

CENTER FOR COMPACT AND EFFICIENT FLUID POWER



A National Science Foundation Engineering Research Center



Dear Friends and Supporters of CCEFP:

Your support creates unprecedented impact across the fluid power research and technology community. We are raising awareness of fluid power innovation; we are educating the next generation of leaders; we are teaching relevant fluid power concepts to hundreds of students each year; we are answering industry's needs with innovative solutions. Your contributions to the Center for Compact and Efficient Fluid Power are critical to our continued success. Your support is utilized for leadership, advocacy, innovation, education, and networking. We appreciate your commitment to building a strong and sustained fluid power community.

CCEFP IMPACT: 2017-2018 CCEFP Annual Report

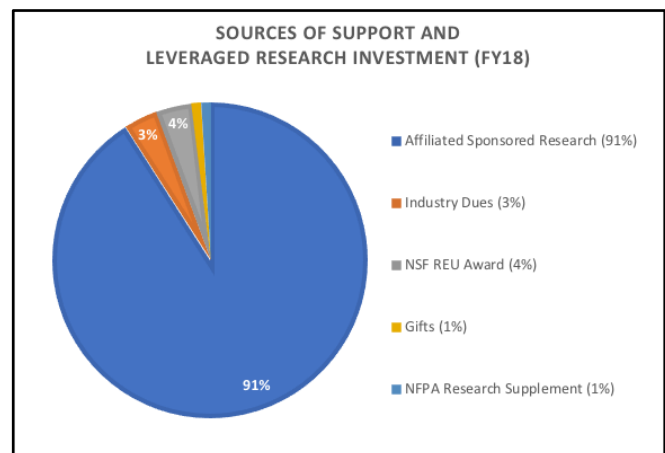


LEAD | The Center's strength resides in its ability to leverage the resources of its research community.

While the CCEFP's ability to directly support research has decreased since graduating from the National Science Foundation in 2016, investment in fluid power research continues to thrive. In years 12 and 13, the CCEFP directly supported over **\$960,000** in fluid power research at the Georgia Institute of Technology, Marquette University, Milwaukee School of Engineering, Purdue University, University of California at Merced, University of Illinois-Urbana-Champaign, University of Minnesota, University of Wisconsin-Madison, and Vanderbilt University. Other universities and organizations indirectly impacted include Iowa State University, Oak Ridge National Laboratory, and Texas A&M University.

In collaboration with the National Fluid Power Association (NFPA), ten affiliated researchers received **\$100,000** in supplemental research awards designed to promote the attendance and representation of fluid power research at annual CCEFP events. Additionally, CCEFP-affiliated faculty were awarded over **\$9,850,000** in associated fluid power research through the National Science Foundation, Department of Energy, Department of Defense, Department of Transportation, Army, and other industry sponsors. The CCEFP is also a recipient of an NSF REU Site award of **\$402,000** which sponsors the participation of undergraduate researchers in fluid power labs over the summer.

The NFPA Pascal Society played an important role in transitioning the CCEFP from NSF funding to industry funding. Since 2014, the Pascal Society has provided **\$2,900,000** in research funding to the CCEFP. Initiated in 2018, the CCEFP's new industry consortium consists of 22 industry members with **\$377,000** in annual dues that allow the Center to sponsor seed research projects and administer the organization. **Prof. Zongxuan "Sunny" Sun** was appointed Director of the new CCEFP industry-sponsored research consortium. In its first year, two industry-selected research projects were funded, and administrative costs were reduced by over 65% to dedicate more funds towards research and fluid power advocacy.





ADVOCATE | CCEFP’s strategic plan includes championing the creation of new sources of government funding for fluid power research. The CCEFP leadership team, along with industry supporters, have raised awareness within the Department of Energy (DOE) regarding the energy saving potential for off-highway vehicles and educated them of the key role that hydraulics plays in improving energy efficiency. To create the **DOE EERE Energy Efficient Commercial Off-road Vehicles Program**, enabling language was added to the FY17

Energy and Water Appropriations bill creating a **\$5,000,000** program for energy saving technology for commercial off-road vehicles. The program has been renewed in FY18 and FY19. To date, this program has appropriated over \$15 million to fluid power research to universities, industry, and government labs. The goal is to increase annual funding to \$10 million for FY20. Annual visits by CCEFP and industry representatives have been conducted to assure continuing congressional support. Affiliated CCEFP researchers have received a total of **\$4,400,000** for three projects which all include industry collaboration. The projects are: *“Efficient, Compact, and Smooth Variable Propulsion Motor,”* PI: James Van de Ven, University of Minnesota; *“Individual Electro-Hydraulic Drives for Off-Road Vehicles,”* PI: Andrea Vacca, Purdue University; and *“Hydraulic Electric Architectures for Mobile Machines,”* PI: Perry Li, University of Minnesota. Other program funding went to research on coatings, tribology, and fluids at Argonne National Laboratory, Oak Ridge National Laboratory, Pacific Northwest National Laboratory, and an engine research project at Caterpillar. The funding announcement for FY19 awards has been published and up to two projects are expected to be selected for support.



