Special Lecture Jul 24th(Mon) Main Room PM(13:00-13:50)

Ping Lu / (San Diego State University)

Ping Lu received his PhD degree in Aerospace Engineering from the University of Michigan, and his BS degree in Aerospace Engineering from Beihang University. He has over 30 years of experience in aerospace engineering research and education. His research expertise and interests are in guidance, control, and autonomous trajectory planning and optimization, and has authored/co-authored close to 200 journal and conference papers in these areas. He was a professor of Aerospace Engineering at Iowa State University until 2016, and since then a Professor and the Chair of the Aerospace Engineering Department at San Diego State University. Prof. Lu is a Fellow of the American Institute of Aeronautics and Astronautics (AIAA). He was the recipient of the prestigious AIAA Mechanics and Control of Flight Award in 2008, and a recipient of NASA Johnson Space Center Director's Innovation Group Achievement Award in 2016. Prof. Lu is the Editor-in-Chief of the *Journal of Guidance, Control, and Dynamics,* the premier international journal in aerospace guidance, control, and astrodynamics/flight dynamics.

「Aerospace Guidance and Computation in 60 Years」

Abstract
It has been 62 years since the start of the Apollo Program that culminated with mankind setting foot on the Moon. The Apollo program gave the birth to the critical aerospace engineering area of guidance as we know it today. Sixty years later on a much broader scale, spacefaring countries around the world are now actively pursuing missions in the cislunar space and on the lunar surface, with NASA's Artemis Program aiming at sending astronauts back to the Moon and beyond. In this presentation we will examine the role of onboard computation in aerospace guidance technology from the Apollo era to today. Fueled by the tremendous increase of onboard computational power, we are witnessing transformational changes in aerospace guidance and control technology where traditional designs are

replaced by a new paradigm known as Computational Guidance and Control (CG&C). Different from other computational branches of engineering and sciences, the computation in CG&C must take place onboard a vehicle, mostly in real time. CG&C allows much more complex guidance and control tasks to be performed than ever before, offering great potential for significant increase in autonomy, capability, and performance without the need for additional hardware or increase in system complexity. This presentation will focus on the transformation of the guidance methods and algorithms for space transportation systems, driven by the demand for higher performance and enabled by advances in theory and computational power. Examples of legacy technology and state-of-the-art guidance algorithms will be provided and contrasted in selected applications.

Special Lecture Jul 25th(Tue) Main Room PM(13:00-13:50)

船瀬　龍（FUNASE Ryu）/ JAXA/ISAS・東京大学 （ JAXA/ISAS, University of Tokyo ）

2007 年，東京大学大学院工学系研究科航空宇宙工学専攻博士課程修了，博士（工学）．東京大学在学中は，超小型人工衛星の研究・開発に携わり，10cm, 1kg の CubeSat（キューブサット）の打ち上げに世界で初めて成功．その後，宇宙航空研究開発機構（JAXA）宇宙科学研究所にて，小惑星探査機「はやぶさ」「はやぶさ 2」，小型ソーラー電力セイル実証機 IKAROS（イカロス）などの深宇宙探査機の設計・開発・運用に携わる．
2012 年，東京大学大学院工学系研究科航空宇宙工学専攻に准教授として着任，2019 年より JAXA 宇宙科学研究所教授（東京大学と兼務）．超小型衛星による低コストで高頻度な深宇宙探査の実現に向けた研究開発および実ミッションを推進している．2014 年，世界初の 50kg の超小型深宇宙探査機 PROCYON（プロキオン）の打ち上げ・運用に成功．2022 年には，NASA アルテミス計画初号機の相乗りで 10kg の超小型探査機 EQUULEUS（エクレウス）を打ち上げ，太陽・地球・月圏における軌道制御技術実証に成功．現在は，長周期彗星探査計画 Comet Interceptor や超小型外惑星探査計画 OPENS 等の超小型探査機ミッションを推進中．

「SLS 初号機相乗り CubeSat EQUULEUS による太陽・地球・月圏における軌道制御技術実証成果と今後の展望」

「 Technology Demonstration Results of Trajectory Control in the Sun－Earth－Moon Region by SLS Artemis-1 CubeSat EQUULEUS and Its Future Perspective 」

Abstract
EQUULEUS is a 6U CubeSat developed by the Japan Aerospace Exploration Agency (JAXA) and the University of Tokyo, aiming to reach the Earth-Moon second Lagrange point (EML2) and perform scientific observations there. After being inserted into a lunar transfer orbit by SLS Artemis-1 on November 16, 2022, the spacecraft completed checkout operations and successfully performed a delta-V maneuver and subsequent trajectory correction maneuver. This enabled a precise lunar flyby as planned and successful insertion into the orbit toward EML2, which will take advantage of multiple lunar gravity assists and the gravity of the Sun. EQUULEUS is equipped with a water propulsion system newly developed by the University of Tokyo, and became the first spacecraft in the world to successfully control its orbit beyond low Earth orbit using water propulsion. The successful precise orbit control in the Sun–Earth–Moon region by EQUULEUS, a 6U CubeSat weighing only 10kg, has opened the possibility of full-scale lunar and planetary exploration by CubeSats. This presentation describes the early operational results of EQUULEUS during its flight to EML2, with special emphasis on its precise orbit determination, guidance, and control results, and also provides an insight into the future of deep space exploration with nano/micro-satellites.

Jul 24th(Mon) Room A AM(9:30-12:00)　Abstracts

ASTRO-2023-A001
「ターゲットマーカーの跳ね返り抑制性能の解析及び実験的評価」
「Analysis and Experimental Evaluation of a Rebound Mitigation of a Target Marker」
* 楠本 哲也(東大・院), 保田 瞬(青学・院), 菅原 佳城(青学), 森 治(JAXA)
Abstract:
Hayabusa2 used artificial landmark called Target Marker (TM) as a navigation aid. To mitigate the rebound motion on an asteroid surface, the TM is composed of a shell and hundreds of small balls. Due to the collision among small balls dissipating the energy, rebound motion becomes smaller. We evaluate the rebound mitigation performance and translational motion after the rebound. We validate the proposed theory by the microgravity experiment conducted in a drop tower. This paper contributes to the design of payloads in asteroid missions.

ASTRO-2023-A002

「スラスタ噴射による月レゴリス飛散現象に対する CFD-DEM 解析」

「CFD-DEM Analysis of Lunar Regolith Dispersal by Plume Impingement」

* 山口 宇弘（慶應大・院），石上 玄也（慶應大）

Abstract:

Plumes exhausted from a landing engine mechanically erodes and scatters particles of regolith-covered planetary surface. The dust due to the particle erosion and dispersal seriously damages extraterrestrial infrastructures on the lunar surface to be built in the future. In this study, a one-way coupled CFD-DEM analytical method is adopted to investigate the particle behavior by the plume impingement. The Apollo lunar module and descent engine are modeled in the CFD framework to obtain gas flow reflected at the surface. The DEM particles are carefully calibrated based on the adhesion and internal friction angles since the viscous erosion is the dominant dispersal mechanism. The results shows that the particle trajectory angle is quantitatievly consistent with that estimated from the Apollo landing video.

ASTRO-2023-A003

「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, 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 continuous injection, and there are few studies using pulsed injection. In this study, the effects of different injection methods (continuous and pulse) on scattering counts through experiments in which gas was injected into a sandbox in vacuum.

ASTRO-2023-A004

「スラスタ噴射がレゴリス飛散現象に与える影響の評価」

「Evaluation of the effect of thruster injection on regolith scattering phenomena」

* 山川 真以子(総研大・院), 徳岡 大河(静大・院), 丸 祐介, 澤井 秀次郎, 大門 優, 森治, 津田 雄一(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. This phenomenon is thought to be influenced mainly by the crater shape and fluid flow generated by thruster injection. These effects are discussed through experiments and simple numerical calculations in which thrusters are injected into a sandbox inside a vacuum chamber.

