CONFERENCE PROGRAM

American Society for
Precision Engineering

36TH ANNUAL MEETING
NOVEMBER 1-5, 2021

RENAISSANCE MINNEAPOLIS HOTEL
THE DEPOT
MINNEAPOLIS, MN, USA

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WELCOME TO THE 36th ANNUAL MEETING!

On behalf of the ASPE members, the organizing and technical committees and the ASPE Board of Directors, ASPE welcomes you to its 36th Annual Meeting in Minneapolis, Minnesota. As the premier precision engineering meeting in the USA, this year's conference will continue the tradition of offering the latest in precision engineering research through oral and poster presentations in the areas of controls and mechatronics, characterization and metrology, micro and nano technology, replicated optics and precision design and manufacturing. Professor Rainer Weiss, Nobel Prize winner and Professor at Massachusetts Institute of Technology will deliver the Keynote Address, which will take place Tuesday evening, November 2nd. The program will bring attendees vital information for their precision engineering endeavors – the latest technical research, unparalleled education opportunities via tutorials taught by experts in the field, commercial vendors that can help achieve high precision results for whatever the challenge, and of course, ample opportunities to build meaningful professional connections.

About Minneapolis. The history of Minneapolis is closely tied to the Mississippi River. Less than 2 blocks from the hotel is the river and Mill Ruins Park where the St. Anthony Falls provided energy to power the largest flour milling region in the world. Grain was brought to these mills from the west by train. The venue for the ASPE meeting is The Depot, a train station from that era. The Pillsbury Dough Boy and Wheaties (Breakfast of Champions from General Mills) started during this time and are still contributing to the economy today. Another agriculture related company from the same time is Cargill Corporation, the largest private company in the U.S. Later, Minneapolis became known for Honeywell and many early computer companies including Control Data, Univac, and Cray Supercomputers. IBM had a disk drive manufacturing in the area and Seagate still has a large presence in Minneapolis. The first implantable heart pacemaker was developed by Earl Bakken in his garage. The resulting company, Medtronic, grew and spawned many other medical device companies. Minneapolis remains a hotbed for medical device manufacturing today. During the week, take some time to walk across the stone arch bridge to the cobblestone street of the original Main Street and see the Pillsbury A-Mill, the largest flour mill in the world for 40 years when it was completed in 1881. Imagine its 2 direct drive waterwheels generating almost 900 kilowatts each (1,200 horsepower each). Then relax and have a drink while overlooking the river.

The organizing committee is proud to present this program for the 36th Annual Meeting of the American Society for Precision Engineering. We welcome your participation whether you are here in person or in your own home.

Organizing and Technical Program Committee

Annual Meeting Chairperson
Don Martin, Martin Mason LLC

Technical Program Committee Chairpersons
Mr. Jim Nelson, 3M Company
Mr. Alexander Sohn, Facebook
Special Session on Replicated Optics

Prof. Michael A. Cullinan, The University of Texas at Austin
Micro-Nano Technologies

Dr. Jonathan D. Ellis, Clerio Vision, Inc.
Metrology Systems

Dr. Stephen J. Furst, Smart Material Solutions, Inc.
Precision Manufacturing

Prof. Richard K. Leach, University of Nottingham
Characterization

Mr. Adam Jaycox, Lawrence Livermore National Laboratory
Precision Design

Prof. David L. Trumper, Massachusetts Institute of Technology
Controls and Mechatronics

Tutorials Chairs
Dr. Vivek G. Badami, Zygo Corporation
Dr. Stephen J. Ludwick, Aerotech, Inc.

Exhibits Session Chair
Dr. Byron R. Knapp, Professional Instruments Company

Students and Young Members Chairs
Mr. Luis A. Aguirre, 3M Company
Prof. Stuart T. Smith, University of North Carolina – Charlotte

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Hongliang Shi, KLA-Tencor
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David L. Trumper, Massachusetts Institute of Technology

ASPE gratefully acknowledges the time and the effort given by the Organizing and Technical Program Committee to bring the precision engineering community this program.

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ASPE would like to thank our Corporate Sponsors.

ASPE LIFETIME ACHIEVEMENT AWARD

Professor Jan van Eijk
MICE bv

Prof. Jan van Eijk is a world leader in the development of high- precision mechatronics and a dedicated teacher committed to promoting and growing the mechatronic community. Prof. van Eijk began his career at the Philips Centre for Manufacturing Technology where he engrained the complementary practices of thoroughly understanding the fine technical details of each problem while articulating them in accessible descriptions that encouraged participation from the broader community. This deterministic approach to mechatronic system design is perhaps best exemplified by his contribution to the architecture of ASML's lithography tools. Prof. van Eijk continues to teach and promote these principles through his consulting company MICE BV, as a partner and trainer at the Mechatronics Academy, and through tutorials at ASPE and euspen meetings.

ASPE DISTINGUISHED SERVICE AWARD

Dr. David L. Trumper
Massachusetts Institute of Technology

David L. Trumper joined the MIT Department of Mechanical Engineering in August 1993, and holds the rank of Professor. He received the B.S., M.S., and Ph.D. degrees from MIT in Electrical Engineering and Computer Science, in 1980, 1984, and 1990, respectively. Following the Bachelor's degree, Professor Trumper worked two years for the Hewlett-Packard Co. After finishing the Master's degree, he worked for two years for the Waters Chromatography Division of Millipore. Upon completing the Ph.D. degree, for three years he was an Assistant Professor in the Electrical Engineering Department at the University of North Carolina at Charlotte, working with Prof. Bob Hocken in the precision engineering group during the start-up of that program. Dr. Trumper's research centers on the design of precision mechatronic systems, with a focus on the design of novel mechanisms, actuators, sensors, and control systems.

He has conducted research in topics including precision motion control, highperformance manufacturing equipment, novel measurement instruments, biomedical and bioinstrumentation devices, and high-precision magnetic suspensions and bearings. Dr. Trumper has been a member of ASPE since 1991, and has previously served on the board of directors and as ASPE President. He has also been co-chair of a series of six topical meetings on the Control of Mechatronic Systems, with the most recent meeting held in virtual format in May, 2020.

** ASPE Staff take full responsibility for the program error and offer our sincerest apologies.*

2021 Scholarships Recipients

Graham J. Siddall ASPE Student Scholarship

The winner of the 2021 Graham J. Siddall ASPE Student Scholarship is Ian L. Heyman. This award includes the ASPE Annual Meeting registration fee and 4 tutorial fees.

With a 10-year student endowment, Graham Siddall will recognize a student scholar in the field of precision engineering. This prestigious award is valued at $1,000 and additionally will support the student winner in the form of waived conference and tutorial fees. Graham Siddall received his BS degree in Production Engineering and Management with First Class honors from the University of Nottingham in England. He received his M.Sc. and Ph.D. degrees in Natural Philosophy (Physics) in 1971 and 1975, respectively, working under the guidance of Professor R.V. Jones at the University of Aberdeen in Scotland.

