

Victor M. Zavala

Richard H. Soit Assistant Professor

Department of Chemical and Biological Engineering

University of Wisconsin-Madison

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EDUCATION

Ph.D. in Chemical Engineering (Process Systems Engineering), 2008

Carnegie Mellon University, Pittsburgh, PA, USA

Advisor: Lorenz T. Biegler

Thesis Title: Computational Strategies for the Optimal Operation of Large-Scale Chemical Processes

B.Sc. in Chemical Engineering (Honors), 2003

Universidad Iberoamericana, Mexico City

APPOINTMENTS

University of Wisconsin at Madison, Department of Chemical and Biological Engineering

Richard H. Soit Assistant Professor. August 2015 - Present

Argonne National Laboratory, Mathematics and Computer Science Division

Argonne Associate (Part-Time). August 2015- Present.

Argonne National Laboratory, Mathematics and Computer Science Division

Computational Mathematician. November 2014 - August 2015

Argonne National Laboratory, Mathematics and Computer Science Division

Assistant Computational Mathematician. October 2010 - October 2014

University of Chicago, Computation Institute

Fellow. December 2011 - August 2015.

Argonne National Laboratory, Mathematics and Computer Science Division

Argonne Scholar. October 2008 -October 2010

ExxonMobil Chemical, Core Engineering and Technology Complex

Research Intern, Process Control. July 2007 - September 2007 and June 2006 - August 2006

Celanese Corporation, Cangrejera Chemical Complex, Mexico

Engineering Intern, Process Engineering. May 2003 - July 2003 and May 2001 - July 2001

HONORS AND AWARDS

- Vilas Faculty Early Career Investigator Award, 2016-2018.
- Department of Energy Early Career Award, 2012-2017.
- Invited Keynote Speaker, 9th International Symposium on Advanced Control of Chemical Processes, 2015.
- Best Paper Award, 5th Workshop on Scientific Cloud Computing (ScienceCloud), 2014.
- Director's Postdoctoral Fellowship at Argonne National Laboratory, 2008-2010.
- Humboldt Fellowship, Humboldt Foundation, 2008-2010 (Not Realized).
- Best Paper Award, IEEE Workshop on Advanced Process Control Applications for Industry, 2007.
- Invited Keynote Speaker, International Workshop on Assessment and Future Directions of Nonlinear Model Predictive Control, 2008.
- Invited Keynote Speaker, 8th International Symposium on Dynamics and Control of Process Systems. Cancun, Mexico. 2007.

CURRENT RESEARCH FUNDING

- co-PI, *MACSER: Multifaceted Mathematics for Rare, High Impact Events in Complex Energy and Environment Systems*, Department of Energy, Office of Science, \$3,818,507 Total (\$500K Allocation to co-PI), 2018-2022.
- PI, *A Multi-Scale Platform for Technology Evaluation and Decision-Making in the Dairy-Water-Energy Nexus*, U.S. Department of Agriculture, \$2.4M Total (\$450K allocation to PI), 2016-2018.
- PI, *Multi-Scale Predictive Control of Coupled Energy Networks*, National Science Foundation-EECS, (\$328K Total), 2016-2018.
- PI, *Multi-Stakeholder Decision-Making for the Development of Livestock Waste-to-Biogas Systems*, National Science Foundation-CBET, (\$300K Total), 2016-2018.
- PI, *Next-Generation Optimization under Uncertainty: Structure-Oriented Algorithms*, Department of Energy, Office of Science Early Career Award, \$150K/yr (\$300K Total), 2016-2017.
- PI, *Incentive-Based Demand Response of Battery Systems*, Johnson Controls, \$150K, 2016-2018

PAST RESEARCH FUNDING

- PI, *Constrained Optimization for Wind Power Production*, General Electric Company, \$75K, 2016.
- co-PI, *The Multifaceted Mathematics Center for Complex Energy Systems*, Department of Energy, Office of Science, \$3,966,460 Total (\$140K Allocation to co-PI), 2016-2017.
- PI, *Next-Generation Optimization under Uncertainty: Structure-Oriented Algorithms*, Department of Energy, Office of Science Early Career Award, \$500K/yr (\$1.5M Total), 2012-2015
- PI, *Development of Methodologies for Large-scale Optimization for Electrical Transmission Planning*, DOE-AOP, Office of Electricity, \$300K/yr, 2010-2015
- co-PI, *Novel Power System Operations Methods for Wind-Powered Systems*, LDRD Award, Argonne National Laboratory, \$350K, 2009-2012
- co-PI, *Building-Wide, Proactive Energy Management Systems for High-Performance Buildings*, DOE-AOP, EERE, \$300K, 2010-2012
- PI, *Nonlinear MPC Assessment for Energy Applications*, General Electric Company, \$50K, 2010

