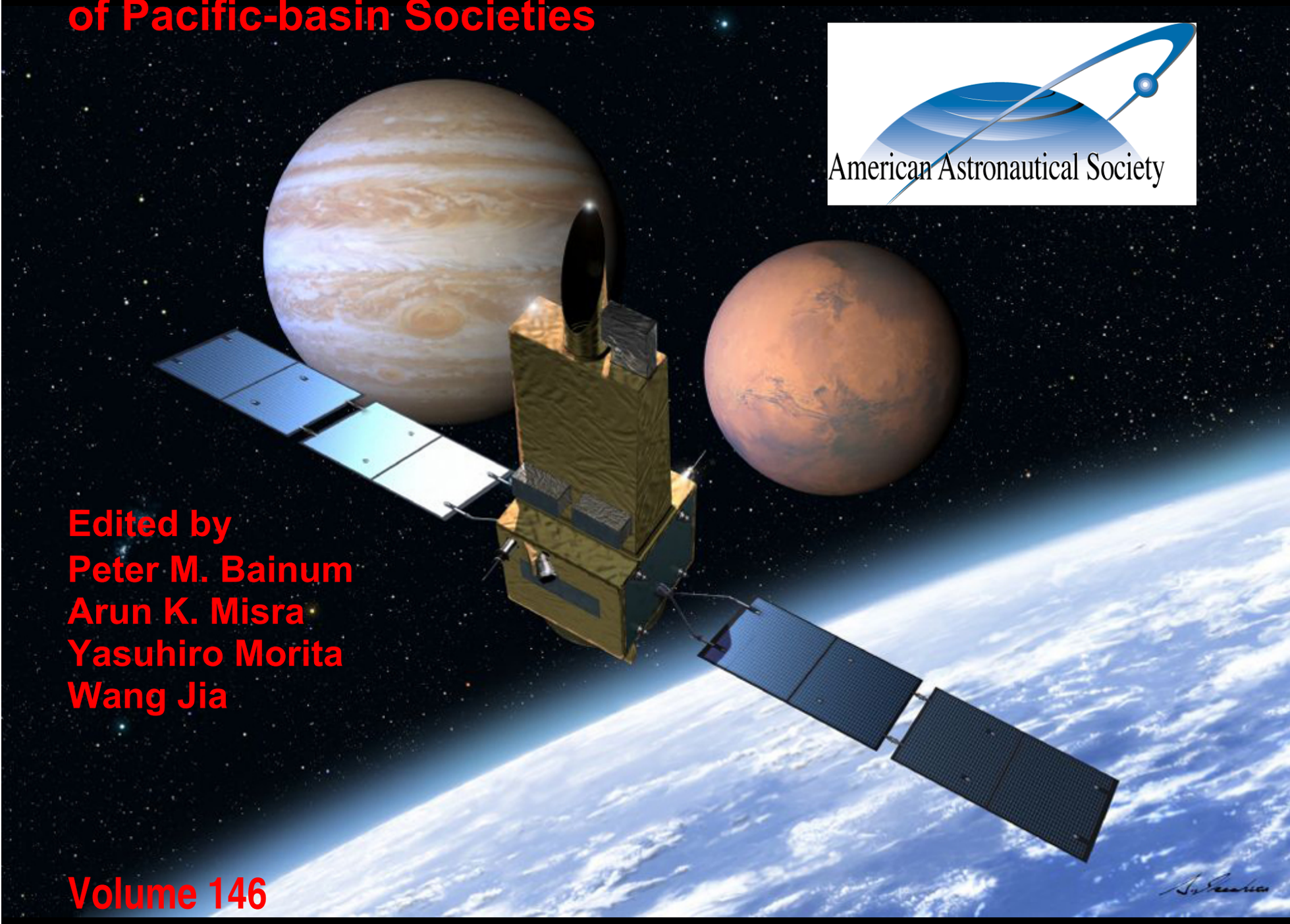
SPACE FOR OUR FUTURE

Thirteenth International Space Conference of Pacific-basin Societies



Edited by
Peter M. Bainum
Arun K. Misra
Yasuhiro Morita
Wang Jia

Volume 146

ADVANCES IN THE ASTRONAUTICAL SCIENCES

SPACE FOR OUR FUTURE

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Frontispiece:

1. The Opening Ceremony
2. A cocktail party at Kodaiji Temple
3. Professor Ryojiro Akiba and his Matsunaga Award
4. Awards Banquet at the Garden restaurant
5. The students awarded
6. Delegates and a Maiko-san
7. The next host and a Maiko-san
8. National and International Space Programs Session
9. A speed of light rickshaw is go for the banquet.

Front Cover Illustration:

JAXA's extreme ultraviolet space spectroscope satellite that is scheduled to be launched in summer of 2013 by the first flight of the Epsilon launch vehicle. Credit: © JAXA.


13th International Space Conference of Pacific-basin Societies
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13th International Space Conference of Pacific-basin
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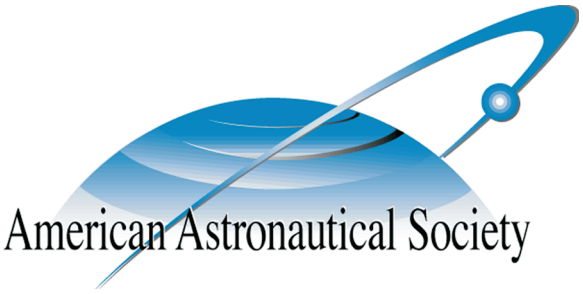

SPACE FOR OUR FUTURE

Volume 146
ADVANCES IN THE ASTRONAUTICAL SCIENCES

Edited by
Peter M. Bainum
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Wang Jia

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FOREWORD

This proceedings volume, which consists of one hard cover bound volume and a CD ROM supplement, includes the available papers presented at the Thirteenth International Space Conference of Pacific-basin Societies (ISCOPS), May 15–18, 2012, Kyoto, Japan. This sequence of ISCOPS volumes is usually published as a part of the AAS *Advances in the Astronautical Sciences* series. Earlier ISCOPS proceedings volumes are available through the American Astronautical Society as follows:

(1) The first symposium was held December 15-19, 1985 in Honolulu, Hawaii and was published as Volume 60, *Advances in the Astronautical Sciences* titled **Space Exploitation and Utilization**.

(2) The second symposium was held June 7-10, 1987 in Beijing, China. This publication was published in China and titled **Proceedings of the Pacific Basin International Symposium of Advances in Space Science Technology and its Applications (PISSTA)**.

(3) The third symposium was held November 6-8, 1989 in Los Angeles, California and was published as Volume 73, *Advances in the Astronautical Sciences* titled **Space Utilization and Applications in the Pacific**.

(4) The fourth symposium was held November 17-20, 1991, Kyoto, Japan and was published as Volume 77, *Advances in the Astronautical Sciences* titled **International Space Year (ISY) in the Pacific Basin**.

(5) The fifth symposium was held June 6-9, 1993, Shanghai, China. This volume was published in China (not available through the AAS).

(6) The sixth symposium was held December 6-8, 1995, Marina Del Rey, California, U.S.A. and was published as Volume 91, *Advances in the Astronautical Sciences* titled **Strengthening Cooperation in the 21st Century**.

(7) The Seventh symposium was held July 15-18, 1997, Nagasaki, Japan, and was published as Volume 96, *Advances in the Astronautical Sciences* titled **Space Cooperation into the 21st Century**.

(8) The eighth symposium was held June 23-26, 1999, Xian, China. This volume was published in China (not available through AAS).

(9) The ninth symposium was held November 14-16, 2001, Pasadena, California, U.S.A. and was published as Volume 110, *Advances in the Astronautical Sciences* titled **Space Development and Cooperation Among All Pacific Basin Countries**.

(10) The tenth symposium was held December 10-12, 2003, Tokyo, Japan, and was published as Volume 117, *Advances in the Astronautical Sciences* titled **Space Activities and Cooperation Contributing to All Pacific Basin Countries**.

(11) The eleventh symposium was held May 16-18, 2007, Beijing, China (not available through AAS).

(12) The twelfth symposium was held July 27-30, 2010, Montréal, Québec, Canada, and was published as Volume 138, *Advances in the Astronautical Sciences* titled **Applications of Space Technology for Humanity**.

Several other sequences or subseries have been established in the *Advances in the Astronautical Sciences* series. Among them are: Astrodynamics (published for the AAS every second year; odd years), Spaceflight Mechanics (annual), Guidance and Control (annual), and AAS Annual Conference proceedings. Proceedings volumes for earlier conferences are still available either in hard copy or in microfiche form. The appendix at the end of this volume lists proceedings available through the American Astronautical Society.

In proceedings volumes of the American Astronautical Society the technical accuracy and editorial quality are essentially the responsibility of the authors because the papers are essentially composed of camera-ready copy provided by the authors. The reader should bear in mind that for an international conference, such as the Thirteenth ISCOPS, many papers were prepared by authors whose native language is not English. The session chairmen and our editors do not review all papers in detail; however, format and layout are improved when necessary by our editors. In some cases the English is improved so it reads better. For this conference, the many authors whose native language is not English are to be congratulated on the quality of material submitted and are to be thanked for their significant contributions to this English-language volume. The editors wish to express their thanks to all those who have contributed to the success of this conference and to authors for their efforts in finalizing material for publication.

Robert H. Jacobs
Series Editor
Advances in the Astronautical Sciences

PREFACE

The Thirteenth Space Conference of Pacific-basin Societies (13th ISCOPS), under the theme "Space for Our Future," was held at the Kyoto International Community House on May 15-18, 2012.

This symposium was the thirteenth in a continuing series of biennial conference co-sponsored by the Japanese Rocket Society (JRS), the American Astronautical Society (AAS), and the Chinese Society of Astronautics (CSA).

In total, we received 102 attendees from 10 countries (Australia, Canada, China, France, Italy, Iran, Japan, Portugal, Slovenia and U.S.A.). More than 70 papers were presented in the International/National Space Programs session, the International Student Conference and Competition, and eight technical sessions. The proceedings volume includes most of the presented technical papers plus all the charts/slides presented in the International/National Space Programs session. The eight technical session topics include: Astrodynamics, Guidance, Navigation and Control, and Space Robotics; Satellite Communications and Broadcasting, On-Orbit and Ground Support Systems; Earth Observation, Small and Micro Satellite Missions and Constellations; Human Space Flight, Space Station, Pacific Space Ports, and Lunar Manned Exploration; Advances in Materials and Space Structures; Space Transportation and Propulsion, Fluid Dynamics and Aerothermodynamics; Current and Future Space Utilization including Micro-gravity and Life Sciences, Space Environment and Debris, and Space Solar Power Systems; Lunar, Planetary and Robotic Exploration.

