INERTIAL 2021
SYMPOSIUM
PROGRAM

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Welcome Message from the Chairs

Dear Colleagues/Friends,

We warmly welcome you to your desk, couch, or location of choice, to present, exhibit, and participate in the 8th IEEE International Symposium on Inertial Sensors and Systems (INERTIAL’21).

This year’s event continues our established tradition, started in 2014 in Laguna Beach, CA, USA of informal international meetings discussing the latest developments in the area of modern inertial sensors and emerging applications enabled by inertial sensors.

The IEEE INERTIAL is sponsored by the IEEE Sensors Council and is the only IEEE event exclusively dedicated to the Inertial Sensors and Systems technology. The adoption and application of this technology is growing fast, with the global inertial sensors and systems market expected to reach $21.7B by next year.

The symposium offers a rare opportunity to meet and network with leaders in the field of inertial sensors and systems in an informal atmosphere of a focused international technical gathering. We hope the atmosphere, breadth and depth of research topics combined with the quality of invited and contributed technical presentations will continue to make the INERTIAL a ‘must attend’ event for you every year.

The INERTIAL has an ambition to establish itself as the premier forum for reporting the latest research, development, and commercialization results in modern inertial sensors technology. You will hear from the world experts the latest in materials and micro-fabrication processes, innovative designs, new physical principles, increased performance, and a growing number of new applications and business opportunities.

The technical program covers three and a half days of technical presentations. By design, this is a single track symposium with high quality oral presentations and exhibitions. Each presentation was carefully reviewed and selected by our Technical Program Committee, after a careful evaluation by at least three independent reviewers – the technical experts in the field. Our 8 distinguished invited speakers will participate in a number of sessions throughout the meeting. The contributed papers will be presented in oral live or prerecorded videos (33 papers) and all of the speakers will participate in one of the 9 live Q&A/panel discussion sessions. Our program will begin on Monday with four tutorials offered in the areas of (i) MEMS Inertial Sensors, (ii) sensor and system applications, (iii) navigation aiding techniques, and (iv) integrated photonics for optical gyroscopes. The tutorials are organized and chaired by Dr. Jenni Strabley from the Honeywell Corporation.

The Digest of Technical Papers for the 2021 IEEE Inertial Sensors contains up to four-page versions of the standard technical papers and 2-pagers of “late news” presentations, all provided to attendees in an electronic form. Most (but not all) presented papers will be available in the IEEE Xplore after the symposium. Our distinguished exhibitors and patrons will be involved throughout the symposium hosting Q&A sessions and available for live discussions during specific time windows. Please be sure to visit their exhibitor pages and talk with them live during the meeting.

Continuing the long standing IEEE Inertial tradition, the Technical Program Committee will select one Best Student Paper (as well as first and second runner up papers). The Award will be announced on Thursday during two separate and time zone convenient sessions in which we will also announce the location for the 2022 meeting. Good luck to all presenting students!

During this year’s virtual meeting we will be conducting an informal zoom virtual background contest. So I encourage everyone to be creative and have some fun with your virtual backgrounds. We will be looking for the most creative, fun, entertaining, or unique backgrounds throughout all the live sessions during the week.

We would like to express our special thanks to the Oversight Committee, the Technical Program Committee, and many experts who contributed their time to evaluate submissions.

We thank the IEEE Sensors Council for sponsoring the 2021 IEEE Inertial Sensors as well as our Patrons and Exhibitors. Our special thanks to Brianna Orr, and the entire staff at Conference Catalysts, LLC for administrative support.

Finally, we thank all speakers, presenters, and attendees for making the 2021 IEEE Inertial Sensors Symposium such a unique event. We hope that you find the INERTIAL’21 Symposium professionally stimulating and enjoyable, and of course, we are looking forward to seeing you back next year for the INERTIAL’22.