JOURNAL PUBLICATIONS

- [1] Y. Cao, L. F. Fuentes-Cortes, S. Chen, and **V.M. Zavala**. Scalable modeling and solution of stochastic multiobjective optimization problems. *Computers & chemical engineering*, 99:185–197, 2017.
- [2] N.-Y. Chiang, R. Huang, and **V.M. Zavala**. An augmented lagrangian filter method for real-time embedded optimization. *Ieee transactions on automatic control*, 2017.
- [3] A. W. Dowling, R. Kumar, and **V.M. Zavala**. A multi-scale optimization framework for electricity market participation. *Applied energy*, 190:147–164, 2017.
- [4] D. W. Griffith, **V.M. Zavala**, and L. T. Biegler. Robustly stable economic nmPC for non-dissipative stage costs. *Journal of process control*, 57:116–126, 2017.
- [5] J. Jalving, S. Abhyankar, K. Kim, M. Hereld, and **V.M. Zavala**. A graph-based computational framework for simulation and optimisation of coupled infrastructure networks. *IET generation, transmission & distribution*, 2017.
- [6] K. Kim, F. Yang, **V.M. Zavala**, and A. A. Chien. Data centers as dispatchable loads to harness stranded power. *Ieee transactions on sustainable energy*, 8(1):208–218, 2017.
- [7] A. M. Sampat, E. Martin, M. Martin, and **V.M. Zavala**. Optimization formulations for multi-product supply chain networks. *Computers & chemical engineering*, 104:296–310, 2017.
- [8] M. M. Santos-Rodriguez, A. Flores-Tlacuahuac, and **V.M. Zavala**. A stochastic optimization approach for the design of organic fluid mixtures for low-temperature heat recovery. *Applied energy*, 198:145–159, 2017.

