# PROGRAM

# 46<sup>th</sup> ANNUAL AAS GUIDANCE, NAVIGATION & CONTROL CONFERENCE

February 2<sup>nd</sup> to February 7<sup>th</sup>, 2024





# **Conference Location**

# BEAVER RUN CONFERENCE CENTER Breckenridge, Colorado

Room check-in at the Beaver Run Resort front desk 4:00 PM daily



# CLASSIFIED SESSION Classified Advances in GN&C and Classified Recent Experiences

TS//SI//TK//NOFORN

THURSDAY, FEBRUARY 1<sup>ST</sup> 8:30 AM – 4:30 PM

# FRIDAY, FEBRUARY 2<sup>ND</sup> 8:30 AM - 12:30 PM

The classified sessions will be held at Lockheed Martin's facility located in Littleton, Colorado.

All eligible conference participants may attend the classified presentations.

Attendees must be US-citizens and must possess the necessary clearances prior to registration.

Pre-registration is required and will be controlled (walk-ins will NOT be admitted).

Questions on clearance requirements or steps on submitting an abstract should be directed to

aas\_special\_session@lists.aero.org

Location of Classified Session:

Lockheed Martin Littleton, CO

# **Conference Registration**

Friday 5:00 PM to 8:00 PM Daily 6:30 AM-10:00 AM and 4:00 PM-6:00 PM

# **Registration Questions**

Michelle Barath Amy Delay 303-887-7724 303-731-9876

# 46<sup>th</sup> Annual AAS Guidance, Navigation & Control Conference Chairperson

Emil Tchilian Ball Aerospace 303-939-4824

emil.tchilian@ballaerospace.com

# Wi-Fi Access

Select "Beaver Run Meeting 3" wireless network. Open a browser window. Enter voucher code: **snow2023** 

# **Conference Website**

https://aas-rocky-mountain-section.org/

Online Program and Pre-print Paper Access read-only

https://www.xcdsystem.com/aas/program/Bh1j <u>kVB/index.cfm</u> \*\*\*QR CODE GOES HERE

**Conference Schedule Overview** 

# Friday, February 2<sup>nd</sup>

Conference Registration	5–8 PM
Welcome Reception	6–9 PM

# Saturday, February 3rd

Breakfast	6:15–7 AM
Morning Sessions (2 parallel)	7–10:30 AM
STEMScape w/ Lunch Break	10:30 AM-4 PM
Astronaut for Children	4–5 PM
Technical Exhibits	5–8 PM

# Sunday, February 4<sup>th</sup>

6:15–7 AM
) 7–10:30 AM
8:30 – 9:00 am
10:30 AM-1:30 PM
el) 4–7 PM
7:30–9:30 PM

# Monday, February 5th

Breakfast	6:15–7 AM
Morning Sessions (3 parallel)	7–10:30 AM
Tutorials	10:30 AM-1 PM
Poster Session Break	8:30 – 9 AM
Afternoon Sessions (4 parallel)	4–7 PM
Celebrate Diversity and,	7:30–8:30 PM
Networking Hour	

# Tuesday, February 6th

6:15–7 AM
7–10:30 AM
8:30–9 AM
10:30 AM-1 PM
4–7 PM

# Wednesday, February 7th

Breakfast	6:15–7 AM
Morning Sessions (2 parallel)	7–10:30 AM

# STUDENT INNOVATIONS IN GN&C (PEAK 5)

#### Session 01

Saturday 7:00 AM - 10:30 AM

This session embraces the wealth of research and innovative projects related to spacecraft GN&C being accomplished in the university setting. Papers in this session address hardware/software research as well as component, system, or simulation advances. Papers submitted must have a student as the primary author and presenter. Papers will be adjudicated based on level of innovation, complexity of problem solved, perceived technical readiness level, applicability and field-ability to near-term systems, clarity of written and verbal delivery, number of completed years of schooling and adherence to delivery schedule. The session will be limited to 8 papers with the top 3 papers receiving monetary awards.

#### **National Chairs**

David Geller, Space Dynamics Laboratory Luke Sauter, USAF/DFAS

#### Local Chairs

David Chart, Sierra Nevada Corp Ian Gravseth, Ball Aerospace

#### Presentations

An Investigation of Transfer Learning for Guidance and Control of Mars Entry, Descent, and Landing Missions (AAS-24-011)

**Laura Jones,** University of Central Florida Tarek Elgohary, PhD University of Central Florida

#### Lost-in-space Position and Time Determination via Star Tracker Observations of Periodic Variable Stars (AAS-24-012)

Linyi Hou, University of Illinois Urbana-Champaign Siegfried Eggl, University of Illinois at Urbana-Champaign Ishaan Bansal, University of Illinois at Urbana-Champaign Clark Davis, University of Illinois Urbana-Champaign

#### RETINA: a highly versatile optical facility for camera-in-the-loop testing of spaceborne Vision-Based Sensors (AAS-24-013)

Fabio Ornati, Politecnico di Milano Paolo Panicucci, Politecnico di Milano Eleonora Andreis, Politecnico di Milano Francesco Topputo, PhD., Politecnico di Milano

### Machine Learning based Attitude Estimation Using Active Lighting Cues Applied to CubeSat Proximity Operations (AAS-24-014)

#### Athip Thirupathi Raj,

University of Arizona – SpaceTREx Jaret Rickel, University of Arizona – SpaceTREx Roshan Adhikari, University of Arizona – SpaceTREx Jekan Thangavelautham, University of Arizona

#### Path Planning for Single-Agent and Multi-Agent Satellite Inspection Problem: Low Thrust Formulation (AAS-24-015)

**Ritik Mishra,** Purdue University Kenshiro Oguri, University of Colorado Boulder

# Saturday, February 3<sup>rd</sup> / Page 3

#### Optimizing Spacecraft Trajectories for Efficient Resource Transport in Cis-Lunar Space (AAS-24-016)

#### Evan Lutchmidat,

The Cooper Union for the Advancement of Science and Art Anubhav Gupta, In Orbit Aerospace Ishaan Patel, In Orbit Aerospace

#### Low-Energy Transfer Design to Quasi-Periodic Orbits in the Bi-Elliptic Restricted Four-Body Model (AAS-24-017)

**Patrick Kelly,** Texas A&M University John L. Junkins, Texas A&M University Manoranjan Majji, Texas A&M University, College Station

#### Robust Cislunar Trajectory Optimization in the Presence of Stochastic Errors (AAS-24-018)

**Scott Kelly**, Utah State University David Geller, Space Dynamics Laboratory

# USING AI/M L IN GN&C (PEAK 1-4)

# Session 02 Saturday 7:00 AM - 10:30 AM

As Guidance, Navigation and Control algorithms become increasingly autonomous, there is a progression towards incorporating natural cutting edge Artificial Intelligence (AI) and Machine Learning (ML) technologies into the capabilities of today's autonomous systems. When combined with established systems and control theory, AI and ML algorithms can harness the wealth of information available from data obtained by sensors and cyberphysical systems over time. This session will highlight research and demonstrations focused on the theory and methods of learning, control, and computational intelligence for GN&C systems. Some example topics for this session include novel applications of AI systems in traditional GN&C systems, performance comparisons between classical GN&C methods and ones that leverage AI or ML, and demonstrations of design and/or test of GN&C methods and ones that leverage AI or ML, and demonstrations of design and/or test of GN&C systems that utilize ML.

#### National Chairs

Christoffer Heckman, University of Colorado, Boulder Patric Hoskins, Naval Research Laboratory

#### Local Chairs

Kip Gwin, Ball Aerospace Hank Steadman, Lockheed Martin Space

#### Presentations

Autonomous Earth-Observing Satellite Scheduling Using Reinforcement Learning with Event-Based Decision Intervals (AAS-24-021)

Mark Stephenson, University of Colorado, Boulder

Hanspeter Schaub, University of Colorado Stability Analysis of Deep Reinforcement Learning for Mulit-Agent Inspection in a Terrestrial Testbed (AAS-24-022)

Joshua Aurand, Verus Research Zachary S. Lippay Henry Lei, Verus Research Steven Cutlip, Verus Research Sean Phillips, Air Force Research Laboratory

#### Meta-Reinforcement Learning for Spacecraft Proximity Operations Guidance and Control in Cislunar Space (AAS-24-023)

#### Giovanni Fereoli,

Politecnico di Milano, University of Colorado BoulderHanspeter Schaub, University of Colorado Pierluigi di Lizia Politecnico di Milano Regina Lee, York University Steve Ulrich, Carleton University

# Interplanetary Trajectory Optimization using Physics Informed Neural Networks (AAS-24-024)

#### Abigail Rolen,

Rensselaer Polytechnic Institute Benjamin Seaman, Rensselaer Polytechnic Institute Sandeep Singh, PhD. Rensselaer Polytechnic Institute

# Performance comparison of a coupled extended Kalman filter-neural network spacecraft chasertarget relative position estimator (AAS-24-025)

Warren Soh, Masters in Space Science Honeywell Aerospace / York University

# Regression Techniques for the Statistics of Correction Maneuvers Magnitudes (AAS-24-026)

Quinn Moon, University of Texas David Geller, Space Dynamics Laboratory

### SPEED-UE-Cube: A Machine Learning Dataset for Autonomous, Vision-Based Spacecraft Navigation (AAS-24-027)

Zahra Ahmed, Stanford University Tae Ha Park, Stanford University Abhijit Bhattacharjee, MathWorks Inc Reza Fazel-Rezai, Russell Graves Ossi Saarela, MathWorks, Reece Teramoto Kautilya Vemulapalli Simone D'Amico, Stanford University

# AAS STEM-SCAPE Event

# Saturday 10:30 AM-4:00 PM

In 2024, we will be hosting an annual STEM event for 100 high school students of diverse background from across the Denver metropolitan area. The event, called AAS STEM-SCAPE for "Student Career Arcs to Professional Engineers," will trace the elements of a successful career journey in aerospace including High School and University education, initial employment and ultimately a rewarding profession. The keynote speaker will be followed by a STEM career panel. The event concludes with a short design project that will be co-led with student volunteers from the University of Colorado. This event is made possible by the charitable donations and support from Lockheed Martin, Ball Aerospace, and CU Boulder.

