

# Workshop on Understanding Cyclic Variability in Internal Combustion Engines

Hosted by

## The Virtual Engine Research Institute and Fuels Initiative (VERIFI)

Advanced Photon Source (APS) Conference Center, Argonne National Laboratory

November 7–8, 2017

### Tuesday, November 7, 2017

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| 7:00-8:00 a.m.       | Registration   |
| 8:00-8:05 a.m.       | John Quintana: Deputy Laboratory Director for Operations<br><b>Welcome to Argonne National Laboratory</b>  |
| 8:05-8:15 a.m.       | Ann Schlenker: Director Center for Transportation Research<br><b>VERIFI at Argonne National Laboratory</b>   |
| 8:15-8:30 a.m.       | Sibendu Som: Group Leader at Argonne National Laboratory<br><b>Workshop Objectives and Mechanics</b>   |
| 8:30-9:00 a.m.       | Michael Weismiller: Program Manager at US DOE<br><b>The Importance of Cyclic Variability in Engines – the DOE Perspective</b>  |
| 9:00-9:45 a.m.       | Ronald Reese: Senior Technical Fellow at FCA USA LLC.<br><b>Birth of an Engine - Conception to Delivery</b>  |
| 9:45-10:15 a.m.      | Coffee break   |
| 10:15-10:45 a.m.     | Magnus Sjoberg: Principal Member of Technical Staff at SNL<br><b>Mitigation of Cycle-to-Cycle Combustion Variability to Enable Highly Efficient DISI Engines</b>                                 |
| 10:45-11:15 a.m.     | Dave Reuss: Research Scientist at University of Michigan<br><b>Causal Analysis of SI Engine Combustion CCV Using Measurements and Simulations</b>  |
| 11:15-11:45 a.m.     | Benjamin Boehm: Research Group Leader at Technical University Darmstadt<br><b>Investigating Chains of Cause and Effect: The Three-Dimensional In-Cylinder Flow and Cycle-to-Cycle Variations</b> |
| 11:45 a.m.-1:00 p.m. | Sponsored Lunch  |
| 1:00-2:00 p.m.       | Tour of the Advanced Photon Source   |
| 2:00-2:30 p.m.       | Brian Kaul: Research & Development Staff at ORNL<br><b>Deterministic Cyclic Variability: Characterization and Control</b>  |
| 2:30-3:00 p.m.       | Charles Finney: Research & Development Staff at ORNL<br><b>Deterministic Cyclic Variability: Modeling and Simulation</b>   |

- 3:00-3:30 p.m. David Hung, Professor at University of Michigan-Shanghai Jiao Tong University  
Joint Institute Shanghai Jiao Tong University  
**Outlier Detection and Cyclic Variability Quantification of Planar In-cylinder Velocity Flow Fields**
- 3:30-4:00 p.m. Coffee break
- 4:00-4:30 p.m. Tony Willcox: Director, Controls & Simulation at Pinnacle Engines, Inc.  
**Test and Simulation Results for Dilution Tolerance Extension on Pinnacle's Ultra-Lean LTC Opposed Piston Sleeve-Valve Engine**
- 4:30-5:00 p.m. Eric Lendormy: Senior Thermofluids and Simulation Expert at Wärtsilä Corp.  
**Cyclic Variations in Medium Speed Engines: Toeing the Issue**
- 5:00-5:30 p.m. Chris Powell: Principal Research Scientist at ANL  
**Experimental and Computational Effort to Capture Shot-To-Shot Variability in Diesel Injection**
- 6:00-7:00 p.m. Sponsored Reception and poster session by Argonne researchers (Gallery)
- 7:15-8:30 p.m. Sponsored Dinner (Guest House)

