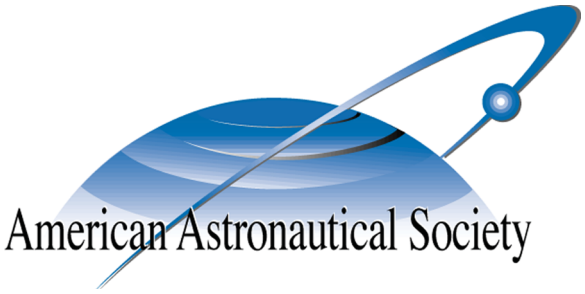
IAA/AAS SCITECH FORUM 2020 on Space Flight Mechanics and Space Structures and Materials

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.



IAA/AAS SCITECH FORUM 2020 on Space Flight Mechanics and Space Structures and Materials

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Yury N. Razoumny
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3nd IAA/AAS Conference on Space Structures and Materials

FOREWORD

This volume of the Series *Advances in the Astronautical Sciences* is dedicated to the 3rd IAA/AAS SciTech Forum on Space Flight Mechanics, and Space Structures and Materials (3rd IAA/AAS SciTech Forum Cyber Edition) held December 8-10, 2020 by International Academy of Astronautics (IAA) and RUDN University in Moscow, Russia in cooperation with American Astronautical Society (AAS). It was the third in a series of events that became a good tradition.

One of the most multinational universities in Russia and in the world – RUDN University, numbering students from more than 160 countries, was chosen as a venue for the 3rd IAA/AAS SciTech Forum Cyber Edition. Nowadays RUDN University with its Training Space Mission Control Center and multiple laboratory infrastructure is an expanding platform for space education, a place for research and discussion connected with space industry in Russia and worldwide, including Russian Mission Control Center in Korolev City, Moscow Region used for control of International Space Station together with Mission Control Center at NASA's Johnson Space Center, Houston, Texas.

The 3rd IAA/AAS SciTech Forum Cyber Edition was attended by leading scientists from Seoul National University (South Korea), University of Texas at Austin (USA), Pennsylvania State University (USA), Purdue University (USA), Texas A&M University (USA), Sapienza University of Rome (Italy), University of Colorado at Boulder (USA), Lomonosov Moscow State University (Russia), Bauman Moscow State Technical University (Russia), Beijing Institute of Technology (China), Symbiosis International University (India), Fluminense Federal University (Brazil) and others.

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).

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The Opening Ceremony began with speeches presented by Deputy Director General for International Cooperation of State Space Corporation "ROSCOSMOS" Mr. Sergey Saveliev and President of RUDN University Prof. Vladimir Fillipov. The Opening Ceremony was continued by the speeches of the Secretary General of the International Academy of Astronautics Dr. Jean-Michel Contant, Vice President of the American Astronautical Society, professor at the Pennsylvania University Prof. David Spencer and accomplished by the speech of the Chair of International Program Committee of the IAA/AAS SciTech Forum, Director of Academy of Engineering of the RUDN University Prof. Yury Razoumny.

The final program was consisted of 82 of high-quality presentations, 12 highlight lectures and 3 round tables. The thematic sessions started on December 8 and continued to the afternoon of December 10. The Forum presentations were made on actual issues of guidance, navigation and control, organization and optimization of space missions, orbital dynamics and determination, space missions and applications, creating space complexes and systems for various purposes, extending the life of space systems by maintaining spacecraft in orbits, removing elements of space debris, ensuring continuous and sustainable automated control of satellite systems, synthesis of space robotics and intelligent systems, creating innovative materials for the space industry, designing spacecraft structures and sensors, improving methods for calculating space structures for space applications and other.

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 exploration such as Prof. Daniele Mortari, Texas A&M University, USA, Prof. Antonio Prado, INPE, Brazil, Prof. Moriba Jah, University of Texas at Austin, USA, Dr. Richard Linares, Massachusetts Institute of Technology, USA and others. The manuscripts presented on the Forum are published as a special volume in AAS Advances in the Astronautical Sciences series by Univelt Incorporated, San Diego, California, USA. A total of 12 Highlight Lectures had been presented throughout the three days of the Forum. The short summaries of lectures are as follows.

Prof. Antonio Prado, INPE (Brazil), ***"A Survey on the Powered Swing-By Maneuvers".***

The Swing-By maneuver is a technique that uses a close approach of a spacecraft with a celestial body to change its energy and angular momentum. There are several research available in the literature to describe this problem, using different models, like the "patched-conics" and the "restricted three-body problem" and with different mission goals. This maneuver was used by several famous spacecraft that studied celestial bodies of the Solar System, like the voyager mission that visited the giant planets of the Solar System.

After this maneuver, a more complex version appeared in the literature that combined the close approach with the application of an impulsive maneuver during this close passage. There are many alternatives for this maneuver, by choosing the magnitude, direction and point of application of the impulsive maneuver. The possibility of making those choices increases very much the potential applications and can lead to optimization problems to maximize gains or losses of energy. It is known that an impulse that is not applied at the periapsis (but inside the sphere of influence of the body approached) and not in the direction of motion of the spacecraft give better results in terms of maximizing energy transfer. A detailed numerical study needs to be done to find the exact values of these variables for maximum energy variations.

There are also several different models for the dynamics used in the literature, sometimes considering the main bodies in circular or elliptic orbits, making "two-body" approximations or

not, etc. The model used makes large differences in many situations, so an accurate study must be done before solving the problem. A maneuver of this type can be used to give or remove energy from the spacecraft, so it has several possible applications, like to insert the spacecraft into a captured orbit around a celestial body, to give extra energy such that the spacecraft can reach the exterior planets of the Solar System or even escape to the interstellar space.

The goal of the present lecture is to make a survey of those maneuvers, with emphasis in the powered version. All the possibilities were shown, and examples of trajectories were calculated. Analytical approximations derived in the literature were also presented and the situations where it can be applied explained. Results obtained from numerical integrations of the equations of motion of the spacecraft under different dynamics completed the presentation, emphasizing the importance of this type of results in a system where analytical equations are valid in limited regions. Another important point that was covered is the importance of taking into account the eccentricity of the primaries, in particular when studying maneuvers near the planets Mars or Mercury, that have orbits with higher eccentricities. The conclusions made a comparison of models and approaches used in this type of maneuver.

Prof. Daniele Mortari, Texas A&M University (USA), ***"Current Status of the Theory of Functional Connections with Applications".***

This highlighted lecture summarizes the mathematical theory and most relevant applications of the Theory of Functional Connections (TFC). This theory is a framework for functional interpolation, which details the general methodology to embed a set of linear constraints in interpolating functionals, a.k.a. functions of functions or higher-order functions. As a result, these interpolating functionals describe the infinite set of interpolating functions. This lecture is designed for a wide spectrum of readers, and only requires basic knowledge of linear algebra, such as nonlinear least-squares, and tensor properties.

The TFC is an analytical framework to obtain constrained expressions, that is, analytical expressions describing all possible functions satisfying a set of constraints. Constrained expressions are provided for a wide class of constraints, including points and derivatives constraints, relative constraints, linear combination of constraints, components, and integral constraints. The first example of TFC application consists how to obtain least-squares solutions of linear and nonlinear ordinary differential equations. Specifically, the solutions have been obtained with the following features: 1) analytical approximate solutions (this allows easy subsequent analysis and further manipulation with derivative and integral), 2) the proposed approach solves initial, boundary, or multi-value problems in the same way (unified method), 3) the approach is very robust, with low condition number, 4) the solutions are usually provided at machine error accuracy, 5) the complexity is very low (solution obtained at msec level, suitable for real-time applications), and 6) the constraint range is independent from the integration range (solution accuracy is well maintained outside the constraints range). The TFC has been successfully extended to n-dimensions (Multivariate TFC). For instance, in 2-dimensional space the TFC provides all surfaces connecting Dirichlet and Neumann boundary conditions. The main purpose of this extension is to derive efficient methods to solve partial and stochastic differential equations. This lecture provides several examples where the theory is successfully applied in aerospace applications such as, orbit propagation, three-body two-impulse Earth-Moon, energy-efficient docking and optimal landing, and many other, time permitting.

Prof. Massimiliano Vasile, University of Strathclyde (UK), ***"Uncertainty Quantification in Astrodynamics".***

This highlight lecture presents an overview of some computational methods for uncertainty quantification in astrodynamics, from the simple propagation of uncertainty in the initial conditions to the more complex modelling of stochastic processes. The lecture illustrates the application of these methods to some examples in astrodynamics where a proper quantification of uncertainty is essential.

The lecture then introduces some computational methods to integrate uncertainty quantification in the design of optimal trajectories, closing the loop between trajectory design and navigation analysis.

Dr. Moriba Jah, The University of Texas at Austin (USA), ***"Toward a space domain digital twin for decision intelligence".***

A new scientific revolution is here, and it is founded upon trans disciplinarity. Like the prior scientific revolution, this one will also result in a transformation of societal views and the understanding of the nature of our lives and the universe writ large. This Renaissance Encore is born out of the need to solve these wicked problems of complex systems.

The space domain is what you get when you mix a wicked problem with a complex system, whose behavior is difficult to model and predict due to unknown dependencies, non-linear causal relationships, incomplete and even contradictory knowledge, competing opinions, and other types of interactions amongst the participants and constituents of the domain.

Given the vast and deep developments of each of these, coupled with globalization and competing interests, problems related to the space domain are finding themselves unsolvable through unidisciplinary or even multidisciplinary efforts because the space domain represents a complex system where the measured aspects of it are not explained by simply aggregating the behaviors of individual participants and constituents. The emergent behavior is more than the individual sum of its parts. Solving wicked problems in a complex system requires trans disciplinarity, which is a fused or holistic solution from the mélange of multiple disciplines concurrently. You'll recognize a transdisciplinary solution when it is difficult if not impossible to identify the unique contribution of any specific discipline to the solution.

Let's look at trying to mitigate collisions on orbit between any two satellite operators. A viable solution will need someone who studies the space weather and environment, an astrodynamicist who understand motion of objects in space, an orbit determination analysis who can take sensor data and turn these into statistical trajectory estimates, a space lawyer who knows the general rules these two operators might be subject to in defining their liability if damage were to occur, a social scientist who can provide cultural context to how these operators might interpret a common space law or policy, and more. There are no naturally occurring situations under which these experts would likely assemble and work concurrently on a transdisciplinary solution.

ASTRIAGraph was developed as a transdisciplinary answer to solve this wicked problem of this complex space traffic system, being a digital twin and library of anthropogenic space objects and elements affecting their behavior, from the effects and impacts of the space environment on them to the laws and policies culturally and geopolitically interpreted an implemented in a variety of ways. ASTRIAGraph is a knowledge graph database of space domain information and models that seeks to take unknown unknowns and transform them to unknown knowns via big data queries,

and from unknown knowns to known knows via multi-source information fusion and advanced methods of inference.

Prof. Ioannis Gitas, Aristotle University of Thessaloniki (Greece), ***"EO Applications in Forest Fire Management: A European Mediterranean perspective".***

In recent years, we have experienced a significant increase in the number of disciplines and activities supported by Earth Observation (EO). Remotely sensed data is considered essential for most environmental monitoring activities worldwide and the EO community is expected to play a key role in local, national and global efforts to address and mitigate climate change and implement the UNFCCC and the 2015 Paris Agreement.

Indeed, remote sensing is now considered critical to addressing key challenges related to climate change, biodiversity loss, land degradation, industrial pollution, water quality and availability, weather forecasting and early warnings, renewable energy, agriculture, forestry and natural ecosystems, coasts and oceans, topographic mapping, national security and natural and man-made hazards such as forest fires, among many others.

Since the initiation of the Landsat (1972) program and the launch of the first Earth observation satellites, various projects have been carried out to test the potential effectiveness and reliability of satellite data in the collection of information related to forest fire management. However, the range of applications has increased significantly in recent years.

Prof. Klauss Schilling, Zentrum fuer Telematik (Germany), ***"NetSat: Pioneering Formation Flight in 3D by Nano-Satellites".***

Technologies for distributed networked systems provide in the context of satellite systems new perspectives for innovative applications in Earth observation and telecommunication. Modern miniaturization approaches enable to realize classical satellite functionalities at continuously decreasing masses. Recent breakthroughs address attitude and orbit control capabilities for satellites at a mass of a few kilograms. Here UWE-4 recently demonstrated orbit control capabilities by electric thrusters, even including a collision avoidance maneuver in 2020. Thus, all key technologies are available for very small satellites to realize sensor networks in orbit in an attractive economical way.

Multi-satellite systems are so far mainly realized as constellations, where each satellite is individually controlled from the ground station. Nevertheless, a more efficient approach is self-organization of the satellite network as formation, where information and control are exchanged and coordinated between the satellites directly. Crucial enabling technologies for formations include inter-satellite links, relative attitude and position determination, autonomous reaction capabilities and networked control for coordination of the satellite system.

These features were realized in the NetSat mission to demonstrate in orbit innovative formation flying in three dimensions. In a 3U-CubeSat with 4 kilograms all functionalities were accommodated including in each satellite 4 GNSS- receivers, precision 3-axis attitude control by miniature reaction wheels, one electric propulsion system to realize the formation capabilities.

On 28.9.2020 NetSat was launched with a Soyuz from Plesetzsk cosmodrome into a polar orbit at 575 km altitude. First a string-of-pearls configuration was initiated to allow appropriate launch and early orbit operations. All satellites exchanged information among each other and with the ground station. After initialization of all subsystems the transition into different three-dimensional configurations for optimum observation geometries is planned.

Dr. Matteo Ceriotti, University of Glasgow (UK), ***"Design of Multiple Near-Earth Asteroid Rendezvous Missions".***

The study of asteroids and comets allow to learn more about the initial stages of the formation of the solar system and how life began. Additional drivers to further asteroid (and near-earth asteroids, NEAs) exploration are planetary defense, scientific demonstration, and future exploitation of their resources. Proximity and in-situ analysis provide valuable data (and samples) that cannot be gathered with Earth-based remote sensing.

The irregularity of their shape, size, gravity, magnetic field and composition makes each of them unique and worth to be studied. A tour of multiple asteroids with rendezvouses can be more appealing than multiple single-asteroid missions (single spacecraft and launch, additional flexibility in selecting targets "on the fly"). However, there are two main challenges associated: the high total impulse (Δv) required, and the large number of possible permutations of asteroids to be analyzed.