#### 10:30 AM Keynote Speaker

12 PM	Mid/Early Career Panel & Lunch
1 PM	Structured Design Activity
(Students-	problem solve w/ CU leader)
3:30 PM	Students Tour Technical Exhibits
	Pizza Buffet
4 PM	Gather at Bus

#### Local Chairpersons

Alexandra Dukes, Lockheed Martin Space Meredith Stephens, Ball Aerospace

# Special Event for Children of Conference Attendees at 4:00 PM

# **Imperial Ballroom**

# Astronaut, Jim Newman

This presentation will inspire our next generation of engineers by offering kids the opportunity to interact with astronaut Jim Newman, a former NASA astronaut who flew on four Space Shuttle missions, STS-51 (1993), STS-69 (1995), STS-88 (1998), STS-109 (2002). He is currently a professor and chair of the Space Systems Academic Group (SSAG) at the Naval Postgraduate School.

Previously, Jim served as NASA's Director, Human Space Flight Programs, Russia from Dec 2002 to Jan 2006 where his responsibilities included oversight of NASA's human space flight program in Russia.

Jim received his Ph.D. in Physics from Rice University in 1984. He came to work at NASA's Johnson Space Center, where his duties included responsibility for conducting flight crew and flight control team training for all mission phases in the areas of Orbiter propulsion, guidance, and control. He was working as a simulation supervisor when selected for the astronaut program.

Jim left NASA in July 2008 to accept a position Professor, Space Systems at as Naval Postgraduate School in Monterey, California. Jim's research interests include the use of CubeSats, rockets, and high-altitude balloons for focused research of National Topics include paradigm-shifts in interest. cost and capability using these platforms with payloads for over-the-horizon comms and other purposes. Hands-on, laboratory projects are used to motivate the research and learning process. Academic productivity includes many publications, presentations, and two patents, authored with students and colleagues.

# TECHNICAL EXHIBITS (COLORADO BALLROOM) Saturday 5:00 PM – 8:00 PM

The Technical Exhibits Session is a unique opportunity to observe displays and demonstrations of state-of-the-art hardware, design and analysis tools, and services applicable to advancement of guidance, navigation, and control technology. The latest commercial tools for GN&C simulations, analysis, and graphical displays are demonstrated in a hands-on interactive environment, and include lessons learned and undocumented features. Associated papers not presented in other sessions are also provided and can be discussed with the author. . Come enjoy and excellent complimentary buffet and interact with the technical representatives and authors. This session takes place in a social setting and family members are welcome!

# Local Chairpersons

Graeme Ramsey, Lockheed Martin Space Andrew Riskus, Ball Aerospace Kristina Forystek, Innovation RM

# **Exhibitors**

Advanced Space	Moog
Ball Aerospace	New Space
Beyond Gravity	Rakon
Blue Canyon Tech	SEAKR Engineering
CubeSpace	Sodern
InnaLabs	Texas A&M Lab
Jena Optronik	Utah State Space
KinetiX Aerospace	Dynamics
Lockheed Martin	Veoware
Sierra Space	

# SUNDAY, FEBRUARY 4th

# AUTONOMOUS CONTROL OF MULTIPLE SPACECRAFT (PEAK 1-4)

# Session 03 Sunday 7:00 AM - 10:30 AM

In recent years, the exploration and habitation of both the Lunar surface and Mars has become popularized in the aerospace community and beyond. With the Moon as the closest celestial body, and Mars as the closest and most hospitable planet near Earth, they are the most obvious next steps in human space exploration. Exploring both bodies poses а unique set of challenges in navigation, mission design, radiation resistance, and autonomous exploration. This session will explore the difficulties present in exploring the Moon and Mars and the innovative GN&C technologies and spacecraft operations that will aid in the crewed and robotic exploration of these bodies.

#### **National Chairpersons**

Islam Hussein, PhD, Trusted Space, Inc. Hanspeter Schaub, University of Colorado Jekan Thangavelautham, University of Arizona

#### Local Chairpersons

Holly Borowski, PhD, Trusted Space Matt Sandnas, SEAKR Engineering, LLC

#### Presentations

Resilient Formation Control for Optimal Space-Based Inspection Under Visual Information Sparsity (AAS-24-031)

Quintin Nelson, Texas A&M

# Multi-Sensor Tasking Strategies for Situational Awareness (AAS-24-032)

Ishan Paranjape, Texas A&M University Suman Chakravorty, Texas A&M University Sean Phillips, Air Force Research Laboratory Islam Hussein, PhD, Trusted Space, Inc. Jeremy Murray-Krezan, PhD Trusted Space Inc. Holly Borowski, PhD, Trusted Space. Joshua Baker, Trusted Space, Inc.

# Application of Trusted Distributed On-board Autonomous Resource Management (AAS-24-033)

Holly Borowski, PhD, Trusted Space Islam Hussein, PhD, Trusted Space, Inc. Sean Phillips, Air Force Research Laboratory Jeremy Murray-Krezan, PhD Trusted Space Inc. Joshua Baker, Trusted Space, Inc. Chad Elliott, Trusted Space, Inc.

# Autonomous Constellation Management using Multi-Agent Reinforcement Learning (AAS-24-034)

**Oliver Chang**, Ball Aerospace. Kedar Naik, Ball Aerospace

# Advances in Coordinating the Aggregation and Disaggregation of Multiple Small Spacecraft as Building Blocks for Robotic Space Stations (AAS-24-035)

Alton Zhang, University of Arizona -SpaceTREx Athip Thirupathi Raj, University of Arizona -SpaceTREx. Jekan Thangavelautham, University of Arizona

# ONBOARD AUTO-NAVIGATION OPTIMIZATION UTILIZING COOPERATIVE MANEUVERING OF PASSIVELY TRACKED SPACECRAFT (AAS-24-036)

**Leonard Vance**, University of Arizona. Jekan Thangavelautham, University of Arizona

Efficient Satellite Constellation Propagation with APC (AAS-24-037)

David Stanley, The University of Illinois

Intent Sharing and Auctions for Emergent Collaboration in Autonomous Earth Observing Constellations (AAS-24-038)

**Lorenzzo Mantovani**, University of Colorado, Mark Stephenson, University of Colorado, Hanspeter Schaub, University of Colorado

# Entry, Descent & Landing GN&C (PEAK 5)

# Session 04 Sunday 7:00 - 10:30 AM

Entry, descent, and landing technologies enable surface exploration of celestial bodies and the safe return of pavloads to Earth. Recent advances in powered flight guidance and in atmospheric entry systems have improved landed mass capability to Mars and has made the reuse of launch vehicle first stages commonplace on Earth. Continued advancements through the collaboration of government, industry and academia will enable even more ambitious capabilities and missions in the future. This session provides а venue for discussina advanced hypersonic entry vehicles, coupled with guidance, navigation and control technologies for powered and unpowered descent and landing systems. Topics include precision navigation and targeting. novel quidance and control methodologies, hazard avoidance, and controlled landings.