ASTRO-2023-A005
「ベント型エアバッグを用いた不整地着陸に関するシミュレーション検討」
「Simulation Study on Slope Landing with Vented Airbag System」
* 滝川 遼太郎（東大・院）, 橋本 樹明（JAXA）
Abstract:
Un-even terrain exploration is a major challenge for future lunar and planetary exploration. We considered applying the vented airbag to slope and rough terrain landings, taking advantage of its flexibility and responsiveness. The conventional one-dimensional, one-degree-of-freedom landing simulation was extended to a two-dimensional, three-degree-of-freedom simulation to confirm the behavior of the entire spacecraft during slope landings. As a result, the exhaust timing was found to have a significant impact on stability, so the exhaust decision algorithm was improved. We were able to significantly improve stability during rough landings.

Jul 24th(Mon) Room A PM1(14:00-16:00)　Abstracts

ASTRO-2023-A006
「OMOTENASHI 姿勢軌道制御系の軌道上運用結果」
「In-orbit Operation Results of OMOTENASHI
Attitude and Orbit Control System」
* 橋本 樹明, 坂東 信尚, 平澤 遼, 森下 直樹, 菊池 隼仁, 廣瀬 史子, 竹内 央, 坂本拓史(JAXA)
Abstract:

OMOTENASHI spacecraft was launched by NASA SLS Artemis-I on November 16, 2022. Its mission was demonstrating semi-hard landing technologies to the moon surface and observing radiation environment of cis-lunar region. However, its initial attitude acquisition was not completed, and the spacecraft lost its power. We are continuing rescue operation till now. In the presentation, we will show the results of the initial attitude operation. Moreover, the separation disturbance from SLS is analyzed in order to estimate OMOTENASHI trajectory.

ASTRO-2023-A007

「はやぶさ２小惑星フライバイ観測のための画像フィードバック姿勢マヌーバ制御系設計」

「Attitude Maneuver Controller Design for Hayabusa2 Asteroid Flyby Observation」

* 涌坪 辰(都立大・研), 照井 冬人(神奈川工大), 三桝 裕也(JAXA)

Abstract:

One of Hayabusa2's extended missions is a flyby observation of Asteroid 2001CC21 in 2026 using the onboard narrow-angle camera fixed on the spacecraft. A fast attitude maneuver is required to track the asteroid in the image during the flyby observation. As one strategy for attitude maneuver "Visual Feedback Attitude Control" is proposed here. The position of the asteroid in the captured images are recognized utilizing image processing and this information is used as feedback signal to the attitude maneuver controller. The performance of this controller is verified from numerical simulation considering actual constraints on sensors and actuators.

ASTRO-2023-A008

「深層強化学習を利用した宇宙ロボットの多目的姿勢制御と形態進化」

「Multi-Target Attitude Control and Morphology Evolution of Space Robots via Deep Reinforcement Learning」

* 伊藤 司聖(早大・院), 柳尾 朋洋(早大)

Abstract:

In this study, we numerically evolve morphologies of space robots that control their attitude through shape maneuvers under conditions of vanishing total angular momentum. We apply deep reinforcement learning to find optimal shape maneuvers for attitude control with the reward setting for control accuracy and control time. We then use the Q-function obtained

in the attitude control to evolve morphologies of space robots via particle swarm optimization. While our previous study evolved morphologies of space robots for a specific attitude change, this study evolves morphologies of space robots so that they are suitable for arbitrary attitude changes, i.e., multi-target attitude control.

ASTRO-2023-A009

「高ダイナミクス対応 GNSS 姿勢決定モジュールの衛星/ロケットへの適用評価」

「Evaluation of high-dynamics GNSS attitude determination module for satellite and rocket applications」

* 坂井 智彦, 松本 秀一, 市川 知範, 新井 久旺(JAXA)

Abstract:

Based on the high dynamics GNSS receiver used in the space transportation system, we conduct research on adaptation to the attitude determination system using the GNSS compass. Because GNSS attitude determination uses carrier waves, signal tracking is more difficult than GNSS stand-alone positioning that uses code positioning. It is important to design signal tracking filters that adapted to the high dynamics of rockets and satellites, and the overlap of the antenna patterns of the two antennas. Integreted navigation system with MEMS IMU will also be reported.

Jul 24th(Mon) Room A PM2(16:15-17:45)　Abstracts

ASTRO-2023-A010

「柔軟構造物をもつ宇宙機の最短時間姿勢マヌーバにおける 2 自由度制御」

「Two-Degree-of-Freedom Control of Spacecraft with Flexible Structures in Minimum-Time Attitude Maneuvers」

* 酒井 貴行(大阪公立大・院), 下村 卓, 山田 克彦(大阪公立大)

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, a feedforward control input is employed for attitude control of a spacecraft with multi-flexible modes. The control input is a continuous-time control input expressed in the form of a time polynomial, which simultaneously achieves attitude maneuver of the spacecraft in an arbitrary direction and

suppression of residual vibration of flexible modes. A two-degree-of-freedom control system, a kind of feedback control, is employed to ensure robustness against modeling errors and disturbances. Finally, we demonstrate through numerical simulation the effectiveness of the proposed controller.

ASTRO-2023-A011

「地球周回低軌道における大型柔軟構造物と超小型衛星の連成運動解析」

「Analysis of Coupled Motion of Large Flexible Structure and Microsatellite in Low Earth Orbit」

* 市村 峻(SED), 宮崎 康行(JAXA)

Abstract:

A constrained mode model has been used for modeling the dynamics of large geostationary satellite with Large Flexible Structure (LFS). On the other hand, it has rarely been used for satellite with small moment of inertia. In addition, the coupled motion of LFS and satellite in Low Earth orbit (LEO) isn't well understood. In this paper, a constrained mode model is applied to satellite with smaller moment of inertia than LFS of 10 m in diameter, and the effect of the flexibility of the structure on the dynamics of the satellite in LEO is estimated. As a result, it was found that the flexibility of the structure has little effect on the translational motion, and the effect on the rotational motion is determined by the ratio of the magnitude of the moment of inertia of the satellite to that of the LFS.

ASTRO-2023-A012

「マイクロ波干渉計を応用した膜面形状測定法」

「Shape reconstruction of membrane structures with microwave interferometry: Experimental results」

* 杉原 アフマッド清志 (JAXA), 和田 武尚 (FIT), 須田 保 (S&MWT), 藤田 雅大 (東大・院), 川﨑 繁男 (S&MWT), 森 治 (JAXA)

Abstract:

Large membrane-deployable antennas have been explored as a light-weight solution to achieve 10m-class antennas for space systems. Operating synthetic aperture antennas on board flexible membrane structures requires the measurement of the membrane shape under deformation and compensating for this to properly synthesize a beam.

In this work we propose to illuminate the membrane-deployed synthetic aperture antenna

with external sources to reconstruct the membrane shape using microwave interferometry. This technique is demonstrated both by simulation and experiment. The new technology demonstrated in this work will serve as a stepping stone towards 100m-class deployable antennas for communication, Earth observation and outer planet exploration.

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

ASTRO-2023-A013
「月重力を利用した地球-月圏軌道遷移手法の検討」
「Investigation of Transfer Method Utilizing Distant Lunar Gravity」
* 伊藤 大智（総研大・院）, 川勝 康弘（JAXA）
Abstract:
It is important to understand the influence of the moon's gravity for saving fuel in various planet-moon systems missions. Previous studies focused on the moon's gravity as a perturbation around the apogee, but it affects spacecraft orbital elements even in low-altitude regions. This study identified the effect called "Distant flyby (DF)," where the moon's gravity leads to changes in orbital elements beyond its sphere of influence. There are two types of DF; DF-A occurs near the apogee, while DF-O occurs during the perigee to apogee transition. Understanding distant flybys offers insights for missions in planet-moon systems.

