第 32 回　アストロダイナミクスシンポジウム（2022 年）アブストラクト集
32nd Workshop on JAXA Astrodynamics and Flight mechanics (2022) Abstract

Special Lecture Jul 25th(Mon) Main Room PM(12:30-13:20)

飯塚清太(IIZUKA Seita)/太田裕介（OTA Yusuke)/瀬戸裕基（SETO Yuki）
（株式会社アストロスケール：Astroscale Inc.）

飯塚清太　プログラムディレクター
2013 年に国立研究開発法人 宇宙航空研究開発機構 (JAXA) に入社後、宇宙輸送技術部門 鹿児島宇宙センター 射場技術開発ユニットにて、射場管制官 (RCO) として、ロケット打上げ業務に従事する。2016 年に株式会社アストロスケールに入社し、デブリ除去衛星実証機「ELSA-d」の通信系エンジニア等を経て、2019 年 9 月より ELSA-d プロジェクトマネージャーとしてミッションを主導。2022 年 6 月より現職。

太田裕介　GNC エンジニア
2018 年に東京大学大学院新領域創成科学研究科修士課程修了。同年、キヤノン電子株式会社に入社し、超小型地球観測衛星の姿勢制御系の開発に従事。2020 年より株式会社アストロスケールにて GNC サブシステムの開発に従事。ELSA- d プロジェクトでは航法誘導制御系の開発・地上試験・軌道上運用を担当。

瀬戸裕基　システムズエンジニア
2015 年に九州大学工学府航空宇宙工学専攻修了後、同年、株式会社アストロスケールに入社。日本法人の創業から現在に至るまで、デブリ除去ミッションの設計や衛星システム、GNC サブシステムの開発に従事。ELSA-d ではミッションコンセプト設計と GNC サブシムテムの設計、軌道設計に従事。

「ELSA-d 軌道上実証成果について」
「ELSA-d demonstration achievement in orbit」

Abstract
ELSA-d (End of life service by Astroscale - demonstration) は、デブリ除去に係る一連のコア技術を実証する世界初の商業ミッションである。2021 年 3 月に無事打上げ・軌道投入に成功し、2021 年 8 月に試験捕獲ミッションを完了した。2022 年 4 月には約

1,700km 離れた位置から 159m まで絶対航法を実施後、搭載センサを用いた相対航法への移行に成功した。これは ELSA-d ミッションにおいて最も困難な運用であり、また軌道上サービスの運用において実現することが最も難しい機能の 1 つとして広く認識されている。

ELSA-d (End of life service by Astroscale - demonstration) is the world's first commercial mission to prove the core technologies necessary for on-orbit satellite servicing in LEO. The spacecraft was successfully launched into an orbit in March 2021, and the test capture mission was completed in August 2021. In April 2022, absolute navigation from 1,700km to 159m was conducted, then a transition to relative navigation using on-board sensors was enabled successfully. This handover has been the most challenging operation of the ELSA-d mission and is widely recognized as one of the more difficult capabilities to prove for satellite servicing operations.

Special Lecture Jul 26th(Tue) Main Room PM(12:30-13:20)

Peter Antreasian/（ OSIRIS-REx Navigation Chief, KinetX, Inc.）

Bio of Dr. Peter G. Antreasian:

Throughout his 30-year career, Peter was fortunate to have explored the asteroids, planets and moons of our solar system as a key Navigation Team member of NASA missions: Galileo, Near Earth Asteroid Rendezvous (NEAR), Mars Odyssey, Mars Exploration Rovers, Cassini-Huygens, Gravity Recovery and Interior Laboratory (GRAIL) and OSIRIS-REx.

Peter began his career at the Jet Propulsion Laboratory planning the 1993 Galileo encounter with 243-Ida as an Orbit Determination member of the Galileo Navigation team. After the Galileo prime mission ended, Peter went on to become the leader of the Orbit Determination teams for NEAR in 1997, Mars Odyssey in 2001, and Cassini in 2003. When the NEAR mission at 433-Eros was coming to an end in 2001, Peter designed, planned and led the end-of-mission operations with several close flyovers of the surface ending with the first-ever landing of a spacecraft on an asteroid.

Before joining the Spacecraft Navigation and Flight Dynamics group at KinetX in 2013 and eventually leading the OSIRIS-REx Navigation Team, Peter led the

navigation of the twin orbiters of NASA's GRAIL mission into synchronous orbit at the Moon in 2012. In addition to the NEAR landing on Eros, Peter was instrumental in the delivery of the Galileo probe to the atmosphere of Jupiter, the landing of the Huygens probe on Titan, the MER rovers on Mars and now the touch and go of OSIRIS-REx on 2101955-Bennu.
Peter earned his BS, MS and PhD degrees in Aerospace Engineering, respectively, from Purdue, University of Texas and University of Colorado. He is happily married to his wife of 28 years with four kids and lives in Colorado. Peter enjoys activities in the mountains and star gazing.

「OSIRIS-REx Navigation Performance at (101955) Bennu」

Abstract
The Sample Return Capsule (SRC) onboard the NASA Origins, Spectral Interpretation, Resource Identification, and Security–Regolith Explorer (OSIRIS-REx) spacecraft is currently carrying samples of the B-type asteroid Bennu for safe return to Earth at the Utah Test and Training Range on September 24, 2023. These samples were collected during the Touch and Go (TAG) sampling event on October 20, 2020, when the spacecraft contacted the asteroid surface for a few seconds at a location less than 1 meter from the target. The unexpected rocky surface required improved ground-based navigation performance, maneuver execution error modeling over pre-launch analysis and modifications to the TAG sequence to use an onboard image-based Natural Feature Tracking algorithm for terminal guidance. The unprecedented navigation performance achieved during TAG was the culmination of experience gained during two years of cruise and two years of increasingly challenging operations at Bennu with the help of extraordinary interagency teamwork between the Flight Dynamics System (FDS), science and spacecraft teams. This presentation will discuss the navigation processes, planning and performance during the proximity operations at Bennu. It will compare the navigation performance through the proximity operation phases to our pre-launch analysis and show how improvements of the small force models governing the spacecraft motion near Bennu considerably improved the down-track state predictions leading up to the successful TAG event.

Jul 25th(Mon) Room A AM(9:30-12:00)　Abstracts

ASTRO-2022-A001

「ツイン CMG によるドローンの姿勢制御」

「Attitude control of drone by using twin CMGs 」

大内 茂人(早大), 稲葉 毅(東海大), * 趙 天翼(東海大・院), 小谷 斉之(釧路高専), 天野 嘉春, 長谷部 信行(早大), 野口 宏実(インフィテック)

Abstract:

Drones are difficult to fly in bad weather such as gusty winds. We developed a drone equipped with two CMGs that can suppress the variation of pitch and roll angles.

ASTRO-2022-A002

「確率バックステッピング法によるセンサノイズの影響を考慮した宇宙機の姿勢追従制御系設計」

「Design of Attitude Tracking Control System for Spacecraft Considering Effects of Sensor Noise by Stochastic Backstepping Method」

* 宮澤 実央(阪大・院), 佐藤 訓志(阪大)

Abstract:

Disturbances acting on spacecraft include stochastic elements that are difficult to predict in advance. In recent years, as the accuracy requirements for observation missions have become more sophisticated, it is required to control the attitude of the spacecraft faster and more accurately. To strictly deal with stochastic uncertainties in the attitude tracking control, we model the attitude motion of the spacecraft as a stochastic system and design a controller based on the backstepping method. Moreover, we guarantee the tracking performance of the proposed controller using stochastic analysis, where the error system is proved to be ultimately bounded in the mean square sense. In addition, an upper bound of the mean-square error is given quantitatively. Finally, simulations are performed to verify the validity of the theory.

ASTRO-2022-A003

「深層強化学習による折紙宇宙機の姿勢制御と形態設計」

「Attitude Control and Morphology Design of Origami-Inspired Spacecraft via Deep Reinforcement Learning」

* 伊藤 司聖(早大・院), 柳尾 朋洋(早大)
Abstract:
This study applies deep reinforcement learning to control the attitude of an origami-inspired spacecraft via shape maneuvers under conditions of vanishing total angular momentum. We evolve the morphology of the spacecraft on a computer by optimizing an objective function defined as the action value function obtained in the attitude control. We also examine different types of objective functions to evolve the morphology and motion patterns of the spacecraft in terms of control time, weight, and the area. Comparisons are made among the resulted morphologies and motion patters of the spacecraft.