The organizing committee of the 13th ISCOPS acknowledges the support of the Research Institute for Sustainable Humanosphere of Kyoto University for providing an excellent technical tour to its Mu Radar site in Shigaraki, Shiga.

The technical support and coordination provided by Prof. Emeritus Peter Bainum, Prof. Arun Misra, and Ms. Zhang Chi are greatly appreciated.

The 14th ISCOPS will be hosted by the CSA in China and is planned for 2014. We look forward to working again with our colleagues from the Pacific-basin to ensure the continued success of the 14th ISCOPS.

Prof. Yasuhiro Morita
Chair, 13th ISCOPS

CONTENTS

NATIONAL AND INTERNATIONAL SPACE PROGRAMS

SESSION A

Chair: Prof. Yoshifumi Inatani (JRS)
ISAS/JAXA, Japan

AAS 12-511

THE FEASIBILITY ANALYSIS OF CHINA COOPERATING WITH THE U.S. IN MARS EXPLORATION

Shan Wenjie* **and Zhang Shu†**

The objective of this study is to analyze the feasibility of the cooperation between China and the United States in Mars exploration. The paper gives an outline of international Mars exploration, and analyzes the feasibility in terms of politics, economy, technology, and international environment. Cooperation between China and the United States in Mars exploration would benefit both parties in sharing the huge project expense, promoting the space usage in a peaceful way, setting up foundation for international aerospace cooperation. Finally, the study gives the prospects and suggestion.
Key Words: Mars Exploration, Feasibility. [View Full Paper]

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AAS 12-512

CURRENT AND FUTURE SPACE PROGRAMS IN JAPAN*

Junjiro Onoda†

[View Full Set of Presentation Slides/Charts]

* Only slides/charts were available for publication for this presentation.

† Prof. Onoda is Director General, ISAS/JAXA; President JRS, Japan.

INTERNATIONAL STUDENTS CONFERENCE AND COMPETITION

SESSION B.1 (Masters Level)
SESSION B.2 (Ph.D. Level)

Chairs:

Shinichi Kimura
Tokyo University of Science,
Japan

Hiroto Habu
JAXA, Japan

Trevor Sorensen
University of Hawaii, U.S.A.

Hou Xiyun
Nanjing University, China

AAS 12-513

DEVELOPMENT AND EVALUATION OF A LOW-COST COTS-BASED CAMERA SYSTEM FOR SPACE APPLICATIONS

Masato Terakura, Hideaki Kogure, Kento Ohya and Shinichi Kimura*

The ability to obtain visual information is crucial for various space activities. We previously developed a very small, high-performance image-processing unit based on commercial off-the-shelf (COTS) technologies, called the high-performance-image acquisition and processing unit (HP-IMAP). HP-IMAP is currently being used successfully on the IKAROS spacecraft to acquire images and to support its operations. Furthermore, we are currently in the process of improving HP-IMAP's optics and image processors. For our first earth observation experiment, we are developing a new camera system for the TSUBAME project. In this paper, we outline the concept of low-cost earth observation sensors based on COTS technologies and its recent developments.
[View Full Paper]

* Tokyo University of Science, Japan.

AAS 12-514

MINIMUM ENERGY STEERING LAW FOR TRACKING MANEUVERS OF SATELLITES WITH CMGS

Takamitsu Inagaki,[*] Takehiro Higuchi[†] and Seiya Ueno[‡]

Control moment gyros (CMGs) are effective torque generator for attitude control of satellites. The model used in this study is a rigid satellite with four CMGs arranged like a pyramid. Almost all steering laws of CMGs are developed based on the pseudoinverse steering law. This study focuses on the steering law that is not based on the pseudoinverse steering law by using receding horizon control. The Minimum Energy (ME) steering law utilizes the characteristic of gimbal rate in the proximity of singularity to avoid singularity. Numerical simulations are conducted to illustrate the advantages of the ME steering law with a comparison with the pseudoinverse steering law. [View Full Paper]

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AAS 12-515

OPTIMAL CONFIGURATION OF CONTROL MOMENT GYROS FOR MINIMUM ENERGY MANEUVERS OF SATELLITES

Eijiro Uematsu,[*] Seiya Ueno[†] and Takehiro Higuchi[‡]

Single Gimbal Control Moment Gyro (SGCMG) is an effective actuator for three axis attitude control of satellites, which can generate higher torque than a reaction wheel. Utilizing the SGCMG system on satellites will make maneuver time shorter and energy consumption more efficient. It is required to reduce energy consumption during attitude maneuver because of limited energy supplies in space. This paper focuses on configuration of a pyramid type 4-SGCMG system, especially initial gimbal angles and pyramid skew angles which restrict the direction of the output torque. The effect of these angles on energy consumption will be clarified. The result of this study indicates that compared with the pyramid skew angle equal to 54.73 degrees which is adopted by number of studies for a spherical angular momentum envelope, the dispersion of energy consumption in each direction of maneuver is reduced by 63% when the skew angle is around 80 to 85 degrees. [View Full Paper]

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AAS 12-516

STATE ESTIMATION OF PLANETARY LANDING VEHICLES WITH WIDE-FIELD INTEGRATION OF OPTIC FLOW

Hirofumi Sakamoto,[*] Takumi Kanazawa[*] and Shinji Hokamoto[†]

In this paper, we apply Wide-Field integration (WFI) of optic flow for the state estimation of a planetary landing vehicle. This study utilizes nonlinear expressions for the Fourier coefficients of the optic flow instead of linearized expressions. By using the nonlinear expressions, it is shown that the vehicle's attitude angles can be estimated as well as its velocity components. First this paper deals with a two-dimensional model and explains how to estimate state variables. Then two three-dimensional models are discussed. Numerical simulation results are shown to evaluate the estimation accuracy.
[View Full Paper]

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AAS 12-517

DEVELOPMENT OF ATOMIC NUMBER DENSITY MEASUREMENT TECHNIQUE IN HIGH ENTHALPY FLOWS USING VACUUM ULTRAVIOLET ABSORPTION SPECTROSCOPY

Akira Kuwahara,[*] Makoto Matsui[†] and Yoshiki Yamagiwa[‡]

The number density measurement system using VUVAS has been developed. This system can access the ground state by the VUV beam from the ICP light source. To decrease the fractional absorption in the light source, the double tube structure was applied. Then, the performance of the light source was demonstrated by cold xenon gases. The VUV beam intensity has the enough power to cause absorption saturation.
[View Full Paper]

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‡ Professor, Department of Mechanical Engineering, Shizuoka University.

AAS 12-518

EFFECT OF REYNOLDS NUMBER AND FLOW CHANNEL GEOMETRY ON REGRESSION FORMULA FOR FORWARD-END FACES IN CAMUI TYPE FUEL GRAIN

Ryuichiro Kanai, [*]Tatsuya Ishiyama, Masahiro Nohara, Hirokazu Izumo, Masashi Wakita,[†] Tsuyoshi Totani and Harunori Nagata

The authors have been developing fuel regression formulas for CAMUI type hybrid rocket motors. A fuel block in a CAMUI-type fuel grain is a short-axis cylinder having two axial ports. Previous experiments showed that an experimental constant in the regression formula for forward-end faces depends on port length L, mean port diameter D, and the Reynolds number of the flow. In this paper, the authors examined these effects more closely to clarify the basic mechanism of these dependencies.
[View Full Paper]

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AAS 12-519

ORBIT EXPRESSIONS IN THE CONTINUOUS POLAR COORDINATE SYSTEM

Jun Matsumoto* **and Jun'ichiro Kawaguchi†**

This paper shows a new strategy to design low-thrust trajectories by using elaborated rotational coordinates which includes two rotational coordinates used in the circular restricted three-body problems around the departure planet and the target planet. Firstly, a straight-line trajectory in these new coordinates is derived analytically. Secondly, by joining this straight-line trajectory, it can be possible to design low-thrust trajectories which satisfy the boundary conditions easily. In this paper, an example trajectory from Earth to Mars is designed. This example shows the effectiveness of this strategy. [View Full Paper]

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AAS 12-520

STUDY FOR DIRECT MEASUREMENT OF ELECTROMAGNETIC THRUST OF ELECTRODELESS HELICON PLASMA THRUSTER

Kenji Takahashi,[*] Takahiro Nakamura,[†] Hiroyuki Nishida,[‡] Shunjiro Shinohara,[§] Takaeshi Matsuoka,[**] Ikkoh Funaki,[††] Takao Tanikawa[‡‡] and Tohru Hada[§§]

Conventional electric propulsion systems have some problems about the lifetime due to the erosion of electrodes caused by contacts between electrodes and the plasma. In order to solve this problem and realize the infinite life-time electric thrusters, we aim for a development of a completely electrodeless electric thruster. We have constructed a laboratory model of the electrodeless plasma thruster adopting the Lissajous plasma acceleration and a thrust stand to measure the electromagnetic thrust for validating our plasma acceleration concept. In this paper, we report the designing of the magnetic circuit using permanent magnets and the thrust stand. And the result of the thrust stand calibration and the progress of the thrust measurements are reported. [View Full Paper]

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AAS 12-521

ELECTRON CYCLOTRON RESONANCE PLASMA CHARGING AND ACCELERATION OF MICRO-PARTICLES FOR SPACE THRUSTER

Shimpei Sakka,[*] Makoto Matsui[†] and Yoshiki Yamagiwa[‡]

A novel space thruster using stardust was proposed. As the stardust, carbon particles of 5 μm in diameter were used as propellant. At first, the particles were negatively charged by electron cyclotron resonance (ECR) plasma. Then, we tried to accelerate the charged particles by an acceleration grid. However this method was difficult to make the large acceleration voltage, because it would discharge between an acceleration grid and plasma. Therefore, we propose a novel method to accelerate particles is charged using the ECR Plasma as an electron source. [View Full Paper]

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AAS 12-522

INVESTIGATION ON DEFLECTION BEHAVIORS OF WRINKLED MEMBRANES GIVEN BY TENSION FIELD THEORY

Tomonori Tanaka and Takashi Iwasa*

A deflection analysis of the wrinkled membranes subjected to a uniformly distributed load was performed by a nonlinear finite element analysis based on the tension field theory and shell theory, and an effectiveness of the deflection shape estimated from the analysis with the tension field theory was investigated from the view points of the shell theory. Through the comparison on the simulation results given by both theories, it was presented that the membrane surface features calculated from the analysis with tension field theory does not always represent the intermediate surface features of the wrinkled membranes given by the analysis with the shell theory. [View Full Paper]

