The paper shows that there is a backlog in the main areas of hydrogen energy in Russia. The implementation of relevant programs on the use of hydrogen in the motor transport complex of the country will create the basic technological foundations of the commercial transition to the Atomic-Hydrogen power industry, which will increase the energy sustainability of the country's economy and ensure the supply of appropriate high-tech energy-technological complexes for export.

Keywords: Hydrogen Energy, international energy consumption, development of transport technologies, energy resources.

[View Full Paper]

[*] Associate Professor, Academy of Engineering, Peoples’ Friendship University of Russia (RUDN University), 6 Miklukho-Maklaya str., Moscow, 117198, Russia.
[†] Graduate Student, Academy of Engineering, Peoples’ Friendship University of Russia (RUDN University), 6 Miklukho-Maklaya str., Moscow, 117198, Russia.
[‡] Student, Academy of Engineering, Peoples’ Friendship University of Russia (RUDN University), 6 Miklukho- Maklaya str., Moscow, 117198, Russia.
[§] Graduate Student, Academy of Engineering, Peoples’ Friendship University of Russia (RUDN University), 6 Miklukho-Maklaya str., Moscow, 117198, Russia.

IAA-AAS-SciTech2018-100
AAS 18-865

STUDY OF OPERATING PRESSURE EFFECT ON THE PERFORMANCE OF EJECTOR FOR LIQUID-PROPELLANT ROCKET ENGINE TESTING

Alexander N. Drozdov,[*] Nikolay A. Drozdov[†] and Igor M. Narozhnyy[‡]

Ejectors (jet pumps, jet devices) are widely used in various branches of engineering. They are used, in particular, in fuel supply systems and in firing bench tests of liquid-propellant rocket engines.

There are different types of ejectors, for example, liquid jet pumps and liquid-gas ejectors. It should be noted that the fluid capacity pumped out by the ejector can vary significantly during operation. Therefore, for rational operation it is necessary to choose the most suitable flow part of the ejector. Despite the simplicity of the design, many issues of the workflow of the ejector and increasing its efficiency currently remain unexplored.

In this regard, experimental bench studies of the liquid-gas ejector performance were carried out when simulating bench tests of liquid-propellant rocket engines with various values of gas flow rates and operating pressures in front of the nozzle. The bench allowed testing the characteristics of various jet devices in a wide range of operating parameters when pumping liquid, gas, and gas-liquid mixture. Experiments have shown that the rational length of the ejector mixing chamber when pumping gas substantially depends on the operational parameters of its operation. With increasing pressure of the working flow, the mixing zone is shifted towards the exit of the ejector. In addition, with increasing pressure of the operating fluid, the efficiency of the ejector first increases and then, passing through a maximum, decreases. Therefore, the well-known proposition that the most optimal for a liquid-gas ejector is the mode in which the process of mixing flows ends directly in front of the diffuser should be added: the optimal mode also depends on the value of the operating pressure.

Interesting results were obtained in the field of high gas content of pumped products. In the presence of a certain amount of liquid, the jet apparatus ejects a larger amount of gas than in the case of pumping out pure gas, and the pressure, created by the ejector, also increases. Consequently, experiments show that there is the possibility of creating a new method for ejecting gas by supplying a certain amount of liquid to the jet apparatus intake.

The obtained results make it possible to select and apply the most suitable flow part of the ejector, including the length of its throat, for efficient operation. [View Full Paper]

[*] Professor, Academy of Engineering, Peoples' Friendship University of Russia (RUDN University), 6 Miklukho-Maklaya str., Moscow, 117198, Russia.
[†] General Director, Innovative Oil and Gas Solutions Limited Liability company, 64/1 Shipilovskaya Street, Moscow, 115682, Russia.
[‡] Senior Lecturer, Academy of Engineering, Peoples' Friendship University of Russia (RUDN University), 6 Miklukho-Maklaya str., Moscow, 117198, Russia.

IAA-AAS-SciTech2018-058
AAS 18-866

THE ANALYSIS OF COMBUSTION PROCESS OF ORGANIC FUEL FOR PROSPECTIVE AEROSPACE EQUIPMENT

Petr P. Oschepkov,[*] Ivan C. Zaev,[†] Sergej V. Smirnov,[‡] Oleg V. Kamyshnikov[§] and Roman O. Kamyshnikov[**]

Vehicles with internal combustion engines play a significant role in many fields, including the space industry. Vehicles with internal combustion engines are used in the production, pre-launch preparation of spaceships and spaceship cargo transportation. The use of alternative fuels for internal combustion engines of transport means is made relevant with the continuous reduction of hydrocarbon fuel reserves. One of the most promising type of alternative fuel is biofuel. This paper presents the results of the calculated analysis of the characteristics of the combustion process of biodiesel fuel with palm oil and hydrogen peroxide additives and the influence of the additives on the combustion process and the ignition-delay period. The calculated analysis performed has shown the effectiveness of the use hydrogen peroxide as an additive in for the selected biofuel to reduce the ignition-delay period and thus increased the power and economical parameters of the engine.

[View Full Paper]

[*] Associate Professor, Academy of Engineering, Peoples' Friendship University of Russia (RUDN University), 6 Miklukho-Maklaya str., Moscow, 117198, Russia.
[†] Associate Professor, Academy of Engineering, Peoples' Friendship University of Russia (RUDN University), 6 Miklukho-Maklaya str., Moscow, 117198, Russia.
[‡] Associate Professor, Academy of Engineering, Peoples' Friendship University of Russia (RUDN University), 6 Miklukho-Maklaya str., Moscow, 117198, Russia.
[§] Associate Professor, Universidad Nacional de San Agustín de Arequipa, 04001, Santa Catalina 117 – Cercado, Arequipa, Perú.
[**] Assistant, Academy of Engineering, Peoples' Friendship University of Russia (RUDN University), 6 Miklukho-Maklaya str., Moscow, 117198, Russia.