ASTRO-2023-A014
「Lobe dynamics にもとづくカオス的遷移軌道の設計」
「Design of Chaotic Transfers Based on Lobe Dynamics」
* 平岩 尚樹（九大・院）, 坂東 麻衣, 外本 伸治（九大）
Abstract:
It is generally challenging to utilize chaotic trajectories for designing transfers with small fuel consumption. This study enables incorporating these trajectories into low-energy transfers by leveraging lobe dynamics. Lobe dynamics describes phase space transport in the chaotic sea based on the “lobe,” the region surrounded by stable and unstable manifolds of a periodic orbit. The proposed method connects the lobe dynamics of several periodic orbits by impulsive inputs and realizes a chaotic transfer. The numerical examples in the standard map are demonstrated, and the application of the proposed method to spacecraft trajectory design is also discussed.

ASTRO-2023-A015

「連続推力を用いた低軌道円軌道間の準最適な軌道遷移」

「Quasi-optimal Continuous-thrust Orbit Transfer between LEO Circular Orbits 」

* 島 岳也(三菱電機), 山田 克彦(大阪公立大学)

Abstract:

In this presentation, the quasi-optimal orbit transfer between LEO circular orbits using continuous thrust will be studied. We extend the Split Edelbaum Strategy, which performs orbit transfer in 3-phase (burn-coast-burn) by directly controlling the semimajor axis and inclination using continuous thrust. Proposed strategy directly controls the right ascension of ascending node as well as semimajor axis and inclination. Numerical simulations confirm the effectiveness of the proposed strategy when the percentage of coasting intervals in the 3-phase is comparatively small.

ASTRO-2023-A016

「データ駆動型スパース同定を用いた共鳴フライバイ軌道設計に関する研究」

「Study on resonant flyby orbit design using SINDy」

* 伊藤 将太(都立大・院), 佐原 宏典(都立大), 近澤 拓弥(東大・院), 尾崎 直哉(JAXA)

Abstract:

An efficient orbit design method utilizing lunar flyby is required for realizing lunar orbiting and beyond lunar missions. Although its use has been considered in actual missions, resonant flyby orbit design is challenging because it requires consideration of complex dynamical models such as the Earth's gravity and the Moon's inhomogeneous gravity field. Therefore, this study proposes an efficient resonant flyby orbit design method using SINDy under the three-body problem.

ASTRO-2023-A017

「LEO を起点とした自在かつ経済的な惑星間地球出発軌道と深宇宙 OTV の検討」

「Investigation of LEO as a parking orbit for flexible/economical interplanetary Earth departure and DSOTV concept」

* 武井 悠人, 佐伯 孝尚, 津田 雄一(JAXA)

Abstract:

The interplanetary departure conditions of deep space probes are diverse. Thus, deep space missions conventionally require dedicated launch vehicles for each and cost greatly. While a significant reduction of unit launch cost per weight to the low Earth orbit (LEO) is expected shortly, the direct interplanetary Earth departure from LEO usually lacks flexibility and efficiency.

This study aims to realize frequent low-cost interplanetary Earth departure by filling the transportation gap between LEO and deep space without sacrificing the arbitrariness of the original LEO, the target V-infinity vector, and the departure epoch. As one solution, this talk introduces the orbital sequence adopting the one-revolution Earth free-return orbit (1rEFRO) and the consequent Earth gravity-assist (EGA). The status of investigating an alternative sequence, and the ISAS/JAXA's concept of deep space orbital transfer vehicle (DSOTV) are also reported briefly.

Jul 25th(Tue) Room A PM1(14:00-15:30)　Abstracts

ASTRO-2023-A018

「燃料消費量とスラスタ噴射誤差による基準軌道からの状態量誤差のトレードオフ」

「Trade-Off between Fuel Consumption and State Variables Error from Reference Trajectory Induced by Delta-V Execution Error」

* 大島 健太(広工大)

Abstract:

Minimum-fuel solutions, which have often been sought in trajectory optimization problems, can place maneuvers at dynamically sensitive locations that may diminish the robustness against delta-v execution errors. The present study considers not only the fuel-optimal problem minimizing the sum of magnitude of delta-vs but also the minimization of the sum of magnitude of state variables errors from a reference trajectory induced by delta-v execution errors. A homotopy path connecting the two problems is explored to reveal the trade-off between them.

ASTRO-2023-A019

「DESTINY+：スパイラル軌道上昇フェーズの軌道設計と運用計画解析」

「DESTINY+: Trajectory design and operation planning analysis of spiral orbit raising phase」

* 山本 高行, 尾崎 直哉, 竹内 央, 市川 勉, 杉本 理英, 三桝 裕也(JAXA), 谷口 正(富

士通)
Abstract:
DESTINY+ will be injected into a highly elliptical orbit around Earth by an Epsilon S rocket with Kick Stage. After that, DESTINY+ gradually raise its altitude in a spiral trajectory using low-thrust ion engines. This presentation provides a trajectory design and operational planning analysis during the spiral orbit raising phase. To escape the radiation belt during the first half of the ascent, the ion engine will be fired in the tangential direction. However, slight errors in thrust and direction may cause deviations from the planned trajectory, potentially leading to the loss of the spacecraft from ground-based observation. We propose a method to continue spiral orbit raising operations under such circumstances.

ASTRO-2023-A020
「太陽極域観測に向けた電気推進を用いた黄道面脱出軌道」
「Out-of-Ecliptic Trajectories with Electric Propulsion for Solar Polar Observations」
* 高尾 勇輝(九大), 尾崎 直哉, 西山 和孝, 月崎 竜童, 田畑 邦佳(JAXA), 小川 秀朗(九大), 鳥海 森(JAXA), 堀田 英之, 八田 良樹(名大), 関井 隆(NAOJ), 今田 晋亮(東大)
Abstract:
One of the biggest objectives of solar physics is to investigate the deep internal structure of the Sun, which can be accomplished by stereoscopic helioseismology, i.e., the observation of multiple locations with different latitudes at the same time. However, escaping from the ecliptic plane to reach a high latitude requires tremendous amount of velocity increment that can hardly be realized using a spacecraft propulsion system alone. This study presents a design method for out-of-ecliptic trajectories using electric propulsion and gravity assists. The orbital inclination is raised repeatedly through repeated Earth encounters controlled by electric propulsion. Optimization of many-revolution trajectories is computationally expensive because of its broad solution space, which makes it difficult to solve using conventional direct or indirect methods. To solve this issue, we propose a surrogate-based approach in which each revolution is approximated using a neural-network-based model.

Jul 25th(Tue) Room A PM2(15:45-17:15)　Abstracts

ASTRO-2023-A021
「WSB 軌道における Deep Space Maneruver と飛行期間の関係」

「Relationship between Deep Space Manerver and Time of Flight on Week Stability Boundary Orbit Transfer」

* 池永 敏憲, 植田 聡史(JAXA)

Abstract:

Week Stability Boundary transfer is strong candidate to Gateway. In logistic missions sevral kinds of cargo will be tranferd. In such situation, there are preferable transfer time may be required. For this purpose, this study asseses the relationship between Deep Spcae Manerver and Time of Flight which will give choices to mission designer of logistic missions.

ASTRO-2023-A022

「DVEGA を用いた複数惑星間ミッションの同時実現可能性の検討」

「Study on the possibility of multiple interplanetary missions with a single launch using DVEGA」

* 西本 慎吾(ANU・院), 川口 淳一郎(ANU)

Abstract:

Along with the recent high demand to explore Jupiter regions, more launch opportunities to those regions are expected. This study investigates the possibility of realizing different insertion conditions to Jupiter for the main and piggyback missions with a single launch. The developed strategy uses the additional maneuver after the DVEGA's maneuver to change the encounter condition to Earth and realizes the different insertion condition to Jupiter. This paper also studies the solar polar observation mission that requires higher relative velocity at the Jupiter insertion as an application of the piggyback mission.

