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**Frontispiece:**
Twelfth ISCOPS Technical Tour to John H. Chapman Space Center, Saint-Hubert, Québec, Canada, 30 July 2010 (Source: Canadian Space Agency).

**Front Cover Illustration:**
STS-124 Photo Image — Located on the exterior of the Destiny laboratory of the International Space Station, the Canadian-built Dextre, also known as the Special Purpose Dextrous Manipulator, is photographed by a crewmember during the STS-124 mission’s second planned spacewalk. The blackness of space and Earth’s horizon provide the backdrop for the scene. (Credit: NASA Photo).
APPLICATIONS OF SPACE TECHNOLOGY FOR HUMANITY

Volume 138
ADVANCES IN THE ASTRONAUTICAL SCIENCES

Edited by
Peter M. Bainum
Arun K. Misra
Yasuhiro Morita
Zhang Chi

Proceedings of the 12th International Conference of Pacific-basin Societies (ISCOPS) held July 27–30, 2010, Montréal, Québec, Canada.

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

This proceedings volume, which consists of one hard cover bound volume and a CD ROM supplement, includes the available papers presented at the Twelfth International Space Conference of Pacific-basin Societies (ISCOPS), July 27-30, 2010, Montréal, Québec, Canada. 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).
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), 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 Twelfth 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 Twelfth International Space Conference of Pacific-basin Societies (12th ISCOPS) was held at the Delta Montréal Hotel on July 27-30, 2010. The theme was “Applications of Space Technology for Humanity.” This symposium was the twelfth in a continuing series of biennial conferences co-sponsored by the American Astronautical Society (AAS), the Chinese Society of Astronautics (CSA), and the Japanese Rocket Society (JRS).

The conference was originally planned to be held in May 2009 in Montréal, Canada. However, due to the threat of swine flu around the world, the organizers decided to shift the period of the conference, based on the discussion with the technical co-chairpersons of CSA and JRS.

In total, 73 attendees from seven countries (China, Japan, U.S.A., Canada, India, Malaysia and Iran) were registered and more than 60 papers were presented in the International/National Space Programs session, the International Student Conference and Competition, and eight technical sessions. This 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 and control; satellite communications, tracking, telemetry and command; satellite remote sensing, meteorology, small satellite systems/constellations; human space flight, space station, and Pacific space ports (including lunar research and exploration); materials and structures; space transportation and propulsion; microgravity sciences, including space debris environment and life sciences; and Moon, Mars and robotic exploration.

The 12th ISCOPS acknowledges the support of the Canadian Space Agency for providing an excellent technical tour of their John H. Chapman Space Center in Saint-Hubert, Québec.

The technical support and coordination provided by Prof. Yasuhiro Morita and Ms. Zhang Chi are greatly acknowledged.

The 13th ISCOPS is scheduled to be hosted by the JRS in Japan in 2012. We look forward to working again with our colleagues from the Pacific-basin to ensure the success of the 13th ISCOPS.

Prof. Emeritus Peter M. Bainum
Prof. Arun K. Misra
AAS Technical Co-Chairs,
12th ISCOPS
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INTERNATIONAL/NATIONAL SPACE PROGRAMS
SESSION A

AAS Chairs: Prof. Peter M. Bainum
Professor Emeritus
Howard University, U.S.A.

Prof. Arun K. Misra
McGill University, Canada

JRS Chair: Prof. Yoshifumi Inatani
ISAS/JAXA, Japan
STATUS OF JAXA ACTIVITIES AND RELATED ISSUES

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.
THE CANADIAN SPACE PROGRAM

David Kendall†

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* Only slides/charts were available for publication for this presentation.
† Dr. Kendall is Director General, Canadian Space Agency, Canada.
ADVANCEMENT OF INTERNATIONAL SPACE EXPLORATION†

Neal Newman†

[View Full Set of Presentation Slides/Charts]

* Only slides/charts were available for publication for this presentation.
† Senior Advisor, NASA Office of International and Interagency Relations, U.S.A.
INDIAN SPACE PROGRAMME:
SPACE TECHNOLOGY FOR SOCIETAL BENEFITS*

Deviprasad Karnik†

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INTERNATIONAL STUDENTS CONFERENCE
SESSION B.1 (Masters Level)
SESSION B.2 (Ph.D. Level)

AAS Chair: Prof. Trevor Sorensen
University of Hawaii, U.S.A.

JRS Chair: Prof. Yasuyuki Miyazaki
Nihon University, Japan

CSA Chair: Dr. Hou Xinyun
Nanjing University, China

AAS Judge: Prof. Krishna D. Kumar
Ryerson University, Canada

JRS Judge: Prof. Yasuyuki Miyazaki
Nihon University, Japan

CSA Judge: Dr. Hou Xinyun
Nanjing University, China

The following paper was not available for publication:

AAS 10-405
SHAPE AND REGOLITH DISTRIBUTION
OF RUBBLE-PILE ASTEROID

Yusuke Zemba*

A spacecraft “Hayabusa” revealed that an asteroid “Itokawa” was a rubble-pile asteroid. The shape and surface regolith distribution of this asteroid was unique. This research purpose is to bring out the formational process of the asteroid. I think “Brazil nut effect” holds the key to the resolution. I conducted experiment on the ground and discuss the effects on grain properties and shaking properties. I ran simulation and compare the simulation results with experimental ones. I also discuss whether the model is reasonable. [View Full Paper]
COPING WITH SPACE ENVIRONMENTAL ISSUES IN DEVELOPMENT OF NEW WIRELESS SPACECRAFT DATA BUS

Tong Ning* and Yunlong Lin†

A wireless spacecraft data bus testbed is constructed based on existing Blue-tooth technology to reduce the bus volume and the design complexity while maintaining the integrity of, or even improving upon, current ground use standards. There is a need to characterize the operation and behaviour of such wireless systems for future space application. Variables include the selected transmission methods, frequencies employed, protocols and the vulnerable environmental effects, such as space radiation, EMI, EMP, HIRF etc., or disruption of proper operations by other sources. This paper describes the dealing with environmental issues that involve the data handling matters such as radiation hardening, interference and jitter management and security implications posed by the space environment. A computing model of LEO radiation environment is introduced followed by the discussion of the effects. Analysis of current wireless components is given to support future ground experimental test. Both computing simulation and ground experimental simulation will be helpful and useful to future wireless spacecraft bus build standard which will regulate components selection, interface design, hardware and software construction and test to cope with the space environmental issues.