IAA-AAS-SciTech2018-094
AAS 18-867

THE WAYS OF EFFECTIVENESS INCREASE OF LIQUID FUEL WITH ORGANIC ADDITION APPLIANCE IN AEROSPACE EQUIPMENT

Salim Soo,[*] Khalil I. Abdel Sater,[†] Alexander A. Khodyakov,[‡] Aleksandr V. Marusin,[§] Igor K. Danilov,[**] Sergey V. Khlopkov[††] and Irina S. Andryushenko[‡‡]

As a result of research carried out by NASA in 2011, oil deposits were discovered on the moon, which are thousands of times larger than Saudi Arabia's reserves, and lunar gravity significantly simplifies the exploration process. This is the same for Mars the planet of the solar system. The presence of oil and complex hydrocarbons on planets can be designed using components of liquid fuels and vegetable oils. An analogue for studying the characteristics of the present liquid hydrocarbons on the planets, as components of a fuel, can be a mixture of diesel fuel. Density, viscosity, mixtures of diesel fuel (DF), lighting kerosene (KER) and peanut, rapeseed oil (PO; RO) have been determined. It was concluded that the most suitable for diesel power supply is a compound consisting of 29% DF, 33% KER and 38% PO (RO). The viscosity of the mixture (M) was about 8.0 $mm^2 \cdot s^{-1}$ (200°C). It was found that at the distillation temperature of M, equal to 180-2500°C, the volume of distillation was 10-50%, which is identical to the parameters of the rate presented at the Federal Standard GOST on DF. It is shown that the distillation of the compounds into separate fractions proceeds mainly at temperatures below the distillation temperature of the DF. Weight reducing and weight increasing of the fractional composition is observed simultaneously, which is due to the presence in the mixtures of high-boiling vegetable oil (VO). It is not possible to disperse mixtures containing VO into separate fractions above 300-3400°C because of the decomposition of this component.

[View Full Paper]

[*] Assistant, Academy of Engineering, Peoples' Friendship University of Russia (RUDN University), 6 Miklukho-Maklaya str., Moscow, 117198, Russia.
[†] Associate Professor, Academy of Engineering, Peoples' Friendship University of Russia (RUDN University), 6 Miklukho-Maklaya str., Moscow, 117198, Russia.
[‡] Associate Professor, Academy of Engineering, Peoples' Friendship University of Russia (RUDN University), 6 Miklukho-Maklaya str., Moscow, 117198, Russia.
[§] Associate Professor, Academy of Engineering, Peoples' Friendship University of Russia (RUDN University), 6 Miklukho-Maklaya str., Moscow, 117198, Russia.
[**] Professor, Academy of Engineering, Peoples' Friendship University of Russia (RUDN University), 6 Miklukho-Maklaya str., Moscow, 117198, Russia.
[††] Assistant, Academy of Engineering, Peoples' Friendship University of Russia (RUDN University), 6 Miklukho-Maklaya str., Moscow, 117198, Russia.
[‡‡] Senior Lecturer, Academy of Engineering, Peoples' Friendship University of Russia (RUDN University),6 Miklukho-Maklaya str., Moscow, 117198, Russia.

IAA-AAS-SciTech2018-016
AAS 18-868

INVESTIGATION OF THE INITIAL STAGE OF DISCHARGE IN AN ABLATIVE PULSED PLASMA THRUSTER

Alexandr A. Antipov[*] and Alexandr V. Bogatyy[†]

The development of discharge in an ablative pulsed plasma thruster is considered. The time of the discharge development stages is determined. It is found out that the development of the discharge is predetermined by the initial stage. The initial stage of discharge in a certain ablative pulsed plasma thruster is investigated. A mathematical model of the charged particles motion in the ablative plasma thruster at the initial stage of discharge is developed.

[View Full Paper]

[*] Postgraduate Student, Research Institute of Applied Mechanics and Electrodynamics, Moscow Aviation Institute, 4 Volokolamskoe shosse, Moscow, 125993, Russia.
[†] Senior Researcher, Research Institute of Applied Mechanics and Electrodynamics, Moscow Aviation Institute, 4 Volokolamskoe shosse, Moscow, 125993, Russia.

IAA-AAS-SciTech2018-026
AAS 18-869

ADVANCED CERAMIC MATERIALS AND 3D PRINTING TECHNOLOGIES IN APPLICATION TO THE ELECTRICALLY POWERED SPACECRAFT PROPULSION

Victor Balashov,[*] Sergey Khartov,[†] Andrey Mogulkin,[‡] Vladislav Nigmatzyanov,[§] Oleg Peysakhovich,[**] Lev Rabinsky[††] and Sergey Sitnikov[‡‡]

The trends of modern and perspective spacecrafts (SC) development are increasing of payload mass and available electric power; enlarging the time of SC active existence; as a result expansion of the range of its mass. To solve the thruster problems there is a need to create a new generation of thrusters, differed, in particular by higher specific impulse, efficiency and long operation time. The problem can be solved by using the electric propulsion (EP). One of the commonly used electric thrusters is hall effect thruster - stationary plasma thruster (SPT), which lifetime is limited by the sputtering of ceramic walls of the discharge chamber. Another perspective type electric propulsion is radio-frequency ion thruster (RIT), also has ceramic discharge chamber. Manufacturing of ceramic discharge chamber of RIT connected with technological problems. Therefore, the development of new ceramic materials, with high resistance to the ion sputtering, and the development of new technological processes of manufacturing discharge chambers is able to increase lifetime and to simplify production of electric thrusters. [View Full Paper]