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AAS 12-523

CARS MEASUREMENT OF ROTATIONAL AND VIBRATIONAL TEMPERATURES ON THE FLAT PLATE BEHIND SHOCK WAVE

Masashi Oguro,[*] Hima Bindu Venigalla,[*] Shota Niinomi,[*] Daiki Sirota,[*] Masanori Ota[†] and Kazuo Maeno[‡]

When reentry vehicle enters from space to the atmosphere, the hypervelocity shock waves are generated in front of body and wings. The surface of the vehicle is exposed to hypersonic non-equilibrium flow with strong radiative heating. Research on the non-equilibrium flow behind shock wave plays a significant role in designing heat shields of reentry vehicles. In this study CARS method is applied to measure rotational and vibrational temperatures of N_2 behind strong shock wave at velocity of 4.1m/s around a flat plate. Experimental data under the flat plate are compared with the data without flat plate to investigate the effect of the flat plate on rotational and vibrational temperatures in the hypervelocity shock-heated flow. Total radiation images behind shock wave are also observed by CCD camera. [View Full Paper]

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AAS 12-524

DEVELOPMENT OF STRENGTH FAILURE MODEL FOR POROUS CHARRING LAYER OF EPDM INSULATION ERODED BY PARTICLE FLOW

Chen Yue*

The new charred layer failure strength model with porous structure was developed from extensive structure analyses of charring layer. In this model, the structure of charred layer was described by porosity, and the mathematical relation between tensile strength, compressive strength and porosity for the material has been derived. The parameters needed by the model can be obtained by the basis of tensile and compressive tests. Predicted critical values showed good agreement with the particles impinging experimental results. [View Full Paper]

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AAS 12-525

IMPORTANT FACTORS ON RECEIVER'S MEASUREMENT QUALITY

Tian Jia,[*] Wang Wei[†] and Shi Pingyan[‡]

PN code ranging technique based on DSSS is widely used in satellite navigation, radar, and aerospace TT&C. phase noise of oscillator, group delay introduced by RF link and filter quantitative error and sampling jitter of ADC introduce big influence on receiver's measurement quality. This article set up mathematics model on basis of analyzing their principles, and set up matlab guide to analyze their influence on receiver's measurement quality. [View Full Paper]

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AAS 12-526

DYNAMICS OF A TETHER CONNECTED TO AN IRREGULAR SHAPED ASTEROID

M. J. Mashayekhi*

Dynamics and stability of a tether connected to an irregular shaped body is studied in this paper. It is shown in this paper that the tether length plays an important role in determining the stability of the tether. It is also shown that although the effect of the irregularity in the shape of the body on the dynamics and stability of the system is usually minor, it can lead to significant change in the tether dynamics for special initial conditions. [View Full Paper]

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AAS 12-527

SATELLITE CONSTELLATION OPTIMIZATION METHOD FOR FUTURE EARTH OBSERVATION MISSIONS USING SMALL SATELLITES

Miguel A. Nunes*

Constellations of small and cost-effective satellites are currently a major interest for future space missions that have never been considered before because of previous prohibitive costs or limited engineering solutions. These limitations are being quickly removed by major advances in embedded technology, specifically with the high computational capabilities with low power consumption. By advancing methods for optimizing satellite constellations, a stronger argument is made for new space missions that use small satellites, making these constellations even more attractive when considering specific mission goals. In this paper a method for satellite constellation optimization based on a Genetic Algorithm is proposed that evaluates the performance of satellite constellations by the interaction of MATLAB® and Satellite Tool Kit. This project proposes a general method to unveil different Earth observation constellation designs and optimize them so it may enable new space missions that may never before even been envisioned.
[View Full Paper]

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AAS 12-528

HAZARD DETECTION FROM HIGH ALTITUDES USING A SINGLE CAMERA

Satoru Kanazawa*

The moon exploration is paid attention as a base of researches and developments. In order to do this, it needs to land more precisely than anything previously proposed. For precise landing, it should improve terrain relative lunar positioning system and hazard detection system. In addition, from the view point of fuel and guidance, hazard detection system are desired it can detect higher altitude with lighter components. This paper shows image processing techniques that can detect sub-pixels obstacles using low-resolution images. It tested by synthetic lunar terrain maps and LRO images and considered effects of internal structure of CMOS image sensor and detection sensitivity.
[View Full Paper]

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AAS 12-529

PROBE MEASUREMENT OF PLASMA PLUME ON ELECTRODELESS HELICON PLASMA THRUSTER USING LISSAJOUS ACCELERATION

Takahiro Nakamura,[*] Hiroyuki Nishida,[†] Takeshi Matsuoka,[‡] Ikkoh Funaki,[§] Shunjiro Shinohara,[**] Takao Tanikawa,[††] Tohru Hada,[‡‡] Konstantin P. Shamrai[§§] and Timofei S. Rudenko[*]

In order to realize a long-lived electric propulsion system, we have been investigating an electrodeless plasma thruster concept utilizing a helicon plasma source and Lissajous plasma acceleration, which uses the static diverging magnetic field and a rotating electric field (REF). Using a laboratory model of the Lissajous acceleration-type thruster, plasma acceleration experiments have been conducted. In the experiments, plasma flow velocity was measured at the center in the thruster using a para-perp type Mach probe. It was observed that the application of the REF power (13.56 MHz, $1.4kV_{p\text{-}p}$) makes in increase in the plasma flow velocity. In addition, axial distributions of the plasma velocity indicate that the particle collision between neutral gas and plasma particle has a significant effect on the plasma expansion process in the magnetic nozzle. [View Full Paper]

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AAS 12-530

IMMERSION AND INVARIANCE BASED COMMAND-FILTERED ADAPTIVE BACKSTEPPING CONTROL OF VTOL VEHICLES

Jinchang Hu* **and Honghua Zhang†**

The main contributions of this article are twofold. Firstly, a guidance law based on nested saturation function combined with the Immersion and Invariance methodology, is proposed for controlling VTOL vehicles subject to mass uncertainty and thrust saturation simultaneously. To simplify the calculations, the virtual attitude extracted from the guidance law is propagated through a command filter, the output of which is tracked by the attitude subsystem. The other contribution of the study is that the influence of the command filter's frequency on the closed-loop system is rigorously analyzed. The main difficulty in proving the stability is that the command filter's tracking performance couldn't be guaranteed when the thrust force encounters the singularity problem. The study avoids this by utilizing the properties of the nested saturation function, and establishes the stability of the overall closed-loop system. Finally, simulations are presented to show the effectiveness of the proposed control scheme. [View Full Paper]

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AAS 12-531

IGNITION INVESTIGATION ON A TRI-FLUID INJECTOR OF HYDROGEN PEROXIDE/KEROSENE

Liu Changbo,[*] Liu Zhirang[†] and Ling Qiancheng[‡]

Hydrogen peroxide/kerosene is a non-hypergolic propellant combination. Three traditional ignition technologies including adding-energy ignition, homogenous catalytic ignition and heterogeneous catalytic decomposition ignition are usually applied, and the third one is the most popular technology of them. For heterogeneous catalytic decomposition ignition, in general, total peroxide flows through catalyst beds to decompose into a overheat oxidizing stream including water vapor and oxygen, the gas mixture auto-ignites with the kerosene subsequently. But the engines require higher throughputs of catalyst beds or their mass and size will be much larger. In order to decrease the mass of the catalyst bed, simultaneously considering the lower throughput bed applying to the large thrust engines, this paper reports a novel tri-fluid injector that only partial peroxide decomposes to ignite other fluids of liquid peroxide and liquid kerosene. The scenario of stepwise ignition is selected for a tri-fluid injector based on the igniting reliability. And it's also a perfect selection for the close-cycle engines to exhaust the propellant potentials. Many test articles are manufactured and several tri-fluid hot fire tests are carried out after a lot of cold flow tests with water and hot fires of secondary propellants. The results indicate that the new tri-fluid injector can ignite reliably and smoothly. [View Full Paper]

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AAS 12-532

FLEXIBLE COUPLED DYNAMICS MODELING OF VARIABLE CONFIGURATION SPACECRAFT ORIENTED CONTROL

Li Cao*

The communication satellite with large deployable antenna is a typical system which has the characteristics of alterable structure, configuration, parameter and centroid during the deployment of the antenna. In the paper, the flexible coupling dynamics equations are built based on modal synthesis-hybrid coordinate method, which can satisfy the requirement of the control system at both appendage level and the spacecraft level. Also, the flexible models of whole spacecraft with any configuration are obtained. An analysis simulation program is developed which has been verified by a typical example and inertial completion. The results show that this research would be practicable and effectual for designing the control system. [View Full Paper]

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ASTRODYNAMICS, GUIDANCE, NAVIGATION AND CONTROL AND SPACE ROBOTICS

SESSION C.1.a
SESSION C.1.b

Chairs:

Hirohito Ohtsuka
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AAS 12-533

NEAR OPTIMAL DEPLOYMENT OF A SPACE ELEVATOR SYSTEM

Mehdi Keshmiri* **and Arun K. Misra†**

Deployment of the subsatellite to a given distance and within a specific time during the initial construction of a space elevator system can be conducted in many different ways with different costs. Modeling a space elevator tethered system, this paper analyzes the dynamics of the sub-satellite deployment in this initial stage and examines different strategies for the deployment in order to determine a near optimal solution for the subsatellite deployment. Motion of the system is assumed to be confined to the orbital plane and a nondimensional form of the equations of motion is utilized in the analysis. The near optimal deployment is solved through a parameter optimization. In order to construct the parameter optimization problem, time dependent functions are approximated by a set of finite series expansion of polynomial functions with unknown coefficients. The problem thus formulated is then solved numerically for three different strategies using genetic algorithms. The numerical results are compared and it is concluded that the least cost deployment corresponds to fixed orbital motion of the system.
Keywords: Space elevator systems, Tethered satellite systems, Optimal deployment.
[View Full Paper]

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AAS 12-534

EQUILIBRIUM CONFIGURATIONS AND CONTROL OF A MOON-ANCHORED TETHERED SYSTEM

Alexander A. Burov,[*] Anna D. Guerman[†] and Ivan I. Kosenko[*]

We study the problem of a Moon-tethered system with variable tether length in the framework of the restricted elliptic three-body problem. We consider spatial motion of the tether. Analysis is focused on three classes of pulsing configurations, that is, the solutions when the tether length varies proportionally to the distance between Earth and Moon. It is shown that such solutions exist only in the orbit plane; we examine their stability. The dynamics behavior of the system shows both regular and chaotic properties. [View Full Paper]