Michael Larsen
IEEE INERTIAL 2021 General Chair
IEEE Inertial Sensors & Systems Symposium 2021 Organizers

Symposium Chair:
Michael Larsen, Northrop Grumman, USA

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Jenni Strabley, Honeywell, USA
Shuji Tanaka, Tohoku University, Japan
Tsuchiya Toshiyuki, Kyoto University, Japan
Technical Reviewers

Jalal Ahamed          Ryan Knight
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Jenna Chan            Vasco Lima
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The conference organizers gratefully acknowledge the generous support provided by the following:

IEEE

IEEE Sensors Council
Technical Program: Monday, March 22
Program is listed in UTC Time.

6:45 AM – 7:00 AM
Opening Remarks
Michael Larsen (Northrop Grumman), Ron Polcawich (DARPA)

7:00 AM – 9:30 AM
Tutorial: Integrated navigation solutions for new mobility applications
Domenico Accardo, Università degli Studi di Napoli Federico II, Italy

9:30 AM – 10:00 AM
Break/Open Discussion

10:30 AM – 11:30 AM
Social Hour

11:30 AM – 2:00 PM
Tutorial: Navigation Aiding Techniques
JP Laine, DRAPER, USA

2:00 PM – 4:30 PM
Tutorial: Innovative intelligence in MEMS Inertial Sensors
Chris Kim, STMicroelectronics, USA

4:30 PM – 5:00 PM
Break/Open Discussion

5:00 PM – 7:30 PM
Tutorial: Towards integrated optical gyroscopes
Kerry Vahala, California Institute of Technology, USA

7:30 PM – 8:00 PM
Break/Open Discussion

8:00 PM – 10:30 PM
A1L-A: MEMS Gyroscopes I USA
Session Chair(s): Brian Grantham (DEVCOM AvMC)

8:00 PM
Invited Talk: Platform Technologies for High-Performance Inertial Sensors
Jeff DeNatale, Teledyne Technologies, USA
Technical Program: Monday, March 22 (cont.)
Program is listed in UTC Time.

8:25 PM
Monocrystalline 4H Silicon Carbide-on-Insulator Substrates for Nav-Grade Planar BAW Gyroscopes
Benoit Hamelin, Jeremy Yang, Zhenming Liu, Farrokh Ayazi
Georgia Institute of Technology, United States

8:50 PM
Vibration Immune, Long-Term Stable and Low Noise Synchronized Mass MEMS Gyroscope
Igor Prikhodko{1}, John Geen{1}, Carey Merritt{1}, Sam Zhang{1}
{1} Analog Devices, United States

9:15 PM
Effect of EAM on Quality Factor and Noise in MEMS Vibratory Gyroscopes
Dameng Wang, Andrei Shkel
University of California, Irvine, United States

9:40 PM
Q&A Panel

10:30 PM – 11:00 PM
Break/Open Discussion
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Monday, March 22 / Tuesday, March 23
Program is listed in UTC Time.

11:00 PM – 1:10 AM
B1L-A: Rate Integrating Gyroscopes – USA / China
Session Chair(s): Takashiro Tsukamoto (Tohoku University), Haoran Wen

11:00 PM
A High-Performance Rate-Integrating Hemispherical Resonant Gyros with 0.00753°/h Bias Instability
Yongmeng Zhang{1}, Sheng Yu{2}, Kechen Guo{1}, Jiangkun Sun{1}, Xuezhong Wu{1}, Dingbang Xiao{1}
{1}National University of Defense Technology, China; {2}National University of Defense Technology, Hunan MEMS Research Center, China

11:25 PM
Identification of Gain Mismatches in Control Electronics of Rate Integrating CVGs
Daryosh Vatanparvar, Andrei Shkel
University of California, Irvine, United States

11:50 PM
Invited Talk: R&D FOR COMMERCIALIZATION OF MEMS RATE INTEGRATING GYROSCOPE: CHALLENGES AND PRACTICAL APPROACHES
Ryunosuke Gando, Toshiba, Japan

12:20 AM
Live Q&A

1:10 AM – 1:30 AM
Break/Open Discussion
Tuesday, March 23
Program is listed in UTC Time.