Designing multiple NEA rendezvous trajectories is a complex global optimization problem, which can be split into two coupled subproblems: the first is combinatorial, identifying an ordered sequence of n asteroids to visit. Given the NEAs known to date, trillions of permutations between asteroids exist. The second subproblem is the solution of the optimal control problem of each transfer leg, to evaluate the feasibility and optimality of the solution.

We first investigated to use solar sailing, due to its intrinsic capability to provide high Δv required for the multiple legs of the mission. We developed a specific shape-based trajectory approximation fitting exponential and trigonometric functions, which allowed to approximate the trajectory rapidly, optimizing static parameters only. This was then used within a methodical tree-search that scans sequences of asteroids incrementally, keeping and growing solely those which are feasible. We built a database of feasible sequences and associated trajectories, depending on the launch date and the performance (characteristic acceleration, or area-to-mass ratio) of the solar sail.

Then, we realized that for a fast assessment of possible sequences, only an estimate of the Δv and time of flight of each leg is required. To this end, we investigated the use of Artificial Neural Networks (ANNs) to quickly estimate the cost and duration of transfers between pairs of asteroids (or Earth-asteroid). After tuning and training, the ANN was employed in the sequence search. Only the most promising sequences are subsequently fully optimized, to obtain the full trajectory and control history. This ANN-based method resulted up to 100x faster than the one based on shapes, and errors in Δv and flight time of up to 7% in average. We were therefore able to consider further mission options. A multiple asteroid mission ending with return to Earth would be extremely valuable for the analysis of several collected asteroid samples. Within the multiple asteroid mission, one specific asteroid can be targeted, for example because of its interesting properties or for orbit characterization as potentially hazardous object. Finally, an "interest" value associated to each asteroid, such that interesting asteroids are favored even if at the cost of additional Δv or longer time of flight. Trajectory options for each of these scenarios were found using low-thrust propulsion.

Dr. Mauro Pontani, Sapienza Università di Roma (Italy), ***"Spacecraft Guidance and Control Based on Second-Order Optimality Conditions".***

Spacecraft trajectory optimization is concerned with the determination of the direction and magnitude of the propulsive thrust that drive a space vehicle toward specified conditions, while minimizing either propellant consumption or time of flight. However, in practical scenarios, deviations from the nominal trajectory, related to either the imperfect modeling of the space vehicle or

unpredictable environmental conditions, affect the real dynamics. Driving a spacecraft along a specified path thus requires defining the corrective actions aimed at compensating the nonnominal flight conditions. The Variable-Time-Domain Neighboring Optimal Guidance (VTD-NOG) belongs to the class of implicit guidance approaches and is aimed at finding the corrective control actions about the reference trajectory. This must be an optimal path that satisfies the second-order sufficient conditions for optimality. This recently introduced algorithm is quite general and can be adopted for dynamical systems with a generic number of state and control components and an arbitrarily large parameter set. The main difficulties encountered in former formulations of neighboring optimal guidance are the occurrence of singularities for the gain matrices and the challenging implementation of the updating law for the time-to-go. A fundamental original feature of the VTD-NOG is the use of a normalized time domain for the nominal trajectory and the related vectors and matrices. As a favorable consequence, the gain matrices remain finite for the entire time of flight and no extension of their domain is needed. In addition, the updating formula for the time-to-go derives analytically from the natural extension of the accessory optimization problem associated with the original optimal control problem. This extension leads to obtaining new equations for the sweep method, which provides all the time-varying gain matrices, computed offline and stored in the onboard computer. In this mathematical framework, the guidance termination criterion finds a logical, consistent definition, and corresponds to the upper bound of the interval of the normalized time. VTD-NOG identifies the trajectory corrections while assuming that the thrust is always aligned with the vehicle longitudinal axis. The attitude control system must be capable of maintaining the actual spacecraft orientation sufficiently close to the correct alignment dictated by the desired thrust direction (generated by VTD-NOG). To do this, two different attitude control systems are considered: (a) thrust vectoring, in conjunction with side jets, and (b) reaction wheels. Two distinct algorithms are employed for generating the feedback control action for systems (a) and (b). The attitude scheme interacts iteratively with VTD-NOG, in the context of a unified architecture for 6DOF spacecraft guidance and control. Three mission scenarios of practical interest are considered: (a) low-thrust LEO-GEO orbit transfer, (b) orbit injection of the upper stage of a launch vehicle, and (c) lunar ascent and orbit insertion. Nonnominal flight conditions are modeled, such as (i) errors on the initial conditions, (ii) some relevant harmonics of the Earth gravitational field, and (iii) unpredictable fluctuations of the propulsive thrust. Monte Carlo simulations prove the effectiveness of the guidance and control architecture based on VTD-NOG & attitude control in the three mission scenarios of interest.

Dr. Pini Gurfil, Technion – Israel Institute of Technology (Israel), ***"Constellation Design for Time Difference of Arrival Regional Geolocation".***

Time difference of arrival-based geolocation allows for the position estimation of a terrestrial emitter by measuring its signals with 3 or more receivers. This type of geolocation, also known as a hyperbolic fix, is used by a variety of satellite and aircraft systems worldwide. Existing systems do not provide continuous coverage of a target area, instead relying on infrequent passes of satellites or keeping aircraft in flight for extended periods of time. In this study, we design constellations of satellites which can provide continuous geolocation services in a specific target region. The problem of time difference of arrival-based geolocation is described in detail, and several estimation algorithms are proposed for its solution. These estimators include the extended Kalman filter, and two versions thereof which incorporate the Earth surface constraint. The lower bounds of the

estimation errors are developed in the form of the Cramér-Rao lower bound and the position dilution of precision.

The constellations are then designed using global optimization techniques of exhaustive search and genetic algorithms with the aim of minimizing the position dilution of precision, which is a variant of the Cramér-Rao lower bound. The constellations resulting from the initial optimization are then analyzed in terms of the main constellation cost drivers - the number of orbital planes and the number of satellites. The regional coverage of the constellations is also tested, as the initial optimization does not consider the entire region of interest. The design methodology and the efficacy of the estimation algorithms are demonstrated with Monte Carlo simulations of geolocation with one of the resulting constellations. The constellation is shown to provide consistent coverage with a low estimation error, and the estimator is shown to be efficient.

An overview of the many aspects of constellation design is given, with a discussion of how these considerations pertain to the specific problem at hand. With the choice of constellation types the study proceeds to focus on the methods of selecting the constellation parameters. Despite the chosen constellations already greatly reducing the dimensionality of the design space, an exhaustive search would still have been prohibitively time intensive without further constraints. Thus, a constraint reducing the number of ground tracks in the constellation was implemented for the exhaustive search. The genetic algorithm approach is significantly more efficient, and as such no such constraint is necessary.

The result of the exhaustive searches and genetic algorithm is a large set of constellations, many of which having similar performance at first glance. To distinguish among them, the optimization is extended to a multi-objective problem with the addition of the number of satellites and the number of distinct orbital planes as secondary objective functions. This allows for the large field of candidate constellations to be reduced to a pareto set, which is more amenable to analysis. These constellations are then analyzed to evaluate how well they perform from several different perspectives - regional coverage, fuel cost, geolocation accuracy and long-term performance. The result of this process is a set of constellations which can provide continuous TDOA-based geolocation coverage of a specific region with high estimation accuracy.

Prof. Roberto Furfaro, University of Arizona (USA), ***"Deep Reinforcement Meta-Learning Techniques for Autonomous Space Guidance and Control".***

Autonomous exploration of small and large bodies of the solar system requires the development of a new class of intelligent systems capable of integrating in real-time stream of sensor data and autonomously take optimal decisions. Over the past few years, there has been an explosion of machine learning techniques involving the use of deep neural networks to solve a variety of problems ranging from object detection to image recognition and natural language processing. The recent success of deep learning is due to concurrent advancement of fundamental understanding on how to train deep architectures, the availability of large amount of data and critical advancements in computing power (use of GPUs). One can ask how such techniques can be employed to provide integrated and closed loop solutions for space autonomy as well as Guidance, Navigation and Control (GNC). In this lecture, we discuss deep reinforcement learning and meta-learning (i.e. "learn-to-learn) methodologies and their application to GNC in a variety of scenarios relevant to space exploration.

Dr. Richard Linares, Massachusetts Institute of Technology (USA), ***"Astrodynamics applications in space traffic management and deep space exploration".***

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 currently in LEO. These constellations have the potential to 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.

Mr. Sergey Prokhorov, State Space Corporation "ROSCOSMOS" (Russia), ***"SPHERE complex program of space information technologies".***

"Sphere" is a development of the ideology of multi-satellite systems, already implemented in the GLONASS system, to solve global navigation problems. The Sphere system will provide consumers with mobile communications and surveillance services anywhere on Earth, which will contribute to the further informatization of society.

IAA/AAS SciTech Forum 2019
Co-Chairs: Prof. Yury Razoumny
Prof. Filippo Graziani
Prof. Anna D. Guerman
Dr. Jean-Michel Contant

3rd IAA/AAS CONFERENCE ON SPACE FLIGHT MECHANICS

ORBITAL DYNAMICS AND DETERMINATION

Session Chairs:
Robert Melton, *The Pennsylvania State University, USA*
Antonio Prado, *Instituto Nacional de Pesquisas Espaciais, Brazil*

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Vu Tan Hoang A.V. Fedorov, Moscow Aviation Institute, Russia

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GUIDANCE, NAVIGATION AND CONTROL

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Kathleen Howell, *Purdue University, USA*

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Ning Chen, Yasheng Zhang, Wenhua Cheng, Huafei Diao, Space Engineering University, China

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Alexey Grushevskii, Yury Golubev, Victor Koryanov, Andrey Tuchin, Denis Tuchin, Keldysh Institute of Applied Mathematics, Russia

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Shuaihao Cui, Qingchen Zhang, Junwei He, Space Engineering University, China

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Mikhail Shchurov, Alexey Rudnitskiy, Tatyana Syachina, Pavel Zapevalin, Astro Space Center at P.N. Lebedev Physical Institute of the Russian Academy of Sciences, Russia

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Guohui Zhang, Xinhong Li, Gangxuan Hu, Zhibin Zhang, Space Engineering University, China

23. IAA-AAS-SciTech2020-103

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Vladislav Zubko, Alexander Sukhanov, Andrey Belyaev, Space Research Institute of the Russian Academy of Sciences, Russia

Konstantin Fedyaev, Military University of the Ministry of Defense, Russia

Vsevolod Koryanov, Bauman Moscow State Technical University, Russia

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Dmitry A. Andrikov, Yury N. Razoumny, Denis A. Andrikov, RUDN University, Russia

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Filippo Graziani, *Sapienza University of Rome, G.A.U.S.S. Srl, Italy*
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Malaya Kumar Biswal M, Ramesh Naidu Annavarapu, Pondicherry University, India

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Malaya Kumar Biswal M, Noor Basanta Das and Ramesh Naidu Annavarapu, Pondicherry University, India

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Alessandra Ferreira, Rodolpho Moraes, Othon Winter, São Paulo State University, Brazil
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Anatoli Unitsky, Arsen Babayan, Astroengineering Technologies LLC, Belarus

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Malaya Kumar Biswal M and Ramesh Naidu Annavarapu, Pondicherry University, India

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Roman Chernogorov, Oleg Perevedentsev, Institute of Biomedical Problems of the Russian Academy of Sciences, Russia
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Maximilian Boettcher, Kai Leidig, Susann Paetschke, University of Stuttgart, Germany
Sabine Klinkner, Renuganth Varatharajoo, Yew-Chung Chak, A.S. Mohd Harithuddin, University Putra Malaysia, Malaysia
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Alexander Yefremov. Alexandra Vorobyeva, RUDN University, Russia

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Natan A. Eismont, Maxim V. Pupkov, Vladislav A. Zubko, Andrey A. Belyaev, Nikita A. Simbiryov, Ravil R. Nazirov, Space Research Institute of Russian Academy of Sciences, Russia
Konstantin S. Fedyaev, Military University of the Ministry of Defense, Russia

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Alexander Sukhanov, Space Research Institute of Russian Academy of Sciences, Russia

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Yury Razoumny, RUDN University, Russia
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Mauro Pontani, Paolo Teofilatto, Sapienza University of Rome, Italy

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Shamil Biktimirov, Skolkovo Institute of Science and Technology, Russia

40. IAA-AAS-SciTech2020-048
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Wang Hao, Zhang Zhanyue, Li Zhi, Xu Yiqiao, Song Yining, Space Engineering University, China

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Conceptual design of space solar power constellation for future Lunar exploration
John Connell, Cato Meaker, Aditi Nilvarna, Parande Tayyebi, Maxime Falduto, Filippo Maria Ferrucci, Gongling Sun, International Space University, France

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Arthur Dula, *Law Office of Art Dula, USA*
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Irina Chernykh, Stanislav Kopylov, RUDN University, Russia

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Alexander Travnikov, Alexey Ispolinov, RUDN University, Russia

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Ekaterina Kiseleva, RUDN University, Russia

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Andrey Dementev, RUDN University, Russia

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Marianna Ilyashevich, Anastasia Belousova, RUDN University, Russia

49. IAA-AAS-SciTech2020-060
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Aslan Abashidze, Vladimir Savelev, RUDN University, Russia

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Alexander Solntsev, Anastasia Otrashevskaya, RUDN University, Russia

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Elina Morozova, Yaroslav Vasyanin, Intersputnik International Organization of Space Communications, Russia

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Dongping Sun, Denis Gugunskiy. RUDN University, Russia

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Organizational-economic modeling in the organization of production in the epoch of digital economy

Alexander Orlov, Bauman Moscow State Technical University, Russia

3rd IAA/AAS CONFERENCE ON SPACE STRUCTURES AND MATERIALS

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Hamed Ahmadloo, *Beijing Institute of Technology, Beihang University, China*
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Malaya Kumar Biswal M, Ramesh Naidu Annavarapu, Pondicherry University, India

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Jiping An, Xinhong Li, Junwei He, Space Engineering University, China

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Event-based denoising method for space targets imaging
Yasheng Zhang, Jun He, Pengju Li, Space Engineering University, China

57. IAA-AAS-SciTech2020-061
Event-based sensing for space target recognition
Yasheng Zhang, Pengju Li, Jun He, Space Engineering University, China

58. IAA-AAS-SciTech2020-063
Device for tightness control of spacecraft design elements
Konstantin Voronov, Aleksey Telegin, Samara National Research University, Russia

59. IAA-AAS-SciTech2020-072
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Konstantin Voronov, Ivan Tkachenko, Dmitriy Ryazanov, Artem Ionov, Maksim Ivanushkin, Samara National Research University, Russia