[View Full Paper]

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† Assistant Professor, Department of Earth and Space Science and Engineering, York University, 4700 Keele Street, Toronto, Ontario M3J 1P3, Canada.
REFINING MEMBRANE STRUCTURAL MODEL VIA VIBRATION EXPERIMENT IN VACUUM CHAMBER

Mitsue Hasome*

In this paper, behavior of flexible membrane is discussed. In recent years, there have been a lot of attentions given to the use of membranes for space structure applications. As for the solar sail of spinning type in Japan has no rigid structure supporting its membrane, this mechanism has the advantage in its simple and lightweight structure, however, the attitude control is difficult due to the flexible membrane. I verify behavior of flexible membrane by numerical simulations using multi particle model (MPM). The multi particle model is using multi particle method which replaces membrane by spring, damper and mass. Compare with result of MPM and experimental result, refining membrane structural MPM. [View Full Paper]

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FEEDBACK-BASED TIME OPTIMAL CONTROL SYSTEM FOR RAPID ATTITUDE MANEUVER WITH MICRO CONTROL MOMENT GYROS

Kyohei Akiyama*

Time optimal control logic with CMGs has great advantages achieving rapid attitude maneuvers and the avoidance of the singularities of the CMG system. However, two disadvantages have been come from this time optimal control logic. Firstly, it needs long time to calculate the optimized solution using the on-board computer on small satellites. Secondly, time optimal control without feedback is less robust. In this paper feedback-based time optimal control logic for rapid attitude maneuvering using Micro control moment gyros is proposed. This logic has improved rapid attitude maneuvering with a CMG system. [View Full Paper]

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This paper proposes a new systematic way of deriving quasi-periodic relative orbits for formation flight under general perturbation environment. A periodic property of relative orbits is usually desired for general formation flight missions. Although it is possible to design perfect periodic orbits analytically based on the two-body problem, the periodicity is deteriorated due to the perturbation forces such as gravity of third bodies, geopotential perturbation and dissipative forces in real environment. The method in this paper enables to design quasiperiodic relative orbits by the singular value analysis using a mathematical structure of an approximated state transition matrix. In addition, this paper evaluates the effectivity of the method, such as the relationship between the quasiperiodicity of derived quasi-periodic orbits and the similarity to the base orbits obtained from two-body problem. [View Full Paper]
ROBUST ADAPTIVE CONTROL USING PARTICLE FILTER FOR FUTURE SPACE TRANSPORTATION

Masashi Miura*

Future space transportation systems should be highly reliable, responsive, frequently operable and usable for many different types of missions flexibly. Then it is necessary for the control system of future space vehicles to have high robustness and high performance in adapting to wide-range flight conditions, property variations and unusual situations. This research suggests an adaptive control system using particle filter as the controller that satisfies these requirements. [View Full Paper]

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CONTROL OF ATTITUDE DYNAMICS OF A SATELLITE USING FLUID RINGS

Nona Abolfathi Nobari

Studied in this paper is the three-dimensional attitude control of a satellite using fluid rings. These rings, which act as attitude actuators, contain a special type of fluid and that is regulated to generate the torque required to stabilize the satellite attitude. Although three fluid rings are enough to stabilize satellites attitude angles about the three orthogonal directions, a set of four fluid rings in a pyramidal configuration is used to add redundancy to the system. In this paper, the mathematical model of the attitude dynamics of the system is developed. The natural dynamical behaviour of the system without applying any control torque is simulated to study the damping effect of the fluid rings on the satellite attitude. Varying the pyramidal configuration angle, the platform which produces the largest total damping torque is obtained. However, the results of natural damping are not satisfactory, and hence, designing a controller is necessary. It is concluded, as control actuator, that the fluid rings are capable of producing the sufficient torque to stabilize the disturbances. Finally, the effect of the failure of one fluid ring on the performance of the actuators and the satellite is analyzed to prove the merit of using a redundant set of actuators. [View Full Paper]

* Second Place, Ph.D. Level Competition. Ph.D. Candidate, Department of Mechanical Engineering, McGill University, 817 Sherbrook Street West, Montreal, Canada, Postal Code: H3A 2K6.
INFLUENCE ANALYSIS OF MEASUREMENT ERRORS ON EKF BASED SATELLITE ATTITUDE DETERMINATION METHOD

Yuanyuan Jiao*

The Extended Kalman filter (EKF) is the workhorse of the spacecraft attitude estimation. However, the accuracy of this method largely depends on the fitness of measurement model. In this paper, we aim to analyze the influence of measurement errors to EKF based attitude determination approach. The measurement errors, which are divided into structural error and nonstructural error by their influences, are analyzed in principle. In the setting of the combination of star sensors and gyros, according to the property of innovation, we employ the technique of correlation test to analyze the influences of different kinds of errors. Promising experimental results show the effectiveness of our previous analysis. [View Full Paper]

* Ph.D. Level Competition. Ms. Yuanyuan Jiao, Department of Mathematics and Systems Science, National University of Defense Technology, Changsha, Hunan, China 410073.
SURVIVABILITY IMPROVEMENT USING LOGISTICS NETWORK FOR FUTURE SUSTAINABLE MANNED MARS EXPLORATION

Yasuhiro Akiyama*

Hazard management of human space missions are focus on only short term hazard ever. However, logistics risk such as lack of spear parts or consumables endanger astronaut’s life in Mars exploration. In this research, I focus on survivability of astronauts in Mars base against logistics risk. So, new logistics system is constructed in this research. This system can manage resources from a long-term view and Transportation system and resource management system are integrated. Optimization to minimize IMLEO suggest the advantage of this system. However, the necessity of new technologies such as nuclear propulsion are suggested too. [View Full Paper]

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ATTITUDE CONTROL OF A DEPUTY SATELLITE USING COULOMB FORCING FOR THE PURPOSE OF ON-ORBIT SERVICING

Paul Iliffe*

This paper discusses the planar attitude control of a deputy satellite encircling a central satellite body. Attitude and positional control are achieved by exploiting the spacecraft charges, a Lyapunov based control law, a switching control logic changing between attitude and attitude-positional control and a temporary guidance ellipse method. The desired attitude is defined as the deputy satellite body fixed y-axis pointing towards the composite satellite centre of mass. In translational terms the target path (nominal reference motion) is a Clohessy Wiltshire bounded solution relative to the central satellite body. Appropriate feedback gain factors lead to convergence of the deputy satellite to the target attitude and position. [View Full Paper]

* First Place, Ph.D. Level Competition. Title: Mr., Department of Mechanical and Aerospace Engineering, Laboratory for Space Systems, Tokyo Institute of Technology, Ishikawadai 1 Bld., Ookayama Campus, Meguro-ku, Tokyo, Japan.
INTELLIGENT DIAGNOSIS FOR LAUNCH SYSTEM USING MAHALANOBIS TAGUCHI SYSTEM

Yoshitaka Yoneda*

Launch systems should be more intelligently to improve operational and economical performance without decreasing safety and reliability. One of solutions is autonomous diagnosis of launch vehicle. In this study, effectiveness of autonomous check-out operation using MT system that used on quality engineering is verified.

[View Full Paper]

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

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McGill University, Canada

JRS Chair: Prof. Yasuhiro Morita
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The following paper was not available for publication:

AAS 10-423
“Space Network Control System Design,” by Wang Baohua and Fang Dong, Xi’an Satellite Control Center, China (Paper Withdrawn)
ON UTILIZATION OF SOLAR SAILS IN TRIANGULAR LIBRATION POINT MISSIONS IN THE EARTH-MOON SYSTEM*

Xi-yun Hou,†‡ Jing-shi Tang†‡ and Lin Liu†‡

Abstract: In the real solar system, due to various perturbations, the triangular libration points of the earth-moon system are unstable. However, there are quasi-periodic orbits around them. These orbits show mild instability. Due to the instability, orbit control is necessary for the spacecrafts around these points. In the paper, solar sails were taken to fulfill the control. Numerical simulations were made in the earth-moon system. The results showed that taking the surface of the solar sail as the control parameter can achieve better results.

Key Words: restricted three-body problem, triangular libration point, earth-moon system, solar sail.

