

CENTER FOR COMPACT AND EFFICIENT FLUID POWER



A National Science Foundation Engineering Research Center



CCEFP FPMC IEC Face to Face Meeting

October 20, 2017

Agenda



- Roll sign up sheet
- Review of anti-trust policy
- CCEFP sustainability packet review
- CCEFP strategic thrusts
 - DOE Off-highway program
 - ARM robotic program
 - Fluid Power manufacturing

CCEFP Antitrust Policy Review

ANTITRUST GUIDELINES

It is the intention of the Center for Compact and Efficient Fluid Power (CCEFP) that all activities conducted by its Industrial Advisory Committees and other working groups will be in conformance with all Federal Antitrust Laws.

Areas of particular concern include:

- Any effort undertaken whether expressed or implied, that could be considered to restrain trade or act as a barrier to commerce to any individual or group of individuals will be avoided.
- Meetings of members will be structured. There should be proper notification, agenda, and observance of rules of procedure and minutes of the meeting. Adherence to the business items on the agenda will avoid any appearance of conflict.
- Members must take special care to avoid making statements or engaging in conduct prohibited by CCEFP policy and by-laws. Should members have any doubt concerning the propriety of any matters under discussion at such meetings, they must immediately disassociate themselves from the discussion and, if necessary, leave the meeting.

Responsibility for compliance rests with every member of the CCEFP, NFPA and related committees along with any invited guests or participants. Suspected violations of this notice should be communicated to your company representative or responsible CCEFP employee.

Note: Copies of CCEFP anti-trust policy available upon request.

CCEFP Sustainability Packet Contents

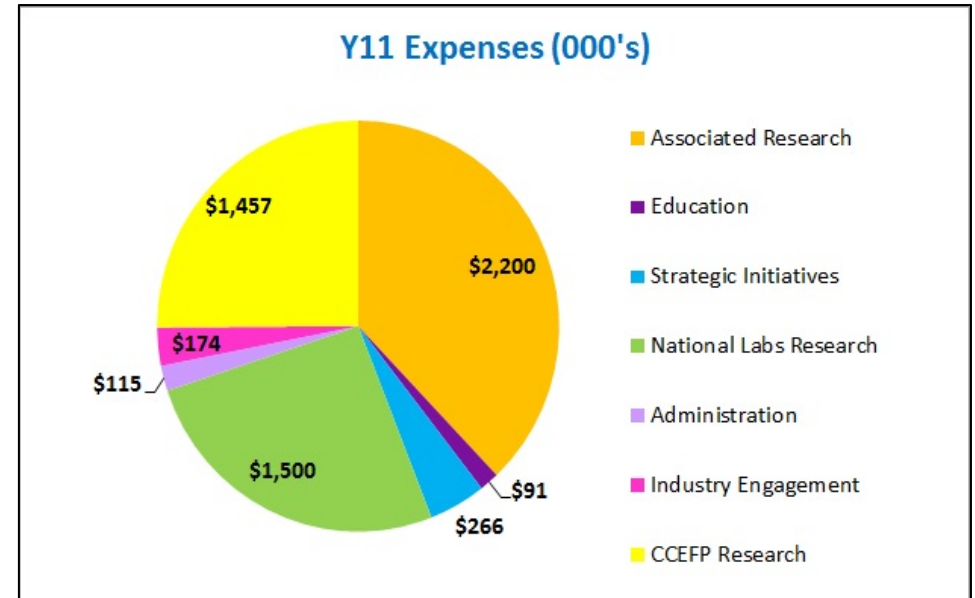
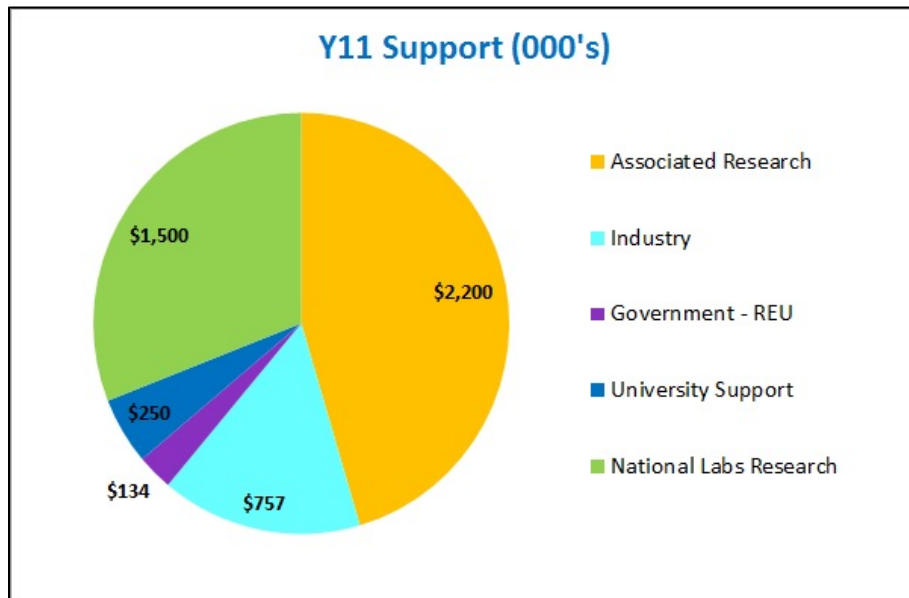


- CCEFP Year11 annual report
- CCEFP overview brochure
- CCEFP promotional flyer
- CCEFP research consortium collaboration agreement
- CCEFP SOPs -001 & -002
- CCEFP 1-page value proposition
- CCEFP Sponsorship structure
- Industry collaborator letter of support template

CCEFP Annual Report



- Describes funding raised, activities supported and impact summary in the key areas of Lead, Innovate, Advocate, Educate and Network.