# **National Chairpersons**

Henry Cordova, NASA Johnson Space Center Lloyd Strohl, III, MS, Blue Origin Local Chairpersons

Jeffrey Gillette, Relative Dynamics, Inc. Jennifer Goss, Sierra Space Corporation

#### Presentations

# Improvements in Martian Entry Vehicle Navigation using Satellite Constellations (AAS-24-042)

Robert Halverson, University of Minnesota Andrew Brevick, University of Minnesota Kyle Houser, University of Minnesota Kirsten Strandjord, University of Minnesota Ryan Caverly, University of Minnesota

# Optimizing End-to-End EDL Trajectories for High-Mass Mars Missions (AAS-24-043)

Christopher Davami, San Diego State University; Ping Lu, San Diego State University Breanna Johnson, NASA Aaron J. Rosengren, University of California SD

# Evolution of the GNC Sensor Suite for Dragonfly Entry, Descent, Flight, and Landing at Titan (AAS-24-044)

**Robin Vaughan**, JHU Applied Physics Lab Timothy McGee, Point Mass Technologies LLC Benjamin Schilling, JHU Applied Physics Lab Benjamin Villac, JHU Applied Physics Lab Glenn Creamer, JHU/APL Sarah Stevens, JHU Applied Physics Lab Alice Cocoros, JHU Applied Physics Lab

# Flight Performance Comparison of Bank-Angle Steering and Alpha-Beta Steering for Mars Entry Systems (AAS-24-045)

Daniel Engel, University of Illinois Zachary Putnam, JHU Applied Physics Laboratory Robyn Woollands, University of Illinois Soumyo Dutta, NASA Langley Research Center

# A guidance algorithm using angle-of-attack modulation for aerogravity assist maneuvers (AAS-24-046)

**Divinaa Burder**, Lockheed Martin Joseph Whitman, Lockheed Martin

# Predictor-Corrector Aerocapture Guidance using Convex Programming (AAS-24-047)

**Jens Rataczak**, University of Colorado Boulder Jay McMahon, CCAR Iain Boyd, Ph.D., University of Colorado Boulder

# Towards Predictive Control with Atmospheric Adaptation for Martian Entry Vehicles (AAS-24-048)

Robert Halverson, University of Minnesota Ryleigh McGiveron, University of Minnesota Maziar Hemati, University of Minnesota **Ryan Caverly**, University of Minnesota

# POSTER SESSION BREAK (PEAK 1 – 5 Hallway) Sunday 8:30 AM – 9:00 AM

Focused poster session breaks will take place with unique posters displayed in the main foyer, allowing the poster presenters to interact with the attendees one-on-one or in small groups. The posters not in the focus session each day will be on display in the hallway but not attended.

# Local Chairpersons

Graeme Ramsey, Lockheed Martin Space Andrew Riskus, Ball Aerospace Kristina Forystek, Innovation RM Presentations Hardware-In-The-Loop Test For Autonomous Asteroid Rendezvous Using Robust Guidance And Control Strategies (AAS-24-P01)

Tomohiro Ishizuka, ISAE-SUPAERO Jérôme Puech, ISAE-SUPAERO Ginevra Cianci, Politecnico Di Torino Stéphanie Lizy-Destrez, ISAE-SUPAERO

# Solar Electric Propulsion GN&C Pointing State Overview for the Emirates Mission to the Asteroid Belt (AAS-24-P02)

**Riccardo Calaon**, University of Colorado Boulder Cody Allard, Laboratory for Atmospheric and Space Physics - CU Boulder Hanspeter Schaub, University of Colorado

## The Orbital Regime Index: A Comprehensive Parameter to Determine Orbital Regions Around Minor Bodies (AAS-24-P03)

**Carmine Buonagura**, Politecnico di Milano Carmine Giordano, Politecnico di Milano Fabio Ferrari, University of Bern Francesco Topputo, PhD, Politecnico di Milano

# Smart Jackets for Lunar Robotics GNC (AAS-24-P04)

**Anna Dinkel**, University of Arizona Andrea Torres, University of Arizona – SpaceTREx Jekan Thangavelautham, University of Arizona

# Automated Constrained Maneuver Design for Asteroid Payload Delivery (AAS-24-P05)

Julian Hammerl, University of Colorado Boulder Thibaud Teil, Laboratory of Atmospheric Space Physics, CU Boulder Hanspeter Schaub, University of Colorado

#### Standalone Commercial OPNAV for Deep Space Operations (AAS-24-P06)

Josh Baumann, Rhea Space Activity; Christopher Grasso, PhD, Blue Sun Enterprises Christopher Dinelli, Rhea Space Activity Mo Brethower, Rhea Space Activity Robert Thompson, PhD, Rhea Space Activity Salma Benitez, Rhea Space Activity Shawn Usman, Rhea Space Activity Elliott Hastings, Elliott Hastings, PhD, MSci, Rhea Space Activity

#### Autonomous Guidance Navigation and Control of Interstellar Object Detection Spacecraft (AAS-24-P07)

Adam Nekolny, University of Arizona – SpaceTREx Vivek Verma, University of Arizona – SpaceTREx Jekan Thangavelautham, University of Arizona

# **ADVANCES IN NAVIGATION (PEAK 1-4)**

# Session 05

# Sunday 4:00 PM - 7:00 PM

Recent advances in Position, Navigation, and Timing (PNT) seek to push the boundaries of spacecraft navigation and timing technology and address the shortcomings of current PNT systems. With proliferation of large-scale constellation deployments in Earth orbit and the need for maintaining a safe orbital environment for all techniques new PNT operators. and robust architectures are required to complement the existing ground based and GNSS systems. Lunar, interplanetary, and interstellar mission concepts require novel ways for collecting and processing observations from non-traditional sources. In this session, we will explore novel and advanced ground-based, space-based, and autonomous spacecraft PNT approaches. Of particular interest are methods for inter-satellite navigation and lostin-space scenarios as well as new filterina techniques for processing optical observations, pulsar observations, and other deep space signals of opportunity. As the world continues to work towards expanded lunar exploration and long-term habitation. new techniques, algorithms, and technoloav are needed to enable in-situ autonomous exploration in cislunar space.

# **National Chairs**

Evan Anzalone, NASA Marshall Space Flight Center Christopher DSouza, NASA/JSC

# Local Chairs

Lee Barker, Lockheed Martin Space Erin Griggs, Trusted Space, Inc.

#### Presentations

Investigation on Moon-Based Sensor Placement for Cislunar Orbit Determination with Exclusion Zones (AAS-24-051)

**Erin Jarrett-Izzi**, United States Space Force Kenshiro Oguri, University of Colorado Michele Carpenter, Draper Labs John Danis, Draper Labs

LIDAR Based Visual Odometry Implementation to Support Lunar Lander Navigation (AAS-24-052)

**Emerson Oliver**, Moonshot Aerospace Kelly Barber, Moonshot Aerospace John Christian, Rensselaer Poly Mike Hansen, Intuitive Machines

# The USNO Guidance and Navigation Catalog V1.1 (AAS-24-053)

**Gregory Hennessy**, US Naval Observatory Julien Frouard, US Naval Observatory

Autonomous Cislunar Orbit Determination via Two-Satellite Formation using Relative Position Measurements Only (AAS-24-054)

Omar Awad, Draper Laboratory

Invariant Kalman Filtering on the Two-Frames Group for Spacecraft Full-State Estimation (AAS-24-055)

**Daniel Newberry**, Missouri University Henry Pernicka, Missouri University Light-Robust and Autonomous Spin Pole Estimation and Shape Modeling of Asteroids using Infrared Imagery (AAS-24-056)

**Koundinya Kuppa**, University of Colorado Ann Dietrich, Draper Labs Jay McMahon, CCAR

# OSIRIS-REx Earth Return Orbit Determination Analysis and Performance (AAS-24-057)

Jason Leonard, KinetX

# OSIRIS-REx Earth Return & Entry: Targeting Strategy and Maneuver Performance (AAS-24-058)

Daniel Wibben, KinetX Peter Antreasian, KinetX Andrew Levine, KinetX Jim McAdams, KinetX Samantha Rieger Kenneth Getzandanner, NASA Goddard Anna Montgomery, KinetX Jason Russell, KinetX

# **SMALL BODY EXPLORATION (PEAK 5)**

# Session 06 Sunday 4:00 PM - 7:00 PM

Recent years have seen an amazing array of planetary exploration missions to asteroids, comets, and other small solar system objects, with several new missions in various phases of development. This has led to the practical application of innovations in optical navigation, modeling, and autonomy that sensors, are accomplish demanding mission essential to objectives, such as characterizing the small body operating after arrival, in а micro-gravity environment, and in some cases navigating to the surface. This session solicits GN&C experiences, lessons learned. successes. and future challenges associated with the exploration of asteroids, comets, and other small bodies, and how these GN&C capabilities may be applied to other exploration applications.