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AAS 12-535

THE ATHLETICS EQUATION AND STABILITY OF GYRO-SPACECRAFT WITH FLEXIBLE ACCESSORY

Qiao Guodong,* Li Tieshou* and Wang Dayi*

The athletics equation and stability of gyro-spacecraft with flexible accessories and controlled-wheels is researched in the paper. The mechanics model is established. The Lagrange equation is utilized to conclude the athletics equation based-on oscillation model analysis results. The stability of nonlinear equation zero-roots to some variables is proved; the sufficient and necessary conditions of asymptotic stability are given. The conclusion that the incomplete damp by wheel-velocity feedback can not always guarantee asymptotic stability, but can damp the centre-body and flexible accessories on certain conditions is proved. [View Full Paper]

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AAS 12-536

ROBOTIC AUTONOMY IN SPACE: VISION-BASED CONTROL OF ROBOTIC CAPTURE OPERATION

Benoit Larouche* **and Z. H. Zhu†**

On-orbit servicing (OOS) consisting of assembly, repair, and maintenance tasks of spacecraft using satellite robot manipulators is an emerging technology and promises to be a key element in the future of space exploration as missions are becoming more complex and expensive. The OOS usually employs a robotic manipulator mounted onto a satellite to capture, service, and refuel other orbiting satellites. One of the critical phases of OOS is the capture of the object satellite, where the chase satellite's robotic manipulator approaches the free-floating object satellite to capture it. If not properly controlled, the object satellite and the robot may be pushed away from each other or the endeffector/object may be damaged by the contact force. The key examination point of this paper is the vision based guidance and control of the robotic manipulator. The system employs pure photogrammetry as guidance and performs the capture of a non-cooperative target. In order to improve, both in terms of time and strains, the capture operation, several strategies are examined and implemented including, dynamic digital damping, visual compensation, and weighted capture criteria. Kalman filter is used in the vision system in order to capture a target in motion. The first step is the approach which aligns the gripper in the most likely orientation to result in a successful capture. The second is the capture which involves bringing the gripper within range and determining whether or not the target is within its grasp. The final stage is bringing the target to a relative halt with minimal force and disturbances to the target. Once captured, a hybrid speed-force controller is developed to limit the amount of force applied to the grasping bar of the target while propagating the speed and direction of the target in order to smoothly bring the target to a halt. Testing results have demonstrate the proposed control system is effective and robustness. [View Full Paper]

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AAS 12-537

A STUDY OF THE ORBIT DETERMINATION FOR A SPACECRAFT BY USING MODIFIED ORBIT ESTIMATOR

Tsutomu Ichikawa*

The error budget analysis is presented which quantifies the effects of different error sources in the Earth-based orbit determination process when the orbit estimation filter is used to reduce radio metric data. The estimator strategy differs from more traditional filtering methods in the nearly all of the principal ground system calibration errors affecting the data are represented as filter parameters. Error budget computations were performed for a Venus mission interplanetary cruise scenario for cases in which only X-band Doppler data were used to determine the spacecraft's orbit, X-band ranging data were used exclusively, and combined set in which the ranging data were used in addition to the Doppler data. Random nongravitational accelerations were found to the largest source of error contributing to the individual error budgets.
[View Full Paper]

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AAS 12-538

APPLICATION OF THE FORMATION FLYING ANALYTICAL MODELS TO THE PRISMA MISSION

Drago Matko,[*] Tomaž Rodič,[*] Sašo Blažič,[†]
Gregor Klančar and Gašper Mušič[*]

In the paper close formation flying equations are reviewed with respect to different manoeuvres and taking into account the required fuel consumption. Three scenarios are designed including parallel flying with in-track displacement demonstrating high-resolution optical dual satellite imaging and radar interferometric constellation, circumvolution as well as encircling of the target demonstrating debris observation and parallel flying with the radial displacement demonstrating fractionated spacecraft and accurate pointing of the formation. The designed scenarios were applied to a set of formation flying experiments, performed by SPACE-SI and OHB Sweden in September 2011 with Prisma satellites Mango and Tango. The results of the experiment are presented and the formation flying model predicted and measured data are compared. [View Full Paper]

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AAS 12-539

A DESIGN OF SMALL CIRCULAR HALO ORBITS AROUND THE L2 OF THE EARTH-MOON SYSTEM

Keita Tanaka* **and Jun'ichiro Kawaguchi†**

This paper discusses how to design small halo-type periodic orbits around the collinear points using low-level continuous acceleration typified by electrical propulsion systems. It starts with considering the linearized form of the equations of motion and develops the acceleration control law to make small halo orbits. [View Full Paper]

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AAS 12-540

TRAJECTORY DESIGN OF DESTINY MISSION

Mai Bando,[*] Masaki Nakamiya,[†] Yasuhiro Kawakatsu, Chikako Hirose[†] and Takayuki Yamamoto[†]

The trajectory design of the interplanetary mission "Demonstration and Experiment of Space Technology for INterplanetary voYage, DESTINY" is discussed. The trajectory optimization of low-thrust spacecraft pose a difficult design challenge. Moreover, DESTINY mission requires many constraints for the orbital design. In advance of optimizing the whole transfer mission, we investigated the basic theory to design which can take into account such constraints. [View Full Paper]

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AAS 12-541

EARTH REVOLUTION SYNCHRONOUS ORBITS AND AERO-GRAVITY ASSISTS TO ENHANCE CAPABILITIES FOR INTERPLANETARY MISSIONS BY SUB-PAYLOAD SPACECRAFT

Naoko Ogawa,[*] Yuya Mimasu,[*] Keita Tanaka,[†] Tomohiro Yamaguchi,[‡] Kazuhisa Fujita,[§] Shinichiro Narita[*] and Jun'ichiro Kawaguchi[**]

This paper proposes a strategy for sub-payload spacecraft to extend possibility of interplanetary exploration without interrupting the mission by the main spacecraft. Combination of Earth revolution synchronous orbits and aero-gravity assists at Earth will allow sub-payload spacecraft to control its departure timing, C3 energy and destination independently. A case study of a possible sub-payload bound for Mars is shown and a preliminary mission sequence is presented. [View Full Paper]

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AAS 12-542

EARTH-MOON TRANSFERS INVOLVING PERIODIC ORBITS AND INVARIANT MANIFOLDS THROUGH ISOMORPHIC MAPPING

Marco Giancotti,[*] Mauro Pontani[†] and Paolo Teofilatto[†]

Several families of periodic orbits exist in the context of the circular restricted three-body problem. This work studies the planar motion of a spacecraft among these periodic orbits in the Earth-Moon system modeled as a planar circular restricted 3-body problem. A new cylindrical representation of the coordinates, recently introduced by the authors, is used with two purposes: (i) determine periodic orbits around the Earth and the Moon and (ii) investigate the relations between their manifolds and those of the Lyapunov orbits at the libration points. This research proves how heteroclinic connections between manifolds of distinct periodic orbits can be detected in a straightforward fashion through this original cylindrical representation. Moreover, optimal constant-energy maneuvers are determined through the use of an alternative three-dimensional mapping. [View Full Paper]

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AAS 12-543

THE RESPONSIVE AND MOBILE CONCEPT OF GUIDANCE AND CONTROL SYSTEM OF EPSILON ROCKET

Hirohito Ohtsuka,[*] Kensaku Tanaka,[*]
Yasuhiro Morita[†] and Makoto Tamura[†]

The Epsilon Rocket has the technology inherited from Guidance & Control (G&C) system of M-V rocket, and has also more advanced 'responsive and mobile' functions. This G&C system is capable of various LEO missions, SSO missions and small type Planetary Exploration missions. Some Guidance laws are pre-installed for each typical orbit.

M-V was capable of launch of various sub-payloads. The Guidance software has the various kinds of utilities for their sub-payloads from M-V's lessons-learned. The estimation logic of angle-of-attack is installed in the G&C Flight Software to demonstrate the estimation in actual flight toward future cost reduction without the 'LAMU'.

1st stage and 2nd stage Guidance are designed based on the M-V Guidance Logic. 3rd Stage Guidance under spinning has a Rhumb-line Control function. The Rhumb-line G&C system realizes the reduction of liquid fuel consumption of Post Boost Stage (PBS). The 'LVIC' guidance law suitable for the low thrust propulsion is adopted on its PBS. The Control Logic of 1st stage and 2nd stage has the robustness for the uncertainties of the vibration absorber to reduce its sinusoidal environmental condition for payload. We will present the new Solid Motor Side Jet (SMSJ) for roll control on the 1st stage, which contributes for cost reduction. The SMSJ is composed of newly designed three Hot Gas Valves (HGV) and solid fuel propellant. We will present the firing tests results of HGV Engineering Model. [View Full Paper]

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AAS 12-544

STABILITY ANALYSIS OF ADAPTIVE CONTROL BASED ON CHARACTERISTIC MODEL FOR THE MINIMUM-PHASE MIMO SYSTEM

Yong Wang[*†]

In this paper, a stability analysis framework of adaptive control based on characteristic model for the SISO minimum-phase system is generalized to the MIMO minimum-phase system, which parameterizes the high-order, minimum-phase system to the lower-order linear model via a special decoupling method, and analyzes the stability of the complex sampled-data adaptive system via the stability analysis method of sampled-data system based on the approximated discrete-time model. Moreover, based on the idea, a decentralized modeling method helpful to design the decentralized controller, is proposed and applied in the attitude controller design of a kind of hypersonic vehicle. Simulation results show that the proposed methodology achieves excellent tracking performance. [View Full Paper]

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AAS 12-545

PERFORMANCE EVALUATION FOR POINTING CONTROL SYSTEM OF THE BALLOON-BORNE TELESCOPE

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The balloon-borne telescope is a planetary observation method launching a telescope to the altitude of more than 30 km by a stratospheric balloon. To conduct the long duration observation, the flight gondola has to equip with a pointing control system in order to catch and keep the target star in the field of view of the telescope during the flight. This research aims to develop the high accuracy pointing control system and conduct the technology demonstration flight. The goal of the pointing control is set as 0.1 arcsec. This paper introduces the results of the ground test and simulation study to evaluate the performance of the pointing control system. [View Full Paper]

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AAS 12-546

THE RESEARCH ON THE KEY TECHNIQUE OF THE PHYSICS PACKAGE OF RUBIDIUM ATOMIC CLOCK

Zhai Hao,[*] Zhang Jun,[†] Tu Jianhui,[‡] Yang Wei,[‡]
Cui Jingzhong[*] and Zhang Weiwen[§]