- [9] M. Sharara, A. Sampat, L. W. Good, A. S. Smith, P. Porter, **V.M. Zavala**, R. Larson, and T. Runge. Spatially explicit methodology for coordinated manure management in shared watersheds. *Journal of environmental management*, 192:48–56, 2017.
- [10] J. Yu, **V.M. Zavala**, and M. Anitescu. A scalable design of experiments framework for optimal sensor placement. *Journal of process control*, 2017.
- [11] Y. Cao, C. D. Laird, and **V.M. Zavala**. Clustering-based preconditioning for stochastic programs. *Computational optimization and applications*, 64(2):379–406, 2016.
- [12] N.-Y. Chiang and **V.M. Zavala**. An inertia-free filter line-search algorithm for large-scale nonlinear programming. *Computational optimization and applications*, 64(2):327–354, 2016.
- [13] N.-Y. Chiang and **V.M. Zavala**. Large-scale optimal control of interconnected natural gas and electrical transmission systems. *Applied energy*, 168:226–235, 2016.
- [14] A. W. Dowling, G. Ruiz-Mercado, and **V.M. Zavala**. A framework for multi-stakeholder decision-making and conflict resolution. *Computers & chemical engineering*, 90:136–150, 2016.
- [15] L. F. Fuentes-Cortes, A. W. Dowling, C. Rubio-Maya, **V.M. Zavala**, and J. M. Ponce-Ortega. Integrated design and control of multigeneration systems for building complexes. *Energy*, 116, Part 2:1403–1416, 2016.
- [16] L. F. Fuentes-Cortes, Y. Ma, J. M. Ponce-Ortega, G. Ruiz-Mercado, and **V.M. Zavala**. Valuation of water and emissions in energy systems. *Applied energy*, 2016.
- [17] **V.M. Zavala** and M. Anitescu. Scalable nonlinear programming via exact differentiable penalty functions and trust-region newton methods. *Siam journal on optimization*, 24(1):528–558, 2014.
- [18] M. C. Burkhart, Y. Heo, and **V.M. Zavala**. Measurement and verification of building systems under uncertain data: a gaussian process modeling approach. *Energy and buildings*, 75:189–198, 2014.
- [19] **V.M. Zavala**. Inference of building occupancy signals using moving horizon estimation and fourier regularization. *Journal of process control*, 24(6):714–722, 2014.
- [20] P. Morales-Valdes, A. Flores-Tlacuahuac, and **V.M. Zavala**. Analyzing the effects of comfort relaxation on energy demand flexibility of buildings: a multiobjective optimization approach. *Energy and buildings*, 85:416–426, 2014.
- [21] **V.M. Zavala**. Stochastic optimal control model for natural gas networks. *Computers & chemical engineering*, 64:103–113, 2014.
- [22] **V.M. Zavala** and A. Flores-Tlacuahuac. Stability of multiobjective predictive control: a utopia-tracking approach. *Automatica*, 48(10):2627–2632, 2012.
- [23] Y. Heo and **V.M. Zavala**. Gaussian process modeling for measurement and verification of building energy savings. *Energy and buildings*, 53:7–18, 2012.
- [24] **V.M. Zavala**. Real-time optimization strategies for building systems. *Industrial & engineering chemistry research*, 52(9):3137–3150, 2012.
- [25] E. M. Constantinescu, **V.M. Zavala**, M. Rocklin, S. Lee, and M. Anitescu. A computational framework for uncertainty quantification and stochastic optimization in unit commitment with wind power generation. *Ieee transactions on power systems*, 26(1):431–441, 2011.
- [26] **V.M. Zavala** and M. Anitescu. Real-time nonlinear optimization as a generalized equation. *Siam journal on control and optimization*, 48(8):5444–5467, 2010.
- [27] **V.M. Zavala**. Stability analysis of an approximate scheme for moving horizon estimation. *Computers & chemical engineering*, 34(10):1662–1670, 2010.
- [28] **V.M. Zavala** and L. T. Biegler. Optimization-based strategies for the operation of low-density polyethylene tubular reactors: moving horizon estimation. *Computers & chemical engineering*, 33(1):379–390, 2009.
- [29] **V.M. Zavala** and L. T. Biegler. Optimization-based strategies for the operation of low-density polyethylene tubular reactors: nonlinear model predictive control. *Computers & chemical engineering*, 33(10):1735–1746, 2009.
- [30] **V.M. Zavala** and L. T. Biegler. The advanced-step nmpe controller: optimality, stability and robustness. *Automatica*, 45(1):86–93, 2009.
- [31] **V.M. Zavala**, E. M. Constantinescu, T. Krause, and M. Anitescu. On-line economic optimization of energy systems using weather forecast information. *Journal of process control*, 19(10):1725–1736, 2009.
- [32] L. T. Biegler and **V.M. Zavala**. Large-scale nonlinear programming using ipopt: an integrating framework for enterprise-wide dynamic optimization. *Computers & chemical engineering*, 33(3):575–582, 2009.

- [33] R. Huang, **V.M. Zavala**, and L. T. Biegler. Advanced step nonlinear model predictive control for air separation units. *Journal of process control*, 19(4):678–685, 2009.
- [34] **V.M. Zavala**, C. D. Laird, and L. T. Biegler. A fast moving horizon estimation algorithm based on nonlinear programming sensitivity. *Journal of process control*, 18(9):876–884, 2008.
- [35] **V.M. Zavala**, C. D. Laird, and L. T. Biegler. Fast implementations and rigorous models: can both be accommodated in nmpc? *International journal of robust and nonlinear control*, 18(8):800–815, 2008.
- [36] **V.M. Zavala**, C. D. Laird, and L. T. Biegler. Interior-point decomposition approaches for parallel solution of large-scale nonlinear parameter estimation problems. *Chemical engineering science*, 63(19):4834–4845, 2008.
- [37] **V.M. Zavala** and L. T. Biegler. Large-scale parameter estimation in low-density polyethylene tubular reactors. *Industrial & engineering chemistry research*, 45(23):7867–7881, 2006.
- [38] **V.M. Zavala**, A. Flores-Tlacuahuac, and E. Vivaldo-Lima. The bifurcation behavior of a polyurethane continuous stirred tank reactor. *Chemical engineering science*, 61(22):7368–7385, 2006.
- [39] **V.M. Zavala**, A. Flores-Tlacuahuac, and E. Vivaldo-Lima. Dynamic optimization of a semi-batch reactor for polyurethane production. *Chemical engineering science*, 60(11):3061–3079, 2005.