#### **National Chair**

Jason Leonard, KinetX

# Local Chairs

Anubhav Gupta, M.S., In Orbit Aerospace, Inc. & University of Colorado Boulder Daniel Kubitschek, Univ of Colorado - LASP

# Presentations

Stochastic Spacecraft Maneuver Design Around Small Bodies Using Convex Formulations (AAS-24-061)

**Spencer Boone**, ISAE-SUPAERO Tomohiro Ishizuka, ISAE-SUPAERO Staphanie Lizy-Destrez, ISAE-SUPAERO

# Robust Guidance and Control for The Experimental Phase of ESA's HERA Mission (AAS-24-062)

Thomas Frekhaug, Universidad de Carlos III Jesús Gil-Fernández, ESA/ESTEC Manuel Sanjurjo-Rivo, Universidad Carlos III Manuel Soler Arnedo, University Carlos III Madrid

Leveraging Resonant Terminator Orbits for the Trajectory Design of OSIRIS-APEX at (99942) Apophis (AAS-24-063)

Gavin Brown, KinetX Daniel Wibben, KinetX Peter Antreasian, KinetX

# The Preliminary Mission Design of the Emirates Mission to Explore the Asteroids (EMA) (AAS-24-064)

Jeff Parker, Advanced Space, LLC Fatema Al Hameli, UAE Space Agency Jeremy Knittel, PhD, LASP Michael Caudill, Advanced Space, LLC Sai Chikine, Advanced Space Sandeep Baskar, Advanced Space Andrew Koehler, Advanced Space Paul Imler, Advanced Space

Autonomous Asteroid Flyby Capability for the Emirates Mission to the Asteroid Belt (EMA) (AAS-24-065)

Thibaud Teil, LASP

# Silhouette-Based Pole Estimation and Shape Reconstruction of Asteroid 269 Justitia (AAS-24-066)

Jacopo Villa, University of Colorado Boulder Jay McMahon, CCAR Jeremy Knittel, PhD, LASP Koundinya Kuppa, University of Colorado, Boulder

Lucy Mission Design Strategy in a Dynamic Operations Environment from Launch Through First Asteroid Encounter (AAS-24-067)

Jim McAdams, KinetX Dale Stanbridge, KinetX Daniel Wibben, KinetX Andrew Levine, KinetX Jeroen Geeraert, PhD, KinetX Joel Fischetti, KinetX Coralie Adam, KinetX Kevin Berry, Vicki, NASA Goddard Space Flight Center

Orbit Determination for Lucy's First Asteroid Encounter: The Dinkinesh (1999VD57) Flyby (AAS-24-068)

Jeroen Geeraert, PhD, KinetX

# **Social Event**

# **Casino Night**

# Sunday 7:15 PM – 9:30 PM Breckenridge Ballroom

Brought to you by Casino Party USA

- 2x Roulette
- 2x Craps
- 3x Blackjack
- 3x Texas Hold'em
- 4x Slot Machines

Family Members of conference attendees are welcome! (However only conference attendees are eligible for prizes; family members cannot compile chips with attendee).

**PRIZES!** Chips will be exchanged for raffle tickets at the end of the event (9:30) with prize winners determined in the following 15 minutes. Prizes include a Breckenridge Ski Day Pass, AAS Pint Glasses, and more.

A light dinner buffet will be provided.

# MONDAY, FEBRUARY 5<sup>th</sup> TRIPLE MORNING SESSIONS

#### ADVANCES IN GN&C HARDWARE PART 1 (PEAK 4)

# Session 07 Monday 7:00 AM - 10:30 AM

Many programs depend on heritage, but the future is advanced by those willing to design and implement new and novel architectures, technologies, and algorithms to solve GN&C problems. This session is open to papers with topics ranging from theoretical formulations to innovative systems and intelligent sensors that will advance the state of the art, reduce the cost of applications, and speed the convergence to hardware, numerical, or design trade solutions.

#### National Chair

Steeve Kowaltschek, European Space Agency

#### Local Chairs

Teagan Northrup, Ball Aerospace Tyler Thomas, Ball Aerospace

#### Presentations

Robust Cable-Actuated Shape Control of a Flexible Solar Sail Boom for the CABLESSail Concept (AAS-24-071)

**Soojeong Lee**, University of Minnesota Ryan Caverly, University of Minnesota

#### High-Agility SmallSats via CMGs and Onboard Trajectory Optimization (AAS-24-072)

Bryan Rogler, Blue Canyon Technologies Matt Baumgart, Blue Canyon Technologies **Matt Carton**, Blue Canyon Technologies Travis Burch, Blue Canyon Technologies Bryce Peters, Blue Canyon Technologies Eric Sims, Blue Canyon Technologies Elena Trenholme, Blue Canyon Technologies

# Micro-thruster ACS Architecture for Precision Pointing of 6-meter exo-Earth Imaging Space Telescope (AAS-24-073)

**Cameron Haag**, Jet Propulsion Laboratory Kati Balachandran, Jet Propulsion Laboratory Oscar Alvarez-Salazar, Jet Propulsion Laboratory Colleen Marrese-Reading, Jet Propulsion Laboratory Steven Arestie, Jet Propulsion Laboratory

# RVS® 3000-X LIDAR – Applications from Docking to Sample Return and Lunar Landing (AAS-24-074)

Max Möller, Jena-Optronik GmbH Christoph Schmitt, Jena Optronik GmbH Thomas Kämpfe, Jena-Optronik GmbH Christian Kracht, Jena-Optronik GmbH Keyvan Kanani, Airbus Defence and Space Lukas Scheunemann, Jena-Optronik GmbH Rene Pforr, Jena-Optronik GmbH Michael Windmüller, Jena Optronik GmbH Michael Schwarz, Jena Optronik GmbH

# Development of a family concept for highly adaptive reaction wheels for SmallSats and geostationary satellites (AAS-24-075)

Friedrich Bartels, M.Sc., Astro- und Feinwerktechnik Adlershof GmbH Stephan Stoltz, Astro-und Feinwerktechnik Adlershof GmbH Sebastian Scheiding, Dr., Astro-und Feinwerktechnik Adlershof GmbH Thomas Hellwig, Dr, Astro-und Feinwerktechnik Adlershof GmbH Niklas Flex, Astro-und Feinwerktechnik Adlershof GmbH Christian Raschke, Dr., Astro-und Feinwerktechnik Adlershof GmbH

# EURISA: developing a European IMU for scientific and commercial applications (AAS-24-076)

Jean-Jacques Bonnefois, iXBlue Louis Dutheil, PhD, Exail Guillaume Lecamp, iXblue Stève Masson, Airbus Defence and Space

Stephan Theil, PhD, DLR German Aerospace Center

# Accelerometer sensor AQUILA and equipment 3AA for space missions (AAS-24-077)

Alberto Torasso, InnaLabs Ltd Rabin Francis, Innalabs Flavio Felici, InnaLabs Ltd Jeroen Vandersteen, European Space Agency (ESA)

# Precision Inertial Reference Unit for Satellite Pointing and Stabilization (AAS-24-078)

Douglas Meyer, Northrop Grumman

## ADVANCES IN IN GN&C SOFTWARE PART 1 (PEAK 5)

# Session 08 Monday 7:00 AM - 10:30 AM

Successful GN&C system performance is often dependent on innovative software. This session open to all development processes is and systems ranging from vehicle code used to operate the spacecraft system, ground software used for operations/analysis, or simulations/frameworks used to test, validate, or develop GN&C systems. The intent is to include current best practices as well as challenges in software development such as the future inclusion of complex systems like artificial intelligence, machine learning, vision processing, iterative numerical and solvers.

# **National Chairs**

Paul Graven, Cateni Patrick Kenneally, Laboratory for Atmospheric and Space Physics (LASP)

#### Local Chairs

Ann Dietrich, The Charles Stark Draper Laboratory Levi Smith, Lockheed Martin Space

# Verification of the Generalized Aerospace Simulation in Simulink (AAS-24-081)

#### Nicholas Olson, Jacobs ESSCA

Juan Orphee, NASA Marshall Space Flight Center Matthew Hawkins, Jacobs Space Exploration Group Justin Ganiban, Jacobs ESSCA

#### Model-Based GN&C Fault Management (AAS-24-082)

Paul Graven, Cateni John Hanson, PhD, CrossTrac Engineering

# Robust Level 1 Differential Correction Using Screens and Windows (AAS-24-083)

Rodney L. Anderson, Jet Propulsion Laboratory/Caltech Robert Easton Martin Wen-Yu Lo, Jet Propulsion Laboratory

# ELAPSE: A FlatSat Software and Processing Unit for Deep-Space Autonomous GNC Systems Testing (AAS-24-084)

**Davide Perico**, Politecnico di Milano Gianfranco Di Domenico, Politecnico di Milano Gianmario Merisio, PhD, Neuraspace Francesco Topputo, PhD, Politecnico di Milano

# De-risk New AOCS/GNC V&V Technologies for Industrial Efficiency (AAS-24-085)

Stefan Winkler, Airbus Defence and Space

Utilizing Optimal Bi-Impulse Orbit Transfers to Realize Finite Burn Maneuvers in the Presence of Third body and Perturbing Effects (AAS-24-086)

James McElreath, Texas A&M University Manoranjan Majji, Texas A&M University

## Advances in High Precision Partial Derivative Approximation for Black Box Functions of n Variables (AAS-24-087)

**Koya Yamamoto**, Texas A&M University Patrick Kelly, Texas A&M University John L. Junkins, Texas A&M University

# Challenges and Solutions in Managing Liquid Propellant Dynamics (PEAK 1-3)

# Session 09 Monday 7:00 AM – 10:30 AM

Predicting, managing, and controlling the interaction of liquid propellants with the dynamics of a space vehicle continues to present broadreaching challenges in modeling, control theory, and systems engineering. Emerging concepts in launch systems, planetary landers, and large spacecraft strive to eliminate the mass penalties traditional propellant management of technologies while increasing performance and operational capability. This session explores advances in slosh modeling and slosh suppression in both microgravity and high-g flow regimes, particularly in the context of vehicle dynamics, test-based or semi-empirical methods, vehicle-CFD co-simulation, and novel techniques for sensing, estimation, and/or control of liquid motion. In addition, efforts to verify and validate dynamic models are of particular interest given the unique scaling challenges between ground test capability and the flight environment.