The physics package of the rubidium atomic clock is the discriminator of the atomic clock, determining the stability, accuracy and the aging rate of the rubidium atomic clock. To improve the stability is the key technique for the physics package of rubidium atomic clock. The optimizing design technique and optics filter technique were adopted in this paper to improve the short term stability of rubidium atomic clock. The parameter optimization technique was applied to get the zero light shift (ZLS) and zero temperature coefficient (ZTC) condition that are close to the superposition. On the bases of the design, the light shift, collision shift and microwave power shift were synthesized as temperature coefficient while the corresponding approach was offered. By this way the long term stability of rubidium atomic clock is improved. The stability of the rubidium atomic clock was improved in large extent with application of above research. Its short term stability $\sigma_y(1s)$ can be below 3×10^{-12}, while the stability $\sigma_y(1day)$ can be better than 3×10^{-14}. [View Full Paper]

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SATELLITE COMMUNICATIONS, BROADCASTING, ON-ORBIT AND GROUND SUPPORT SYSTEMS

SESSION C.2

Chairs:

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Joseph Yuen
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AAS 12-547

DETECTION PERFORMANCE OF UPGRADED "POLISHED PANEL" OPTICAL RECEIVER CONCEPT ON THE DEEP-SPACE NETWORK'S 34 METER RESEARCH ANTENNA*

Victor A. Vilnrotter†

The development and demonstration of a "polished panel" optical receiver concept on the 34 meter research antenna of the Deep Space Network (DSN) has been the subject of recent papers [1,2]. This concept would enable simultaneous reception of optical and microwave signals by retaining the original shape of the main reflector for microwave reception, but with the aluminum panels polished to high reflectivity to enable focusing of optical signal energy as well. A test setup has been installed on the DSN's 34 meter research antenna at Deep Space Station 13 (DSS-13) of NASA's Goldstone Communications Complex in California, and preliminary experimental results have been obtained. This paper describes the results of our latest efforts to improve the point-spread function (PSF) generated by a custom polished panel, in an attempt to reduce the dimensions of the PSF, thus enabling more precise tracking and improved detection performance. The design of the new mechanical support structure and its operation are described, and the results quantified in terms of improvements in collected signal energy and optical communications performance, based on data obtained while tracking the planet Jupiter with the 34 meter research antenna at DSS-13. [View Full Paper]

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AAS 12-548

A SOFTWARE DEVELOPMENT AND VERIFICATION PLATFORM FOR ON-BOARD COMPUTERS ON SMALL SATELLITES

Shinichi Kimura, Takaichi Kamijo, Yuhei Aoki and Sotaro Kobayashi*

With the increasing complexities of small satellite missions, high performance and high reliability has become more important for the on-board computers. To meet these requirements, higher reliability, complexity, and efficiency is required in software as well as hardware. We propose a software development and verification framework to enhance recursive use of software for the on-orbit computers. In this framework, the software can be constructed by software blocks based on a GUI software development kit without specialized knowledge about the hardware. In this study, we present an outline of the software development and verification framework to enhance recursive use of software for the on-orbit computers. [View Full Paper]

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AAS 12-549

FAULT-TOLERANT RESEARCH OF HIGH PERFORMANCE SOFT-CORE PROCESSOR BASED ON FPGA

Lingbo Kong,[*] Xinsheng Wang,[†] Bo Li,[‡] Bo Yang[‡] and Kaixing Zhou[*]

There are a lot of high energy particles in spatial environment, which always breakdown electronic chips and lead to faulty in on-board Components. Therefore, highly reliable processors are needed to solve the problems such as Single Event Upset (SEU) and Total Ionizing Dose (TID) effects which other ground processors do not need to consider. In this paper, we choose LEON3 as the Soft-kernel based on FPGA and implement fault-tolerant methods on it by modifying the open source codes. First we analyze the architecture of LEON3, and then propose the fault-tolerant strategy. The main fault-tolerant strategies include the triple modular redundancy (TMR) design of assembly line storage unit in integer processing, Hamming code checking of the register file and cyclic redundancy check (CRC) of cache storage units in the instruction cache and data cache where SEU easily occurs. The fault-tolerant strategies make the design of the LEON3 soft processors comprehensive. At last we use the Model sim's function of injecting data with single-bit or multi-bit upset into the specified position of FPGA configuration file; it could simulate the occurrence of SEU in this storage unit. The fault-tolerant strategies are verified through this method. The simulation result shows that performance of SEU protection is significantly improved. [View Full Paper]

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EARTH OBSERVATION, SMALL AND MICRO SATELLITE MISSIONS AND CONSTELLATIONS

SESSION C.3

Chairs:

Imada Takane
JAXA, Japan

Z. H. Zhu
York University, Canada

AAS 12-550

DESIGN OF AN ELECTRODYNAMIC TETHER NANOSATELLITE MISSION FOR SPACE DEBRIS REMOVAL DEMONSTRATION AND RADIO SCIENCE EXPERIMENT

Z. H. Zhu*

This paper proposes a mission concept of using nanosatellite formation flying with an electrodynamic tether (EDT) to achieve a set of engineering and scientific objectives. The engineering objectives of this mission are to perform a pioneering mission that will demonstrate deployment and stabilization of an EDT with an end-mass, current collection using bare EDT, field effect electron emission, and spacecraft de-orbiting by EDT technology using the low-cost nanosatellite platform. In addition, the mission will provide a new approach to (i) the understanding of coherent backscatter in the high-frequency long-range SuperDARN radar in order to improve the interpretation of convective motion in the F-region ionosphere at high latitudes, and (ii) the detection of EM radiation from conducting tether to validate theoretical prediction. The mission will employ heritage nanosatellite design with minimal modification to achieve a high level of fidelity, thereby minimizing potential risks. The details of nanosatellite designs for both the chief and deputy nanosatellites are explained. Finally, the implementation plan of the mission is also highlighted. [View Full Paper]

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AAS 12-551

SMALL SAR SATELLITE

Kiyonobu Ono,[*] Takashi Fujimura,[†]
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This paper introduces a new small SAR satellite that follows the small optical sensor satellite, ASNARO. USEF, NEDO and NEC are developing ASNARO satellite, which is a small LEO satellite (total mass<500kg) with the high resolution (GSD <0.5m) optical earth observation sensor. For the next mission, NEC has started the development of a new small SAR satellite as one of small earth observation satellite series using our small standard bus NEXTAR. This small SAR satellite has the following features, i.e. high resolution better than 1m, satellite mass is 500kg class, compatible with various rockets, short term and low cost development, and compatible operation and ground segments with ASNARO. [View Full Paper]

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AAS 12-552

TARGET DETECTION BY LEVEL SET IN DIGITAL PROCESSING OF SYNTHETIC APERTURE RADAR

Yan Zhang,* Honglin Li* and Yalin Li*

A new target detection arithmetic is introduced based on synthetic aperture radar for digital processing technology. A simulation is set up and the target can be detected effectively. And a series of experiments show that the arithmetic is practicable and can be applied in the aerospace field of remote sensing for target detection.
[View Full Paper]

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AAS 12-553

IN-FLIGHT CALIBRATION FOR GOSAT TANSO

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Akihiko Kuze[*] and Masakatsu Nakajima[*]

Keywords: GOSAT, greenhouse gases, FTS, Calibration. [View Full Paper]

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AAS 12-554

THE USE OF ONBOARD REAL-TIME DYNAMICAL COMPENSATION IN HIGH-ACCURACY IMAGE NAVIGATION OF REMOTE SENSING SATELLITE

Lv Wang[*], Shen Yili[†], Cheng Weiqiang[‡], Xu Haiyu[§]

A technology base on onboard real-time dynamical compensation to promote the accuracy of image navigation of the Chinese new generation geosynchronous earth orbit meteorological satellite was introduced in this paper. For the application of the technology, the remote sensing image information downloaded from FY-4 satellite will be navigated to the ideal image, which can be used to ground process to improve the weather report product. The theory, scheme, some important tests and experiments are put in the paper to introduce the mission. [View Full Paper]

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AAS 12-555

DATA COLLECTION MICRO-SATELLITE SYSTEM TASK ANALYSIS AND CONSTELLATION DESIGN

Zhao Yanbin,[*] Lu Qing,[†] Liu Peiling[†] and Ye Shalin[†]

Data Collection micro-Satellite System (Ab. DCSS) is a system which is designed to provide low-cost, two-way low data rate communications in order to collect and forward the information that comes from the ground. The DCSS system offers the solution of cumbersome and cost effective terrestrial communications between devices that are geographically dispersed. Due to its considerable commercial benefit, we are carrying on a project to develop such system. In this paper, we first illustrate a couple of similar DCSS systems developed by overseas branches, and analyze their task requirements and necessity of constructing the system. Secondly, we demonstrate the application fields where the DCSS system could be utilized under our mission demands, and provide an outline design concept of the DCSS system. Thirdly, we show the constellation design for the DCSS system, and analyze its global coverage capability. Finally, we elaborate the general design strategy of developing the micro-satellite used in the DCSS system.
[View Full Paper]

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HUMAN SPACE FLIGHT, SPACE STATION, PACIFIC SPACE PORTS AND LUNAR MANNED EXPLORATION

SESSION C.4

Chairs:

Misuzu Ohnuki
Space Frontier Foundation,
Japan

Charles J. Lauer
Rocketplane Global, Inc., U.S.A.

