第 34 回　アストロダイナミクスシンポジウム（2024 年）アブストラクト集
34th Workshop on JAXA Astrodynamics and Flight mechanics (2024) Abstract

Special Lecture Jul 29th(Mon) Main Room PM(17:35-18:25)

Dario Izzo / (ESA)

Dario Izzo is currently the scientific coordinator of ESA's Advanced Concepts Team. Graduated as a Doctor of Aeronautical Engineering from the University Sapienza of Rome in 1999. He later took a second master in "Satellite Platforms" at the University of Cranfield in the UK and completed his Ph.D. in Mathematical Modelling at the University Sapienza of Rome where he taught classical mechanics and space flight mechanics. He published more than 200 papers and pioneered the use of emerging AI techniques for space, with a particular early focus on evolutionary computations and neural computations. Dario Izzo is also the recipient of the Humies Gold Medal for the creation of an AI system having human-competitive capabilities in the design interplanetary trajectories (2013) as well as the Barry Carlton Award (2024).

「Differentiable intelligence in space flight dynamics」

Abstract
In this presentation, I will explore recent advancements in space flight dynamics through the lens of what I call differentiable intelligence. This emergent paradigm, rooted in the evolution of automated differentiation techniques and neural models is transforming the landscape of aerospace engineering. I will delve into several pioneering projects—eclipseNETs, G&CNETs, thermoNETs, and geodesyNETs—each demonstrating the profound impact of differential intelligence on various aspects of space flight dynamics and control. Additionally, I will highlight a few innovative use and computation of state transition tensors for differentiable event representations, showcasing how these tools may find their use in the design of advanced space missions. By examining these diverse, yet interconnected, applications we advocate that they collectively represent a broader trend of leveraging differential information to increase the efficiency of several space flight mechanics elements

Special Lecture Jul 30th(Tue) Main Room PM(13:00-13:50)

植田 聡史（UEDA Satoshi）/ JAXA 研究開発部門（JAXA Research and Development Directorate）

2002 年東京大学大学院工学系研究科航空宇宙工学専攻修士課程修了．専門は，制御工学，飛行力学，システム最適化．同年宇宙開発事業団入社．宇宙ステーション補給機「こうのとり」（HTV）の航法誘導制御系の開発，運用に従事．2009 年の HTV1 号機から 2017 年の HTV6 号機まで連続成功に貢献．2011 年~2012 年の欧州宇宙機関/欧州宇宙技術研究センター（ESA/ESTEC）訪問研究員を経て，2015 年に相模原キャンパスに着任．小型月着陸実証機 SLIM の航法誘導制御系および軌道計画を担当，並行してはやぶさ２の着陸降下軌道制御運用に参画．2020 年度より，研究開発部門第一研究ユニット相模原領域研究領域主幹．SLIM ミッションでは着陸降下基準軌道，動力降下誘導アルゴリズムを大学研究者等と共同で考案し，実装した．研究活動では，軌道制御への深層学習技術の適用に関心があり，将来ミッションに向けた検討を進めている．

「アストロダイナミクスから見た小型月着陸実証機 SLIM の飛行結果」

「Flight Results of Small Lunar Landing Demonstrator SLIM from an Astrodynamics Perspective」

Abstract

The SLIM (Smart Lander for investigating Moon) mission successfully demonstrated pinpoint lunar landing technology in January 2024. The landing accuracy was confirmed to be within 100 meters. The technology required for pinpoint lunar landing consists of a variety of elements including a vision-based navigation system that accurately detects the relative position of the spacecraft to the lunar surface, a propulsion system that operates stably, a landing and descent reference trajectory that is in harmony with the system design, mature spacecraft navigation, guidance, and control technology, and precise guidance algorithms to accurately guide the spacecraft to its target state. In addition to the above, the SLIM mission applied a variety of innovations related to astrodynamics from launch to landing. For example, lunar transfer orbits via lunar swing-by and weak stability boundary to reduce propellant consumption, rapid orbit determination for onboard navigation initialization just prior to landing, and navigation, guidance, and control during landing sequences with accuracy and robustness, including emergency operational procedures for off-nominal events. This presentation will provide the on-orbit operation results of the SLIM mission and discuss the

future of lunar missions.

Jul 29th(Mon) Room A AM(9:30-12:00)　Abstracts

ASTRO-2024-A001

「Use of stable Lagrange points for improving Lunar GNSS」

* Cormier Luis(UoN, PhD Student)

Abstract:

With several upcoming Lunar missions needing increasingly precise positioning techniques, international efforts to develop navigation systems for the Moon have been heavily researched in recent years. While much of this research focuses on either the direct use of terrestrial GNSS signals, or the development of new GNSS-like systems around the Moon, preliminary research suggests augmentation satellites around the stable L4 and L5 Lagrange points may improve the geometric dilution of precision of GNSS signals by up to two orders of magnitude compared to terrestrial GNSS signals alone. This talk will discuss some of the simulations and work performed to date in investigating the effects of utilising these two Lagrange points, and plans to progress with these studies moving forwards.

ASTRO-2024-A012

「データ駆動型関数同定を用いた共鳴フライバイ軌道設計に関する研究」

「Resonant Flyby Trajectory Design using Symbolic Regression in CRTBP」

* 伊藤 将太(都立大・院), 佐原 宏典(都立大), 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-2024-A003

「Cislunar 系における弾道軌道の深層生成モデルを用いた Zeroshot 生成」

「Zeroshot generation using a deep generative model of ballistic trajectories in the Cislunar system」

* 畠山 祥(総研大・院), 伊藤 将太(都立大・院), 柳瀬 利彦(PFN), 尾崎 直哉(JAXA)

Abstract:
Designing cislunar trajectories is complex due to the nonlinearity of the four-body dynamical system, particularly in generating initial guess trajectories, which typically require expert knowledge and huge computational resources. Recent advances in deep generative models has shown the potential of machine learning in trajectory design, such as using meta-reinforcement learning and conditional variational auto-encoders. This study employs a Patch Time Series Transformer (PatchTST) to generate ballistic trajectories in the cislunar system. PatchTST treats time series data as patches, preserving local information and handling long series efficiently. This approach significantly simplifies obtaining high-quality initial trajectory estimates.

ASTRO-2024-A004
「強化学習を用いたハイブリッドソーラー電力セイルのロバスト最適軌道設計」
「Reinforcement Learning Aided Robust Trajectory Optimization of Hybrid Solar Power Sail」
* 中条 俊大（東工大），荒井 湧介（東工大・院）
Abstract:
Reinforcement learning is getting popular in the research field of trajectory optimization. It is particularly useful for robust optimization under stochastic uncertainties such as navigation error and control error. It is easy to implement without complex mathematical knowledge at the expense of computation cost, with convenient programming libraries available. In this study, we report the preliminary result of robust trajectory optimization of the hybrid solar power sail, which utilizes both solar electric propulsion and solar radiation propulsion, and compare it with the conventional deterministic trajectory optimization. All the computation is performed using MATLAB Reinforcement Learning Toolbox.

ASTRO-2024-A005
「LiteBIRD 軌道設計」
「Trajectory Design of LiteBIRD」
* 池永 敏憲，中村 涼，山元 透，堂谷 忠靖(JAXA)
Abstract:
LiteBIRD is the Light satellite for the study of B-mode polarization and Inflation from cosmic background radiation detection which is planned by Institute of Space and Astronautical Science of Japan Aerospace Exploration Agency. LiteBIRD uses Lissajous orbit around

Lagrange point 2 of the Sun-Earth system. Author employed the transfer trajectory of Plank launched by European Space Agency to reduce the total delta-V. This paper shows the results of the trajectory design of LiteBIRD using the manifolds connecting to Lissajous orbit.

ASTRO-2024-A006
「JAXA 宇宙探査イノベーションハブにおける AI 分野研究の取組みと今後の課題について」
「JAXA Space Exploration Innovation Hub Center's activities about Artificial Intelligence Research」
* 山崎 雅起(JAXA)
Abstract:
The JAXA Space Exploration Innovation Hub aims to build an automatic and autonomous next-generation mobility system that can be developed for future lunar exploration and Mars. This presentation will introduce examples of research on AI and robotics technologies for lunar exploration conducted by the Space Exploration Innovation Hub, and will describe AI and robotics technologies for the construction of next-generation mobility systems.

Jul 29th(Mon) Room A PM1(13:00-15:05)　Abstracts

ASTRO-2024-A007
「1 駆動系スピン型着陸機の地上模擬実験のための実験環境開発と飛行試験」
「Development of Flight Simulation Environment and Experiment for Single Actuator Spinning Lander」
* 中川 果帆（東大・院）, 楠本 哲也, 津田 雄一（JAXA）
Abstract:
This study considers a minimum-configuration, small, and simple lander. A small lander with a minimum configuration and moderate accuracy can realize a high-risk but high-return/high-frequency landing system.

The lander proposed in this study has two solid rocket motors with constant thrust for the propulsion system, which is small, simple, and cost-effective. Two solid rocket motors are mounted on gimbals. The lander is spin-stabilized, and its vertical position and velocity are controlled by a single actuator that controls two gimbals symmetrically. A flight simulation environment in a ground environment with drone technology is developed and preliminary

experiments are conducted.

ASTRO-2024-A008
「はやぶさ２#の小惑星 2001CC21 フライバイにおけるスルーマヌーバの検討」
「The Study of the Slew Maneuver in the Hayabusa2# Flyby of Asteroid 2001 CC21」
* 岩城 拓弥, 三桝 裕也, 坂東 信尚, 津田 雄一(JAXA)
Abstract:
The asteroid explorer Hayabusa2, after returning to Earth in 2020, is currently on the way to a flyby of the asteroid 2001 CC21 in 2026, aiming to capture as many high-resolution images as possible by maneuvering its attitude. Due to hardware constraints and complexities of on-orbit software modifications, these maneuvers must be executed in a simple manner. This study investigates the use of a slew maneuver, where the probe changes its attitude at a constant angular rate shortly before its closest approach to the asteroid, to increase the opportunity for high-resolution imaging.

ASTRO-2024-A009
「RHC を利用したオンボード小天体降下手法の研究」
「Research of small body descnet using receding horizon control」
* 吉川 健人, 津田 雄一(JAXA)
Abstract:
In the proximity operation of small bodies, descent technology to the target point is essential for accessing its surface. The author proposes a guidance method that uses simple Receding Horizon control for onboard loading. This paper describes the details of the proposed guidance method.