ASTRO-2023-A023

「フライバイサイクラーによる ISO の高速応答軌道設計」

「Rapid-Response Trajectory Design for ISO via Flyby Cycler」

* ヴィダル ピエール(ESTACA, master student)

Abstract:

DESTINY+ is an upcoming JAXA interplanetary mission expected to fly by the (3200) Phaethon asteroid. Pierre's internship contributed to DESTINY+'s orbital mission design, by performing a simulation on Python of ISO (Interstellar Object), to predict where there enter the Solar System, get their initial position, and their detectability, to anticipate an orbital rendezvous.

We can deduce from the results that most of them enter the Solar System near the Solar apex. The internship stopped at the detectability criteria, and the next step is to propagate the position vector into a trajectory, to get the detectability of the ISO inside the Solar System. Then, it will be possible to solve the Lambert Problem to get the optimal interplanetary orbit from Earth to the asteroid.

Jul 24th(Mon) Room B AM(9:30-12:00)　Abstracts

ASTRO-2023-B001

「空気抵抗を用いたコンステレーション面内展開の解析」

「In-plane deployment analysis of satellite constellation using atmospheric drag」

* 井本 悠太(阪大・院), 佐藤 訓志, 山田 克彦(阪大)

Abstract:

This study examines an atmospheric drag-based deployment method for satellite constellations without fuel consumption.

Since the rate of the argument of latitude changes depending on the semi-major axis, it is possible to separate the in-plane positions of satellites if they take different semi-major axis trajectories.

Therefore, when the cross-section of each satellite is appropriately changed, each satellite can be deployed to its designated position due to the effect of the atmospheric drag.

In this study, the required cross-section trajectories and resulting orbit trajectories of satellites in the required constellation are mathematically formulated.

In addition, the validation and the practical example of the proposed analytical model are introduced.

ASTRO-2023-B002

「Artificial Potential Field strategy for spacecraft swarm formation gathering」

* Ruggiero Dario(POLITO, PhD student), Capello Elisa(POLITO)

Abstract:

Recently swarm of smaller satellites are getting the attention of the space community for their properties of scalability, robustness, and flexibility. Once spacecrafts are released, the GNC subsystem must guarantee the spacecrafts to be gathered in formation. Distributed Artificial Potential Field based algorithms are investigated. The proposed approach can be

generalized, and allows to minimize the data needed to reach the formation. This guidance algorithm allows spacecrafts gathering around the target position at the required distance. Some simulations are performed to show the performance of this approach.

ASTRO-2023-B003

「地球周回軌道で実現する超精密編隊飛行：軌道力学の探求」

「Ultra-Precision Formation Flying in Earth Orbit: Exploring Astrodynamics」

* 伊藤 琢博(JAXA)

Abstract:

Possible use of Earth orbit is presented for ultra-precision formation flying. The Earth orbit is beneficial as its transportation cost to the desired orbit is relatively small and coarse autonomous formation control is attained by using the Global Navigation Satellite System. Its feasibility hinges on whether there exist specific Earth orbits satisfying the small disturbance environment for the rigid and continuous formation control and the favorable observation conditions. The developed theory of orbital motion elucidates that the magnitudes of each disturbance are characterized by the semi-major axis, mean eccentricity, and size of formation. The suitable orbits are found in high Earth orbit for the triangular laser-interferometric gravitational wave telescope with 100 km in size, and in middle Earth orbit for the linear infrared interferometer with 0.25 km in size.

ASTRO-2023-B004

「磁気フォーメーションフライトによる分散アンテナの衛星仕様検討」

「Satellite Specification Research for Distributed Antennas Using Electromagnetic Formation Flight」

* 沈 彗央（総研大・院）, 高橋 勇多（東工大・院）, 柴田 拓馬（室蘭工大）, 坂井 真一郎（ISAS）

Abstract:

Although the large antennas in orbit are expected to reduce the overall cost by splitting them up using formation flight technology, highly accurate position control is required. Electromagnetic formation flight (EMFF) can be considered to realize this technology, as they do not use fuel and are therefore suitable for long-term missions. This study proposes specifications for a formation-flight satellite, including the electromagnetic coils used for attitude control of EMFF. The optimum calculations are performed for the number of

satellites, and not only the coil specifications but also the distance between satellites, the maximum current value and the power consumption value are proposed.

ASTRO-2023-B005
「Formation Flight around Halo Orbit in CR3BP using Center Manifold」
* 羅 ミニョン（PU・院）
Abstract:
With an increasing interest in space missions in multi-body systems, study for formation flight strategies in such system also has been actively demanded. In a Circular Restricted 3 Body Problem (CR3BP) system, a periodic orbit is usually non-elliptical and mostly unstable. However, a few orbits in certain types of orbital families found in CR3BP are stable, and thus natural formation flight can be achieved. In this talk, halo orbits, one of the well-known periodic orbits in the CR3BP configuration, and the natural flight formation with its key characteristics will be introduced.

Jul 24th(Mon) Room B PM1(14:00-16:00)　Abstracts

ASTRO-2023-B006
「Comet Interceptor ミッションにおける彗星フライバイ時のダスト衝突解析と航法誘導制御系設計」
「Dust Impact Analysis and Guidance, Navigation and Control Design during Comet Flyby for Comet Interceptor Mission」
* 佐々木 貴広, 尾崎 直哉(JAXA), 笠原　慧(東大), 矢野 創, 船瀬 龍(JAXA)
Abstract:
One of the challenges for the guidance, navigation and control (GNC) system of the Comet Interceptor mission is to maintain the spacecraft's attitude against impact effects by cometary dust. In this study, a dust impact model is derived and the GNC design is proposed through Monte Carlo analysis.

ASTRO-2023-B007
「Stereo Visual Odometry のための特徴点選択に関する検討」
「Study on Feature Points Selection Scheme for Stereo Visual Odometry」

* 本橋 優俊（東大・院），久保田 孝（JAXA）
Abstract:
Visual Odometry (VO) is a method to estimate a robot's position and pose by tracking feature points in sequential images. For planetary exploration rovers, however, VO is time-consuming processing, especially in the stereo matching of feature points. To address this issue, this research proposes a VO method that separately selects the feature points used for rotation estimation and those used for posture estimation. It was confirmed by the verification with the actual rover that the proposed method can reduce the time required for VO processing while maintaining the estimation accuracy.

ASTRO-2023-B008
「惑星探査での画像航法における太陽条件にロバストな初回マッチング用テンプレート作成手法」
「A robust method against Solar condition to generate Initial Template Image for Optical Navigation in Planetary Exploration」
* 竹尾 洋介（JAXA），岡田 尚基, 巳谷 真司, 松本 祐樹, 大野 剛（JAXA）
Abstract:
A template matching is one of typical methods for optical navigation of decent/landing operation in planetary exploration. In the case of uploading initial template from the ground, however, it is severe operation condition to prepare the template by remote-sensing corresponding to solar condition of decent. In this study, to maintain the accuracy of optical navigation, we propose robust generation method of the template image against the solar condition by increasing contrast using histogram equalization to take Phobos landing as an example . In addition, we propose the remote-sensing operation strategy to maintain the robustness.