After working in surface metrology at Rank Taylor Hobson in Leicester, England, Dr. Siddall was awarded a Lindemann Research Fellowship to the United States where he joined the team at Stanford University working on the NASA/Stanford Gyro Relativity Experiment. His work at Stanford focused on developing the metrology techniques and equipment needed to manufacture the very precise spherical quartz rotors used in the cryogenic gyroscopes for the GP-B space mission. Following this, Dr. Siddall joined Hewlett-Packard Labs in Palo Alto, working in the X-ray and E-beam Lithography group, primarily in the area of precision stage design. He went on to become the Vice President of research, development and engineering at GCA Corporation which marked the beginning of a long and distinguished stint in semiconductor capital equipment. Following GCA, in 1988, Dr. Siddall joined Tencor Instruments in California as Vice President of Technical Marketing and later became its first Chief Operating Officer. Over the next ten years the Company grew tenfold and merged with KLA in 1997, to form KLA-Tencor Corporation, where Dr. Siddall led the multi-billion dollar Wafer Inspection Group as Executive Vice President. In July 1999, he left KLA to join Credence Systems, a semiconductor test equipment company, as its President and Chief Executive Officer and then later, as Chairman of the Board, before retiring in October 2005.

Following a number of Board positions in the semiconductor and electronics industry, most recently as Chairman of the Board of DCG Systems, Inc., Dr. Siddall has now relocated to the Pacific Northwest and has developed an interest in the area of eye research and the mitigation of eye disease. He is an active member of the University of Washington Medicine Eye Institute Community Action Board and has become an investor in the field of medical instrumentation startups. In 2016 he was awarded an Honorary Doctorate (D.Sc.) by Aberdeen University for his technical, business and philanthropic achievements.

ASPE Student Scholarships

ASPE is proud to award two student scholarships for the 36th Annual Meeting. This year's scholarship recipients are Zhidi Yang and Hilary Johnson. The ASPE Student Scholarships include a waiver of the Annual Meeting registration fee and 4 tutorials fees.

STUDENT CHALLENGE

Luncheon
Monday, November 1
12:30 PM – 1:30 PM
Hiawatha 1 & 2

Working Session
Monday, November 1
5:30 PM – 11:00 PM
Hiawatha 1 & 2

Student Judging & Presentations
(Everyone is welcome to attend)
Tuesday, November 2
12:30 PM – 1:30 PM
Hiawatha 3

Award Presentation
Thursday, November 4
12:00 PM – 1:30 PM
Great Hall

Student Challenge Organizing Committee

- Luis A. Aguirre – 3M Company
- Kumar Arumugam – NIST
- Dipankar Behara – UT Austin
- Paul Brackman – Zeiss
- Raymond C. Cady – Corning
- Jacob Cole – UNC Charlotte
- Liam G Connolly – UT Austin
- Tim Dalrymple
- Drew Devitt – New Way Bearings
- Chunjie Fan – UNC Charlotte
- Mark T. Kosmowski – Electro-Scientific Industries, Inc.
- Mark Schmitt
- Don Martin – Martin Mason LLC
- Senajith Bandara Rekawa – Lawrence Berkeley Laboratories
- Nilabh Roy – Canon Nanotechnologies
- Stuart Smith – UNC Charlotte
- Alex Sohn – Facebook Reality Labs
- Trevor Stolber – 3M company

The Student Challenge and Its Mission

The American Society for Precision Engineering is hosting its 7th Annual Student Challenge. The Student Challenge was created to help ASPE develop new talent that not only understands the basic engineering principles, but talent who can also use their hands to quickly build prototypes that demonstrate those principles. The Student Challenge endeavors to bring together students who are studying in the areas of precision engineering – controls and mechatronics; machine design, precision manufacturing, characterization, metrology and micro and nano technologies – and organizations looking for students who are studying in these areas.

The 2021 Challenge

The goal of the Student Challenge is to build an instrument that uses the Watt balance principle to measure a series of masses. Voice coil actuators will be supplied to provide the necessary forces to counteract the weight of the masses. Measurement of displacement and velocity will be achieved using optical knife edge sensors (KES), the characteristics of which will be provided. For more precise displacement measurement in the final assembly at the competition, a Lion Precision capacitance gage (model #CPL591) having a measurement range of 0.5 mm will be available to each team.

Grading for the challenge will be based on design and creativity of the instrument (10%), a comprehensive uncertainty budget (20%), a preliminary design report (20%), and performance at the competition (50%) for accuracy, linearity and repeatability.

Mechblocks, voice coil actuators, voltage to current amplifiers, knife edge sensors, a supplied 16 bit ADC (4 channel) and 16 bit DAC (2 channel), and the Lion Precision capacitance gages will be the only components that can be used. A National Instruments myRIO will be supplied (if necessary) for controlling the assembled instrument and acquiring position information. A complete spreadsheet containing detailed information plus component STEP files will be available to all teams.

CHALLENGE SPONSORS

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Lawrence Livermore National Laboratory

KEYNOTE ADDRESS

Tuesday, November 2, 2021
6:00 PM – 7:00 PM
Great Hall

Dr. Rainer Weiss, MIT
on behalf of the LIGO Scientific Collaboration

ASPE is pleased to announce that **Dr. Rainer Weiss** will be the Keynote Speaker at the 36th Annual Meeting in Minneapolis.

RAINER WEISS SB ’55; PhD ’62 (NAS) is a Professor Emeritus at Massachusetts Institute of Technology (MIT). Previously Dr. Weiss served as an assistant physics professor at Tufts University and has been an adjunct professor at Louisiana State University since 2001. Dr. Weiss is known for his pioneering measurements of the spectrum of the cosmic microwave background radiation, his inventions of the monolithic silicon bolometer and the laser interferometer gravitational wave detector and his roles as a co-founder and an intellectual leader of both the COBE (microwave background) Project and the LIGO (gravitational-wave detection) Project. He has received numerous scientific and group achievement awards from NASA, an MIT excellence in teaching award, the John Simon Guggenheim Memorial Foundation Fellowship, the National Space Club Science Award, the Medaille de l’ADION Observatoire de Nice, the Gruber Cosmology Prize, and the Einstein Prize of the American Physical Society. Dr. Weiss is a fellow of the American Association for the Advancement of Science, the American Physical Society, The American Academy of Arts and Sciences; and he is a member of the American Astronomical Society, the New York Academy of Sciences, and Sigma Xi.

He received his B.S. and Ph.D. in physics from MIT. Dr. Weiss is a member of the NAS and has served on nine NRC committees from 1986 to 2007 including the Committee on NASA Astrophysics Performance Assessment; the Panel on Particle, Nuclear, and Gravitational-wave Astrophysics; and the Task Group on Space Astronomy and Astrophysics.