* Only an abstract of this paper was available for publication. A similar paper was presented at the 27th International Symposium on Space Technology and Science, July 5-10 2009, Tsukuba, Japan, 2009.
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FORMATION MANEUVERING IN THE VICINITY OF THE SUN-EARTH/MOON L2 LIBRATION POINT USING SOLAR RADIATION PRESSURE

Kamran Shahid* and Krishna Dev Kumar†

In this paper the use of solar radiation pressure for spacecraft formation flying at the L2 Sun-Earth/Moon collinear libration point is presented. The system consisting of a leader and a follower satellite is considered. The leader satellite is assumed to be in a fixed halo trajectory and the follower satellite position relative to the leader satellite is controlled using two angles and area; these are varied based on a higher order sliding mode control technique to achieve the desired formation control. The stability of the proposed controller is established using Lyapunov theory. The performance of the proposed controller is tested through numerical simulation of the governing nonlinear equations of motion and is applied for both formation maintenance and reconfiguration in the elliptical restricted three-body problem. The effects of initial state errors, non-natural formations and optical solar sail material degradation are considered. The numerical results demonstrate the effectiveness of the proposed control technique for precise satellite formation flying using solar radiation pressure at the L2 libration point. Furthermore, control inputs on the order of 10 degrees and 4 m2 for area change are sufficient to control formation reconfiguration changes as large as 25 km. [View Full Paper]

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ON BALLISTIC ACQUISITION
OF SHORT PERIOD OUT-OF-ECLIPTIC TRAJECTORIES*

Michihiro Matsumoto and Jun’ichiro Kawaguchi†

Abstract: This paper presents new orbital synthesis results to achieve ballistic and short period out-of-ecliptic trajectories, instead of using electric propulsion or solar sail acceleration. The strategy developed utilizes a Jovian gravity first, followed by polar very high speed gravity assists by Earth or Venus. So far, the use of very high speed gravity assists has been conceived not practically useful. However, this paper presents those still effectively contribute to amending the trajectories periods, and to acquiring small sized out-of-ecliptic ballistic trajectories. The biggest advantage of this strategy is to reduce propellant mass carried drastically.


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COMPUTER SYSTEMS AND ALGORITHMS 
FOR SPACE SITUATIONAL AWARENESS: 
HISTORY AND FUTURE DEVELOPMENT

Brian C. Weeden* and Paul J. Cefola†

There is a growing international need for Space Situational Awareness (SSA), defined as knowledge of objects in Earth orbit and the space environment. Up until recently, the majority of SSA has primarily been done by the United States and Russia, which currently operate significant space surveillance tracking networks and maintain catalogs of space objects. These efforts are largely done for military and national security purposes. More recently, the European Space Agency (ESA) has initiated an SSA Program which will build upon existing European ground-based radar and optical sensors to develop a European SSA system. Emerging space States, particularly in South Asia, are also looking to develop SSA capabilities to support increased military use of space and to protect civil and commercial space assets. This paper outlines the history of mathematical algorithms and computer systems development used for space surveillance and space object catalog work primarily in the United States and to a lesser degree in Russia. It also analyses the advantages and disadvantages of various techniques and approaches and how the accuracy and development of SSA data products has been impacted by events. Based on the analysis of the traditional SSA software shortcomings and these new possibilities, the paper outlines a new initiative to develop an open source software package that combines a variety of features and algorithms in a package that is open to use and development by all. [View Full Paper]
PRECISE ORBIT DETERMINATION AND REGIONAL GRAVITY RECOVERY WITH SHORT ARCS FROM GRACE MISSIONS

Jing-shi Tang,†‡ Lin Liu†‡ and Xi-yun Hou†‡

Abstract: The GRACE satellites launched in 2002 aim at fine resolution in both spatial and time aspects with the help of intersatellite measurements. These observations, especially the range rate with an accuracy of 0.1µm/s, have been proved quite helpful in obtaining temporal gravity field. In this paper, we focus on regional gravity field recovery around Antarctica and utilize overflying short arcs to study it. The preliminary results are previewed and the further plan is discussed.

Key Words: GRACE, Antarctica, Temporal Gravity Field, Short Arc.
SATELLITE FORMATION FLYING USING AERODYNAMIC DRAG
AND/OR SOLAR RADIATION PRESSURE

Surjit Varma* and Krishna Dev Kumar†

In this paper satellite formation flying using differential solar radiation pressure and/or aerodynamic drag is evaluated. The nonlinear dynamics describing the motion of the follower satellite relative to the leader satellite is considered and the stability of such a formation in the presence of external perturbations is investigated. Several cases are considered to examine the performance of the proposed control strategy to maintain the relative motion of the follower satellite by correcting for any initial offset errors and external perturbations that tend to disturb the formation system. Numerical simulation results confirm that the suggested methodology using differential solar radiation pressure and/or aerodynamic drag yields reasonable formation keeping precision and its effectiveness in ensuring formation maneuvering.

Keywords: Satellite formation flying, Solar radiation pressure, Aerodynamic drag.

[View Full Paper]
THE ANALYSIS OF CONTRADICTION AND SOLUTION FOR STABILITY OF LAUNCH VEHICLE

Yunfei Yang,† Guang Li,‡ Yu Chen‡ and Xudong Qin*  

The control parameter can not be traded off against the upper limit, the lower limit and normal states in the design of launch vehicle attitude control system. That is, the attitude control system can meet the demand in the states of upper limit and lower limit but can’t in the normal state and vice versa. The cause of the problem is presented in this paper that the parameter deviation of the launch vehicle is large and the frequency of rigid body in upper limit state is close to the first-order elastic vibration frequency. Therefore, the contradiction exists in the motion stability performance of the rigid body, sloshing and elastic vibration. Then the detailed solution to deal with this phenomenon is described and the feasibility of each solution is analyzed as well. With the design of the launch vehicle’s entire body and the control subsystem, the problem proposed in this paper provides an important reference for improving the control system performance of the launch vehicle. [View Full Paper]

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NEAR-EARTH ASTEROID SURVEY MISSION CONCEPT USING SOLAR SAILING TECHNOLOGY

Mai Bando* and Hiroshi Yamakawa†

The purpose of this paper is to investigate the possibility of asteroid survey mission enabled by advanced solar sailing technology. The study is focused not on the solar sail spacecraft itself but on its orbital dynamics to realize the missions. A novel NEA flyby survey mission with a light-weight solar sail spacecraft to increase the accessibility to NEAs located in the vicinity of the Earth’s orbit is proposed. Numerical study suggests that our approach increase the opportunities in proximity to NEAs which have eccentric and inclined orbits. [View Full Paper]
OPTIMAL PERIODIC CONTROL LAW FOR SATELLITES USING DFC WITH NON-LINEAR GAIN

Takehiro Higuchi* and Seiya Ueno†

Periodic control of satellites expands the usage of the existing satellites and the satellites that will be launched in the future. This paper introduces new control law for satellites to follow the periodic constraints with minimum energy consumption. The control law is designed using ideas from optimal control theory combined with delayed feedback control (DFC) with non-linear gains. The control law is applied to 3 different types of space structures to examine its ability. The results show that the control law has robustness to various types and various conditions of space structures to follow the periodic motion. [View Full Paper]
ATTITUDE DETERMINATION AND CONTROL SUBSYSTEM
OF JC2SAT-FF MISSION