ASTRO-2023-B009
「推力と質量の不確定性下における Moving stereo を用いたオンボード誘導航法に関する予備解析」
「Preliminary analysis on Moving stereo-based on-board guidance and navigation under thrust and mass uncertainties」
* 大月 幸穂, 西村 尚（東大・院），武井 悠人, 津田 雄一（JAXA）
Abstract:

In the Hayabusa2 mission, a guidance and navigation method using moving stereo was implemented in asteroid rendezvous phase. Moving stereo is a range estimation technique where a spacecraft follows a zig-zag path and captures images, allowing for the estimation of the range between a chaser and a target by comparing the target's positions in the images. In addition to the captured images, the spacecraft's thrust and mass are also considered for estimating the moving distance in moving stereo calculations. However, estimating the thrust and mass accurately is challenging, and this uncertainty can impact the accuracy of spacecraft position estimation, ultimately affecting the docking precision. Therefore, this paper aims to evaluate the docking error resulting from uncertainties in thrust and mass. Additionally, the reduction in error achieved by incorporating on-board Doppler measurements was assessed.

Jul 24th(Mon) Room B PM2(16:15-17:45)　Abstracts

ASTRO-2023-B010
「固体ロケットモータの点火タイミングを考慮した Touch-and-Go Sampling Probe の誘導則に関する考察」
「A Study on Ignition Timing of Solid Rocket Motors for Guidance Law of Descending Phase with Touch-and-Go Sampling Probe」
* 大木 春仁, 楠本 哲也, 中川 果帆(東大・院), 森下 直樹, 岩渕 頌太, 臼杵 智章, 鳥居 航, 三浦 政司, 津田 雄一(JAXA)
Abstract:
In Hayabusa and Hayabusa-2 mission, the spacecrafts themselves landed on the asteroids for obtaining the samples, then they had to take the risk of breakdown by touchdown. We have suggested touch-and-go probe as an ultimately simple sampling device with solid rocket motor. This motor has a negative character that the thrust cannot be controlled once ignited and the burning time is short. This paper discusses the study of ignition timing of solid rocket motors for guidance law of descending phase with touch-and-go sampling probe. We simulate the landing case study and analyze the robustness against the initial condition error.

ASTRO-2023-B011
「遠方ターゲットに対して適用可能なビーコンを用いた相対航法誘導」

「Relative Navigation and Guidance Using Beacons Applicable to Long-range Targets」
* 藤田 雅大(東大・院), 杉原 アフマッド清志, 森 治, 津田 雄一(JAXA)
Abstract:
In order to realize relative navigation and guidance for distant targets to which optical navigation cannot be applied, we propose the use of beacons. The parent spacecraft estimates the direction of arrival of the beacon transmitted by the child spacecraft. It then estimates the relative orbit of the child using only its angular information. Even if the SNR is low, it is possible to estimate the direction of arrival of radio waves. Therefore, the proposed methodology can be applied to the relative navigation and guidance distant targets. We have studied methods for estimating the direction of arrival of beacons and schemes of navigation and guidance using only angle information through numerical simulations and experiments. In this presentation, the status of these investigations will be reported.

ASTRO-2023-B012
「はやぶさ２＃における自然地形を利用した航法に関する研究」
「Study for Natural Feature Tracking Navigation of Hayabusa2#」
* 三桝 裕也(JAXA)
Abstract:
After bringing Asteroid Ryugu's sample back to Earth on December 6th, 2020, Hayabusa2 started the extended mission. The next destination is the asteroid 1998 KY26, and it will arrive at this asteroid in 2031. This asteroid is a fast rotator, which is a very small asteroid of several tens of meters in size and spinning at a high-speed rotation period of 10 minutes. Such a body has a special physical environment where centrifugal force is stronger than gravity on the surface of the asteroid. In such an environment, the target marker cannot be stationary on the asteroid surface, and the touchdown method proven for Ryugu cannot be used. Therefore, we are considering applying the touchdown method without relying on the target marker by adding a new function of natural feature tracking. In this study, we present the preliminary analysis for such a new function based on the installed on-board function of Hayabusa2.

ASTRO-2023-B013

「探査機基準座標上での相対運動モデルに基づいた
探査機フライバイにおける自律的誘導航法方法の検討」
「Navigation and Guidance Method for Autonomous High-speed Flyby Based on Spacecraft-Centered Reference Frame Formulation」
* 鶴谷 柊朔（東大・院），津田 雄一（JAXA）
Abstract:
The current control methods for deep space explorer require communication with the Earth to obtain the result of orbit calculation held on the ground, whose robustness is so low. Therefore, the technology of autonomous navigation and guidance technologies using the small amount of information and computational resources available to explorer is possible to increase the feasibility of deep space projects. This research proposes a control method using dynamics model derived from the equation of relative motion to the target asteroid on the explorer-centered coordinate system, which is evaluated by flyby simulation of Hayabusa 2.

ASTRO-2023-B014
「レゴリスによるはやぶさ２航法カメラ光量低下とターゲットマーカトラッキングの改良」
「Camera Degradation by Regolith in Hayabusa2 and Revision of Target Marker Tracking」
* 尾川 順子(JAXA), 照井 冬人(神奈川工大), 三桝 裕也, 吉川 健人, 大野 剛(JAXA), 保田 誠司, 松島 幸太(NEC), 檜原 弘樹, 佐野 淳平(NECSpace), 武井 悠人, 佐伯 孝尚, 津田 雄一(JAXA)
Abstract:
はやぶさ２ミッションでは，第一回タッチダウンで航法カメラに付着したレゴリスにより光量が 40%まで低下したことにより，ターゲットマーカトラッキング（TMT）等の自律画像航法が想定通りに動作しなくなった．本発表では実際の光量低下状況，および第二回タッチダウンに向けて TMT を使用可能とするために行った解析と改良について報告する．

ASTRO-2023-B015
「ターゲットマーカーの突起形状が水平方向の移動抑制に与える影響の評価」
「Evaluation of the Effect of Spikes on Target Marker on Horizontal Movement Reduction」
* 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 successfully landed on an asteroid by dropping a spherical artificial target with four spikes on its surface, called a Target Marker, at the target position. While methods to suppress bounce have been studied during development and in previous research, reduction of horizontal movement has rarely been examined. The purpose of this study is to investigate how the shape of the spikes on the Target Marker affects the suppression of movement. The behavior was analyzed based on parameters such as the number and length of spikes and the angle of contact with the ground, and the effect on movement was evaluated using a two-dimensional numerical analysis model.

ASTRO-2023-B016
「Feature-based optical navigation around Phobos」
* Ciccarelli Edoardo(PhD candidate), Baresi Nicola(Lecturer)
Abstract:
In the coming years, the Martian Moons eXploration mission will be the first of its kind to reach and study Phobos over a prolonged period, opening the doors to a deeper characterization of its internal composition. Recent publications from our research group have shown the effect of adopting different orbit geometries and different types of data in characterising Phobos's gravitational environment. Following up on these analyses we investigated the effect of adopting optical data in the estimation chain. It was found that the adoption of features-based optical navigation would significantly help to refine the knowledge of the moon's libration angle and gravity field.

ASTRO-2023-B017
「Int-Ball2: プロペラ空気抵抗極性を積極的に利用したコンパクトな高トルク推進システム」
「Int-Ball2: Compact high-torque propulsion system actively utilizes propeller air drag polarity」
* 巳谷 真司, 西下 敦青, 平野 大地(JAXA)
Abstract:
We have developed a compact omni-directional propulsion system capable of six-degree-of-freedom flight control in a zero-gravity environment in an inboard pressurized section such as the ISS. When employing an air propulsion propeller as an actuator, the design must

take into account the effects of angular momentum and air resistance of each individual propeller due to its rotating property. When high thrust is required under the volume resource limitation of a robot, a small number of large propellers are used, and the propeller axes are arranged in a radial direction from the near center of gravity. This would cause an imbalance in the magnitude of the 3-axitial torque if only the thrust moment torque is considered. We devised a configuration that reinforces the torque output by actively utilizing the polarity of the air drag generated by the propeller rotation as output torque. This configuration was applied to the Int-Ball2 and its effectiveness was confirmed through thrust tests.