ASTRO-2024-A010
「外乱環境下における宇宙機の目標位置・速度・加速度への誘導法」
「A Spacecraft Guidance Method for Desired Position, Velocity, and Acceleration under Disturbances」
* 渡邉 泰之(MELCO)
Abstract:
This paper presents a guidance method for spacecraft to reach desired position, velocity,

and acceleration using the closed-form solution of Hill's equations with external force acceleration described as time polynomials. In many cases, the Clohessy-Wiltshire (C-W) solution is used for spacecraft guidance around targets. The C-W solution results in discontinuous velocity at the boundaries which requires impulsive acceleration in infinitesimal time, whereas the solution with time-polynomial acceleration provides continuous acceleration and resolves the velocity discontinuity. Although spacecraft reach their targets using the solution in ideal modeled environments, unmodeled effects disturb their planned trajectories in orbit and cause position errors. Therefore, it is necessary to repeatedly replan the trajectories at some time intervals and the solution with time-polynomial acceleration enables guidance which maintains the continuous velocity and acceleration conditions.

ASTRO-2024-A011

「Comet Flyby Simulation with Precise Dust Modeling for Comet Interceptor Mission」

* Oliver Scholts Sebastian(TU Delft, M2)

Abstract:

The Comet Interceptor mission to be launched in 2029 aims to perform a detailed flyby analysis of a long period dynamically new comet.　To satisfy the pointing requirements for the scientific measurements of a close flyby, high-fidelity modelling of dust particle impacts on spacecraft attitude is necessary. This research focuses on developing precise dust modelling techniques to simulate the interactions between the spacecraft’s attitude and cometary dust particles. By incorporating a higher fidelity model of the dust impacts, it is evaluated how varying particle sizes, velocities, number densities and impact angles influence the spacecraft's rotational dynamics. This comprehensive approach enables the development of more robust attitude control strategies and impact mitigation techniques for the more sensitive components of the spacecraft, ultimately contributing to the mission's goal of capturing unprecedented scientific data from the comet's environment.

Jul 29th(Mon) Room A PM2(15:20-17:25)　Abstracts

ASTRO-2024-A002

「群知能を用いた深宇宙探査機マルチスイングバイ軌道設計最適化手法に関する研究」

「A Study on the Optimization Method Using PSO for Spacecraft Trajectory Design with

Multi Gravity Assist」

* 安福 亮(東大・院), 尾崎 直哉(JAXA), 西成 活裕, 柳澤 大地(東大)

Abstract:

In spacecraft trajectory design with multi gravity assist, optimization methods using evolutionary algorithms, which approximates the behavior of groups of social animals, have been researched besides traditional empirical approaches. However, evolutionary algorithms typically determine initial conditions randomly, preventing us from taking advantage of valuable prior knowledge on trajectory design derived from past optimizations. This study introduces and evaluates a new approach where initial conditions are informed by prior knowledge, which is in this case prior optimization results, integrating useful prior knowledge into evolutionary algorithms for improved trajectory design.

ASTRO-2024-A013

「最適フィードバック制御のもとでの周期軌道とそのファミリ—の解析」

「Analysis of Periodic orbit and their family with optimal control input 」

* 鶴田 彩乃（九大・院）, Henry Damenick B., Peterson Luke(Colorado Univ.), 平岩 尚樹（九大・院）, Pan Shanshan, 坂東 麻衣, 外本 伸治（九大）, Scheeres Daniel J.(Colorado Univ.)

Abstract:

The trajectory optimization problem of a continuous low-thrust propulsion machine can be expressed as an optimal control problem. By introducing 6-dimensional state variables and adjoint variables of the same dimension, a 12-dimensional simultaneous differential equation, the Euler-Lagrange equation, can be derived as a necessary condition for the optimal solution. In this study, the Eulerian Lagrangian equations are considered as a 12-dimensional Hamiltonian dynamical system, and the 12-dimensional dynamical structure around a periodic orbit with optimal feedback control is analyzed by dynamical systems theory. As a particularly important result, the existence of a family of periodic orbits with optimal control inputs is confirmed.

ASTRO-2024-A014

「変分法と力学系理論による探査機の軌道設計」

「Orbital Design of Space Probes using Variational Methods and Dynamical System theory」

* 柴山 允瑠(京大)

Abstract:
本講演では，制限 3 体問題の変分構造に基づいた周期軌道と準周期軌道の数値解法を紹介する．また，McGehee の変換により無限遠点が周期軌道になるように変換し，その安定多様体を数値計算することで，深宇宙探査軌道を設計する．

ASTRO-2024-A015
「間接法による小天体周りの低推力アシスト周期軌道」
「LOW-THRUST ASSISTED PERIODIC ORBITS AROUND SMALL BODIES VIA INDIRECT METHOD」
* パン シャンシャン，坂東 麻衣（九大）
Abstract:
This research focuses on low-thrust assisted periodic orbits (LTAPOs) around small bodies within the Hill Three-Body Problem (Hill3BP). LTAPOs are defined by periodic motion achieved through the implementation of a bang-bang control strategy. The problem is initiated by perturbing the natural motion to provide an initial state. The minimum-fuel problem, arising from the discontinuous control law, is addressed using an indirect method and resolved through a homotopy process from the minimum-energy problem to the minimum-fuel problem. This study systematically investigates the dynamical structures of LTAPOs, delving into aspects such as the solution space and orbital stability.

ASTRO-2024-A016
「グラフを用いた低エネルギー遷移軌道の設計とゼロ速度曲面に相補的な境界面の同定」
「Graph-Based Design of Low-Energy Transfers and the New Boundary Surface Complementary to the Zero Velocity Surface」
* 大島 健太（広工大）
Abstract:
The present work develops a graph-based framework for computing low-energy transfer trajectories in a multi-objective fashion. Trajectories are discretized into periapsis-to-periapsis arcs in a practical manner by introducing special apsis conditions, with which pivotal dynamical objects in the low-energy regime such as the zero-velocity surface, the newly identified boundary surface, and periodic orbits associate. The complementary roles of the boundary surfaces will be highlighted in the talk. Flight time and delta-v

characteristics for transitioning among the arcs represent weighted directed graphs, to which efficient pathfinding algorithms are available. Initial guess solutions are obtained from paths in the graphs that are optimized to minimize the fuel cost. The framework is shown to be effectively applicable to distinct phase-space regions in a unified manner demonstrating its versatility in the complex dynamical environment.

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

ASTRO-2024-A017
「SLIM の着陸位置決定と将来ミッションにおける着陸位置決定高精度化に向けた技術的課題」
「SLIM landing position determination and technical issues to improve positioning accuracy for future lander missions」
* 竹内 央, 冨木 淳史, 杉本 理英(JAXA)
Abstract:
レンジドップラ観測による SLIM の月面着陸位置決定結果を示すと共に、将来の着陸機ミッションの位置決定高精度化に向けた課題を考察する。

ASTRO-2024-A018
「超小型衛星の実測 GNSS データに基づく群知能アルゴリズムを利用した地球超低軌道における大気密度推定手法の構築」
「Estimation of atmospheric density in VLEO based on GNSS data from a nanosatellite using swarm intelligence algorithm」
* 酒井 智基（北大・院）, 高橋 裕介（北大）
Abstract:
The very Low Earth Orbit (VLEO), which is at an altitude range of 100-400 km, the lower region of the thermosphere, will become a hub for future satellite operations.
However, the atmospheric density, which is critical parameter for satellite missions, has not been fully clarified because of the difficulty of observations in this region,
In 2017, from the flight demonstration of the deployable nanosatellite EGG mission, intermittent GNSS data in this region was obtained.
In this study, this data was utilized to estimate atmospheric density using a swarm intelligence algorithm.

ASTRO-2024-A019

「深宇宙コンステレーションにおける衛星間測距を用いた半自律的軌道決定」

「Semi-Autonomous Orbit Determination Using Inter-Satellite Ranging in Deep Space Constellations」

* 王 方成(東大・院), 尾崎 直哉(JAXA)

Abstract:

The utilization of small satellites in deep space exploration is anticipated to reduce costs and enable rapid mission execution. However, the antenna resources available for satellite operations in deep space are limited, necessitating the autonomy of satellite operations. This study proposes and verifies through simulations a method for semi-autonomous orbit determination of multiple satellites in deep space by using inter-satellite ranging via optical communication, thereby reducing the need for communication with a limited number of satellites. The results of this approach are reported in this paper.

ASTRO-2024-A020

「月測位実証ミッションにおける軌道および時刻の真値系精度検証」

「Accuracy Validation of Satellite Orbit and Clock for Lunar Navigation Satellite System」

* 岩渕 真和, 中野 将弥, 片桐 征治 (Fujitsu) , 秋山 恭平, 河手 香織, 村田 眞哉, 小林 雅弥, 牧野 克省, 竹内 央, 杉本 理英, 市川 勉 (JAXA)

Abstract:

The Lunar Navigation Satellite System (LNSS) is a lunar satellite constellation that provides position and time information to users of lunar activities. This system requires the precise position and time (true value) of the lunar positioning satellites and the lunar receiver which is intended for lunar users. This paper describes a method for calculating the true value and a method for verifying the accuracy of the satellite orbit and clock estimation.

ASTRO-2024-A021

「天体上/天体回りの移動体への実時間測位に関する一考察」

「A Study on Positioning Service to the Vehicles on/around A Celestial Body」

* 川口 淳一郎(ANU)

Abstract:

Deploying the global positioning system on/around celestial bodies, such as the moon, satellites, planets or small bodies requires huge initial investment. A key is in establishing unique absolute clocks' network on/around the celestial bodies. The timing issue accompanies the range measurement at the same time and is never separable. This study presents an innovative way in simultaneous range measurement with clock synchronization based on the iterative correction method working on affordable transceivers which start functioning asynchronously and do not have to be synchronized from the beginning in advance. The system works by flying vehicles themselves over the region of interest. The vehicles in turn provide the positioning service to the vehicles in the region. The system commences functioning with modest investment.