[*] Lead Researcher, Research Institute of Applied Mechanics and Electrodynamics, Moscow Aviation Institute, 4 Volokolamskoe shosse, Moscow, 125993, Russia.
[†] Professor, Research Institute of Applied Mechanics and Electrodynamics, Moscow Aviation Institute, 4 Volokolamskoe shosse, Moscow, 125993, Russia.
[‡] Engineer, Research Institute of Applied Mechanics and Electrodynamics, Moscow Aviation Institute, 4 Volokolamskoe shosse, Moscow, 125993, Russia.
[§] Engineer, Research Institute of Applied Mechanics and Electrodynamics, Moscow Aviation Institute, 4 Volokolamskoe shosse, Moscow, 125993, Russia.
[**] Student, Research Institute of Applied Mechanics and Electrodynamics, Moscow Aviation Institute, 4 Volokolamskoe shosse, Moscow, 125993, Russia.
[††] Director, Institute 9, Moscow Aviation Institute, 4 Volokolamskoe shosse, Moscow, 125993, Russia.
[‡‡] Associate Professor, Moscow Aviation Institute, 4 Volokolamskoe shosse, Moscow, 125993, Russia.

IAA-AAS-SciTech2018-021
AAS 18-870

SHAPE OPTIMIZATION OF NICKEL ANODES USED IN THE PRODUCTION OF GALVANIC COATINGS OF ROCKET ENGINE

Marianna Yu. Malkova[*] and Alexander N. Zadiranov[†]

Production of electroplates of rocket engines traditionally uses hot-rolled sheet nickel anodes, the main disadvantages of which are: small specific surface, high volume of anode scrap formation. The purpose of the study is to investigate and develop the process of cathode electroforming of spherical deposits and their subsequent usage as soluble nickel anodes. A laboratory setup and cathode mount of original design was developed for the generation of spherical deposits. Cathode deposits of spherical shape with 0.9-1.2 cm diameter and fine profile and surface quality were obtained as a result of the experiment. Utilizing spherical anodes in nickel electroplate coating production showed that this process is accompanied by 98-99% dissolution of loaded anode mass with the reduction of specific cost almost by 25%. [View Full Paper]

[*] Professor, Academy of Engineering, Peoples' Friendship University of Russia (RUDN University), 6 Miklukho-Maklaya str., Moscow, 117198, Russia.
[†] Professor, Academy of Engineering, Peoples' Friendship University of Russia (RUDN University), 6 Miklukho-Maklaya str., Moscow, 117198, Russia.

IAA-AAS-SciTech2018-106
AAS 18-871

ALTERNATIVE STRATEGIES IN ASTRONAUTICS DURING THE ENERGY CRISIS

Vitaly Melnikov,[*] Georgy Polishchuk,[†] Kseniya Benevolskaya,[‡] Oleg Samusenko[§] and Gennadiy Rumyantsev[**]

With the general trend of hydrocarbon exhaustion in the long run, constantly increasing cargo flows into space can be provided with electromagnetic accelerators. Due to unbearable for manned flights g-load, astronauts will have to make flights in oxygen-hydrogen carrier vehicles, the transition to which corresponds to global trends in cosmonautics. Production of oxygen-hydrogen fuel is possible not only on Earth, but also in space, which significantly expands the capabilities of astronautics. Ice comets and asteroids, Martian polar ice caps, ice breaks up to 60 km wide on the Moon surface are all sources of water. The developments of oxygen-hydrogen fuel production systems that use the process of water electrolysis, and also systems for its storage and carriers refueling in space are already underway. Studies of unidentified flying objects (UFOs) indicate in them usage of energy from the environment and lead us the possibility of switching all vehicles to fundamentally more powerful clean energy. [View Full Paper]

[*] Professor, Academy of Engineering, Peoples' Friendship University of Russia (RUDN University), 6 Miklukho-Maklaya str., Moscow, 117198, Russia.
[†] Professor, Academy of Engineering, Peoples' Friendship University of Russia (RUDN University), 6 Miklukho-Maklaya str., Moscow, 117198, Russia.
[‡] Assistant Professor, Academy of Engineering, Peoples' Friendship University of Russia (RUDN University), 6 Miklukho-Maklaya str., Moscow, 117198, Russia.
[§] Associate Professor, Academy of Engineering, Peoples' Friendship University of Russia (RUDN University), 6 Miklukho-Maklaya str., Moscow, 117198, Russia.
[**] Professor, Academy of Engineering, Peoples' Friendship University of Russia (RUDN University), 6 Miklukho-Maklaya str., Moscow, 117198, Russia.

IAA-AAS-SciTech2018-107
AAS 18-872

TRANSMISSION AND RECEPTION OF ENERGY FROM LASER SPACE SOLAR POWER PLANTS

Vitaly M. Melnikov,[*] Georgy M. Polishchuk,[†] Oleg E. Samusenko,[‡] Anastasiya N. Yatsenko[§] and Viktoria D. Novikova[**]

The atmospheric transparencies windows indicating the need to shift the wavelength of the laser to 1.4 microns, which will require significant material science efforts, are presented. It is indicated that even in the worst weather conditions today can be selected laser wavelength, providing up to 20% absorption. In the situation with the difficulties of balloon reception, mainly because of the terrorist threat, you should probably accept such losses and abandon the use of balloons. Data from the history of development of aerostat balloons are given, their technological and operational difficulties are pointed out. It is noted that the angle reflector on the ground photo module can provide accurate guidance of the laser beam. At ground reception of laser radiation by solar panels their efficiency is 15-30% higher than to the solar spectrum. The environmental impact of laser systems is much less than the microwave (microwave) analogues. The features of network inverters and ground infrastructure of laser space solar power plants are described. [View Full Paper]

[*] Professor, Academy of Engineering, Peoples' Friendship University of Russia (RUDN University), 6 Miklukho-Maklaya str., Moscow, 117198, Russia.
[†] Professor, Academy of Engineering, Peoples' Friendship University of Russia (RUDN University), 6 Miklukho-Maklaya str., Moscow, 117198, Russia.
[‡] Associate Professor, Academy of Engineering, Peoples' Friendship University of Russia (RUDN University),6 Miklukho-Maklaya str., Moscow, 117198, Russia.
[§] Assistant, Academy of Engineering, Peoples' Friendship University of Russia (RUDN University), 6 Miklukho-Maklaya str., Moscow, 117198, Russia.
[**] Student, Academy of Engineering, Peoples' Friendship University of Russia (RUDN University), 6 Miklukho-Maklaya str., Moscow, 117198, Russia.