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Jae Jun Kim, Leonardo Herrera, Brij Agrawal, Naval Postgraduate School, USA

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Maria Cindra Fonseca, *Universidade Federal Fluminense, Brazil*
Kharun Makhmud, *RUDN University, Russia*

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Roman Kezerashvili, The City University of New York, USA
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Vera Galishnikova, Moscow State University of Civil Engineering, Russia
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Viktor Galkin, Andrey Paltievich, Evgeniy Galkin, Moscow Aviation Institute, Russia

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Method of neutralization of components liquid rocket fuel by peat-shungite sorbent-catalyst
Irina Minenkova, Aleksey Buryak, Aleksey Uleanov, Aleksey Sobolev, Svetlana Popova, Institute of Physical Chemistry and Electrochemistry, Russia

65. IAA-AAS-SciTech2020-074
Nondestructive diagnostic of diamond-like carbon coatings used for space applications
Carlos Suasnavas, Mstislav Makeev, RUDN University, Russia

66. IAA-AAS-SciTech2020-075
Boron Nitride Nanotubes for Space Radiation Shielding
Suruchi Kumar, Neeru Bhagat, Rupali Nagar, Symbiosis Institute of Technology, India

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Balanced microwave mixer parameters prediction under the influence of ionizing radiation
Kirill Cherkasov, Sergey Meshkov, Boris Khlopov, Bauman Moscow State Technical University, Russia
Mstislav Makeev, RUDN University, Russia

68. IAA-AAS-SciTech2020-088
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Meena Laad, Rahee Walambe, Ketan Kotecha, Varad Nerlekar, Nishita Agrawal, Bhargav Yagnik, Symbiosis Institute of Technology, India

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Synthesis of low-temperature powder materials for space industry
Pavel Shibaev, Ramilya Shaikhetdinova, Kazan National Research Technical University, Russia
Sergey Novokschenov, Voronezh State Technical University, Russia
Anton Sinitsin, Vologda State University, Russia

70. IAA-AAS-SciTech2020-095

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Engel Galimov, Nazirya Galimova, Pavel Shibaev, Kazan National Research Technical University, Russia

Vladimir Fedyaev, Kazan Scientific Center of the Russian Academy of Sciences, Russia

Ilgiz Galiev, Kazan State Agrarian University, Russia

Vladimir Samoylov, Egor Danilov, NIIgrafit, Russia

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Svetlana Shambina, *RUDN University, Russia*

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Anatoli Unitsky, Arsen Babayan, Astroengineering Technologies LLC, Belarus

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Rabah Mohammed Amin, Berrezzoug Salima, Belgacem Wahiba, Algerian Space Agency, Algeria
Slimane Zohra, University of Ain Temouchent, Algeria

73. IAA-AAS-SciTech2020-027
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Wahiba Belgacem, Rabah Mohammed Amin, Algerian Space Agency, Algeria
Belgacem Nassima, University of Tlemcen, Algeria

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Igor Garanzha, Saad Musaed Gubran, RUDN University, Russia

75. IAA-AAS-SciTech2020-049
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Sergey Safronov, Ivan Tkachenko, Maksim Ivanushkin, Samara National Research University, Russia

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Ivan Kaurov, Samara National Research University, Russia

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Lu Yang, Junwei He, Jiping An, Baowei Tang, Space Engineering University, China

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Olga Saltykova, Yury Razoumny, RUDN University, Russia

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Session Chairs:
Li Ying, *Land space technology corporation LTD, China*
Dmitry Koroteev, *RUDN University, Russia*

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Study of wireless methods of transmission of electricity to remote objects
Dmitriy Strebkov, Nikolay Bobovnikov, Federal Scientific Agroengineering Center, Russia

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Alexey Bykov, Sergei Androsov, Space Rocket Centre "Progress", Russia
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80. IAA-AAS-SciTech2020-091
About saving momentum
Yury Razoumny, Sergei Kupreev, RUDN University, Russia

81. IAA-AAS-SciTech2020-094
Testing on-board electronic equipment for temperature effects
Alexey Bykov, Space Rocket Centre "Progress", Russia
Alina Denisyuk, Samara National Research University, Russia

3rd IAA/AAS CONFERENCE ON SPACE FLIGHT MECHANICS

ORBITAL DYNAMICS AND DETERMINATION

Session Chairs:
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IAA-AAS-SciTech2020-007
AAS 20-301

ALGORITHM TO CONTROL SERVICING MODULE IN COLLOCATION WITH TARGET IN GEO

Hoang Vu Tan*

The problem of a service module orbit control when servicing Geostationary satellite is considered. The service module must be in collocation with the target during the inspection process. The service module is active, and the target is passive one. Based on the model spacecraft relative motion and results of analysis of their uncontrolled motion, an algorithm to control low-thrust engines is developed to keep the servicing module in collocation with the target in GEO for a given time interval. [View Full Paper]

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IAA-AAS-SciTech2020-013
AAS 20-302

POSSIBLE AREAS OF ACCUMULATION OF THE SPACE MASSES IN THE SOLAR SYSTEM

Lubov Avdanina,[*] Alexander Samokhin,[†] and Tatiana Salnikova[‡]

In this paper we study the possibility of capture the cosmic bodies (dust particles, comets or asteroids) by the Solar system planets. The problem of determining the zones of accumulation of material bodies is very important for the safety of space flights. Let's consider a three-body problem (Sun, Jupiter, Particle) in the following setting. Jupiter moves in its circular orbit around the Sun. The material point is in space far away from the center of mass of the Sun and moves in the plane of Jupiter's circular orbit with parabolic velocity relative to the Sun. Without taking into account the gravitational perturbation of Jupiter, this point would move along the keplerian parabolic orbit forward to the Sun. It means that this mass point will leave the limits of the Solar system forever within a finite time. Let among an ensemble of such particles there are particles falling into the sphere of influence of Jupiter. Then, after passing the material point near Jupiter and leaving its sphere of action, the velocity of the material point relative to the Sun in the current position may become comparable to the circular velocity relative to the Sun. So, these points, moving along a circular or elliptical orbit, won't be able to leave Solar system. Trajectories of the points are calculated by numerical integration of differential equations of perturbed Keplerian motion for different initial positions of the material points and different directions of their velocities. After passing of material point near Jupiter and leaving its sphere of action, the velocity of the material point relative to the Sun is compared with the circular velocity at each step of integration to determine the trajectories on which the gravitational impact of Jupiter leads to further movement of an asteroid or comet along a circular trajectory relative to the Sun. As a result of numerical simulations, the areas of possible accumulations of space masses are found. The problem in the considered setting can be applied to various systems of this type, for example, Earth, Moon, Particle. The results of numerical simulations should be taken into account when planning space missions. [View Full Paper]

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IAA-AAS-SciTech2020-037
AAS 20-303

A NOVEL GEO ON-ORBIT SERVICE SYSTEM ARCHITECTURE

Yasheng Zhang,[*] Ning Chen,[†] Zhi Li,[‡] and Wenhua Cheng[§]

In this paper, a novel GEO on-orbit service system architecture named NUWA Project is proposed for GEO debris removal. This project combines debris removal, on-orbit 3D printing and on-orbit assembly, which can not only effectively alleviate the current crowded situation of GEO orbit resource tensions, but also reuse of debris and reduce the cost of development and launch of new spacecraft. In addition, it can also replace the damaged components to improve the working life of GEO satellites. [View Full Paper]

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IAA-AAS-SciTech2020-084
AAS 20-304

COMPREHENSIVE RESEARCH OF PRACTICALLY RELEVANT LUNAR ORBITS AND SUBSTANTIATION OF THE ACCURACY OF THEIR DETERMINATION

Pavel G. Kozlov,[*] and Evgeny V. Titov[†]

The paper reviews a general classification of lunar orbits with reference to their practical and scientific relevance. This framework is used to assess the completed lunar missions and to analyze the available orbit determination accuracy. Near-circular lunar orbits and halo-orbits around the collinear libration points are specified as focal for the research. The scope of practical problems involving these groups of orbits includes determination of the corresponding initial conditions, high-precision orbit propagation, and design of laser orbit determination systems with corresponding performance analysis. Provisional design values of the orbit determination accuracy are presented for some of these trajectories. [View Full Paper]

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IAA-AAS-SciTech2020-106
AAS 20-305

USING GRAVITY ASSIST FOR LANDING ON THE VENUS

Ravil R. Nazirov,[*] Natan A. Eismont,[†] Vladislav A. Zubko,[‡] Andrey A. Belyaev,[§] Ludmila V. Zasova,[**] Dmitry A. Gorinov,[††] and Alexander V. Simonov[‡‡]

Current research is devoted to the problems connected with Venera-D which includes extending accessible landing areas on the surface of Venus. Classical approaches to extending reachable areas are considered. A new method is also proposed. The proposed method shows a radical increase in the possible accessible landing areas on the Venus surface compared to traditional methods. The method is based on the use of gravity assist maneuver near Venus for the transition to a resonant orbit with a period of 1:1 to the orbital period of Venus. Calculations made in this research confirm that methods allow cover all the Venus surface with an increase of ΔV no more than 200 m/s. [View Full Paper]

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GUIDANCE, NAVIGATION AND CONTROL

Session Chairs:
Daniel Scheeres, *University of Colorado, USA*
Kathleen Howell, *Purdue University, USA*

IAA-AAS-SciTech2020-014
AAS 20-306

ON ANOMALY DETECTION METHODS AND APPLICATIONS IN SPACE SYSTEMS

Tagir Sadretdinov,[*] Petr Mukhachev,[†] and Anton Ivanov[‡]

In this paper we review main techniques used in academic literature for detecting spacecraft anomalies and we discuss main strengths and weaknesses of these techniques. Special attention is drawn to recent trends in statistical approaches and deep learning. We will focus on applications to spacecraft telemetry anomaly detection, analyze main subsystems addressed by different authors. We find that some of the approaches have not yet been used in spacecraft telemetry analysis. We show that electrical power system and attitude determination and control system are the most widely represented in publications. In the end we will provide a brief comparison of used methods and a view of future developments in the field. [View Full Paper]

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IAA-AAS-SciTech2020-038
AAS 20-307

THE WAY TO REDUCE THE IMPACT OF LOCAL OBJECTS AND IMITATION-TYPE INTERFERENCES UPON THE ACCURACY AND THE AVAILABILITY OF NAVIGATION SUPPORT FOR CATEGORIZED AIRCRAFT LANDING USING SATELLITE RADIO NAVIGATION SYSTEMS

Georgy V. Krinitsky,[*] Maria D. Leonova[*] and Vladimir N. Konoplev[†]

Aircraft landing systems based on global navigation satellite system (GNSS) are widely used. It is necessary to ensure navigation equipment stable operation under conditions of radio interference and multipath propagation of signals in order to ensure safety during approach. GNSS information processing algorithm is considered, providing useful signals spatial selection out of imitation-type interferences, as well as from signals reflected from aircraft structural elements or structures at the airport. The efficiency of this algorithm is evaluated. [View Full Paper]

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IAA-AAS-SciTech2020-051
AAS 20-308

MODEL-BASED FDI ARCHITECTURE APPLIED TO AN ACTIVE VIBRATION CONTROL SYSTEM ON A FLEXIBLE SPACECRAFT

Paolo Iannelli,[*] Federica Angeletti,[†] and Paolo Gasbarri[‡]

Very large space structures - due to their scientific relevance, cost and extremely limited possibilities of maintenance and repair - are good candidate to gain significant advantage from Fault Detection and Isolation (FDI) techniques. In this paper, a model-based strategy is implemented onboard a satellite equipped with a very large mesh reflector provided with a distributed network of smart actuators/sensors used to actively counteract undesired elastic vibrations generated by the coupling with the rigid body dynamics and onboard noisy equipment. In particular, the design of a model-based FDI architecture, made up of a bank of Unknown Input Observers (UIOs), able to detect and isolate, with adequate responsiveness, a piezo-actuator failure occurring in the Active Vibration Control (AVC) system during classical attitude manoeuvres, is addressed. The design of the proposed UIOs, derived by the Linear Matrix Inequality (LMI) problem, which provides the necessary and sufficient condition for their existence, is based on the linearized 3D state-space model of the controlled spacecraft, under the assumption that all the uncertainties, exogenous disturbances and measurement noises are neglected. Furthermore, the D-stability concept is integrated in the standard formulation of the UIO to adjust the dynamics of the observers both to make them react quickly enough to any type of failure and to limit the highest frequency poles of the observers. Finally, the effectiveness of the proposed FDI architecture and its robustness against modelling uncertainties and measurement noise is assessed and discussed based on an extensive Monte Carlo simulation campaign. [View Full Paper]

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IAA-AAS-SciTech2020-062
AAS 20-309

CHARACTERISTIC ANALYSIS OF CYCLE SLIP DETECTION METHOD FOR PRECISE POINT POSITIONING

Jun Wang,[*] Chaoyi Han,[†] Wei Wang,[‡] Yanfeng Hu,[§] Wei Fu[**] and Zengkai Shi[††]

In precise point positioning, cycle slip can result in incorrect positioning results. By studying cycle slip detection methods such as Doppler observation method, ionospheric residual method and combined MW method, three experimental schemes of precise point positioning (PPP) cycle slip detection methods were designed, and verified by experiments with specific observation data. The characteristics of PPP cycle slip detection methods were compared and analyzed, and the applicable scope of such methods were expounded, providing a theoretical basis for cycle slip detection and correction of PPP.