INNOVATE | Each year, the CCEFP will review and assess its research strategy based on technology trends and opportunities, industry recommendations and representation, and availability of support. Due to limited resources, the Center determined that pursuing government funding for off-highway vehicles best represented the desires of the CCEFP industry-sponsored consortium. Affiliated efforts related to off-highway vehicles research include pursuit of a powertrain research center. Previous success executing the CCEFP research

strategy are still on-going. Due to CCEFP’s leadership and advocacy, fluid power has been identified as as a motion control contributor in the Department of Defense (DOD) Advanced Robotics for Manufacturing (ARM) Institute and NSF has identified soft robotics as a primary topic in the 2018 Emerging Frontiers in Research Innovation (EFRI) Program.



EDUCATE | Hands-on research experience is the best way to educate students and the future workforce. As an outcome of the new CCEFP industry-sponsored consortium and the support of the NFPA Pascal Society, the following research projects are affiliated with the CCEFP and serve as program content for CCEFP Summits. CCEFP-affiliated fluid power research projects:

PROJECT	PI & INSTITUTION	SPONSOR
Science of Pattern Coating onto Heterogeneous Surfaces Using a Hybrid Tool	Prof. Tequila Harris Georgia Institute of Technology	NSF, NFPA
Polymer-Enhanced Fluid Effects on Mechanical Efficiency of Hydraulic Pumps	Paul Michael, Milwaukee Sc of Engrg Prof. Ashlie Martini, University of California-Merced	CCEFP, NFPA
Individual Electro-Hydraulic Drives for Off-Road Vehicles	Prof. Andrea Vacca Purdue University	DOE, NFPA
High Efficiency Hydraulic Pump-Motors Employing Partial Stroke Piston Pressurization	Prof. Tom Chase University of Minnesota	NSF, NFPA
Liquid Piston Gas Compressor/Expander for Compressed Air Energy Storage (CAES) and CO2 Sequestration	Prof. Perry Li University of Minnesota	NSF, NFPA

Understanding the Transient Nature of Wind Turbine Response to Create Advanced Controls to Improve the Efficiency of a Hydraulic Drivetrain Wind Turbine	Prof. Kim Stelson University of Minnesota	NSF, NFPA
Modeling and Optimization of Trajectory-Based HCCI Combustion	Prof. Zongxuan Sun University of Minnesota	NSF, NFPA
Efficient, Compact, and Smooth Variable Propulsion Motor	Prof. James Van de Ven University of Minnesota	DOE, NFPA
Seamless Electric to Hydraulic Conversion	Prof. Eric Severson University of Wisconsin-Madison	CCEFP, NFPA
Hydraulic Electric Architectures for Mobile Machines	Prof. Perry Li University of Minnesota	DOE

Other impacts include infrastructure investment to fluid power teaching laboratories. The best way to transform fluid power is to expose and teach the next generation of engineers. An alumni donation to the University of Minnesota resulted in improvements to the fluid power teaching facilities of which over 400 undergraduate students enroll each year. The existence of the Center was instrumental in this investment.

CCEFP affiliated faculty are actively promoting fluid power technology in synergistic ways. Since 2017, these include:

- Five patents awarded to faculty related to fluid power initiatives
- Published over 35 papers
- Engaged more than 44 graduate students; 14 have graduated since 2017
- Advised 32 undergraduate researchers through the CCEFP REU Program
- Volunteered on NFPA Roadmapping Committee, volunteered on NFPA Education Committee, offered technology demonstrations for a local STEM camp, advised an industry master’s student on hydraulic hand tools, and designed and developed a new graduate level fluid power course.



NETWORK | The CCEFP is an industry-sponsored research consortium with associated support for faculty and students by the Pascal Society of the NFPA Education and Technology Foundation. Industry representatives from 22 companies along with faculty and student researchers have attended three CCEFP Summits held at Sun Hydraulics, the University of Kentucky, and the University of Minnesota. During each of these events, special program features were offered such as facility tours, a Noise-Vibration-Harshness workshop, and a tour of new fluid power research and teaching laboratories. The Center hosted monthly Industry Engagement Committee (IEC) teleconferences and the CCEFP Webinar Series, both among the most popular activities with industry. Due to the new industry consortium, registration for the CCEFP Webinar Series is limited to CCEFP and NFPA industry membership. Over 89 individuals have registered for the Webinar Series, 82% of which are from our collaborating industry supporters.

In late 2018, the CCEFP, 13 fluid power industry contributors, and the National Lab network led by Argonne proposed a DOE National Lab Technologist-In-Residence (TIR) Program to focus on collaborative fluid power R&D projects that leverage the unique expertise and facilities that exist in the DOE national lab complex to overcome specific challenges and barriers that industry identifies as being critical to their needs. The DOE TIR Program exists to catalyze strong lab-industry relationships that result in significant growth in high-impact collaborative research and development. Often, industry is unfamiliar with the National Lab resources and expertise and lab researchers are unfamiliar with the most pressing industry problems.