INTERNATIONAL SPACE POLICY AND LAW

Session Chairs:
Irina Shatalova, *Peoples' Friendship University of Russia (RUDN University) Russia*
Adu Nikez, *Peoples' Friendship University of Russia (RUDN University) Russia*

IAA-AAS-SciTech2018-114
AAS 18-873

CURRENT ISSUES OF INTERNATIONAL SPACE LAW

Aslan Kh. Abashidze*

The international legal norms governing the space activities of states were introduced in the 21st century in the form of an already established system of norms of international space law, aimed at responding in general to the challenges of the new century. The specificity of international space law is that it is intended to prejudge the behavior of individual states in the field of space activities for many decades and even centuries ahead. Accordingly, the established international legal regime of use of outer space is recognized by all states and the international community as a rule of conduct for centuries. However, many issues are acutely on the agenda of the international community today: the fight against the militarization of outer space, the creation of an international space organization, use of nuclear power sources in outer space, space debris mitigation and remediation measures, non-legally binding United Nations instruments on outer space, legal aspects of space traffic management, application of international law to small-satellite activities, legal models for activities in the exploration, exploitation and utilization of space resources. Responses to these modern challenges should be provided by our generation. In this respect doctrinal developments of international law scholars are in high demand today in the field of international space law.

The article is published in the framework of the grant of the Russian Foundation for Basic Research "BRICS and the Peaceful Uses of Outer Space" 17-03-00427.

[View Full Paper]

* Professor, Law Institute, Peoples' Friendship University of Russia (RUDN University), 6 Miklukho-Maklaya str., Moscow, 117198, Russia.

IAA-AAS-SciTech2018-115
AAS 18-874

CURRENT ISSUES OF MINING ACTIVITIES ON CELESTIAL BODIES: INTERNATIONAL LAW ASPECTS

Albert M. Khayrutdinov*

Industrial society cannot do without the consumption of natural resources. Currently, the volume of mined mineral resources in the world increases every year and is estimated at billions of tons. The constant increase in the volume of extraction and production of minerals often occurs at the expense of compliance with environmental norms. The mining industry has a significant impact on the environment: millions of tons of harmful substances are emitted into the atmosphere, millions of cubic meters of contaminated wastewater are discharged into the water bodies, and a huge amount of solid waste is stored on the surface of the earth. As a rule, the area of territories affected by the activities of mining enterprises is incomparable with the development territory itself, and often exceeds the area of adjacent cities.

Some of the factors as to why the extraction of natural resources on the celestial bodies might be relevant due to existing earth-related environmental problems is discussed.

The purpose of this paper is to find a solution to the problem of regulation of mining activities on the Moon and celestial bodies in the context of modern international space law.

[View Full Paper]

* Assistant, Law Institute, Peoples' Friendship University of Russia (RUDN University), 6 Miklukho-Maklaya str., Moscow, 117198, Russia.

IAA-AAS-SciTech2018-116
AAS 18-875

GUIDELINES ON LONG-TERM SUSTAINABILITY OF OUTER SPACE ACTIVITIES: FUTURE PERSPECTIVES

Irina Al. Chernykh*

Sustainability of outer space activities is the cornerstone of success in the modern international relations on the exploration and use of outer space. In 2018 UN COPUOS had to adopt the Guidelines for the long-term sustainability of outer space activities by the General Assembly Resolution but could not reach the consensus on the main provisions of the document. Some of States delegates suggested to endorse the Compendium of the approved guidelines, not finishing the draft process the whole document. This article explores the guidelines on the long-term sustainability and their importance, as well as defines future perspectives of its acceptance. Firstly, this paper includes the comprehensive analysis of the guidelines. Secondly, the research accumulates the data about the drafting process of the Guidelines and contains its rather-legal analysis from the proposals of different States. Thirdly, it strives to identify and predict whether the Guidelines will be approved or not in the future perspective. The research methodology rests on the UN COPUOS documents, soft law and national legislation of the States that are engaged in space activities on the issues, which have been touched on. The paper ends up with the conclusion that the Guidelines should be adopted in General Assembly Resolution and should become a basic document in the questions of sustainability, safety and longevity of outer space activities. The article is published in the framework of the grant of the Russian Foundation for Basic Research "BRICS and the Peaceful Uses of Outer Space" 17-03-00427. [View Full Paper]

* Assistant, International Law Department, Peoples' Friendship University of Russia (RUDN University), 6 Miklukho-Maklaya str., Moscow, 117198, Russia.

IAA-AAS-SciTech2018-104
AAS 18-876

SPACE TECHNOLOGIES TO FORM LEXICAL STRUCTURE OF ACADEMIC DISCOURSE

Svetlana V. Dmitrichenkova* and Elena A. Dolzhich†

The present paper is devoted to describe the features of lexical composition for academic discourse structure under the influence of advancements in space and aerospace technologies. The focus is set on terminological issues of borrowings and the ways they are adapted to the language system. Quickly advanced development of space technologies in the 21st century led to the notable increase in the number of special lexical units from the space field, cohesion of scientific society using uniform terms in order to work in a single information field and exchange information. Loanwords are lexemes that appear in the language system as a result of satisfying the need for naming a new thing or concept due to the emerging technologies to provide unambiguous understanding in exact sciences. The concept of terms and terminology is a key issue in science, since the term provides accuracy, clarity and understanding of scientific thought. English vocabulary widely penetrated into the term systems of other languages because of the rapid economic, scientific and technological development of English-speaking countries and due to the fact that traditionally the language of international science is English. The study of space term system in academic discourse is especially important, since helps to ensure effective communication in the global scientific community and to create specialized dictionaries, vocabularies for educational purposes. The methods of research are defined by goals and objectives. The object of this study is Spanish space science terminology. A method of structural analysis and a descriptive method have been used as the basic research methods with the use of such techniques as observation, comparison, interpretation, generalization. Source language material are monographs of specialists in this field of knowledge and research papers devoted to studying space science problems. [View Full Paper]