ASTRO-2024-A022

「超小型宇宙機用の ToF 測距センサの動作検証」

「Operation verification of ToF ranging system for ultra-small satellites」

* 芝田 朋世(都立大・院), 杉原 アフマッド清志(JAXA), 鳥阪 綾子(都立大), 森 治(JAXA)

Abstract:

Recently, as missions using multiple small/ultra-small satellites operating in deep space have become important, ranging technology between two objects has become indispensable. We propose a simple Time-of-Flight (ToF) sensor using a small RF beacon, aiming to meet the constraints of extreme compactness within a 5-10 cm size enclosure, light weight and power efficiency. We have demonstrated a prototype of this sensor and shown that it can measure distances within 5 meters with an accuracy of approximately 1 meter. However, the variation of ranging error with distance and the feasibility of long-distance ranging are issues that need to be addressed. We report the process of experiments and analysis related to these issues.

Jul 30th(Tue) Room A PM1(14:00-16:05)　Abstracts

ASTRO-2024-A023

「火星サンプルリターンの低コスト化を実現する不確定性を考慮した
深宇宙ランデブー軌道解析」

「Stochastic Trajectory Design of Deep Space Rendezvous for Low-Cost Mars Sample

Return」
* 伊東 理紗(慶應・学), 尾崎 直哉(JAXA)
Abstract:
Returning samples from Mars is expected to provide significant scientific knowledge about the formation of planets and the origin of life. The LifeSpringsMars Mission, a mission concept designed by a multinational consortium, aims to return samples from Columbia Hills on Mars at a low cost. To achieve cost reduction, the mission plans to transfer samples in deep space instead of transferring samples in Mars' low orbit. However, relaying samples in deep space has a high risk of losing samples, so trajectory design that accounts for uncertainties of Mars Ascent Vehicle is required. This paper presents a method to optimize the rendezvous trajectories between multiple spacecraft by extending stochastic trajectory optimization using Unscented Transform. Finally, numerical examples demonstrate the feasibility of the proposed mission architecture.

ASTRO-2024-A024
「DESTINY+のスパイラル軌道上昇フェーズにおける軌道運用解析」
「DESTINY+ Flight Dynamics Operation Analysis for the Spiral Orbit Raising Phase」
* 藤本 和真(富士通), 山本 高行, 竹内 央, 市川 勉, 杉本 理英, 今村 裕志, 高島 健, 谷口 正(JAXA)
Abstract:
DESTINY+ is an interplanetary flyby mission to the (3200) Phaethon asteroid. In the beginning of the mission, DESTINY+ spacecraft will be launched into a highly elliptical orbit around the Earth and gradually raise its orbital altitude operating its ion thrusters until it reaches the moon's gravity field. To demonstrate the technology of operating ion thrusters in a planetary orbit, it is important to assess the feasibility of flight dynamics operations during the spiral orbit raising phase. This presentation presents the simulation results of the entire flight dynamics operations, from orbit planning to orbit determination, based on the latest operational conditions.

ASTRO-2024-A025
「将来の深宇宙探査に向けた推進機の得意領域の分類」
「Classification of Thrusters Expertise Areas for Future Deep Space Exploration」
* 小澤 翼(九大・院), 高尾 勇輝(九大), 月崎 竜童, 張 科寅(JAXA)

Abstract:
Asteroid exploration has been accelerated in recent years. This study investigates mission designs for candidate asteroids that are scientifically attractive, mainly chosen from the main belt, using multiple propulsion, i.e., chemical engine, ion engine, and Hall thruster. Since the trajectory design with the electric propulsion system is largely dependent on the thruster specifications, namely, thrust and specific impulse, comprehensive understandings that classify expertise regions according to the characteristics of each electric propulsion are required for the future deep space mission design. Therefore, trajectory optimization has been conducted in a discretized manner with Direct Collocation and Nonlinear Programming (DCNLP) to explore the optimal design variables that minimize propellant consumption. The trade-off between delta-V and time of flight for each candidate asteroid is provided to get insight into the consideration of the future mission.

ASTRO-2024-A026
「ハイブリッド微分動的計画法を用いた NRHO から LLO への遷移軌道最適化に関する研究」
「A Study on the Application of Hybrid Differential Dynamic Programming for NRHO to LLO Transfer Orbits」
* 大上 耕平(東工大・院), 尾崎 直哉(JAXA), 中条 俊大(東工大)
Abstract:
Earth-Moon Near Rectilinear Halo Orbits (NRHO) are candidates for the reference orbit of the Gateway. Transfer from NRHO to Low Lunar Orbit (LLO) using electric propulsion is of critical importance. However, low-thrust multi-revolution trajectory optimization is challenging, as trajectories often diverge, leading away from the intended destination due to strong perturbations from Earth. We implemented Hybrid Differential Dynamic Programming (HDDP) for these transfers, which is a variant of Differential Dynamic Programming (DDP), computing local optimal control by solving a second-order expansion of the Bellman equation. This study introduces technical strategies to address these challenges for descending to LLO.

ASTRO-2024-A027
「消費推薬量を抑えるためのスラスタ配置を考慮した MMX 接近降下フェーズの設計」
「Design of the MMX Approach Descent Phase to Reduce Propellant Consumption

Considering Thruster Configuration」

* 松本　祐樹, 巳谷 真司, 岡田 尚基, 竹尾 洋介, 吉川 健人, 木村 洸貴(JAXA), 山口 智宏(MELCO), 上野 竜雄(MESW), 安濟 貴夫, 渡邉 泰之, 渡辺 健太郎, 遠山 大介(MELCO)

Abstract:

Martian Moons eXploration (MMX) is a sample return mission from a Mars satellite (Phobos) currently planned in Japan. The descent and landing sequence on Phobos includes an approach descent phase (ADP) to 2.2 km above the landing target point from the quasi-satellite orbit (QSO), a vertical descent phase (VDP) from 2.2 km to 10 m altitude, and a free-fall phase from 10 m altitude.　Especially in the ADP, the ΔV consumption and terminal guidance error change for each landing target point due to the QSO orbit characteristics, the shape of Phobos, and MMX-specific constraints such as thruster assignment and the attitude during the VDP. Therefore, in this presentation, we show the design of the ADP to reduce propellant consumption and the consumed ΔV and terminal guidance error for each landing target point by a comprehensive analysis.

Jul 30th(Tue) Room A PM2(16:20-18:00)　Abstracts

ASTRO-2024-A028

「地球接近小惑星の軌道解析」

「Orbital analysis of near-Earth asteroids」

* 吉川 真(JAXA)

Abstract:

Currently, the orbits of more than 1.36 million asteroids have been obtained, of which approximately 35,000 are near-Earth asteroids. Here we studied how asteroids approach the Earth, Moon, and Mars. We also calculated the orbital evolution of asteroids, especially those with orbital periods close to one year, and found that many of them have quite complex resonance relationships with the Earth. We report on these results.

ASTRO-2024-A029

「連続推力を用いた衛星コンステレーションの準最適な軌道展開」

「Quasi-optimal deployment for satellite constellation using continuous thrust」

* 島 岳也(三菱電機), 山田 克彦(大阪公立大学)

Abstract:
In this presentation, the quasi-optimal deployment for satellite constellation using continuous thrust will be studied. We use the Split Edelbaum Strategy (SES), which performs orbit transfer in 3-phase (burn-coast-burn) by directly controlling the semimajor axis and inclination using continuous thrust. Quasi-optimal solutions for specified RAAN (Right Ascension of the Ascending Node) and AoL (Argument of Latitude) deployments are realized by using SES. Numerical simulations confirm the effectiveness of the proposed deployment strategy for satellite constellation.

ASTRO-2024-A030
「LEO を起点とした自在かつ経済的な惑星間地球出発軌道の検討（第二報）」
「Investigation of LEO as a parking orbit for flexible/economical interplanetary Earth departure (second report)」
* 武井 悠人, 大木 優介, 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. In addition to the previously reported solution, this talk introduces the orbital sequence adopting the Lunar gravity assist (LGA) and the consequent powered Earth gravity-assist (PEGA) as an alternative solution. The status of on-going discussion about ISAS/JAXA's concept of deep space orbital transfer vehicle (DSOTV) are also reported briefly.

ASTRO-2024-A031
「宇宙デブリー解消のため宇宙認証システムに関する研究」
「Research of Space Certification System for Space Debris Resolution」
* 金 東宣(卒業生)
Abstract:

The Rep. of Korea is advanced to the next step for space development of New Space Era and private space industry. Expectations from industries are also full. But, basically, we must to be thinking about resolution of space debris problem in near earth. More efficient regulation and ideas on newly manufactured and operated artificail space objects, separately technical treatment solutions to existing space debris that have already been neglected, must to be considered for future space debris reduction. In this paper, we discuss about introducing space worthiness system plus space properness certificatoin system for newly producted artificail space objects with as the central isuue　of cube sat.

Jul 29th(Mon) Room B AM(9:30-12:00)　Abstracts

ASTRO-2024-B001
「ステップおよび連続時間入力による柔軟構造宇宙機の高速 3 軸姿勢マヌーバ」
「High Speed Three Axis Attitude Maneuver of Flexible Spacecraft
Using Step and Continuous-Time Input」
* 酒井 貴行, 下村 卓, 山田 克彦(大阪公大・院)
Abstract:
In the three-axis attitude maneuver of a spacecraft with flexible structures, two types of feedforward control inputs are applied to achieve both attitude control of the spacecraft and suppression of residual vibrations in the flexible structures. The feedforward control inputs employed are step-type control inputs and continuous-time control inputs. Additionally, a two-degree-of-freedom control system that simultaneously uses both feedforward and feedback control is adopted. It is demonstrated that this approach can improve pointing control accuracy in the presence of structural damping and other disturbances.

ASTRO-2024-B002
「膜面展開構造物を含む小型衛星の地球低軌道での姿勢解析」
「Analysis of small satellite's attitude with deployable membrane structures in LEO」
* 勝又 晴日, 小松 雄高, 鈴木 新一（JAXA）
Abstract:
JAXA is developing a series of small demonstration satellites. The third satellite in the series, RAISE-3 has asymmetric deployable membrane structures, one of which is to demonstrate reducing deorbit time. Since JAXA has never developed a small satellite like RAISE-3 before,

possible effect on the attitude control system of the satellite bus and feasibility of the demonstration mission have been evaluated.
At first, we analyzed impact of four major disturbance torques from space environments to this structure.
Secondly, we analyzed the attitude dynamics of the satellite after the end of operation.
Finally, we analyzed and compared the deorbit performance of the satellite before and after deployment.

