# Center for Compact and Efficient Fluid Power (CCEFP)

## University of Minnesota (lead institution)

***Transforming fluid power for novel applications in industries throughout the economy***

***A National Science Foundation Engineering Research Center since 2006***

***Partner Institutions:***

- ***Georgia Institute of Technology (GT)***
- ***Milwaukee School of Engineering (MSOE)***
- ***North Carolina Agricultural and Technical State University (NCAT)***
- ***Purdue University (PU)***
- ***University of Illinois at Urbana-Champaign (UIUC)***
- ***Vanderbilt University (VU)***

The Center for Compact and Efficient Fluid Power (CCEFP) is a network of researchers, educators, and industry working together to transform the fluid power industry and how the relevant knowledge and technologies are studied, applied, and taught. Through research, we are creating hydraulic and pneumatic technology that is compact, efficient, and effective. Through education and outreach, we are transferring this knowledge to diverse audiences—students of all ages, users of fluid power, and the general public.

Fluid power is used in a wide range of industries, including manufacturing, transportation, aerospace, construction, agriculture and medical devices. The work of the Center will bring dramatic change to fluid power applications in all these industries. Improved *efficiency* will significantly reduce petroleum consumption, energy use, and pollution. Improved *effectiveness* will make fluid power clean, quiet, and safe for its millions of users around the world. And improved *compactness*, also made possible through the work of the Center, will enable fluid power to perform tasks that are not presently possible.

> *Fluid power is the science and technology dealing with the generation, control, and transmission of pressurized fluids and gases.*

For example, nearly all U.S. manufacturing plants rely on fluid power in their production of goods. The use of fluid power is so prevalent that any improvements in efficiency will have an important impact on energy consumption. Migrating fluid power more broadly to new applications in the transportation sector will cause even more energy to be saved. Since there is currently no other feasible technology for high-power, high-force applications, fluid power is essential for large equipment; but the intrinsic bandwidth and power density advantages of fluid power have yet to be exploited on smaller-scale, portable, and self-powered systems. Examples of innovative technology that will result from Center research include devices that improve mobility for the ailing and elderly, autonomous rescue and service robots, and fluid-powered portable hand tools.

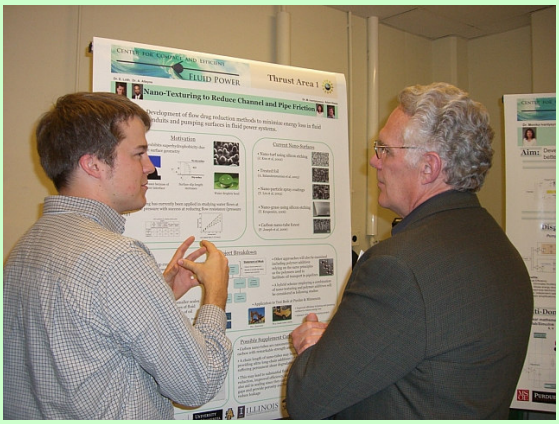
### Research

The CCEFP has four research goals: to dramatically improve the energy efficiency of fluid power in current applications; to improve the efficiency of transportation by developing fuel-efficient hydraulic hybrid vehicles; to develop un-tethered, portable, human-scale fluid power devices; and to make fluid power clean, quiet, safe, and easy to use. The research needed to realize these goals is being conducted in three coordinated thrust areas and demonstrated in five test beds:

***Thrust 1 – Efficiency:*** The goal of the efficiency thrust is to develop fluid power components and system configurations that are both energy efficient and have high performance. On/off valve-based control and displacement control will replace inefficient throttling control approaches. Energy is saved through regeneration. Component efficiency can be improved over a wide operating range via optimized tribological surfaces. Engineered fluids will also significantly improve efficiency.

***Thrust 2 – Compactness:*** The CCEFP is creating compact, portable power supplies by tightly coupling the energy source to the fluid, using chemo-fluidic actuation or free-piston engine compressors. Approaches, such as open accumulator, that can significantly increase the capacity of energy storage are being developed. Composite and functionally graded materials, integrated into a unified system, will minimize weight and volume.

***Thrust 3 – Effectiveness:*** Noise, vibration, leakage, and awkward interfaces limit current and potential applications of fluid power. The CCEFP is developing novel user interfaces and breakthrough technology for sound reduction and leakage elimination. This will expand uses of fluid power from heavy equipment to innovative portable and self-powered applications including orthoses (orthopedic prostheses), wearable tools, and rescue robots.




**An industry member and a student discuss a research project during the annual site visit.**

***Test Beds:*** Center research is demonstrated in five test beds: an excavator, sUV (small Urban Vehicle), compact rescue crawler, fluid power-assisted portable hand tools, and fluid power-assisted orthoses. The excavator represents a current application of fluid power, demonstrating a dramatic improvement in efficiency. The sUV demonstrates the use of fluid power to improve efficiency in the transportation sector. The compact rescue crawler, fluid power-assisted portable hand tools, and fluid power-assisted orthoses demonstrate the radical transformations and social impacts possible with the next generation of un-tethered, portable, human-scale fluid power devices.