* Professor, Academy of Engineering, Peoples' Friendship University of Russia (RUDN University), 6 Miklukho-Maklaya str., Moscow, 117198, Russia.
† Associate Professor, Academy of Engineering, Peoples' Friendship University of Russia (RUDN University), 6 Miklukho-Maklaya str., Moscow, 117198, Russia.

IAA-AAS-SciTech2018-117
AAS 18-877

SYSTEM OF THE MODERN INTERNATIONAL SPACE LAW

Alexander Travnikov[*] and Irina Al. Chernykh[†]

Today, there are different approaches to the building of the law systems in the theory of law. In the foreign science, legal scholars pay special attention to the history, drawing up one or another system and consider sidelines of science. In Russia, system of law begins from the theoretical aspects and is supported by unitized units. Despite that, system of any branch of law is very important in the process of studying law. The aim of this article is to combine Russian and foreign approaches for the creation of the modern system of international space law that will include theoretical, institutional and additional elements. The article is published in the framework of the grant of the Russian Foundation for Basic Research "BRICS and the Peaceful Uses of Outer Space" 17-03-00427.

[View Full Paper]

[*] Assistant Professor, Law Institute, Peoples' Friendship University of Russia (RUDN University), 6 Miklukho-Maklaya str., Moscow, 117198, Russia.
[†] Assistant, Law Institute, Peoples' Friendship University of Russia (RUDN University), 6 Miklukho-Maklaya str., Moscow, 117198, Russia.

IAA-AAS-SciTech2018-118
AAS 18-878

SPACE DEBRIS SAFETY AND MITIGATION: SOME INTERNATIONAL LEGAL ASPECTS

Aslan Abashidze[*] and Alexander Solntsev[†]

The presence of debris in Outer space should be considered a form of environmental degradation on a universal level. The term 'space debris' refers to the remnants of human activities in outer space: defunct satellites, spent rocket upper stages, and parts of these objects. In fact, the pollution does not occur in the territory of any state, but in a sovereign-free area that is open to all states for utilization. The article considered some international legal aspects of the prevention of the formation and removal of space debris. The authors analyzed provisions of international acts, adopted at universal level (United Nations, International Telecommunication Union, International Standards Organization) and regional level (European Space Agency). Special attention paid to the implementation of space debris mitigation standards into national legislation of the different countries of the World. [View Full Paper]

[*] Professor, Law Institute, Peoples' Friendship University of Russia (RUDN University), 6 Miklukho-Maklaya str., Moscow, 117198, Russia.
[†] Associate Professor, Law Institute, Peoples' Friendship University of Russia (RUDN University), 6 Miklukho-Maklaya str., Moscow, 117198, Russia.

IAA-AAS-SciTech2018-119
AAS 18-879

CORRELATION OF INTERNATIONAL SPACE LAW AND NATIONAL LEGISLATION IN THE FIELD OF SPACE ACTIVITIES

Mira Kulikpayeva*

Within the framework of the progressive development of international law, new branches are appearing, among which is the international space law. The object of this branch is the realization of space activities, based on the exploration and use of outer space for peaceful purposes. Today, a number of states are actively involved in space activities and are seeking to join the club of space powers. As practice shows, any activity requires its international legal and national legal regulation. In this regard, it is interesting to research the correlation between the basic UN treaties on outer space and national legal norms.

[View Full Paper]

* Associate Professor, Law Institute, Peoples' Friendship University of Russia (RUDN University), 6 Miklukho-Maklaya str., Moscow, 117198, Russia.

IAA-AAS-SciTech2018-120
AAS 18-880

THE REGIONAL AFRICAN SATELLITE COMMUNICATIONS ORGANIZATION (RASCOM): INTERNATIONAL LEGAL STATUS

Bukuru Jean-Baptiste*

Various developed countries have launched satellites in space over the years while many developing countries haven't due to lack of adequate resources and technologies for the effective exploration and exploitation of space. The fast evolution of today's technologies and huge potential resources of space has awakened the African countries to tap into the technology era to create elaborate strategies in the field of exploitation of space. The African states, hence established the Regional African Satellite Communications Organization (RASCOM) to deal with the issues of the use of space. This organization was created in the 1990's and since then more than 45 African countries have become members of this first Pan-African space organization. This paper discusses the international legal status of the Regional African Satellite Communications Organization, analyses different relevant documents and addresses challenges that may arise between states and companies in connection with the activities of RASCOM. [View Full Paper]

* Assistant, Law Institute, Peoples' Friendship University of Russia (RUDN University), 6 Miklukho-Maklaya str., Moscow, 117198, Russia.

IAA-AAS-SciTech2018-121
AAS 18-881

THE ROLE OF NON-BINDING NORMS IN INTERNATIONAL SPACE LAW

Denis Gugunskiy*

The most effective solution regulating the peaceful use of outer space in recent decades is instruments that are not legally binding for states, but states, guided by the goal of sustainable development, follow the provisions of such documents. Such documents, including the UNGA resolutions, as mentioned earlier, are not legally binding and are interpreted by some contemporary scholars as "soft law". Soft law can be a rule, it is a non-legally binding but vital, helping you to make a difference. The emergence of key issues in the area of space activities has forced the international community to pursue regulatory measures to address them. [View Full Paper]

* Senior Lecturer, Law Institute, Peoples' Friendship University of Russia (RUDN University), 6 Miklukho-Maklaya str., Moscow, 117198, Russia.

