



AEROSPACE MECHANISMS SYMPOSIUM

45th AEROSPACE MECHANISMS SYMPOSIUM

Houston, Texas
December 2 - 4, 2020

Hosted by NASA Johnson Space Center and Lockheed Martin Space
Organized by the Mechanisms Education Association

SYMPOSIUM OBJECTIVES

This symposium is concerned with the problems of design, fabrication, test, and operational use of aerospace mechanisms. Emphasis is on hardware developments. The symposium provides a social and technical forum for personnel active in the field of mechanisms technology, as well as providing a source of information for others interested in this field. The symposium rotates among eight NASA Centers and attracts papers and attendees from all over the world.

SYMPOSIUM LOCATION

The Omni Houston Hotel in Houston, Texas is the site for all technical sessions.



SYMPOSIUM ACTIVITIES

The planned technical and social activities provide an opportunity for attendees to become professionally and personally acquainted. Dress attire is business casual unless otherwise noted.

MECHANISMS COURSES - On Monday and Tuesday, November 30 - December 1, three separate courses will be offered in the same hotel as the AMS. **Be sure to use the hotel booking link below when you make your hotel reservations.** Registration for the Aerospace Mechanisms Symposium is **not** included in any class price.

Space Mechanisms Course (Nov 30 - Dec 1)

Launchspace is providing a special edition of its Space Vehicle Mechanisms course. This course explores the technologies required for successful space mechanisms design and offers a detailed look at many of the key components common to most mechanisms. The materials necessary to achieve high performance are discussed.

Examples of the many types of mechanisms are included for illustration. In addition, the mechanisms relationships and interfaces with other vehicle systems are explored. The course includes design and analysis examples to demonstrate principles involved in understanding how mechanisms should work and how design margins should be evaluated during the evolution of a program.

Register at: <https://www.launchspace.com/blog/fundamentals-of-space-vehicle-mechanisms/>

The special symposium price for this course is \$995. The textbook, "Space Vehicle Mechanisms: Elements of Successful Design", edited by P.L. Conley, will not be provided but can be purchased commercially by attendees.

Compliant Mechanisms Design (Nov 30 - Dec 1)

Traditional rigid-body mechanisms consist of rigid links connected at movable joints. A compliant mechanism is a mechanism that gains at least some of its mobility from the deflection of flexible members rather than from movable joints only. This two-day course focuses on the basics of compliant mechanisms, modeling and simulation, materials selection, failure prevention and design.

Register at: <https://www.launchspace.com/blog/compliant-mechanism-design-course/>

The price for this course is \$995.

Rolling-Element Bearings: Fundamentals and Mechanics (Nov 30 - Dec 1)

Examine fundamental geometry, kinematics, Hertzian contact mechanics, internal load distributions, preloading, stiffness and various nonlinear relationships of rolling-element bearings. Explore how system performance characteristics are affected by both internal bearing parameters and various bearing row configurations. Learn about boundary influences, such as fit-ups and relative thermal expansions, and gain knowledge related to the design, sizing, analysis and troubleshooting of rolling-element bearings. Venue is limited to 30 attendees and a minimum of 10 attendees is required to hold the course.

Register at:

https://www.halpinengineeringllc.com/bearing_class_registration.html

Symposium price for this course is \$1095.

CHECK-IN - On Tuesday evening, December 1, from 6:00-8:00 PM, check in and registration will be in the Omni Houston Hotel Lobby. Symposium materials, including symposium proceedings, will be available, along with light refreshments in La Reserve Room.

RECEPTION - On Wednesday evening, December 2, a reception will be held in the Greenway Ballroom in the Omni Houston Hotel. Supplier displays and poster papers will be exhibited during the evening along with demonstrations by local high school FIRST Robotics teams. A buffet dinner will be served. The exhibits will be open for the enjoyment of all attendees and guests.

SYMPOSIUM BANQUET - On Thursday evening, December 3, the symposium dinner for all attendees and guests will be in the Morian Hall of Paleontology at the Houston Museum of Natural Science. Founded in 1909, the purpose of the Houston Museum of Natural Science has always been to "enhance in individuals the knowledge and delight in natural science and related subjects." The Museum houses the Burke Baker Planetarium, Wortham GIANT Screen Theatre, Cockrell Butterfly Center and a fascinating variety of permanent exhibit areas that examine astronomy, space science, Native American culture, paleontology, energy, chemistry, gems and minerals, seashells, Texas wildlife and much more.