## Education

The Center's partnership network and research programs combine to enable the development and delivery of innovative education and outreach programs relevant to fluid power to middle and high school students, undergraduate and graduate students, engineers, industry practitioners, and the general public. Informed by the research work of the Center, these programs will enrich the understanding of fluid power technology and heighten the interest in technology and engineering among an increasingly diverse student population.

Current education and outreach programs include the following:

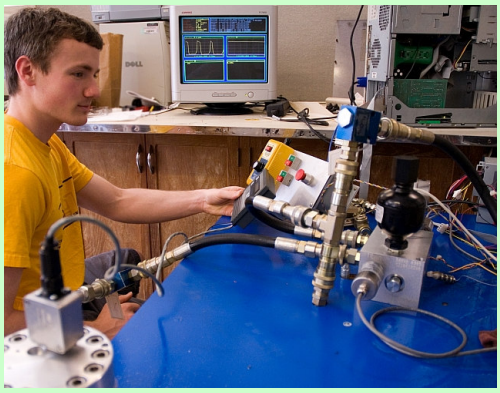
- Working with Project Lead the Way to add fluid power content to PLTW's engineering curriculum for middle and high schools, now taught nationwide.
- Developing fluid power labs augmented with take-home laboratory modules that can be used in universities, technical colleges, and high schools.
- Revising the undergraduate curriculum so all mechanical engineers at the participating institutions understand fluid power.
- Developing specialized fluid power courses for Center graduate and advanced undergraduate students.
- Building an industrial internship program for our undergraduate and graduate students.
- Developing hands-on short courses and distance education in fluid power for industry.
- Collaborating with the Science Museum of Minnesota in the development of permanent and traveling fluid power exhibits that will serve as models for others around the country.
- Producing a documentary on fluid power in conjunction with Twin Cities Public Television.
- Staffing a booth at the International Exposition for Power Transmission 2008, part of the largest trade show in North America. This will improve industry awareness of CCEFP activities.
- Offering summer REU and RET programs at all of our partner universities, enabling teachers, undergraduate, and graduate students to work in cross-disciplinary research teams.
- Working with tribal colleges in Minnesota and Wisconsin to promote engineering among Native American students and to provide mentoring services.
- Participating in educational outreach programs for underrepresented minorities and females interested in engineering through our network of universities and associated Louis Stokes Alliances for Minority Participation (LSAMP) and Alliances for Graduate Education and the Professoriate AGEP programs.

## Industrial Collaboration/Technology Transfer

More than sixty fluid power manufacturers, distributors, and suppliers have become supporting members of the Center—an unprecedented demonstration of industry support. In addition, many of these companies contribute equipment and provide project champions who work actively with the universities on project and test bed research. Our strategic initiatives focus on frequent engagement and open communication with industry. The CCEFP Industrial Advisory Board (IAB) meets on a bi-weekly basis to keep abreast of center developments and provide guidance. In addition, some of our industry members are also represented on the Center's other oversight bodies, the Education Advisory Board and the Executive Committee. Communication is facilitated with newsletters, correspondence, surveys, focal interest groups, the annual CCEFP meeting, and project updates via internet webcasts.

**Giving high school students hands-on fluid power experience at Georgia Tech**

## Facilities



**A grad student in the lab at the University of Minnesota**

As the lead institution, the University of Minnesota (UM) provides the headquarter space for Center administration, as well as lab space. Primary lab space consists of more than 25,000 square feet among all of the universities, including the Fluid Power Control Laboratory (UM), Fluid Power and Motion Control Lab (GT), MAHA Fluid Power Lab (PU), Center for Intelligent Mechatronics (VU), Caterpillar Electromechanical Systems Lab (UIUC), and the Fluid Power Institute (MSOE). The supporting lab space includes Center for Diesel Research (UM), Composites Laboratory (UM), Nanofabrication Center (UM), Materials Research Science and Engineering Center (UM), Center for Transportation Studies (UM), Integrated Acoustics Lab (GT), Rapid Prototyping and Manufacturing Institute (GT), Tribology Lab (GT), Microfluidics Lab (PU), Multi-scale Manufacturing Center (PU), Human Dynamics and Control Lab (UIUC), Institute for Human-Machine Studies (NCAT), Rapid Prototyping Center (MSOE), and Nanotechnology Center (MSOE).

## Center Configuration, Leadership, Team Structure

The Research Leadership Team consists of the Director (UM), Deputy Director (UM), and Thrust Leaders (from GT, PU, and UIUC). Research strategy is directed by the Executive Committee, which includes the Research Leadership Team and a representative from our other partner and outreach institutions (VU, MSOE, and NCAT) as well as two representatives from our Industrial Advisory Board and one student from our Student Leadership Council.

Partnering institutions bring expertise in the following disciplines: acoustics, biomedical engineering, chemistry, composite materials, computer science, controls, fluid mechanics, heat transfer, human factors, internal combustion engine, mechanical design, numerical methods, robotics, systems dynamics, and tribology. Disciplines cross all institutional (both partner and outreach) boundaries, making for significant multi-disciplinary collaboration among our researchers.

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