CCEFP Overview Brochure



- Brief history of the CCEFP.
- Our mission, vision and strategy.
- What we do; how we do it and the resulting impact in each of our five key value propositions:



LEAD



ADVOCATE



NETWORK



INNOVATE



EDUCATE

CCEFP Collaboration Agreement



A. Description of participation

- Seat on the IEC (primary strategic input from industry)
- Access to CCEFP pre-competitive research results, progress and proposal plans to achieve goals

B. Intellectual property

- The UNIVERSITY shall own all rights, titles and interests in any invention, work or other form of intellectual property (each, a “UNIVERSITY INVENTION”) created, authored or conceived of solely by employees and/or students of the UNIVERSITY in the performance of work under the CONSORTIUM.
- Allows for joint inventions with industry
- Unconditional right to publish the results of the pre-competitive research done within CONSORTIUM

C. Term and termination

- Allowable any time with (90) day written notification

D. Boilerplate legal issues such as assignment, governing law, etc.

CCEFP Standard Operating Procedures (SOPs) -001 & -002



1. SOP-001 CCEFP and Industry Committee Management

PURPOSE

The purpose of this SOP is to describe the CCEFP and Industry Engagement Committee (IEC) management structures, roles, and responsibilities.

INTRODUCTION

The CCEFP Director will provide leadership for the strategic, research and administrative functions of the CCEFP. The CCEFP Deputy Directors and support staff will assist the Director in implementing the strategic direction, guiding the research process and administering the day-to-day operations of the CCEFP. The IEC will provide industry perspective to key CCEFP activities, such as research areas of focus, project selection, and project progress.

2. SOP-002 CCEFP Sponsored Research

PURPOSE

The purpose of this SOP is to describe the CCEFP processes for sponsored research including updating the Center research strategy, call for proposals, project selection, and progress updates.

INTRODUCTION

The CCEFP Director will maintain and update a research strategy that is used to determine priorities for research funding and strategic initiatives. Working with the Industry Engagement Committee (IEC), the Director will issue a call for pre-competitive research proposals. Any U.S. university is eligible to apply. CCEFP projects are typically authorized funding for a 2-year funding period. Regular updates on project progress will be scheduled with CCEFP industry supporters.

CCEFP 1-page Value Proposition



CENTER FOR COMPACT AND EFFICIENT FLUID POWER

A National Science Foundation Engineering Research Center



The CCEFP is dedicated to meeting the technology and workforce development needs of the U.S. fluid power industry. By combining the financial and volunteer contributions of many companies and individuals in a concerted effort, the Center creates the resources, partners, and opportunities needed to tackle industry's greatest challenges.

WHAT YOU GET

Through support and engagement, companies can:

- Stay abreast of new developments in fluid power technology
- Access leading researchers and research facilities
- Interact with and recruit fluid power knowledgeable students with systems engineering experience
- Gain competitive insights by networking with customers, suppliers, and competitors
- Focus Center-funded research on industry needs
- Ensure fluid power visibility at a national level
- Participate in government-funded initiatives

HOW WE DO IT

- Provide access to research progress and results
- Invite sponsors to networking events attended by researchers and students
- Allow sponsors to designate funds toward research topic areas
- Invite sponsors to appoint one representative to serve on the Industry Engagement Committee (IEC)
- Solicit IEC research topic recommendations for CCEFP call for proposals
- Encourage IEC participation in the Center's proposal review process, research progress, and mentorship
- Notify, explain, and provide collaboration opportunities on government fluid power initiatives
- Designate funds for research, events, education programs, and operating costs (to be capped annually)
- Publish an annual report of funds raised and activities supported

CCEFP Sponsorship Structure



Company size	Annual global fluid power sales	CCEFP Sponsorship
Very Large	Over \$1.5 billion	\$60,000
Large	Between \$500 million and \$1.5 billion	\$40,000
Medium	Between \$50 and \$500 million	\$20,000
Small	Between \$10 and \$50 million	\$10,000
Start-Up	Below \$10 million	\$1,000

- 1-page summary of the values provided by CCEFP to its supporters.
- Possible attachment to collaborator's agreement when seeking company approval.

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Small	Between \$10 and \$50 million	\$10,000
Start-Up	Below \$10 million	\$1,000
Sponsorship Responsibilities & Opportunities		
Recommend the selection of pre-competitive CCEFP-funded fluid power research projects		✓
Invitation to CCEFP Summits, Fluid Power Innovation & Research Conference, and other special events		✓
Participation in Industry Engagement Committee monthly teleconferences, research, and special topic webinars		✓
Early access to research progress and results		✓
Networking opportunities with students, faculty, and other industry supporters		✓
Notification of government funding programs and industry/academic partnerships		✓
Leverage government relations initiatives creating fluid power research programs		✓
Optional tax-deductible donation		✓
Sponsorship Supports		
CCEFP research projects, events, fluid power government relations programs, webinars, supplemental research grants, travel, and operations		✓