ASTRO-2022-A004
「浮遊状態の宇宙飛行士の関節駆動による非ホロノミック姿勢変更」
「Nonholonomic Attitude Reorientation of Free-floating Astronauts by Joint Actuation」
* 久保 勇貴(JAXA), 川口 淳一郎(ANU)
Abstract:
When a human or a robot actuates its joints in a free-floating state, the attitude motion becomes nonholonomic, i.e., the final attitude changes according to the joint actuation procedure. In this presentation, we describe a method for an astronaut in microgravity to reorient to a desired attitude by only actuating his/her joints using the nonholonomic property. The presenters derive an approximate analytical solution of attitude motion for the rectilinear joint actuation and propose an efficient nonholonomic attitude reorientation method. A free-floating astronaut is a good example for the rectilinear joint actuation because it is easy for humans to reproduce the rectilinear joint actuation intuitively and satisfies the constraints of the joint actuation range.

ASTRO-2022-A005
「3 次元運動による非ホロノミック性を利用した宇宙機の姿勢変化」
「Attitude Change of Spacecraft by Non-honolonomic Features Generated from Motion in Three-dimensions」
* 竹内 咲希(九大・院), 坂東 麻衣, 外本 伸治(九大)
Abstract:
Variable-structured spacecraft can change their attitude under no external forces/torques by utilizing non-holonomic features generated from transformational motions. This method

conserves the total angular momentum, and the spacecraft attitude can be changed under the restriction that the configuration of the spacecraft is the same before and after the transformational movement. In previous research for non-holonomic systems, two-dimensional space systems were mainly dealt with. This paper deals with the three-dimensional space systems and discusses the effect of the three-dimensional transformational movement on its attitude change.

Jul 25th(Mon) Room A PM1(13:30-15:00)　Abstracts

ASTRO-2022-A006

「地球観測衛星のためのグランドトレース配置を考慮した最適コンステレーション設計」

「Optimal constellation design for Earth observation considering ground track placement」

* 井本 悠太(阪大・院), 佐藤 訓志, 山田 克彦(阪大)

Abstract:

In this study, the optimal design problem of satellite constellations for Earth observation missions is formulated as a multi-objective optimization problem that determines the ground track configuration.

Then, the mission performances such as revisit time and fuel consumption are mathematically formulated as objective functions and they are used to evaluate the overall constellation performance.

By solving the optimal design problem using multi-objective optimization, a set of optimal constellations that minimize objective functions can be obtained.

ASTRO-2022-A007

「Quasi-Satellite Orbit 上における軌道安全性と電力系の同時最適化」

「Simultaneous Optimization of Orbit safety and Power System on Quasi-satellite Orbit」

* 大木 優介(JAXA)

Abstract:

The spacecraft is going to stay around Phobos on quasi-sattelite orbits (QSO) in Martian Moon eXploration mission. The spacecraft experiences long eclipce depending on the season and the eclipce is not simply periodic because there are two eclipces of Mars and Phobos and the spacecraft goes around Phobos which goes around Mars. There are some cases that the load of battery becomes hiah depending on the pattern of eclipce. Therefore,

this presentaion provide a new guidance method relizing simultaneous optimization of orbit safety and depth of discharge of the battery.

ASTRO-2022-A008

「確率的軌道最適化による航法誘導制御方策の統合的最適化」

「Integrated Optimization of Guidance Navigation and Control Strategy via Stochastic Trajectory Optimization Approach」

* 柿原 浩太(AE), 尾崎 直哉(JAXA), 石川 晃寛(東大), 近澤 拓弥(東大・院), 中須賀 真一, 船瀬 龍(東大)

Abstract:

In deep space exploration with micro/nano-spacecraft, the relatively high cost of trajectory correction and orbit determination is an important issue. In this study, a method is proposed to optimize the scheduling of the trajectory correction and the orbit determination in an integrated manner to minimize the amount of control required for trajectory correction. The problem is formulated by using the stochastic trajectory optimization technique. The probability distribution of the augmented state is parameterized, and the propagation of the parameters is formulated. The objective function and constraints are evaluated from those parameters, and the trajectory correction time and orbit determination time are optimized. The optimization problem was solved for sample problems. These numerical simulations show the validity of the proposed method.

Jul 25th(Mon) Room A PM2(15:15-17:15)　Abstracts

ASTRO-2022-A009

「力学系理論と太陽輻射圧による摂動の準解析的な検討」

「Semi-Analytical Approach on Dynamical System Theory and Solar Radiation Pressure」

* 中宮 賢樹（帝京大）, McInnes Colin (UofG)

Abstract:

This paper provides an efficient method to rapidly assess the effect of solar radiation pressure and injection errors on halo orbit dynamics for preliminary mission planning purposes. An approximate semi-analytical approach to compute the deviation of a solar sail spacecraft during motion along a Halo orbit is proposed. Afterwards, the accuracy of the proposed approach is evaluated.

ASTRO-2022-A010

「Stationkeeping of Periodic Orbits Using High-Order Target Phase Approach」

* Fu Xiaoyu, Baresi Nicola(Surrey Space Centre, University of Surrey), Armellin Roberto(Auckland Space Institute, University of Auckland)

Abstract:

To maintain the periodic orbits in a three-body regime, a high-order Target Phase Approach (TPhA) is proposed in this work. Two crucial maps, the phase-angle Poincare map and high-order maneuver map are established respectively for the determination of stationkeeping epochs and calculation of of correction maneu- vers. A stochastic optimization framework tailored for the TPhA-based station- keeping process is leveraged in search of the fuel-optimal and error-robust TPhA parameters. Quasi-Satellite orbits around Phobos are investigated to demonstrate the validity and efficiency of this approach in both low- and high-fidelity mod- els.

ASTRO-2022-A011

「ソーラーセイルの姿勢制御に基づいた地球-月系 L2 周りの小さな準周期軌道」

「Small-amplitude quasi-periodic orbits of solar sails around Earth-moon L2」

* 中条 俊大(東工大)

Abstract:

Libration point orbits around the Earth-moon L2 are useful for the lunar surface observation. However, the amplitude of the classical halo orbits is usually in the order of 10,000 km, and the geometry with respect to the moon varies. In this study, we newly propose small-amplitude quasi-periodic orbits, controlled by solar radiation pressure. By utilizing the active attitude control of solar sails, the amplitude can be made smaller to the order of 1,000 km.

ASTRO-2022-A012

「Chance-constraint optimization of interplanetary trajectories with a hybrid multiple-shooting approach」

* マルモ ニコラ（Sapienza/DIMA），ザボリ アレッサンドロ（Sapienza/DIMA）

Abstract:

Stochastic uncertainties and disturbances may deviate a spacecraft from the designed optimal trajectory. To provide an added layer of robustness, additional propellant is usually

allocated for ground-based correction maneuvers. This approach is often time-consuming and the estimated propellant margins excessive.
This manuscript proposes a systematic approach to overcome these issues by exploiting quantitative information concerning the system uncertainty in the optimization process. A linear feedback control law is used to steer the probability distribution of the spacecraft state towards a target distribution at an assigned final time.
The well known fixed-time orbital rendezvous is considered as a study case. The proposed approach uses a hybrid single/multiple-shooting strategy to propagate the probability distribution in an effective way. Preliminary results show the possibility of reducing the final dispersion with a modest increase of fuel consumption.

Jul 26th(Tue) Room A AM(9:30-12:00) Abstracts

ASTRO-2022-A013
「地球月三体系における周期軌道への月スイングバイを用いた軌道投入」
「Orbit Injection using Lunar Swing-by to Periodic Orbit in the Earth-Moon System」
* 小松 龍世(総研大・院), 川勝 康弘(JAXA)
Abstract:
Many missions, including the Artemis program, have been envisioned based on the premise of continuous access to the Moon. The periodic orbits in Circular Restricted Three-Body Problem with Earth-Moon system are characterized by the fact that the orbit relative to the Moon is preserved. By using these periodic orbits, mission orbit options can be increased. We propose a method of using a lunar swing-by to inject an orbit into such a periodic orbit. This method can suppress the ΔV required for orbit injection compared to orbit injection from a lunar transfer orbit to a lunar orbit. In this work, we clarify the conditions of the lunar swing-by to inject the orbit into the periodic orbit.

ASTRO-2022-A014
「時間多項式を外力とする Hill 方程式の閉形式解」
「A Closed-form Solution of Hill's Equations with Time Polynomials as External Force」
* 渡邉 泰之(MELCO)
Abstract:
A closed-form solution of Hill's equations with external force and its application to spacecraft guidance are presented. Hill's equations around circular orbits have been widely used for

spacecraft proximity guidance such as rendez-vous and formation flight. The well-known Clohessy-Wiltshire solution has a closed form on the condition of no external force exerted on spacecraft. In the case that the acceleration of external force is expressed as time polynomials, a closed-form solution of Hill's equations can be derived, which contains the C-W solution internally. The solution provides the benefit that spacecraft trajectories satisfying multiple constraints are obtained straightforward by calculating the polynomial coefficients in linear equations. Guidance strategies are also developed with the obtained acceleration profiles. Several numerical examples reveal the effectiveness of this guidance method using the solution.