TUTORIALS

Wednesday October 27 – Tuesday November 2, 2021

Wednesday, October 27, 2021 – AM Tutorials - 8:30 AM - 12:30 PM

"Emerging Nanofabrication Technologies"
Dr. S.V. Sreenivasan, University of Texas at Austin

"Linear Motors"
Dr. Renato Lyra, Aerotech

Wednesday, October 27, 2021 – PM Tutorials – 1:30 PM – 5:30 PM

"System Identification"
Dr. Stephen Ludwick, Aerotech

Thursday, October 28, 2021 – AM Tutorials – 8:30 AM – 12:30 PM

"Precision Balancing, Static Balance in Precision Engineering"
Dr. Jan de Jong, University of Twente

"Scrum for Hardware Design"
Dr. David G. Ullman and Dr. Joshua Tarbutton, UNC Charlotte

Thursday, October 28, 2021 – PM Tutorials - 1:30 PM - 5:30 PM

"Angle Metrology"
Bryon Faust, National Institute of Standards and Technology (NIST)

Friday, October 29, 2021 – AM Tutorials – 8:30 AM – 12:30 PM

"Diamond Turning of Freeform Optics"
Dr. Matt Davies, University of North Carolina at Charlotte

Friday, October 29, 2021 – PM Tutorials - 1:30 PM - 5:30 PM

"Vibrometry"
Tobias Ban, Vibrations Inc.

Monday, November 1, 2021 – AM Tutorials - 8:30 AM - 12:30 PM

"Principles of Precision Machine Tool Design – 1"
Mark Stocker, Cranfield Precision, Division of Fives Landis Ltd.

"Vibration Isolation"
Han Hartgers & Ronald Kappel, Integrated Dynamics Engineering

"Modern Optical Fabrication"
Dr. Jessica DeGroote-Nelson, Optimax

Monday, November 1, 2021 – PM Tutorials - 1:30 PM - 5:30 PM

"Principles of Precision Machine Tool Design – 2"
Mark Stocker, Cranfield Precision, Division of Fives Landis Ltd.

Tuesday, November 2, 2021 – AM Tutorials – 8:30 AM – 12:30 PM

"Introduction to Lens Design"
Dr. Julie Bentley, University of Rochester

"Flexures – 1"
Dr. Stuart Smith, UNC Charlotte; Dr Kumar Arumugam, NIST; and Dr. Marijn Nijenhuis, University of Twente

"Thermal Effects – 1"
Dr. Theo Ruijl, MI Partners

Tuesday, November 2, 2021 – PM Tutorials – 1:30 PM – 5:30 PM

"Automated Surface Defect Inspection"
Drew Schiltz, Zeiss Industrial Quality Solutions

"Flexures – 2"
Dr. Stuart Smith, UNC Charlotte; Dr Kumar Arumugam, NIST; and Dr. Marijn Nijenhuis, University of Twente

"Thermal Effects – 2"
Dr. Theo Ruijl, MI Partners

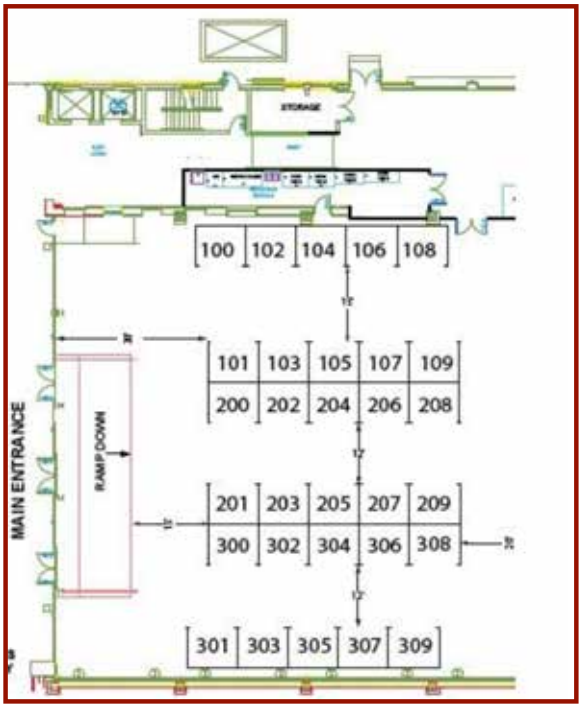
"Optical Alignment Techniques"
Robert Parks, Optical Perspectives Group

COMMERCIAL EXHIBITION & FLOORPLAN

Wednesday, November 3
9:00 AM to 6:00 PM
Depot Pavilion

Thursday, November 4
9:00 AM to 6:00 PM
Depot Pavilion

Friday, November 5
9:00 AM to 1:00 PM
Depot Pavilion



Organization	Booth #
ABTech Inc	102
Aerotech, Inc	100
Ametek Precitech	101
Attocube Systems Inc	308
Bal-TEC Micro Surface Engr. Inc	300 & 302
Chardon Tool	209
Corning Tropel Corporation	103
DEWESoft, LLC	207
Heidenhain Corporation	201
IST Precision	306
K&Y Diamond	200
Kern Precision Inc.	202
Lion Precision	109

Organization	Booth #
Micro-LAM, Inc.	304
Moore Nanotechnology Systems	204
New Way Air Bearings	203
NTS Development & Engineering	107
Optical Perspectives Group	106
Praecis, Inc	104
Professional Instruments Company	108
Queensgate, a brand of Prior Scientific	208
Renishaw, Inc.	301
Schneider Optical Machines Inc	309
Starrett Tru-Stone Technologies	206
UNC-Charlotte	205
Vermont Photonics	305

COMMERCIAL SESSIONS

Wednesday, November 3
1:30 PM - 3:00 PM
Great Hall

Chairpersons
Byron R. Knapp, Professional Instruments Company
Brian P. O'Connor, Aerotech, Inc.

The Commercial Sessions are open to all attendees of the 36th ASPE Annual Meeting and to guests of exhibitors. During the Commercial Sessions, ASPE's Exhibitors make brief presentations on their products and services. This provides participants with the opportunity to receive timely information on technologies that have been commercialized into products and services, as well as information on advances that can be expected in the near future. Each commercial presentation is 2 minutes, and each organization is listed in the order that it will present.