Supporter Commitment Letter



Company ABC Letterhead

Date

Professor Kim A. Stelson, Director
Center for Compact and Efficient Fluid Power
University of Minnesota
111 Church Street S.E.
Minneapolis, MN 55455

Dear Professor Stelson:

It is the intention of Company ABC to participate as a research consortium collaborator with the Center for Compact and Efficient Fluid Power as of July 1, 2018. We recognize the Center's need to plan finances for upcoming years; therefore, this non-binding letter of support will be used for planning purposes only. Company ABC's non-binding commitment extends for a period of three years and will follow the guidelines in the Research Consortium Collaboration Agreement. As a research consortium collaborator, Company ABC and its representatives will:

- stay abreast of new developments in fluid power technology
- have access to leading researchers and research facilities
- interact with and recruit fluid power knowledgeable students with systems engineering experience
- gain competitive insights by networking with customers, suppliers, and competitors
- help focus Center-funded research on industry needs
- ensure fluid power visibility at a national level

Company ABC intends to pledge support in the amount of \$_____, annually, based on the CCEFP Sponsorship Structure. It is our understand that these funds will be used for research, events, strategic initiatives, education programs, and operating costs. We recognize that funds may be designated towards broad research areas within fluid power that will be used to support projects identified during the CCEFP project selection process.

It is Company ABC's desire to help continue CCEFP's on fluid power research and technology by supporting fluid power innovation and educating the next generation of leaders.

Sincerely,

Name
Title
Company ABC

- Nonbinding letter
- 3-year commitment
- Needed for our financial planning.
- Detailed terms provided in industry agreement.
- Requested return date of 12/15/17.

CCEFP Sustainability Summary



- CCEFP provides clear value in the areas of Leadership, Innovation, Advocating, Education and Networking.
- Fluid power is facing a strong challenge from other technologies, most notably electrical power.
- Innovation is the key to maintaining and growing market share.
- Leveraging government sources of support is key to sustainability.
- We are at a critical crossroads with respect to CCEFP continuation and need industry's support.

CCEFP Strategic Thrusts

DOE Off-road Funding Opportunity Announcement (FOA)



Department of Energy (DOE) Office of Energy Efficiency and Renewable Energy (EERE) Energy Efficiency Research and Development for Fluid-Power Systems In Off-Road Vehicles

Funding Opportunity Announcement (FOA) Number: DE-FOA-0001815
FOA Type: Initial
CFDA Number: 81.086

FOA Issue Date:	10/17/2017
Informational Webinar: (details on EERE Exchange at https://eere-Exchange.energy.gov)	11/1/2017 2:00 PM ET
Submission Deadline for Concept Papers:	11/20/2017 5:00 PM ET
Anticipated Date for Concept Paper Recommendation Notifications	12/6/2017
Submission Deadline for Full Applications:	1/18/2018 5:00 PM ET
Expected Timeframe for EERE Selection Notifications:	March 2018
Expected Timeframe for Award Negotiations	May 2018

Executive Summary

Means of Submission	Concept Papers, Full Applications, and Replies to Reviewer Comments must be submitted through EERE Exchange at https://eere-Exchange.energy.gov , EERE's online application portal. EERE will not review or consider applications submitted through other means. The Users' Guide for Applying to the Department of Energy EERE Funding Opportunity Announcements is found at https://eere-Exchange.energy.gov/Manuals.aspx .
Total Amount to be Awarded	\$3,000,000
Average Award Amount	\$1,000,000-\$1,500,000
Types of Funding Agreements	Cooperative Agreements
Period of Performance	36 months with three 12 month budget periods
Performance of Work in the United States/Eligibility	As a condition of this announcement, all applicants must propose that 100% of the direct labor cost for the project (including contractor/sub recipient labor) will be incurred in the United States. See Section III. A.
Eligible Applicants	Individuals, Domestic Entities, Foreign Entities, Incorporated Consortia, Unincorporated Consortia, subject to the definitions in Section III.A.
Cost Share Requirements	Refer to the cost share table in Section III.B.
Submission of Multiple Applications	Applicants may submit more than one application to this FOA, provided that each application describes a unique, scientifically distinct project. All applications must be for a stand-alone project that is not dependent or contingent upon another application submitted to this or any other FOA.
Application Forms	Required forms and templates for Full Applications are available on EERE Exchange at https://eere-Exchange.energy.gov .
FOA Summary	<p>The Office of Energy Efficiency and Renewable Energy (EERE) is issuing, on behalf of the Vehicle Technologies Office (VTO), this Funding Opportunity Announcement (FOA) entitled "Energy Efficiency Research and Development (R&D) for Fluid-Power Systems In Off-Road Vehicles."</p> <p>The objective of this FOA is to research technologies that can improve the energy efficiency of fluid power systems for commercial off-road vehicles . Construction, mining, and agriculture equipment represent the majority of fuel consumption in off-road vehicles, and this equipment relies heavily on fluid-power systems (i.e. hydraulics) to actuate most of their functions. They are preferred over electric motors because of their high specific power density and ability to tolerate shock and harsh environments. However, current fluid-power systems have poor efficiency. Research in this area can provide decreased operating costs for these key domestic industries.</p>

2-3 awards of \$1-1.5M each over a three year period.