James Lee,∗ Anton de Ruiter,† Alfred Ng,‡
Casey Lambert,** Yuri Kim†† and Keisuke Yoshihara‡‡

This paper presents an overview of the attitude determination and control subsystem for an on-going internationally collaborated nano-satellite formation flying mission: JC2Sat-FF (Japan Canada Joint Collaboration Satellites—Formation Flying), which is a joint project between the Canadian Space Agency (CSA) and the Japan Aerospace Exploration Agency (JAXA). Among other mission objectives, the primary objective of this mission is to demonstrate along track formation keeping technology of the spacecrafts using atmospheric drag control. For this purpose, JC2Sat-FF mission will be flying two nano-satellites in a low earth orbit in an along-track formation using differential atmospheric drag as the means of formation control, which is a novel feature of this mission and presents unique challenges in view of the satellite attitude control. Techniques to address the challenges are discussed in the paper. [View Full Paper]

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THE RESEARCH OF MICRO SILICON ACCELEROMETER FOR ENGINEERING APPLICATION

Wang Wei, He Sheng, Xing Chaoyang, Yu Haicheng, Zhao Caifan*

With the rapid development of the technique of MEMS in the past several decades, the utility of the technology in the field of the inertial devices become more and more significant. Nowadays micro-silicon accelerometer’s investigation has made great progress in laboratory conditions at home, but it can’t meet the capability of domestic micromachining in existence and the application requirement in inertial technology field because it still has a series of problem in aspects of consistency, long time stability and engineering practicality. With those problems, this article discusses the development of “Sandwich-style” closed loop electrostatic force feedback micro-silicon accelerometer’s engineering sample. Testing results indicate the developed micro-silicon accelerometer’s performance of long time stability, consistency, reliability and adaptability in application environment has been made better, and its advanced engineering work is in progress. [View Full Paper]

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FREQUENCY SENSITIVITY ANALYSIS ON THE LOX/KEROSENE STAGED COMBUSTION CYCLE ENGINE

Li Bin,† Du Dahua‡ and Zhang Guitian†

The linear small deviation dynamic transmission matrix models of a LOX/Kerosene staged combustion cycle engine are developed using modular modeling method. Following the frequency characteristics analysis technology of transfer function, the frequency sensitivity of the engine are investigated. The research can provide original basis for the POGO and dynamic study of liquid rocket engine. [View Full Paper]
THEORETICAL AND EXPERIMENTAL INVESTIGATION OF THE CHARACTERISTICS OF HYDROSTATIC AND HYDRODYNAMIC FACE SEAL IN TURBOPUMP

Hu Xudong,* Zhao Weigang,† Zhang Guitian* and Chen Jianhua†

The hydrostatic and hydrodynamic face seal has been applied in civil products successfully because of low power loss, zero leakage, high rotating speed and long life. Mechanism of the form of liquid film is addressed, analytical method adapt to the modal is built. The static characteristics of spiral grooves face seal including opening force, leakage, power, frictional torque, and so on, which affected by operating parameters and structural parameters are analyzed. With water as lubrication, the performance of the hydrostatic and hydrodynamic face seal is simulated and analyzed by experimental test. [View Full Paper]
INVESTIGATION OF VIBRATION CHARACTERISTICS FOR HIGH SPEED RIGID ROTOR OF LOX/KEROSENE ROCKET ENGINE

Li Bin,* Zhao Wu,† Li Xiangyang,† Zhang Guitian†† and Huang Daoqiong†

It was found radial displacement had a great variety scope and unexpected spectrum lines in frequency domain during hot fire test of turbine-oxidizer pump. The fault may relate to excitation forces which were generated in annular seal clearance, turbo blade tip, and rub-impact between the rotor and stator. Based on the structure, equation of motion on rigid disk, rigid support, Rayleigh beam modeling in regard to the dynamic stiffness of annular seal and the liquid action was built for the purpose of vibration characteristics identification. Comparisons were made between simulation results and hot fire test results, the paper put forward the reasons of the doubtful radial displacement and unexpected spectrum lines. The vibration characteristics can provide some evidences to distinguish between the 2 kinds of faults and normal running.

[View Full Paper]

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ATTITUDE CONTROL OF MINIATURE SATELLITES USING NANOWHEELS AND CONTROL MOMENT GYROS

Suketu Patel,* Krishna Dev Kumar,† Alfred Ng‡ and Godard**

Design and development of a low-cost customizable ACS applicable to nano class (1-10 kg) satellites is presented. The focus is turned to optimal design and configuration of the reaction wheel module. The design is made to satisfy control requirements for worst case disturbances in a LEO orbit. The performance of the developed actuator is then verified through performing attitude control using two different configurations. The same module is also used as momentum wheel for attitude control with control moment gyros (CMGs). [View Full Paper]
SATELLITE COMMUNICATIONS, TRACKING, TELEMETRY, AND COMMAND
SESSION C.2

AAS Chair:  Dr. Keith E. Wilson
            Jet Propulsion Laboratory,
            U.S.A.

JRS Chair:  Dr. Hiroki Kohata
            JAXA, Japan
FINAL RESULTS OF THE BIDIRECTIONAL OPTICAL LINK BETWEEN THE OCTL AND THE OICETS SATELLITE

Keith E. Wilson, Abhijit Biswas, Joseph Kovalik, Malcolm Wright and William T. Roberts*
Yoshihisa Takayama,†
Shiro Yamakawa‡

During the period May 21, to June 11, 2009 JPL conducted a 50 Mb/s downlink, 2Mb/s uplink bidirectional optical link between its Optical Communications Telescope Laboratory (OCTL) at the Table Mountain Facility Wrightwood California and JAXA’s Optical Inter-satellite Communications Engineering Test Satellite (OICETS). This paper describes the experiment between the OICETS and the OCTL ground station and the precursor experiments that validated the OCTL performance. The multi-beam propagation design—milliwatt level three communications beams and four beacon beams totaling less than 2 watts transmitted power— for scintillation mitigation is described. Measured uplink and downlink bit error rates were $10^{-4}$ and $10^{-6}$, respectively indicating signal to noise at the spacecraft and ground receivers of 10-dB to 16-dB. Our experiment results show a robust link under a variety of atmospheric conditions including sustained winds of up to 23 km/hr with gusts up to 40 km/hr. with downlink signal strengths validating our propagation models. [View Full Paper]
JAXA’S COMMUNICATIONS RESEARCH AND DEVELOPMENT SATELLITES

Hiroki Kohata,* Naoya Tomii† and Tetuso Satoh†

There are two types of satellites in the satellite communications field, mobile communications satellite and fixed communications satellite. JAXA developed and launched these two types of communications research and development satellites in the past several years. The aim of these R&D satellites is to demonstrate the world’s most advanced information and telecommunication satellite networks. This paper describes satellite technologies of these two different types of communications R&D satellites and their plans and results of communications experiments. [View Full Paper]
In order to suppress the strong narrowband interference in the direct sequence spread spectrum (DSSS) system, a new locally optimal detector (LOD) based on maximum entropy probability estimation is proposed. The maximum entropy probability estimation is used to mathematically express the probability density function (PDF) of observation noise in LOD, and a new nonlinear Gauss-Newton algorithm based on LMS initial parameter design is adopted to estimate the Lagrange weights of maximum entropy PDF. This interference rejection technology can reduce the error from PDF estimation, and meanwhile doesn’t need any exercise data. The simulation results indicate that the LOD based on maximum entropy probability estimation can forcefully suppress narrowband interference and represent the triangle relation characteristic of DS signal. When the input JNR is 20dB, the JNR improvement after LOD is respectively improved for 30dB and 26dB compared with linearly adaptive FIR filter and nonlinearly adaptive ACM filter, meanwhile the SNR is respectively improved for 3.1dB and 1.6dB, and the JNR improvement is larger for larger input JNR. [View Full Paper]
OPTIMAL ESTIMATORS OF DOPPLER AND DELAY FOR DEEP-SPACE NAVIGATION APPLICATIONS