ASTRO-2022-A015

「インパルスΔVの総和を直接的かつ自動的に最小化するための変数変換」

「Regularized Formulation for Direct Nonlinear Trajectory Optimization with Automatic Removal and Addition of Impulsive Delta-V」

* 大島 健太(広工大)

Abstract:

The present study introduces regularized variables to define velocity changes, i.e., delta-v, in the direct multiple shooting procedure to solve nonlinear trajectory optimization problems. The proposed formulation avoids the notorious singularity due to null delta-v in derivatives of a cost function and keeps the physical meaning of delta-v through constraints. This favorable property leads to a directly applicable direct method to nonlinear trajectory optimization problems that can automatically remove unnecessary delta-v or add necessary delta-v to minimize the sum of delta-v and satisfy local optimality. The method is applied to several test cases from benchmark ones to highly chaotic transfer problems to demonstrate its effectiveness.

ASTRO-2022-A016

「Lobe dynamics によるカオス的遷移軌道の解析」

「Analysis of Chaotic Trajectories Based on Lobe Dynamics」

* 平岩 尚樹（九大・院）, 坂東 麻衣, 外本 伸治（九大）

Abstract:

In trajectory design, leveraging natural dynamics is essential to lower fuel consumption. Among natural trajectories, chaotic trajectories are difficult to utilize for trajectory design but

have the potential to save much fuel consumption. To deal with chaotic trajectories, this study focuses on lobe dynamics, which can describe phase space transport in the chaotic sea. Periapsis Poincare map, whose surface of section lies in periapsis passages, is used to represent lobe dynamics, and the dynamical structure of chaotic trajectories is analyzed based on lobe dynamics.

ASTRO-2022-A017

「超小型月探査機シリーズ HOKUSHIN のミッション概要と探査軌道設計」

「Mission Summary and Trajectory Design for Lunar Explorer CubeSat HOKUSHIN」

* 武田 浩平, 中澤 幸大, 小町 咲葵(東北大・院), 藤田 伸哉, 桒原 聡文(東北大)

Abstract:

The HOKUSHIN series is a lunar exploration technology demonstration Cubesat being developed by Tohoku University and Hokkaido University. The first cubesat will be launched in 2023 to demonstrate a ranging system and a propulsion system at LEO. The second Cubesat will be injected into a Molniya-type lunar frozen orbit after a low-thrust transition using Weak Stability Boundary (WSB). We present an overview of the HOKUSHIN-1 and the mission plan for HOKUSHIN-2.

Jul 26th(Tue) Room A PM1(13:30-15:00)　Abstracts

ASTRO-2022-A018

「多面型液晶デバイスを応用した極高精度相対位置・姿勢アクチュエータ」

「Multi-faceted Reflectivity Control Devices: High Precision Relative Position and Attitude Actuator for Formation Flight Applications」

* 杉原 アフマッド清志（JAXA），杉浦 圭佑（青学・院），森 治（JAXA）

Abstract:

A new reflectivity control device is proposed which is capable of controlling both magnitude and direction of solar radiation pressure forces acting on the device.

When mounted on a given satellite, the device is capable of imparting both force and torque as high precision controled output to the satellite, in the order of nano-Newtons and pico-Newton-metres.

For formation flying missions, the device may be applied to microwave and optical interferometry as well as gravitational wave detector missions.

The device concept and capability are presented, followed by several example scenarios to

explore the future missions this device may enable.

ASTRO-2022-A019

「磁束ピンニング効果を用いた磁気浮上による擾乱抑制機構における指向方向制御 の導入」

「Introduction of directional control in disturbance suppression mechanism by magnetic levitation using flux pinning effect」

* 小林 寧々（法政・院），柴田 拓馬（室蘭），坂井 真一郎（JAXA）

Abstract:

In recent years, strict requirements have been imposed on the disturbance control and temperature control of space telescopes. A magnetic levitation type disturbance suppression mechanism using the magnetic flux pinning effect generated during the superconducting state has been proposed for the suppression of micro-disturbances and heat transfer. The authors aim to improve the pointing accuracy by applying a direction control to the mission part of the mechanism using antimagnetic force. Using the experimental set-up, we have verified the performance of levitation interval control method. The experimental results are reported.

ASTRO-2022-A020

「コイルを横配置させた薄型デュアルリアクションホイールの軌道上姿勢制御実験」

「An Attitude Control Experiment on Orbit for Dual Reaction Wheel System Using Horizontal Coil Configuration」

* 平社 信人(群馬高専), 鈴木 颯太, 伊藤 優介, 萩原 想大, 齊藤 創(群馬高専・専攻科), 今井 雅文(新居浜高専), 徳光 政弘(米子高専), 北村 健太郎(九工大), 野上 正和(信正商事), 柳原 健也(小野塚精機), 今井 一雅(高知高専)

Abstract:

In this report, an attitude control system for 2U cubesat “KOSEN-1” as Innovative-2 on orbit is conducted. Then the attitude control system for the cubesat is adopted a dual reaction wheel system which each reaction wheel is rotated to opposite direction with a time lag as control variable. Moreover, the reaction wheel is used as a novel thin actuator which the configuration of the coils is deployed horizontally for rotation axis. To confirm some effectiveness of the dual reaction wheel system for the cubesat, the attitude control experiment on orbit is executed and the obtained data are evaluated.

Jul 26th(Tue) Room A PM2(15:15-17:15)　Abstracts

ASTRO-2022-A021

「柔軟構造物をもつ宇宙機の最短時間姿勢マヌーバに関する研究」

「Minimum-Time Attitude Maneuver of Spacecraft with Flexible Structures」

* 酒井 貴行(阪公大・院), 下村 卓, 山田 克彦(阪公大)

Abstract:

For spacecraft with flexible structures such as solar array paddles, residual vibration causes disturbance. To avoid the occurrence of residual vibration, it is essential to provide appropriate control inputs during attitude maneuvers. In this study, we present the results of a fundamental investigation of attitude maneuvers for spacecraft with multiple flexible modes. First, we show the response of the spacecraft attitude when a symmetric shape control input is given and calculate the conditions under which vibration control and attitude control can be achieved simultaneously. Second, we discuss the results of optimization calculations with respect to the parameters of the control inputs. Finally, we demonstrate through numerical simulations the effectiveness of the proposed method for determining the parameters of the control inputs.

ASTRO-2022-A022

「スピン型ソーラーセイル形状制御装置の開発状況」

「Development Status of Shape Control Device for Spinning Solar Sails」

* 高尾 勇輝, 森 治(JAXA), 渡邊 秋人(サカセ), 武井 祥平, 江川 主民, 藤井 樹里(nomena)

Abstract:

Shape control of solar sails can extend a potentially flat sail to a three-dimensional variable structure. In previous research, the first author proposed a novel shape control method for spinning solar sails and demonstrated its feasibility through a ground experiment. Although this experiment was successful from the viewpoint of demonstration, the experimental facility was handmade and hence there is still room for improvement in control accuracy. To pursue better performance, the authors are currently developing a new shape control device with which we consider to perform flight demonstration in the near future. In this presentation, the latest status of the shape control device under development and its experimental results are reported.

ASTRO-2022-A023

「ブーム展開型傘型ソーラー電力セイルの非対称展開」

「Study on Asymmetric Deployment of Umblella-shaped Solar Power Sail Composed of Self-Extensible Booms」

* 多々良 飛鳥（総研大・院），立川 璃子（日大・院），島袋 秀晃（日大・学），宮崎 康行（JAXA）

Abstract:

Solar sail missions with small satellites have been actively proposed in recent years. The authors are studying umbrella-shaped sail structure for small satellites to utilize solar radiation disturbance caused by local deformation of the sail membrane for attitude and trajectory concurrent control rotating the sail structure with single-axis gimbal. The sail membrane is deployed by four cantilevered self-extensible booms wrapped around cylinders to reduce weight. In order to show the feasibility of the proposed sail structure, the effect of asymmetric self-extension of boom for the entire sail structure is investigated and reported in this presentation.