20% minimum. Project Teams may provide cost share in the form of cash or in-kind contributions. Cash contributions may be provided by the Prime Recipient or Sub-recipients. Allowable in-kind contributions include, but are not limited to: rental value of buildings or equipment, the value of a donated service or resource, or third party in-kind contribution.

CENTRAL TIME	PROJECT TITLE	INVESTIGATORS	INSTITUTIONS
1:00 PM	Welcome, DOE Program Overview and Timeline	Kim Stelson	CCEFP
1:05 PM	Energy Saving Wheel Loader Proof of Concept	Kim Stelson	University of Minnesota
1:20 PM	Waste Heat Recovery with the Stirling Power Unit	Eric Barth	Vanderbilt University
1:40 PM	Opportunities for Lightweighting with Composite Material	Sue Mantell	University of Minnesota
2:00 PM	Variable Linkage Traction Motor, Power Dense Electric to Hydraulic Conversion, & Kinetic Energy Storage	James Van De Ven	University of Minnesota
2:20 PM	3-D Printed Electroactive Adaptable Frictional Surfaces	Jose Garcia & Brittany Newell	Purdue University
2:40 PM	Efficient Architectures and Components for Off-road Vehicles	Perry Li	University of Minnesota
3:00 PM	Energy Use Study and Characterization of Duty Cycles for Off-highway Machines	Paul Michael, Jose Garcia, Mike Gust	MSOE, Purdue University, UMN
3:20 PM	Methodologies and Tools for Design and Control of Hydraulic Hybrids, Including the Power System-in-the-Loop	Zoran Filipi	Clemson University
3:40 PM	Hydraulic Free Piston Engine for Off-Road Vehicles	Zongxuan Sun	University of Minnesota
4:00 PM	Autonomous and Connected Off-Road Vehicles	Zongxuan Sun	University of Minnesota
4:20 PM	Improving Energy Efficiency Over Off-road Vehicle Life Cycles	Brian Steward	Iowa State University
4:40 PM	Optimization and Experimental Validation of Mechanically Controlled Variable Displacement Pump	John Lumkes	Purdue University

Example: Energy Saving Wheel Loader (ESWL)

Hydraulic hybridization

- Drive Circuit
- Load Circuit



Optimized architecture

- Advanced pump
- Dual metering Valve

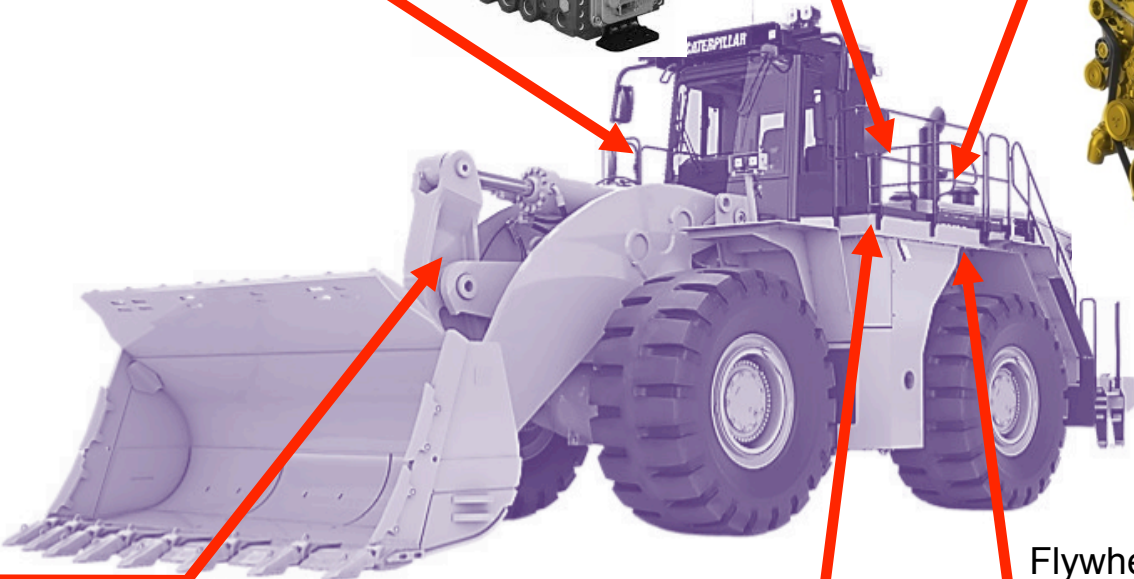
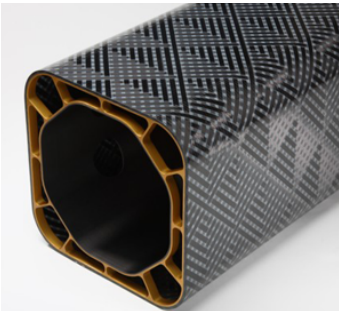