#### **National Chairs**

Jeff Brouwer, BSE, MSEE, Blue Origin Jeb Orr, Blue Origin

# Local Chair

Uday Shankar, JHU Applied Physics Laboratory

# Low-G Slosh Workshop Results: State of the Art, Gaps and Forward Work 2023 (AAS-24-091)

William Benson, NASA Kennedy Space Center Neil Dennehy, NASA Engineering and Safety Center Tannen VanZwieten, NASA Engineering & Safety Center Brandon Marsell, NASA Launch Service Program
Advancements in Frequency Domain Analysis Tool of Dual Centerline Propellant Tanks for Space Vehicle Stability and Design (AAS-24-092)

Han Woong Bae, Marshall Space Flight Center NASA Jing Pei, NASA Langley Research Center Justin Ganiban, Jacobs ESSCA Juan Orphee, NASA Marshall Space Flight Center

### Validation of a Low-g Slosh Mechanical Model with an Apollo-Era Separation Anomaly (AAS-24-093)

William Elke, III, Ph.D., NASA Langley Research Center

### Mastering the Cryogenic Frontier: Predicting Sloshing in Cryogenic Propellant Tanks (AAS-24-094)

Daniel Hauser, NASA Glenn Research Center Mohammad Kassemi, NASA Glenn Research Center Olga Kartuzova, NASA Glenn Research Center Michael Baker, NASA Glenn Research Center John Mishic. NASA Glenn Research Center

Exploring Cryogenic Propellant Behavior in Low-Gravity Environments, Insights from the Saturn AS-203 Vent Experiments and CFD Analysis (AAS-24-095)

Daniel Hauser, NASA Glenn Research Center Justin Pesich, NASA Glenn Research Center

# Modeling Low-G Slosh Using Negative Mass (AAS-24-096)

Matthew Wittal, NASA Brennan McCann, Embry-Riddle Aeronautical University Marco Fagetti, Embry-Riddle Aeronautical University Morad Nazari, Embry-Riddle Aeronautical University Jonathan Pitt, Aegis Aerospace, Inc

Principles of Fluid Dynamic Similarity Analysis for Slosh Experiments (AAS-24-097)

Jed Storey, NASA

Modeling Nutation Damping due to Fuel Slosh for the Interstellar Mapping and Acceleration Probe (IMAP) Mission (AAS-24-098)

Corinne Lippe, JHU Applied Physics Laboratory Brenton Duffy, JHU Applied Physics Laboratory

# POSTER SESSION BREAK (PEAK1-5 HALLWAY)

# Monday 8:30 AM – 9:00 AM

Focused poster session breaks will take place with unique posters displayed in the main foyer, allowing the poster presenters to interact with the attendees one-on-one or in small groups. The posters not in the focus session each day will be on display in the hallway but not attended.

## Local Chairs

Graeme Ramsey, Lockheed Martin Space Andrew Riskus, Ball Aerospace Kristina Forystek, Innovation RM

#### Presentations

Development of a GPU based Single Board Computer for Space Applications (AAS-24-P08)

Gates West, Moog; Jonathan Struebel, Moog

# Toward Development and Validation of Velocimeter Lidar Simulator (AAS-24-P09)

Ramchander Bhaskara, Texas A&M University Manoranjan Majji, Texas A&M University, College Station

### Exploration of Lighting Sequences of LEDs inside a controlled environment for accurate depiction of LEO Lighting conditions for GNC Applications (AAS-24-P10)

Athip Thirupathi Raj, University of Arizona -SpaceTREx; Connor Sturgeon, University of Arizona – SpaceTREx Jekan Thangavelautham, University of Arizona

# Monday, February 5<sup>th</sup> / Page 35

# Open-Source Propellant Sloshing Modeling and Simulation (AAS-24-P11)

Brian Gonzalez, Georgia Institute of Technology Pablo Martin Garcia, Georgia Institute of Technology Rabia Shahid, Georgia Institute of Technology Evan Sanchez, Georgia Institute of Technology Justin Effendi, Georgia Institute of Technology Alvaro Romero-Calvo, Georgia Institute of Technology

### Auriga Star Tracker new features (AAS-24-P12)

**Benoit Gelin**, Sodern; Lionel Oddos-Marcel, Sodern

Mobile Controlled Environments: A Framework for Enabling and Simplifying Precision Tasks on Off-World Surface Environments (AAS-24-P13)

Jed Storey, NASA

### Design, Fabrication, and Flight of the Cost-And Risk- Reducing Quadcopter System for GNC Testing (AAS-24-P15)

William Elke, III, Ph.D., NASA Langley Research Center James Johnson, University of Minnesota Will Roslansky, University of Minnesota Demoz Gebre-Egziabher, University of Minnesota Ryan Caverly, University of Minnesota Tutorial Kalman Filter Basics (PEAK 5) 11:00 AM – 1:30 PM Mathworks Chris D'Souza

# SMALL SATELLITE GN&C (PEAK 4)

# Session 10 Monday 4:00 PM - 7:00 PM

In recent years, small satellites including NanoSats and CubeSats have seen greater use for a range of applications in government, commercial, and educational sectors. At the high end of this mass range, ESPA-class spacecraft now trusted platforms for scientific and are missions. These missions defense require advanced technology insertion (GN&C, on-board processing) while advancing manufacturing practices to achieve higher production rates. Some key challenges related to increasing production volume include supply-chain management, automated production and testing, and design for manufacturing approaches. This session is open to papers covering advanced technology insertion small sats on (e.g., propulsion, optical communications, proximity operations. sails. etc.), advanced drag manufacturing practices (e.g., best practices for satellite production, automation, and design for manufacturing) and operation practices (autonomous mission or conops). Papers on practical mission experience in these areas are welcomed.

# **National Chair**

Scott Palo, University of Colorado Boulder

# Local Chairs

Devon Sanders, Blue Canyon Technologies Elvis Silva, Blue Canyon Technologies

### Presentations

GN&C Flight Experience and Lessons Learned from Bio Sentinel: A 6U Deep Space Cubesat (AAS-24-101)

Jesse Fusco, NASA Ames Research Center Terry Stevenson, PhD, KBR Wyle Services Robert Nakamura, NASA Ames Research Center

Development and testing of GA-EMS Novel Attitude Determination and Control System (AAS-24-102)

**Daniel Bowden**, General Atomics Rusty Anderson, General Atomics

From LEO to Mars: GNC solutions for non-LEO missions on a common software platform (AAS-24-103)

**Bryan Rogler**, Blue Canyon Technologies Michael Ferenc, Blue Canyon Technologies Will Flowers, Blue Canyon Technologies Devon Sanders, Blue Canyon Technologies

Challenges and Robust Design of Remote Sensing Spacecraft Flying in VLEO (AAS-24-104)

Drew Engelmann, EOI Space

# Anomaly Resolution to Maintain On-orbit Operations of GA-150 Satellite (AAS-24-105)

**Ted Danielson**, General Atomics Rusty Anderson, General Atomics Chris Van Poolen, General Atomics

## Transfers to Lunar Orbit Through GTO Rideshare and Their Applications to Small-Satellites (AAS-24-106)

**Devin Langford**, Missouri University Henry Pernicka, Missouri University

# Blue Canyon On-Orbit GN&C Systems: Then and Now (AAS-24-107)

Bryan Rogler, Blue Canyon Technologies **Michael Ferenc**, Blue Canyon Technologies Will Flowers, Blue Canyon Technologies Devon Sanders, Blue Canyon Technologies

# Optimization of Solar Array Drive Assembly (SADA) Panel Rotation (AAS-24-108)

Andrew Jennings, General Atomics Rusty Anderson, General Atomics

# ADVANCES IN GN&C HARDWARE PART 2 (PEAK 5)

# Session 11 Monday 4:00 PM-5:10 PM

Many programs depend on heritage, but the future is advanced by those willing to design and implement new and novel architectures, technologies, and algorithms to solve GN&C problems. This session is open to papers with topics ranging from theoretical formulations to innovative systems and intelligent sensors that will advance the state of the art, reduce the cost of applications, and speed the convergence to hardware, numerical or design trade solutions.