[View Full Paper]

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IAA-AAS-SciTech2020-064
AAS 20-310

APPLICATION OF CONVEX OPTIMIZATION METHODS TO THE SPACECRAFT REORIENTATION PROCESS

Fei Sun* and Xinhong Li†

During spacecraft reorientation, the rotational motion guiding the spacecraft is constrained by its permissible direction, which usually leads to non-convex optimal control problems. In this paper, on the basis of the existing kinematic and dynamical constraints, other constraints are introduced to transform the problem into constraints on the feasible direction of the spacecraft. At the same time, a very important feature of the convex optimization method is its ability to handle various combinations of the above types of constraints, and in combination with Schur's priming and accurate updates of the attitude quaternion, the set related to the constrained spacecraft orientation is convexly parameterized to give a convex optimization expression for the spacecraft containing the constraints, and the necessary control moments on the spacecraft are determined. Finally, the experimental simulation of the reorientation process is carried out using the dual spacecraft system as an example, and the simulation results such as the geodetic error and the control moment are given, which are in line with the theoretical expectations and prove the feasibility of the convex optimization method for the spacecraft reorientation problem under the constraints. [View Full Paper]

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IAA-AAS-SciTech2020-067
AAS 20-311

MODEL-FREE OPTIMAL ATTITUDE CONTROL OF SPACECRAFT WITH EXTERNAL DISTURBANCES AND INPUT SATURATION BASED ON DEEP REINFORCEMENT LEARNING

ZhiBin Zhang,[*] XinHong Li,[†] DingZhan Yu,[‡] JiPing An,[§] WanXin Man,[**] and GuoHui Zhang[††]

This paper is devoted to optimal attitude control for rigid spacecraft in the presence of parametric uncertainties, control torque saturation and external disturbances. Specifically, an optimal controller based on deep reinforcement learning (DRL) is proposed. The DRL controller is a model-free controller, which can continuously learn according to the feedback of the environment and achieve high-precision attitude control of the spacecraft, furthermore, there is no need to adjust the controller parameters repeatedly. Considering the continuity of the state space and action space for spacecraft, the Deep Deterministic Policy Gradient (DDPG) algorithm based on the actor-critic architecture is adopted. Firstly, the general steps of designing DRL controller are presented. Then, the controller based on DDPG algorithm is created and trained in the simulation environment. Finally, the effectiveness and robustness of the controller are verified by four groups of simulation examples. Experimental results show that after 462 episodes of training, the agent has learned the ideal control policy. The controller has strong robustness against uncertain inertial parameters and external disturbances, and can achieve attitude stabilization control of spacecraft under the continuous external disturbances. [View Full Paper]

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IAA-AAS-SciTech2020-076
AAS 20-312

PHYSICS-INFORMED NEURAL NETWORKS FOR OPTIMAL INTERCEPT PROBLEM

Enrico Schiassi,[*] Andrea D'Ambrosio,[†] Roberto Furfaro,[‡] and Fabio Curti[§]

The novel Extreme Theory of Functional Connections (X-TFC) method is employed to solve the optimal intercept problem. With X-TFC, for the first time, Theory of Functional Connections (TFC) and shallow Neural Networks (NNs) trained via the Extreme Learning Machine (ELM) algorithm are brought together as a class of PINN methods and applied to solving a broad class of ODEs and PDEs. In particular, the unknown solutions (in strong sense) of the ODEs and PDEs are approximated via particular expressions, called constrained expression (CEs), defined within TFC. A CE is a functional that always analytically satisfies the specified constraints and has a free-function that does not affect the specified constraints. In the X-TFC method, the free-function is a single-layer NN, trained via ELM algorithm. According to the ELM algorithm, the unknown constant coefficients appear linearly and thus, a least-squares method (for linear problems) or an iterative least-square method (for nonlinear problems) is used to compute the unknowns by minimizing the residual of the differential equations. In this work, the differential equations are represented by the system arising from the indirect method formulation of optimal control problems, which exploits the Hamiltonian function and the Pontryagin Maximum/Minimum Principle (PMP) to obtain a Two-Point Boundary Value Problem. The proposed method is tested by solving the Feldbaum problem and the minimum time-energy optimal intercept problem. It is shown that the major advantage of this method is the comparable accuracy with respect to the state of the art methods for the solution of optimal control problems along with an extremely fast computational time. In particular, the low computational time makes the proposed method suitable for real-time applications. [View Full Paper]

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IAA-AAS-SciTech2020-108
AAS 20-313

LASER NAVIGATION AND SELENODETIC SUPPORT FOR LUNAR MISSIONS

Aleksey A. Chubykin,[*] Vladimir A. Katenin,[†] and Sergey A. Martynov[‡]

The article presents new technologies and methods of using laser instruments for navigation and selenodetic support for lunar missions at all stages of the Moon exploration proposed by the Russian Academy of Sciences. The key technologies and methods of those are the following: technology for active navigation of lunar mission objects; method for pseudoranging coordinate determination (with a decimeter accuracy) and divergence of the time scales (with a nanosecond accuracy) for GLONASS and lunar mission objects; method for active laser ranging navigation on lofted trajectories using the orbital constellation of passive artificial Moon satellites (AMS); technology for highly accurate coordinate and time support for the AMS using the Moon's surface landmarks and based on ranging and elevation measurements; technology for laser navigation for lunar-based users equipped with laser retroreflectors and beacons using the spacecraft (reference points) on near-lunar orbits; technology for multi-satellite Moon's shape monitoring.

[View Full Paper]

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MISSION DESIGN AND OPTIMIZATION

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IAA-AAS-SciTech2020-024
AAS 20-314

DESIGNING THE RETURN TRAJECTORY OF A SPACECRAFT FROM A CIRCUMLUNAR ORBIT WITH A LANDING IN A GIVEN REGION OF THE EARTH

Mikhail S. Konstantinov*

A method for designing the return trajectory from a circumlunar orbit to the Earth has been developed. A single-impulse launch from a given elliptical circumlunar orbit is considered. Ballistic descent in the Earth's atmosphere with a landing in a given region is assumed. The criterion for optimizing the analyzed trajectory is the value of the required velocity impulse when starting from a circumlunar orbit. The amount of axial overload during atmospheric descent is considered as a limitation. An important feature of the method is the absence of any iterative procedures when determining the initial approximation of the trajectory characteristics. [View Full Paper]

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IAA-AAS-SciTech2020-031
AAS 20-315

OPTIMAL PATH PLANNING FOR TRIANGULAR SPACECRAFT FORMATIONS IN CIRCULAR AND ECCENTRIC ORBITS

Karthick Dharmarajan[*] and Giovanni B. Palmerini[†]

The ability of a spacecraft formation to maintain a stable relative geometry is often critical to the success of the mission. Typical optimal path planning and control algorithms, aimed to minimize the effort and indeed the consumption, have been revisited for the case of a triangular formation. The constraints coming from collision risk avoidance during the maneuver and from a maximum allowed inter-satellite distance to preserve the formation links are considered together with the typical requirement of configuration stability. The control strategy is applied to different dynamic models, namely circular – also including J2 effect – orbits and eccentric ones. Several simulations have been carried on investigating the behavior of the optimal continuous control action, computed by applying the well-known Linear Quadratic Regulator. [View Full Paper]

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IAA-AAS-SciTech2020-035
AAS 20-316

REMOTE SENSING APPLICATION IN MONITORING AND ASSESSMENT OF ECO-SYSTEM FOR POLLINATORS

Schubert Maignan,[*] Robert Hausler,[†] Irina Tkachenko,[‡] Abdelraouf M. Ali,[§] and Evgenia Kozhanova[**]

Rapid industrialization and economic growth have led to significant environmental implications, recognizing the importance and significance of developing strategies to ensure environmentally sustainable urban and rural development, identifying new alternatives for environmental quality monitoring and management, both in society and in industry. Honeybees, whose most important function is to pollinate many plants, are one element of the ecosystem that affects a number of natural cycles in a complex manner. The identification of their roles in sustainable global production and the types of natural and anthropogenic factors that influence their populations is especially essential in recognizing the importance of anthophilous as bioindicators. Therefore, the first part of this paper discusses the main pollination and pollinator biology issues that affect their position as bioindicators. Second part focuses on remote sensing, which is widely used to supply pollination proxies. This paper is a review study based on a combined approach that includes an assessment of the effects of the environment such as "Ozone" effects in the pollinators, atmospheric ozone monitoring using satellite remote sensing technology, assessment of the stability and dynamics of landscapes, using satellite technologies, and the integration of these parameters and its effects on the pollinators. [View Full Paper]

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IAA-AAS-SciTech2020-040
AAS 20-317

RESEARCH ON THE METHOD OF ON-ORBIT SERVICE MISSION PLANNING FOR HIGH ORBIT SPACECRAFT

Rui Song,[*] Xumin Song,[†] and Weilin Wang[‡]

This paper studies the relative motion modeling and mission planning methods of high-orbit spacecraft for on-orbit services. Based on the C-W equation, the single-pulse spiral cruise trajectory, single-pulse circumnavigation trajectory, and single-pulse circumnavigation trajectory are constructed. Considering that the single-pulse flight period is too long, the design methods of the multi-pulse ramp approach and multi-pulse circumnavigation are further studied. Secondly, considering the constraints of lighting conditions, obstacle constraints, specific path constraints, only angle measurement, and target continuous maneuvering, the approach to target maneuver planning is studied. Finally, the validity of the planning model and algorithm is verified by numerical simulation.

[View Full Paper]

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IAA-AAS-SciTech2020-044
AAS 20-318

A SUN-FOLLOWING OPTICAL OBSERVATION ORBIT FOR GEO TARGET

Ning Chen,[*] Yasheng Zhang,[†] Wenhua Cheng,[‡] and Huafei Diao[§]

Space-based optical observation is an important approach to obtain GEO target information and affected by observation distance and sun illumination angle. In this paper, a sun-following optical observation orbit and its design method are proposed. Based on Johnson Criteria and STK/EOIR simulation, the distance and angle constraints are obtained. Then, by keeping the semi-major axis, inclination and RAAN same as the target's and properly modifying the eccentricity, perigee argument and mean of anomaly, an optical observation orbit is designed. In this orbit, spacecraft can periodically follow sun illumination and achieve continuous long-term and effective optical observation of GEO target. [View Full Paper]

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IAA-AAS-SciTech2020-052
AAS 20-319

ADVANCED METHODS OF LOW COST MISSION DESIGN IN THE PLANETARY SYSTEMS

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

The implementation of the deep space expeditions using gravity assists maneuvers to the outer Solar system is the one of main priorities of modern astrodynamics. The realization of the cosmic projects using spacecraft–orbiters around the Jovian Galilean moons and especially the descent modules implementation on their surface is one of the basic focuses of the current international cosmic space researches collaboration (perspective projects ESA "JUICE", Russian "Laplace-P"). It is shown that the diversity of the multibody gravity of the Jovian system, not only complicates the accurate ballistic mission analysis, but allows constructing effective mission scenarios using gravity assist.

[View Full Paper]

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IAA-AAS-SciTech2020-053
AAS 20-320

APPLICATION OF ARTIFICIAL INTELLIGENCE IN SPACE INFORMATION SUPPORT MISSION PLANNING

Shuaihao Cui,[*] Qingchen Zhang,[*] Junwei He,[*] and Kehai Xiang[†]

With the rapid development of Artificial Intelligence (AI) technology and the Space Technology, Space Information Support has been deeply integrated with AI technology. The Mission Planning of Space Information Support is characterized by varied missions, fine processes, complex constraints and difficult coordination. By analyzing the characteristics of Space Information Support and the difficulties in mission planning, this paper explores the application mode of Artificial Intelligence in Space Information Support Missions, and puts forward several intelligent planning system frameworks based on Space Information Support Missions. [View Full Paper]

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IAA-AAS-SciTech2020-081
AAS 20-321

MILLIMETRON MISSION ORBITAL DESIGN AND NAVIGATION SUPPORT

Alexey G. Rudnitskiy,[*] Mikhail. A. Shchurov,[†] Tatiana A. Syachina,[†] and Pavel R. Zapevalin[†]

This is an overview of the work carried out for Millimetron space observatory mission orbital and navigation support. At the current stage of the mission development, it is required to estimate the orbital configuration with high accuracy taking into account the requirements of the mission scientific program. Several orbital configurations were considered and the capabilities and limitations of each of them were assessed. In addition, we provide description of the algorithms that were implemented to date as part of the Center for ballistic and navigation support of Millimetron mission. [View Full Paper]

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IAA-AAS-SciTech2020-082
AAS 20-322

MULTI-SATELLITE AUTONOMOUS OPERATION SYSTEM MODELING BASED ON ABMS

Guohui Zhang,[*] Xinhong Li,[†] Gangxuan Hu,[‡] and Zhibin Zhang[§]

The autonomous operation of the satellite means that the satellite can realize self-management and complete various tasks without human intervention by using modern control technology such as artificial intelligence. Agent based modeling and simulation is an effective way to solve the problem of satellite autonomous operation modeling. In this paper, multi satellites are selected as the research object, and the overall architecture of the simulation system is designed. This paper analyzes the behavior and characteristics of agents such as ground, satellite, target and environment, and establishes a simple satellite autonomous operation system through computer simulation method, which effectively simulates the interaction between the satellite and itself, the target and the environment, and finally completes the given task process. The simulation model has guiding significance for further research on autonomous operation of satellites. [View Full Paper]

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IAA-AAS-SciTech2020-103
AAS 20-323

USING GRAVITY ASSISTS FOR FLIGHT DESIGN TO TRANS-NEPTUNIAN OBJECT (90377) SEDNA

Vladislav A. Zubko,[*] Alexander A. Sukhanov,[†] Konstantin S. Fedyaev,[‡] Vsevolod V. Koryanov,[§] and Andrey A. Belyaev[**]

A presented research is devoted to the problem of using gravity assist maneuvers for flight design to trans-Neptunian object (90377) Sedna which is one of the most distant objects in the Solar system with an orbital period more than 10 thousand years. A number of possible flight trajectories to Sedna were com- posed by using a patched conics section method including Venus, Earth and Jupiter flyby to minimize required total ΔV. The flight scheme with launch date in 2029 year with 30 years' time of flight and gravity assist maneuvers near Venus and Earth provided the minimum of total ΔV was found. Also, a possibility of attaining several asteroids during the flight to Sedna was investigated.