Jul 25th(Tue) Room B PM1(14:00-15:30)　Abstracts

ASTRO-2023-B018
「惑星大気を利用する宇宙探査機の空力減速」
「Aero-Braking for Spacecraft at Planet Atmosphere」
* 金 東宣
Abstract:
Deceleration of spacecraft which is arriving at target planet in solar system include moon is essential to settle into the target body orbit. It is common method which use inverse thrust force of spacecraft. The deceleration method of spacecraft which is applied planet atmosphere drag force for fuel saving, is called Aero-Braking of Spacecraft. As like inverse thrust force of spacecraft is applied several times repeatedly, the method of using aerodynamic drag force of planet atmosphere is also accomplished repeatedly at near periapsis of planet orbit. Mars upper atmosphere has very thin density and so destruction dangerous of spacecraft by friction heat is relatively low. In this paper discuss theoretical analysis of aero-braking deceleration sequence by mars atmosphere for spacecraft

ASTRO-2023-B019
「木星エアロキャプチャで拓く新たな深宇宙探査」
「Pushing the Limit of Deep Space Exploration by Jovian Aerocapture 」
* 臼杵 智章(東大・院), 津田 雄一(JAXA)
Abstract:
In general, deep space exploration beyond Jupiter tends to take a long period of time. This has been a major barrier to the budgeting of deep space exploration programs. In the Juno

spacecraft case, 99.4% of the mission time is spent waiting for observations because the all-chemical propulsive spacecraft design has limited ΔV performance and cannot place spacecraft into a low science orbit. Jovian aerocapture could be an effective solution to this problem.
This paper discusses the benefits and technical challenges of Jupiter aerocapture. The feasibility of direct interior exploration of Jupiter's Great Red Spot and interior satellite exploration using aerocapture technology is also discussed.

ASTRO-2023-B020
「Mission design for small satellite Earth aerobraking」
* ベルテ マックスミリアン, 鈴木 宏二郎（東大）
Abstract:
Aerobraking is appealing for low-cost planetary exploration. This method of orbit control has been demonstrated by several large satellite missions, but has yet to be performed by a small satellite. This presentation proposes a nanosatellite aerobraking mission for Earth orbit.

Jul 25th(Tue) Room B PM2(15:45-17:15)　Abstracts

ASTRO-2023-B021
「着陸脚地面間の摩擦力低減による垂直離着陸ロケットの耐転倒性向上に関する研究」
「Improvement of Tipping Resistance of Vertical Takeoff and Landing Rocket by Reducing Friction Force between Landing gear legs and Ground」
* 坂田 泰生(静大・院), 丸 祐介, 河野 太郎, 森 治, 澤井 秀次郎(JAXA), 能見 公博(静大)
Abstract:
It is known that a lunar/planetary spacecraft is less likely to tip over during landing if the frictional force between the landing legs and ground is small. In this study, we assume a vertical takeoff and landing rocket that lands on flat, level ground, and consider improving tipping resistance by actively reducing the coefficient of friction between the landing gear legs and ground. We evaluated the landing behavior of the rocket when the coefficient of friction is changed by simulation. We considered wheels as a means of actually changing the coefficient of friction, and then evaluated the landing behavior for model of a rocket

when the wheels are attached to the tip of the landing gear legs by experiment.

ASTRO-2023-B022

「再使用ロケット実験機の現状と帰還飛行のダイナミクスに関する研究」

「Present status of reusable rocket experiment and study on re-entry flight dynamics」

* 野中 聡(JAXA)

Abstract:

For verifications of key technologies to realize the construction of future reusable space transportation systems, we progress in a technical demonstration study at a system level using a small flight demonstrator. The demonstrator is called “reusable vehicle experiment, RV-X”. For the development of future reusable systems, moreover, we study the re-entry flight of reusable vehicle to minimize the propellant requirements for landing. We suggest a flight profile with nose-first entry and turnover maneuver to decelerate using aerodynamic drag force. In this paper, present status of the research on reusable vehicle for flight demonstrations and aerodynamic studies of re-entry flight are reported.

ASTRO-2023-B023

「エアブリージングエンジンを搭載した再使用観測ロケットの飛行軌道検討とその技術課題」

「Investigation of Flight Trajectory of Reusable Sounding Rocket with Air-breathing Engines and its Technical Issues」

* 丸 祐介, 小林 弘明, 大山 聖, 坂本 勇樹, 三浦 政司(JAXA), 江口 光(室蘭工大), 山城 龍馬(JAXA), 佐藤 哲也(早大), 野中 聡(JAXA)

Abstract:

ISAS has been studying a reusable sounding rocket. We are also considering a system that can increase payload or reduce the system size by installing an air breathing engine. In this presentation, we will analyze flight trajectory of the rocket and discuss the characteristics of the flight trajectory for using the air-breathing engine. In addition, we will extract technical issues specific to the rocket and discuss how to deal with them.

ASTRO-2023-C001

「二次形式の最適フィードバック制御による人工的な平衡点とその力学構造」

「Equilibria and Dynamical Structures with Quadratic Optimal Control」

* 鶴田 彩乃（九大・院）, 坂東 麻衣（九大）, Scheeres Daniel J.(Colorado Univ.), 外本 伸治（九大）

Abstract:

In this paper, we derive the new equilibrium points realized by continuous optimal control inputs and investigate the dynamical structure around them. Using the Euler-Lagrange equation, which is a necessary condition for optimal control problems, the equations of motion of a dynamical system with optimal control inputs that minimize the cost function in the quadratic form are described in terms of state and adjoint variables. Based on these equations of motion, conditions for equilibrium points are derived and the properties of equilibrium points in two-body and Hill three-body problems are analyzed. The stability and dynamical structure around unstable equilibrium points will also be investigated.

ASTRO-2023-C002

「確率ノイズを用いた円制限三体問題の大域的な解析」

「Global analysis of the Circular Restricted Three-Body Problem using Stochastic Noise」

* 森光 翔平(九大・院), 坂東 麻衣, 外本 伸治(九大)

Abstract:

In optimal control problems, the optimal cost for an initial value is called the value function. Attractive sets, which are contours of the value function, allow us to analyze the global properties of the optimal control problem.

However, it is difficult to obtain the value function of the Circular Restricted Three-Body Problem because of its strong nonlinearity.

In this study, we show that can be obtained more easily than the usual nonlinear optimal control problems by using one of the methods for solving nonlinear stochastic optimal control problems called the path integral optimal control and attractive set of the Circular Restricted Three-Body Problem is discussed.

ASTRO-2023-C003

「Bounded orbits around small moons in the J2-perturbed elliptic-restricted three-body model 」

* 陳 泓儒(九大), 三好 海斗(九大・院)
Abstract:
The confirmed MMX and HERA-Juventas and -Milani missions are targeting Martian moons and the binary asteroid system's moon Dimorphos, respectively, where the dynamics are very different from that around the other asteroids or big planetary moons ever visited. The orbit of the small moon and its vicinity are significantly perturbed by the non-spherical gravity field of the planet as well as the relative positions of the primary system. Consequently, orbits and the stability information derived in the simplified circular-restricted three-body problem are not very true for small moon missions. In this paper, the J2 gravitational term of the primary body (or the planet) and the zonal terms of the moon are considered in the orbit design. Orbita stability and bounded quasi-periodic orbits and the stability are derived in the J2-perturbed elliptic three-body problem, which can be easily shifted to the full-ephemeris model without suffering much change.

ASTRO-2023-C004
「リアプノフ再設計法を用いた宇宙機の LPO 飛行のための制御則設計」
「Controller design using Lyapunov redesign for spacecraft flying in libration point orbits」
* 拝生 俊哉(名大・院), 椿野 大輔(名大)
Abstract:
This paper deals with an orbit maintenance problem for spacecraft in the L2 libration point orbits (LPO) in Cislunar space. The contribution of this paper is to derive a control law that maintains a periodic orbit even in the presence of bounded unknown disturbances. Design procedure of the proposed control law is divided into two steps. A nominal control law is designed based on a linearized equation of motion in the circular restricted three-body problem. Then, the nominal control law is augmented so that nonlinearities and disturbances are compensated. The latter step is carried out with Lyapunov redesign. The effectiveness of the proposed control law is evaluated through numerical simulations under the disturbances caused by the gravitational effect of the Sun.