ASTRO-2022-A024

「Design of a Square Solar Sail for Interplanetary Missions」

* サントス ルラ バホス レチシア，平木 講儒 (Kyutech)

Abstract:

This project intends to create a solar sail capable of interplanetary trips for future space travels. Because Mercury is the least researched planet in the solar system, a mission to this planet is being considered. Solar sails for interplanetary missions can be many meters long and too flexible, making controlling the attitude of a flexible body challenging. As a result, we recommend a square sail with a coilable boom. The sail is linked to the boom tips and deploys alongside them. Because of its simplicity and symmetric deployment, the Palmer-Shaffer origami design was chosen. Furthermore, sail and booms might deform and wrinkle during sail deployment and rotation. Because the sail in this scenario is highly long, asymmetry during deployment and deformations in the sail can generate torque capable of spinning the spacecraft. The undesirable torque created is predicted to affect the spacecraft's attitude control.

Jul 25th(Mon) Room B AM(9:30-12:00)　Abstracts

ASTRO-2022-B001

「惑星探査ローバのための環境認識・経路計画方式の自律選択法」

「Environment Recognition and Path Planning Method Selection Scheme for Planetary Rover」

* 本橋 優俊（東大・院），久保田 孝（JAXA）

Abstract:

A planetary exploration rover needs an autonomous navigation system to drive to the destination. In the conventional navigation system, complicated and computationally demanded methods are used to guarantee the rover's safety. As a result, it takes a long time to traverse even though in the environment suitable for driving. It is needed to automatically switch the behavior mode according to the complexity of the environment to improve the driving efficiency. To this end, the authors propose a monocular image-based behavior mode selection scheme for the planetary rover. The behavior modes are selected based on the number of obstacles and their position which are acquired from the monocular image. The simulation results showed that the proposed method successfully reduced the traveling time while ensuring the rover's safety.

ASTRO-2022-B002

「展開型ターゲットマーカーを用いた着陸の誘導航法制御」

「Guidance, Navigation, and Control for the Landing Using Deployable Target Marker」

* 楠本 哲也(東大・院), 森 治(JAXA)

Abstract:

A spherical landmark called target marker is used for the guidance and navigation of touchdowns in the Hayabusa2 mission. Even though using multiple markers as navigation aids would contribute to higher landing accuracy, conventional target markers are not used for that purpose because they are not discernable from a spacecraft. In this study, we propose a new type of target markers that is a deployable and identifiable membrane. We investigate the guidance and control of a spacecraft utilizing the multiple target markers on the target body surface for conducting accurate landing.

ASTRO-2022-B003

「固体ロケットモータを用いたOMOTENASHIの月面セミハードランディングのパラメータ最適化手法と運用計画について」

「Parameter Optimization Method and Operation Plan of OMOTENASHI's Lunar Semi-Hard Landing with a Solid Rocket Motor」

* 森下 直樹, 徳永 翔, 橋本 樹明(JAXA)

Abstract:

A parameter optimization strategy is developed to maximize the success probability of a semi-hard landing on the Moon by OMOTENASHI. Monte Carlo simulations are performed and the optimized parameters obtained by the simulations are stored in a database. In actual operation, the optimized parameters can be read from the database to immediately find the optimized parameters to generate commands for landing. In this talk, we will present the method for determining the optimized parameters and operation plan in detail.

ASTRO-2022-B004

「分離小型プローブによる着陸探査機の内外環境の状態推定」

「State Estimation of Internal and External Environment of a Lander by a Separated Small Probe」

* 大槻 真嗣, 吉光 徹雄(JAXA), 前田 孝雄(TUAT), 吉川 健人(JAXA), 國井 康晴(CU), 宇佐美 尚人(JAXA)

Abstract:

Small probes as the MINERVA series and LEV are installed to the Japanese landers for planetary explorations. It is expected for a small probe that value of a mission by a lander is increased and various risks are reduced by recording a condition at landing. In this presentation, we will mention the method of measurement or estimation of landing conditions by internal sensors of the small probe, and also the method of recording the characteristics of the external environment after landing. Concretely, this paper explains in detail the estimation method of the state of the internal environment in the probe including the lander such as impact acceleration at landing, residual velocity at landing, and inclination of the lander at the start of free fall; further, the estimation method of the state of the external environment near the landing site, such as mechanical characteristics and temperature of the ground, is appeared.

ASTRO-2022-B005

「スパイクを持つ球型ターゲットマーカーの跳ね返り挙動に関する研究」
「Research on Bounce Behavior of Spherical Target Marker with Spikes」
* 保田 瞬(青学・院), 楠本 哲也(東大・院), 菅原 佳城(青学), 森 治(JAXA)
Abstract:
Hayabusa and Hayabusa2 touched down on the asteroids and collected rock samples. To ensure a safe landing on the asteroids, a marker called Target Marker was dropped at the target landing site in advance. The purpose of this study is to clarify the mechanism of shock dissipation by the structure of Target Marker, and the interaction between the spikes attached to prevent rolling and shock absorption. The impact dissipation mechanism and the effect of spikes on bounce behavior were investigated by numerical analysis of a plane model using Non-smooth DEM. In addition, Monte Carlo Simulation was performed to investigate the final resting position of Target Marker.

Jul 25th(Mon) Room B PM1(13:30-15:00)　Abstracts

ASTRO-2022-B006
「電波干渉法を適用した相対電波航法の初期検討」
「Initial Study on Relative Radio Navigation by Applying Radio Interferometry」
* 藤田 雅大(東大・院), 杉原 アフマッド清志, 森 治, 津田 雄一(JAXA)
Abstract:
A real-time and highly accurate relative navigation method is required to realize cooperative missions of multiple spacecraft in deep space. We have been studying a method to estimate the relative orbit of a target satellite by measuring the arrival direction of beacon emitted from the satellite. Radio interferometry is applied to estimate the orbit. This method aims at real-time and highly accurate orbit estimation based only on angle information in environments where optical navigation cannot be applied, such as at long distances or in environments with severe optical conditions. In this presentation, we will report the initial results of the study.

ASTRO-2022-B007
「非同期 1Way 測距と深宇宙編隊飛行の航法への応用に関する一考察」
「A Study on Asynchronous One-Way Ranging Scheme with Application to Deep Space Formation Flight 」
* 川口 淳一郎(ANU), 藤田 雅大（東大・院）

Abstract:
The asynchronous one-way ranging scheme has been studied and developed by the authors. It successfully demonstrated the actual hardware verification recently. This helps small entities such as startups perform autonomous interplanetary missions avoiding heavy reliance on the agency assets. The scheme enables not only the range measurement but also the clock synchronization between two entities. It utilizes CDMA spread spectrum communication and is suitable for multiple paths among the formation.

The paper presents how effectively the scheme establishes the clock synchronization among the formation consisting of multiple spacecraft. And also, the paper extends and presents the idea on how the formation configuration is determined using the scheme. This will work and identify the configuration even in deep space, while it requires only uplink signal from the ground station on the Earth.

ASTRO-2022-B008
「小型月着陸実証機 SLIM におけるスピンモジュレーション除去手法開発」
「A proposal of the method for removing spin-modulation in SLIM(Smart Lander for Investigating Moon)」
* 森 光太朗, 谷口 正(富士通), 市川 勉, 竹内 央, 坂井 真一郎, 植田 聡史, 伊藤 琢博(JAXA)
Abstract:
In orbit determination of a spinning space craft, it is considered to be one of the causes of the accuracy lowering, that spin modulation which vibrates in synchronization with spin is added to the Doppler signal because of the change due to the effect of spin of the relative speed between the antenna of the space craft and that of the ground station. In this method, by simulating the rotational motion of the spinning space craft from the on-board attitude history and angular velocity history, the spin modulation can be estimated and removed from the Doppler signal.

Jul 25th(Mon) Room B PM2(15:15-17:15)　Abstracts

ASTRO-2022-B009
「詳細な磁気モデルに基づく宇宙機の電磁ドッキング・分離制御」
「Electromagnetic docking and separation control of spacecraft based on a detailed

magnetic model」

* 田島 颯(東大・院), 高橋 勇多(東工大・院), 柴田 拓馬(室蘭工大), 坂井 真一郎(JAXA)

Abstract:

Recently, large space structures have been demanded increasingly, and is considered to be realized by small spacecraft docking as construction methods. The structures with docking small spacecraft are superior to monolithic structures for flexibility against failures because of replacement of a failed satellite. In docking system, propulsion systems are mainly used, but electromagnetic interactions can overcome disadvantages of propulsion systems, such as contamination. For such a reason, this study focuses on docking and separation technology using electromagnetic interactions. Most research on spacecraft control using electromagnetic interactions have been used dipole approximations to calculate magnetic field, to reduce computational load. However, it is thought that the short distance control is important in docking systems. Therefore, this study proposes an electromagnetic docking and separation control based on an exact magnetic field model while considering computational load.