1:30 AM – 4:05 AM
B2L-A: MEMS Gyroscopes II Asia
Session Chair(s): Ryuta Araki (SUMITOMO PRECISION PRODUCTS CO)

1:30 AM
Invited Talk: High Performance Rate-Integrated MEMS Gyroscope Around the Corner
Xiao Dingbang, National University of Defense Technology, China

2:00 AM
Theoretical Consideration of Mismatch Compensation for MEMS Resonator Having Unaligned Principle Axes
Takashiro Tsukamoto, Shuji Tanaka
Tohoku University, Japan

2:25 AM
The Parametric Amplification in MEMS Gyroscopes Based on Triple Resonant Frequency Signal
Kai Wu, Kuo Lu, Qingsong Li, Hao Zhang, Ming Zhuo, Xuezhong Wu, Dingbang Xiao
National University of Defense Technology, China

2:50 AM
Mode-Matched Multi-Ring Disk Resonator Using Single Crystal (100) Silicon
Jianlin Chen, Takashiro Tsukamoto, Shuji Tanaka
Tohoku University, Japan

3:15 AM
Q&A Panel

4:05 AM – 4:30 AM
Break/Open Discussion

8:00 AM – 10:35 AM
B3L-A: MEMS Gyroscopes III Europe
Session Chair(s): Raphaël Levy (Onera)

8:00 AM
Invited Talk: High performance MEMS accelerometer and gyro with a unique SMD and digital interface
Antoine Filipe, Tronic’s Microsystems SA, France

8:30 AM
Exploiting Nonlinearities for Frequency-Matched MEMS Gyroscopes Tuning
Jacopo Marconi{1}, Giacomo Bonaccorsi{1}, Daniele Giannini{1}, Luca Falorni{2}, Francesco Braghin{1}
{1}Politecnico di Milano, Italy; {2}STMicroelectronics, Italy

8:55 AM
Digital Control of MEMS Gyroscopes: A Robust Approach
Fabrizio Saggin{2}, Cécile Pernin{2}, Anton Korniienko{2}, Gérard Scorletti{2}, Christophe Le Blanc{1}
{1}Asygn, France; {2}Ecole Centrale de Lyon, Laboratoire Ampère, France
Tuesday, March 23 (cont.)
Program is listed in UTC Time.

9:20 AM
600 µdps/√Hz, 1.2 mm² MEMS Pitch Gyroscope
Marco Gadola{1}, Marc Sansa Perna{2}, Monica Allieri{1}, Philippe Robert{2}, Thierry Verdot{2}, Audrey Berthelot{2}, Giacomo Langfelder{1}
{1}Politecnico di Milano, Italy; {2}Université Grenoble Alpes, CEA-Leti, France

9:45 AM
Live Q&A

10:35 AM – 11:00 AM
Break/Open Discussion (Moderated by Coventor)

11:00 AM – 1:35 PM
B4L-A: MEMS Inertial Europe
Session Chair(s): Joan Giner (Bosch)

11:00 AM
Invited Talk: AI + MEMS
Markus Ulm (Bosch Sensortec)

11:30 AM
Experimental Investigation of Parametric Evasion Properties of Resonant Sensors Using Electrostatic Gap-Closing Actuation
Jerome Juillard{2}, Antonio Somma{2}, Alexis Brenes{1}
{1}LISITE, ISEP, France; {2}UMR8507, CNRS, CentraleSupélec, Université Paris-Saclay, Sorbonne Université, France

11:55 AM
Analysis and Compensation of Cross-Axis Sensitivity in Low-Cost MEMS Inertial Sensors
Tobias Hiller{1}, Lukas Blocher{1}, Milos Vujadinović{1}, Zsigmond Péněk{2}, Alexander Buhmann{1}, Hubert Roth{3}
{1}Robert Bosch GmbH, Germany; {2}Robert Bosch Kft, Hungary; {3}University of Siegen, Germany

12:20 PM
Finding the Critical Impact Energy for Micro Debris Generation in MEMS Inertial Sensors
Leonardo Gaffuri Pagani{1}, Luca Guerinoni{2}, Luca Falorni{2}, Patrick Fedeli{2}, Gaçomo Langfelder{1}
{1}Politecnico di Milano, Italy; {2}STMicroelectronics, Italy

12:45 PM
Live Q&A

1:35 PM – 2:35 PM
Social Hour

3:00 PM – 5:55 PM
B5L-A: Accelerometers – Europe / USA
Session Chair(s): John Reinke (Honeywell International)
Tuesday, March 23 (cont.)
Program is listed in UTC Time.