V. Vilnrotter, K. Andrews, A. Tkacenko and J. Hamkins*

Deep-space navigation uses estimates of range and Doppler to update and improve spacecraft trajectory solutions. However, the transmission of tones or PN sequences drain power and bandwidth that could be better used for transmitting additional science data from the spacecraft. Our scheme uses a conventional uplink ranging signal, but the downlink is replaced with an asynchronous telemetry signal whose timing relative to the acquired uplink signal is measured. This measurement, along with the acquired timing of the received telemetry, enables the round-trip light-time to be computed on the ground. In this paper, the structure of the joint maximum likelihood estimator for range and Doppler is derived, and its performance determined relative to Cramér-Rao bounds via simulation and analysis. Performance of individual frequency estimators based on conventional Costas loop phase estimates where the delay is assumed to be known, and of delay-tracking loops that assume known frequency and phase are also derived, and contrasted with the performance of the optimum Doppler-delay estimator. Advantages of this new approach include the ability to simultaneously collect ranging measurements and transmit the highest supported telemetry rate throughout the pass, and compatibility with suppressed carrier signaling and higher order modulations. This approach could result in significant additional ranging data and total data volume return for future missions. [View Full Paper]

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SATELLITE REMOTE SENSING, METEOROLOGY AND SMALL SATELLITE SYSTEMS/CONSTELLATIONS
SESSION C.3

AAS Chair: Dr. Alfred Ng
Canadian Space Agency,
Canada

JRS Chair: Prof. Shinichi Kimura
Tokyo University of Science,
Japan
A CONSTELLATION OF GREENHOUSE GASES MONITORING SMALL SATELLITES

Yunlong Lin*

The globe climate change is an essential issue in this world. We are currently investigating the use of small satellite remote sensing for the monitoring of greenhouse gases from space. The three greenhouse gases monitoring small satellites will be on Sun-synchronous orbit and form a constellation to provide best land coverage and at least 280 cloud-free measurements in an area of 400 km × 400 km each month. The spatial heterodyne spectrometer with Infrared sensor array on-board each satellite could provide detailed spectral images of CO₂, CH₄ and H₂O in a spatial resolution of 1 km × 1 km. In this paper, the scientific needs and orbital considerations for this constellation are introduced followed by descriptions and discussions of the micro-technology application in both payload design and small satellite platform design. The spacecraft presented is about 65 kg in mass and 50 cm × 50 cm × 50 cm in volume and 45% of the mass is taken up by the payload. The total weight of the space systems including adapter and releaser for satellites to be released from the launch is about 320 kg. Furthermore, the mission operating system including ground stations and control centre is studied and is briefly described in the end. [View Full Paper]

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A HIGH-PERFORMANCE IMAGE ACQUISITION AND PROCESSING UNIT USING FPGA TECHNOLOGIES

Shinichi Kimura, Masato Terakura, Akira Miyasaka,*
Nobuomi Sakamoto,† Naoki Miyashita,‡
Ryu Funase and Hirotaka Sawada**

It is becoming imperative to have visual capabilities for space activities. We have developed a very small, high-performance image processing unit that is based on COTS technologies. It has a 500 MIPS calculation capability in a single, 50 mm × 50 mm printed circuit board, and it incorporates various types of interfaces using field-programmable gate array (FPGA) technology. The camera is called the high-performance image acquisition and processing unit (HP-IMAP). The HP-IMAP technologies are being utilized in the IKAROS (Interplanetary Kite-craft Accelerated by Radiation of the Sun) that was launched May 21, 2010. In this article, we describe the HP-IMAP and technical demonstration in IKAROS mission. [View Full Paper]
THE AZIMUTH AMBIGUITIES SUPPRESSION USING NULL-STEERING TECHNIQUE IN SYNTHESIS APERTURE RADAR

Yuepeng Song, Xiangwu Gao and Ruliang Yang

The azimuth and range ambiguities in space-borne Synthetic Aperture Radar (SAR) limit the range of pulse repetition frequency (PRF), so the swath width and azimuth resolution can not be improved simultaneously. Null-steering technique in array antenna designing can suppress the azimuth ambiguities by producing nulls at the azimuth-ambiguous responses, which can settle the contradiction. In this paper, two null-steering methods are firstly introduced. Then we proposed a simple null-steering method which could null the ambiguities adaptively without computing covariance matrix, and the weights are invariable in a certain azimuth angle (or Doppler frequency). The validity of this method is shown by the computer simulation. Null-steering error caused by antenna attitude error is proposed and its effect on azimuth ambiguity rate (AAR) is analyzed. [View Full Paper]
This paper presents the results from the study on the feasibility of JC2Sat formation flying using differential drag technique. The results indicate that formation flying is feasible at 650 km but becomes difficult at 700 km. Methods were investigated to increase the drag panel area with minimum bus structure modifications. This re-design is presented and together with an increase in pitch limit, the feasibility of JC2Sat achieving the formation flying is high. [View Full Paper]
SPACECRAFT FORMATION FLYING FOR TROPICAL RESOURCES AND ENVIRONMENTAL MONITORING: A PARAMETRIC STUDY

Harijono Djojodihardjo* and A. Salahuddin M. Harithuddin†

Tropical Earth Resources Satellites and a large host of operational satellites with similar missions and high-definition three-dimensional images has motivated the present study to look into Near-Earth Spacecraft Formation Flying for Earth Pointing Tropical Environmental Monitoring. The potential of spacecraft formation flying as space platform to carry out such mission in the light of small spacecrafts technological progress and availability leads the study to focus into two aspects: the dynamics of relative motion of multiple spacecrafts and the desirable ground tracks beneficial for tropical environmental and resources monitoring missions. For this purpose, relative motion dynamics incorporating Clohessy-Wiltshire Equation for circular orbits as well as Tschauner-Hempel Equation for more general elliptical orbit will be reviewed. A parametric study is carried out to obtain information on various Spacecraft Formation Flying configurations for near earth orbits of interest. Based on the results of the parametric study corresponding ground-tracks are projected to gain better understanding on the overall spacecrafts characteristics for Earth Pointing Tropical Environmental Monitoring mission analysis purposes. It is envisioned that parametric study carried out to obtain relevant orbital characteristics can then be followed by Multi-Disciplinary Optimization for design and application of small satellite missions at a later stage.

Keywords: orbital mechanics, spacecraft formation flying, tropical remote sensing.