Engine management including on/off

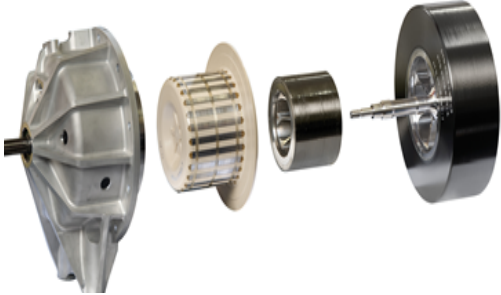


Weight reduction

- Composite boom and bucket



Flywheel energy storage

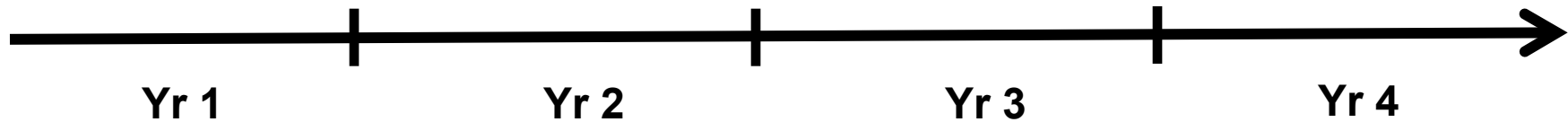


Heat Recovery

- Stirling engine
- Run AC
- Charge battery
- Charge accumulator



ESWL Project Timeline



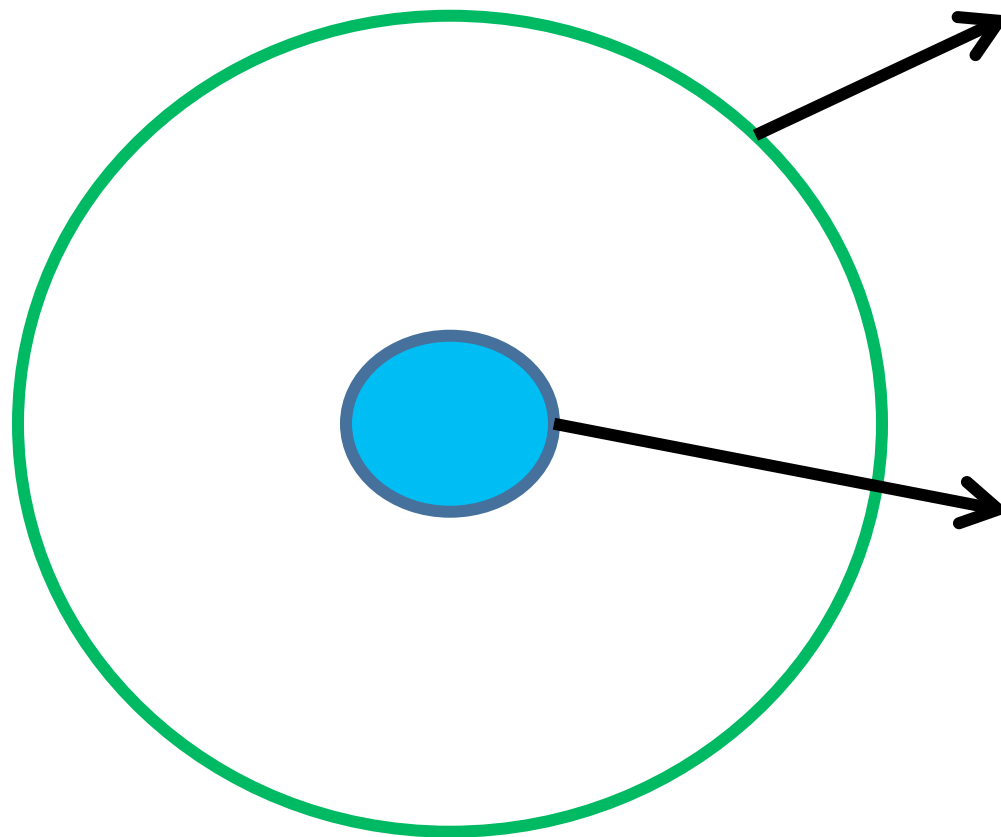
Year 1: Detailed modeling & simulation studies; finalize system design.

Year 2: Source components and verify performance on dyno test setup.

Year 3: Install system onto test vehicle and resolve system issues.

Year 4: Conduct thorough field tests, summarize results, issue report.

ESWL Project Team Structure



Industry advisory team

- Made up of interested IEC members.
- Progress/results updates provide a minimum of twice/year.

Project run team

- University led projects with support from CCEFP industry members.
- Individual PIs meet frequently with their research teams.
- Project manager to guide cohesive effort of all research teams on a bimonthly basis.

ESWL Industry Project Run Team Members



- Components providers...pumps, valves, accumulators, fluids, hoses/fittings, flywheel energy storage, engine starter and controllers.
- Demonstration vehicle
- Test facilities...both lab and field evaluation.
- Engineering design services for retrofit of machine.
- 3D composite printing support.

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Hydraulic Free Piston Engine for Off-Road Vehicles