IAA-AAS-SciTech2018-122
AAS 18-882

DISASTER RISK REDUCTION AND INTERNATIONAL SPACE LAW

Dmitry Kruglov*

International initiatives aimed at using information obtained through space activities for the prevention, mitigation of disasters and for relief operations are being considered. The international legal mechanisms for improving this activity are examined. It is demonstrated that the use of such space technology, as Earth observation, meteorology, navigation and telecommunications satellite systems, plays an essential role in prevention of natural and man-made disasters and reducing all the negative consequences caused by them.

[View Full Paper]

* Postgraduate Student, Law Institute, Peoples' Friendship University of Russia (RUDN University), 6 Miklukho-Maklaya str., Moscow, 117198, Russia.

INDEX

NUMERICAL INDEX*

VOLUME 170 ADVANCES IN THE ASTRONAUTICAL SCIENCES, IAA SCITECH FORUM ON SPACE FLIGHT MECHANICS AND SPACE STRUCTURES AND MATERIALS

(First IAA/AAS SciTech Forum on Space Flight Mechanics and Space Structures and Materials, 13–15 November 2018, Moscow, Russia)

* Unless otherwise indicated all papers appear in Volume 170, *Advances in the Astronautical Sciences*.

AAS 18-813 A Recurrent Deep Architecture for Quasi-Optimal Feedback Guidance in Planetary Landing, Roberto Furfaro, Ilaria Bloise, Marcello Orlandelli, Pierluigi Di Lizia, Francesco Topputo and Richard Linares (IAA-AAS-SciTech2018-086)

AAS 18-814 Dynamical Aspects of Spatial Use of Gravity Assist Maneuvers for the Solar Probes, Alexey Grushevskii, Yury F. Golubev, Victor Koryanov, Andrey Tuchin and Denis Tuchin (IAA-AAS-SciTech2018-005)

AAS 18-815 Construction of the Moon-to-Earth Trajectory to the Earth Entry Interface Point Using Multi-Impulse Transfer, Nadezhda M. Gavrikova (IAA-AAS-SciTech2018-012)

AAS 18-816 Distribution of Correction Thrusters Under Delta-V Constraints in Local Horizontal Plane, Anna Okhitina, Yaroslav Mashtakov and Stepan Tkachev (IAA-AAS-SciTech2018-057)

AAS 18-817 The Optimization of Interplanetary Flight to Phobos with a Jet Engine of Combined Low and High Limited Thrust, Alexander S. Samokhin, Marina A. Samokhina, Ilia S. Grigoriev and Maxim P. Zapletin (IAA-AAS-SciTech2018-015)

AAS 18-818 Expansion of the Transport Capabilities of the Space System Based on the Proton-M Rocket with the Use of Electric Propulsion and a Gravitational Maneuver Near the Earth at the Beginning of an Interplanetary Flight, Mikhail S. Konstantinov (IAA-AAS-SciTech2018-056)

AAS 18-819 Method for Choosing Measurement Moments of Radio Altimeter-Vertical for Orbit Parameters Correction, Gennadiy N. Rumyantsev, Vitaly M. Melnikov, Georgy M. Polishchuk and Oleg E. Samusenko (IAA-AAS-SciTech2018-127)

AAS 18-820 Development and Launch of Mini-Elevator Demonstration CubeSat STARS-Me, Masahiro Nohmi and Yoji Ishikawa (IAA-AAS-SciTech2018-046)

AAS 18-821 Space Trajectory Optimization: Differential Evolution Redux, Robert G. Melton (IAA-AAS-SciTech2018-076)

AAS 18-822 Algorithm of the B-Plane Delivery Error Estimation for the Mission to Venus, Alexander S. Gammal, Andrew G. Tuchin and Denis A. Tuchin (IAA-AAS-SciTech2018-011)

AAS 18-823 Space Navigator: A Tool for the Optimization of Collision Avoidance Maneuvers, Leonid Gremyachikh, Dmitrii Dubov, Nikita Kazeev, Andrey Kulibaba, Andrey Skuratov, Anton Tereshkin, Andrey Ustyuzhanin, Lubov Shiryaeva and Sergej Shishkin (IAA-AAS-SciTech2018-068)

AAS 18-824 Interstellar Flights Via Alcubierre Warp Drive, Michael Fil'chenkov and Yuri Laptev (IAA-AAS-SciTech2018-003)

AAS 18-825 The Use of Computer-Based Simulators to Train Cosmonauts for the Fulfillment of the Program of Scientific-Applied Research, Andrey A. Kuritsyn, Elena V. Popova and Maksim M. Kharlamov (IAA-AAS-SciTech2018-020)

AAS 18-826 Ecological Impact on the Environment from Laser Space Solar Power Plants in the Problem of Development and Development of the Arctic and Continental Shelf, Vitaly M. Melnikov, Georgy M. Polishchuk, Anastasiya N. Yatsenko, Galina I. Balandina and Viktoria D. Novikova (IAA-AAS-SciTech2018-108)

AAS 18-827 Satellite Formation Control Via Deep Reinforcement Learning, Jacob Broida and Richard Linares (IAA-AAS-SciTech2018-061)

AAS 18-828 Optimal Tether-Assisted Space Debris Disposal, Wei Shi Wang and Arun K. Misra (IAA-AAS-SciTech2018-065)

AAS 18-829 An Advanced Remote Sensing CubeSat Constellation for Multi-Spectral EO Imaging, Riccardo Di Roberto and Filippo Graziani (IAA-AAS-SciTech2018-077)

AAS 18-830 Magnetorquers Attitude Control for Differential Aerodynamic Force Application to Nanosatellite Formation Flying Construction and Maintenance, Uliana Monakhova, Danil Ivanov and Dmitry Roldugin (IAA-AAS-SciTech2018-071)