[View Full Paper]

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IAA-AAS-SciTech2020-112
AAS 20-324

CONTROL APPROACH TO SPACE WHEELED ROVER STABILITY EVALUATION

Dmitry A. Andrikov,[*] Yury N. Razoumny,[†] and Denis A. Andrikov[‡]

Autonomous movement with steering for space wheeled rover is one of the most difficult automation challenges: it depends on constraints on mobility, speed of motion, lack of environmental structure, density of hazards, and typical lack of prior information, and is somewhat related to minimizing wheel slip. The task of space rover movement control on the planetary surface requires the creation of control approach for example intelligent control systems that the work deals with a highly solve system-wide problems of detecting / recognizing status and situations, predicting the behavior of a vehicle in conditions of incomplete, contradictory information. The space rover control approach, we show the simulation confirms that proposes an approach to the decomposition of the "Rover-Environment-Operator" system, where the vehicle is considered as part of a metasystem that includes the covering of a planetary terrain as an element of the external environment. Some insight about the control process is also discussed in the paper such as diagrams wheel velocity as a target for stability. [View Full Paper]

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SPACE MISSIONS AND APPLICATIONS

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IAA-AAS-SciTech2020-018
AAS 20-325

INTERPLANETARY CHALLENGES ENCOUNTERED BY THE CREW DURING THEIR INTERPLANETARY TRANSIT FROM EARTH TO MARS

Malaya Kumar Biswal M[*] and Ramesh Naidu Annavarapu[†]

Mars is the next destination after Earth to support terrestrial life. Decades of Mars exploration has fascinated space explorers to endeavour for a human expedition. But human Mars enterprise is complicated than conventional mission as the journey is endowed with a profusion of distinct challenges from terrestrial planet to the planetary surface. To perceive and overcome the implications of interplanetary challenges, we conducted a study to manifest every challenge encountered during interplanetary transit from Earth to Mars. Our study concluded entire challenges were attributed to the options for trajectory correction and maneuvering, management of space vehicles, the hazards of exposure to galactic radiation, effects of crew health in a microgravity environment, deficit solar power production, hazards of nuclear elements, psychologic and health effects, interrupted communication interlink from the ground, the complication in fuel pressurization and management, recycling of space wastes, execution of the extra-vehicular activity, and Mars orbital insertion. The main objective of this paper is to underline all possible challenges and its countermeasures for a sustainable crewed mission beyond low earth orbit in forthcoming decades. [View Full Paper]

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IAA-AAS-SciTech2020-019
AAS 20-326

ORBITAL AND PLANETARY CHALLENGES FOR HUMAN MARS EXPLORATION

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The space challenges do exist at every stride on a human expedition to Mars that arise due to galactic natural phenomena and artificial technologies. This paper emphasizes on Mars orbital and planetary challenges encountered from orbit to the surface exploration. The Mars orbital challenges embrace hazards of cosmic radiation and asteroid impact in orbit, disrupted communication relay from the ground, the intelligence of planetary weather clearance, and execution of successful entry, descent, and landing. Comparably planetary challenge encompasses identifying scientific landing site, an intrusion of erratic environment and weather, complexity in in-situ resource extraction and exploitation, navigation and surface mobilization, and retarded communication from relay orbiters. The prime intent of this study is to present every prospective challenge and its recommendations impending human settlement on Mars. [View Full Paper]

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IAA-AAS-SciTech2020-021
AAS 20-327

STUDYING THE APPLICATION POINT IN THE POWERED SWING-BY IN THE SUN-MERCURY SYSTEM

Alessandra Ferreira,[*] Rodolpho Moraes,[†] Antonio Prado,[‡] and Othon Winter[§]

The goal of the present paper is to study the variations of energy given to a spacecraft by a maneuver where the spacecraft passes close to Mercury and uses its gravity, combined with an impulse applied inside the sphere of Influence of Mercury, but not necessarily at the periapsis, to make the modification of the energy. Different values for the magnitude and direction of the impulse applied is used. A maneuver like this one can be used to help to insert the spacecraft into a captured orbit around the Sun or Mercury, or to give extra energy to the spacecraft to go to other places. Trajectories of the space vehicle relative to the Sun are also classified according to its characteristics. [View Full Paper]

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IAA-AAS-SciTech2020-022
AAS 20-328

ECOSPACE PROGRAM AS A MEANS OF SAVING THE EARTH'S BIOSPHERE AND HUMAN CIVILIZATION

Anatoli Unitsky[*] and Arsen Babayan[†]

Earth's ecology has suffered significant damage. Some of its mineral resources are near depletion. Many years of attempts to restrain further growth and development, as well as the widespread introduction of resource-saving technologies, have not yielded noticeable results. Outer space is the only source of unlimited energy, mineral resources, expanse, and unique technological environment. EcoSpace program reveals the content of the rescue space vector of industrialization. It defines technological solutions for the geospace transportation system, including the equatorial linear city and space industrial necklace. It also relates to technological solutions for eco-oriented technologies, which are necessary for people on Earth. [View Full Paper]

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IAA-AAS-SciTech2020-032
AAS 20-329

ASSESSMENT OF EFFICIENCY, IMPACT FACTOR, IMPACT OF PROBE MASS, PROBE LIFE EXPECTANCY, AND RELIABILITY OF MARS MISSIONS

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This paper describes the trend and various mathematical analysis method to determine significant spacecraft parameters performed over gathered and estimated data of Mars Probes. We have acquired a sum of 64 data from 64 spacecrafts and sorted out to 47 data for precision results. These data were extended to employ various regression analysis technique to obtain a relation between spacecraft mass and mean lifetime. The analysis showed that the curve fitting function of the mean lifetime of spacecraft is better than the constant function at 0.05 level that directly reflects that the mass of the spacecraft affects reliability. Additionally, we have interpreted other parameters of the spacecrafts that encompasses the proportionality of mission attempts, efficiency and reliability of spacecraft, impact and impact of probe mass on its mean lifetime, the time lag between consecutive mission attempts, and approximately interpreted mean lifetime of upcoming missions from the extrapolated data. Further, the significance of these parameters was discussed for a prospective and sustained mission. [View Full Paper]

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IAA-AAS-SciTech2020-069
AAS 20-330

USING TELEMEDICINE TECHNOLOGIES TO REDUCE HEALTH RISKS IN LONG-TERM LUNAR EXPEDITIONS

Roman V. Chernogorov,[*] Oleg V. Perevedentsev,[†] and Vladimir M. Levanov[‡]

During long-term lunar expeditions, the conditions of work of the crews will differ from the conditions of EVA in low-earth orbit. For medical support of EVA on the lunar surface, it is necessary to use an intelligent telemedicine system, which makes it possible to increase the autonomy of making and implementing decisions to prevent the development of various medical situations. Such system, in addition to registration and telecommunication units, includes decision making modules, based on machine learning methods. The tasks of these modules include identifying situations and trends that signal an increase in the risks to the cosmonaut's health. [View Full Paper]

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IAA-AAS-SciTech2020-078
AAS 20-331

DESIGN OF A LOW-COST S/X DUAL BAND SATELLITE GROUND STATION FOR SMALL SATELLITE MISSIONS

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This paper describes the design of a novel low-cost prime focus (4.5 m) satellite ground station by the University of Stuttgart's Institute of Space Systems (IRS) in cooperation with Universiti Putra Malaysia (UPM) and Malaysian Space Agency (MYSA). The antenna station design supports left- and righthand circular polarization transmission in 2025-2110 MHz, reception in 2200-2290 MHz (license S-band), and 2380-2450 MHz (Amateur Radio S-band). A separate channel offers reception in 7900 - 8400 MHz (X-band) with a fixed circular polarization. Instead of costly industrial-standard CCSDS transceivers, full-duplex software-defined radios (SDR) are used. The ground station is equipped for interoperability with existing infrastructure and a successful remote operation. [View Full Paper]

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INSTRUMENTATION FOR MODELLING RADIATION CONDITIONS IN THE NEAR-EARTH SPACE

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The near-Earth space is filled with charged particles of different origins. Different particle species affect the planet and objects above the surface in different ways and raise interest within different scientific branches. Many experimental data have been acquired and many instruments and models to describe and use them in different applications have been developed by the scientific community by now. We present a concept of the instrumentation which would comprise all the major tools, models, and experimental data to ensure a comprehensive description and modelling of the radiation environment in the near-Earth space. [View Full Paper]

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AAS 20-333

A MANMADE EXPERIMENT AIMED TO CLARIFY THE GRAVITY LAW IN THE SOLAR SYSTEM

Alexander P. Yefremov[*] and Alexandra A. Vorobyeva[†]

Ultra-sensitivity of a planet's gravity assist to changes of the test-body impact parameter prompts a space experiment testing the nature of the gravitational field in the Solar system. The Sun, Earth and Venus serve as the space lab with a primitive space probe (space ball) as a test body moving on a ballistic trajectory from the Earth to Venus (rendering GA) and backwards to the Earth's orbit. We explain why in Newton and Einstein gravity, the probe's final positions (reached at the same time) may differ greatly; an Earth's observer can measure the gap. [View Full Paper]

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AAS 20-334

POSSIBILITIES FOR USING A SPACECRAFT IN AN ORBIT AROUND THE COLLINEAR SUN-EARTH LIBRATION POINT TO STUDY NEAR-EARTH ASTEROIDS

Natan A. Eismont,[*] Maxim V. Pupkov,[†] Konstantin S. Fedyaev,[‡] Vladislav A. Zubko,[§] Andrey A. Belyaev,[**] Nikita A. Simbiryov,[††] and Ravil R. Nazirov[‡‡]

The possibility of extending the mission of a spacecraft in an orbit around the collinear Sun-Earth libration point and using of the spacecraft to study Near-Earth asteroids after the completion of the main mission is discussed. It is proposed to direct the spacecraft to the trajectory of a close approach to an asteroid in order to estimate its mass by its gravitational influence on the spacecraft trajectory. As an example, we consider the SRG Space Observatory launched in 2019 which can be used in 2029 after completing its mission objectives for studies of the Apophis asteroid as well as some other Near-Earth asteroids. [View Full Paper]

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AAS 20-335

ON A MULTIPLE ASTEROID FLYBY MISSION

Alexander Sukhanov*

Results of the preliminary mission analysis for a low-cost mission with the goal of exploration of several asteroids by one spacecraft from a flyby trajectory are presented. This analysis was made for the start of the mission in 2029. To reach the main asteroid belt, it is proposed to use the Earth-Venus-Earth flight. The suggested scheme of the subsequent flight includes multiple gravity assist maneuvers (swingbys) near the Earth; such a scheme provides a large choice of asteroids for exploration from a close distance between each pair of gravity assist maneuvers near the Earth. A few big asteroids were selected as primary targets of the mission, among them the triple (216) Kleopatra asteroid. Various smaller asteroids that can be encountered together with the primary ones were found. The mission analysis is to be continued, its final goal is described and the mission outline is suggested in Conclusion. [View Full Paper]

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APPLICATION OF DEEP LEARNING NETWORKS FOR THE ANALYSIS OF REMOTE SENSING SATELLITE IMAGES

Teklay T. Yifter,[*] Yury N. Razoumny, [†] and Vladimir Yu. Razoumny[‡]

The paper presents the results of training and validation of neural network models on satellite data labeled to detect satellite dishes from the imagery. The goal of the study is to develop a system of neural network models for recognizing satellite dishes from optical satellite images. In the course of the work, studies and analysis of neural networks of various architectures were carried out, three sets of the best neural network models were selected and the parameters of their effectiveness were given in detecting the satellite. The objective of the study was to detect and draw a bounding box around the detected objects. The description of algorithms and methods of data storage is given, including initial and labeled images, service data, structures of neural networks, and weights of synaptic connections. In the work, three independent series of computational experiments were performed with the selection of neural network models that showed the best generalizing results. With the help of the developed and trained neural networks, satellite dishes can be tracked and detected from data obtained from satellite images with recognition accuracy of 93.65%. The results of the research were used to create software and mathematical tools based on machine learning methods for equipping geographic information systems to identify objects of interest from satellite images. [View Full Paper]

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AAS 20-337

APPLICATIONS OF NEUROMATHEMATICS IN RESEARCH AND RISK MANAGEMENT OF SPACE SYSTEMS

Yury N. Razoumny[*] and Ivan V. Stepanyan[†]

This article is devoted to application of the neuromathematical methods in some aspects of space research and risk management. The results of the first part of the research were used to create neural network tools for equipping geographic information systems to identify objects on satellite images. Deep neural networks were used for analysis photographs of the Earth and identifying items with a specific geometry. In the second and third parts of the research considered neuromathematical methods for determining the functional state of astronauts in the process of performing operator activities. The second part of research is aimed at developing practical possibilities for constructing coverage diagrams of neural network clusters with specified classes and assessing the informativeness of clusters. This neural network algorithm for analyzing stabilometry data can be useful in building systems for operational control and monitoring of cosmonauts before flight and after returning to Earth. In the third part, we proposed a method that made possible to establish a correlation between the dynamics of the flow of visual information and the response of the operator's physiological state. The results of the work are applicable to assess the working conditions of cosmonauts and risk management, when stress is a leading factor of risk, in order to prevent fatigue and accidents. [View Full Paper]

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SATELLITE CONSTELLATIONS AND FORMATION FLYING

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IAA-AAS-SciTech2020-025
AAS 20-338

DEPLOYMENT STRATEGIES OF A SATELLITE CONSTELLATION FOR POLAR ICE MONITORING*

Mauro Pontani† and Paolo Teofilatto‡

This research considers a constellation of 16 satellites equipped with SAR sensors and tailored to monitoring the polar ice evolution, with a suitable revisit time over the regions of interest. Satellite deployment includes three phases: (i) orbit injection, performed by the upper stage of the launch vehicle, (ii) orbit plane selection, and (iii) orbit phasing. This work is primarily focused on phase (ii). Carrier spacecraft are proposed as a valuable option to place the majority of satellites in their orbits. Two distinct strategies are proposed to complete this task. The first strategy is based on the use of chemical propulsion, combined with the perturbing action due to Earth oblateness. The second strategy considers the use of low-thrust electric propulsion, in conjunction with nonlinear orbit control. A comparison between these two approaches is drawn, in terms of deployment time and final mass ratio of the carrier. Orbit phasing concludes the constellation deployment, and is carried out by each satellite. A tradeoff is proven to exist between phasing time and propellant expenditure. [View Full Paper]

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AAS 20-339

SATELLITE FORMATION FLYING FOR GRAPHIC IMAGE DEMONSTRATION IN THE SKY: MISSION DESIGN

Shamil N. Biktimirov*

We study mission design for a satellite formation flying for graphic image demonstration in the sky. Since the approach for image demonstration relies on direct sunlight reflection using solar reflector-equipped satellites, we firstly define geo-metrical requirements for the mission. We propose the procedure to select the target orbit for an image demonstration mission, formation's orbital configuration, and reflector parameters. To deploy the required orbital configuration all satellites are assigned to bounded reference trajectories defined with respect to formation's geometrical center, where the reference trajectories are defined with the aid of the analytical solutions of HCW equations corresponding to PCO orbits. [View Full Paper]

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SATELLITE CONSTELLATION RECONFIGURATION METHOD BASED ON IMPROVED PSO ALGORITHM

Zhanyue Zhang,[*] Hao Wang,[†] Zhi Li,[‡] Yiqiao Xu,[§] and Yining Song[**]

A method of satellite constellation reconfiguration based on an improved PSO algorithm was presented. This method used a multi-satellite launch to reconfigure constellations without affecting the initial constellation configuration. Reconfigurable time and cost metrics were quantified, and the processing of a multi-satellite launch was introduced. Constellation failure cases were divided into multi-satellite failure in a single orbital plane and multi-satellite failure in different orbital planes. Constellation reconfiguration models for different failure cases were established. An improved particle swarm optimization (IPSO) algorithm was presented to solve the models. Simulation results show that the IPSO algorithm has better performance in handling constellation reconfiguration problems. [View Full Paper]