FACILITY TOURS - On Friday afternoon, December 4, there will be an opportunity to tour either NASA Johnson Space Center or Space Center Houston. Admission and transportation are provided with symposium registration. The NASA JSC option is a private tour open to all attendees and guests; space is limited to 261 persons so register early.



GUEST ACTIVITIES - Houston is a major city in Texas not too far from the Gulf of Mexico. There are many museums, parks, theatres, events, etc. See Houston's visitor's guide at www.visithoustontexas.com. Many holiday events will be happening especially at the nearby Galleria.

PRESENTERS' MEETINGS - Presenting authors are required to attend a complimentary breakfast on the day of their presentation. (Note - only the presenters, not all authors of the paper.) This gathering gives the session participants an opportunity to meet their Session Chair and each other, and to review the session arrangements. The Symposium AV help will be available to discuss presentation requirements.

SYMPOSIUM INFORMATION

REGISTRATION - Advance registration is requested to facilitate planning and commitments. Please register on www.aeromechanisms.com. The registration fee is \$750 (\$350 for full-time professors, \$300 for full-time students and \$250 for retirees). Late registration for the symposium may be done at the hotel on Tuesday evening, December 1, and each day of the symposium. **NOTE: If the registration payment is received after 11:59pm EDT (GMT-4) November 6, 2020 the registration fee is \$850 for all. Also, any registrations started but unpaid before this deadline will be also be revised to the late registration fee of \$850 for all.** This fee covers all sessions, proceedings, break refreshments, reception, symposium banquet, tour, lunch for three days, and specified bus transportation. Guest tickets are \$30 for the reception and \$50 for the banquet (Late registration, \$40 reception, \$75 banquet).

Refund Policy - If a registration is cancelled, the Mechanisms Education Association will refund all fees paid less \$50, if cancelled by November 16, 2020.

After November 16, no refunds are given due to monetary commitments by the Mechanisms Education Association for the symposium expenses. Alternatively, a registration may be transferred to another employee if the original registrant cannot attend if the request for the transfer is done prior to the symposium by contacting our registration point of contact (Alice Pfeiffer at CTP).

HOTEL RESERVATIONS - A block of rooms has been reserved at the Omni Houston Hotel (www.omnihotels.com/hotels/houston). The hotel features wireless internet, 24-hour fitness center, 2 pools, spa, bar and restaurant on site. Rooms at the Omni Houston Hotel are offered at a special rate of \$125 (which is the government per diem) for stays from November 29 to December 6 for attendees. Attendees must make their own reservations directly with the hotel. Use the link below (preferred method) or if you call the hotel, mention the 45th Aerospace Mechanisms Symposium. **Make your reservations by November 9, 2020 to ensure the special rate.** After November 9, reservations may be made at the prevailing hotel rate. Reservation link:

<https://www.omnihotels.com/hotels/houston/meetings/aerospace-mechanisms-symposium-11302020>

Omni Houston Hotel
Four Riverway
Houston, TX 77056 USA
(713) 871-8181

TRANSPORTATION - Houston is served by William P. Hobby Airport (HOU) and the George Bush Intercontinental Airport (IAH). Taxi/Ridesharing service and car rentals are available at both airports. The airports are approximately 25 miles from the Symposium location.

DR. GEORGE HERZL AWARD - At each symposium, an award is given to the author(s) of the "Best Paper." The award is based on paper content, presentation delivery, and visual aids. This award was established in honor of Dr. George Herzl of Lockheed Martin, a co-founder of the Aerospace Mechanisms Symposium.

DR. CHARLES COALE AWARD - Each year the Mechanisms Education Association sponsors a child to attend Space Camp in honor of Dr. Charles Coale of Lockheed Martin. Dr. Coale was the leader of the symposium for more than 20 years and had a special interest in helping children.

GRANTS - Each year the Mechanisms Education Association awards grants to several high school FIRST Robotics teams. The Mechanisms Education Association may also provide an AMS attendance stipend to student authors.