ASTRO-2022-B010

「宇宙機自動ドッキング機構地上試験ダイナミクスシミュレータの開発」

「Development of Dynamics Simulator for Spacecraft Automated Docking Mechanism Ground Test」

* 水野 光(JAXA)

Abstract:

Automated docking technology is a key technology for the future mission such as resupply to manned lunar orbit bases. One of the planned missions of the HTV-X is a demonstration of on-orbit automatic docking system. JAXA is working on the application of model-based development methods/methodologies to the demonstration of automated docking technology. Since model accuracy is a key in the model-based development, it is essential to have a method and equipment to verify the validity of the mechanical and control models. In this study, dynamics simulator is developed for the automatic docking verification facility, which was introduced for performing ground tests of soft capture function of automatic docking system, to enable quick turn-uround of automatic docking tests and Improvement of reproducibility with the real environment.

ASTRO-2022-B011

「宇宙機自動ドッキングシステムを対象とした複合物理・システムレベルモデルの構築とその活用」

「Multi-physics and system-level model construction and utilization targeting spacecraft automatic docking system」

* 河津 要(JAXA)

Abstract:

Automated docking is identified as key technology for various space activities and missions. However, it is difficult to realize comprehensive evaluation and verification of spacecraft automatic docking system by ground test due to the cost of covering a huge number of conditions and issues with reproducing the operating conditions on orbit. Furthermore, the system includes dynamic interaction and complex relationships among multi-physics domains. Therefore, model-based approach to evaluate dynamic behaviour including each interaction across multi-physics domains is proposed in this study. This approach is realized using Modelica modeling language that allows acausal modeling of complex cyber-physical systems. Moreover, a toolchain based on Functional Mockup Interface realizes analytical evaluation that covers the necessary objects and key physics. This approach is applied to docking feasibility evaluation and trade-off on safety measure.

ASTRO-2022-B012

「協力物体に対する複数の輝点航法標識を用いた深宇宙ランデブドッキング」

「Deep Space Rezendvous Docking with a Cooperating Target Using Multiple Markers」

* 西村 尚（東大・院）, 武井 悠人, 津田 雄一（JAXA）

Abstract:

Rendezvous docking (RVD) is an important technology that can be applied to sample delivery and refueling in space, increasing the degree of freedom in space exploration. However, considering its implementation in deep space, where the payload weight is limited, simple and low-weight RVD system is required. This paper applies the relative navigation algorithm using artificial landmarks, which was demonstrated on the deep space probe Hayabusa2, to RVD system. The feasibility of low-resource relative navigation using multiple markers was investigated.

ASTRO-2022-B013

「はやぶさ２拡張ミッションにおける 1998 KY26 近傍運用の初期検討」

「Preliminary Study on Asteroid Proximity Operations for the Hayabusa2 Extended Mission to 1998 KY26」

* 菊地 翔太(NAOJ), 三桝 裕也, 佐伯 孝尚, 武井 悠人, 池田 人, 吉川 真, 津田 雄一(JAXA)

Abstract:

After the successful sample return from Ryugu, Hayabusa2 started its extended mission, which was designed to rendezvous with the near-Earth asteroid 1998 KY26 in 2031. The target asteroid has a diameter as small as 20?40 m and a rotation period as short as 10.7 min. To explore the fast-rotating asteroid even in such a distinctive environment, this research investigates possible asteroid proximity operations as a preliminary mission design.

ASTRO-2022-B014

「スラスタ噴射によるレゴリス飛散現象とクレーター形状の関連」

「Relation between regolith scattering and crater shape」

* 山川 真以子(総研大・院), 丸 祐介, 澤井 秀次郎, 大門 優, 藤田 和央, 森 治, 津田 雄一, 吉川 真(JAXA)

Abstract:

When a spacecraft fires its thrusters near the surface of a celestial body, objects on the surface of the body are scattered in the vertical direction and adhere to the instruments mounted on the spacecraft, degrading their performance. We predict that celestial surface objects are scattered according to the wall angle of the crater created by the thruster plume. The relationship between the crater shape and the object dispersal angle is not fully understood. Mechanisms of crater formation include viscous erosion, which creates craters with a small wall angle, and bearing capacity failure, which creates craters with a large wall angle. Here, we experimentally clarify the transition point between the two crater formation mechanisms when the thruster plume penetrates soil with various shear strength values and the dependence of regolith dispersal angle on crater wall angle.

ASTRO-2022-B015

「ホーンによる空中サンプル受け渡し挙動解析」

「Behavior Analysis of Sample Delivery Mechanism with Horn」

* 中川 雄登(東大・院), 森 治, 佐伯 孝尚(JAXA), 菅原 佳城(青学大), 津田 雄一(JAXA)
Abstract:
It is considered to use orbiter and lander in deep space sample return missions. In such a case, it is important to ensure that the sample is passed from lander to orbiter. However, how to deliver samples is a challenge. To deliver samples, an sample delivery mechanism with a horn is considered. In this mechanism, several parameters such as the repulsion coefficient of the sample capsule are supposed to affect the capture rate. In this study, the behavior of the sample capsule is analyzed by using numerical calculations.

ASTRO-2022-B016
「Comet Interceptor ミッションによる彗星核の高速フライバイ撮像」
「High-speed flyby imaging of cometary nucleus by Comet Interceptor mission」
* 坂谷 尚哉(JAXA), 亀田 真吾(Rikkyo Univ.), 尾崎 直哉, 佐々木 貴弘(JAXA)
Abstract:
Comet Interceptor is selected as ESA's F-class mission, which will be lunch in 2028. While other cometary missions in the past visited the short period comets (SPC), Comet Interceptor's target is a long period comet (LPC), which has been less heated by the Sun than SPC. This mission will bring us new insights of the cometary nucleus shape, morphology, composition, and plasma science. Comet Interceptor will be made of a mothership and two smaller probes, both of which encounter the target body via high-speed flyby. One probe named B1 will be supplied by JAXA. We are developing the B1 camera system (NAC/WAC) to capture the LPC's nucleus. NAC/WAC system consists of an electrical box, narrow angle camera, and wide angle camera. In this presentation, we present the design of NAC/WAC system, new imaging techniques during the high-speed flyby, and its usage for optical navigation.

ASTRO-2022-B017
「Ejecta flux estimation after an impact crater: a methodology」
* Trisolini Mirko, Colombo　Camilla(PoliMi), 津田 雄一(ISAS / JAXA)
Abstract:
This work is part of the Horizon-2020 MSCA project CRADLE (Collecting Asteroid-Orbiting Samples) and it is based on the study of novel concepts for asteroid exploration and sample collection missions. Specifically, the objective of the project is to assess the feasibility of

performing in-orbit sample collection. To this aim, in this work, we present a methodology to estimate the number of particles the spacecraft would be able to collect by generating an ejecta cloud releasing a small kinetic impactor onto the asteroid surface. The methodology estimates the fluxes of particles around the asteroid using the concept of representative fragments. As the spacecraft moves within these particle fluxes, we estimate the impact rate of the particles on the spacecraft and the cumulative number of impacts. We apply this methodology to a spacecraft hovering around asteroid Ryugu.

Jul 26th(Tue) Room B PM1(13:30-15:00)　Abstracts

ASTRO-2022-B018

「B-DECIGO 衛星の三角形フォーメーションフライトにおけるドラッグフリー制御精度」

「Triangle Formation Drag-free Control of B-DECIGO Spacecraft」

* 神谷 俊夫, 中川 弘喜, 堀 惇史(NEC)

Abstract:

B-DECIGO is a space gravitational wave telescope with baseline length of 100km. B-DECIGO will observe the gravitational waves generated from black-hole and neutron-star binary coalescences.

The formation control of a long-distance, drag-free, low-thrust, near-geostationary orbit for triangle formation by three satellites is presented. A precise control can be performed by multivariable controller with micro-newton thrusters. Dynamics simulations, which is dominated by a drag and noises of sensors and actuators, show that the first-trial design meets tight control requirements, and demonstrates mission feasibility.

ASTRO-2022-B019

「大気摩擦に対する適応機構を加えた一般化正準変換に基づくフォーメーション追従制御」

「Formation tracking control based on the generalized canonical transformations with an adaptive mechanism for the atmospheric drag」

* 濱中 勇希(阪大・院), 佐藤 訓志(阪大)

Abstract:

For an ultra-precise formation control, a control method that can directly treat the satellite motion as a nonlinear relative orbital motion is useful. We have developed a formation

tracking control method for port-Hamiltonian systems based on the generalized canonical transformations. Here, the nonlinear relative orbital motion is modeled as a port-Hamiltonian system, and the error system for a given reference formation trajectory is constructed using the generalized canonical transformations. Then, by stabilizing the equilibrium point of the error system, asymptotic trajectory tracking is achieved. So far, that method considers only the gravitational perturbation as a disturbance. In this study, we additionally take the atmospheric drag into account. By introducing an adaptive mechanism for the atmospheric drag, asymptotic tracking to the reference formation trajectory is theoretically guaranteed even when the atmospheric drag coefficient is unknown.