ASTRO-2023-C005
「Gravity perturbations over low-thrust trajectories using equinoctial elements」
*Josué Cardoso dos Santos (ISAS/JAXA), Takuto Shimazaki (University of Tokyo),Yasuhiro Kawakatsu (ISAS/JAXA)

Abstract:
This research presents investigations about gravitational effects over the trajectory of a spacecraft under a low-thrust acceleration model using Fourier Series expansion. The differential Gauss variational equations are adopted to describe the dynamics where the main singularities are removed by the use of orbital variables known as equinoctial. Our focus regarding the gravitational disturbances is related to the ongoing analysis of the effects due to the Earth's flattening at the poles and the third-body perturbation due to the Moon. The outcomes are important for the understanding and design of the dynamics adopted in projects such as DESTINY+ mission, a JAXA initiative that will launch a spacecraft to escape the Earth in a spiral trajectory, swing-by with the Moon and potentially have a flyby with two asteroids. The current planned launch date is mid of 2024.

Jul 24th(Mon) Room C PM1(14:00-16:00)　Abstracts

ASTRO-2023-C006
「Finding EKRAN-2 debris using Random Forrest and K-Nearest Neighbors methods」
* Vu Hoang Long(九大・院), 陳 泓儒, 花田 俊也(九大)
Abstract:
With more than 29000 space object in Earth orbit, the need for a method to adequately detect and identify on-orbit objects is growing. This research introduces a novel Machine Learning-based method to classify fragments from EKRAN-2, a Russian broadcasting spacecraft exploded in 1978 due to dead batteries. Our study involves using four orbital elements measured by observatories on the ground: topocentric declination, right ascension, and their rate of chances as features to identify the observed object. Random Forest, a Supervised Learning algorithm based on Decision Tree, and K-Nearest Neighbors, an algorithm based on class distribution, are used. Both methods have high performances on testing data set with high precision and F1 scores. Our approach demonstrates an application of Machine Learning in Space Debris Identification.

ASTRO-2023-C007
「地球超低軌道における超小型衛星の実測データを用いた大気密度推定手法の構築」
「Construction of a method for estimating　atmospheric density in very low Earth orbit using positioning data obtained by nanosatellite」
* 酒井 智基（北大・院），高橋 裕介（北大），永田 靖典（JAXA）
Abstract:

The atmospheric density in very low Earth orbit (VLEO) is a crucial factor for nano/small satellite operations.The profile of the atmospheric density is ,however, not clear yet because of the difficulty to obtain data in VLEO.In 2016—2017,The deployable nanosatellite EGG mission was conducted and sparse positioning data was obtained
by the global positioning system (GPS).In order to utilize this data for atmospheric density estimation, we constructed a methodology employing machine learning approach, and estimated atmospheric density at altitudes around 200 km.

ASTRO-2023-C008
「分離カメラの画像を用いた自己位置姿勢と小惑星重力の同時推定」
「Simultaneous Estimation of Spacecraft Orbit-Attitude and Asteroid Gravity based on Deployable Camera Images」
* 菊地 翔太(NAOJ)
Abstract:
The Hayabusa2 impact experiment at Ryugu demonstrated that a deployable camera is a useful payload to conduct remote-sensing observation without jeopardizing spacecraft safety, particularly for a small-body mission. However, scientific analyses of deployable camera images require precise information on observation conditions, necessitating the attitude and orbit estimation of the deployable camera itself. In addition, its orbital motion could also provide insight into the weak gravity of a small body. For this reason, this paper proposes an algorithm to simultaneously calibrate the obtained images, reconstruct the attitude and orbital motion, and estimate the gravitational parameter.

ASTRO-2023-C009
「DMOODS, orbit determination software for asteroids and deep space probes」
* 竹内 央(JAXA)
Abstract:
軌道決定ソフトウェア DMOODS の機能を紹介し、探査機(はやぶさ２,Omotenashi,EQUULEUS 等)や小天体(Ryugu,2001CC21, Phaethon 等)の軌道決定に使用された例を示す。

Jul 24th(Mon) Room C PM2(16:15-17:45)　Abstracts

ASTRO-2023-C010

「Robust control strategy of periodic orbits via a hybrid multiple-shooting approach」

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

Abstract:

This manuscript proposes a systematic approach for the design of a nominal robust trajectory and an associated closed-loop control law, where quantitative information concerning uncertainty on the system dynamics are directly accounted for in the optimization process. The proposed method is applied to perform orbital control of a NRHO. Recurring corrective maneuvers are evaluated and imparted on the probe to keep the deviation from the nominal trajectory within a prescribed limit.

ASTRO-2023-C011

「Near-Optimal Control に基づいたソーラーセイルによる月周回軌道の制御性能評価」

「Performance Evaluation of Near-Optimal Control of Solar Sail on Lunar Orbit」

* 中条 俊大（東工大）

Abstract:

Lunar orbits are useful for lunar surface observation and have been of particular interest inspired by the Artemis program. However, because spacecraft are exposed to perturbation due to the Earth gravity and the irregular gravity field of the moon, the eccentricity shifts as time passes, and thus frequent orbit control is necessary to avoid collision with the moon. In this presentation, we show how the near-optimal control of solar sails extend the orbit lifetime without consuming propellant.

ASTRO-2023-C012

「Orbital Mechanics near Close Planetary Moons」

「Orbial Mechanics near Close Planetary Moons」

* Baresi Nicola(SSC), Dell'Elce Lamberto(Inria)

Abstract:

Upcoming missions towards remote planetary moons will fly in chaotic dynamic environments that are significantly perturbed by the oblateness of the host planet. In this presentation, we will be overviewing the equations of the Zonal Hill Problem that govern the

dynamic evolution of a satellite subject to the gravitational attraction of a moon and its oblate host planet. Despite time-periodic effects, the system remains populated by families of quasi-periodic trajectories that can be used as a baseline for the proximity operations of future planetary moons explorers such as MMX.

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

ASTRO-2023-C013
「固体モータのジンバル制御とリアクションホイールによるタッチアンドゴーサンプリングプローブの姿勢制御」
「Attitude control of Touch-and-Go Sampling Probe with gimballed solid rocket motors and reaction wheel」
* 中川 果帆, 楠本 哲也(東大・院), 臼杵 智章(JAXA), 大木 春仁(東大・院), 三浦 政司, 津田 雄一(JAXA)
Abstract:
As a new sample return mission method, a system using Touch-and-Go sampling probes has been proposed. By making the probe a simple system, we aim to install multiple probes on the spacecraft and make sample-return safer. In this study, we attempt to control the attitude of the probe by gimbal control of multiple solid rocket motors and reaction wheels. We perform simulations and analyze spin stability and triaxial stability.

ASTRO-2023-C014
「磁気トルカを使用した極軌道における２U キューブサットの姿勢制御実験」
「An experimental study on attitude control system with magnetorquer for 2U-size cubesat on polar orbit」
* 齊藤 創, 松井 翼, 赤石 大輔(群馬高専・専攻科), 井上 永遠, 平社 信人(群馬高専)
Abstract:
In this report, an attitude control system for 2U cubesat as Innovative Project on polar orbit is conducted. Then the attitude control system for the cubesat is adopted magnetorquer system consisted of permanent magnet and thin coil of square shape, the authors construct an effective attitude control system for the 2U-size cubesat with consideration of feature of the polar orbit. To confirm some effectiveness of the proposed attitude control system for the cubesat on polar orbit, some experiments on the orbit and on ground are executed and

the obtained data are evaluated.