PROGRAM:

TUESDAY, 1 DECEMBER 2020

6:00-8:00 CHECK-IN - Lobby - Refreshments in the La Reserve

WEDNESDAY, 2 DECEMBER 2020

7:00 Wednesday Presenters' Breakfast - Westbury Salon

7:00 CHECK-IN AND REFRESHMENTS - 2nd Floor Lobby near the Post Oak Ballroom

8:15 INTRODUCTORY REMARKS - Post Oak Ballroom

Brandan Robertson, Host Chairman, NASA Johnson Space Center, Houston, TX
Edward Boesiger, General Chairman, Lockheed Martin Space, Sunnyvale, CA
Vanessa Wyche, Deputy Center Director, NASA Johnson Space Center, Houston, TX

8:30 SESSION I - INSTRUMENTS

Session Chair: Claef Hakun, NASA Goddard Space Flight Center, Greenbelt, MD

- Nanometric Positioning with IASI-NG's Beam Splitter Mechanism Actuator
Francois Barillot, Jocelyn Rebufa, Gladys Jaussaud & Adrien Guignabert, Cedrat Technologies, Meylan, France
- Spectrometer Scan Mechanism for Encountering Jovian Orbit Trojan Asteroids
Kenneth Blumenstock, Alexander Cramer, Joseph Church, Jason Niemeyer, Fil Parong, Sam Zhao & Nerses Armani, NASA Goddard Space Flight Center, Greenbelt, MD; Kenneth Lee, ATA Aerospace, Greenbelt, MD
- Point Ahead Mechanism for Deep Space Optical Communication - Development of a New Piezo-Based Fine Steering Mirror
Adrian Guignabert, Thomas Maillard, Francois Barillot, Olivier Sosnicki & Frank Claeysen, Cedrat Technologies, Meylan, France;
- Design, Development and Verification of the METimage Mechanisms
Sebastian Rieger & Armin Jago, Airbus Defense & Space, Friedrechshafen, Germany
- Challenges of the Development of a Compliant Focus Mechanism Submitted to the Harsh Martian Environment for the ExoMars Rover Mission
Antoine Verhaeghe, Gerald Perruchoud, Philippe Schwab, Mathias Gummy, Julien Rouvinet & Lionel Kiener, Centre Suisse d'Electronique et de Microtechnique S.A., Neuchâtel, Switzerland

10:35 SESSION II - RELEASE MECHANISMS

Session Chair: Jared Dervan, NASA Marshall Space Flight Center, Huntsville, AL

- Lessons Learned from Qualification of HDRM for Ultralight LP-PWI Boom for ESA JUICE Mission
Maciej Borys, Ewelina Ryszawa, Łukasz Wiśniewski, Maciej Ossowski & Jerzy Grygorczuk, Astronika Sp.Z.o.o, Warsaw, Poland
- Development of a Family of Resettable Hold-Down and Release Actuators based on SMA Technology and Qualification of Different Application Systems
Marcelo Collado Martinez, Cayetano Rivera & Javier Inés, Arquimea Ingenieria, S.L., Madrid, Spain; José San Juan, University of the Basque Country, Leioa, Spain; Charlie Yeates & Michael Anderson, ESR Technology Ltd, Warrington, UK;

Francisco Javier Rivas, Airbus Defence and Space, Madrid, Spain; Mónica Iriarte, AVS, Elgoibar, Spain; Jens Steppan, SpaceTech GMBH, Immenstaad, Germany; Calem Whiting & Karine Murray, Surrey Satellite Technology Limited, Guildford, UK

- Development and Post-Testing Anomalies of the Parker Solar Probe Clamshells Development
Mark Bryant, Johns Hopkins University Applied Physics Laboratory, Laurel, MD

11:50 LUNCH

Lunch for AMS Attendees in the Greenway Ballroom

12:50 SESSION III - SAMPLING FROM ROVER

Session Chair: Louise Jandura, Jet Propulsion Laboratory, Pasadena, CA

- Mars 2020 Rover Adaptive Caching Assembly: So Many Challenges
Milo Silverman & Justin Lin, Jet Propulsion Laboratory, Pasadena, CA
- Sealing Station Mechanisms for the Mars 2020 Rover Sample Caching Subsystem
Jesse Grimes-York & Sean O'Brien, Jet Propulsion Laboratory, Pasadena, CA
- Design and Development of a Robust Chuck Mechanism for the Mars 2020 Coring Drill
Anthony Barletta, Jet Propulsion Laboratory, Pasadena, CA
- Percussion Mechanism for the Mars 2020 Coring Drill
Kyle Chrystal, Jet Propulsion Laboratory, Pasadena, CA
- STIG: A Two-Speed Transmission Aboard the Mars 2020 Coring Drill
Timothy Szwarc, Jet Propulsion Laboratory, Pasadena, CA;
Jonathan Parker, Sierra Nevada Corp, Durham, NC;
Johannes Kreuser, CEROBEAR GmbH, Herzogenrath, Germany