The following paper was not available for publication:

AAS 12-559

"Technical Business and Market Factors in Pacific Basin Spaceport Developments," by Charles J. Lauer, Rocketplane Global, Inc. (Paper Withdrawn)

AAS 12-556

HTV-R CONCEPT STUDY

Takane Imada* **and Yusuke Suzuki***

Japan contributes essential services for space experiments and enables human activities included as part of the international partnership to the ISS program by utilizing the HTVs (Kounotori). As the next step of on-orbit service, JAXA has commenced technical research into cargo return from orbit. The HTV was used in research as the base design and a return vehicle was added to enhance performance. The combined vehicle is called the "HTV-R" and this research will pave the way to acquiring the critical technologies necessary for human space flight. [View Full Paper]

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AAS 12-557

STUDY FOR THE NEW USAGE OF HTV

Daisuke Tsujita,[*] Hirohiko Uematsu[†] and Hiroshi Sasaki[‡]

The H-II Transfer Vehicle (HTV) is a Japanese unmanned cargo transfer vehicle developed for the International Space Station (ISS) re-supply and waste disposal purposes. Both HTV1 and HTV2 completed the mission successfully. Continuously, the HTV is planned to be launched once a year through HTV7. Under the circumstance that the achievement is evaluated highly and the expectation for the new usage of HTV is increased, we report some case studies in the paper. [View Full Paper]

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AAS 12-558

COMMERCIAL SPACEPORTS: THE GATEWAY FOR NEW SPACE UTILIZATION

Misuzu Ohnuki*

Commercial human spaceflight, especially space tourism is driving the creation of new space markets. The US space policy has been dramatically changed to open the market for commercial companies to develop human space vehicles. Suborbital space vehicle development is also turning a corner. In addition, especially in the suborbital area, other new markets will also be emerging such as microgravity experiments, earth observation, remote sensing, small satellite launching, and so on. Commercial spaceports are a necessary anchor infrastructure to create new space markets which will be able to build B to C markets in addition to B to B / B to G markets.
Key Words: Commercial Spaceport, Human Spaceflight, Space Utilization, PPP, Dual Use. [View Full Paper]

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ADVANCES IN MATERIALS AND SPACE STRUCTURES

SESSION C.5

Chairs:

Takayuki Imoto
JAXA, Japan

Taft H. Broome, Jr.
Howard University, U.S.A.

AAS 12-560

INFLUENCE OF VOIDS ON THE MATRIX OF C/C COMPOSITE

Tang Min,[*] Gao Bo[†] and Shi Hongbin[‡]

The relationship between the voids and matrix properties C/C composite was studied via homogenization theory. The samples were prepared by the low- damaged method, the voids content of matrix was measured by mercury intrusion method, and the microstructure of matrix was scanned by Micro-CT. Based on the probability density function of the void content, the geometry model of matrix, established by Python, was satisfied with real distribution. The calculation method was reliable by producing the matrix of coal pitch. The result was shown that the influence of voids content on the elastic properties of matrix is significant, while the size is weak. [View Full Paper]

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AAS 12-561

DEVELOPMENT OF CARBON/CARBON-SILICON CARBIDE COMPOSITE FOR SPACE MIRRORS

Li Ruizhen,[*] Li Jin[†] and Cui Hong[‡]

One of the key technologies for the high performance reconnaissance satellites and large-scale space telescopes with reflective mirrors is the fabrication of a very light-weight material with high specific stiffness, low thermal expansion and high thermal conductivity. As the most preferential candidate material, carbon/carbon-silicon carbide(C/C-SiC) composite offers many special advantages, such as: no toxicity, easy assembly, ultra-lightweight capability. Several reinforcement architecture and densification methods including molding randomly oriented milled carbon fibers, needling perform, liquid silicon infiltration (LSI) and chemical vapor reaction (CVR) can be utilized to meet the requirement of preparation of C/C-SiC and are summarized in this paper. [View Full Paper]

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SPACE TRANSPORTATION AND PROPULSION, FLUID DYNAMICS AND AEROTHERMODYNAMICS

SESSION C.6

Chairs:

Makoto Yoshida
JAXA, Japan

Liu Wei
China Aerospace Science and
Technology Corp., China

The following paper was not available for publication:

AAS 12-564
"Developments of Microwave Rocket and Its Advantages as a Low-cost Mass Transportation System to the Space," by Toshikazu Yamaguchi, University of Tokyo, Japan

AAS 12-562

A VISION OF FUTURE SPACE TRANSPORTATION SYSTEMS

Ryijiro Akiba* **and Nobuhiro Tanatsugu†**

This paper presents our concepts of the future space transportation systems to exchange visions among space communities in order to align their efforts towards purposes as coherent as possible. The core ideas are assembling space facilities in space, air launches with up to medium size rockets and recoveries with lifting surfaces, preferably shifting configurations. Stressed are amalgamation of aeronautics and astronautics, public participation to aerospace activities and mitigation of various regulative obstacles to those vigorous efforts. [View Full Paper]

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AAS 12-563

RESEARCH, DEVELOPMENT AND FLIGHT TEST OF SUBSCALE REUSABLE WINGED ROCKETS

Kyoshiro Itakura,[*] Shintaro Miyamoto, Gaku Sasaki, Takaaki Matsumoto[†] and Koichi Yonemoto[‡]

Since 2005, Space Systems Laboratory at Kyushu Institute of Technology has been studying fully reusable suborbital space transportation system as the first step for realizing space plane. The experimental systems of structure, recovery system, avionics system and ground system except propulsion system, are developed by the laboratory. In addition, many essential technologies for the reusable system have been also developed, such as liquid oxygen and hydrogen tanks and navigation, guidance and control system. In this paper, the essential technologies required for the reusable suborbital space transportation system are described. Finally, the flight experiment system and the result of winged rocket launch are also reported. [View Full Paper]

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AAS 12-565

COMBUSTION CHARACTERISTICS OF HYBRID ROCKET MOTOR USING GAP-BASED SOLID FUEL

Yutaka Wada,[*] Toshiyuki Katsumi[†] and Keiichi Hori[†]

Hybrid rockets using Glycidyl Azide Polymer (GAP) as a solid fuel has been studied. Linear burning rate spectrum of GAP was spread with a dilution of polyethylene glycol (PEG), and basically, self combustible mixtures are used for the gas hybrid rocket motor, and non-self combustible mixtures for traditional hybrid motor. Ultrasonic measurement is employed using three sensors especially developed for this use to evaluate the instantaneous surface regression rates in the traditional hybrid motor. Results from three sensors set at the upstream, middle and downstream of 1.3m length motor give indispensable information for the establishment of the flame model of hybrid motor. [View Full Paper]

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AAS 12-566

COMBUSTION MECHANISM AND THRUSTER APPLICATION OF HAN-BASED GREEN PROPELLANT

Toshiyuki Katsumi,[*] Junichi Nakatsuka,[†] Shujiro Sawai[‡] and Keiichi Hori[‡]

Hydroxylammonium nitrate (HAN) based solutions have been investigated as candidates for the green monopropellant. However, those high burning rate characteristics have hampered the application. In order to elucidate the mechanism of extremely high burning rates of some HAN based solutions, the combustion characteristics of HAN aqueous solutions were studied. It was found that the role of the two-phase region is very important and the intense boiling of water by superheat is responsible for the high burning rate. Hydrodynamic instability was taken into account and the pressure dependency of the instability was estimated. It was found that the instability is strongly affected by Markstein number. HAN-based monopropellant was applied to the thrusters of the small-sized experimental mockup of the supersonic aircraft, and used at the first free fall test. Their operation was successful and described in detail. [View Full Paper]

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AAS 12-567

STUDY ON APPLICATION OF DBD PLASMA ACTUATOR FOR SIDE FORCE CONTROL OF HIGH-ANGLE-OF-ATTACK SLENDER BODY

Hiroyuki Nishida,[*] Taku Nonomura,[†] Ryoji Inaba,[‡] Masayuki Sato[‡] and Satoshi Nonaka[§]

We have analyzed the asymmetric separation flow over a slender body at high angle of attack by numerical simulations aiming a control of the asymmetric vortices using a dielectric barrier discharge (DBD) plasma actuator. The Reynolds Averaged Navier Stokes/Large-Eddy Simulation hybrid method (RANS/LES) was adopted with the high-order compact spatial difference scheme. First, for investigating the characteristics of the asymmetric separation flow, the simulation of the flow field over the slender body was conducted for various angle of attack and bump height. Note that the bump is added near the body apex to simulate the symmetry-breaking imperfection. When the angle of attack or the bump becomes higher, the asymmetricity of vorticities becomes stronger. The side force has nonlinearity with the angle of attack or the bump height. Next, numerical simulations of the flow control using a plasma actuator were conducted. The side force coefficient can be continuously controlled in response to output power of the actuator within about ±1.0 on an average by the actuator's actuation at the aft body. However, the flow control effect is totally difference between starboard-side actuator's actuation and port-side actuator actuation. In addition, it is strongly influenced by the angle of attack. [View Full Paper]

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AAS 12-568

TECHNICAL FINDINGS OF HTV PROPULSION SYSTEM ASSOCIATED WITH ITS DYNAMIC CHARACTERISTICS

Shunichiro Nakai,[*] Mio Yamamoto,[†] Taizou Shiiki,[‡] Shinichiro Ishizaki,[§] Shinichi Takata,[**] Koichi Matsuyama[††] and Shinobu Matsuo[‡‡]

The H-II Transfer Vehicle (HTV) is JAXA's unmanned cargo transfer spacecraft that delivers supplies to the International Space Station (ISS).HTV is a large spacecraft which measures 10 meters in length and 4.4 meters in maximum diameter. One of the common challenges in operating a spacecraft propulsion system is to manage its dynamic characteristics, such as the water hammer at priming, propellant GHe saturation effects and thruster cross-coupling for example. In smaller systems, these dynamic characteristics are maintained within acceptable limits by careful selection of the propulsion elements. However, also careful operating management is necessary in larger propulsion systems, such as the one used in HTV. This paper presents an overview of the HTV propulsion system, its operational characteristics and the work being done to implement design and procedural modifications to effectively manage dynamic characteristics effects during various mission phases in orbit. [View Full Paper]

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AAS 12-569

THE DEVELOPMENT OF HTV EXPOSED PALLET MULTI-PURPOSE

Kana Yamamoto,* Michio Isayama,† Satoru Nakazato,‡
Hiroshi Yamamoto§ and Tsutomu Fukatsu**

The H-II Transfer Vehicle (HTV) is a Japanese unmanned transportation system for the International Space Station (ISS) launched by H-IIB launch vehicle from Tanegashima in Japan. The Logistics Carrier of HTV is composed of the pressurized section which carries the pressurized cargos and the unpressurized section which carries the Exposed Pallet. The Exposed Pallet (EP) carries the external cargos which are used in the external area of ISS. The EP is transported from unpressurized section of HTV to Japanese Experiment Module Exposed Facility (JEM-EF) or the ISS Mobile Servicing System (MSS) on the MBS payload ORU Accommodation (POA) via the Space Station Remote Manipulator System (SSRMS). At the HTV1 and the HTV2, the EP was transported to JEM-EF and the interface between the Cargo and EP was designed for particular cargo. From HTV3, the EP has been modified as Multi-Purpose Type Exposed Pallet (EP-MP) to have flexibility for combination of cargo interface and also for berthed location. This paper outlined the design result of EP-MP for the several combination of cargo. [View Full Paper]

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AAS 12-570

DEVELOPMENT OF A HYPERSONIC SHOCK TUBE FOR PLANETARY ENTRY AEROTHERMODYNAMICS

Gouji Yamada,[*] Shota Ago,[†] Takashi Matsuno[‡] and Hiromitsu Kawazoe[§]