ASTRO-2022-B020
「太陽-地球系 L2 点でのソーラーセイルフォーメーションフライトにおける姿勢・軌道制御」
「Attitude and Orbit Control in Solar Sails Formation Flight around Sun-Earth L2 point 」
* 杉浦 圭佑（青学・院），高尾 勇輝, 杉原 アフマッド 清志（JAXA），菅原 佳城（青学），森 治（JAXA）
Abstract:
The spatial resolution of astronomical observations with a single-disk telescope depends on the telescope size. In order to overcome this physical limitation in space-based astronomical observations, this study proposes interferometric observations by satellite formation flight. Formation flight interferometers can achieve a resolution equivalent to that of a large telescope by continuously changing the observation baseline between spacecraft. In previous studies, fuel was consumed in this process. Therefore, the use of a solar sail was considered, placing the formation flight around the Sun-Earth L2 point. The orbit can be tracked by the thrust order of the solar sail because of the proximity to the equilibrium point. This approach is expected to achieve formation flight interferometer without fuel consumption by controlling the orbit and attitude with the solar sails.

Jul 26th(Tue) Room B PM2(15:15-17:15)　Abstracts

ASTRO-2022-B021
「展開型膜面エアロシェルを用いた低弾道係数金星エアロキャプチャミッションについて」
「On Low-Ballistic-Coefficient Venus Aerocapture Mission with Deployable Membrane

Aeroshell」

* 鈴木 宏二郎（東大）

Abstract:

The application of low-ballistic-coefficient atmospheric entry using deployable membrane aeroshell to Venus aerocapture mission was investigated. Though significant reduction in the fuel mass is expected by the aerocapture, the aerodynamic heating environment becomes much more severe than the case of Mars because of higher entry velocity and denser atmosphere. However, when we increase the diameter of the aeroshell, shallow entry path angle becomes available, resulting in lower peak heating and larger apoapsis altitude that allows us to use electric propulsion to raise the periapsis up to the safe range. After the aerothermodynamics and trajectory analyses, the aeroshell with 10m diameter seems promising for the Venus aerocapture mission by a 100kg micro-satellite.

ASTRO-2022-B022

「ゴム気球を用いた薄殻エアロシェル大気突入カプセルの自由飛行試験」

「Rubber balloon experiment for reentry capsule with thin shell type capsule」

* 高澤 秀人(北大・院), 末永 陽一(東大・院), 宮下 岳士(北大・院), 平田 耕志郎(東京農工大・院), 若林 海人(北大・院), 高橋 裕介(北大), 永田 靖典, 山田 和彦(JAXA)

Abstract:

A new concept of thin shell-type capsule for deep space exploration, which has a light and large aeroshell to allow efficient aero-deceleration, has been proposed.

To evaluate the dynamic instability of the capsule's attitude at a low Mach number region, a free flight test by a rubber balloon drop (RERA) was conducted.

The capsule, Rera, reached an altitude of 25km, and then, separated from the balloon.

RERA started free flight, and finally splashed down in the ocean.

In the experiment, we successfully acquired acceleration, angular velocity, magnetic field, pictures, HK, and GPS data.

Oscillation of the capsule's attitude was observed during flight.

ASTRO-2022-B023

「展開型エアロシェル大気圏突入技術の RATS 飛行実証実験シリーズ」

「RATS flight demonstration experiment series for deployable aeroshell atmospheric-entry technology」

* 永田 靖典, 山田 和彦, 中尾 達郎, 羽森 仁志（JAXA）, 鈴木 宏二郎（東大）
Abstract:
Deployable aeroshells have the potential to innovate atmospheric entry technology. Our deployable aeroshell has a simple structure in which deployment is completed by filling the inflatable ring with gas. For the actual use of the deployable aeroshell, it is necessary to demonstrate the performance of the deployable aeroshell in an actual atmospheric entry flight environment and to further improve the technical proficiency of the deployable aeroshell. We are conducting and proposing a series of multiple sounding rocket experiment, named RATS, to improve the technical proficiency step-by-step. Through these experiments, we aim to establish the manufacture technology of large-scale aeroshells and to obtain the planetary orbit insertion technology by aero-capture, which can be applied to planetary exploration.

ASTRO-2022-B024
「抗力変調エアロキャプチャにおける軌道解析と極超音速風洞を用いたエアロシェル分離試験による成立性の評価」
「Evaluation of feasibility by trajectory simulation and aeroshell separation test using hypersonic wind tunnel in drag-modulated aerocapture」
* 宮盛 剛(東理大・院), 山田 和彦(JAXA), 小柳 潤(東理大)
Abstract:
In recent years, nano-satellite technology has developed rapidly and drastically. Furthermore, nano-satellites are expected to be applied to planetary explorations because of the low cost and short development time. Drag-modulated aerocapture using a deployable flexible aeroshell is being considered as a suitable orbital insertion technology for nano-satellite. The feasibility of this technology depends on two key factors: the existence of an entry corridor and the reliable and proper jettison of the aeroshell during atmospheric entry. In this study, the corridor was obtained by trajectory analysis in a two-dimensional plane. In addition, the behavior during aeroshell jettison was evaluated using a hypersonic wind tunnel. These results will be presented.

Jul 25th(Mon) Room C AM(9:30-12:00)　Abstracts

ASTRO-2022-C101
「 Space Domain Awareness for Cislunar Space: Characterization and Uncertainty

Quantification」

* Machuca Pablo(UC San Diego), Rosengren Aaron(UC San Diego)

Abstract:

Maintaining a catalog of objects beyond GEO (xGEO) represents a new challenge for Space Domain Awareness (SDA). With the Lunar Gateway and increased international efforts to explore and exploit the Moon and cislunar space, a plethora of dynamically complex xGEO orbits are expected to be populated in the coming years. This study aims to address topics of fundamental significance for the upcoming challenge of xGEO SDA, including: (1) characterization of common trajectories of interest (e.g., transfers between halo orbits and to distant retrograde orbits); (2) effective and intuitive parameterization of the orbital motion of xGEO objects in multi-body environments (based on a piecewise geocentric and selenocentric orbital element representation); and (3) quantification of uncertainties involved the orbit determination (OD) process, with an understanding on how uncertainty propagation affects viewing geometries, surveillance volumes, and required revisit rates for xGEO catalog maintenance.

ASTRO-2022-C002

「超小型探査機 EQUULEUS の軌道設計手法とその設計状況」

「Trajectory design resutls for 6U CubeSat EQUULEUS」

* 川端 洋輔(東大), 近澤 拓弥(東大・院), 船瀬 龍(東大/JAXA)

Abstract:

EQUULEUS (EQUilibriUm Lunar-Earth point 6U Spacecraft) is a 6U CubeSat which is being developed by the University of Tokyo and the Japan Aerospace Exploration Agency (JAXA). EQUULEUS will be launched soon by NASA's Space Launch System rocket as a piggyback and transfer to an Earth-Moon L2 (EML2) quasi-Halo orbit via invariant manifolds and lunar flybys. We present EQUULEUS trajectory design method and its latest trajectory design results.

ASTRO-2022-C003

「火星衛星探査計画 MMX における惑星保護に関わる衝突確率解析」

「Impact Probability Analysis for Planetary Protection of Martian Moons eXploration」

* 岩渕 真和, 中野 将弥, 小林 雅弥, 西村 和真(FUJITSU), 池田 人, 坂本 拓史(JAXA)

Abstract:

The Martian Moons eXploration (MMX) Mission conduct scientific observations of Mars and the Martian satellite (Phobos, Deimos) after the transition from Earth to the Martian sphere, and collect samples of the Martian satellite to return to Earth. The COSPAR Planetary Protection policy has been established as a guideline of international standards for the conservation of objects to be explored and the protection of the environment of the geosphere. In accordance with this policy, MMX designs the trajectory so that the probability of impact with a celestial body is less than the specified value for 50 years after launch. In this paper, we discuss the impact probability analysis of Mars, Europa and Enceladus.