2:55 BREAK

3:10 SESSION IV - POTPOURRI OF POSTERS

Session Chair: Lance Lininger, Lockheed Martin Space, Denver, CO

- Development of the Next Generation Battery Cell Isolation Switch
Ruben Betancourt & Michel Knight, Ensign-Bickford - NEA Electronics Inc., Moorpark, CA
- A Fast-Acting Self-Energized, Low-Cost Valve for Air Cannons
Lee Brown, Electronics Development Corporation, Columbia, MD
- Development of a Low-Shock Separation Nut Out of the Pyrotechnic Class
Sebastien Perez, Frederic Miralles & François Degryse, Pyroalliance, Les Mureaux, France
- Lubricant Degradation in High-Load, High-Cycle Actuator Test Using Heritage Harmonic Drives for the Multi-Angle Imager for Aerosols Instrument
Michelle Easter, Jet Propulsion Laboratory, Pasadena, CA
- Multi-Mission Deployable Boom: Spring Mechanism Design, Failure Investigation, and Resolution
Christine Gebara & Paul Lytal, Jet Propulsion Laboratory, Pasadena, CA
- NSI Performance Improvement Through the use of Automation

Jason Kozmic, Bill Gratzl & Hobin Lee, Chemring Energetic Devices, Downers Grove, IL

- Microvibrations Modelling and Measurement on Sentinel 4 UVN Calibration Assembly using a Piezoelectric 6 Component Force Dynamometer
Benoit Marquet, Université de Liège, Centre Spatial de Liège, Angleur, Belgium
- Lubrication Concept Evaluated for Geared Actuators under Starved Conditions
Erik Nyberg & Ichiro Minami, Luleå Tekniska Universitet, Luleå, Sweden; Jonny Hansen, Scania CV AB, Södertälje, Sweden
- Development of a Universal and Scaleable Mechanism Control Electronics Configured to Application Solely by Parameter and Software Configuration
Udo Rapp & Juan Camilo Garcia Hernandez, Airbus Defence & Space, Friedrichshafen, Germany
- Eddy Current Effects in Spacecraft Mechanisms
Emilia Wegrzyn, Surrey Space Centre, Guildford, United Kingdom; Claudia Allegranza, ATG Europe, Noordwijk, The Netherlands; Thomas Adam, Florian Liebold & René Seiler, ESA/ESTeC, Noordwijk, The Netherlands

4:45 SESSION V - BEARINGS & TRIBOLOGY

Session Chair: Lionel Gaillard, ESA/ESTeC, Noordwijk, The Netherlands

- Recovery and Operational Best Practices for Reaction Wheel Bearings
Michael Dube, NASA Langley Research Center, Hampton, VA; Jeff Fisher, Fisher Aerospace, Sunnyvale, CA; Stuart Loewenthal, Lockheed Martin Space, Sunnyvale, CA; Peter Ward, The Aerospace Corporation, El Segundo, CA
- Laboratory Studies of Spacecraft Fluid Lubricant Mobility and Film Thickness
Peter Frantz James Helt & Steve Didziulis, The Aerospace Corporation, El Segundo, CA
- Efficacy of Lead Naphthenate for Wear Protection in High Vacuum Space Mechanisms
Jason Galary, NYE Lubricants, Inc., Fairhaven, MA
- Bearing Anomaly for the Sentinel 6 Supplemental Calibration System
Gale Paulsen, Dylan Van Dyne, Fredrik Rehnmark & Phil Chu, Honeybee Robotics Spacecraft Mechanisms Corporation, Altadena, CA; Ted Iskenderian, Jet Propulsion Laboratory, Pasadena, CA

6:00-10:00 RECEPTION - Omni Houston Hotel - Greenway Ballroom

Posters are displayed, invited component suppliers display current products and provide tutorials, FIRST Robotics Team demonstrations, and a buffet meal.