ASTRO-2024-B003
「群論によるアプローチを用いた四元数回転表現の見直し」
「Quaternion representation of rotations using a group theory approach」
* 石原 有喜(帝京大・院), 中宮 賢樹(帝京大)
Abstract:
In this study, we discuss the mathematical background of the quaternion representation of rotations from the viewpoint of group theory. In the field of group theory, in three dimensions, the quaternions used for rotations form a group, while the quaternions to be rotated form an algebra. Therefore, we consider rotation representations using quaternions in relation to the Lie group and the Lie algebra. Furthermore, we apply the group theory approach to two-dimensional rotation representations and to examine their group structures in comparison with the group structures in three-dimensional rotation representations.

ASTRO-2024-B004
「はやぶさ 2 小惑星フライバイ撮像における画像フィードバック姿勢マヌーバ」
「Visual Feedback Attitude Maneuver for Hayabusa2 Asteroid Flyby Imaging」
* 照井 冬人(KAIT), 三枡 裕也(JAXA)
Abstract:
小惑星探査機「はやぶさ 2 」は 2026 年 7 月に小惑星 2001CC21 へのフライバイ撮像を計画している。撮像に用いるカメラは探査機本体に固定されており、相対的に高速に移動する小惑星フライバイ撮像のためには探査機の姿勢マヌーバを実施する必要があるが、この姿勢マヌーバは小惑星との最接近距離の大きさに応じて、その必要性の有無が分かれることを数値シミュレーションにより評価した結果を示す。

ASTRO-2024-B005

「はやぶさ 2 拡張ミッションにおけるリアクションホイール劣化状況を想定した姿勢制御」

「Attitude Control Assuming Reaction Wheel Degradation Situation in Hayabusa2 Extended Mission」

* 小坂 岳文(NEC), 神谷 俊夫(明星大), 保田 誠司(NEC), 三桝 裕也, 津田 雄一(JAXA)

Abstract:

In Hayabusa2 extended mission, there are concerns that spacecraft's Reaction Wheel (RW) satisfies life requirement due to the long time that has passed since launch, resulting in loss of these function. RW failure will have a critical impact on all the aspect of operations such as ion engine propulsive cruise, communication and observation. This paper presents operational design and attitude control method that assumes spacecraft's operation continues even in the event of RW failure up to two axes in the extended mission. In addition, we show evaluation results of effectiveness of the attitude control system through flight experiments simulating RW failure situations. These attitude control systems design enable to expand Hayabusa2's mission and also contribute to development of long-term cruise technology for future space exploration missions.

ASTRO-2024-B006

「Improvements in Rhumb Line Control: Minimizing Nutation and Enhancing Fuel Efficiency」

* Ranno Paolo Ernesto(KTH), Sawai Shujiro, Ito Takahiro(JAXA)

Abstract:

This study aims to enhance the rhumb line control (RLC) attitude maneuver, a simple and reliable technique used by spin-stabilized bodies such as rockets and various spacecraft. It addresses the inherent nutation motion that occurs during RLC maneuvers, which frequently necessitates a subsequent active nutation control (ANC) maneuver to eliminate residual nutation motion at the end of RLC. In some cases, ANC can consume significant amounts of fuel. The primary objective is to improve the RLC efficiency by minimizing the residual nutation angle at the end of the maneuver, potentially reducing or eliminating the need for ANC. This strategy could lead to substantial fuel savings, extending mission durations and improving overall spacecraft performance across various applications.

ASTRO-2024-B007

「球棒型モジュラーロボットのモデル化と自己変形に関する一検討」

「A Study on Modeling and Self- Transformation of a Ball-Stick Type Modular Robot」

* 片岡 英輔(東大・院), 橋本 樹明(ISAS/JAXA), 久保田 孝(明大)

Abstract:

Modular robots that can change their shape according to the environment are expected to be utilized for the exploration of geysers on Enceladus and vertical holes on the Moon, which are difficult to explore with conventional robots. Modular robots are very complicated to generate behaviors autonomously because multiple modules are assembled and transformed in three dimensions, so modeling is necessary. In order to study the reconfiguration function, we present a consideration of the mathematical modeling for a modular robot that combines a sphere-shaped module and a stick-shaped module.

ASTRO-2024-B008

「Quadruped Contact-Implicit Model Predictive Control for Martian Terrain: Based on Inverse Dynamics Trajectory Optimization」

* BIAN JINGLI(九州大学・院)

Abstract:

Scientific exploration of planetary surfaces is an ideal activity for legged robots. However, locations with significant exploration potential often feature steep and rugged terrain, posing formidable challenges to the robots' planning and control capabilities. Recent research on contact-implicit model predictive control based on inverse dynamics trajectory optimization has demonstrated the potential for robots to perform more complex tasks and overcome such difficult terrains. In this study, we focus on the uneven and steep terrain of the Martian surface and introduce a series of progressive innovations into the controller. These advancements enable faster and more reliable contact-implicit model predictive control for quadrupedal robots, allowing them to achieve stable motion without a predetermined fixed contact sequence.

ASTRO-2024-B009

「モータ故障時の安全性を考慮したマニピュレータの駆動方法」

「Safety maneuver for a space manipulator against motor failures」

* 相子 康彦, 津田 雄一(JAXA), 上野 誠也(横国大)
Abstract:
Manipulators are expected to be used in future space missions. A variety of missions are proposed in many future visions, including crew support in space stations or capturing scientific samples for space explorers and so on. These missions strongly require that malfunctions should be in the safe range, even in the case of a hardware failure. In this presentation, it is defined that the function named "degree of danger" which indicates the risk of impact on the crew or surrounding devices in the case of failures of the driving motors. The authors propose a method to generate safety maneuver that minimizes the "degree of danger".

ASTRO-2024-B010
「月の溶岩チューブ探査におけるマルチロボット位置推定」
「A Study on Multi-robot Posture Estimation in Lunar Lava Tube Exploration」
* 住田 圭吾（東大・院），久保田 孝（明大），橋本 樹明（JAXA）
Abstract:
Multi-robot exploration in lunar lava tubes requires precise posture estimation of robots. In a closed, dark environment such as lava tubes, it is difficult to estimate the posture by self-location estimation or to estimate the posture of all robots directly from a base station. Therefore, when estimating the posture of all robots, the estimation must be performed via robots between the base station and the target robot. In this paper, we propose a method for accurately estimating the posture of a robot in such cases, and demonstrate its effectiveness through simulations.

ASTRO-2024-B011
「惑星探査ローバの知能化についての検討」
「Intelligent in Rover: A Study on the Enhancement of Planetary Exploration」
* 本橋 優俊（東大・院），橋本 樹明（JAXA），久保田 孝（明大）
Abstract:
A rover is required to drive autonomously on the planet's surface for efficient exploration. However, human support has sometimes been required because conventional rovers could not cope with environmental changes. This makes exploration inefficient. To address this

issue, the rover needs to become intelligent, that is, have the ability to appropriately cope with environmental changes and adapt to unknown environments. To this end, this research first proposes schemes to select path planning and localization methods according to the environment. Then, the novel concept of a navigation system is described which is currently being considered to realize intelligence.

Jul 29th(Mon) Room B PM2(15:20-17:25)　Abstracts

ASTRO-2024-B012
「スライディングモード制御を用いたコンステレーション展開制御に関する研究」
「Study on constellation deployment control with sliding mode control」
* 井本 悠太(阪大・院), Mancini Mauro(POLITO), Ruggiero Dario(POLITO, PhD student), Capello Elisa(POLITO), 佐藤 訓志, 山田 克彦(阪大)
Abstract:
本研究では、地球周回衛星コンステレーションの面外軌道展開を対象に、低推力推進によるロバストな軌道制御法を提案する。
非線形制御を用いた衛星の軌道制御の従来研究としてリアプノフ関数ベースの制御手法が提案されているが、当該手法は外乱や摂動力をすべて既知としている。
そこで本研究では、制御手法としてスライディングモード制御を利用し、未知外乱やモデル化誤差に対するロバスト性が高い軌道制御法を提案する。

ASTRO-2024-B013
「FACTORS ミッションのための抗力差を用いた二衛星編隊飛行制御の設計」
「Design of two-satellite formation flight control with differential drag for the FACTORS mission」
* ベルテ マックスミリアン(東大), 丸 祐介, 齋藤 義文, 三谷 烈史, 篠原 育, 浅村 和史(ISAS/JAXA)
Abstract:
FACTORS is a mission proposal being led by ISAS/JAXA, to perform particle sampling, field observation, and imaging in the Earth's auroral oval at polar latitudes. Two satellites will be used in formation flight, to obtain simultaneous measurements. The satellites have an eccentric orbit passing through the atmosphere at perigee and are equipped with active attitude control. This opens the possibility for low-propellant orbit control using differential

aerodynamic drag, by adjusting the flow-facing area of the satellites during an atmospheric pass. Numerical results are presented on approaches for differential drag control compatible with the scientific requirements. Operational implications are discussed.

ASTRO-2024-B014

「深宇宙ランデブドッキングへの Moving stereo ベースの誘導航法の適用に関する解析」

「Analysis of the application of moving stereo-based guidance and navigation to deep-space rendezvous and docking」

* 大月 幸穂, 天川 海音（東大・院）, 津田 雄一（JAXA）

Abstract:

In order to improve the flexibility and scalability of future space missions, the OTV concept, where mission executed with two vehicles; mission vehicle and orbit transfer vehicle (OTV), has been proposed, and rendezvous and docking technology for the latter to the former is a key technology for this concept. Considering the uncertainties of mass which is a challenge unique to this concept, and the requirements of high autonomy and low resource unique to deep space, the application of moving stereo-based guidance and navigation, which has been proven in Hayabusa2, is considered as a baseline method to achieve highly accurate guidance and navigation. In this study, we quantitatively evaluate the accuracy of this method and provide guidelines for further improvement of autonomy.

ASTRO-2024-B015

「測角航法誘導における比例航法とムービングステレオの比較」

「Comparative Study of Propotional-navigation and Moving-stereo in Angle-Only Navigation」

* 久島 明洋, 中川 果穂(東大・院), 津田 雄一(JAXA)

Abstract:

In order to realize deep space rendezvous and docking, radio
navigation by beacons is proposed. However, it is unobservable to estimate position and velocity of target by only direction of arrival. One solution to this problem is "moving-stereo", which makes target's position and velocity observable through parent spacecraft increase speed while observing. The other solution is "proportional-navigation", which does not need information like position or velocity and just keep direction of arrival constant. In this study we compare these two methods in terms of fuel consumption and robustness in many

situations and discuss application to deep space exploration.