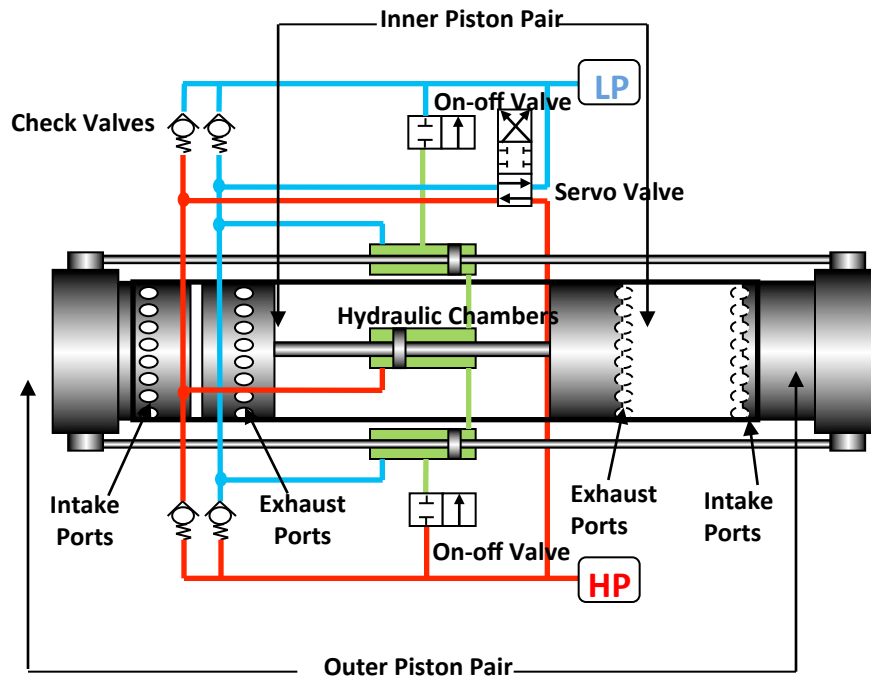
Georgia Institute of Technology | Milwaukee School of Engineering | North Carolina A&T State University | Purdue University
University of Illinois, Urbana-Champaign | University of Minnesota | Vanderbilt University

Zongxuan Sun
Department of Mechanical Engineering
University of Minnesota





Project Objective



The project objective is to provide an efficient and flexible power source for off-road vehicles.

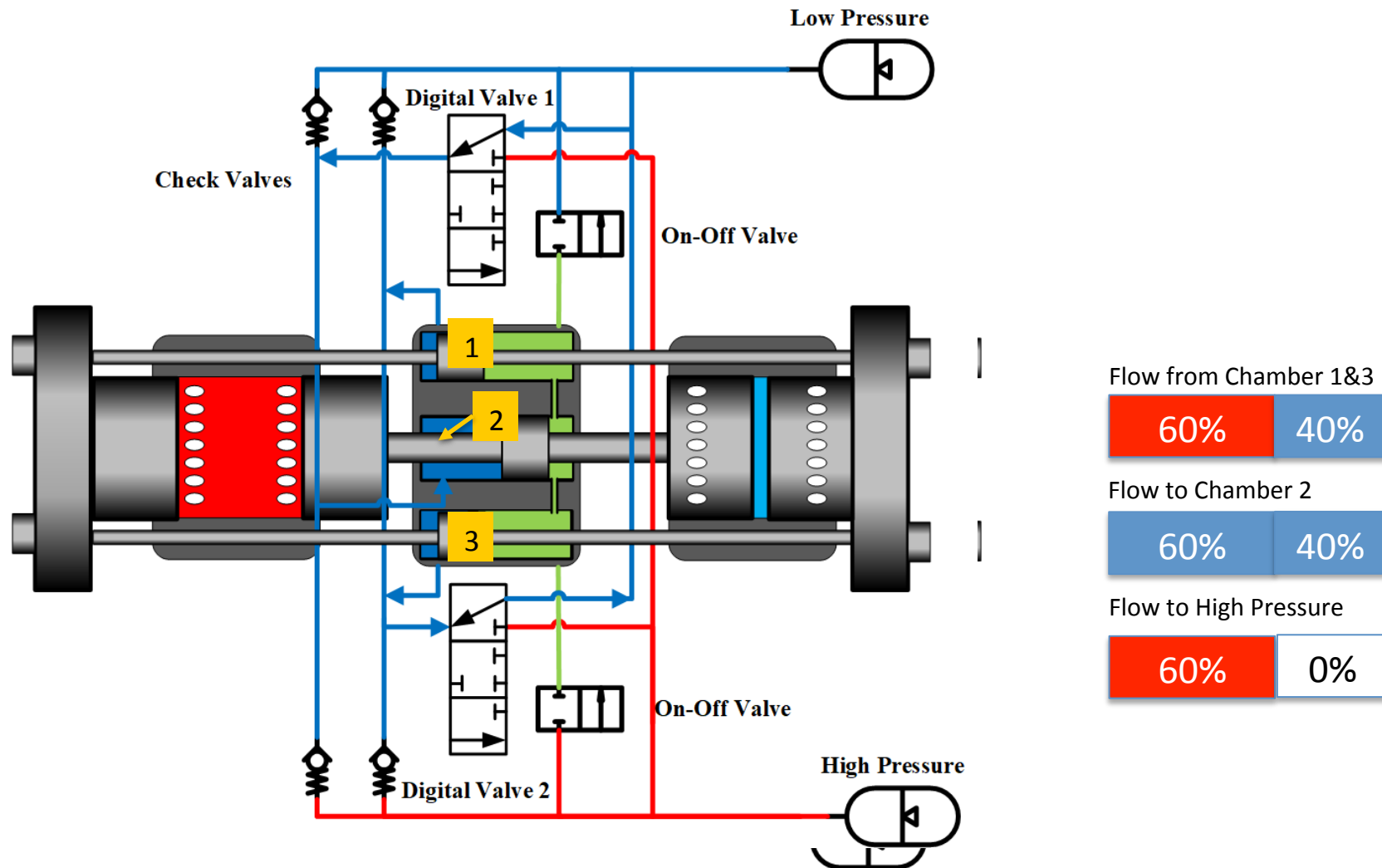
Challenges of Off-Road Vehicles:

- Low efficiency for part load engine operation.
- Throttling loss
- Development cost and time due to many different types of off-road vehicles and the relatively small volume for each type of vehicle.