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AAS 20-341

CONCEPTUAL DESIGN OF SPACE SOLAR POWER CONSTELLATION FOR FUTURE LUNAR EXPLORATION

John M. Connell,[*] Cato Meaker,[*] Aditi S. Nilvarna,[*] Parande Tayyebi,[*] Maxime Falduto,[*] Filippo M. Ferrucci,[*] and Gongling Sun[†]

In the near future, there will be a multitude of lunar missions through the efforts of space agencies, such as the Artemis program of the USA, the Chang'e lunar exploration program of China, and through commercial stakeholders. Sustainable power supply is critical for both robotic missions and human settlement on the moon, especially in areas of increased global interest, namely the South Pole, despite the lack of sunlight for solar power. This report proposes a conceptual design solution to face the existing challenges by using space solar power generated in lower lunar orbit and transmitting the power to a lunar surface station. This report contains the mission architecture, constellation orbit selection, flight formation, and trade-off study based on current technologies for a space solar power constellation. It describes the concept of three small satellites to be placed in an 86° frozen, circular lunar orbit with a 120° difference in argument of perigee. The spacecraft will collect solar energy via photovoltaic cells, store it as direct current (DC) in lithium-ion batteries, and transmit wireless power through microwave radiation to lunar ground stations. [View Full Paper]

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A DISTRIBUTED SPACE SURVEILLANCE CONSTELLATION DESIGN BASED ON STAR SENSORS

Fei Feng,[*] Huisheng Yao,[†] Wei Qi,[‡] and Di Zhao[§]

The Space-based Space Surveillance (SBSS) performs more excellently than ground-based space surveillance system in Space Situational Awareness (SSA). But it is also limited in the quantity of available observer satellites and the high cost. It is well known that the star sensor is a necessary onboard sensor for attitude determination. But more importantly, it can also be regarded as the optical sensor to observe space debris and obtain angular measurements to determine their orbits. In this paper, first, we propose a low-cost and distributed space-based observation concept based on star sensors belonging to a large number of existing LEO satellites. Then, taking the scanning circle theory into consideration, we establish the observation model and design a surveillance constellation for GEO space debris. Additionally, the performance of the surveillance constellation including the access frequency, the duration of observed interval and the synchronous observation times are analyzed in numerical simulations. Taking a 2° field of view sensor as an example, the probability of a GEO object being observed synchronously by more than two observer satellites is more than 40%, and it almost frees from the influence of the earth shadow. The proposal means a large number of satellites with star sensors can be regarded as multipurpose space surveillance platforms. The obtained large observation data will provide a new and efficient approach for space debris Initial Orbit Determination (IOD) and cataloging. [View Full Paper]

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SPACE POLICY AND LAW

Session Chairs:
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IAA-AAS-SciTech2020-017
AAS 20-343

SOLAR ENERGY IN OUTER SPACE: LEGAL QUESTIONS, ISSUES AND SOLUTIONS

Irina Chernykh[*] and Stanislav Kopylov[†]

In the context of global energy crises related to the traditional energy sources, such as oil or gas, as well as in the connection with modern challenges and threats caused by the instability of the world energy markets there is a necessity to expand and use the objects of energy complex that use renewable energy sources. International legal cooperation in this area has become possible thanks to the UN activities and IRENA. States which do not have good characteristics from the solar resources of map's point of view, but are interested in implementing such projects, are forced to turn their attention to the alternative methods of obtaining this type of energy. One of these "projects" is the recently proposed initiative of China to place special installations in the near-earth space. The usage of such kind of energy would be a reason for different interstate disputes due to the uncertainty in international legal regime of space energy sources in accordance with international space law. Controversies and different approaches on the use and exploitation of certain kinds of space resources are a striking case in point. The solution of this problem could be built on the experience of other international law's branches. [View Full Paper]

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ISSUES OF LIABILITY FOR DAMAGE CAUSED BY FOREIGN SPACE OBJECTS

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The purpose of this study is to analyze the current state of space activities in the context of its global commercialization and prepare proposals regarding the determination of the status of non-governmental legal entities (primarily commercial organizations) as subjects of civil law relations responsible for damage caused by space objects under their direct control during the launch, orbital flight and during the return to Earth of these objects, which are proposed to be defined as "operators of space activities." In other words, the result of this study should be proposals on how to separate their international public space law from international private law, the norms of which should regulate relations in the field of liability for damage caused by foreign space objects on the surface of the Earth, an aircraft in flight and a space object at all stages his movement. At the same time, the article proposes to preserve the international responsibility of states for damage caused by a space object, the operator of which was government bodies or their officials.

[View Full Paper]

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REMOTE SENSING FOR THE PURPOSE OF INTERNATIONAL LEGAL REGULATION OF MIGRATION

Ekaterina V. Kiseleva*

After a brief introduction into the systemic approach to the international legal regulation of migration and the nature of remote sensing, a review of juxtapositions between the two as elaborated by scholars is presented, with some intersections of remote sensing, migration and Sustainable Development Goals concluding the paper. The general principles governing cooperation between states in migration and space fields partly reinforce each other, but in some aspects need to be reconciled. The former include the fundamental of using the means available to states for the benefit of increasing human security, protecting persons in distress, e.g. in situations of those seeking the foreign territory for protection from persecution and travelling at risk of a shipwreck; the latter, *de lege ferenda*, touches the prospects of expanding and transforming the right to freedom of movement beyond the Earth, i.e. to the space where the state sovereignty is outlawed whereas some elements of control over individual movements belong to the heart of the very idea of a state as a subject of international law. The forced migration area of international cooperation is rich in practices by the United Nations High Commissioner for Refugees who employs the remote sensing technologies to achieve a range of goals. In combatting migration occurring in breach of relevant laws, remote sensing methods and data use can also be advantageous, for example, in identifying the brick kilns where the modern-day slaves are likely to be found and where the share of migrants is considerable. Finally, prosperity/poverty evaluations, migration factors analysis can be built upon the nighttime light use and some analogous findings opened via the remote sensing. [View Full Paper]

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ECONOMY IN SPACE: INTERNATIONAL LEGAL ISSUES AND DEVELOPMENT PROSPECTS

Andrey An. Dementev*

The idea of commercializing space and various activities and issues related to it has long been on the agenda of the international economic community, for more than a decade. Although many ideas today remain largely utopian (although this does not mean their impossibility), over the past few years the phrase "space economics" has been heard more and more often, both at the doctrinal level and in the practical environment. Within the framework of this article, the author analyzes and emphasizes the growing importance of space activities for the global and national economies, including developing countries.

[View Full Paper]

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AAS 20-347

THE DEMILITARISATION OF OUTER SPACE AND INTERNATIONAL LAW

Aslanbek K. Bisultanov[*] and Sergey Vl. Kogay[†]

Since early stages of the formation of a legal system of outer space use States faced questions about the demilitarization of outer space, including the moon and other celestial bodies. The United Nations General Assembly during its 21st session on December 19, 1966 approved the adoption of the Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies via resolution 2222 (XXI). Article IV of the Treaty indirectly distinguished the legal regime of the entire outer space in relation to the issue of demilitarization and established special restrictions regarding the moon and other celestial bodies. Thus, the conditions hereof establish an absolute prohibition on use of nuclear or any other weapons of mass destruction in outer space such as bacteriological, chemical and etc. as well as a ban on use and testing of any type of weapons on the moon and other celestial bodies. The full demilitarization of the moon and celestial bodies is also provided by the Agreement Governing the Activities of States on the Moon and Other Celestial Bodies adopted by the resolution 34/68of the United Nations General Assembly in 1979.1963 Treaty Banning Nuclear Weapon Tests in the Atmosphere, in Outer Space and Under Water and 1977 Convention on the Prohibition of Military or Any Other Hostile Use of Environmental Modification Techniques set a prohibitive regime that applies inter alia to actions in outer space. However, despite the existence of these international agreements, which define the demilitarized regime in outer space as well as on the moon and other celestial bodies, the extreme uncertainty in terms of partial demilitarization of outer space raises a number of legal issues. [View Full Paper]

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AAS 20-348

INTERNATIONAL LEGAL ASPECTS OF REGULATION OF SATELLITE TELEVISION BROADCASTING

Marianna Ilyashevich[*] and Anastasia A. Belousova[†]

One of the advancing vectors of the development of contemporary interstate relations are the Sustainable Development Goals 2030, that reflect the aspirations of the international community towards a more harmonic and just global order. Development of information and communication technologies in the context of SDGs, including the satellite television broadcasting, form a precondition for ensuring access to quality education, effective opposition against inequality within a State and between them, as well as facilitation of a comprehensive and sustainable industrialization and innovations. Of crucial importance is that activities in outer space are being conducted with due respect to the interests of all participants and based on international treaties and the "soft law" acts, which play a specifically significant role in that area. Operation of satellite television broadcasting is, firstly, covered by the Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies of 1967. Beyond that, the UN General Assembly Resolution No. 37/92 "Principles Governing the Use by States of Artificial Earth Satellites for International Direct Television Broadcasting" (the Principles) adopted on 10 December 1982 holds a significant place. The said document contains provisions on conduct of direct television broadcasting, which obtained approval of the majority of States-members of the United Nations. Nevertheless, it is ought to keep in mind that the developed States, which can be characterized as "Spacefaring Nations", raised their disagreement with relation to certain provisions of the document. This, firstly, involves disagreement with the provision stipulating that consent of the State, which territory will be covered by the satellite signal, must be obtained, and; the provision, pursuant to which a State will bear international responsibility for activities of private corporations conducting satellite broadcasting. In this connection its ought to mention that despite 30 years that have passed since the moment the Principles 1982 were adopted, States were still unable to align their positions, which would promote conclusion of a treaty. All this dictates a necessity for certain legal boundaries and consultation mechanisms between the participants of such activities to be created.

[View Full Paper]

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AAS 20-349

INTERNATIONAL HUMAN RIGHTS LAW AND SPACE LAW: INDEPENDENT PARADIGMS OR INTERRELATED MATTERS?

Aslan Abashidze[*] and Vladimir Savelev[†]

Since the emergence of international human rights law and space law, legal science has been dominated by the view that these international legal paradigms exist in parallel from each other. However, is this really the case? To investigate it, the main purpose of this work is to identify the growing interdependence be-tween such areas of international law in the context of the development of space activities and their growing influence in the life of mankind. The research will include a factors analysis that increase of branches interdependence, as well as examples of rights that are closely related to space activities.

[View Full Paper]

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REMOTE SENSING AS AN INSTRUMENT FOR IMPLEMENTING INTERNATIONAL ENVIRONMENTAL AGREEMENTS

Alexander M. Solntsev[*] and Anastasia M. Otrashevskaya[†]

The article is dedicated to the application of remote sensing technologies for the implementation of international environmental agreements. Remote sensing has become a common instrument since 1972, when the first Landsat satellite was launched and it became widespread and still plays an important role for various issues of the international law. The first decades of remote sensing were characterized by scientific exploitation, but now it is a tool for global environmental monitoring, and the technologies have been also improved (in the field of satellite technology, an increase in the number of available sensors that perform more frequent measurements, and growing awareness, etc.). The authors pay much attention to the Global Terrestrial Observing System (GTOS) — an interagency programme of FAO, UNEP, UNESCO, WMO and ICSU — has worked towards raising awareness regarding the utilization of remote sensing data in supporting sustainable development during statutory meetings of the different multilateral environmental agreements. The utilization of remote sensing data, together with in situ data and information, has generated great interest among the States parties to those Conventions in terms of reporting and overall monitoring of the sustainable use of natural resources. Particularly it concerns the aspects of access to information obtained by remote sensing, application of technologies for the implementation of international environmental agreements (technology remote sensing of primary productivity on species richness, remote sensing of climate variables, remote sensing technology structure and topography of the habitat). The prospect of further application of the remote control instrument is a subject for legal investigation. [View Full Paper]

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IMPACT OF THE COVID-19 PANDEMIC ON SATELLITE COMMUNICATIONS IN RUSSIA: EXPERIENCE OF THE INTERSPUTNIK INTERNATIONAL ORGANIZATION OF SPACE COMMUNICATIONS

Elina Morozova[*] and Yaroslav Vasyanin[†]

Although the new Covid-19 coronavirus disease of 2019 has not yet reached outer space, here, on the Earth, it has already significantly affected the most common and capitalized type of space activities – satellite communications. Understandably, this pandemic is mostly considered to have only negative effects on people's everyday life. However, the impact of Covid-19 with respect to the satellite communications market is not so one-sided. In this regard, this paper is aimed at describing and analyzing the effects that the Covid-19 pandemic has had so far on the satellite communications market in Russia as experienced by the Intersputnik International Organization of Space Communications – an international intergovernmental organization with 50 years' experience in this industry. [View Full Paper]

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IAA-AAS-SciTech2020-080
AAS 20-352

GLOBAL NAVIGATION SATELLITE SYSTEMS AND INTERNATIONAL SPACE LAW

Dongping Sun* and Denis Gugunskiy†

Global Navigation Satellite Systems are timing, positioning, navigation systems which working by earth-orbiting satellites. Currently, there are four major global satellite navigation systems, respectively: GPS (U.S.), Galileo (EU), GLONASS (Russia) and Beidou (China). These systems are complicated systems using satellite positioning techniques to provide users with accurate and timely navigation information, which has the tremendous application value in the field of air traffic control, marine navigation and military affairs, and so on. The current regulation of these systems is based on the principles and norms of international space law. At the same time with the development of global satellite navigation technologies and its industrial use, new issues and threats could be appeared in the international legal regulation of this space activities. The use of satellite navigation technology in the field of military reconnaissance would break the principle of national sovereignty. Commercial use of remote sensing data could violate the natural resources sovereignty of the remote-sensed country. Abovementioned examples show that issues under international space law in the field of global satellite navigation are required to be analyzed. Due to this fact the aim of this paper is to fulfill comprehensive and comparative-legal research of the current international legal regime of the global navigation satellite systems. Reaffirming and continuing to comply with the principles of existing international law, improving the existing international law on global navigation satellite the law are effective ways to resolve the dispute at this stage. [View Full Paper]

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IAA-AAS-SciTech2020-111
AAS 20-353

ORGANIZATIONAL-ECONOMIC MODELING IN THE ORGANIZATION OF PRODUCTION IN THE EPOCH OF DIGITAL ECONOMY

Alexander I. Orlov*

Statistical methods of production quality management are an integral part of the theory and practice of production organization in aerospace and other knowledge-intensive industries. The experience in this field and results of Institute of High Statistical Technologies and Econometrics of Bauman Moscow State Technical University are presented.