Organization	Category
ABTech Inc	Air Bearings
New Way Air Bearings	Air Bearings
Professional Instruments Company	Air Bearings
IST Precision	Engineering Services
NTS Group	Engineering Services
UNC-Charlotte	Engineering Services
Corning Tropel Corporation	Optics and Metrology
Optical Perspectives Group	Optics and Metrology
Vermont Photonics	Optics and Metrology
Zeiss	Optics and Metrology
Bal-TEC Micro Surface Engr. Inc	Precision Components
Heidenhain Corporation	Precision Components
Praecis, Inc.	Precision Components
Renishaw, Inc.	Precision Components
Starrett Tru-Stone Technologies	Precision Components

Organization	Category
Aerotech, Inc	Precision Motion
Attocube Systems Inc	Precision Motion
Chardon Tool	Precision Tools
K&Y Diamond	Precision Tools
Micro-LAM, Inc.	Precision Tools
DEWESoft, LLC	Sensors
Lion Precision	Sensors
Ametek Precitech	Ultra Precision Machine Tools
Kern Precision Inc.	Ultra Precision Machine Tools
Moore Nanotechnology Systems	Ultra Precision Machine Tools
Schneider Optical Machines Inc	Ultra Precision Machine Tools

ASPE 2021 Annual Meeting
Oral Sessions

Session 1 – Optomechanical sensing for Gravity, Acceleration, and Optical Power

Wednesday, November 3, 2021, 8:30 AM - 10:00 AM

Session Chair:
Felipe Guzman, Texas A&M University
Jon Pratt, National Institute of Standards and Technology

1. **Four Challenges Met in the Development of Laser Metrology for the LISA Gravitational Wave Detector***
   Spero, R. (California Institute of Technology)

2. **An Electrostatic Force Balance as a Primary Standard to Measure High Laser Power by a Multiple Reflection System**
   Schulze, S.; Keck, L.; Rogers, K.; Simonds, B.; Artusio-Glimpse, A.; Williams, P.; Lehman, J. (National Institute of Standards and Technology); Seifert, F. (National Institute of Standards and Technology;University of Maryland); Newell, D. (National Institute of Standards and Technology); Theska, R. (Technische Universität Ilmenau); Schlamminger, S.; Shaw, G. (National Institute of Standards and Technology)

3. **Membrane-based Optomechanical Accelerometry by a Multiple Reflection System**
   Chowdhury, M.D.; Agrawal, A.R.; Pluchar, C.M.; Wilson, D.J. (University of Arizona)

4. **An Experiment to Test the Mechanical Losses of Different Bonding Techniques in Fused Silica**
   Carter, J.J. (Max Planck Institute for Gravitational Physics (Albert Einstein Institute); Institut für Gravitationsphysik der Leibniz Universität Hannover); Birckigt, P. (Fraunhofer Institute for Applied Optics and Precision Engineering; Institute of Applied Physics, Abbe Center of Photonics, Friedrich-Schiller-Universitat Jena, Albert-Einstein-Str.) Gerberding, O. (Institut für Experimentalphysik); Li, Q. (Institute of Applied Physics, Abbe Center of Photonics, Friedrich-Schiller-Universitat Jena, Albert-Einstein-Str.); Strüning, R. (Institut für Gravitationsphysik der Leibniz Universität Hannover); Ullsperger, T. (Max Planck Institute for Gravitational Physics (Albert Einstein Institute); Koehlenbeck, S.M. (Albert Einstein Institute); Institut für Gravitationsphysik der Leibniz Universität Hannover)

5. **A New Spin on Kibble: A Self-Calibrating Torque Realization Device**
   Comden, Z. (National Institute of Standards and Technology; University of Maryland); Schlamminger, S. (National Institute of Standards and Technology) Perera, C.W.; Seifert, F.; (National Institute of Standards and Technology; University of Maryland); Newell, D.; Hendricks, J.; Goldstein, B.; Chao, L. (National Institute of Standards and Technology)

Session 2 – Precision Design

Wednesday, November 3, 2021, 10:30 AM - 12:00 PM

Session Chair:
Adam Jaycox, Lawrence Livermore National Laboratory

1. **Internal Feature Design for Increased Damping by Captured Powder**
   Schmitz, T.L. (The University of Tennessee, Knoxville; Oak Ridge National Laboratory); Corson, G.; Compton, B. (The University of Tennessee, Knoxville); Gomez, M. (Oak Ridge National Laboratory)

2. **Characteristics of Additively Manufactured Auxetic Materials for Spindle Vibration Mitigation**
   Kim, J.; Hegde; H. (Texas A&M University); Kim, H. (Korea Institute of Industrial Technology; Korea Polytechnic University); Lee, C. (Texas A&M University)

3. **High-speed Large-range Flexure-based Six-Axis Positioner**
   Yang, Z.; Hopkins, J. (University of California, Los Angeles)

4. **Improving Support Stiffness of Flexure Mechanisms by Statically Balancing**
   de Jong, J.J.; Theans, S.; Epping; L.J.; Brouwer, D.M. (University of Twente)

5. **Multi-Material Component Optimization via Hybrid Manufacturing**
   Jared, B.H.; Miramontes, E.; Hamel; W.R.; Penney, J.; Schmitz, T.L. (The University of Tennessee, Knoxville); Robbins, J. (Sandia National Laboratories)

6. **Design of the Mechanical System for the Quantum Electro-mechanical Metrology Suite**
   Keck, L. (National Institute of Standards and Technology; Technische Universität Ilmenau); Schlamminger, S. (National Institute of Standards and Technology); Seifert, F. (National Institute of Standards and Technology; University of Maryland); Newell, D. (National Institute of Standards and Technology); Theska, R. (Technische Universität Ilmenau); Haddad, D. (National Institute of Standards and Technology)

Session 3 – Micro Nano

Thursday, November 4, 2021, 8:30 AM - 10:00 AM

Session Chair:
Michael A. Cullinan, The University of Texas at Austin

1. **Accounting for Shrinkage in Functional Ceramic Structures Printed Through Two-Photon Polymerization**
   Cortes, J.; Mettry, M.; Worthington, M.; Chandrasekaran, S.; Panas, R.M. (Lawrence Livermore National Laboratory)

2. **Design and Verification of a Lens Focus Module Based on a Bi-directional Thermoelectric Actuator**
   van den Buecken, N. (NTS-Group, Eindhoven University of Technology)

3. **Large-Area Stitch-Free 3D Nano-Printing Based on Two-Photon Polymerization**
   Lu, W.; Shao, Q. (The Chinese University of Hong Kong); Chen, S. (The Chinese University of Hong Kong; Oxford-CityU Centre for Cerebro-Cardiovascular Health Engineering (CoCHE)

4. **Testing for Torsion During Nanoindentation**
   Fan, C.; Smith, S.T. (The University of North Carolina at Charlotte)

5. **Experimental Characterization of Heat Affected Zones for Fabricating Near-net Shaped Microscale Features**
   Behera, D.; Liao, A.; Cullinan, M.A. (The University of Texas Austin)

6. **Precision Systems for a Conformable, Capillary-Driven, Continuous Roll-to-Roll Nanoimprint Lithography Process**
   Pandya, P.N.; Jain, A. (The University of Texas at Austin); Gilpin, R.; Baines, J. (E+R Group); Sreenivasan, S.V. (The University of Texas at Austin)

Session 4 – Controls & Mechatronics

Thursday, November 4, 2021, 10:15 AM - 12:00 PM

Session Chair:
David L. Trumper, Massachusetts Institute of Technology

1. **Piezoelectric Shunt Damping in Cryogenic Conditions: Application to a Flexure-based Mechanism**
   Ambaum, N.; Vermeulen, J.P.M.B. (Eindhoven University of Technology); Mokrani, B. (ASML Netherlands)