Solutions:

- Modularity
- Variable compression ratio
 - Advanced combustion strategy
 - Multi-fuel operation
- Fast response time
- Higher power density
- Internally balanced

Independent Pressure and Flow Rate Control



Project Plan



- Our previous work has focused on precise and robust motion control for the FPE, including motoring and firing tests and designed the “Virtual Crankshaft” mechanism.
- Recent work on independent pressure and flow control shows the potential to apply the HFPE to off-road vehicles: significantly improve both engine and hydraulic efficiency.
- The plan for this project is to develop a new prototype of the hydraulic free piston engine with the latest combustion and hydraulic components and implement the independent pressure and flow control.
- The project will include experimental study of the energy and productivity benefit of using the HFPE for off-road vehicles.



Industry Collaboration

Industry members are invited to collaborate on (not limited to):

- Combustion sub-system
- Valve and pump sub-system, novel fluid
- Applications to specific off-road vehicles



Autonomous and Connected Off-Road Vehicles

Georgia Institute of Technology | Milwaukee School of Engineering | North Carolina A&T State University | Purdue University
University of Illinois, Urbana-Champaign | University of Minnesota | Vanderbilt University

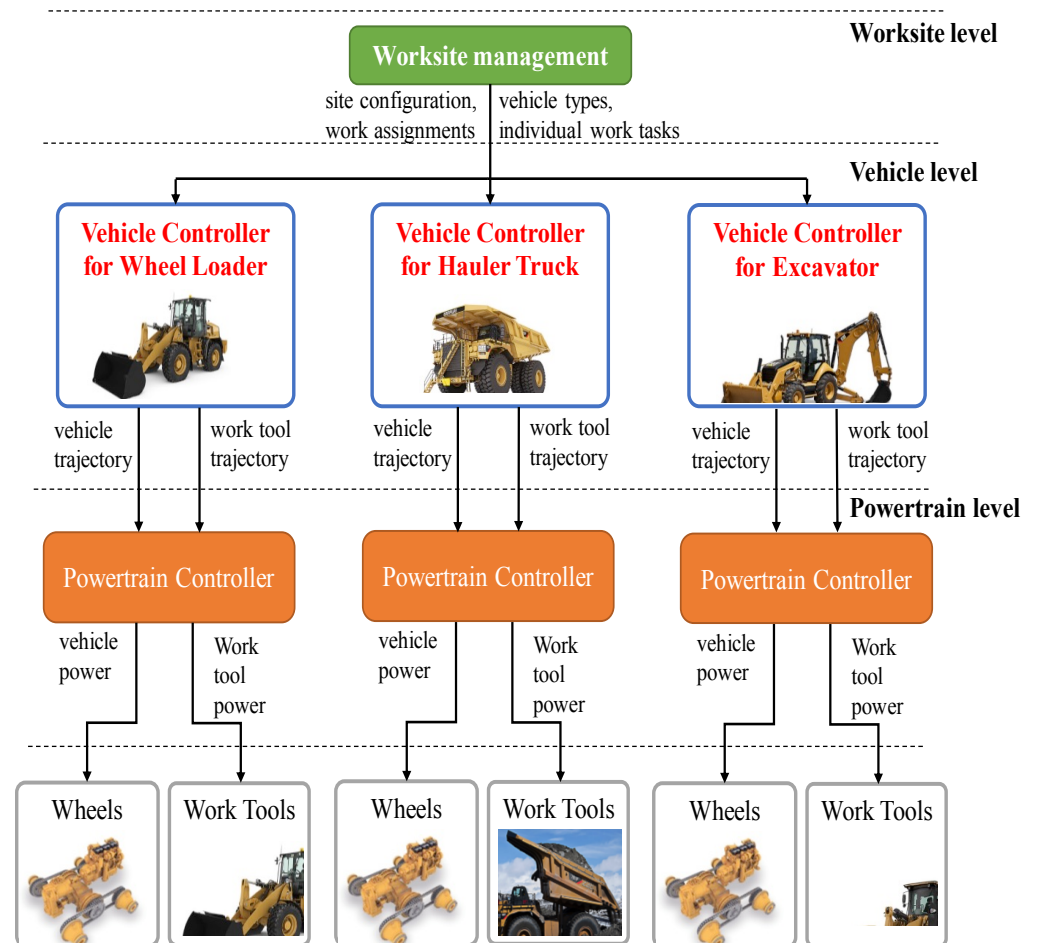
Zongxuan Sun
Department of Mechanical Engineering
University of Minnesota



Autonomous and Connected Off-Road Vehicles



- Energy saving can be achieved at three levels: work site level, vehicle level and powertrain level.
- There are technical challenges to fully realize the benefits of real-time optimization of vehicle dynamics and powertrain operation. Efficient and safe testing methods are required to evaluate connected vehicle applications.