[View Full Paper]

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3rd IAA/AAS CONFERENCE ON SPACE STRUCTURES AND MATERIALS

SPACECRAFT STRUCTURES AND SENSORS

Session Chairs:
Hamed Ahmadloo, *Beijing Institute of Technology, Beihang University, China*
Marina Rynkovskaya, *RUDN University, Russia*

IAA-AAS-SciTech2020-033
AAS 20-354

CONCEPTUAL DESIGN OF MARS LANDER WITH NOVEL IMPACT INTRIGUING SYSTEM

Malaya Kumar Biswal M[*] and Ramesh Naidu Annavarapu[†]

Planetary landing is the ultimate principle of extraterrestrial exploration. But effectuating successful landing is a strenuous assignment because lander may experience a malfunction and can perform defective landing at any stage due to numerous factors. Here from the perspective of inefficient impact attenuator, we propose a design of Mars lander with a novel impact absorber fabricated from alloyed silicon-chromium spring damper integrated with a dual cylinder of distinct diameter to counteract the pressure variance exerted during landing. In addition to this, we have reviewed the past landing missions and discussed the approach to design and fabrication. Finally, from the derived formulations, we have displayed the preliminary results and we expect that the attenuator may bear an impact force of 20-140 kN for grounding 0.2-1.0-ton class crewed or cargo landers on Mars. [View Full Paper]

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IAA-AAS-SciTech2020-054
AAS 20-355

SIMULATION OF PROJECTILES IMPACT ON THE DOUBLE-LAYER SHIELD OF SPACECRAFT

Jiping An,[*] Xinhong Li,[†] and Junwei He[‡]

The experiment and numerical simulation are effective means to analyse the impact effect of space debris on the spacecraft shield. The paper simulates the projectile impact on double-layer shield of spacecraft and describes the methods and steps detailly. The hydrodynamic equations are used to describe the mechanical properties of metal materials under high-speed impact. The damage of the spacecraft shield is numerical simulated with different projectile velocities and impact angles. The results proved that the impact angle and the impact velocity have important influence on the fragmentation shape of the projectiles and the damage effect of the spacecraft shield. [View Full Paper]

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AAS 20-356

EVENT-BASED DENOISING METHOD FOR SPACE OBJECTS IMAGING

Yasheng Zhang,[*] Jun He,[†] and Pengju Li[‡]

Event cameras are a new type of dynamic imaging bionic sensors. These devices can capture brightness changes and output event stream asynchronously. Besides, these devices have the advantages of high dynamic range, high time resolution, low power consumption, and working during both day-time and night-time conditions. Such characteristics make event cameras more advantageous in the detection and tracking of space debris. Due to the environmental factors and the event cameras' structure, the output of event cameras has the problem of background noise and noise at the edges of the objects, which affects the quality and effect of space debris imaging. In this paper, we propose a method for reducing the noise in the event stream, based on the outlier degree and edge features. This method first, based on the uncorrelated characteristics of background noise, filters out the background noise. Secondly, this method eliminates the noise at the edges of the objects. The experimental results indicate that after processing by the method, the number of events of the objects in the three different scenarios on the ground has been reduced by 80.8%, 81.5%, and 83.4%, respectively. In addition, with the reduction of invalid events, the method reduces the bandwidth for data transmission and enhances the applicability of the event cameras in space debris recognition and removal. [View Full Paper]

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IAA-AAS-SciTech2020-061
AAS 20-357

EVENT-BASED SENSOR FOR SPACE TARGET RECOGNITION

Yasheng Zhang,[*] Pengju Li,[†] and Jun He[‡]

Aiming at the problems of overexposure and motion blur in observing objects with traditional CCD-based imaging sensors, this paper proposes a new type of method based on Dynamic Vision Sensor for Space target recognition. Dynamic Vision Sensors are biologically inspired vision systems that asynchronously measure per-pixel brightness changes. With a high temporal resolution, high dynamic range and low power consumption, it can work in low and robust light, reduce motion blur existing in Traditional camera, and provide more accurate astronomical accuracy. In this paper, we propose using event-based sensors for space targets finding and recognition and using pedestrians on the ground as the test target. The method of using Distribution Aware Retinal Transform features combined with classifiers can obtain a higher detection rate for targets. We believe this work proves the feasibility of event-based sensors in optical space imaging and recognition.

[View Full Paper]

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IAA-AAS-SciTech2020-063
AAS 20-358

DEVICE FOR TIGHTNESS CONTROL OF SPACECRAFT DESIGN ELEMENTS

Konstantin Voronov[*] and Aleksey Telegin[†]

In order to timely detect problems caused by negative factors of outer space, it is necessary to control the tightness of the spacecraft structural elements. The paper describes the design of the spacecraft tightness control device, describes its components, as well as the principle of operation. The advantage of this device in comparison with other similar devices is that it allows you to monitor the surface of the spacecraft, determine the location of the leak and measure the parameters of the impacting high-speed dust particles, while this device does not interfere with the operation of the main systems. [View Full Paper]

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IAA-AAS-SciTech2020-072
AAS 20-359

EVALUATION OF A MULTIPARAMETER SPACECRAFT SENSOR FOR MATERIALS PROPERTIES CONTROL

Konstantin Voronov,[*] Ivan Tkachenko,[†] Dmitriy Ryazanov,[‡] Artem Ionov,[§] and Maksim Ivanushkin[**]

Spacecraft are subject to multiple impacts of outer space factors. Nowadays, polymer materials are widely used in the design of small spacecraft. However, due to erosion caused by ionospheric particle flow and ultraviolet radiation, the volatile products leave the surface of materials and deposit on sensitive optical elements and the spacecraft antennas. The article examines existing methods for measuring the characteristics of a substance deposited on the surface. A new method and sensor design to investigate the destructive effects of the outer space factors on a spacecraft have been proposed. [View Full Paper]

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IAA-AAS-SciTech2020-098
AAS 20-360

DEEP LEARNING WAVEFRONT SENSING FOR IMAGING SATELLITES

Jae Jun Kim,[*] Leonardo Herrera,[†] and Brij Agrawal[‡]

Large aperture imaging satellites can provide high resolution imaging capabilities for both astronomical observatory and earth imaging applications. On-orbit wavefront sensing and correction can provide cost-effective means to achieve large apertures in space. In this paper, deep learning based wavefront sensing models are investigated using the point source imagery data as well as the scene based imagery data, which can be readily derived from the imaging sensors already equipped in the imaging satellite platform. This will eliminate the need for a dedicated wavefront sensor and reduce the overall complexity of the optical system. The performance of the deep learning wavefront sensing models based on point source and scene images are evaluated against deep learning wavefront sensing model based on multiple wavefront sensor imagery data. [View Full Paper]

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ADVANCED SPACE MATERIALS

Session Chairs:
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IAA-AAS SciTech2020-005
AAS 20-361

TORUS SOLAR SAIL FLIGHT DYNAMICS UNDER ACCELERATION VIA LIGHT PRESSURE AND THERMAL DESORPTION COATING

Roman Ya. Kezerashvili[*] and Olga L. Starinova[†]

We study the flight dynamics of the torus-shaped solar sail that undergoes acceleration due to the solar radiation pressure and the thermal desorption of coating material from the sail surface. We describe the dynamics of such solar sail as the discrete dynamic system motion since there are trajectory sections where the sail experiences only the light pressure and light pressure force along with an additional force due to coating material desorption. The second phenomenon acceleration is short-lived, occurs only, when a specific sail temperature is reached, and its value is orders of magnitude greater than the light pressure acceleration. [View Full Paper]

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IAA-AAS-SciTech2020-042
AAS 20-362

EVALUATING OF THE LATERAL STABILITY FOR STEEL BEAMS USING DIFFERENT DESIGN STANDARDS

Vera V. Galishnikova,[*] Tesfaldet H. Gebre,[†] and Shishay B. Gebreslassie[‡]

Structural steel sections are increasingly popular in appropriate construction projects mainly due to their excellent strength to weight ratio. Thus, for proper design of lateral torsional buckling of members depends on out-of-straightness, boundary conditions, residual stress, load-height effect, moment gradient and restraint, etc. This paper compares the design approach by Evaluating the strength curves and Lateral Stability of Steel Beams section using main international structural steel design standards including the Russian Federation, Australian, Canadian, United states of America and European standards. The comparative study is performed for a compact rolled I sections with different slenderness and lateral bracing lengths. The study presents the assessment and comparison of the lateral stability of steel beams by considering the strength and lateral torsional buckling curves using different international design codes. Considering wide flange section with different lateral bracing length, the paper Evaluating the slenderness and lateral torsional buckling of the sections with different standards. [View Full Paper]

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METHOD OF PRODUCTION OF DETAIL "FRAMING SEGMENT" FOR AVIATION EQUIPMENT

Voktor I. Galkin,[*] Andrey R. Paltievich,[†] and Evgeniy V. Galkin[‡]

The article presents the peculiarities of production of framing segment by the method of bending in the three-roll bending machine. Framing element is a rolled steel section of unlocked type, it refers to the group of details which are used in the forming of aircraft body frame, in particular airframes of planes and space rocket systems. The elaborated method of bending of framing blank part provides considerable geometric parameters of bending maintaining the rigidity of its cross-section. [View Full Paper]

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METHOD OF NEUTRALIZATION OF COMPONENTS OF LIQUID ROCKET FUEL BY PEAT-SHUNGITE SORBENT-CATALYST

Minenkova Irina,[*] Uleanov Aleksey,[*] Sobolev Aleksey,[*] Popova Svetlana,[*] and Buryak Aleksey[*]

On the basis of such natural materials as peat and shungite, a sorbent-catalyst has been proposed that can be applied to decontaminate the sites of spills of 1,1-dimethylhydrazine and its transformation products. It is shown that in less than a hundred days the peat-shungite sorbent-catalyst is able to completely disinfect the soil containing 1,1-dimethylhydrazine and the products of its transformation. The presence of a potassium-phosphate buffer in the composition of the sorbent-catalyst promotes the reclamation of soils contaminated with 1,1-dimethylhydrazine. [View Full Paper]

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IAA-AAS-SciTech2020-074
AAS 20-365

NONDESTRUCTIVE DIAGNOSTIC OF DIAMOND-LIKE CARBON COATINGS USED FOR SPACE APPLICATIONS

Carlos Suasnavas[*] and Mstislav Makeev[†]

Space applications involve a considerable challenge due to harsh environmental conditions. High temperatures, cryogenic temperatures, ultra-high vacuum pressures and space irradiation make up the group of conditions that have a significant impact on the performance of materials used in the construction of all types of systems or mechanisms which are sent into space. Highly attractive and promising materials for utilization in the aerospace industry easily lose their properties when exposed to the previously mentioned conditions. One of these materials is graphene, and given its potential, alternatives have been sought to make its use possible in space applications. The alternative is to cover the graphene with diamond-like carbon (DLC) coatings, since this nanostructure has properties of high hardness, wear resistance and, in addition, DLC coatings are chemically inert. Diamond-like carbon coatings have a universal protective role, not only for graphene, but for any element that is threatened in such adverse space conditions. Thus, space telescopes have DLC coatings on their lenses so that they are protected and get the plus of capturing all the radiation in the infrared spectrum, being another important property of diamond-like carbon coatings. By virtue of the impact and importance of DLC coatings in the aerospace industry, this work aims not only to make a review of current and future applications, but also to propose an optimization method related to the diamond-like carbon properties that are gotten from destructive characterization methods. It is proposed the idea of being able to predict properties, traditionally obtained through destructive methods, from those properties obtained thanks to non-destructive characterization methods. Particular emphasis is placed on predicting the hardness of DLC coatings from the numerical value of the refractive index. [View Full Paper]

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BORON NITRIDE NANOTUBE FOR SPACE RADIATION SHIELDING

Suruchi Kumar,[*] Neeru Bhagat,[†] and Rupali Nagar[‡]

Space radiation causes a lot of degradation in structural materials used by engineers and astronauts in different space research operations. These radiations can potentially introduce noise in the electronic systems leading to communication and navigation issues. These radiations contain neutron, cosmic rays and harmful energetic particles that can impose great threat to astronaut's health and cause biological changes resulting in diseases like cancer, genetic mutation etc. The problem in space explorations is the ionizing radiation, due to the particle's high energy levels, which ionizes matter coming in contact with the radiation. Thus, here is a need to mitigate these effects of ionizing radiation to the space structures and also to our astronauts by manufacturing efficient radiation shields. Boron Nitride nanotubes (BNNTs) are nano sized hollow tubes formed by boron (B) and nitrogen (N) atoms. The structure of BNNTs is similar to carbon nanotubes (CNTs) where each carbon–carbon bonds is replaced by boron-nitrogen bond which is almost identical in bond length. BNNTs are a superior choice for radiation shielding, organic photovoltaic packaging and other specific applications. BNNTs have better thermal stability, higher thermal conductivity and also a good chemical stability compared to CNTs. This can be a huge evolution to the space industries since the usage of this high technology material can by far be the best solution to the problems faced by astronauts and scientists on long distance space programs. If sufficient amount of research and testing is done on this material, it is believed that the BNNTs material could be used in different parts of space shuttles and in building spacesuits for the astronauts and it will possibly take the next generation to Mars and beyond. [View Full Paper]

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BALANCED MICROWAVE MIXER PARAMETERS PREDICTION UNDER THE INFLUENCE OF IONIZING RADIATION

Kirill V. Cherkasov,[*] Sergey A. Meshkov,[†] Mstislav O. Makeev,[‡] and Boris V. Khlopov[§]

Nanodevices that make it possible to give the equipment new qualitative characteristics and to increase the efficiency of performing the functions assigned to them are used for spacecraft hardware creation. An example of such promising electronic nanoscale components are resonant tunneling diodes based on multi-layered nanoscale AlGaAs nanoheterostructures. At the same time, stringent requirements are imposed to the space-based nanodevice reliability. They are dictated by hard operating conditions on the one hand and the increasing spacecraft active shelf life on the other. In this paper, the methodology of predicting reliability of A3B5 resonant tunneling diodes and non-linear radio signal converters based on them is considered. The results of calculating the kinetics of the parameters of a balanced microwave frequency mixer based on resonant tunneling diodes under the influence of ionizing radiation are presented. [View Full Paper]