2. **Intelligent Online Scan Sequence Optimization for Uniform Temperature Distribution in Laser Powder Bed Fusion**
   Okwudire, C.E.; Ramani, K.S.; He, C. (The University of Michigan)

3. **Thermal Error Compensation for Large Machine Tools**
   Ibabe, B.I.; Colinas-Armijo, N. (IDEKO); López de Lacalle, L.N. (EHU-UPV); Aguirre, G. (IDEKO)

4. **Magnetically Levitated XYZ-Nanopositioning Sample for X-Ray Microscopy**
   Heyman, I.; Ibrahim, M.; Zhou, L. (University of Texas at Austin)

5. **Frequency-dependency and Coupled Dynamics of Near Field Acoustic Levitation Bearing**
   Guo, P.; Wang, Y. (Northwestern University)

6. **Contact-free, Electrostatically-levitated Reticle Handoff in Photolithography Tools***
   Bhushan, B.M.; Trumper, D.L. (Massachusetts Institute of Technology)

7. **Active Control of High Frequency Regenerative Chatter Vibrations with Machine Tool Feed Drives**
   Sencer, B.; Dumanli, A. (Oregon State University)

Session 5 – Replicated Optics

Thursday, November 4, 2021, 1:30 PM - 3:00 PM

Session Chair:
Jim Nelson, 3M Company

1. **Single Point Diamond Turning of CVC SiC Using the Micro-LAM Process**
   Shahiniah, H.; Zhong, Y.; Turnbull, R.; Bodlapati, C.; Navare, J.; Mohammadi, H. (Micro-LAM, Inc.)

2. **Simulation and Comparative Metrology of Diamond Dies, Metal Molds, and Replicated Microlens Arrays for Mass Fabrication**
   Eaton, P. (North Carolina State University); Furst, S.J.; Cates, N.; Micklow, L. (Smart Material Solutions, Inc.); Pankow, M. (North Carolina State University)

3. **Metrology of Ultra-High Precision Stamped Metallic Optical Mirrors for Photonics Packaging and Ultraviolet LED Applications**
   Chen, Y.; Johnstone, R.; Hii, K.; Vallance R.R. (CudoForm, Inc.)

4. **Precision in Roll-2-Roll Printed Electronics: Keynote**
   Spaan-Burke, T.M.; van der Nolle, R.; de Vries, J.; Daneshkhah, B.; Felius, M.; Overschie, P.; Hannot S. (IBS Precision Engineering)

5. **Single-Point Diamond Turning of Features with Large Azimuthal Slope**
   Sohn, A.; Naples, N. (Facebook Reality Labs)

Session 6 – Replicated Optics

Friday, November 5, 2021, 8:30 AM - 10:00 AM

Session Chairs:
Jonathan D. Ellis, University of Arizona
Richard K. Leach, University of Nottingham

1. **Qualitative Edge Topology Inspection and Interpretation by Enhanced Knife-Edge Interferometry**
   Lee, C.; Wang, Z. (Texas A&M University)

2. **The Effect of Motion Blur on Photogrammetric Measurements of a Robotic Moving Target**
   Isa, M.A. (University of Nottingham); Leach, R.K. (University of Nottingham; Taraz Metrology); Branson, D.; Piano, S. (University of Nottingham)

3. **Preliminary Study on Fluorescence Strobo-Stereoscopy for 3D Surface Imaging**
   Guo, X.; Lee, C. (Texas A&M University).

4. **Ultra-High-Speed Micromachining Spindle Metrology under Radial Loading Conditions**
   Nahata, S.; Ozdoganlar, O.B.(Carnegie Mellon University)

5. **Lateral Shift Mapping for Absolute Metrology of Acylindrical X-ray Telescope Mirrors**
   Wisniewski, H.J. (The University of Arizona); Whalen, M.M; Heilmann, R.K.; Shattenburg, M.L. (Massachusetts Institute of Technology); Chalifoux, B.D. (The University of Arizona)

6. **A Pilot Study on Uncertainty Analysis for Stereo-vision Photogrammetry**
   Lifei, R. (The Hong Kong Polytechnic University; Zhejian University); Fai, C.C. (The Hong Kong Polytechnic University); Yanlong, C. (Zhejian University) Da, L. (The Hong Kong Polytechnic University); Jiangxin, Y.; Yanpeng, C. (Zhejian University)

Session 7 – Precision Manufacturing
Friday, November 5, 2021, 10:30 AM - 12:00 PM

Session Chair:
Stephen J. Furst, Smart Material Solutions, Inc.

1. **Single Point Diamond Cutting of High-Aspect Ratio V-Grooves: Alternative Flank Cutting Strategy and Preliminary Burr Formation Analysis**
   Rangel, O.F.; Tutunea-Fatan, R. (Western University); Bordatchev, E.V. (National Research Council of Canada)

2. **Tool Wear Evaluation Using a Constrained-motion Dynamometer**
   Gomez, M. (Oak Ridge National Laboratory); Schmitz, T.L. (Oak Ridge National Laboratory; University of Tennessee, Knoxville)

3. **Integral Blade Rotor Milling Improvement by Physics-guided Machine Learning**
   Corson, G. (University of Tennessee, Knoxville); Karandikar, J. (Oak Ridge National Laboratory); Schmitz, T.L. (University of Tennessee, Knoxville; Oak Ridge National Laboratory)

4. **A New Diamond Turning Model for Generating a Scratch-Free Surfaces in AL 6061 with Embedded Hard Particles**
   Ding, X.; Roblee, J. (AMETEK Precitech Inc.)

5. **Ductile Cutting Regime in Diamond Milling of Monocrystalline Silicon**
   Groeb, M. (Kern Microtechnik GmbH; Technical University of Darmstadt); Fritz, M. (Kern Microtechnik GmbH); Groeb, J. (Independent Researcher); Ensinger, W. (Technical University of Darmstadt)

6. **Ultrafast Laser Stress Figuring of Fused Silica Mirrors**
   Laverty, K.A.; Arnold, I.J.; Chalifoux, B.D. (University of Arizona)

ASPE 2021 Annual Meeting
Poster Sessions

Wednesday, November 3, 2021, 3:30 PM – 5:00 PM
Thursday, November 4, 2021, 3:30 PM – 5:00 PM

1. **Fundamental Precision Limit of Frequency Measurement of Linear Harmonic Oscillators**
   Wang, M. (National Institute of Standards and Technology; University of Maryland); Zhang, R. (Worcester Polytechnic Institute); Ilic, R. (National Institute of Standards and Technology); Liu, Y. (Worcester Polytechnic Institute); Aksyuk, V.A. (National Institute of Standards and Technology)