3:00 PM
Resonant Accelerometer with Compliant Parallel Motion Linkage Force Amplification Mechanism
Omer HaLevy, Stella Lulinsky, Slava Krylov
Tel Aviv University, Israel

3:25 PM
SWaP Reduction for High Dynamic Navigation Grade Accelerometer Based on Quartz VBA Technology
Rachid Taibi, Olivier Jolly, Thomas Kerrien, Pascal Labarthe, Karl Aubry, Gauthier Le Bihan, Stéphanie Michel
ixblue, France

3:50 PM
A 10 Nano-G/Hz Resonant MEMS Accelerometer Employing Anti-Aliasing Control
Milind Pandit{1}, Guillermo Sobreviela{1}, Callisto Pili{1}, Philipp Steinmann{1}, Douglas Young{1}, Chun Zhao{2}, Colin Baker{1}, Ashwin Seshia{2}
{1}Silicon Microgravity Ltd., United Kingdom; {2}University of Cambridge, United Kingdom

4:15 PM
Megahertz Bandwidth Bulk Micromachined Optomechanical Accelerometer with Fiber Optical Interconnects
Daniel Domínguez, Lisa Hackett, Michael Miller, Jennifer Restrepo, Katya Casper, Matt Eichenfield
Sandia National Laboratories, United States

4:40 PM
Method for the Synchronization of Data Recorders by Coupling Accelerometer Data
José Ricardo Scarpari{3}, Camila Deolindo{1}, Maria Adelia Aratanha{1}, Maurício Ribeiro{1}, Anderson de Souza{2}, Elisa Kozasa{1}, Daisy Hirata{3}, José Elias Matieli{3}, Roberto Gil Annes Da Silva{3}, Carlos Henrique Forster{3}
{1}Hospital Israelita Albert Einstein, Brazil; {2}Instituto de Pesquisas e Ensaio em Voos, Brazil; {3}Technological Institute of Aeronautics, Brazil

5:05 PM
Live Q&A

5:55 PM – 6:30 PM
Break/Open Discussion

7:00 PM – 10:05 PM
B6L-A: Atomic Sensors – Europe / USA
Session Chair(s): Philippe Bouyer (Institut d’Optique Graduate School)

7:00 PM
Invited Talk: Atom Interferometer Accelerometer
John Close (Australian National University)
Tuesday, March 23 (cont.)
Program is listed in UTC Time.

7:30 PM
The Development of a High Data Rate Atom Interferometric Gravimeter (HIDRAG) for Gravity Map Matching Navigation
Benjamin Adams{2}, Calum Macrae{2}, Mani Entezami{2}, Kevin Ridley{2}, Archie Kubba{2}, Yu-Hung Lien{2}, Sachin Kinge{1}, Kai Bongs{2}
{1}Toyota Motor Europe, Belgium; {2}University of Birmingham, United Kingdom

7:55 PM
Invited Talk: Packaging for Cold Atom Sensors
Dana Anderson (ColdQuanta)

8:25 PM
Cold Atom Interferometers Based on Diffractive Optics and Integrated Photonics
Jongmin Lee
Sandia National Laboratories, United States

8:50 PM
Scale-Factor Stability Control Technique for Closed-Loop All-Fiber Interferometric Optical Gyroscope
Michal Skalský, Jiří Fialka, Ladislav Kopečný, Zdeněk Havránek
Brno University of Technology, Czech Rep.