## **National Chair**

Steeve Kowaltschek, European Space Agency

### Local Chairs

Teagan Northrup, Ball Aerospace Tyler Thomas, Ball Aerospace

### Presentations

High Dynamic Range Stray Light Test Method (AAS-24-111)

Nathan Everett, BS, MS in Physics, Redwire Space

# Monday, February 5<sup>th</sup> / Page 41

### AURICAM space camera: AURIGA™ sister is born (AAS-24-112)

Laurent Majewski, Sodern Catherine Delelis, Sodern Gary Degliame, Sodern Benoit Gelin, Sodern

### The ASTRO APS3 Star Tracker – Qualification Test Results and Market Introduction (AAS-24-113)

Uwe Schmidt, Jena-Optronik GmbH Sebastian Hartmann, Jena-Optronik Ingolf Steinbach, Jena-Optronik GmbH Martin Griebel, Jena-Optronik GmbH Steffen Schwarz, Jena-Optronik GmbH

# Advances in GN&C Software Part 2 (PEAK 5)

# Session 12 Monday 5:10 PM – 7:00 PM

Successful GN&C system performance is often dependent on innovative software. This session is open to all development processes and systems ranging from vehicle code used to operate the spacecraft system, ground software used for operations/analysis, or simulations/frameworks used to test, validate, or develop GN&C systems. The intent is to include current best practices as well as challenges in future software development such as the inclusion of complex systems like artificial intelligence, machine learning, vision processing, and iterative numerical solvers.

# **National Chairs**

Paul Graven, Cateni Patrick Kenneally, Laboratory for Atmospheric and Space Physics (LASP)

### Local Chairs

Ann Dietrich, The Charles Stark Draper Laboratory Levi Smith, Lockheed Martin Space

#### Presentations

Impulsive Stability Analysis of Spacecraft with Rotating Flexible Solar Arrays (AAS-24-121)

**João Vaz Carneiro**, University of Colorado Cody Allard, LASP Hanspeter Schaub, University of Colorado

# Monday, February 5<sup>th</sup> / Page 43

### Optical Disturbance Rejection in an Archetypal Payload Mirror System via Two-Stage H-infinity Shaping (AAS-24-122)

Richard Chiang, The Aerospace Corporation Howard Ge, The Aerospace Corporation **Michael Andonian**, Ph.D., The Aerospace Corporation Devon Feaster, The Aerospace Corporation Jason Ly, Ph.D., The Aerospace Corporation

Complex Spacecraft Dynamics Analysis Using Prescribed Time-Varying Sub-Structure Modeling (AAS-24-123)

Leah Kiner, University of Colorado Hanspeter Schaub, University of Colorado Cody Allard, LASP

Detumbling the Starfish Space Otter Pup: Control and Operational Analysis (AAS-24-124)

Trevor Bennett, BS, PhD, Starfish Space

Robust Adaptive Suppression of a Noncollocated Optical Payload System with Large Plant Uncertainty and Unknown Periodic Disturbances (AAS-24-125)

**Richard Chiang**, The Aerospace Corporation Michael Andonian, Ph.D., The Aerospace Corporation Wei Huang, The Aerospace Corp Howard Ge, Ph.D., The Aerospace Corporation Devon Feaster, The Aerospace Corporation Jason Ly, Ph.D., The Aerospace Corporation

# **ADVANCES IN PROPULSION I (PEAK 1-3)**

Session 13 Monday 4:00 PM - 7:00 PM

The development of advanced propulsion technologies is critical for enabling spacecraft platforms ranging from CubeSats to ambitious human and robotic space exploration missions. Innovative developments in chemical, electric, nuclear, and propellant less propulsion will provide higher performance and greater operability, enabling new approaches ranging from launch to interstellar travel. This session will highlight advanced propulsion technologies and enabling subsystems matured by NASA, DOD, industry, and academia.

# **National Chairs**

Ron Litchford, PhD, PE, NASA Jeffrey Sheehy, NASA

# Local Chairs

John Abrams, Analytical Mechanics Associates (AMA) Emanuel Grella, Analytical Mechanics Associates

# Presentations

Vulcan Centaur - Next Generation Launch Services (AAS-24-131)

John Reed, United Launch Alliance

**Bipropellant Engine Development for Deep Space Missions (AAS-24-132)** 

Alan Frankel, Frontier Aerospace

# RAMFIRE: Hot-Fire Testing of an Al6061-RAM2 Nozzle (AAS-24-133)

**Ben Williams**, NASA MSFC Tessa Fedotowsky, NASA MSFC

# Monday, February 5<sup>th</sup> / Page 45

### NASA's Compact High-Efficiency Rotating Detonation Rocket Engine for Mars Interplanetary Missions (AAS-24-134)

Thomas Teasley, NASA Marshall Space Flight Center Shawn Skinner, NASA Joseph Hernandez-McCloskey, NASA

GN&C Considerations for Nuclear Thermal Propulsion Missions (AAS-24-135)

Barry Miller, Lockheed Martin Space **Douglas Gitomer**, Lockheed Martin Space

A Versatile Minimum Viable Multi-Launch NTP Architecture for Space Exploration (AAS-24-136)

Craig Foulds, USNC Michael Eades, USNC Paolo Venneri, USNC

### Development of High-Power Lithium Magnetoplasmadynamic Thrusters for Human Mars Missions (AAS-24-137)

James Polk, JPL Edgar Choueiri, Princeton University Anna Sheppard, Dr., JPL Eric Smith, JPL Dan Goebel, Dr., JPL Richard Hofer, Ph.D., JPL Lee Johnson, Dr., JPL Adam Martin, Dr., NASA Marshall Spaceflight Center Kurt Polzin, NASA-MSFC

# Monday, February 5<sup>th</sup> / Page 46

### On-Orbit Characterization of the Advanced Composite Solar Sail System (ACS3) Propulsion Technology Demonstrator (AAS-24-138)

**Keats Wilkie**, NASA Langley Research Center Jeannette Heiligers, Delft University of Technology

Livio Carzana, Delft University of Technology Andrew Heaton, NASA Marshall Space Flight Center

Benjamin Diedrich, Axient/DCI LLC Ivan Bertaska, NASA/MSFC

Andres Dono, NASA Ames Research Center Ted Hendriks, Metis Technology Solutions

# SOCIAL EVENT

# Diversity, Equity, and Inclusion (DEI) Cocktail Hour

# Monday 7:15 PM - 8:30 PM

Celebrate diversity in aerospace and STEM by networking with colleagues from typically underrepresented areas of the workforce. The event will be lightly structured with networking games and provide a space to encourage connection. Enjoy making a new friend, or gaining a new perspective, in this revamped event.

Heavy appetizers will be served.

**Local Chair** Ann Dietrich, Draper Labs

# AUTONOMOUS RPOD, SERVICING, COLLISION AVOIDANCE PART 1 (PEAK 1-4) Session 14 Tuesday 7:00 AM – 10:30 AM

Rendezvous and Proximity Operations continue to develop into more and more relevant fields for research with each passing year. Autonomous rendezvous, proximity operations, and docking (RPOD) systems are key enablers to supporting objectives such as commercial servicing of existing spacecraft, orbital debris removal, on-orbit refueling, the next generation of space tugs and asteroid missions, or even placing boots on the lunar surface again. This session explores all aspects of enabling technologies for Navigation, Guidance and Control, Computer Vision, Robotics, Mechanisms, and Safety of Flight to support this class of missions.

# **National Chairs**

Jack Brazzel, NASA Johnson Space Center Bo Naasz, NASA

# Local Chairs

AJ Berning, Blue Origin Jim Carrillo, Blue Origin DeAnn Redlin Sanders, Ball Aerospace Brady Young, Lockheed Martin Space

# Presentations

Lockheed Martin LINUSS(TM) GN&C - On Orbit Experiences (AAS-24-141)

**Brian Janisch**, Lockheed Martin Space Phillip Maple, Lockheed Martin Space Ryan Cutter, Lockheed Martin Space Bryan Bishop, Lockheed Martin Space David Barnhart, PhD, Lockheed Martin Space

# SLD Transporter LEO RelNav sensing strategy and Navigation Performance (AAS-24-142)

Matthew Hilsenrath, Lockheed Martin Space

Guidance, Navigation, and Control for Laser-Based Non-Cooperative Target Detumbling (AAS-24-143)

**Corey Marcus**, University of Texas at Austin Andres Dono, NASA Ames Research Center Renato Zanetti, University of Texas at Austin

Evaluating Delta-v Dispersions Using Linear Covariance Techniques with Applications to Rendezvous and Docking (AAS-24-144)

David Woffinden, NASA Johnson Space Center

Pose estimation of CubeSats via sensor fusion and Error-State Extended Kalman Filter (AAS-24-145)

Deep Parikh, IIT Kanpur

Rendezvous Fiducial Implementation in a Vehicle Life Cycle (AAS-24-146)

Eugene Skelton, NASA; Andres Velasquez, WVRTC

Sensor Fusion of Monocular Cameras and Inertial Measurement Units for Free-Flyers: Applications to Spacecraft Servicing, Assembly and Manufacturing (AAS-24-147)

Ali Hasnain Khowaja, Texas A&M University Manoranjan Majji, Texas A&M University

Automated Assembly of Tensegrity Structures using Monocular Vision Navigation Algorithms (AAS-24-148)

James McElreath, Texas A&M University Manoranjan Majji, Texas A&M University

### Exploring Frontiers – The Moon and Mars (PEAK 5) Session 15 Tuesday 7:00 AM – 10:30 AM

In recent years, the exploration and habitation of both the Lunar surface and Mars has become popularized in the commercial and private aerospace communities. With the Moon as the closest celestial body, and Mars as the closest and most hospitable planet near Earth, they are the most obvious next steps in human space exploration. Exploring both bodies poses a unique set of challenges in navigation, entry into a highly variable atmosphere, radiation resistance, and autonomous exploration. This session will explore the difficulties present in exploring the Moon and Mars and the innovative GN&C technologies.