[View Full Paper]
HUMAN SPACE FLIGHT, SPACE STATION, AND PACIFIC SPACE PORTS AND LUNAR RESEARCH AND EXPLORATION
SESSION C.4

AAS Chair: Prof. Yunlong Lin
York University, Canada

JRS Chair: Dr. Yukio Koyari
JAXA, Japan

The following paper was not available for publication:

AAS 10-447
“Architecture Study for Japanese Human Lunar Exploration,” by Naoki Sato,
JAXA, Japan (Paper Withdrawn)
HHT FUTURE PLAN

Yukio Koyari,* Hiroshi Sasaki,† Tsutomu Fukatsu,‡ Hirohiko Uematsu,** and Takane Imada††

JAXA announced its long-term vision for the next 20 years called as “JAXA Vision toward 2025” in April 2005. Based on the vision, JAXA will develop the future system, such as orbital transfer vehicle, free flyer unit and manned transportation, based on the know-how accumulated through HTV operations. The successful first flight of HTV and H-IIB in 2009 is one of the important milestones in JAXA’s long-term vision. In parallel, JAXA is conducting the study of the upgrade of HTV such as recovery system, human transportation vehicle, free flyer and lunar exploration system. This paper describes JAXA’s next step after the successful HTV launch. [View Full Paper]

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VERIFICATION APPROACH FOR HUMAN-RATED SPACE SYSTEMS

Charlotte M. Pappageorge,† Mark Arend,‡ Benjamin D. Herbert,‡
G. Fitz Vernon,** Darko Filipi** and Kenneth J. Bocam††

Orbital Sciences Corporation designed, built, and verified developmental flight test hardware intended for future use on human spaceflight missions that ranged in complexity from simple harnesses to advanced solid rocket motors. This paper recommends a comprehensive verification approach for human-rated space systems based on this experience.

Human spaceflight necessitates increased scrutiny by the certifying government authority and customer in comparison to unmanned space systems due to the risk to human life. As a result, verification of a human-rated design requires rigorous assessment and documentation far beyond a checklist-style compliance matrix common elsewhere in the aerospace industry. Verification documentation must also be clear enough to allow for correct understanding and interpretation by individuals who have not been intimately involved in the design process yet need to approve the flight worthiness of the vehicle.

Orbital Sciences used a verification method based verification approach for the developmental flight test hardware. As analyses and tests were completed, documentation was released that identified which requirements were verified by those events, either in part or in whole. This paper describes lessons learned and complications encountered with the verification method based approach. In particular, this approach necessitated that reviewers assess multiple verification documents before concluding that any individual requirement was verified. As a result, Orbital recommends and explains a requirements-based verification approach for human-rated space systems. In addition, the developmental program was treated as such during the requirement definition phase, but treated as a full-fledged human-rated space system during the verification phase. This experience highlights the importance of advanced detailed verification planning during requirements definition for human-rated space systems. [View Full Paper]
DEVELOPING WIRELESS DATA BUS FOR FUTURE HUMAN FLIGHT MISSIONS

Yunlong Lin*

The extensive ground use of wireless communication stimulates the application of wireless data bus in space, particularly for the application in human flights. The current ground wireless systems such as Bluetooth and WiFi have advantages of less complex and flexibilities in system configuration. They are standardized and efficient, smaller and more economical than wired bus. One effective wireless bus solution recently proposed has been a Bluetooth communication bus, to reduce bus volume and design complexity while maintaining the integrity of the design and even improving upon current standards. In this paper, a test bed is introduced for the design and construction of such Bluetooth wireless spacecraft data bus. The tests include frequency selection, transmission method, power consumption, effective range, network access and control, EMI and EMP compatibility. The test results indicate that the interfaces are simplified while maintaining high data rates due to the plug and play features and the reducible use of cables and connectors. The building cost and estimated development cycle are reduced by using existing standardized hardware/software and the reliability might be increased if further studies of space qualification can be conducted. [View Full Paper]

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HTV VEHICLE DESIGN AND ITS FIRST FLIGHT RESULT

Yukio Koyari,* Hiroshi Sasaki,† Yusuke Suzuki,‡ Koji Yamanaka,**
Dai Asoh†† and Takane Imada‡‡

H-II Transfer Vehicle (HTV) is an unmanned transfer vehicle launched by HIIB rocket and will support the International Space Station (ISS) logistics operations with the other unmanned service vehicles such as Russian Progress and European ATV. On September 11, 2009, JAXA successfully conducted the first launch operation of the combination of H-IIB and HTV with cargo at Tanegashima Space Center. The HTV arrived at the ISS and berthed for 43 days for exchanging the cargo and waste. Finally, the first HTV finished its mission as planned by the destructive re-entry on November 2, 2009. This paper presents the result of the launch operation with unique characteristics of HTV design. [View Full Paper]
DESIGN OF AN AUTONOMOUS ROBOTIC MANIPULATOR FOR USE IN FUTURE SPACE AND PLANETARY EXPLORATION

Benoit P. Larouche* and Z. H. Zhu†

Space exploration is a costly and risky endeavour combining the very forefront of technology and knowledge. The need to maximize return while managing the risks leads to many novel solutions. The current field of autonomous robotics leads to many advantages capable of overcoming the difficulties of communication, distance, and hazardous environment. The ability to employ an autonomous robotic system as precursor to human exploration, to complete mundane tasks such as initial outpost set-up and resupply, allows for maximizing the results of any mission. The true benefit is seen in the synergy between human and robots providing enhanced reality and ability. This paper will closely examine the design of an autonomous robotic manipulator (RM) system capable of supporting future exploration missions. The system will employ a custom robotic manipulator, vision system, force sensors, and adaptable evaluative target for tracking. We will present the development of the RM and vision system and proceed to develop a capture operation that will involve the dynamic control of the arm, path planning and predictive motion planning as well as contact dynamics. The system will employ foreknowledge of the targets shape and grasping point as well as generic mechanical properties in order to achieve the task autonomously and safely. [View Full Paper]

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SPACEPORTS FOR COMMERCIAL SPACE ACTIVITIES IN JAPAN – WHICH IS THE VERY INFRASTRUCTURE TO CREATE NEW SPACE COMMERCE

Misuzu Onuki

The US has been the only nation to have developed commercial spaceports in the last 15 years since California Spaceport got the very first license in 1996 just after the license approval function had moved from Department of Transportation to FAA/AST and expanded their license issuance to spaceport operators and sites in addition to commercial rocket launch activities. Now the US has eight commercial spaceport and there is a new trend for spaceport development all over the world in such locations as Sweden, Spain, Dubai, Singapore, Curacao and so on. Japan is one of the countries which has been interested in establishing its own spaceports and targeting as the Asian hub for the next generation based on the market demand for spaceflight offering the views from space of familiar places close to home and birthplace. Commercial spaceports are expected to facilitate space commercialization, local industrialization, and promote education in addition to tourism industries. [View Full Paper]
DESIGN OF A SCIENTIFIC LUNAR MICRO-LANDER MISSION


Since the Clementine mission in 1994, a number of lunar missions using small spacecraft have flown, including Lunar Prospector, SMART-1, Selene-A, Chang’e-1, and Chandrayan-1. Despite the increase in knowledge of lunar science provided by these all these missions and the original lunar missions of the 1960s and 1970s, there is still some valuable science that can be performed by very small spacecraft, especially landers. Such valuable science includes using an imager of the lander to examine rock strata of a nearby cliff (especially fault scarps), characterizing the tenuous lunar atmosphere and transfer of molecules from the polar cold traps using a mass spectrometer, and using a small gamma-ray spectrometer to analyze exotic rock types at specific lunar geological “hot spots.” A candidate science mission to the Aristarchus Plateau was selected because of the value of the science and the size of the target. Using a new launch capability being developed by the Hawaii Space Flight Laboratory at the University of Hawaii, and using the latest in micro-technology for spacecraft, it will soon be possible to do a small lander mission to the Moon for under $50 million including launch costs. Two candidate mission designs are presented for placing 30-100 kg lunar lander onto the surface. At the low end is a 60-kg lander that includes 5 kg of science payload and launched on the Hawaiian launch vehicle, and at the high end of the design space is a larger lander containing 10 kg science payload and launched on a conventional launch vehicle such as the PSLV. [View Full Paper]
MATERIALS AND STRUCTURES
SESSION C.5

AAS Chair: Prof. Taft H. Broome, Jr.
Howard University, U.S.A.