CONFERENCE PUBLICATIONS (PEER-REVIEWED)

- [1] **V.M. Zavala** and M. Anitescu. MPC as a DVI: implications on sampling rates and accuracy. In *56th ieee conference on decision and control (cdc)*. IEEE, 2017, To Appear.
- [2] A. W. Dowling, A. Dyreson, F. Miller, and **V.M. Zavala**. Economic assessment and optimal operation of csp systems with tes in california electricity markets. In *Aip conference proceedings*. Vol. 1850. (1). AIP Publishing, 2017, p. 160006.
- [3] A. W. Dowling, T. Zheng, and **V.M. Zavala**. Economic assessment of concentrated solar power technologies: a review. *Renewable and sustainable energy reviews*, 72:1019–1032, 2017.
- [4] A. Dowling and **V.M. Zavala**. Redesigning decision-making architectures to exploit multi-scale electricity markets. In *Foundations of computer-aided process operations*, 2017, To Appear.
- [5] A. Dowling and **V.M. Zavala**. Resolving conflicts among stakeholders in real-time operations. In *Foundations of computer-aided process operations*, 2017, To Appear.
- [6] H. Tian, Q. Lu, R. B. Gopaluni, and **V.M. Zavala**. Multiobjective economic model predictive control of mechanical pulping processes. In *55th ieee conference on decision and control (cdc)*. IEEE, 2016, pp. 4040–4045.
- [7] H. Tian, Q. Lu, R. B. Gopaluni, **V.M. Zavala**, and J. A. Olson. Economic nonlinear model predictive control for mechanical pulping processes. In *2016 american control conference (acc)*. IEEE, 2016, pp. 1796–1801.
- [8] **V.M. Zavala**. A multiobjective optimization perspective on the stability of economic mpc. *Ifac-papersonline*, 48(8):974–980, 2015.
- [9] J. Kang, N. Chiang, C. D. Laird, and **V.M. Zavala**. Nonlinear programming strategies on high-performance computers. In *Proc. of the ieee conference on decision and control, osaka, japan*, 2015.
- [10] N. Chiang, C. G. Petra, and **V.M. Zavala**. Structured nonconvex optimization of large-scale energy systems using pips-nlp. In *Power systems computation conference (pscc), 2014*. IEEE, 2014, pp. 1–7.
- [11] **V.M. Zavala**. Real-time resolution of conflicting objectives in building energy management: an utopia-tracking approach. In *Proceedings of the 5th national conference of ibpsa-usa*, 2012, pp. 1–6.
- [12] M. Lubin, C. G. Petra, M. Anitescu, and **V.M. Zavala**. Scalable stochastic optimization of complex energy systems. In *2011 international conference for high performance computing, networking, storage and analysis (sc)*. IEEE, 2011, pp. 1–10.
- [13] B. A. Robbins and **V.M. Zavala**. Convergence analysis of a parallel newton scheme for dynamic power grid simulations. In *Proceedings of the first international workshop on high performance computing, networking and analytics for the power grid*. ACM, 2011, pp. 3–10.
- [14] A. Kannan and **V.M. Zavala**. A game-theoretical model predictive control framework for electricity markets. In *Communication, control, and computing (allerton), 2011 49th annual allerton conference on*, Sept. 2011, pp. 1280–1285.

- [15] **V.M. Zavala** and M. Anitescu. Achieving higher frequencies in large-scale nonlinear model predictive control. In *49th IEEE conference on decision and control (cdc)*. IEEE, 2010, pp. 6119–6124.
- [16] **V.M. Zavala**, A. Botterud, E. Constantinescu, and J. Wang. Computational and economic limitations of dispatch operations in the next-generation power grid. In *Innovative technologies for an efficient and reliable electricity supply (citres), 2010 IEEE conference on*. IEEE, 2010, pp. 401–406.
- [17] **V.M. Zavala**, E. M. Constantinescu, and M. Anitescu. Economic impacts of advanced weather forecasting on energy system operations. In *Innovative smart grid technologies (isgt), 2010*. IEEE, 2010, pp. 1–7.
- [18] **V.M. Zavala**, J. Wang, S. Leyffer, E. M. Constantinescu, M. Anitescu, and G. Conzelmann. Proactive energy management for next-generation building systems. In *Fourth national conference of ibpsa-usa, new york city, new york august 11*. Vol. 13, 2010.
- [19] A. Alessandri, M. Baglietto, G. Battistelli, and **V.M. Zavala**. Advances in moving horizon estimation for nonlinear systems. In *49th IEEE conference on decision and control (cdc)*. IEEE, 2010, pp. 5681–5688.
- [20] **V.M. Zavala**, M. Anitescu, and T. Krause. On the optimal on-line management of photovoltaic-hydrogen hybrid energy systems. *Computer aided chemical engineering*, 27:1953–1958, 2009.
- [21] **V.M. Zavala**, C. D. Laird, and L. T. Biegler. Fast solvers and rigorous models: can both be accommodated in nmPC. In *Proceedings of the IFAC workshop on nonlinear model predictive control for fast systems*, 2006.