### **National Chair**

William E. Frazier, Jet Propulsion Laboratory

## Local Chairs

Mitchell Hebert, Draper Jeff Parker, Advanced Space, LLC

## Perturbation Modeling and Navigation Tuning for a Crewed Station in Near Rectilinear Halo Orbit (AAS-24-151)

**Clark Newman**, a.i. solutions, Inc. Jacob Hollister, a.i. solutions, Inc. Diane Davis, a.i. solutions, Inc.

### Vision-Based Navigation for the LUMIO CubeSat Mission (AAS-24-152)

Paolo Panicucci, ISAE-SUPAERO & CNES Felice Piccolo, Politecnico di Milano Antonio Rizza, Politecnico di Milano Gianmario Merisio, PhD, Neuraspace Francesco Topputo, PhD, Politecnico di Milano Roger Walker, Dr, ESA

# Tuesday, February 6<sup>th</sup> / Page 51

**Cislunar Orbit Trajectory Design using Predictive Control Techniques (AAS-24-153)** Jill Davis, Missouri University Ryan Caverly, University of Minnesota

### Smart Sandbags as a Sensor Network for Autonomous Lunar Construction (AAS-24-154)

**Siva Muniyasamy**, University of Arizona Jekan Thangavelautham, University of Arizona

# Generalized Linear Targeting for Cislunar Flight (AAS-24-155)

**David Geller**, Utah State University David Woffinden, NASA Johnson Space Center Brayden Barton, Utah State University

### A Survey of Three-Body Orbit Family Visibility Metrics Using Terrestrial Tracking Networks (AAS-24-156)

Matthew Bolliger, Advanced Space

Hopscotching Between Roller-Coasters: Very Low Delta-V Transfers Between Useful Periodic Orbits in the Earth-Moon System (AAS-24-157)

Tim McElrath, JPL/Caltech Rodney L. Anderson, JPL/Caltech Gregory Lantoine, NASA / Caltech JPL

## POSTER SESSION BREAK (PEAK1-5 HALLWAY) Monday 8:30 AM - 9:00 AM

Focused poster session breaks will take place with unique posters displayed in the main foyer, allowing the poster presenters to interact with the attendees one-on-one or in small groups. The posters not in the focus session each day will be on display in the hallway but not attended.

## Local Chairperson

Graeme Ramsey, Lockheed Martin Space Andrew Riskus, Ball Aerospace Kristina Forystek, Innovation RM

### Presentations

Segmented Surface Vehicle Route Estimation using Ansys ODTK 7.8 (AAS-24-P16)

Alfred Lynam, Ansys Government Initiatives (AGI) James Woodburn, AGI Jens Ramrath, AGI

## Roll Torque Mitigating Trajectories for Multi-Body Solar Sail Orbits (AAS-24-P17)

Aaron Houin, NASA Marshall Space Flight Center Daniel Tyler, NASA Marshall Space Flight Center Rohan Sood, The University of Alabama

Launch and Early Operation Sun Acquisition for a Low Earth Orbit (LEO) Satellite with a Limited Sensor Suite (AAS-24-P18)

**Sam Douglass**, General Atomics Rusty Anderson, General Atomics

## Control of Buoyancy-Assisted Robots for Exploration of Extreme Environments on Mars and Titan (AAS-24-P19)

Vivek Verma, University of Arizona Jekan Thangavelautham, University of Arizona

## Platform for Low-Cost, Low-Risk Testing of Entry Descent and Landing System Technologies (AAS-24-P20)

**Demoz Gebre-Egziabher**, University of Minnesota Vincent Twin, University of Minnesota Marcus Murbach, NASA Skye Gagnon, University of Minnesota Jeffrey Neumann, University of Minnesota Alessio Gardi, University of Minnesota

# Attitude Control for precise Sciences (ACES) Project (AAS-24-P21)

Galen Savidge, Ann & H.J. Smead Department of Aerospace Engineering Sciences at CU Boulder Julian Bulliard, University of Colorado Boulder, Ann & H.J. Smead Department of Aerospace Engineering Sciences Chrishma Hunter Singh-Derewa, University of Colorado Boulder, Ann & H.J. Smead Department of Aerospace Engineering Sciences

Anshul Jain, University of Colorado Boulder

# System Engineering Challenges for a Remote Sensing Spacecraft Flying in VLEO (AAS-24-P22)

John Kearns, EOI Space

# Spacecraft Detection and Segmentation for Rendezvous and Docking in Cluttered Environments (AAS-24-P23)

**Ike Witte**, Johns Hopkins University Applied Physics Lab

Tuesday, February 6<sup>th</sup> / Page 54

# Tutorial

# Using Cubesat Images for Pose Estimation (PEAK 5)

# 10:45 AM - 1:15 PM

Simeone D'Amico Mathworks

Tutorial

Basilisk Spacecraft Simulation Tool (PEAK 1-4)

1:15 PM - 3:45 PM

**Details TBD** 

# **TUESDAY, FEBRUARY 6th**

# AUTONOMOUS RPOD, SERVICING, COLLISION AVOIDANCE PART 2 (PEAK 1-4) Session 16 Tuesday 4:00 PM - 7:00 PM

Rendezvous and Proximity Operations continue to develop into more and more relevant fields for research with each passing year. Autonomous rendezvous, proximity operations, and docking (RPOD) systems are key enablers to supporting objectives such as commercial servicing of existing spacecraft, orbital debris removal, onorbit refueling, the next generation of space tugs and asteroid missions, or even placing boots on the lunar surface again. This session explores all aspects of enabling technologies for Navigation, Guidance and Control, Computer Vision, Robotics, Mechanisms, and Safety of Flight to support this class of missions.

## **National Chairs**

Jack Brazzel, NASA Johnson Space Center Bo Naasz, NASA

### Local Chairs

AJ Berning, Blue Origin Jim Carrillo, Blue Origin DeAnn Redlin Sanders, Blue Origin Brady Young, Lockheed Martin Space

#### Presentations

Generating Orbital Elements for Natural Motion Circumnavigation Guidance (AAS-24-161)

Donald Tong, Boeing

A Real-Time Factorization-Free First-Order Method for Nonconvex Spacecraft Rendezvous Guidance (AAS-24-162)

**Govind Chari**, University of Washington Behçet Açıkmeşe, University of Washington Mehran Mesbahi, University of Washington

Assessing Linear Time Invariance Assumptions for State Transition Models of the Relative Elliptical Restricted Three Body Problem (AAS-24-163)

Christian Hosek, North Carolina State University

Short-Term Loitering in the Vicinity of Gateway's Near-Rectilinear Halo Orbit in the Circular Restricted Three-Body Problem (AAS-24-164)

**Lorin Nugent**, Advanced Space, LLC Matthew Bolliger, Advanced Space Aurélie Héritier Diane Davis, a.i. solutions, Inc. Kathleen C. Howell, Purdue University

Stochastic sampling-based motion planning for relative spacecraft motion with passive collision-avoidance (AAS-24-165)

**Taralicin Deka**, University of Colorado Boulder Jay McMahon, CCAR (Colorado Center for Astrodynamics Research)

Evader Guidance Strategies in an Orbital Pursuer-Evader Game with an Uncertain Pursuer Objective (AAS-24-166)

**Stephanie Halsey**, Air Force Institute of Technology David Curtis, Air Force Institute of Technology Eric Prince, Maj., Space Force

# ORION'S ARTEMIS I MISSION GN&C (PEAK 5)

Session 17 Tuesday 4:00 PM - 7:00 PM

NASA's Orion spacecraft is built to take humans farther than they've ever gone before. Orion will serve as the exploration vehicle that will carry the crew to space, provide emergency abort capability, sustain the crew during the space travel, and provide safe re-entry from deep space return velocities. Orion flew its first mission. Artemis I, launching atop NASA's new heavy-lift rocket, the Space Launch System on Nov 16, 2022. After a record-breaking mission, the Orion spacecraft splashed down on Dec 11, 2022, having travelled more than 1.4 million miles on a path around the Moon and returning safely to Earth. This session will be the first opportunity to hear the preliminary mission assessments from the GN&C team that supported the mission.