JRS Chair: Prof. Yasuyuki Miyazaki
Nihon University, Japan

CSA Chair: Prof. Shi Hongbin
CASC, China
PREDICTION OF A SPECIAL 4D CARBON/CARBON COMPOSITE ON PROPERTIES

Shi Hongbin,*, Tang Min† and Wang Xuekun‡

According to a 4-directional in-plane carbon/carbon composite, a model of unit cell is proposed, which truly reflects the braided manner and coincides with the actual configuration of the composite. Surface-based cohesive behavior is used to simulate the interfacial debonding at the fiber bundle/matrix interfaces. Stiffness and thermal expansion coefficient are predicted by using finite element method. Murakami’s damage is introduced to simulate the mesoscopic damage behavior of fiber bundle. Numerical examples are given and compared with experimental results to demonstrate the nonlinear constitutive relation. Calculation results are basically identically with the experiment values. [View Full Paper]

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THE DYNAMICS OF SQUARE TYPE SPINNING SOLAR SAIL

M. Yamazaki* and Y. Miyazaki†

The Spinning solar sail is expected to be a future space exploration system. Considering the dynamic deformation of the sail membrane is indispensable factor in designing the spacecraft. It is necessary step in order to put the gossamer structure to practical use. In this presentation, the dynamic property of the square type spinning solar sail is revealed, and the design issue of the membrane of a spinning solar sail is summarized. [View Full Paper]

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A NEW ALGEBRAIC TECHNIQUE
FOR TRACKING ERRORS IN DYNAMICAL SYSTEMS

Taft H. Broome, Jr.*

How might the world community of engineers put new life into its research enterprise? This paper considers this question from two points of view shared by engineering leaders in the USA. The point of view called “thinking out of the box” calls for research works aimed at abstract multidisciplinary ends. The aim of this paper is to make a contribution to the philosophy of engineering. The point of view called “opportunism” calls for the extraction of practical solutions to practical problems from means to these abstract ends. This paper discovers a new structure in abstract algebra and applies it to the practical problem of tracking errors in dynamical systems. [View Full Paper]

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SPACE TRANSPORTATION AND PROPULSION
SESSION C.6

AAS Chair: Dr. Wanping Zheng
Canadian Space Agency, Canada

JRS Chair: Prof. Harunori Nagata
Hokkaida University, Japan

CSA Chair: Prof. Zhou Jun
CASC, China

The following papers were not available for publication:

AAS 10-454
“A Vision for Next Flagship Launch Vehicle of Japan,” by Yasuhiro Saito, JAXA, Japan (Paper Withdrawn)

AAS 10-455
“Flight Results and Future Plan of the H-IIB Launch Vehicle,” by Makoto Arita, JAXA, Japan (Paper Withdrawn)
ADVANCED SOLID ROCKET LAUNCHER AND BEYOND

Yasuhiro Morita, Keiichi Hori, Takayuki Imoto, Hirohito Ohtsuka, Apollo Fukuchi and Ryojiro Akiba

What should we evolve the solid rocket launchers in the near future? The JAXA is developing the Advanced Solid Rocket (ASR), or recently nicknamed Epsilon rocket, as a successor to the M-V launch vehicle, the world best performance solid rocket system that can be utilized even for planetary missions. Epsilon rocket is a result of next-generation technologies including a highly intelligent autonomous check-out system and a mobile launch control, which is connected to not only the solid rocket but also future space transportation systems. It aims at improving the efficiency and the cost performance of the launch system. Far beyond this effort, the attention should be directed toward a revolution of the manufacture. The Low melting temperature Thermoplastic Propellant (LTP), now at the experimental stage, is expected to convert a large-scale and inefficient manufacture process to one of a small-scale and high utilization frequency, resulting in a significant cost reduction. This paper reveals the direction toward evolution of the next generation solid-propellant rockets: simplification of the launch system and the manufacture process. [View Full Paper]
THE STUDY OF MINIATURIZED PROPULSION FOR SMALL SPACECRAFTS

Zhou Jun*

As a significant sub-system for most space vehicles, the space propulsion system was used to provide the power for vehicle attitude control, orbit maneuver, and so on. Under the circumstance to develop the micro-propulsion system for micro space shuttle, micro-satellite, and micro deep space exploration vehicle (with a mass between 1~100kg), a 1 Newton bi-propellant thruster using the propellants of H$_2$O$_2$/C$_n$H$_{2n+1}$OH and stainless steel material was designed. Using the method of numerical simulation, contours of temperature, pressure, Mach number and velocity in rectangular combustion chamber and nozzle were achieved, and the influence of near-wall layer was analyzed. Moreover, the fire test was conducted and fire properties of the engine were obtained.

[View Full Paper]

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Neglecting the two-phase flow in nozzle and emphasizing the heat transfer and phase change, numerical simulation of Al₂O₃ particle evaporation was carried out for SRM using the high energy propellant by Euler-Lagrangian method. Results show that, in the high temperature chamber, about 40% of particle evaporated, and most of particle escaped from the rocket nozzle, due to the phase change process, flow field uneven exits.

Key Words: numerical analysis, two-phase flow, particle, phase change.
REGRESSION PROGRESS OF FUEL GRAIN IN CAMUI TYPE HYBRID ROCKET MOTOR

Harunori Nagata,* Akihito Kakikura,† Mitsunori Ito,‡ Yudai Kaneko,‡ Kazuhiro Mori,† Kenta Ueshima,† Tsutomu Uematsu** and Tsuyoshi Totani††

Static firing tests clarified how the fuel flow rate varies with the progress of fuel regression in a ‘cascaded multistage impinging-jet’ (CAMUI) type hybrid rocket motor. The fuel gasification rate decreases with progressing fuel regression because of two causes. One is decreasing gas flow density in ports. The other is decreasing area of end faces. The fuel gasification rate decreases rapidly when end faces disappear. A simple model of the regression progress was proposed. Fuel grains collected after firing tests with various burning duration approved this model. The model serves as a foundation to develop regression formulas applicable to this unconventional type fuel grain.