ASTRO-2023-C015

「金沢大学衛星の非自律的姿勢制御系の実装」

「Implementation of non-autonomous 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 the implementation of the non-autonomous attitude control system of the Kanazawa University satellite.

ASTRO-2023-C016

「高精度光学式ジャイロを用いたHiZ-GUNDAM衛星の高速姿勢変更後の指向安定性について」

「On Pointing Stability of HiZ-GUNDAM Satellite After Agile Attitude Maneuvers Under Rate Bias Error of High-Precision Fiber Optic Gyros」

* 神谷 俊夫, 小坂 岳文(NEC)

Abstract:

This paper shows an approach to technical issues of autonomous attitude maneuver of HiZ-GUNDAM satellite. For the mid-term pointing stability required in every 120 s in the mission, when using an attitude determination filter based on an extended Kalman filter using a star tracker and rate gyros, the gyro bias estimation error on attitude drift is considered as a major cause as well as the effect of micro-vibration disturbances. On the other hand, the rate random walk of high-precision fiber optic gyros is suppressed below the measurable level, so it is difficult to perform numerical simulations using a conventional mathematical gyro error model. Therefore, in this paper, we evaluate the feasibility of mid-term pointing stability by attitude maneuver simulations using actual gyro measurement data. In addition, by comparing the evaluation results based on the conventional method, we show the validity

of applying the conventional evaluation model to high-precision fiber optic gyros.

ASTRO-2023-C017
「画像に基づく角運動量ベクトルと慣性テンソルの同時推定」
「ALGEBRAIC AND SIMULTANEOUS ESTIMATION OF ATTITUDE MOTION AND INERTIA PROPERTIES」
* 川口 淳一郎(ANU), 楠本 哲也(東大・院)
Abstract:
Despite for decades of the studies on the estimation method of the angular velocity vector based on a series of images captured by the servicer space-craft to the target body. Recent debris removal inevitably heavily relies on the motion estimation of the target debris, un-cooperated body. Reliable and robust capturing in proximity operation is a key in debris removal. This pa-per presents the method of direct estimation of both the dynamical attitude motion and the inertia properties, excluding reliance on the a priori infor-mation. It is on the bootstrap estimation process algebraically. The authors present and reveals the concrete description of the method. It does not re-quest the satellites that may be removed on-orbit to carry prescribed 3D tar-gets aboard.

Jul 25th(Tue) Room C PM1(14:00-15:30)　Abstracts

ASTRO-2023-C018
「HELIOS-R ミッションにおける単眼カメラと膜面マーカを用いた膜形状推定」
「Estimation of Membrane Shape using Monocular Camera and Membrane Surface Markers in HELIOS-R Mission」
* 西村 尚, 鶴谷 柊朔（東大・院）, 渡邊 秋人（サカセ・アドテック）, 高尾 勇輝（九大）, 松下 将典（東大）, 森 治（JAXA）
Abstract:
HELIOS-R is one of the demonstration themes planned to be installed on JAXA's RAISE-4 mission, aiming to demonstrate the on-orbit functionality of a lightweight and compact membrane structure with power generation and antenna capabilities. In order to verify the membrane structure and evaluate its deployment behavior, it is necessary to assess the three-dimensional shape of the membrane. Therefore, in this mission, we developed a method to estimate the three-dimensional shape of the membrane surface using a

monocular fisheye camera and retroreflective markers on the membrane surface. In this presentation, we describe the algorithm for membrane shape estimation and the results of ground testing.

ASTRO-2023-C019

「可変構造宇宙機の関節構造が非ホロノミック拘束を利用した姿勢変化に与える影響」

「Effect of Joints Structure of Transformable Spacecraft on Attitude Change Utilizing Non-holonomic Constraint」

* 竹内 咲希（九大・院）, 坂東 麻衣, 外本 伸治（九大）

Abstract:

Spacecraft with movable parts can change their attitude through transformation by utilizing non-holonomic features for angular momentum conservation. Previous studies predetermined the structure of the movable parts, and the discussion on the effect of the structure of movable parts on attitude change has remained considerable. However, this discussion may contribute to extending the mission continuity when their attitude controllers are broken. We set an optimization problem on the structure of joints as an example of movable parts. This study discusses the effects of joint structure on attitude change from the optimization result.

ASTRO-2023-C020

「モーメンタムバイアス型可変構造宇宙機の太陽光圧下での姿勢制御」

「Attitude Control for Momentum-biased Transformable Spacecraft under Solar Radiation Pressure」

* 久保 勇貴(JAXA), 中条 俊大(東工大)

Abstract:

Transformable spacecraft, whose structure can be adaptively reconfigured by multiple actuatable joints, can perform simultaneous body reconfiguration and attitude reorientation by taking advantage of its redundant degrees of freedom. Furthermore, by combining structure and attitude control with solar radiation pressure (SRP), advanced solar sailing can be performed where multiple constraints can be simultaneously satisfied. In this study, we propose a structure and attitude control method for a biased-momentum transformable spacecraft under SRP. The control method contributes to generate desired SRP thrust while maintaining target attitude and body configuration.

Jul 25th(Tue) Room C PM2(15:45-17:15)　Abstracts

ASTRO-2023-C021

「複数輝点航法標識を用いた深宇宙ランデブドッキングにおける近接光学航法」

「Proximity Optical Navigation for Deep Space Rendezvous and Docking Using Multiple Artifitial Markers」

* 西村 尚, 大月 幸穂（東大・院）, 武井 悠人, 津田 雄一（JAXA）

Abstract:

In recent years, Deep Space Rendezvous and Docking (DS-RVD) has garnered significant attention in the realm of deep space exploration. DS-RVD enables expanded exploration capabilities and low-risk space missions, thereby contributing to the advancement of deep space exploration. Navigational functionality plays a crucial role in realizing DS-RVD; however, existing techniques employing LiDAR or deep learning are ill-suited for the resource-constrained and autonomous nature of deep space environments. Therefore, this paper proposes a low-resource navigation system and algorithm utilizing multiple optical navigation markers and a monocular camera. The practicality of the proposed system is assessed in terms of computational cost, accuracy, and anomaly detection capabilities.

ASTRO-2023-C022

「深宇宙探査機のための自動囲い込み式爪型ドッキング機構の検討」

「A Study of a automatic enclosing claw-type docking mechanism for deep space spacecrafts」

* 徳安 彰大, 田中 友悠（東工大・院）, 中西 洋喜（東工大）

Abstract:

Deep-space exploration technology is increasingly advanced nowadays. Rendezvous docking in deep space is expected to be one of the next-generation key technologies. To achieve these missions, a low-resource docking system that can be installed on a deep-space spacecraft is required. In addition, more autonomous docking is required because such docking has so far been performed only in the vicinity of the Earth, where remote control and monitoring from the ground are easy. In this presentation, the authors propose a novel claw-type docking mechanism that mechanically encloses the docking target immediately after initial contact to ensure secure docking.

ASTRO-2023-C023

「無重力空間におけるホーン構造を用いた物体移送ダイナミクスに関する研究」

「A Study on Free Space Object Transfer Dynamics Using Horn Structure in Zero-Gravity Environment」

* 中川 雄登（東大・院）, 森 治, 佐伯 孝尚, 津田 雄一（JAXA）

Abstract:

In this research, a study is conducted to design horns for free space object transfer in a zero-gravity environment. Utilizing horns for object transfer has the potential to enable the capture and transfer of objects even with low precision compared to conventional methods. However, the capture with horns is influenced by parameters such as object entry conditions and angular velocity, making it crucial to understand the impact of these parameters. The insights gained from this study can be applied, for example, to sample transfer between mother and daughter spacecraft in deep sample return missions.