### **National Chairs**

David Dannemiller, NASA Johnson Space Center Robert Gay, MS - Aerospace Engineering, BS -Architectural Engineering, NASA JSC

#### Local Chairs

Divinaa Burder, Lockheed Martin Space Harvey Mamich, Lockheed Martin Space

#### Presentations

Artemis I: Historical Retrospective on Orion GNC Design (AAS-24-171)

### Robert Gay, NASA JSC

David Dannemiller, NASA JSC Greg Holt, NASA JSC Jeremy Rea, PhD, NASA Greg Loe, Lockheed Martin Space Mark Tedesco, NASA JSC Christopher D'Souza, NASA JSC Nathan Collins, US Air Force Academy, HQ USAFA/DFAS

# Optimized Trajectory Correction Burn Placement for the NASA Artemis I Mission (AAS-24-172)

David Woffinden, NASA JSC Collin York, Purdue University Randy Eckman, NASA JSC Shane Robinson, NASA JSC

## Orion's Powered Flight Guidance Performance During Artemis I (AAS-24-173)

Thomas Fill, C.S. Draper Laboratory

## Orion Artemis I Entry Performance (AAS-24-174)

Mark Kane, NASA JSC Jeremy Rea, PhD, NASA Luke McNamara, NASA JSC

## Artemis I Orion Orbit Control System Performance (AAS-24-175)

Nicklaus Richardson, Draper Michael Martin, Draper John Marcy, Lockheed Martin Space Rodolfo Gonzalez, NASA Tuesday, February 6<sup>th</sup> / Page 59

Orion Artemis I Descent and Landing Performance (AAS-24-176)

Mark Kane, NASA/JSC Brian Bihari Jacobs Marina Moen, NASA

Design and Simulation of Modified PID Controller for Human-Rated Spacecraft (AAS-24-177)

Elisabeth Gambone, NASA Michael Foster Thomas Kirven Henry Morrow

# Modular Safety Critical FSW using NASA cFS and FOSS RTOS (AAS-24-178)

Levi Smith, Lockheed Martin Space **Mikayla Whiteaker**, Lockheed Martin Space Mark Foster, NASA/CACI Sheena Miller, NASA/Jacobs James Neeley, Lockheed Martin Space

## **RECENT EXPERIENCES (PEAK 5)**

## Session 18 Wednesday 7 AM - 10:30 AM

This session focuses on recent experiences in spaceflight GN&C, providing a forum to share insights gained through successes and failures. Discussions typically include GN&C experiences ranging from Earth orbiters to interplanetary spacecraft. This session is a traditional part of the conference and has shown to be most interesting and informative.

### **National Chairs**

Henry Cordova, NASA Johnson Space Center Sam Thurman, NASA Jet Propulsion Laboratory

### Local Chair

Jim Chapel, Lockheed Martin Space

### Presentations

Early Pointing Functionality and Performance of the Deep Space Optical Communications Terminal on-board Psyche (AAS-24-181)

### Oscar Alvarez-Salazar, Jet Propulsion

Laboratory Dylan Conway, JPL Christopher Pong, JPL Herrick Chang, JPL David Zhu, JPL John Liu, JPL

### JUICE Guidance Navigation & Control Sub-System: overall in-flight performance and Vision-Based Navigation on-ground validation (AAS-24-182)

**Pascal Regnier**, Airbus Defence & Space Jonathan Grzymisch, European Space Agency (ESA) Wednesday, February 7<sup>th</sup> / Page 61

### Early Lucy Flight Experience with Unexpected Spacecraft Dynamics (AAS-24-183)

**Thomas Kennedy**, Lockheed Martin Space Philip Good, Lockheed Martin Space Russ Gehling, Lockheed Martin Space Kristen Francis, Lockheed Martin Space

Lunar Flashlight Mission - An Overview (AAS-24-184)

Philippe Adell, NASA-Jet Propulsion Laboratory

### LOFTID Tech Demonstration Mission (AAS-24-185)

John Reed, United Launch Alliance

### Cradle to Grave: The Multiple Operational Configurations of CloudSat Following Hardware Anomalies (AAS-24-186)

Heidi Hallowell, Ball Aerospace Ian Gravseth, Ball Aerospace

### OSIRIS-REx Earth Return & Entry: Navigation Operations & Lessons-Learned (AAS-24-187)

Kenneth Getzandanner, NASA Goddard Space Flight Center

### Entry, Descent, and Landing Analysis for the OSIRIS-REx Sample Return Capsule (AAS-24-188)

Mark Johnson, Lockheed Martin Space Eric Queen Anthony Williams, NASA Langley Research Center Soumyo Dutta, NASA Langley Research Center Scott Francis, Lockheed Martin Space Angelica Deguzman, Lockheed Martin Space

## IMAGE PROCESSING for NAVIGATION (PEAK 1-4) Session 19 Wednesday 7 AM – 10:30 AM

Image Processing (IP) is a critical step in many GN&C and ADCS algorithms, including attitude determination from star cameras and optical navigation from imaging sensors. Applications occur in various mission phases including interplanetary cruise, planetary orbit, proximity operations, descent and landing, and surface operations. An image from a visible, IR, LIDAR, or similar sensor can offer a wealth of information about a space vehicle's navigation state, but this information must be distilled into measurements that can be ingested by a navigation algorithm. Therefore, the success of algorithms which rely on image data depends on how effectively these algorithms perform IP---defined here as the process of extracting the salient pieces of information from an image in the presence of noise, clutter, and other real-world issues. This session is dedicated to papers that explore the relationship between IP algorithms and the broader problem of GN&C. Topics include IP algorithms; feedback/ feedforward between IP GN&C: hosting platforms/architectures and between CPUs. FPGAs. GPUs. and other processing units; challenges with on-board realtime IP; on-board rendering; testing, verification, and validation of IP algorithms; and lessons learned from past experiences.

# **National Chairs**

Coralie Adam, KinetX, Inc. Kevin Kobylka, Rensselaer Polytechnic Institute

### **Local Chairs**

Adam Boylston, Analytical Mechanics Associates Jastesh Sud, Blue Origin

# Presentations Methods for Analytic Reflected Radiant Flux Modelling in Observing Space Vehicles (AAS-24-191)

**Kevin Kobylka**, Rensselaer Polytechnic Institute Derek Hutton, Lockheed Martin Space

## Vision-based Relative Navigation about Small Bodies using Star Trackers (AAS-24-192)

Felice Piccolo, Politecnico di Milano Claudia Balossi, Politecnico di Milano Paolo Panicucci, Politecnico di Milano Mattia Pugliatti, Politecnico di Milano Francesco Topputo, PhD, Politecnico di Milano Simone Becucci, Leonardo S.p.A. Marcella Belcari, Leonardo S.p.A. Francesco Capolupo, European Space Agency

# Moon Limb-based Autonomous Optical Navigation using Star Trackers (AAS-24-193)

**Claudia Balossi**, Politecnico di Milano Felice Piccolo, Politecnico di Milano Paolo Panicucci, Politecnico di Milano Mattia Pugliatti, Politecnico di Milano Francesco Topputo, PhD, Politecnico di Milano Simone Becucci, Leonardo S.p.A. Marcella Belcari, Leonardo S.p.A. Francesco Capolupo, European Space Agency

### Evaluating Image Processing Algorithms for Dragonfly Optical Navigation (AAS-24-194)

Stephen Jenkins, Johns Hopkins University Applied Physics Lab **Ike Witte**, Johns Hopkins University Applied Physics Lab Benjamin Schilling, Johns Hopkins Applied Physics Lab Timothy McGee, Point Mass Technologies LLC Gunner Fritsch, Johns Hopkins University Applied Physics Laboratory Samuel Bibelhauser, Johns Hopkins University Applied Physics Lab

### LIDAR Based Terrain Relative Navigation with Terrain Contour Matching (TERCOM) (AAS-24-195)

Emerson Oliver, Moonshot Aerospace **Kelly Barber**, MS, Moonshot Aerospace Alexa Ling, Moonshot Aerospace Mike Hansen, Intuitive Machines

## Point Cloud Random Consensus via Gaussian Process Regression for Outlier Detection and Noise Removal (AAS-24-196)

**Ickbum Kim**, Rensselaer Polytechnic Institute Sandeep Singh, PhD, Rensselaer Polytechnic Institute Lucy Optical Navigation Performance during the (152830) Dinkinesh Encounter (AAS-24-197)

**Erik Lessac-Chenen**, KinetX Aerospace, Inc. Coralie Adam, KinetX, Inc.

### Vision Sensor Aided Autonomous Mobility and Navigation for a Flatworm-Inspired Robot in Planetary Extreme Environments (AAS-24-198)

**Rebekah Cutler**, University of Arizona Athip Thirupathi Raj, University of Arizona Jekan Thangavelautham, University of Arizona Notes

### 2024 Planning Committee:

**Emil Tchilian** Stephen Lutgring Graeme Ramsey David Chart Ian Gravseth Cody Griffin Jastesh Sud Matt Sandnas Elvis Silva AJ Berning Hank Steadman **Rachel Mamich** Alyssa Farber Erin Griggs **Uday Shankar** Scott Piggott

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