THURSDAY, 3 DECEMBER 2020

7:00 Thursday Presenters' Breakfast - Westbury Salon

8:00 SESSION VI - DEPLOYMENT

Session Chair: Damon Delap, NASA Glenn Research Center, Cleveland, OH

- Parker Solar Probe MAG Boom Design, Analysis and Verification
Weilun Cheng, Calvin Kee & John Wirzburger, Johns Hopkins University Applied Physics Laboratory, Laurel, MD
- Development of a Low-Shock Payload Fairing Jettison System

Boris Halter, Josef Zemann, Simon Wieser, Beatrice Burkhart, Mathias Burkhalter, Alberto Sánchez & Oliver Kunz, RUAG Space Switzerland, Zurich, Switzerland

- Deployment Mechanism for an Earth Re-Entry Deployable Decelerator
Carl Kruger, NASA Ames Research Center, Moffett Field, CA
- Lessons Learned During the Development, Qualification, and Production of the MM Solar Array
Thomas Pace, Lockheed Martin Space, Sunnyvale, CA
- Solid-State Hinge Mechanism for Simple Panel Deployment System
Thomas Rose, William Hensley & William Francis, Rocco, Longmont, CO

10:05 BREAK

10:20 SESSION VII - ROVER MECHANISMS

Session Chair: Bill Caldwell, NASA Ames Research Center, Moffett Field, CA

- Mars 2020 Motor Bearing Failure, Investigation and Response
Dave Suffern, Jeff Mobley & Stephen Smith, Sierra Nevada Corporation, Durham, NC
- Mars 2020 maxon Commercial Motor Development from Commercial-Off-the-Shelf to Flight-Qualified Motors, Gearboxes, and Detent Brakes: Overcoming Issues and Lessons Learned
Michael LoSchiavo & Rebecca Mikhaylov, Jet Propulsion Laboratory, Pasadena, CA; Robin Phillips & Lynn Braunschweig, maxon motor ag, Sachseln, Switzerland
- Mars 2020 Center Differential Pivot Restraint: Flexurized Spring System Providing Compliance for Rover Mobility Deployment Prior to Landing
Matt Cameron & Kevin Liu, Jet Propulsion Laboratory, Pasadena, CA

11:35 LUNCH

Lunch for AMS Attendees in the Greenway Ballroom

12:35: SPECIAL PRESENTATION

EVA 23 - Lessons Learned from a Spacewalking Close Call

Chris Hansen, Manager, EVA Office at NASA Johnson Space Center

Hear why water and space suits don't mix in micro-gravity



1:35 SESSION VIII - MANNED SPACE AND AN UPDATE TO AIAA S-114-2005

Session Chair: Chris Hansen, NASA Johnson Space Center, Houston, TX

- Astrobee Free-Flyer Nozzle Mechanism
Earl Daley, NASA Ames Research Center, Mountain View, CA

- Major Design Choices and Challenges that Enabled the Success of the Ejectable Data Recorder System
Jeff Hagen, Michael Burlone & Kristina Rojdev, NASA Johnson Space Center, Houston, TX
- Design and Test of the Orion Crew Module Side Hatch
Lance Lininger, Lockheed Martin Space, Denver, CO; Kyle Gotthelf, Honeybee Robotics, Longmont, CO
- Design, Development, Testing, and Flight of the Crew Dragon Docking System
Jaret Matthews, Caitlin Driscoll, Edward Fouad & Andrew Welter, SpaceX, Hawthorne, CA;
Marc Jamulowicz & Jessica Ipnar, Dynamic Concepts, Inc., Huntsville, AL
- Highlights of the Next Generation AIAA Moving Mechanical Assemblies Standard
Brian Gore & Leon Gurevich, The Aerospace Corporation, El Segundo, CA

3:40 BREAK

3:55 INVITED PRESENTATION - NASA Astronaut Don Pettit, who is a veteran of two long-duration stays aboard the International Space Station, one space shuttle mission, and a six-week expedition to find meteorites in Antarctica.



7:00-11:00 BANQUET - Morian Hall of Paleontology at the Houston Museum of Natural Science. Busses start loading at 6:00 PM
Dinner, planetarium and numerous scientific exhibits.