ASTRO-2024-B016

「Modeling of energy capture and transmission of a formation flying applied to Space-Based Solar Power mission」

Cardoso Franco Thais(ITA, PhD candidate), * Nahuel Sousa Fagonde Caio(UFABC, researcher), Gomes dos Santos Willer(ITA, professor)

Abstract:

Space-Based Solar Power (SBSP) holds the promise of renewable energy by harnessing solar power in space and transmitting it to Earth via microwaves. This method allows for continuous, 24/7 energy capture without atmospheric losses. To avoid launching robust structures with large solar panels, the concept of multiple smaller satellites with a common control law, known as formation flying, has emerged. To optimize the incident irradiation, capture and transmission of the SBSP, this work studies and models the attitude dynamics of the formation by tracking the Sun and avoiding satellite occlusion. For the transmission, the feasibility of two concepts is examined: the first, where all the satellites in the formation transmit to Earth, and the second, where one satellite collects energy from the others satellites and solely transmits the total energy to Earth. The viability of the SBSP is analyzed based on the number and size of the panels, as well as the orbital altitude of the system.

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

ASTRO-2024-B017

「小型衛星用 VSCMG 実用化に向けた実験機開発」

「Development of Experimental Model for Practical Use of VSCMGs for Small Satellites」

* 鳥居 壮瑠(横国・院), 倉田 昇祈(横国・学), 樋口 丈浩(横国)

Abstract:

Variable Speed Control Moment Gyro (VSCMG) is an attitude control device which can generate higher torque than other devices, and maneuver satellite attitude quickly and accurately without any propellant. It is expected to satisfy the demand for highspeed attitude change. In the previous study, semi-optimal control law which enables fast maneuver without avoiding singularity and small VSCMGs prototype are developed. The purpose of this study is to success the experiment of VSCMGs using semi-optimal control law and the

prototype for practical use. This paper presents FB control using the prototype and its development process.

ASTRO-2024-B018
「はやぶさ 2 のスピン運用実験」
「On-orbit verification of a spin operation in HAYABUSA2 mission」
* 木村 洸貴, 大野 剛, 三桝 裕也, 津田 雄一(JAXA)
Abstract:
A spin stabilization method is commonly used for a deep space explorer when it needs to be in a safe mode. In the case of faults in reaction wheels or reaction control systems, the feasibility of a spin operation plays an important role in the survivability of its explorer. In this study, an on-orbit spin control experiment using a limited number of reaction wheels is conducted using HAYABUSA2, which is currently navigating in deep space, and its attitude behavior is analyzed. The outcome of this experiment is expected to be the practical preparation for the following verification of the novel autonomous solar tracking control system utilizing solar radiation pressure.

ASTRO-2024-B019
「深層強化学習と尻尾機構を利用したソーラーセイルの姿勢制御と形態進化」
「Tail-driven attitude control and morphology evolution of a solar sail 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 attitude control and morphology evolution of a solar sail under solar radiation pressure. We introduce a tail mechanism for arbitrary and efficient attitude control of the solar sail. While a longer and heavier tail can reduce control time, such a tail can be power consuming. We thus have refined the length and mass of the tail to balance control time and power consumption based on the results of attitude control and particle swarm optimization.

ASTRO-2024-B020
「非ホロノミック性を利用した姿勢制御に向けた可変構造宇宙機の関節軌道の設計」

「Planning Joint Trajectory of Variable-structured Spacecraft for Attitude Control Utilizing Non-holonomic Features」

* 竹内 咲希（九大・院），坂東 麻衣, 外本 伸治（九大）

Abstract:

Non-holonomic features allow variable-structured spacecraft to change their attitude by moving their movable parts due to the momentum conservation law. Thus, planning appropriate joint motion results in the desired attitude change. Because this method only requires the driving forces of joints, which can be obtained from a photovoltaic system, it is one possible way to extend spacecraft operation terms. Although the methods of motion planning have already been established in two-dimensional motion, some problems to be resolved remain in three-dimensional motion. This study discusses planning the three-dimensional joint motion to achieve the desired attitude change.

ASTRO-2024-B021

「極軌道における２Ｕキューブサットの姿勢制御実証実験の評価」

「An Estimation Study on Attitude Control System for 2U-size cubesat on polar orbit」

* 長壁 孝太朗(群馬高専), 松井 翼, 井上 永遠, 剣持 和歩, 赤石 大輔(群馬高専・専攻科), 滝谷 優太(群馬高専), 大畑 リヒト(群馬高専・専攻科), 今井 雅文(大気物理研究所), 北村 健太郎(宇宙システム工学科), 今井 一雅(電気情報工学科), 徳光 政弘(総合工学科), 平社 信人(群馬高専)

Abstract:

In this report, an attitude control system for 2U-size cubesat as Innovative Project on polar orbit is described. Then three attitude control methods for the 2U-size cubesat are implemented as novel dual reaction wheel system and two magnetorquer systems with permanent magnet system or usual coil system on polar orbit. Then some experiments of the attitude control system on polar orbit are executed, the obtained attitude result data are analyzed and evaluated. As a result, it is considered that the implemented the attitude control system for the 2U-size cubesat are effectiveness.

ASTRO-2024-B022

「広角カメラを使用した２Ｕキューブサットの姿勢角検出システム」

「A Study on Attitude Detection System with Omni-directional Camera for 2U-size Cubesat」

* 松井 翼(群馬高専・専攻科), 長壁 孝太朗(群馬高専), 井上 永遠, 剣持 和歩, 赤石 大

輔(群馬高専・専攻科), 滝谷 優太(群馬高専), 大畑 リヒト(群馬高専・専攻科), 今井 雅文(大気物理研究所), 北村 健太郎(宇宙システム工学科), 今井 一雅(電気情報工学科), 徳光 政弘(総合工学科), 平社 信人(群馬高専)
Abstract:
In this report, an attitude detection system with capturing image of omni-directional camera for 2U-size cubesat is described. The omni-directional camera is adapted to the ultra-small satellite to specify some fixed allocation of some celestial body such as Solar, Lunar and center of the Earth direction from the view of the satellite on orbit relatively. Then it is revealed that a pixel grid of capturing image with strong distortion for the omni-directional camera is formulated and analyzed as direction vector. To evaluate the proposing attitude detection system for the satellite, some experiments on orbit are executed.

Jul 30th(Tue) Room B PM1(14:00-16:05)　Abstracts

ASTRO-2024-B023
「フォーメーションフライトを用いたX線望遠鏡ミッションの検討」
「A Study of X-ray Telescope Mission Utilizing Formation Flight」
* 永田 楓馬(崇城大・院), 下田 孝幸(崇城大)
Abstract:
In X-ray astronomy, the observation of high-energy phenomena such as black holes (BH) requires high-resolution imaging capabilities. To enhance the resolution of X-ray telescopes, extremely long focal lengths are necessary. However, with a single satellite, it is challenging to secure sufficient focal length due to dimensional constraints. Therefore, recent attention has focused on using formation flight (FF) technology to deploy two satellites in space, effectively creating a large telescope. This presentation introduces the overview of X-ray telescopes utilizing FF and summarizes the requirements for formation flight. Then, the technical issues related to formation flying for X-ray telescopes are discussed.

ASTRO-2024-B024
「パドルを用いた空力による編隊飛行制御手法に関する検討」
「Formation Flight Control Method Using Aerodynamic Force with Paddles」
* 大坪 恵人（東工大・院）, 渡邉 奎（東工大）, 天木 祐希, 小林 大輝, 荒井 湧介, 吉村 大樹, 尾関 優作, 川口 雄生, 喜多村 章悟（東工大・院）, 中条 俊大, 中西 洋喜（東

工大）
Abstract:
Satellite formation flights have attracted attention because large-scale spacecraft systems can be realized virtually using multiple low-cost small satellites. A formation flight control method that changes the aerodynamic forces acting on the satellite using paddles is presented. The proposed method has an advantage over the control method using aerodynamic changes associated with attitude changes proposed in previous studies, in that it allows attitude changes during orbit control. In this presentation, an overview of the proposed control method and the evaluation results obtained using numerical simulations are presented. And the method is planning to demonstrate partially on a satellite named "GRAPHIUM" under development at the Tokyo Institute of Technology.

ASTRO-2024-B025
「地球周回軌道における大気抵抗差と vision-based 航法を用いた相対軌道制御に関する研究」
「Research on relative orbit control using differential drag and vision-based navigation in Earth orbit」
* 渡邉 奎, 中条 俊大, 中西 洋喜, 谷津 陽一(東工大), 小林 寛之, 高橋 健一郎, 天木 祐希, 大坪 恵人, 安田 萌恵, 小林 大輝, 荒井 湧介, 田代 克樹, 尾関 優作, 吉村 大樹, 川口 雄生, 吉田 英生(東工大・院), 宮本 清菜(東工大), 片岡 淳, 田中 香津生(早大), 森 椋平, 須賀 友也, 小笠原 聖純(早大・院), 山本 一毅(早大・学)
Abstract:
In recent years, there has been interest in distributed space systems using small satellites that can be developed at low cost. However, small satellites often have severe limitations on the amount of propellant. In addition, the use of intercommunication to estimate relative positions among the satellites is not versatile and costly. In this study, we consider relative orbit control using differential drag and vision-based navigation and examine its feasibility.

ASTRO-2024-B026
「深宇宙ランデブ・ドッキングのためのベイズ最適化を用いたシミュレータに基づいたパラメータチューニング」
「Simulator-based Parameter Tuning for Deep Space Rendezvous and Docking Using Bayesian Optimization」

* 佐々木 貴広, 坂東 信尚, 佐伯 孝尚, 津田 雄一(JAXA)
Abstract:
Simulator-based tuning methods can consider a nonlinearity and other factors due to various error models, such as alignment and navigation errors implemented in the simulator, and can easily optimize over the entire mission phase. This paper proposes the application of Bayesian optimization to parameter tuning for deep space rendezvous and docking missions.