AAS 18-831 Relative Motion Control of Two Satellites by Changing the Reflective Properties of the Solar Sails Surface, Yaroslav V. Mashtakov, Tatyana Yu. Petrova and Stepan S. Tkachev (IAA-AAS-SciTech2018-078)

AAS 18-832 The Research Method of Controlled Movement Dynamics of Tether System, Yury N. Razoumny, Sergei A. Kupreev and Arun K. Misra (IAA-AAS-SciTech2018-113)

AAS 18-833 The Joint Solution of Problem of Evasion and Keeping in a Neighborhood Reference Orbit, Zay Yar Win, Veniamin V. Malyshev, Vladimir T. Bobronnikov and Aleksandr V. Starkov (IAA-AAS-SciTech2018-091)

AAS 18-834 Optimal Low-Thrust Trajectories Using Nonsingular Equinoctial Orbit Elements, Mauro Pontani (IAA-AAS-SciTech2018-044)

AAS 18-835 The Algorithm for Solving the Task of Choosing the Optimal Two-Tier Satellite Constellation for Continuous Coverage of the Spherical Layer of Near-Earth Space, Daniele Mortari, Yury N. Razoumny, Oleg E. Samusenko, Viktoria D. Novikova and Nguyen Nam Quy (IAA-AAS-SciTech2018-112)

AAS 18-836 A Historical Review and Future Prospects of Space Tourism, Yi-Wei (Eva) Chang and Jeng-Shing (Rock) Chern (IAA-AAS-SciTech2018-090)

AAS 18-837 Mathematical Model of ERS Data Processing Ground Segment Operation in Terms of Processing Distribution, Andrey Emelianov, Lubov A. Grishantseva, Ksenia I. Zubkova, Veniamin V. Malyshev, Nguyen Viet Hoai Nam, Aleksandr V. Starkov and Zay Yar Win (IAA-AAS-SciTech2018-024)

AAS 18-838 Intelligent Structuring of the Earth Remote Sensing Methods for Detecting and Identification of Radioactive Sources of Ionizing Radiations, Dmitry Panov, Alexander Sukhorukov, Yury N. Razoumny, Dzhordzh Kovkov and Sergey Eroshkin (IAA-AAS-SciTech2018-080)

AAS 18-839 Technique of Estimating the Volume of Storage and Transmission of Information from Synthetic-Aperture Radar Satellite in Data Centers in Digital Economic Issues, Yury N. Razoumny, Guo Shuhong, Alexander Sukhorukov, Dzhordzh Kovkov and Sergey Eroshkin (IAA-AAS-SciTech2018-099)

AAS 18-840 The Program for Estimation of the Earth Remote Sensing Plans, Maxim P. Zapletin and Abylai T. Zhakypov (IAA-AAS-SciTech2018-088)

AAS 18-841 Space-Based Monitoring Capabilities for the Evaluation of Inland Water Resources: Application to Nigeria, Seidu O. Mohammed, Yury N. Razoumny, Alexandr Orlovskiy, Vasily Lobanov and Yaroslav Vasyunin (IAA-AAS-SciTech2018-111)

AAS 18-842 Calibration of Upper Atmospheric Model Based on the Precision Orbit of a Spherical Satellite, Wang Junyu and Wang Zhaokui (IAA-AAS-SciTech2018-037)

AAS 18-843 Fuzzy Logic Application Approach in Control of Automatic Spacecraft, Alexander N. Drozdov, Nikolay A. Drozdov and Igor M. Narozhnyy (IAA-AAS-SciTech2018-101)

AAS 18-844 The Assessment of Operational Capability of the Space-Based Hyperspectral Complex, Sergey A. Zotov, Y. V. Dmitriev, Sergey Y. Shibanov, Timofey V. Kondranin, Igor N. Polyakov and Anastasia G. Zotova (IAA-AAS-SciTech2018-041)

AAS 18-845 The Algorithm of Computing the Scattering Phase Function of Reflected Solar Radiation from Objects of Arbitrary Shape, Igor Polyakov and Sergey Zotov (IAA-AAS-SciTech2018-042)

AAS 18-846 Nano Star Tracker AZDK-1, Marat K. Abubekerov, Andrey I. Zakharov, Mike E. Prokhorov, Oleg Yu. Stekolchshikov, Maksim S. Tuchin and Nikolay Yu. Gostev (IAA-AAS-SciTech2018-030)

AAS 18-847 Understanding Reliability of the Thermoelectric Devices for Space Application, Shehak Sattar and Alexey Osipkov (IAA-AAS-SciTech2018-098)

AAS 18-848 System of Multidimensional Attractors of the Stress-and-Strain Behavior in Elastic Continuous Media, Anatoly A. Speranskiy and Yefim M. Malitikov (IAA-AAS-SciTech2018-069)

AAS 18-849 The Analysis of Destruction Causes and Condition Diagnostics of Hot Die Forging for Space Industry, Anna V. Kornilova, Mohamed I. Abu Mahadi, Alexander I. Selishchev and Tavkil H. Ayupov (IAA-AAS-SciTech2018-009)

AAS 18-850 Production Nickel Composite Materials Reinforced with Ultrafine Powders, Obtained from Aerospace Industry Waste, Marianna Yu. Malkova and Alexander N. Zadiranov (IAA-AAS-SciTech2018-019)

AAS 18-851 Development of a Universal Ultrasonic Reactor for Processing of Rare Earth Metal Ores on the Moon, Marianna Yu. Malkova, Alexander N. Zadiranov, Moises Romero and Prashanta Dkhar (IAA-AAS-SciTech2018-027)