2. **CNC Machining and Metrology Training: ACE Program Update**
   Schmitz, T.L. (University of Tennessee, Knoxville; Oak Ridge National Laboratory); Cornelius, A.; Dvorak, J.; Nazario, J. (University of Tennessee, Knoxville); Betters, E. (University of Tennessee, Knoxville; Oak Ridge National Laboratory); Smith, S.; Blue, C. (Oak Ridge National Laboratory); Harmon, J.; Morrison, M.; Blevins, T.; Hopkins, J. (IACMI – The Composites Institute)

3. **Optical Knife-edge Displacement Sensor Modeling**
   Zameroski, R. (University of Tennessee, Knoxville); Gomez, M. (Oak Ridge National Laboratory); Schmitz, T.L. (University of Tennessee, Knoxville; Oak Ridge National Laboratory)

4. **Stability Analysis of a Constrained-motion Dynamometer**
   Gomez, M. (Oak Ridge National Laboratory); Schmitz, T.L. (University of Tennessee, Knoxville; Oak Ridge National Laboratory)

5. **Tool Wear Evaluation Using a Constrained-motion Dynamometer**
   Gomez, M. (Oak Ridge National Laboratory); Schmitz, T.L. (University of Tennessee, Knoxville; Oak Ridge National Laboratory)

6. **CNC Machining Considerations for WAAM Preforms**
   Dvorak, J.; Cornelius, A.; Corson, G.; Zameroski, R.; Jacobs, L.; Penney, J. (University of Tennessee, Knoxville); Schmitz, T.L. (University of Tennessee, Knoxville; Oak Ridge National Laboratory)

7. **Surface Metrology of a DED Lens AM Part: Optical Microscope***
   Morgan, W.; Yazzie, J.; Wilson, W. (Navajo Technical University); Valdez, M.O.; Montano, J.D. (V&M Global Solutions LLC), Haliday, H.S.; Shamugam, R.; Romani, M. (Navajo Technical University)

8. **Surface Metrology of a DED Lens AM Part: Contact Surface Profilometer***
   Yazzie, J.; Morgan, W.; Wilson, W. (Navajo Technical University); Valdez, M.O.; Montano, J.D. (V&M Global Solutions LLC), Haliday, H.S.; Shamugam, R.; Romani, M. (Navajo Technical University)

9. **Effects of Surface Treatments on ABS Mechanical Properties for Fused Filament Fabrication**
   Shen, J.; Patterson, M.R.; Marshall, E.; Dvorak, J.; Romberg, S.; Compton, B. (University of Tennessee, Knoxville) Schmitz, T.L. (University of Tennessee, Knoxville; Oak Ridge National Laboratory)

10. **A Prototype Contamination Inspection System for DUV/EUV Reticles**
    Papadakis Ktistakis, I.; Pawlowski, M.E.; Walsh, J.; Loke, C.; Bendiksen, A.; Munden, R.; Roux, S. (ASML)

11. **A Torsion Pendulum for Chip-scale Relative Gravimetry**
    Pratt, J.R.; Schlamminger, S. (National Institute of Standards and Technology); Agrawal, A.R.; Wilson, D.J. (University of Arizona)

12. **Optomechanical Inertial Sensors***
    Guzman, F. (Texas A&M University)

13. **Remote Bayesian Updating for Milling Stability**
    Karandikar, J. (Oak Ridge National Laboratory); Ramsauer, C.; Leitner, D. (University of Tennessee, Knoxville); Schmitz, T.L. (Oak Ridge National Laboratory; University of Tennessee, Knoxville); Bleicher, F. (University of Tennessee, Knoxville)

14. **Accounting for Shrinkage in Functional Ceramic Structures Printed through Two-photon Polymerization**
    Cortes, J.; Mettry, M.; Worthington, M.; Chandrasekaran, S.; Panas, R.M. (Lawrence Livermore National Laboratory)

15. **Precision Stamp-based Thin-film Material Transfer System Using Soft-robotic Manipulation**
    Ahn, S.; Zhou, L. (University of Texas at Austin)

16. **Ductile Cutting Regime in Diamond Milling of Monocrystalline Silicon**
    Groeb, M. (Kern Microtechnik GmbH; Technical University of Darmstadt); Fritz, M. (Kern Microtechnik GmbH); Groeb, J. (Independent Researcher); Ensinger, W. (Technical University of Darmstadt)

17. **Milling Force Prediction Case Study for Non-standard Geometry Endmill Using Structured Light Scanning**
    No, T. (University of Tennessee, Knoxville); Gomez, M. (Oak Ridge National Laboratory); Schmitz, T.L. (University of Tennessee, Knoxville; Oak Ridge National Laboratory)

18. **Force-controlled Electrode Holder for Lathe-type Electrochemical Discharge Machine**
    Furutani, K.; Tsuchiya, T. (Toyota Technological Institute)

19. **In-process Machining Process Monitoring Based on Impedance Model of Dielectric Coating Layer at Tool-chip Interface**
    Chun, H.; Kim, J.; Lee, C. (Texas A&M University)

20. **Microfabrication and Experimental Investigation of Drag Reduction and Fouling Resistance Potential of Asymmetric Triangular Riblets**
    Hamilton, B.W.; Tutunea-Fatan, R. (Western University); Bordatchev, E.V. (National Research Council of Canada); Farzaneh, A.; Hopkins, J.B. (University of California Los Angeles)

21. **A set of Turing Complete Mechanical Logic Elements and a Simple Logic Circuit**
    Sun, F.; Panas, R.M.; Bekker, L.; Pascall, A.J. (Lawrence Livermore National Laboratory)

22. **A Dynamic Athermalization Approach for Precision Machine Designs***
    Hijkoop, E.G.; Verbaan, K.; van Swaaij, S. (NTS-Group)

23. **Self-Sensing Hysteresis-Type Bearingless Motor**
    Homiller, L.; Zhou, L. (University of Texas at Austin)

24. **Time-domain Based Early Detection of Chatter Vibrations**
    Bahtiyar, K.; Sencer, B. (Oregon State University)

25. **Volumetric Two-Photon Polymerization Based on Computer-Generated Holograms**
    Fu, Z. (The Chinese University of Hong Kong); Liu, K. (Tsinghau University); Wang, Y. (The Chinese University of Hong Kong; Centre for Perceptual and Interactive Illetelligence Ltd.); Chen, S. (The Chinese University of Hong Kong; Tsinghau University)

26. **Parallel 3D Nanofabrication Using 1000 Programable Laser Foci**
    Ouyang, W. (The Chinese University of Hong Kong); Han, F.; Chen, C. (The Chinese University of Hong Kong; Tsinghau University)

27. **Control Co-design for Magnetically-suspended Stages with Light Weight and Flexible Structure**
    Wu, J.; Zhou, L (University of Texas at Austin)

28. **Study on Non-Axisymmetric 3D Curved Surface Turning by Driven-Type Rotary Tool Synchronized with Sprindle**
    Ishizuka, A.; Morimoto, Y.; Hayashi, A.; Kaneko, Y.; Suzuki, N. (Kanazawa Institute of Technology)

29. **Scaleable Positioning System for Minimal Time to Market and Low Cost***
van den Braber, R.; Verbaan, K. (NTS-Group)

30. **Innovation in Nanopositioning***
Raby, A.; Bartlett, G. (Prior Scientific Instruments Ltd.)