ASTRO-2024-B027
「可変形状空力 FF 実証のための FF ターゲット分離シーケンスおよび分離機構」
「FF target separation sequence and separation mechanism for aerodynamic FF demonstration using variable shape function」
* 高橋 健一郎(東工大・院), 渡邉 奎, 中条 俊大, 中西 洋喜, 谷津 陽一(東工大), 小林 寛之, 天木 祐希, 大坪 恵人, 安田 萌恵, 小林 大輝, 荒井 湧介, 田代 克樹, 尾関 優作, 吉村 大樹, 川口 雄生, 吉田 英生(東工大・院), 宮本 清菜(東工大), 片岡 淳, 田中 香津生(早大), 森 椋平, 須賀 友也, 小笠原 聖純(早大・院), 山本 一毅(早大・学)
Abstract:
We are developing a microsatellite named "GRAPHIUM." The mission of this satellite is to demonstrate formation flying using its variable shape function to alter aerodynamic forces. The formation flying demonstration begins with the separation of a picosatellite-sized target from the main satellite, then followed by configuring the formation flying. If the separation speed and direction are not appropriate, the main satellite and the target may drift too far apart to achieve formation flying. Therefore, a precise separation mechanism is essential. This presentation describes the target separation sequence and explains the requirements and conceptual design of the separation mechanism based on that sequence.

Jul 30th(Tue) Room B PM2(16:20-18:00)　Abstracts

ASTRO-2024-B028
「小型外惑星探査機 OPENS における三角形形状の薄膜構造物の収納方法の差異により生じる展開挙動の変化」
「Changes in deployment behavior caused by different stowage methods for triangular-shaped thin-film structures in OPENS, a small outer planet explorer」

* 米田 大晟(青学・院), 楠本 哲也, 杉原 アフマッド清志(JAXA), 菅原 佳城, 武田 真和(青学), 森 治(JAXA)
Abstract:
In spacecraft, thin-film structures are used for solar sails and other applications because they are extremely lightweight and can cover a large area. The small space probe OPENS is also equipped with a lightweight thin-film structure with power generation and antenna functions. However, thin-films are very flexible and their behavior can easily become unstable, so it is necessary to simulate their deployment behavior on the ground. This study will analyze the deployment behavior of the thin-film structure of OPENS using Malti Particle Method and compare the deployment behavior with that of the actual machine.

ASTRO-2024-B029
「マニピュレータを用いた小型物体捕獲のための単眼カメラによる運動推定と経路最適化」
「Single Camera-Based Motion Estimation and Path Optimization for Small Object Capture Using a Manipulator」
* 青野 郁也（東大・院）, 相子 康彦, 武井 悠人, 津田 雄一（JAXA）
Abstract:
Recent advancements in space science missions and the increasing pace of space activities have created a growing need for capturing small objects. Manipulators are well-suited for this task due to their ability to handle objects of diverse shapes.To achieve a cost-effective solution, we propose a method that utilizes a single camera mounted on the manipulator's end-effector to estimate the target object's motion. This research has a two-fold objective: first, to develop an algorithm for estimating the target object's motion using a single camera mounted on the manipulator's end-effector; and second, to optimize the manipulator's path for efficient object estimation.

ASTRO-2024-B030
「深宇宙サンプルリターンのための親子型探査機間の自動囲い込み式爪型ドッキング機構の検討」
「A study on an automatic enclosing claw-type docking mechanism between parent-child spacecraft for a deep space sample return mission」
* 田中 友悠, 徳安 彰大, 吉田 英生(東工大・院), 中西 洋喜(東工大)

Abstract:
In recent years, a deep space exploration became more actively. A deep space sample return mission using a parent-child type spacecraft has been planned as the next generation of exploration. In this mission, the parent ship handles navigation from the earth to just above the target astronomical object, and the child ship lands to the object to collect samples. We have proposed a "automatic enclosing claw-type docking mechanism" for the docking between two spacecrafts during this mission, which has wide error tolerance and cages with an initial contact. In this presentation, we describe concepts, requirements and design of the docking mechanism, and evaluate the ability by testing with prototype model.

ASTRO-2024-B031
「ブーム型三角形膜の形状解析」
「Structural analysis of boom-supported triangular membrane」
* 清水 隆貴(青学・院), 中篠 恭一(東海大), 森 治(JAXA)
Abstract:
In recent years, missions to deploy thin-film structures by booms have been considered, aiming at making small spacecrafts more multifunctional and sophisticated. However, care must be taken to avoid unexpected solar light pressure torque due to wrinkles and other causes in the membrane, so to research the shape of wrinkles is important. In this study, numerical analysis using the finite element method(FEM)was performed on the boom-type triangular membrane being considered for HELIOS-R and OPENS. We will clarify that the differences of the analysis results between two elements of FEM, wrinkle shape, and sensitivity by the tension direction.

Jul 29th(Mon) Room C AM(9:30-12:00)　Abstracts

ASTRO-2024-C001
「不整地への安定した着陸のための逆止弁による流量制御付きエアバッグ着陸システム－気体流出流量の機体着陸挙動への影響－」
「Airbag landing system with flow control by relief-valves for improving landing stability on Uneven surface - Effect of gas flow rate on spacecraft landing behavior ?」
* 立澤 快大(静大・院), 丸 祐介, 森 治, 河野 太郎, 澤井 秀次郎(JAXA), 能見 公博(静大)

Abstract:

A challenge for future lunar and planetary exploration is to establish landing gear that enable stable landings on uneven terrain.To adress this challenge, this study proposes a landing system that incorporates airbags at the tips of the landing legs, which expel gas to the exterior during compression.The purpose of this research is to clarify the effects of the gas outflow rate within the airbags on the landing behavior of the spacecraft. To achieve this, we conducted two-dimensional drop tests and simulations under conditions with varying numbers of vents through which air could escape, thereby changing the gas outflow rate. The results demonstrated that setting an appropriate gas outflow rate enables stable landings.When the gas outflow rate is too low, the spacecraft bounces;when the gas outflow rate is too high, ground collision of the spacecraft occurs.

ASTRO-2024-C002

「スラスタ噴射に起因するレゴリスの飛散軌跡と飛散量の評価」

「Evaluation of regolith dispersal trajectory and amount of dispersal caused by thruster jetting 」

* 山川 真以子(総研大・院), 丸 祐介, 澤井 秀次郎, 大門 優, 森 治(JAXA)

Abstract:

When a spacecraft fires its thrusters near the surface of a celestial body, regolith is scattered and adhere to the instruments mounted on the spacecraft, degrading their performance. The first main direction of regolith dispersal follows the crater wall shape. We compare the results of simple numerical calculations with the results of an experiment in which thrusters are injected into a sandbox in a vacuum chamber and therefore it was possible to identify the overall shape of the crater, which is necessary for estimating the direction of dispersal and the amount of circulating dispersal. The influence of the interference of multiple thrusters on the regolith trajectory after dispersal was also investigated.

ASTRO-2024-C003

「木星エアロキャプチャにおける Mid-High L/D エアロシェルの有効性評価」

「Mid-to-High L/D Aeroshell Effectiveness for Jovian Aerocapture 」

* 臼杵 智章(東大・院), 津田 雄一(東大)

Abstract:

Aerocapture orbit insertion scheme significantly increases payload capability with shorten

trip time. On the otherhand, robust lifting aeroshell technology is required in order to withstand aerodynamic heating and atmospheric uncertainty. We evaluate effectiveness of high lift to drag ratio (L/D) aeroshell for Jupiter exploration mission, and found that high L/D design with simple exit guidance logic can provides sufficient apoapsis guidance precision.

ASTRO-2024-C004

「車輪装着脚を用いた垂直離着陸ロケットの着陸安定性に関する研究」

「Study on Landing Stability of Vertical Takeoff and Vertical Landing Rocket with Wheel Attached Legs」

* 坂田 泰生(静大・院), 丸 祐介, 森 治, 河野 太郎, 伊藤 琢博, 澤井 秀次郎(JAXA), 能見 公博(静大)

Abstract:

Research and development of reusable rocket is underway to reduce the cost and frequency of space transportation. Vertical takeoff and vertical landing reusable rocket have a long, vertical body with a high center of gravity, making them less stable. One of the factors that cause the vehicle to fall down is the frictional force between the landing gear and the ground. In this study, we assume a landing reusable rocket that lands on a flat, level surface, and consider improving landing stability by reducing the frictional force between the landing legs to the landing legs by attaching wheels. An omni-directional wheel called an Omni-wheel is proposed as the attachment mechanism, and its behavior and effectiveness are verified through drop tests and simulations of a small test model attached with the Omni-wheel and one-way clutch to suppress translational movement after landing.

ASTRO-2024-C005

「ベント型エアバッグ着陸システムの不整地着陸への適用」

「Application of a Vented Arbag Landing System to Uneven Terrain Landings」

* 滝川 遼太郎(東大・院), 橋本 樹明(JAXA)

Abstract:

In order to achieve uneven terrain landings with a lightweight and low-cost spacecraft, we chose a vented airbag as an impact absorption system. We extended existing airbag mathematical models to be applicable for assessing stability during uneven surface landings, and we confirmed through simulations that the timing of venting has a major impact on stability. We proposed a new algorithm for determining the exhaust timing, and succeeded

in improving the stability against landing site inclination and lateral speed of the aircraft. We also present the results of our experiments.

ASTRO-2024-C006
「オール電化衛星と推進システムの研究開発」
「An Overview of R&Ds on All-electric Propulsion Satellite Systems」
* 船木 一幸(JAXA)
Abstract:
Currently, it is said that approximately 70% of satellites in operation is propelled by electric propulsion systems. This presentation provide a brief overview of the R&D status of the propulsion and related subsytem for the engineering test satellite 9 (ETS-9) to be launched in 2025 that is going to test medium power Hall thruster and xenon propulsion system. In addition, R&D status targeting at near-future system is briefly included in the talk
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Jul 29th(Mon) Room C PM1(13:00-15:05)　Abstracts

ASTRO-2024-C007
「点広がり関数を用いた彗星同定アルゴリズムの検討」
「A Study of Comet Identification Algorithms Using Point Spread Functions」
* 都筑 大樹(東大・院), 藤原 正寛, 坂谷 尚哉, 佐々木 貴広, 尾崎 直哉, 船瀬 龍, 橋本 樹明(JAXA)
Abstract:
Identification of the comet to be explored is important for the success of comet exploration missions. If the object with the highest brightness value in the image is a comet, the comet can be identified only by extracting bright spots as described above. However, if there are bright spots other than comets, it is necessary to discriminate between comets and fixed stars. In this study, we propose a method to discriminate between comets and fixed stars using a point spread function, which is a physical model that represents the brightness distribution of the bright spots of the comet to be searched for. In this presentation, we report the results of the study.