ASTRO-2022-C004

「高次ダイナミクスを考慮した Lissjous 軌道間の 1 インパルス遷移」

「Single-Impulse Transfers Between Lissajous Orbits in High-Order Dynamics」

* 島崎 拓人(東大・院), 川勝 康弘(宇宙研)

Abstract:

We discuss a methodology for single-impulse transfers between Lissajous orbits around the same Lagrange point in the circular restricted three-body problem. In the case of the linearized dynamics, a complete transfer strategy was developed by Canalias et al. (2003) leveraging the hyperbolic invariant manifolds emanating from Lissajous orbits. This approach is valid for Lissajous orbits of small-amplitudes, but neglects the high-order dynamics, which becomes dominant in high-amplitude and vertical-Lyapunov-like Lissajous orbits. The purpose of this study is to extend the linear transfer problem to high-order nonlinear dynamics in CR3BP by means of the Lindstedt-Poincare semi-analytical approach. A framework based on the linear solutions and a possible extension to halo orbit are presented.

ASTRO-2022-C102

「軌道部品接続法を用いたフライバイ往還軌道設計」

「Flyby Round Trip Trajectory Design by Trajectory Parts Connecting Method」

* 伊藤 大智（総研大・院）, 川勝 康弘（JAXA）

Abstract:

“Trajectory Parts Connecting Method” is one of the methods for initial study for deep space mission design. It treats Keplerian orbits as parts and designs sequences by combining them. We can construct possible sequences comprehensively under the given condition at

a low computational cost by this method. This study extends the method to allow multiple indicators to be considered during the initial study. It makes it possible to find a suitable solution for the mission from the entire solution space. This presentation discusses the method using the Saturn flyby round trip as an application. The study provides insights into initial guesses for the actual mission design.

Jul 25th(Mon) Room C PM1(13:30-15:00)　Abstracts

ASTRO-2022-C007

「押し付け動作のみでの把持を実現するトラス構造把持エンドエフェクタの研究」

「An end-effector for gripping truss structures requiring only a pushing motion」

* 中西 洋喜（東工大）, 川口 直毅, 多賀 啓介（東工大・院）

Abstract:

This paper presents an end-effector for capturing space targets requiring only a pushing motion. Capture and gripping technology for non-cooperative targets in space are essential for future orbital-services, such as space debris removal. Non-cooperative targets are not dedicated markers and grapple fixtures, so the authors focus on the truss structures which are often equipped with the targets. We developed an end-effector for gripping truss structures requiring only a pushing motion. It has a simple and easy-to-operate mechanism that can contact detection, gripping, and returning to a standby state with one motor and springs. This presentation describes the design, development, and experimental results of the end-effector. In addition, the application of the end-effector to the docking mechanism of a deep-space sample return spacecraft will also be discussed.

ASTRO-2022-C008

「故障を考慮した搭乗員支援マニピュレータの最適軌道」

「Optimal trajectory of crew support manipulator considering motor failure」

* 上野 誠也(横国大), 竹内 健人(横国大・学), 相子 康彦(TECS)

Abstract:

Manipulators installed in a space station to support the crews' jobs are necessary to be designed that the crew will not be harmed even if a motor failure occurs. In this presentation, the risk for the crew against the motor failure is defined as the criterion, and the optimum trajectory is obtained by numerical calculation. For a two-link manipulator as an example of numerical simulation, the criterion can be expressed in hand coordinates. It was shown that

the obtained optimum trajectory is connected of two types of sub-trajectories. One is a bang-bang input trajectory that passes in the steepest direction of criterion. The other is a singular input trajectory that passes through the local minimum valley of the criterion.

Jul 25th(Mon) Room C PM2(15:15-17:15)　Abstracts

ASTRO-2022-C009

「はやぶさ２拡張ミッションにおけるスピン運用の概要」

「Overview of Spin Operation in Hayabusa2 Extended Mission」

* 大野 剛, 武井 悠人, 岩城 拓弥, 高尾 勇輝, 三桝 裕也, 津田 雄一(JAXA)

Abstract:

The Hayabusa2 mission achieved the return to the Earth with collected soil samples from the asteroid Ryugu and was concluded with great success in December 2020. It has now started its "extended mission" in which it aims for the flyby and rendezvous exploration of asteroids called 2001CC21 and 1999KY26 in 2026 and 2031, respectively. Since it is a long journey for an extra mission, the spin operation of the originally three-axis stabilised spacecraft is being studied to reduce the operation frequency. In this paper, an overview of the spin operation is presented.

ASTRO-2022-C010

「可変反射率デバイスによる宇宙機の三軸姿勢制御に関する初期検討」

「Initial study of 3-axis attitude control of spacecraft using reflectivity control device」

* 小林 寛之(東工大・院), 中条 俊大, 中西 洋喜(東工大)

Abstract:

Reaction wheel is used for attitude control of a general spacecraft, but it is constantly driven so disturbing vibration occurs.

It is expected to realize a highly accurate attitude control system without internal disturbance by using the solar radiation pressure controlled by a reflectivity control device (RCD) that can change the optical characteristics.

However, a 3-axis attitude control method that considers the position and orientation of the RCD has not been established.

In this presentaion, author explain to derive the placement requirement and construct the torque distribution law to realize 3-axis attitude control only with RCD.

In addition, Proposing a PWM drive method and verify its usefulness by focusing on the slow attitude response of solar radiation pressure for devices that are expected to be driven ON/OFF in two values.

ASTRO-2022-C011

「はやぶさ２拡張ミッションに向けた 1 軸 RW やイオンエンジンを使った姿勢制御方式の検討」

「Attitude Control Using 1-Axis Reaction Wheel and Ion Engines for the Hayabusa2 Extended Mission」

* 高尾 勇輝, 三桝 裕也, 大野 剛, 津田 雄一(JAXA)

Abstract:

In the extended mission, Hayabusa2 is scheduled to take additional 10 years to fly to its new target asteroids. To get through this long-period mission, we have been considering a new attitude control method that can save propellant and reaction wheel (RW) lifetime. For coast arcs, a bias momentum controller exploiting solar radiation pressure is developed to allow for sun-pointing attitude motion using any one of the four RWs. For thrust arcs, more sophisticated control is enabled by gimballing the the ion engines.

ASTRO-2022-C012

「金沢大学衛星の姿勢制御系の実装」

「Implementation of attitude control system for the Kanazawa Univeristy sattelite 」

* 軸屋 一郎（金大）

Abstract:

The Kanazawa University satellite is a 50 kg-class small satellite whose main purpose is to detect sudden celestial bodies, and is under development with the aim of launching it next year. Due to the demands of astronomical missions and the demands of solar cell charging, it is planned to be sun-oriented at all times. Attitude control plays an important role because it is equipped with a solar cell paddle deployment mechanism. In this presentation, we will explain implementation isssues of the attitude control system of the Kanazawa University satellite.

ASTRO-2022-C013

「光学航法を用いた地球近傍小惑星の自律的な探査」

「Autonomous NEA Exploration with Onboard Optical Navigation」

* 高橋 翔太(CU Boulder・院), シアーズ ダニエル(CU Boulder)

Abstract:

Autonomous capabilities are enabling technologies for future near-Earth asteroid (NEA) exploration missions. A challenge in such missions is the poor a priori information of the target bodies, which requires the intensive support from ground stations for navigation and orbit control in a conventional approach. This study proposes an autonomous exploration scheme built around onboard optical navigation and trajectory control to remove the ground in the loop. Measurements of DVs are used to break the scale invariance of the optical measurements. Covariance analyses are performed for the proximity operation phases, which helps us understand the required measurement accuracies. The end-to-end numerical study with various noises and biases shows the approach is robust.

ASTRO-2022-C014

「Navigation analyses and trade-offs for the Martian moon exploration mission around Phobos」

* Ciccarelli Edoardo(University of Surrey), Baresi Nicola(University of Surrey)

Abstract:

The MMX mission is planned to be launched in 2024 and is designed to closely examine the two Martian moons, Phobos and Deimos. Presently, five planar Quasi Satellite Orbits (QSO) with different reference altitudes around Phobos are under consideration in order to characterize and study the geophysical environment of the Martian moon. Preliminary navigation analyses carried out by our research group revealed that quasi-periodic trajectories, such as spatial retrograde orbits (3D QSOs) and in-plane Swing QSOs, could be capable of delivering better information on the gravitational field of the moon. To solidify and build upon these findings we have used a more complete dynamical model that considers the coupling between Phobos's libration motion and Mars's oblateness.

ASTRO-2022-C015

「はやぶさ２拡張ミッションにおける超近接フライバイ」

「Super Proximal Asteroid Flyby of Hayabusa2 Extended Mission」

* 三桝 裕也, 岩城 拓弥, 宇佐美 尚人, 坂東 信尚, 津田 雄一(JAXA)
Abstract:
Hayabusa2, the asteroid explorer brought Asteroid Ryugu's sample back to Earth on December 6th, 2020. All the mission operations went successful, and the spacecraft still has half of the ion engine fuel left. The investigation team of Hayabusa2's extended mission selected Asteroid 1998 KY26 as the next destination, and it will arrive at this asteroid in 2031. In the meantime, it is planned to perform a flyby at Asteroid 2001 CC21 in 2026. Hayabusa2 was originally designed for rendezvous operations, so its navigation cameras are fixed at the spacecraft, leading to operational limitations. Therefore, during flybys, it is necessary to move the spacecraft's attitude to follow the asteroid while it passes by. In this study, we introduce the overview and the operation technique about the asteroid flyby mission of Hayabusa2 extended mission.