BOOK CHAPTERS

- [1] N.-Y. Chiang and **V.M. Zavala**. Emerging optimal control models and solvers for interconnected natural gas and electricity networks. In, *Alternative energy sources and technologies*, pp. 89–115. Springer, 2016.
- [2] K. Kim and **V.M. Zavala**. Large-scale stochastic mixed-integer programming algorithms for power generation scheduling. In, *Alternative energy sources and technologies*, pp. 493–512. Springer, 2016.
- [3] **V.M. Zavala** and L. T. Biegler. Nonlinear programming strategies for state estimation and model predictive control. In, *Nonlinear model predictive control*, pp. 419–432. Springer, 2009.

RESEARCH MENTORING

• Postdoctoral (Former Institution-Department)

- Yankai Cao (Purdue-Chemical Engineering), 2016-Present
- Alexander Dowling (Carnegie Mellon-Chemical Engineering), 2015-2017, Now Faculty at University of Notre Dame
- Kibaek Kim (Northwestern-Industrial & Systems Engineering), 2014-2016, Now Staff at Argonne National Laboratory
- Nai-Yuan Chiang (Edinburgh-Mathematics), 2013-2015, Now Staff at United Technologies
- Yeonsook Heo (Georgia Tech-Architecture), 2011-2013, Now Faculty at University of Cambridge

• Doctoral (Former Institution-Department)

- Sungho Shin (Seoul National University, Chemical Engineering), 2016-Present
- Yicheng Hu (Zhejiang University, Chemical Engineering), 2016-Present
- Ranjeet Kumar (IIT-Bombay, Chemical Engineering), 2015-Present
- Apoorva Sampat (Institute of Chemical Technology, Chemical Engineering), 2015-Present
- Jordan Jalving (Colorado State University, Chemical Engineering), 2015-Present

• Undergraduate (Institution)

- Jose Renteria (UW-Madison), 2016-Present
- Sang Il Kwon (UW-Madison), 2017-Present
- Mahad Siad (UW-Madison), 2016-2017
- Tian Zheng (UW-Madison), 2015-2017
- Yan Ma (UW-Madison), 2015-2017
- Mauricio Tombini (UNIOESTE, Brazil), 2016

- Siyu Chen (Zhejiang University), 2016
- Jeewanh Lee (UW-Madison), 2015

SCIENTIFIC COMMUNITY ACTIVITIES

- Technical Editor, Mathematical Programming C, 2015-Present
- Associate Editor, Journal of Process Control, 2017-Present
- SIAM Diversity Advisory Committee, 2015-Present
- AIChE Midwest Research Conference Programming Committee, 2015-Present
- Department of Energy Advanced Computing Tech Team (ACTT), 2015-2017
- Area Chair, Energy Processes, Advanced Control of Chemical Processes Conference, 2018
- Area Chair, AIChE Computing and Systems Technology Division, 2018-2019
- Cluster Organizer “Applications in Science and Engineering”, ICCOPT, 2016.
- Session Organizer “High-Performance Computing for Stochastic Programming”, ICSP, 2016.
- Session Organizer “Optimization of Energy Systems”, ISMP, 2015.
- Session Organizer “Stochastic Optimization of Complex Systems”, SIAM Conference on Optimization, 2014
- Session Organizer “Emerging Applications of Large-Scale Optimization”, INFORMS Annual Meeting, 2013
- Track Organizer “Scientific and Engineering Applications of Optimization”, ICCOPT, 2013
- Session Organizer “Modeling, Optimization, and Simulation for Power Grid”, SIAM CSE, 2013
- International Programming Committee, Nonlinear Model Predictive Control, 2012
- Session Organizer, “Real-Time Optimization”, ISMP, 2012
- Organizer “Mathematics for the Analysis, Simulation, and Optimization of Complex Systems”, DOE, 2011