ASTRO-2024-C008

「火星衛星探査計画 MMX でのフォボス形状モデル復元に関する初期検討」
「Preliminary Study on Shape Modeling of Phobos for the Martian Moons eXploration (MMX) mission」
* 菊地 翔太, 松本 晃治(NAOJ), 平田 成(会津大), 竹尾 洋介(JAXA)
Abstract:
Shape models of target bodies are among the most mission-critical products in small-body exploration, particularly for geological analyses and surface landing. The Martian Moons eXploration (MMX) mission plans to create shape models of Phobos after arriving at the moon. The plan involves reconstructing both global and local shapes of the moon based on optical observations from multiple quasi-satellite orbits at different altitudes. Stereophotoclinometry (SPC) is a promising algorithm for generating high-fidelity shape models and has thus been widely used in space missions. This presentation will introduce the SPC-based shape modeling strategy in the MMX mission, with a particular focus on observation methods.

ASTRO-2024-C009
「深宇宙ランデブードッキングにおける複数輝点航法標識の識別同定手法に関する解析」
「Analysis of discrimination and identification methods for multiple bright spot navigation landmarks in deep-space rendezvous and docking」
* 天川 海音, 大月 幸穂(東大・院), 津田 雄一(JAXA)
Abstract:
In order to reduce risk and maximize mission outcomes in space exploration missions, a functional differentiation between orbital transfer vehicle and mission vehicle has been proposed. Since these two aircraft are assumed to carry out sample delivery and other operations in deep space, rendezvous docking is a key technology for this purpose.
Considering the unique requests of limited resources and high autonomy in deep space, Hayabusa2 achieved high precision landing by using retroreflective landmarks as navigation aid during the proximity phase to the asteroid.
In rendezvous and docking between spacecraft, an optical method using retroreflective landmarks, as in the case of Hayabusa2, is considered to be useful for achieving highly accurate guidance and navigation.
In this study, we propose a method for identification of landmarks regardless of the distance from the target, and quantitatively evaluate the navigation guidance accuracy.

ASTRO-2024-C010

「Physics-Informed Neural Networks の小惑星内部解析への応用」

「Application of Physics-Informed Neural Networks to Asteroid Interior Analysis」

* 渋川 雅人(総研大・院), 尾崎 直哉(総研大)

Abstract:

Understanding the interior of asteroids is important for planetary and solar system formation studies. Methods are used to estimate internal information by impacting high-speed objects and observing crater formation. However, there are challenges related to environmental differences and computational costs when comparing impact experiments conducted on asteroids with those conducted on the ground, as well as with numerical simulations. In this study, we develop a low-computational-cost simulation method for crater formation that mimics the asteroid environment using Physics-Informed Neural Networks, which are neural networks that incorporate the laws of physics.

ASTRO-2024-C011

「はやぶさ２拡張ミッションにおける小惑星 2001CC21 フライバイ時のオンボード光学航法」

「Onboard Optical Navigation for Flyby of Asteroid 2001 CC21 in Hayabusa2 Extended Mission」

* 尾川 順子(JAXA), 山田 学(千葉工大), 藤原 正寛, 楠本 哲也, 三桝 裕也, 佐伯 孝尚, 津田 雄一(JAXA)

Abstract:

In the Hayabusa2 extended mission, the spacecraft will perform a flyby of asteroid 2001 CC21 in 2026. We are planning onboard optical navigation for this event. We have previously performed ground-based optical navigation on the ground in 2018, and onboard navigation using a target marker during asteroid touchdown. However, onboard navigation using images of an asteroid approaching at high speed presents many challenges, unlike those previous instances. In this presentation, we report the current status of our investigations.

ASTRO-2024-C012

「ラグランジュ点近傍領域におけるリサジュー軌道間２インパルス遷移の理論構築」

「Towards an analytical framework for in-plane two-impulse transfers between Lissajous orbits」

* 島崎 拓人(東大・院), Pushparaj Nishanth(ノッティンガム大), 川勝 康弘(JAXA)

Abstract:

We present an analytical framework for in-plane two-impulse transfers between two Lissajous orbits around a single collinear libration point in the linearized circular restricted three-body problem. We formulate two-impulse transfers as a two-point boundary value problem with a fixed time of flight (ToF). We explicitly derive and numerically verify the solution, along with its subsets corresponding to transfers involving invariant manifolds. Despite the simplicity of the model, the solution encompasses non-trivial properties of the transfers, such as spatial and temporal constraints arising from the bounded distribution of invariant manifolds. These general properties are discussed and compared with results from existing literature. We further investigate the relation between ΔV and the spatial constraints numerically. Our main results demonstrate improved feasibility compared to single-impulse transfers with minimum additional cost, regardless of the amplitude size.

ASTRO-2024-C013

「The Dynamics about Asteroid (162173) Ryugu and its Comparison with (101955) Bennu」

* Fu Xiaoyu(UoL, Postdoctoral Research Associate), Soldini Stefania(UoL, Senior Lecturer)

Abstract:

The dynamical environment around the asteroid (162173) Ryugu is analyzed in detail using a constant-density polyhedron model based on the measurements from the Hayabusa2 mission. Six exterior equilibrium points (EPs) are identified along the ridge line of Ryugu. The initial periodic orbit (PO) families are computed and analyzed, including distant retrograde/prograde orbit (DRO/DPO) families and fifteen PO families emanating from the EPs. The fifteen PO families are further divided into three categories: seven converge to an EP, seven reach Ryugu's surface, and one exhibits cyclic behavior during its progression. Bifurcated PO families are identified and computed from the initial PO families, including ten families from the DROs, fifteen from the DPOs, and twenty-five associated with the EPs. A comparison is made for the dynamical environments of Ryugu and Bennu to evaluate the similarities and differences in the evolution of EPs and progression of PO families in top-shaped asteroids.

ASTRO-2024-C014

「月周回衛星の接触軌道要素と平均軌道要素の変換に関する一考察」

「A study on the transformation between osculating and mean orbital elements of lunar orbiting spacecraft」

* 北村 憲司(MELCO), 山田 克彦(大阪公立大学)

Abstract:

Space operations are becoming increasingly active in cislunar space, and it is expected that more and more spacecraft will be inserted into lunar orbit for various missions. As with Earth-orbiting satellites, the transformation between osculating orbital elements and mean elements is considered crucial for managing the orbit prediction or control of spacecraft around the Moon. This study focuses on medium to high altitude lunar orbiting spacecraft, where the tidal force by Earth is dominant, and utilizes the Lie-perturbation method to investigate the transformation between osculating and mean elements.

ASTRO-2024-C015

「Research on Asteroid Flyby Control and Candidate Selection Strategy for DESTINY+ Extended
Mission」

* Ribeiro Nuno(KTH Graduate Student)

Abstract:

This research focuses on asteroid flyby control and candidate selection for the DESTINY+ extended mission. The goal is to ensure the satellite maintains an asteroid in its images and achieves the desired closest approach for high-quality pictures. Asteroids are selected based on observable time, relative velocity, orbit uncertainty, estimated diameter, and phase angle. Using Extended Kalman Filters (EKF) and Least Squares Methods, the simulation models spacecraft trajectories and orientations through initial body pointing, trajectory correction maneuvers (TCM), final body pointing, and camera pointing. Results from multiple simulations are analyzed to enhance optical navigation reliability and choose the target asteroid.

ASTRO-2024-C016

「追従誤差に依存する可変ゲイン制御器を用いたポート・ハミルトン系のフォーメーション軌道追従制御」

「Formation Trajectory Tracking Control of Port-Hamiltonian Systems with Variable Gain Controller Depending on the Tracking Error」

* 矢部 俊典(阪大・院), 佐藤 訓志(阪大)

Abstract:

In this study, a nonlinear control method is proposed to control the relative positions of spacecraft precisely. The relative orbital motion of spacecraft is represented by port-Hamiltonian systems, and an error system for a given reference trajectory is constructed using generalized canonical transformations that can preserve the port-Hamiltonian structure. Then, we design a variable gain controller that considers the effect of actuator saturation due to micro-thrusters. Under the derived stability conditions, the variable gains are optimized. The proposed controller can both expand the upper limit of the stabilizable error and improve the tracking performance in the presence of input saturation.

ASTRO-2024-C017

「Feasibility Analysis of Formation Topology using Nonlinear Control for Solar-Based Space Power」

* Cardoso Franco Thais(ITA, PhD candidate), Nahuel Sousa Fagonde Caio(UFABC, researcher), Gomes dos Santos Willer(ITA, professor)

Abstract:

Space-Based Solar Power (SBSP) offers the potential for renewable energy by capturing solar power in space and transmitting it to Earth via microwaves, enabling 24/7 energy capture without atmospheric losses and reducing storage costs. However, large solar panels are required, which are impractical and expensive to launch with current technology. As a solution, this work explores the concept of SBSP using formation flying evaluating the performance of nonlinear and adaptive control methods applied in two topologies, the Noncoplanar Oscillator and String of Beads. The maintenance of orbital movement will be verified using orbital perturbations such as the Earth's gravitational inhomogeneity, solar radiation pressure, aerodynamic drag and the influence of the Sun and Moon. And the effect of different orbital altitudes, eccentricities and inclinations, including LEO, MEO and GEO, will be evaluated with regard to inter-satellite drift, solar energy captured and consumption

of propellant.

ASTRO-2024-C018
「衝突を用いた宇宙機間物資移送方式における回転運動の影響」
「Effect of Rotational Motion on Inter-Spacecraft Material Transfer Utilizing Collision」
* 中川 雄登（東大・院）, 森 治, 佐伯 孝尚, 津田 雄一（JAXA）
Abstract:
In sample return explorations where the lander and transfer vehicle cooperate, it is necessary to transfer the acquired sample from the lander to the transfer vehicle. As a sample transfer method, we have studied the Free Space Capture method, where the lander puts the sample into a spherical container and throws it over the transfer vehicle. This method utilizes the collision between the sample container and container capturing structure and has the benefit of not requiring a driving mechanism for capture. In this presentation, the effect of rotational motion when capturing a container will be reported.