ASTRO-2022-C016
「Convex-based Autonomous Guidance for Perturbed Relative Dynamics」
* Giovanardi Enrico Mario , * Litteri Walther (ISAE-SUPAERO)
Abstract:
In this work we propose the solution of a landing problem on the Martian satellite Phobos through successive convex optimization (SCVX) exploiting a high-fidelity relative dynamics model in presence of orbit perturbations. The Tschauner-Hempel equations were enhanced with 3rd order central body's gravitational contribution; Phobos' gravity and J2 of Mars were considered, creating a new relative dynamics model. The SCVX programming with lossless convexification was used for expressing the fuel optimal problem. The landing manoeuvre was conceived with a surface collision avoidance constraint and a descent cone and confirmed its effectiveness for future on-board applications.

ASTRO-2022-C103
「探査ローバのための脚部が受ける支持力と振動加速度の関係性に関する実験的調査」
「Experimental Investigation of Relationship between Supporting Force and Acceleration of Vibration for Planetary Exploration Rovers」
* 渡邉 智洋, 飯塚 浩二郎(芝浦工業大学)
Abstract:
In this investigation, it was confirmed that the supporting force changes by the value of

vibratory acceleration. This survey measured the supporting force when the rod was dragged while vibrating. The value of vibratory acceleration changed in each measurement condition. In the survey results, it has been confirmed that there is a borderline vibratory acceleration that changes ground rigidity. When vibratory acceleration is smaller than the borderline value, the supporting force with vibration is bigger than one without vibration. When the vibratory acceleration is bigger than the borderline value, the supporting force with vibration is smaller than the one without vibration. In this condition, the ground particles flow, and the ground becomes soft. Flowing the ground particles happens because the ground particles are pushed away by the impact of vibration. Using this control method, It is possible to develop a new movement method for planetary exploration rovers.

Jul 26th(Tue) Room C PM1(13:30-15:00)　Abstracts

ASTRO-2022-C017

「月着陸ミッションにおける垂直降下誘導則およびシーケンス最適化」

「Vertical Descent Guidance and Sequence Optimization for Lunar Landing Mission」

* 佐々木 貴広, 菊池 隼仁, 狩谷 和季, 古賀 勝(JAXA)

Abstract:

In many lunar landing missions, several hovering points are set during the vertical descent phase, which is the final landing sequence, in order to detect obstacles and switch between range-finders with different measurement ranges. In this study, we propose a method to simultaneously optimize both descent trajectory and hovering point selection considering several constraints such as fuel consumption, horizontal/vertical distance, and landing error. Through Monte Carlo simulations, the effectiveness of the proposed method is demonstrated.

ASTRO-2022-C018

「月惑星探査機に適用するリリーフバルブによる、流量制御型エアバッグシステムに関する研究」

「Research on Flow-controlled Airbags with Relief-valves Aimed at Lunar/Planetary Exploration Spacecraft Landing Gear」

* 鈴木 基生(静大・院), 澤井 秀次郎, 丸 祐介, 森 治, 河野 太郎(JAXA), 能見 公博(静大)

Abstract:

This study investigates landing methods using a flow-controlled airbag with a relief valve. By adjusting the gas outflow using a relief valve, the lander is landed with the gas remaining in the airbag. The shock-absorbing and shape-variable properties of the airbags are expected to enable the lander to land on complex ground. In this paper, the results of one-dimensional drop tests of an airbag conducted to confirm the validity of a theory for analyzing airbag behavior are reported. Based on the theory, landing dynamics will be analyzed using a simulation model of a lander equipped with airbags.

ASTRO-2022-C019

「セマンティックな地図に基づく位置推定の不確実性を考慮した経路計画」

「Path Planning for Exploration Rovers with Uncertain Localization based on Semantic Maps」

* 鈴木 大和（東大・院），久保田 孝（JAXA）

Abstract:

There are various types of terrain on the surface of the planet. Therefore, in order to recognize and avoid risky types of terrain, image-based terrain classification methods are being studied. However, originally there is no semantic distinction between traversable and untraversable for non-geometric hazards. Hence, whether a specific terrain type is traversable or not is decided by human experts. In addition, it is necessary for rovers to consider uncertain position estimation to robustly avoid untraversable terrain areas. This paper examines a chance-constrained path planning method that robustly avoids semantically untraversable areas by simulation based on experimental data.

Jul 26th(Tue) Room C PM2(15:15-17:15)　Abstracts

ASTRO-2022-C020

「タッチアンドゴーサンプリングプローブのシステム的検討」

「Sysytematic Study for Touch-and-Go Sampling Probe」

* 大木 春仁, 楠本 哲也(東大・院), 三浦 政司, 森下 直樹, 臼杵 智章, 岩渕 頌太(JAXA), 藤田 雅大(東大・院), 津田 雄一(JAXA)

Abstract:

This paper discusses the systematic study of new sample-return mission with Touch-and-Go sampling probe. In Hayabusa and Hayabusa-2 mission, the spacecrafts themselves landed on the asteroids for obtaining the samples. They accomplished the sample-return

successfully, however these spacecrafts had to take the risk of breakdown because they themselves landed on the celestial body. If it is possible that sampling probe lands independently, space mission can get more flexible. The main topic of this paper is the basic idea of new sampling return mission with touch-and-go probe. We simulated the landing case study and confirmed the feasibility.

ASTRO-2022-C021

「火星衛星探査計画 MMX 探査機の着陸ダイナミクスの検討」

「Study of Landing Dynamics of Spacecraft in the Martian Moons Exploration」

* 大槻 真嗣, 馬場 満久, 藤田 和央, 今田 高峰(JAXA), 姫野 武洋(UT), 尾崎 伸吾(YNU), 石上 玄也(KU), 前田 孝雄(TUAT), 高橋 正樹(KU), 小林 泰三(Rits), 北薗 幸一(TMU), 竹澤 晃弘(WU), 能見 公博(SU)

Abstract:

In this paper, we mention the development status of landing gear of the Martian Moons Exploration (MMX) spacecraft; especially, in-house study status with university researchers are described. The MMX spacecraft is larger than the conventional probe of Japan, and it is planned to stay on the surface of the Martian moon, for example, Phobos, for several hours after landing. And, the impact acceleration and the kinetic energy at landing are problems, because the gravity of the Martian moon is bigger than other asteroids. In the meantime, the restoring force by the gravity is not adequate; thus, trip-over and rebound are easily caused. This paper describes the details of countermeasures on the issues of landing gear, which can be satisfied even under such severe conditions.

ASTRO-2022-C022

「天体表面へのスラスタのパルス噴射によるレゴリス飛散現象に関する研究」

「Experimental study on the scattering of regolith due to thruster pulse injection to celestial surface」

* 徳岡 大河(静大・院), 山川 真以子(総研大・院), 馬場 満久, 森 治, 藤田 和央, 丸 祐介, 澤井 秀次郎(JAXA), 能見 公博(静大)

Abstract:

When landing on a celestial surface, a spacecraft pulses injection toward the celestial surface while adjusting. The plume causes regolith to scatter and adhere to mission equipment, degrading its performance. However, most of the previous studies have used

only steady injection, and there are few studies using pulsed injection. In this study, the effects of different injection methods (steady and pulse) on the crater mode, maximum wall angle, scattering angle, and appearance of scatter were investigated through experiments in which gas was injected into a sandbox in vacuum.

ASTRO-2022-C023

「Space research activities in the aerospace division of the University of Liverpool 」

* ソルディニ ステファニア(University of Liverpool)

Abstract:

We present research projects in the area of: (1) Origami robotic and Additive Manufacturing with a new paradigm in space mission design. Our concept of next generation of shape-change origami solar sails (OrigamiSat) involves modulating the local sail reflectivity and the use of 4D material. (2) DART and HERA mission's planetary science research in the area of asteroid internal structure and fate of ejecta. (3) Next generation of planetary defense mission concepts to asteroids with the newly £1.9M investment from UK Research and Innovation (UKRI) in the REMORA (REndezvous Mission for Orbital Reconstruction of Asteroids: A fleet of Self-driven CubeSats for Tracking and Characterising Asteroids) project (4+3 years funding).