A hypersonic shock tube is newly developed to simulate atmospheric entry flight conditions. Compression characteristics are investigated by compression tests and numerical analysis of compression process and the optimum operating condition is obtained. Measurements of shock velocity are conducted to investigate the performance of the shock tube and the result is compared with typical flight conditions. The shock tube can simulate orbital entry flight conditions for Earth entry and typical entry flight conditions for Mars entry. [View Full Paper]

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AAS 12-571

INFLUENCE OF ELASTIC DEFORMATION ON UNSTEADY MULTI-BODY SEPARATION

Lin Yanzhong,* Chen Bing, Zhang Xu and Xu Xu

A dynamic mesh technique for simulating the dynamics and trajectory of multiple moving bodies is presented. To analyze the influence of the store's aero-elastic deformation on its motion trajectory, radial basis functions were integrated into Chimera grid technique. The code capability was demonstrated by simulation of the 2D release of a missile from a two-dimensional aerofoil. In the case of the navigation of aircraft in low altitude and high-speed flight, the simulation predicted the trajectories of the missile with different aero-elastic deformations, which were compared with the trajectory of rigid missile. The results show that when the aero-elastic deformation reached a critical value, the trajectory of the missile appeared an obvious deviation, and the deviation increased with the augment of the deformation values. Furthermore, if the deformation is periodically, the deformation rate of the missile has an obvious influence on the separating trajectory at a determined deformation value, and the influence is sensitive to the oscillation frequency of the store. [View Full Paper]

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AAS 12-572

APPLICATION OF THE SCALING TECHNOLOGY IN NUMERICAL STUDY ON THE AERODYNAMIC CHARACTERISTICS OF LAUNCH VEHICLE

Xiaowei Wang,[*] Wei Liu,[†] Yufei Li[‡] and Zhaohui Gao[‡]

The scaling technology is applied in the numerical calculation of the aerodynamic characteristics of a new Launch Vehicle to reduce the calculation cost by decreasing the grid node number. The feasibility of substituting the prototype Launch Vehicle with a model one in the grid partition and numerical calculation is theoretically analyzed firstly. The model Launch Vehicle featuring small size is geometrically similar as the prototype one. And then a numerical example is presented to explain this method in detail. The results indicate that application of scaling technology in calculating the aerodynamic characteristics of a large size Launch Vehicle can evidently decrease the calculation cost and intensity. [View Full Paper]

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AAS 12-573

THE DEVELOPMENT STATUS OF THE EPSILON LAUNCH VEHICLE

Takayuki Imoto,[*] Yasuhiro Morita,[*] Shinichiro Tokudome[*] and Hirohito Ohtsuka[†]

The Epsilon launch vehicle has two main objectives. One is to evolve the highly efficient launch vehicle using the solid rocket system technologies that we have obtained for more than fifty years. The other is to meet the needs of the small satellites whose market will grow in the near future definitely. The needs and the demands of the small satellites have been flowdowned to the requirements of the Epsilon launch vehicle. As a next generation launch system, the Epsilon launch vehicle has several special features. The level of user friendliness is increased including more accurate orbit insertion precision, lower acoustic environment and lower separation shock level. It is optimized from the point of view of both cost and performance. This paper describes the system design of the Epsilon launch vehicle.

Key Words: Rocket Science, Space Transportation, Solid Propellant. [View Full Paper]

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AAS 12-574

RESEARCH AND DEVELOPMENT PROGRESS OF SPACE TRANSPORTATION PROPULSION R&D CENTER IN JAXA

Makoto Yoshida,[*] Takeshi Kanda,[†] Keiichiro Noda[‡] and Teiu Kobayashi[§]

Space transportation propulsion R&D center has conducted the wide scope of research and development activities from trouble shooting of the operating rocket engine to advanced research on air breathing engine for future space transportation systems since its establishment. In this paper, research and development progress in space transportation propulsion R&D center will be presented. The main activities in liquid rocket engine field is the development of LE-X, which is going to be the main engine of the first stage of the evolved H-2A/B launch vehicle, namely, H-X. The current status of this engine is to demonstrate the technology before full scale development. LE-X is characterized by high-thrust expander bleed cycle engine, high-fidelity simulations and analyses for reliability and risk-based design process, and the related technology level should be raised to TRL 5 to mitigate development risk. [View Full Paper]

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AAS 12-575

OVERVIEW OF LE-X RESEARCH AND DEVELOPMENT PROGRAM

Hideo Sunakawa*

JAXA has begun the trade study of the Japan's next flagship launch system, which aims for significantly reduced cost and high reliability comparable to the human space flight. LE-X is the booster liquid rocket engine for the next flagship launch vehicle. The LE-X applies the open expander cycle. The design of the LE-X engine thrust chamber and FTP is progressing, and currently in the production phase of the full scale component test. High fidelity simulation tools are prepared to mitigate liquid rocket engine major technical issues. The full scale thrust chamber and FTP tests are planned to be conducted in 2013. These full scale component tests results will be the world first demonstration of the open expander booster engine. [View Full Paper]

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AAS 12-576

CRITICAL PERFORMANCE OF TURBOPUMP MECHANICAL ELEMENTS FOR ROCKET ENGINE

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It is generally acknowledged that bearings and axial seals have a tendency to go wrong compared with other rocket engine elements. And when those components have malfunction, missions scarcely succeed. However, fundamental performance (maximum rotational speed, minimum flow rate, power loss, durability, etc.) of those components has not been grasped yet. Purpose of this study is to grasp a critical performance of mechanical seal and hybrid ball bearing of turbopump. In this result, it was found that bearing outer race temperature and bearing coolant outlet temperature changed along saturation line of liquid hydrogen when flow rate was decreased under critical pressure. And normal operation of bearing was possible under conditions of more than 70,000 rpm of rotational speed and more than 0.2 liter/s of coolant flow rate. Though friction coefficient of seal surface increased several times of original value after testing, the seal showed a good performance same as before. [View Full Paper]

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AAS 12-577

DEVELOPMENT AND TEST OF THE LOX/LNG REGENERATIVE COOLED ROCKET ENGINE

Kohei Taya,[*] Yasuhiro Ishikawa,[*] Hiroyuki Sakaguchi,[*] Kenichi Kimoto[*†] and Yutaka Sato[‡]

IHI Corporation and IHI Aerospace have been developed LOX / LNG (Liquefied Natural Gas) regenerative cooled rocket engine since 2008. This paper describes the design of the 100kN thrust level class LOX/LNG regenerative cooled rocket engine and the results of sea level firing test. The engine adopted Gas Generator Cycle because of the system robustness for LNG's behavior at super-critical condition. It will be the first practical engine with regenerative cooled chamber in the world making use of LNG or Methane as propellant. [View Full Paper]

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AAS 12-578

PRESSURE AND GEOMETRY SCALING OF FLOWFIELD AND COMBUSTION CHARACTERISTICS OF GASEOUS HYDROGEN AND GASEOUS OXYGEN SHEAR-COAXIAL INJECTORS

Xiaowei Wang,[*] Wei Liu[†] and Yufei Li[‡]

Theoretical, numerical and experimental studies on the scaling of the cold mixing and combustion flowfields in shear-coaxial single element injector chambers with gaseous oxygen and gaseous hydrogen are reported. Large eddy simulations of single-element injector chambers at different chamber pressures and different sizes were carried out, and single-element injector heat sink chambers were designed and hot-fire tested at chamber pressures from 0.92 to 6.1MPa and different sizes. Wall temperature measurements were used to evaluate the similarity of combustion flowfields in the tests. The results of numerical calculations and experiments declared the similarities of cold mixing and combustion flowfields of different chamber pressures and sizes. [View Full Paper]

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AAS 12-579

POST-FLIGHT ANALYSIS OF HAYABUSA; ASTEROID SAMPLE RETURN CAPSULE

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HAYABUSA(MUSES-C); an asteroid explorer returned to the earth after the 7 years of lengthy and troubled voyage, and its capsule reenters into the Earth's atmosphere. It performed a safe reentry flight and recovery. For the design of the capsule, many considerations were made due to its higher entry velocity and higher aerodynamic heating than those of normal reentry from earth orbit. Taking into account the required functions throughout the orbital flight, reentry flight, and descent/recovery phase, the capsule was deigned, tested, manufactured and flight demonstrated finally. The paper presents the concept of the design and qualification approach of the small space capsule of the asteroid sample and return mission. And presented are how the reentry flight was performed and a brief overview of the post flight analysis primarily for these design validation purposes and for the better understanding of the flight results.
[View Full Paper]

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AAS 12-580

TECHNICAL DEMONSTRATIONS FOR REUSABLE SOUNDING ROCKET SYSTEM

Satoshi Nonaka,[*] Hiroyuki Ogawa,[*]
Yoshihiro Naruo[*] and Yoshifumi Inatani[†]

A fully reusable sounding rocket is proposed and conceptually designed in ISAS/JAXA. In phase A in the proposed project, technical demonstrations for key technologies to develop the reusable sounding rocket are planed as follows; 1) reusable engine development and repeated operations, 2) reusable insulation development for cryogenic tank, 3) aerodynamic design and model flight demonstration for returning flight, 4) cryogenic liquid propellant management demonstration, 5) landing gear development and 6) health management system construction. In this paper, the present system design of the reusable sounding rocket and technical demonstrations are summarized.
[View Full Paper]

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CURRENT AND FUTURE SPACE UTILIZATION:
Including Microgravity and Life Sciences, Space Environment and Debris, Space Solar Power Systems and International Collaborations

SESSION C.7

Chairs:

Yasuhiro Kawakatsu,
JAXA, Japan

Z. H. Zhu
York University, Canada

AAS 12-581

ELECTROSTATIC LEVITATION FURNACE FOR THE INTERNATIONAL SPACE STATION

Keiji Murakami,[*] Naokiyo Koshikawa,[*] Koichi Shibasaki,[*] Takehiko Ishikawa,[†] Junpei Okada,[†] Tai Nakamura,[*] Yukiko Yamaura,[‡] Tatsuya Arai,[‡] Naoki Fujino[‡] and Tetsuya Takada[‡]

JAXA has been utilizing Japanese Experiment Module "Kibo" of the International Space Station (ISS) since August 2008 and has obtained significant results through its first phase utilization. The primary purpose of this phase was to examine Kibo's capability as a space laboratory as well as to conduct selected scientific themes. In the second phase which began in 2010, we plan to challenge variety of themes to contribute to the society such as practical researches aiming industrial applications, technology demonstration for future space activities, and cultural and educational precursor experiments.