**Wednesday, November 8, 2017**

- 7:30-8:00 a.m. Registration
- 8:00-8:30 a.m. Dan Haworth: Professor of Mechanical Engineering at Penn State University  
**In-Cylinder LES: A Historical Perspective**
- 8:30-9:00 a.m. Christian Angelberger: Expert Engine Combustion Modeling at IFP Energies Nouvelles  
**Applying LES to Understand Non-Cyclic Engine Combustion Phenomena**
- 9:00-9:30 a.m. Federico Millo: Full Professor at Politecnico di Torino  
**Modelling CCV and Knock in Downsized Turbocharged SI Engines**
- 9:30-10:00 a.m. *Coffee break*
- 10:00-10:30 a.m. Seunghwan Keum, Staff Researcher at GM R&D  
**Industry perspective on cycle to cycle variation in IC engines**
- 10:30-11:00 a.m. Keith Richards: President and Co-owner of Convergent Science Inc.  
**Predicting Cyclic Variability in an IC Engine Using a RANS Turbulence Model**
- 11:00-11:30 a.m. Stefano Fontanesi: Professor at University of Modena at Reggio Emilia  
**Understanding the Origin of Engine CCV via LES: Strengths, Weaknesses and Needs**
- 11:30 a.m.-Noon Michele Battistoni: Professor at University of Perugia

## **Multi-Cycle Simulations of Fuel and Water Injection Strategies with Knock Occurrence**

Noon-1:00 p.m.	Sponsored Lunch
1:00-1:30 p.m.	Muhsin Ameen: Mechanical Engineer at ANL <b>Numerical Prediction of CCV using the Parallel Perturbation Model</b>
1:30-2:00 p.m.	Saumil Patel: Postdoc Researcher at ANL <b>A Low-Mach, Spectral Element Simulation of the TCC-3 Engine</b>
2:00-2:30 p.m.	Noah Van Dam: Postdoc Researcher at ANL <b>Simulations of Flow, Spark and Combustion Variability in an Optically Accessible DISI Engine</b>
2:30-3:00 p.m.	Janardhan Kodavasal: Mechanical Engineer at ANL <b>Insights into Cyclic Variability using Machine Learning</b>
3:00-3:30 p.m.	Riccardo Scarcelli: Research Engineer at ANL <b>GDI Combustion Work at Argonne: The Impact of Ignition Characteristics on Combustion Stability under Lean and EGR Dilute Operation</b>
3:30-3:35 p.m.	Doug Longman: Section Manager at Argonne National Laboratory <b>Thank You</b>
3:45-5:45 p.m.	<b>Two parallel sessions, i.e., “Tours” and “One-on-One”</b>  <b>Two tours for everyone (buses leave from the APS Auditorium)</b> <ul style="list-style-type: none"><li>• Engine facilities and Rapid Compression Machine</li><li>• Argonne Leadership Computing Facility and Visualization Lab</li></ul> Each stop takes about 35-40 minutes, Buses back to the Guest House  <b>“One-on-One” (The VERIFI team will email room information to individuals who signed up for this session)</b>

### ***Tour Descriptions***

#### **Engine Facilities and Rapid Compression Machine**

Argonne’s engine testing capability spans from light duty to heavy duty, with engines ranging in size from 0.5L up to 19L. Argonne’s facilities include state-of-the-art instrumentation for in-cylinder visualization and regulated and un-regulated emissions characterization (gaseous and particulate). These experiments generate high-quality data for validation of VERIFI simulations. Argonne is also the only national laboratory with a rapid-compression machine for generating very controlled, engine-like conditions for studying fuel ignition and combustion properties.

#### **Advanced Photon Source**

The Advanced Photon Source (APS) is a user facility at Argonne, which produces the brightest x-ray beams in the Western hemisphere, enabling multi-disciplinary research that advances science. A

dedicated hutch at APS allows VERIFI researchers to gain fundamental understanding of fuel injection and spray phenomena (such as cavitation and jet interactions) and aid advanced model developments.

### **Argonne Leadership Computing Facility**

The Argonne Leadership Computing Facility is a user facility at Argonne that provides the computational science community with a world-class computing capability dedicated to breakthrough science and engineering. The tour will include a visit to Argonne's 10-petaflop MIRA supercomputer. The VERIFI team uses these facilities and collaborates extensively with ALCF scientists to scale up engine calculations.

### **One-on-One Session**

VERIFI experts will be available for discussions with industry representatives to understand their computing needs and provide guidance on how VERIFI projects could help them design and optimize next-generation engines and fuels. Argonne will provide a list of VERIFI experts available for discussion.