FRIDAY, 4 DECEMBER 2020

7:30 Friday Presenters' Breakfast - Westbury Salon

8:30 SESSION IX - COMPLIANT MECHANISMS

Session Chair: Adam Dokos, NASA Kennedy Space Center, Kennedy Space Center, FL

- Micro-Vibration Attenuation Using Novel Flexible Pivot Design
Luc Blecha, Yoël Puyol, Simon Hayoz, & Fabrice Rottmeier, Almatech SA, Lausanne, Switzerland; Martin Humphries, SpaceMech Ltd., Bristol, UK
- Compliant Mechanisms Made by Additive Manufacturing
Lionel Kiener, Hervé Saudan, Florent Cosandier, Gérald Perruchoud, Vaclav Pejchal, Sébastien Lani & Antoine Verhaeghe, Centre Suisse d'Electronique et de Microtechnique S.A., Neuchâtel, Switzerland

- Flexible Waveguides for RF Transmission across PSP HGA Rotary Actuator
Deva Ponnusamy, Weilun Cheng, Ted Hartka, Devin Hahne, Calvin Kee, Mike Marley & David Napolillo, Johns Hopkins University Applied Physics Laboratory, Laurel, MD

9:45 BREAK

10:00 SESSION X - ACTUATORS

Session Chair: Benjamin Nickless, NASA Langley Research Center, Hampton, VA

- Thermal Vacuum Testing Lessons Learned for Small Stepper Motors and a CubeSat Translation Mechanism
Alex Few, Lynn Albritton & Don McQueen, NASA Marshall Space Flight Center, Huntsville, AL
- Design and Development of the GPM Solar Array Drive Assembly, Orbital Performance and Lessons Learned
Alejandro Rivera & Glenn Bock, KBR Inc. - Space Engineering Division, Greenbelt, MD; Alphonso Stewart, Jon Lawrence, Daniel Powers, Gary Brown & Rodger Farley, NASA Goddard Space Flight Center, Greenbelt, MD
- Two-Axis Antenna Pointing Mechanism Qualification for Juice Mission Dual-Band Medium Gain Antenna
Jorge Vázquez, Mikel Prieto, Jon Laguna & Antonio Gonzalez, Sener Aeroespacial, Gexto, Spain

11:15 SPECIAL PRESENTATION ABOUT NASA JOHNSON SPACE CENTER

11:45 TECHNICAL SESSIONS CONCLUSION

Stu Loewenthal, Lockheed Martin Space, Sunnyvale, CA

- Herzl Award Presentation

Brandan Robertson, NASA Johnson Space Center, Houston, TX

- Wrap up and logistics

12:00 LUNCH

Lunch for AMS Attendees in the Superior Ballroom, Section D

1:00-5:00 TOUR

1:00 Buses depart hotel for tour

5:00 Approximate time buses return to hotel (at least one bus will go directly to William P. Hobby Airport after tour)

SYMPOSIUM ORGANIZING COMMITTEE

Host Chair - Brandan Robertson, NASA JSC

General Chairman - Edward A. Boesiger, Lockheed Martin Space
Deputy Chairman - Stuart H. Loewenthal, Lockheed Martin Space

William Caldwell, NASA ARC
Damon C. Delap, NASA GRC
Jared A. Dervan, NASA MSFC
Adam G. Dokos, NASA KSC
Michael J. Dube, NASA NESC
Carlton L. Foster, NASA MSFC (retired)
Lionel Gaillard, ESA/ESTeC
Claef F. Hakun, NASA GSFC
Christopher P. Hansen, NASA JSC
Louise Jandura, JPL
Alan C. Littlefield, NASA KSC (retired)
Ronald E. Mancini, NASA ARC (retired)
Fred G. Martwick, NASA ARC
Donald H. McQueen, Jr., NASA MSFC
Robert P. Mueller, NASA KSC
Benjamin J. Nickless, NASA LaRC
Joseph W. Pellicciotti, NASA HQ
Minh Phan, NASA GSFC
Joseph P. Schepis, NASA GSFC
Donald R. Sevilla, JPL
James E. Wells, NASA LaRC
Jonathan P. Wood, Lockheed Martin Space

www.aeromechanisms.com