9:15 PM
Live Q&A

10:05 PM – 10:30 PM
Break/Open Discussion (Moderated by Northrop Grumman)
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Program is listed in UTC Time.

11:00 PM – 2:00 AM
B7L-A: Aided Navigation - Asia / USA
**Session Chair(s):** Charles Lange (Johns Hopkins University Applied Physics Laboratory)
Toshiyuki Tsuchiya (Kyoto University)

11:00 PM
Sensor Fusion to Improve State Estimate Accuracy Using Multiple Inertial Measurement Units
Ujjval Patel, Imraan Faruque
Oklahoma State University, United States

11:25 PM
Simulation Design of Thermopile and Magnetometer Aided INS/GPS Navigation System for UAV Navigation
Atsumi Toda, Yoshikazu Koike
Shibaura Institute of Technology, Japan

11:50 PM
Performance Analysis of 3D NDT Scan Matching for Autonomous Vehicles Using INS/GNSS/3D LiDAR-SLAM Integration Scheme
Surachet Srinara, Chi-Ming Lee, Syun Tsai, Guang-Je Tsai, Kai-Wei Chiang
National Cheng Kung University, Taiwan

12:15 AM
FaSter: Fast, Stable, Expendable and Reliable Radio Map for Indoor Localization
Md Abdulla Al Mamun, David Vera Anaya, Mehmet Rasit Yuce
Monash University, Australia

12:40 AM
**Invited Talk: Magnetic Navigation Aiding**
Aaron Canciani (U.S. Air Force)

1:10 AM
Live Q&A

2:00 AM – 2:30 AM
Break/Open Discussion
**Wednesday, March 24**

Program is listed in UTC Time.

**11:00 AM – 12:00 PM**

Social Hour

**12:00 PM – 2:30 PM**

**C1L-A: Human Activity Recognition - Europe / USA**

**Session Chair(s):** Sina Askari (ECS Federal - DARPA SETA), Radwan Noor (King Abdulaziz City for Science and Technology)

**12:00 PM**

Towards the Automatic Data Annotation for Human Activity Recognition Based on Wearables and BLE Beacons

Florenc Demrozi\{2\}, Marin Jereghi\{1\}, Graziano Pravadelli\{1\}

\{1\}Computer Science, University of Verona, Italy; \{2\}University of Verona, Italy

**12:25 PM**

Insole-Based Real-Time Gait Analysis: Feature Extraction and Classification

Arif Reza Anwary\{3\}, Damla Arifoglu\{4\}, Michael Jones\{1\}, Michael Vassallo\{2\}, Hamid Bouchachia\{1\}

\{1\}Bournemouth University, United Kingdom; \{2\}Royal Bournemouth Hospital, United Kingdom; \{3\}Swansea University, United Kingdom; \{4\}University College London, United Kingdom

**12:50 PM**

Trains Detection Using State of Polarization Changes Measurement and Convolutional Neural Networks

Petr Dejdar, Vojtech Myska, Petr Munster, Radim Burget

Brno University of Technology, Czech Rep.

**1:15 PM**

Improved Sensor Based Human Activity Recognition via Hybrid Convolutional and Recurrent Neural Networks

Sonia Perez-Gamboa, Qingquan Sun, Yan Zhang

California State University San Bernardino, United States

**1:40 PM**

Live Q&A

**2:30 PM – 3:00 PM**

Break/Open Discussion

**3:00 PM – 5:05 PM**

**C2L-A: Industry MEMS Inertials - Europe / USA**

**Session Chair(s):** Jenna F. Chan (U.S. Army CCD Army Research)

**3:00 PM**

Purely Inertial Navigation with a Low-Cost MEMS Sensor Array

Lukas Blocher\{3\}, Wolfram Mayer\{3\}, Marco Arena\{3\}, Dušan Radović\{2\}, Tobias Hiller\{3\}, Joachim Gerlach\{1\}, Oliver Bringmann\{4\}

\{1\}Albstadt–Sigmaringen University, Germany; \{2\}Bosch Sensortec GmbH, Germany; \{3\}Robert Bosch GmbH, Germany; \{4\}University of Tuebingen, Germany
Wednesday, March 24 (cont.)
Program is listed in UTC Time.