[View Full Paper]
COMPARATIVE RESEARCH OF NONTOXIC PROPELLANT SCHEME APPLIED IN VARIABLE THRUST ENGINE BASED ON THE ANALYTIC HIERARCHY PROCESS

Li Qinglian,*, Yang Leichao,† Sun Mingbo‡ and Wang Zhen-guo**

Adopting nontoxic propellants has been becoming the essential tendency of the development of aerospace propulsion technology. According to integrated performance, the nontoxic propellant schemes including gaseous oxygen/alcohol, gaseous oxygen/kerosene, liquid oxygen/kerosene, hydrogen peroxide/kerosene and nitrogen oxide/propane are selected to be optimized for the last propellant scheme of future variable thrust engine adopted by large maneuver platform. The Analytic Hierarchy Process is used to evaluate the task with the given background, and the result shows that the gaseous oxygen/alcohol is the optimized scheme for the variable thrust engine system with nontoxic propellant under the same design target. Through analyzing the weightiness of the evaluation criterion, the weighted process of the lower evaluated criterions and the whole Analytic Hierarchy Process, it can be concluded that evaluation results are due to several reasons. [View Full Paper]
Diffusion combustion in a stagnation point boundary layer of a gaseous oxygen jet over a solid fuel was investigated to clarify effects of jet velocity on a similarity condition of fuel regression rates. This combustion field simulates the upstream-end face of the uppermost fuel block of CAMUI type hybrid rocket fuel grain. Increasing the flow velocity from 5.5 m/s to 11.5 m/s caused an increase in the regression rate from 0.22 mm/s to 0.26 mm/s. This result shows that the chemical reaction effect is not negligible in oxidizer impinging region. [View Full Paper]
THE TECHNOLOGY OF THERMAL MANAGEMENT FOR EXPENDABLE SPACE LAUNCH VEHICLE

Cai Qiao-yan, Shen Lin and He Wu-le

An expendable space launch vehicle is heated by a series of thermal sources: thermal environment on the ground, high heat convection flow passing the atmosphere, and heat radiation flux during the final stage or upstage of space launch vehicle staying in the space. This paper discusses the application of thermal management technology on the expendable space launch vehicle from three aspects. The three aspects include thermal management application before launch, flight in the atmosphere and the application on the upstage of vehicle. Through adopting these thermal management measures assure the vehicle flight more inexpensive, higher efficiency, safe and credible.

[View Full Paper]
MICROGRAVITY SCIENCES, INCLUDING SPACE DEBRIS ENVIRONMENT AND LIFE SCIENCES
SESSION C.7

JRS Chair: Prof. Shinichi Yoda, JAXA, Japan

The following papers were not available for publication:

AAS 10-462
“Orbital Debris Related Activities at Kyushu University,” by Toshiya Hanada, Kyushu University, Japan (Paper Withdrawn)

AAS 10-463
“Scientific Experiment Status of the Japanese Experiment Module (JEM) ‘KIBO,’” by Kazuc Veyama, Daisuke Masuda, Ryoichi Kumagai, Makoto Furukawa, Japan Manned Space Systems Corporation (JAMSS); Shinichi Yoda, JAXA, Japan (Paper Withdrawn)
Homogeneous semiconductor alloy crystals of Si$_{0.5}$Ge$_{0.5}$ will be grown aboard the International Space Station (ISS). We are preparing for microgravity experiments. We first invented a new growth method named the traveling liquidus-zone (TLZ) method for growing compositionally uniform alloy crystals. We determined growth conditions for the TLZ method on the ground. In this paper, we describe the current state of preparation for microgravity experiments. [View Full Paper]
MOON, MARS AND ROBOTIC EXPLORATION
SESSION C.8

AAS Chair: Prof. Peter M. Bainum, Professor Emeritus Howard University, U.S.A.
TECHNOLOGY ANALYSIS ON THE MARS SAMPLE-RETURN MISSIONS

Gao Zhaohui,*, Zhang Shu* and Shen Lin*

Exploring the Mars is of greatest importance among missions to explore the planets in the solar system. With the development of the Mars exploration, the requirement of the Mars sample return missions is gaining more and more attention for its promising ability to unveil the Mars. The missions have scientific significance as well as engineering significance which are both discussed in the paper. And the technology analysis on the mission also needs to be implemented from both aspects above. In this paper, we stress the technology analysis from the engineering aspect and give analysis respectively on the mission profile, the structure of the mission, and the critical technologies of the mission. Some conclusions and suggestions are presented at the end of the paper.

Key Words: The Mars; Sample-return mission; Mission profile; Single launch; Double launch.

[View Full Paper]
EVALUATION OF EFFICIENT ATTITUDE OF A MULTI-LEGGED PLANETARY EXPLORATION ROVER WITH ISOTROPIC LEG ARRANGEMENT

Shinji Nishikori* and Shinji Hokamoto†

This study deals with a multi-legged planetary rover with a spherically isotropic leg arrangement. This robot is a reliable system for the exploration on rough terrains, because the rover can continue walking even after overturning. Moreover, this rover can exhibit a rotational motion by utilizing its isotropic shape in addition to quadruped walking motion. This paper discusses two rotational motions; a quasi-static rotational motion and a dynamic rotational motion. This paper investigates reasonable attitudes for the quasi-static rotational motion from the view point of the energy consumption required for traveling. For the dynamic rotational motion, adequate attitudes to resist the shock for kicking and touchdown are discussed. [View Full Paper]

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LORE: LUNAR ORIGINS AND RESOURCE EXPLORER

R. V. Kruzelecky, B. Wong, J. Zou, E. Haddad, W. Jamroz,*
E. Cloutis,† K. Strong,‡ A. Ellery,**
Nadeem Ghafoor and Gita Ravindran††

The LORE Lunar Origins and Resource Explorer miniature payload is proposed for JAXA’s Selene 2 landed lunar mission. LORE is designed to provide, for the first time, systematic exploration of the lunar surface and subsurface ice distribution, implanted H, dust, mineralogy and resources, using UV/VIS/MIR spectroscopy. Preliminary supporting laboratory investigations at the University of Winnipeg suggest that the UV region can provide new geological information unobtainable by other techniques, and in particular, abundances of ilmenite and related lunar oxides, key potential in situ resources for oxygen and solar wind-implanted hydrogen. The LORE stand-off measurement capabilities will be used to provide studies of lunar exospheric diurnal processes with high temporal resolution.

The spectral differences between ilmenite and other lunar minerals in the ultraviolet region will be exploited for mapping ilmenite distribution and abundances on the lunar surface and subsurface. A miniature robotic drill with integral bore-hole probe will facilitate subsurface pristine mapping of the lunar polar regolith stratigraphy and condensed volatile content to elucidate prior impact history and trapped volatile content.

[View Full Paper]

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VISION-BASED TERRAIN ANALYSIS FOR PLANETARY ROVER UTILIZING DYNAMIC TEXTURE

Koki Fujita*

This work proposes a novel vision-based approach for classifying terrain types around a planetary rover in order to improve autonomous mobility in unknown planetary environment. The key technique of the classification scheme is an identification algorithm for a spatio-temporal texture appearing in motion image sequence, called a Dynamic Texture. It is applied to video sequences which are acquired from the rover’s on-board camera. In order to decrease the computational load for estimating Dynamic Texture models with the original method called PCAID algorithm, this work proposes a method combining a system identification method called N4SID with an image compression technique called 2-Dimensional Cosine Transform (2-D DCT). Different types of terrain image sequences are recognized with measurement metrics for the estimated dynamical models. In this paper, some representative metrics are applied to synthetic image sequences, and it is discussed which one is appropriate to distinguish different terrain textures as well as the vehicle’s motion parameters such as a translational velocity. [View Full Paper]