31. **Deep Learning Workflows for Dimensional Metrology with High-Resolution X-ray Computed Tomography**
Tekawade, A. (Argonne National Laboratory); Villarraga-Gomez, H. (Carl Zeiss Industrial Metrology, LLC); Andrew, M. (Carl Zeiss X-ray Microscopy, Inc.) Sforzo, B.A.; Kastengren, A.L.; Powell, C.F. (Argonne National Laboratory)

32. **Design and Verification of a Planar, Flux-Steering Magnetic Actuator***
Anthis, A.F.; Trumper, D.L.; Hamer, T.T. (Massachusetts Institute of Technology)

33. **Advancing Throughput and Image Quality in 3D X-ray Microscopy by Deep Learning Reconstruction Techniques**
Villarraga-Gomez, H. (Carl Zeiss Industrial Metrology, LLC); Andreyev, A.; Andrew, M.; Bale, H.; Sanapala, R.; Terada, M.; Gu, A.; Johnson, B. (Carl Zeiss X-ray Microscopy, Inc.); Omlor, L. (Carl Zeiss, Inc.); Graf vom Hagen, C. (Carl Zeiss X-ray Microscopy, Inc.)

34. **Design of a Polariscope Tool for the Evaluation of Strain in Roll-to-roll Nanofabrication**
Groh, B.T.; Connolly, L.G.; Cullinan, M.A. (University of Texas at Austin)

35. **Optical Fiber Surface Probe Using Mechanically Modulated Fabry Perot Interferometer**
Shabahang, F.; Smith, S.T. (University of North Carolina at Charlotte)

36. **Relaxed Uncertainty Dimensional Metrology for Assembly via Photogrammetry Using Open-Source Libraries**
Nawab, R.; Allen, A.D. (University of North Carolina at Charlotte); Lee, N. (Caterpillar Inc.)

37. **Precision Design and Error Analysis of a Pump Variable Volute Mechanism**
Johnson, H.A.; Slocum, A.H. (Massachusetts Institute of Technology)

38. **Interference Fit, Sub-Micron Piloted Tool Holder**
Arneson, D. (Professional Instruments Company)

39. **Effect of Squeeze Film on Dynamics of an Air Bearing***
Knapp, B.; Arneson, D.; Oss, D. (Professional Instruments Company)

ANNUAL MEETING TOURS

Technical Tour

Tour 1: Zeiss Industrial Metrology

Zeiss Industrial Metrology tour of the North American production facility in Maple Grove, Minnesota where a variety of Coordinate Measuring Machines and other Zeiss devices are manufactured.

Tour 2: The Minnesota Nano Center

The Minnesota Nano Center, or MNC. A state-of-the-art facility for interdisciplinary research in nanoscience and applied nanotechnology. The Center offers a comprehensive set of tools to help researchers develop new micro- and nanoscale devices, such as integrated circuits, advanced sensors, microelectromechanical systems (MEMS), and microfluidic systems. The MNC is also equipped to support nanotechnology research that spans many science and engineering fields, allowing advances in areas as diverse as cell biology, high performance materials, and biomedical device engineering.

The labs and tools of the Minnesota Nano Center are open to all qualified users. We welcome researchers from industry and other academic institutions.

Tour 3: Starrett Tru-Stone

Starrett Tru-Stone is a premier producer of custom precision granite machine bases and accessories. See how large granite machine elements are crafted to impressive levels of geometric specifications. Tru-Stone Technologies is located in Waite Park, Minnesota, in the heart of granite country.

TECHNICAL LEADERSHIP COMMITTEES

The Six ASPE Technical Leadership Committees

The **Precision Manufacturing Technical Leadership Committee (PMTLC)** serves as a focal point and technical resource for ASPE members interested in the full range of processes and machinery employed in the manufacture of precision components, devices, and systems. The goal is to create and provide a vibrant technical community where members can discuss topics of mutual interest, learn from the expertise and experience of other members, and contribute ideas and knowledge to help solve technical challenges and questions face by fellow members. Topical areas addressed by the Committee include, but are not limited to are as follows: 1) mechanical material removal, including cutting and abrasives processes, 2) forming, molding, casting, and additive processes, 3) non-mechanical material removal, including electro-chemical, electro-discharge, and directed, energy processes, 4) coatings and surface treatments, 5) manufacturing machinery, including system design and modeling, machine metrology and performance verification, performance enhancement, and auxiliary systems, 6) material handling, including workholding, alignment and registration, and automation, 7) process control and 8) assembly, including automation and tolerances and alignment

The primary subject area of the **Metrology Systems Technical Leadership Committee (MSTLC)** includes (but is not limited to) instruments, methods and techniques of dimensional metrology, i.e., the measurement of size, form and finish. Additional topic areas may include machine tool metrology, force, mass, etc. More specifically, the areas under the purview of the Committee address the hardware aspects of measurement instruments and will include sub-topics such as 1) instrument hardware design, 2) sensor technologies, 3) systems engineering, 4) instrument classifications and 5) applications.

The **Characterization Technical Leadership Committee (CTLC)** serves as a focal point and technical resource for ASPE members interested in conversion of dimensional metrology ranging from raw data to estimates of well-defined measurands that can be compared meaningfully with specifications, tolerances and function. The goal is to create and provide a vibrant technical community where members can discuss topics of mutual interest, learn from the expertise and experience of other members, and contribute ideas and knowledge to help solve technical challenges and questions faced by fellow members. Examples of topical areas addressed by the Committee include, but are not limited to the following: 1) specification and conformance evaluation of wear surfaces on mechanical components, 2) mid-spatial frequencies (waviness) in optical systems, 3) characterization of point clouds of data with variable spacing, 4) affective engineering and the specification of surfaces for human interaction, 5) evaluation of uncertainty in data maps, 6) knowledgeable and critical awareness of relevant international specifications, 7) functional significance of surface derivatives (slope, curvature) and 8) extension of our characterization emphases to specifying and characterizing 3D features.