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MATERIALS FOR AEROSPACE APPLICATIONS: MACHINE LEARNING METHODS FOR TITANIUM ALLOYS CLASSIFICATION

Meena Laad,[*] Rahee Walambe,[†] Ketan Kotecha,[‡] Bhargav Yagnik,[§] Varad Nerlekar,[**] Nishita Agrawal,[††] and Soham Hudnurkar[‡‡]

Development of various advanced and multifunctional materials has been on the and crack propagation resistance, titanium and its alloys are the, good fatigue resistance fore-front of the material science research for past two decades. With excellent strength-to-weight ratio, exceptional corrosion resistance, good fatigue strength and crack propagation resistance, titanium and its alloys are the most used materials for aerospace applications. This work proposes a classifier based on machine learning techniques such as Decision Tree, Random Forest, Support Vector Machine and Artificial Neural Network. The model shows good classification accuracy and correlation between various thermal properties of pure metals and titanium alloys. [View Full Paper]

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AAS 20-369

SYNTHESIS OF LOW-TEMPERATURE POWDER MATERIALS FOR SPACE INDUSTRY

Pavel B. Shibaev,[*] Sergey L. Novokschenov,[†] Anton A. Sinitsyn,[‡] and Ramilya S. Shaikhetdinova[§]

Statistics show that more than 80% of machines and mechanisms fail as a result of wear of friction parts. Parts of rubbing pairs made of known materials do not meet the requirements of reliability and durability, which hinders the improvement of technology. There are the following ways to solve this problem: creation of new promising materials by powder metallurgy; creation of new anti-friction wear-resistant materials and polymer-based coatings; creation of new lubricants. The work shows the relevance of the development of antifriction materials by powder metallurgy. The obtained antifriction material is described for operation under ordinary conditions, in river or sea water, inert gas and / or high vacuum, in aggressive environments, for the production of plain bearings, gears, which includes a plasticizer consisting of a low-viscosity polar-active mineral oil, calcium soaps, and filler in the form of fine powders, as well as its properties and the method of its production. [View Full Paper]

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IAA-AAS-SciTech2020-095
AAS 20-370

DEVELOPMENT OF TECHNOLOGIES FOR SYNTHESIS OF THERMAL INSULATION AND THERMALLY CONDUCTIVE SYNTACTIC CARBON FOAMS WITH THE TAILOR-MADE PROPERTIES

Engel R. Galimov,[*] Vladimir L. Fedyaev,[†] Nazirya Ya. Galimova,[‡] Pavel B. Shibaev,[§] Ilgiz G. Galiev,[**] Vladimir M. Samoylov,[††] and Egor A. Danilov[‡‡]

The technologies were developed to synthesize thermal insulation and thermally conductive syntactic carbon foams with the required thermophysical and physical mechanical properties to meet the performance requirements. The paper proposes the variants of porous foam synthesis by varying the starting components in specific combinations and ratios in the forms of different binders, hollow microbal-loons, and modifying agents. The paper reveals the influence of the heat treatment conditions and operating conditions on the formation of the tailor-made structure and properties of syntactic carbon foams. It shows that the properties of the designed thermal insulation and thermally conductive foams made using various process approaches comply fully with the specification data.

[View Full Paper]

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STRUCTURAL DESIGN FOR SPACE APPLICATIONS

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IAA-AAS-SciTech2020-023
AAS 20-371

GENERAL PLANETARY VEHICLE

Anatoli Unitsky,[*] and Arsen Babayan[†]

To avoid an eco-resource catastrophe on Earth and be able to continue industrial growth and development, humanity needs to move to the space vector of industrialization. From the standpoint of fundamental physics, the most energy efficient and environmentally friendly geospace transport should use only its internal forces to go to outer space. The General Planetary Vehicle of engineer A. Unitsky (GPV) complies with this and a number of other requirements. The paper describes the structural design, operation principle, geospace flight phases and principal technical and economic indicators of the GPV.

[View Full Paper]

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IAA-AAS-SciTech2020-026
AAS 20-372

NEW DESIGN OF S- BAND PATCH ANTENNA ARRAY FOR A NANO SATELLITE APPLICATIONS

Mohammed Amin Rabah,[*] Zohra Slimane,[†] Salima Berrezzoug,[‡] and Wahiba Belgacem[§]

The field of satellite service has experienced technological advancement in recent years due to the strong demand from the population and industry. Where among the concerns of this industry are antennas, which are essential elements to ensure an operation of emission or reception of electromagnetic waves in the Earth's atmosphere or in space. As part of this work we are proposing a new patch antenna geometry for an S-band array resonates at 2.5 GHz which have optimal characteristics and may meet the criteria for Nano satellite applications in terms of bandwidth and radiation with a gain of 3.09 dBi.

[View Full Paper]

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IAA-AAS-SciTech2020-027
AAS 20-373

BROAD BAND MICRO SCRIPT PATCH ANTENNA FOR NANOSATELLITE APPLICATION

Wahiba Belgacem*, Nassima Belgacem,† and Mohammed Amin Rabah,‡

In this paper, we propose a new design consists of the broad band micro script patch antenna for nanosatellite application. The antenna proposed operating at C band frequency range for transmitting Tx [5.85 to 6.65 GHz] and receiving a signal RX [3.4 to 4.2 GHz]. This antenna proposed built on the (FR4) substrate materiel with micro strip feed line technique adapted to 50 home and it is printed on the roger RT/duroid 5870 with dielectric constant is 2.33, conductivity is 5.8×107, tag (d) =0.0012. The partial ground plane is dimensions 34×9 mm2. A better simulations result is obtained and a good performance we achieved in terms of return loss (S11), gain and radiation pattern. [View Full Paper]

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IAA-AAS-SciTech2020-029
AAS 20-374

STRUCTURAL SOLUTIONS AND WORK UNDER LOAD OF FREE-STANDING BLOCKS OF STEEL CLAMP SCAFFOLDS

**Alexander V. Golikov,[*] Igor M. Garanzha,[†]
Alina A. Timoshenkova,[‡] and Saad M. Musaed[§]**

The paper provides a detailed analysis of the work under load structures of clamp scaffolds and systematizes the features of considering loads and impacts when performing strength calculations. The article analyzes the stress-strain state of free-standing forests. An algorithm for calculating free-standing forests is proposed, considering the features of structural schemes of blocks that are not specified in the normative literature. Based on the results of the analysis of data from a series of numerical experiments, constructive measures are proposed to ensure the load-bearing capacity, rigidity and stability against overturning of spatial blocks of free-standing forests, which will allow installing blocks with a height-to-size ratio exceeding 3,5:1 in open areas (outside buildings and structures) without attachment to existing structures. Another feature of scaffolds is that they are used for not only classic buildings and structures and for the maintenance and repair of various space stations and aircrafts. [View Full Paper]

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IAA-AAS-SciTech2020-049
AAS 20-375

STRUCTURAL DESIGN OF SMALL SATELLITES FOR EARTH REMOTE SENSING BASED ON "AIST-2" UNIFIED PLATFORM

Sergey Safronov,[*] Ivan Tkachenko,[†] and Maksim Ivanushkin[‡]

One of the main fields of small satellites designing in a short time is the transition to the construction of a satellite-based on a unified platform. This approach allows creating a number of satellites that differ in the composition of the target equipment based on the common platform. The article considers the selection process of onboard support systems and observation equipment and describes the principles of creating multi-satellite observation systems based on unified platforms of small spacecraft. As a result, the method for design parameters selecting for unified platforms of small satellites for Earth remote sensing has been developed. [View Full Paper]

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IAA-AAS-SciTech2020-058
AAS 20-376

TESTING THE THERMAL CONTROL SYSTEM FOR SMALL SPACE VEHICLES OF SMALL SATELLITES OF THE "AIST" SERIES BY VERIFYING THE SPACECRAFT THERMAL MODEL BASED ON TELEMETRY DATA OBTAINED BY EXPERIMENTAL OPERATIONAL

Ivan V. Kaurov*

One of the main modern trends in modern space engineering, especially considering the constant increase in the number of spacecraft created and launched into orbit, is the use of an unpressurized platform. This feature is characteristic for small spacecraft (SS). One of the most significant factors affecting the lifespan of SSs is the reliable operation of the thermal control system (TCS). Analysis of the telemetric readings, obtained during the flight tests and the long-term operation of real spacecraft, makes it possible to verify the results of the ground-based testing and the spacecraft thermal model. Testing the TCS for small space vehicles was developed on the basis of experimental data, obtained during operational of SS of the AIST series. Thermal mathematical model of the AIST SS was built using the Siemens NX software package with the integrated NX Space Systems Thermal Simulation module. Such work allows both to clarify the programs and modes of ground-based thermal vacuum testing and thermal model of prototype products, as well as to provide recommendations for upgrading the platform design, ensuring its optimal thermal conditions and the required longevity when using new payloads.

[View Full Paper]

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IAA-AAS-SciTech2020-070
AAS 20-377

A NEW DESIGN OF SOLAR WING'S STRUCTURE

Lu Yang,[*] Junwei He,[†] Jiping An,[‡] and Baowei Tang[§]

According to the principle of folding and unfolding of ladybug's hind wings, this paper proposes a solar wing structure design scheme based on the crease pattern of ladybug's hind wings. First, based on the biological research results of the ladybug's hind wings, a single-vertical origami model of the hind wings was abstracted. Then, the origami model is transformed into a space four-bar linkage that is more conducive to engineering design, and the degree of freedom of the structure is analyzed. Finally, the design of the hinge and the shape of the solar wing is completed, which avoids the problem of thick plate interference during the folding process of the rigid solar wing. Compared with the currently widely used multi-plate solar wing, it has the advantages of fewer additional mechanisms, light weight, and high reliability, which has important reference significance for the design of space deployable structures. [View Full Paper]

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IAA-AAS-SciTech2020-115
AAS 20-378

SYSTEM ANALYSIS OF THE BEHAVIOR OF LAUNCH VEHICLE STRUCTURE UNDER THE INFLUENCE OF EXTERNAL LOADS BASED ON THE PRINCIPLES OF NONLINEAR DYNAMICS

Olga A. Saltykova,[*] and Yury N. Razoumny[†]

This study investigates the behavior of launch vehicle structures (LV) during the launch of spacecraft (SC), particularly the nonlinear dynamics of closed cylindrical shells that approximate these structures. A mathematical model of a cylindrical shell was developed based on the kinematic hypothesis of the first approximation, considering the geometric nonlinearity according to the T. von Karman model, under the action of an external alternating load distributed over the surface. The nonlinear dynamics of the structure were investigated based on their geometric parameters. The reliability of the obtained numerical results is substantiated to solve the resulting system of differential equations in partial derivatives, the Bubnov-Galekin method in higher approximations is used, to solve the Cauchy problem, the Runge-Kutta method of the 4th order is used. It was shown that a change in the geometric parameters of the shell leads to a change in the scenario of the transition of shell vibrations from harmonic to chaotic. [View Full Paper]

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ENERGY SYSTEMS AND PROPULSION

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IAA-AAS-SciTech2020-071
AAS 20-379

STUDY OF WIRELESS METHODS OF TRANSMISSION OF ELECTRICITY TO REMOTE OBJECTS

Dmitry S. Strebkov,[*] and Nikolay Yu. Bobovnikov[†]

In 1999, a wireless method of electricity transmission was proposed, in which a conducting channel is formed between the source and the receiver of electrical energy by the method of photoionization and impact ionization using a radiation generator. The conducting channel is electrically isolated from the radiation generator using an electrical insulating screen transparent for radiation, the conducting channel is connected to a source of electrical energy through a high-voltage high-frequency Tesla transformer and to a receiver of electrical energy through a Tesla step-down high-frequency transformer or a diode-capacitor unit, the electrical conductivity of the channel is increased by forming a surface charge and increase the strength of the electric field and carry out, under the action of Coulomb forces, the movement of electric charges along the conducting channel. Another method of transmitting electricity uses laser radiation and a photodetector as a generator of electrical energy. Low efficiency is associated with imperfect design of the photodetector, uneven distribution of radiation on the surface of the photodetector and switching losses in the photodetector. The aim of the work is to increase the efficiency and electrical power of the wireless transmission system of electrical energy. The design of an experimental device and a method for transmitting electrical energy to stationary and moving objects are proposed. The electric power transmission system can be used for wireless power supply of stationary consumers, unmanned aerial vehicles and space vehicles. Further research is aimed at developing devices and methods for wireless transmission of electrical energy using electron beams and gamma quanta to create a conducting channel. [View Full Paper]

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IAA-AAS-SciTech2020-090
AAS 20-380

AUTOMATED MECHANICAL TESTING OF ON-BOARD RADIO-ELECTRONIC DEVICES

Alexey P. Bykov,[*] Sergei V. Androsov,[†] and Mikhail N. Piganov[‡]

Offers a program and technology for automated mechanical testing of on-board electronic devices. The results of tests of the device for detecting the resonance of structural elements, for strength under the influence of transport loads, for resistance to broadband vibration, for strength and stability under the influence of mechanical shocks, for strength under the influence of linear acceleration are presented. A module for interfacing equipment and test equipment with an automated test facility has been developed. The use of this automation complex makes it possible to solve the problems of rational control of the technological process of mechanical tests. [View Full Paper]

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IAA-AAS-SciTech2020-091
AAS 20-381

ABOUT SAVING MOMENTUM

Yury N. Razoumny,[*] and Sergei A. Kupreev[†]

The possibility of the motion of bodies based on the change in the angular momentum is considered. The examples give reason to believe about the conservation of momentum in a broader sense. A hypothesis has been put forward about the emission/absorption by the body of elementary particles with spin in the plane perpendicular to the velocity vector of the body. Experiments with the motion of bodies in a vacuum chamber are considered. The experiments give grounds for the formation of new physical concepts. The idea of creating a thrust without the use of propellant is proposed. [View Full Paper]

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IAA-AAS-SciTech2020-094
AAS 20-382

TESTING ON-BOARD ELECTRONIC EQUIPMENT FOR TEMPERATURE EFFECTS

Alexey P. Bykov,[*] and Alina A. Denisyuk[†]

The method of testing the onboard radio-electronic means of spacecraft for temperature effects is described. They were carried out within the framework of design and development tests for samples that have passed acceptance tests. The main purpose of the tests was the development of design documentation for assigning the required letter and confirmation of the correct use of the element base. The test results are presented. The tests carried in the ATM2.708.005 chamber. The device was mounted on the heat-dissipating table of the chamber through heat-dissipating paste 131-179 and attached to the table with a bracket. [View Full Paper]

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