The Electrostatic Levitation Furnace (ELF) is one of the experiment facilities for materials science, which will be on board Kibo in the near future. A unique feature of ELF is to levitate a sample material inside the furnace by means of Coulomb's force throughout the fusion/solidification experiments. By utilizing this capability JAXA plans to study thermo-physical properties of many kinds of the oxides which cannot be measured on earth. In addition, creation of new materials is another objective of space experiments using ELF. In the absence of gravity ELF can generate the ultimate environment for the materials, which is expected to contribute to a new discovery.

This paper shows a detailed feature of ELF and its capability as well as typical experiments to be conducted in Kibo for the purposes of scientific research and industrial applications. [View Full Paper]

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AAS 12-582

THE STUDY ON STRUCTURE OF LARGE REFLECTOR FOR SPACE SOLAR POWER SYSTEMS (SSPS)

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SSPS converts solar energy into microwave or laser beam in the geostationary orbit (GEO), and the microwave and laser beam are transmitted to the earth even in day or night and even in cloudy or rainy day. Therefore this system is expected as a means to solve energy and environment problems in the future. The microwave based SSPS has large reflector for gathering of solar light, solar panel and microwave power transmitter. They are large structure of km size. Now as a first step toward realizing SSPS, we study how to assemble structure of 100m size like reflector and panel for antenna and generator on orbit.

The author made structure models of reflector in different styles of 100m size. These models are analyzed for structural properties (mass, stiffness, strength). Furthermore, these models are analyzed the relation between flatness of their models deformed by the disturbances and rate of gathering solar light. From the results of these analyses, the author tries to select the best model of reflector in the size of 100m for SSPS. Therefore, the purpose of this study is to determine proper structure and configuration of model of reflector for SSPS from these models.

The model of reflector is composed of ten thousand segmented mirrors, main truss structure, and bus equipment. Each mass of mirrors, structure and bus is 1000kg. Each segment mirror is a film mirror of 1m×1m square. The structural properties of models were analyzed on finite element method (FEM) by treating mirrors and bus equipment as the point mass. Aluminum alloy is used as main structural material. Furthermore, the author used the data of distribution of illumination of a commercial film mirror which was measured flatness and analyzed in the case that the mirror is exposed to the sun. The author analyzed total distribution of illumination in reflector by superposing this data of one mirror. The deformation of models is caused by disturbances (orbital and attitude control, solar pressure, gravity gradient and atmospheric drag).

From the results of these analyses the author made trade-off of these models and selected the best model of reflector in the point of stiffness (natural frequency), deformation, major principal stress, buckling stress, distribution of illumination, light collection efficiency and ratio of nonuniformity of illumination. The standard model of reflector is 100m×100m square. Performances of other models are evaluated by comparison with this standard model. This paper shows the result of trade-off in analyzed models and the best models the author selected. [View Full Paper]

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AAS 12-583

EXPLORING INNOVATIVE WAYS OF COOPERATION AND TECHNOLOGY TRANSFER BETWEEN JAPAN AND COLOMBIA

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The purpose of the present paper is to review an informal call emitted by Colombian high authorities in the possibility to exchange with Japan a Special Agreement to build, launch and put in geostationary orbit a multi-function satellite for Colombia. The capabilities for that satellite may be: Communication Satellite, Geo Positioning GPS Satellite, Remote Sensing and Observation Satellite, and Meteorological Satellite.

The objective is very complex in order to improve not only technological development but human resource high scientific and technological development. Colombia and Japan shall use that kind of agreement to enhance regional partnership and international cooperation through Diplomatic links. [View Full Paper]

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SPACE EXPLORATION SYSTEMS: Including Advanced Technologies and Flight Systems to Enable Robotic Precursor, Lunar and Other Missions

SESSION C.8

Chairs: Keiji Murakami,
JAXA, Japan

Mark C. Lee
NASA, U.S.A.

The following paper was not available for publication:

AAS 12-584
"Advanced Space Exploration Systems Program," by Mark C. Lee, NASA, U.S.A. (Paper Withdrawn)

The following paper numbers were not assigned:

AAS 12-591 to -600

AAS 12-585

DESTINY MISSION OVERVIEW: A SMALL SATELLITE MISSION FOR DEEP SPACE EXPLORATION TECHNOLOGY DEMONSTRATION

Yasuhiro Kawakatsu* **and Takahiro Iwata***

DESTINY which stands for "Demonstration and Experiment of Space Technology for INterplanetary voYage" is a mission candidate for the third mission of ISAS small science satellite series. DESTINY is launched by an Epsilon launch vehicle, JAXA's next-generation solid fuel rocket, and is firstly placed into a low elliptical orbit. It raises its altitude by the use of ion engine and reaches the Moon. Then, it is injected into transfer orbit for L_2 Halo orbit of the Sun-Earth system by using lunar gravity assist. On the way to L_2 Halo orbit, DESTINY conducts demonstration and experiment on key advanced technology for future deep space missions. This paper presents the overview of DESTINY mission as well as its importance and significance in Japanese space science program. [View Full Paper]

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AAS 12-586

FORMATION FLYING AROUND LIBRATION POINTS OF CIRCULAR RESTRICTED THREE BODY PROBLEM WITH SMALL μ

Zhao Yuhui,[*] Hu Shoucun,[†] Hou Xiyun[*] and Liu Lin[‡]

The success of Hayabusa of JAXA draws more and more attention to asteroid exploration in recent years. Various plans have been proposed and implemented. Long period observations of an asteroid are required to obtain its detailed information. However, it is very difficult for the explorer to orbit a low-mass and irregularly shaped asteroid. In this case, formation flying with the asteroid is considered. Different strategies of formation flying should be adapted for different conditions: when the gravity of the asteroid could be neglected, C-W equation is applicable; when its gravity can't be ignored, the formation flying can be based on the dynamics of libration point L1 in the CRTBP (circular restricted three body problem).

This paper studies the dynamics and control strategies of collinear libration point L1 of CRTBP with small μ. The CRTBP is an appropriate dynamic model for the three body problem system of the Sun, the asteroid and the spacecraft, and figures out the features of the halo orbits in this kind of CRTBP. The magnitude of μ, which is a parameter weighing the gravity of the asteroid, has a significant effect on the stability of the periodic orbit. Orbit control for station keeping of the spacecraft is also discussed and the relationship between energy consumption and the parameter μ is presented. Theoretical analysis and numerical simulations show that formation flying with an asteroid on the basis of halo orbit around libration point is applicable in asteroid exploration. This strategy, in some cases, consumes less orbit control than that of the strategy based on C-W equations. [View Full Paper]

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AAS 12-587

JAPANESE MOON LANDER SELENE-2 AND ITS TECHNOLOGY DEVELOPMENT

Tatsuaki Hashimoto,[*] Takeshi Hoshino,[†] Satoshi Tanaka,[‡] Hisashi Otake,[§] Masatsugu Otsuki[**] and Kazunori Ogawa[††]

JAXA is planning moon exploration missions following Kaguya (SELENE). The first Japanese moon lander is SELENE-2 whose missions include technology demonstrations, scientific observations, investigations for future moon utilization, and social or political purposes. Its phase-A study started in the summer of 2007. SELENE-2 will land on the near side of moon and perform in-situ geological and geophysical observations to improve the knowledge on the origin and the evolution of the moon. Investigations of surface environment are important for future lunar exploration including human activity. It also demonstrates precise landing, hazard avoidance, surface mobility, and night survival technologies. In this paper, recent progress of technology development for SELENE-2 is presented. [View Full Paper]

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AAS 12-588

LAUNCHING LOW MARS ORBITER BY USING AEROBRAKING

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Aerobraking had been successfully used to launch spacecrafts to Mars and greatly reduced the costs. Propulsive maneuver velocity that can be saved using aerobraking is presented. The relation between the time needed in the main phase of aerobraking and the aerobraking parameters is discussed. These parameters include the scale height of the atmosphere, spacecraft's effective surface-mass ratio, drag coefficient and the maximal allowed dynamic pressure. It turns out that the time needed in the main phase is approximately inversely proportional to the surface to mass ratio and the maximal allowed dynamic pressure. Although this paper deals with Mars aerobraking, this approximate relation can also be used for other planetary aerobraking design. [View Full Paper]

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AAS 12-589

ERROR ANALYSIS AND MID-COURSE MANEUVER OF EARTH-MARS TRANSFER ORBIT

Zhao Yuhui,[*] Hou Xiyun[*] and Liu Lin[†]

The trajectory of a spacecraft from the Earth to the Mars consists of three different stages: the trajectory in the Earth's gravitation field, the trajectory in the Mars' gravitation field and the trajectory out of gravitation fields of both the Earth and the Mars which is regarded as the interplanetary cruise stage. As a result of various perturbations, orbit insertion errors, observation and control errors and other factors, the actual transfer orbit of spacecraft from the Earth to the Mars will unavoidably deviate from the nominal transfer orbit and the errors enlarge during the flight due to strong nonlinear effects. Therefore, several trajectory correction maneuvers (TCM) are necessary to complete the mission successfully.

This paper presents the characteristics of the error transition matrix which is in fact the state transfer matrix and figures out the propagation of different kinds of errors during all the three stages of the entire flight. On the basis of the error transition matrix, the additional velocity increments Δv for mid-course maneuvers to eliminate some specific errors are roughly estimated, the result of which is then compared with the results calculated by numerical methods using B plane method and Monte Carlo analysis. The comparison shows that, the error transition matrix could indicate the feature of error diffusion and be used to estimate energy consumption for TCM. This result could also be applied to error analysis and consumption estimation of other interplanetary explorations. [View Full Paper]

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AAS 12-590

ON ORBIT DESIGN AROUND A MICRO GRAVITY ASTEROID

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The interest of exploring small body has been growing over these years, especially the near Earth asteroids which have potential threat to the Earth. The masses of the asteroids are mostly very small compared with that of the planets, so the asteroids' central gravity is too small to have the probe orbit them directly all the time. Therefore, it is necessary to study the orbits around a micro gravity asteroid. In the paper, two kinds of nominal orbits are proposed. One is the quasi-period orbits around the collinear libration point; the other is the formation flying orbits around the asteroid. Due to the inevitable existence of errors, station keeping of the probe is necessary. Solar sails propulsion is used to provide station-keeping at nominal orbits. There are two control techniques including solar sail area variation and solar sail pitch and yaw angle variation considered. Also optimal control laws are used to minimize the control requirements in this paper. Finally, the control results are displayed. [View Full Paper]

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