3:25 PM
Development of a Navigation-Grade MEMS IMU
Burgess Johnson{1}, Curt Albrecht{1}, Todd Braman{1}, Kevin Christ{2}, Patrick Duffy{1}, Dan Endean{1}, Markus Gnerlich{1}, John Reinke{1}
{1}Honeywell International, United States; {2}Medtronic, United States

3:50 PM
Polaris – a Low Cost MEMS Fabrication Platform for Navigation-Grade Inertial Sensors
David Lin, Robert Macdonald, Dorin Calbaza, Jeremy Popp, Tammy Johnson, Emad Andarawis, Marco Aimi
GE Research, United States

4:15 PM
Live Q&A

5:05 PM – 5:30 PM
Break/Open Discussion (Moderated by Inertial Sensor Design)
Thursday, March 25
Program is listed in UTC Time.

2:00 AM
Student Awards and 2022 Promo Asia
Michael Larsen (Northrop Grumman), Olivier Le Traon (ONERA)

8:20 AM – 10:00 AM
DIL-A: Late News Asia
Session Chair(s): Tamio Ikehashi (Waseda University)

8:20 AM
A Technique for Modeling and Simulating Transistor Based MEMS Sensors
Pramod Martha{2}, Anju Sebastian{1}, V Seena{2}, Naveen Kadayinti{3}
{1}Indian Institute of Science, Bangalore, India; {2}Indian Institute of Space Science and Technology, Trivandrum, India; {3}Indian Institute of Technology, Dharwad, India

8:45 AM
A 3-D Capacitive-Detection Electrode for a Single Gold Proof-Mass Three-Axis MEMS Accelerometer
Takashi Ichikawa{2}, Akihiro Uchiyama{2}, Kohei Shibata{2}, Shinichi Iida{1}, Sangyeop Lee{2}, Noboru Ishihara{2}, Katsuyuki Machida{2}, Kazuya Masu{2}, Hiroyuki Ito{2}
{1}NTT Advanced Technology Corp., Japan; {2}Tokyo Institute of Technology, Japan

9:10 AM – 10:00 AM
Live Q&A

10:00 AM – 10:30 AM
Break/Open Discussion

3:00 PM
Student Awards and 2022 Promo Europe / USA
Michael Larsen (Northrop Grumman), Olivier Le Traon (ONERA)

3:20 PM – 5:25 PM
D2L-A: Late News USA
Session Chair(s): Giacomo Langfelder (Politecnico di Milano)
Sina Askari (ECS Federal – DARPA SETA)

3:20 PM
A Sub-Micro-G Resolution Frequency-Modulated Piezoelectric In-Plane Accelerometer
Seungyong Shin, Anosh Daruwalla, Zhenming Liu, Farrokh Ayazi
Georgia Institute of Technology, United States

3:45 PM
A Novel Spring Disk Resonator Gyroscope for Maximizing Q/F
Christopher Cameron{1}, Dustin Gerrard{2}, Janna Rodriguez{1}, Yushi Yang{1}, Eldwin Ng{1}, Thomas Kenny{1}
{1}Stanford University, United States; {2}Waymo, United States
Thursday, March 25 (cont.)
Program is listed in UTC Time.

4:10 PM
Microfabricated Optically Pumped Gradiometer with Uniform Buffer Gases
Austin Parrish{2}, Radwan Noor{1}, Andrei Shkel{2}
{1}King Abdulaziz City for Science and Technology, Saudi Arabia; {2}University of California, Irvine, United States
4:35PM: Live Q&A

5:25 PM
Closing Remarks
Michael Larsen (Northrop Grumman), Ron Polcawich (DARPA)

5:25 PM
Open Discussion

6:15 PM – 7:15 PM
Northrop Grumman Webinar

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