The **Precision Machine Design Technical Leadership Committee (PMDTLC)** serves as a focal point and technical resource for ASPE members interested in the full range of precision machine design principles and techniques employed in the design,

TECHNICAL LEADERSHIP COMMITTEES

The Six ASPE Technical Leadership Committees (continued)

development and production of precision machines and systems. The goal is to create and provide a vibrant technical community where members can discuss topics of mutual interest, learn from the expertise and experience of other members, and contribute ideas and knowledge to help solve technical challenges and questions faced by fellow members. Topical areas addressed by the Committee include, but are not limited to the following: 1) fundamentals principles of Precision Machine Design, 2) error budgeting techniques, 3) precision machine and systems analysis techniques, 4) design challenges to match static and dynamic performance to the error budget and process requirements and the project's budget, 5) project management, 6) machine component design, selection, and optimization, 7) mounting and actuation of optical elements, 8) linear and rotary bearing design, fabrication, and testing 9) design techniques for achieving the typical requirements of high stiffness, low moving mass, high servo bandwidth, all within budget and timescale requirements, 10) design synthesis, 11) thermal management, 12) materials selection and development, 13) process development tools and modeling (e.g. cutting and abrasives processes), 14) metrology: in situ component measurement and machine stability/position measurement, 15) design, specification, and testing of machine environments (thermal, acoustic and floor borne vibrations) and 16) machine system safety.

The **Micro – and Nano – Technologies Technical Leadership Committee (PMTLC)** serves as a focal point and technical resource for ASPE members interested in the full range of precision engineering work occurring on the micro and sub-micro scale. This includes devices, materials and systems whose important features scales are on this scale. The goal is to create and provide a vibrant technical community where members can discuss topics of mutual interest, learn from the expertise and experience of other members, and contribute ideas and knowledge to help solve technical challenges and questions faced by fellow members. Topical areas addressed by the Committee include, but are not limited to the following: 1) MEMS/MOEMS (micromirrors, energy collectors), 2) micro/nano manufacturing processes, scaling challenges, 3) micro-additive manufacturing, 4) CNT-based devices and 5) mechanical metamaterials.

The primary subject area of the **Controls and Mechatronics Technical Leadership Committee (CMTLC)** includes, but is not limited to the following: 1) precision positioning systems, 2) multi-degree-of-freedom control, 3) advances in sensors, actuators, and drives, 4) modeling techniques and model-based mechatronic design, 5) system identification and data-based design, 6) control of friction induced systems, 7) feedforward control, 8) iterative learning control, 9) disturbance estimation and control, 10) autotuning and self-tuning techniques, 11_ active and passive strategies for vibration control, 12) thermal management and control and 13) dynamic error budgeting.

American Society for
Precision Engineering

SAVE THE DATE!
37TH ANNUAL MEETING
OCTOBER 10-14, 2022
HYATT REGENCY
BELLEVUE, WA

SAVE THE DATE

ASPE 2022 PRECISION OPTICAL METROLOGY

WINTER TOPICAL MEETING & WORKSHOP

FEBRUARY 2022 | TUSCON, ARIZONA, USA

American Society for
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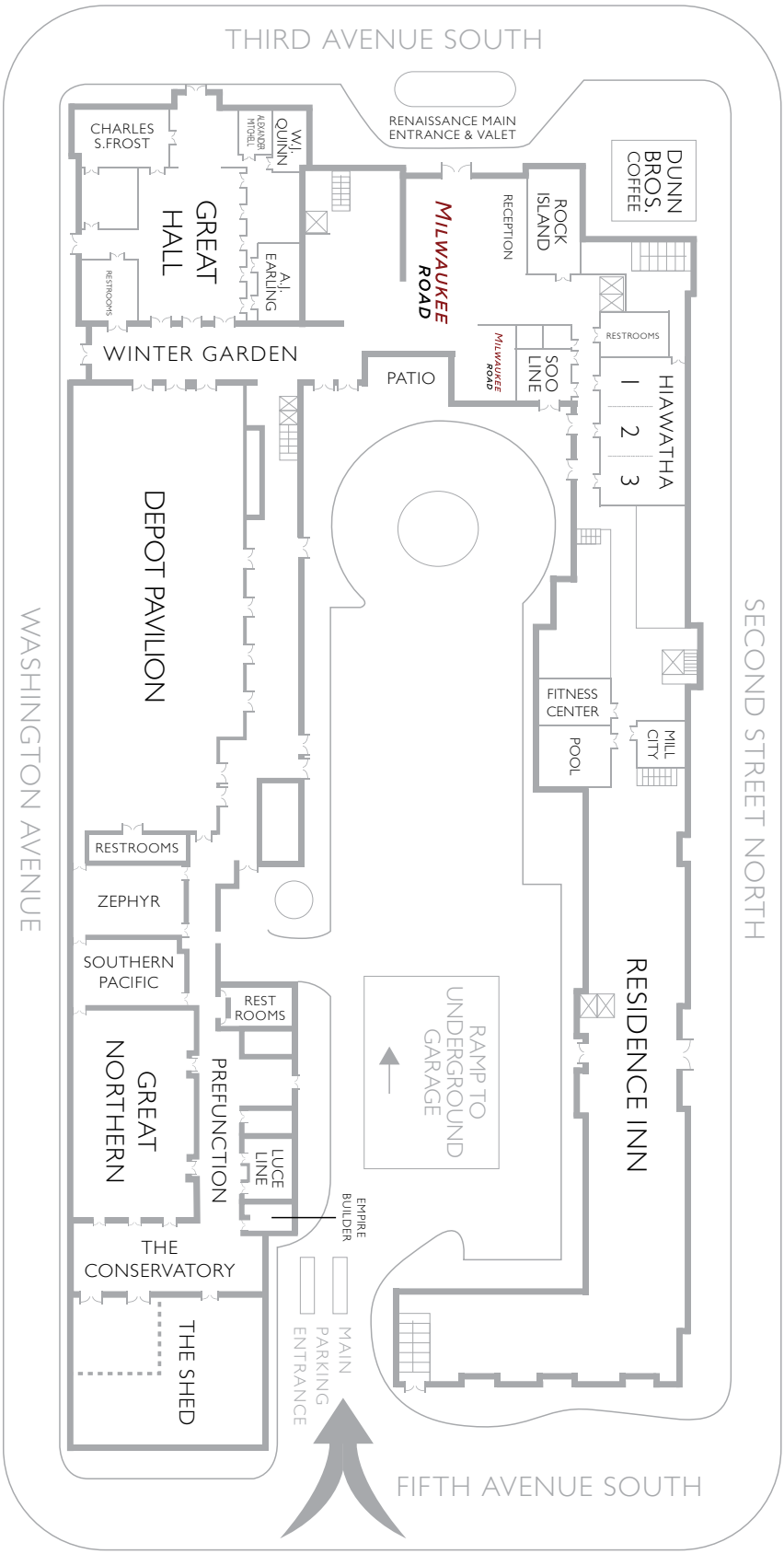
HOTEL FLOOR PLAN



CONFERENCE NOTES

CONFERENCE NOTES

CONFERENCE NOTES

CONFERENCE PROGRAM

American Society for
Precision Engineering

36TH ANNUAL MEETING
NOVEMBER 1-5, 2021

RENAISSANCE MINNEAPOLIS HOTEL
THE DEPOT
MINNEAPOLIS, MN, USA