ASTRO-2024-C019
「マルチコプターによる偏向角のみを制御入力としたホバリング制御の実証」
「Hovering Control of Multicopter using only Tilt Rotor Angles」
* 楠本 哲也(JAXA), 中川 果帆, 大木 春仁(東大・院), 津田 雄一(JAXA)
Abstract:
As a concept for a future sampling probe, we propose a Touch-and-Go probe with solid rocket motors to achieve landing with a simple probe system. One main challenge of this probe is controlling the altitude and attitude using the constant thrust of a solid rocket motor. We investigate the viability of controlling the altitude and attitude by the changes in the angles of the thrust. This study demonstrates the hovering control using only tilt angles by mocking the rocket motors by propellers of a multicopter.

ASTRO-2024-C020
「DESTINY+フライバイ観測におけるモデル予測制御を用いた指向制御精度」
「Pointing Accuracy Using Model Predictive Control for DESTINY+ Flyby」
* 神谷 俊夫(明星大), 小澤 祐亮(NEC)
Abstract:

In recent years, the importance of autonomous control is increasing due to the enhancement of the complexity of spacecraft missions. The DESTINY+ explores the asteroid during a flyby, and conducts the observation in one-chance mission. We apply hybrid control system which performs flyby observations by combining the satellite attitude (three axes) and the gimbal angle control (single axis) of the mission camera TCAP. To achieve highly accurate pointing performance when passing an asteroid, it is required to predict the near future state based on nonlinear optimal control so that the pointing error is minimized considering the actuator and sensor constraints. In this paper, we build a model predictive control-based guidance control, and evaluate the pointing performance of the TCAP. In addition, the results of comprehensive pointing performance at the spacecraft system level, considering the effects of attitude control, vibration disturbance, etc. are presented.

ASTRO-2024-C021

「SLIM における新しい Quick Look システムを用いた運用結果」

「Operation Results Using the New Quick Look System in SLIM」

* 横田 健太朗, 中平 聡志, 秋月 祐樹, 金谷 周朔, 後藤 健太, 伊藤 琢博, 植田 聡史, 坂井 真一郎, 宮澤 優, 福田 盛介, 櫛木 賢一, 澤井 秀次郎(JAXA)

Abstract:

A new Quick Look system using open-source software has been introduced for SLIM operations. This system can display spacecraft telemetry through various visualization panels. It also supports complex processing via a Python API, enabling tasks such as visualizing the spacecraft's position and attitude with 3D models, estimating propellant usage from thruster on-time data, and generating alerts by integrating multiple telemetry sources. Additionally, by employing a time-series database, it allows for immediate sorting and display of both real-time and playback data. Furthermore, it supports telemetry search and display functionalities, as well as text data output across different paths and packets. These features have significantly enhanced operability during critical events in SLIM operations. This presentation will showcase the system's advantages from an operational standpoint, featuring actual operational screens.

ASTRO-2024-C022

「固体ロケットモータ点火による不連続状態変化を考慮した Touch-and-Go Sampling Probe の降下誘導則」
「Descending Guidance Law for Touch-and-Go Sampling Probe Considering Discontinuous State Change due to Solid Rocket Motor Ignition」
* 大木 春仁, 中川 果帆(東大・院), 楠本 哲也, 津田 雄一(JAXA)
Abstract:
We suggest touch-and-go probe (TAG-SP) as an ultimately simple sampling device controlled 6DoF with four solid rocket motor. This motor has a negative character that the thrust is constant once ignited and the burning time is short. This paper discusses guidance law of TAG-SP in descending phase. Different from normal two-point value boundary problem, the discontinuous change of state due to ignition should be considered here. To ensure solvability of optimization problem, successive convexification is used for the algorithm. We simulate the landing case study and analyze the robustness against the initial condition error.

ASTRO-2024-C023
「Advanced Imaging Solution for Small Satellites with a Moving Flat Mirror System」
* SANLI ALPER(KYUTECH & MSU)
Abstract:
In this study, a method to enhance imaging efficiency in small satellite missions using a moving flat mirror for optical telescope subsystems. By adjusting the mirror's angles, the workload of the attitude determination and control subsystem is reduced, eliminating the need for complex systems. Optical analyses assessed the impact on key parameters, including Strehl ratio, Point Spread Function, Modulation Transfer Function and others. The payload, designed to 12U standards, features a primary mirror of 188 mm diameter and an effective focal length of 1000 mm. An electronic and motor component system was designed to facilitate the flat mirror's movement. This innovative approach improves small satellite imaging performance by reducing mass and atmospheric drag and other orbital parameters, offering significant advantages for remote sensing and deep space missions.

ASTRO-2024-C024
「深宇宙ランデブードッキングにおける外乱オブザーバーを用いたスラスラ誤差の推定」

「A Study on Estimation of Thruster Errors Using Disturbance Observer in Deep Space Rendezvous Docking 」

* 石戸 大智(総研大・院), 坂東 信尚, 森 治, 佐伯 孝尚(JAXA)

Abstract:

Multiple spacecraft configurations are currently considered for deep space exploration. In one such configuration, deep space navigation would be carried out using a common Orbital Transfer Vehicle (OTV) while another spacecraft conducts exploration at the target celestial body. In such multi-spacecraft exploration, rendezvous docking (RVD) in deep space is an important technology to improve flexibility. In RVD, the RCS thruster is mainly used for attitude control, and high-precision position and attitude control is required. However, its thrust varies depending on the thruster's characteristics and the temperature environment. Therefore, it can be a major source of error. This study proposes a method to compensate for thruster errors by incorporating a disturbance observer into the controller to improve response and accuracy in attitude control.

ASTRO-2024-C025

「目標天体が円軌道する場合のフライバイ探査機の相対運動の多項式近似法」

「Polynomial Approximation of Non-Linear Relative Motion to Circularly Orbiting Asteroid for Autonomous Flyby」

* 鶴谷 柊朔（東大・院）, 楠本 哲也, 藤原 正寛, 三桝 裕也, 津田 雄一（JAXA）

Abstract:

In order to achieve autonomous flyby guidance and navigation in small-object exploration, it is necessary to perform orbit calculation on the spacecraft, but it is practically difficult to perform precise orbit calculation with an onboard computer that has limited performance. On the other hand, calculation methods including orbit linearization cannot be applied to flyby conditions where the relative velocity is high. In this study, we propose an orbit calculation method that enables highly accurate calculations with a small computational load by analytically deriving approximate polynomial solutions of the equations describing relative orbits while taking non-linearity into account. In this presentation, the outline of the calculation method and the calculation results under real flyby conditions will be presented for the case of a circular orbit of a target object with respect to a star.

ASTRO-2024-C026

「はやぶさ 2#小惑星フライバイにおける多項式近似を用いた自律軌道航法誘導」
「Autonomous Navigation and Guidance With Polynomial Approximation for Asteroid Flyby in Hayabusa 2 Extended Mission 」
* 藤原 正寛, 楠本 哲也, 三桝 裕也, 佐伯 孝尚, 津田 雄一(JAXA)
Abstract:
After successfully returning to Earth, the Hayabusa2 spacecraft continues on its journey to the next ambitious mission: a flyby of asteroid 2001 CC21 in 2026 and a rendezvous with asteroid 1998 KY26 in 2031. During the flyby of 2001 CC21, onboard systems will execute advanced navigation, guidance, and control strategies to maximize scientific outcomes despite the challenges of communication delays. Given the limited onboard processing capabilities, the implementation of complex algorithms is not feasible. To address this, a polynomial approximation method has been developed to linearize the spacecraft trajectory with respect to the asteroid, thereby reducing computational demands. We will report the result of the numerical analysis for the guidance error prediction with the proposed autonomous navigation and guidance algorithm.

Jul 30th(Tue) Room C PM2(16:20-18:00)　Abstracts

ASTRO-2024-C027
「Robust Vision-Based Terrain-Relative Localization for Lunar Landings」
* Knill Maximilian(ETH Zurich Graduate Student), 都筑 大樹(東大・院), 橋本 樹明(JAXA)
Abstract:
This research focuses on comparing various reflectance models and terrains of the lunar surface to enhance the adaptability of image-based navigation. By doing so, we develop a robust and efficient localization algorithm for lunar landings, specifically under challenging and changing illumination conditions. Utilizing elevation data from JAXA's Kaguya and NASA's LRO satellites, we created a simulation environment to generate realistic synthetic lunar images under diverse lighting scenarios. Storing elevation data on the spacecraft's memory enables on-the-fly synthetic image creation for matching with mission photos. This method improves robustness against changes in the seen environment due to varying illumination conditions, increases accuracy in handling terrain and solar angle variations, and provides greater flexibility in launch and landing times.

ASTRO-2024-C028

「Autonomous Optical Navigation using Convolutional Neural Networks: Crater Detection for Cislunar Missions」

* キルダフ ティム UCSD (UC San Diego), マチュカ パブロ SDSU (San Diego State University), ローゼングレン アーロン UCSD (UC San Diego)

Abstract:

Optical navigation (OpNav) will play an important role in the development of cislunar (i.e., Earth-Moon system) autonomous navigation. The introduction of deep learning in recent years has paved a new path for computer vision to be explored. Convolutional neural networks (CNN) can be trained to interpret images of a desired destination and accurately mark key features on its surface. We found that, for a spacecraft orbiting the Moon, a CNN can robustly differentiate craters on the surface of the Moon at various illumination conditions up to 70,000 km. These findings underscore the potential of CNNs in enhancing cislunar OpNav.

ASTRO-2024-C029

「はやぶさ２＃における自然地形を利用した光学航法」

「Optical Navigation of Hayabusa2# using Natural Feature Tracking Scheme」

* 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 this 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-2024-C030

「月探査のためのスカイラインによる星の遮蔽を利用したローバの画像位置推定の精度検討」

「Study on the Accuracy of Image-Based Relative Position Estimation Using Star Occlusion by the Skyline for Lunar Exploration」

* 水沼 健人(東大・院), 橋本 樹明(JAXA)

Abstract:

When exploring craters within the lunar poles using rovers for the purpose of discovering and excavating ice, it is essential to acquire positional information within the permanent shadows. This study focuses on the obscuration of background stars by the skyline, utilizing the positions and shapes of these silhouettes for navigation. In the presentation, we will showcase results from generating simulated images of the lunar environment and evaluating the accuracy of rover position estimation based on these images.