RECENT INVITED TALKS

- **2017** - USDA, MIT, USC, Stanford, UCLA, BYU, McMaster, FOCAPO/CPC, SIAM Conference on Optimization, Wisconsin State Legislature, SIAM Annual Meeting, Universidad de Valladolid (Spain), Universidad Nacional (Colombia), Universidad de Antioquia (Colombia).
- **2016** - U.S.-Mexico Workshop on Optimization, Technical University of Denmark, King Abdullah University of Science and Technology, Argonne National Laboratory, International Symposium on Stochastic Programming (ICSP), International Conference on Continuous Optimization (ICCOPT), Institute for Mathematics and its Applications, Universidad Michoacana, Pacific Northwest National Laboratory, General Electric Company, Dow Chemical Company, Midwest Microgrid Consortium, ITESM (Mexico)
- **2015** - Johns Hopkins University, Princeton University, SIAM CSE, ADCHEM, University of California-Berkeley, Carnegie-Mellon University, AIChE Annual Meeting, IEEE CDC.
- **2014** - University of Southern California, University of Wisconsin-Madison, INFORMS Optimization Society, Illinois Institute of Technology, SIAM Conference on Optimization, Power Systems Computation Conference, Los Alamos National Laboratory, European Control Conference
- **2013** - AIChE-CAST Plenary, Electronics and Telecommunications Research Institute (Korea), Laboratorio Nacional de Energia e Geologia (Portugal), Queen’s University (Canada), Universidad Adolfo Ibañez (Chile), Lawrence Berkeley National Laboratory, SIAM CSE, INFORMS ICS, Purdue University, International Conference on Stochastic Programming (ICSP), International Conference on Continuous Optimization (ICCOPT), DOE Office of Science Advanced Scientific Computing Committee (ASCAC), Institute for Mathematics and its Applications
- **2012** - ABB Corporate Research, Universidad Iberoamericana, International Symposium on Mathematical Programming, INFORMS Annual, Singapore Workshop on Optimization, Texas A&M

SOFTWARE PRODUCTS

- Graph-Based Modeling Framework (PLASMO)
<https://github.com/zavalab/Plasmo.jl>, 2016-Present
- Decomposition for Structured Programming (DSP)
<https://github.com/Argonne-National-Laboratory/DSP>, 2014-Present
- Parallel Interior Point Solver (PIPS)
<https://github.com/Argonne-National-Laboratory/PIPS>, 2011-Present

ACADEMIC COLLABORATORS (Past 48 Months)

- **UW:** Ophelia Venturelli (Biochemistry), Vicki Bier, Jeff Linderoth, James Luedtke (Industrial and Systems Engineering), Rebecca Larson and Krishnapuram Karthikeyan (Biological Systems Engineering), Andrea Hicks and Daniel Noguera (Civil and Environmental Engineering), Thomas Jahns (Electrical Engineering), Michael Ferris (Computer Science), Franklin Miller (Mechanical Engineering), Christos Maravelias, George Huber, Nicholas Abbott, Thatcher Root (Chemical and Biological Engineering).
- **External:** Eric Kerrigan (Imperial College, UK), Bhushan Gopaluni (University of British Columbia, Canada), Gerardo Ruiz-Mercado (Environmental Protection Agency), Frank Curtis (Lehigh), Andrew Chien and John Birge (University of Chicago), Cosmin Petra, Mihai Anitescu, Emil Constantinescu, Sven Leyffer (Argonne), Jean-Paul Watson, John Sirola, Carl Laird (Sandia), Suvrajeet Sen (USC), Andreas Waechter (Northwestern), Antonio Flores (ITESM-Mexico), Fernando D'Amato (General Electric), Kirk Drees, Matthew Ellis, Mohammad ElBsat, and Michael Wenzel (Johnson Controls), Rui Huang and Nai-Yuan Chiang (United Technologies)

INDUSTRIAL COLLABORATORS

- Johnson Controls, 2015-Present
- General Electric Company, 2008-2010, 2015-Present
- Dow Chemical Company, 2015-Present
- United Technologies Research Center, 2015-Present
- BuidingIQ (Building Controls), 2010-2013
- Citizen's Utility Board of Illinois, 2012
- ExxonMobil Chemical, 2004-2008