AAS 18-852 Reliability Prediction of Resonant Tunneling Diodes and Non-Linear Radio Signal Converters Based on Them Under Influence of Temperature Factor and Ionizing Radiations, Mstislav O. Makeev, Vladimir Yu. Sinyakin and Sergey A. Meshkov (IAA-AAS-SciTech2018-060)

AAS 18-853 Diamond-Like Carbon Coatings to Protect the Optical Surfaces of Orbital Telescopes from the Outer Space Factors, Alexey Osipkov, Mstislav Makeev, Pavel Mikhalev, Alexander Machikhin, Vladislav Batshev, Pavel Shiriaev and Konstantin Shishov (IAA-AAS-SciTech2018-079)

AAS 18-854 Research of Anisotropy Structure of Polyamide 12 Parts Obtained by Selective Laser Sintering, Pavel Mikhalev, Pavel Shiriaev and Alexander Provatorov (IAA-AAS-SciTech2018-083)

AAS 18-855 Hybrid Mass and Radiation Sensor Based on Piezoelectric and Thermoelectric Effects, Alexander E. Shupenev, Sergey V. Yanovich, Ivan S. Korshunov, Natalia S. Pankova and Alexander G. Grigoryants (IAA-AAS-SciTech2018-085)

AAS 18-856 Analytical Technologies for Thin Coating Element Material Diagnostics with PXWR Application, Evgeny Egorov (IAA-AAS-SciTech2018-097)

AAS 18-857 Increasing the Strength of the Point Mechanical Connections of Composite Parts by Constructive-Technological Method, Fedor Nasonov, Alexandr Zinin, Sergey Bukharov, Kirill Kharchenko and Georgyi Piskunov (IAA-AAS-SciTech2018-034)

AAS 18-858 Uncertainty Impact on Micro-Vibration Control of an Orbiting Large Adaptive Space Structure, Federica Angeletti and Paolo Gasbarri (IAA-AAS-SciTech2018-067)

AAS 18-859 Microgravity Investigation of Seepage Flows in Porous Media, Evgeniya I. Skryleva, Valeriy F. Nikitin and Vladislav R. Dushin (IAA-AAS-SciTech2018-036)

AAS 18-860 Bending of a Thin Sheet into a Circular Cylinder with Two Free Edges for the Moon Conditions, Sergey N. Krivoshapko, Marina Rynkovskaya and Vladimir Jean Paul (IAA-AAS-SciTech2018-010)

AAS 18-861 Architectural Design and Structures on the Moon, Olga Yu. Suslova and Vera M. Rogozina (IAA-AAS-SciTech2018-102)

AAS 18-862 A Theory for Space Frames with Warping Restraint at Nodes, Vera Galishnikova (IAA-AAS-SciTech2018-105)

AAS 18-863 Lithological Study of Mars Surface by Planet Orbital Stations and Rovers, Alexey F. Georgievskiy, Victoriya M. Bugina, Elena F. Shaleeva and Alexey A. Georgievskiy (IAA-AAS-SciTech2018-103)

AAS 18-864 Hydrogen Energy in the International Energy Strategy and its Relationship with the Prospect of the Development of Transport Technologies, Vladimir N. Konoplev, Andrey S. Korzin, Zakhar G. Melnikov and Georgy V. Belitsky (IAA-AAS-SciTech2018-064)

AAS 18-865 Study of Operating Pressure Effect on the Performance of Ejector for Liquid-Propellant Rocket Engine Testing, Alexander N. Drozdov, Nikolay A. Drozdov and Igor M. Narozhnyy (IAA-AAS-SciTech2018-100)

AAS 18-866 The Analysis of Combustion Process of Organic Fuel for Prospective Aerospace, Petr P. Oschepkov, Ivan C. Zaev, Sergej V. Smirnov, Oleg V. Kamyshnikov and Roman O. Kamyshnikov (IAA-AAS-SciTech2018-058)

AAS 18-867 The Ways of Effectiveness Increase of Liquid Fuel with Organic Addition Appliance in Aerospace Equipment, Salim Soo, Khalil I. Abdel Sater, Alexander A. Khodyakov, Aleksandr V. Marusin, Igor K. Danilov, Sergey V. Khlopkov and Irina S. Andryushenko (IAA-AAS-SciTech2018-094)

AAS 18-868 Investigation of the Initial Stage of Discharge in an Ablative Pulsed Plasma Thruster, Alexandr Antipov and Alexandr V. Bogatyy (IAA-AAS-SciTech2018-016)

AAS 18-869 Advanced Ceramic Materials and 3D Printing Technologies in Application to the Electrically Powered Spacecraft Propulsion, Victor Balashov, Sergey Khartov, Andrey Mogulkin, Vladislav Nigmatzyanov, Oleg Peysakhovich, Lev Rabinsky and Sergey Sitnikov (IAA-AAS-SciTech2018-026)

AAS 18-870 Shape Optimization of Nickel Anodes Used in the Production of Galvanic Coatings of Rocket Engine, Marianna Yu. Malkova and Alexander N. Zadiranov (IAA-AAS-SciTech2018-021)

AAS 18-871 Alternative Strategies in Astronautics During the Energy Crisis, Vitaly Melnikov, Georgy Polishchuk, Kseniya Benevolskaya, Oleg Samusenko and Gennadiy Rumyantsev (IAA-AAS-SciTech2018-106)

AAS 18-872 Transmission and Reception of Energy from Laser Space Solar Power Plants, Vitaly M. Melnikov, Georgy M. Polishchuk, Oleg E. Samusenko, Anastasiya N. Yatsenko and Viktoria D. Novikova (IAA-AAS-SciTech2018-107)

AAS 18-873 Current Issues of International Space Law, Aslan Kh. Abashidze (IAA-AAS-SciTech2018-114)

AAS 18-874 Current Issues of Mining Activities on Celestial Bodies: International Law Aspects, Albert M. Khayrutdinov (IAA-AAS-SciTech2018-115)

AUTHOR INDEX