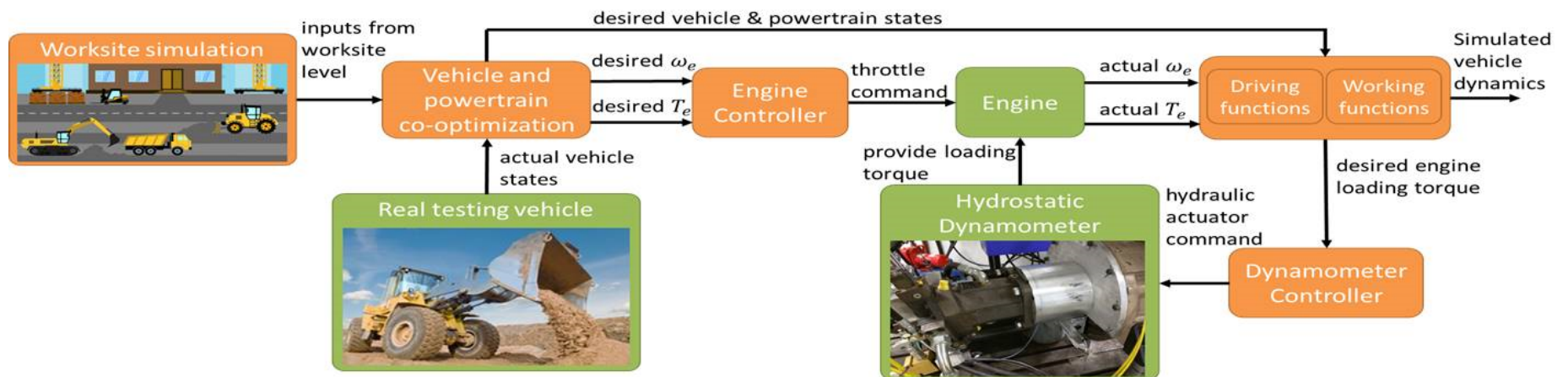


Project Objective and Plan

Objective: develop a systematic and cost effective approach for modeling, control and testing autonomous and connected off-road vehicles.

Plan:

- Develop simulation models for work site multi-vehicle collaborations.
- Develop model based methodology for co-optimization of off-road vehicle dynamics (driving and working functions) and the powertrain dynamics (engine and hydraulics).
- Implementing and testing the systematic control with a HIL testbed.



Industry Collaboration

Industry members are invited to collaborate on (not limited to):

- Defining the specific applications for autonomous and connected off-road vehicles.
- Provide information to facilitate modeling of off-road vehicles.
- Donation and instrumentation of an off-road vehicle.

Soft Robotics EFRI



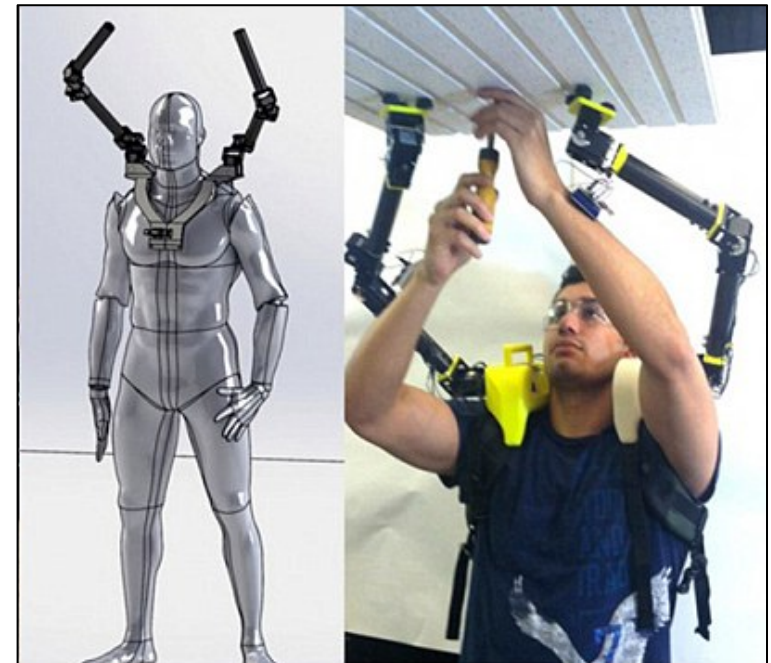
A screenshot of the National Science Foundation (NSF) website. The header includes the NSF logo and the tagline 'WHERE DISCOVERIES BEGIN'. A search bar is visible in the top right. The main navigation menu includes 'Research Areas', 'Funding', 'Awards', 'Document Library', 'News', and 'About NSF'. The 'Funding' section is active, showing a list of links such as 'About Funding', 'Browse Funding Opportunities A-Z', 'Due Dates', 'Find Funding', 'Merit Review', 'Policies and Procedures', and 'Preparing Proposals'. The main content area displays the title 'EMERGING FRONTIERS AND MULTIDISCIPLINARY ACTIVITIES (EFRI): Chromatin and Epigenetic Engineering (CEE) and Continuum, Compliant, and Configurable Soft Robotics Engineering (C3 SoRo) (EFRI-2018)'. Below the title, it mentions 'EFMA to host EFRI FY 2018 Solicitation Informational Webinar' and provides details about a webinar on Thursday, September 7th, from 1:00 to 2:30 pm Eastern time.

- **Estimated Number of Awards:** 13 (4-year awards)
- **Anticipated Funding Amount:** \$26,000,000
- **Letter of Intent Due Date(s) (required) :** September 29, 2017
- **Preliminary Proposal Due Date(s) (required):** October 25, 2017
- **Full Proposal Deadline(s):** February 23, 2018

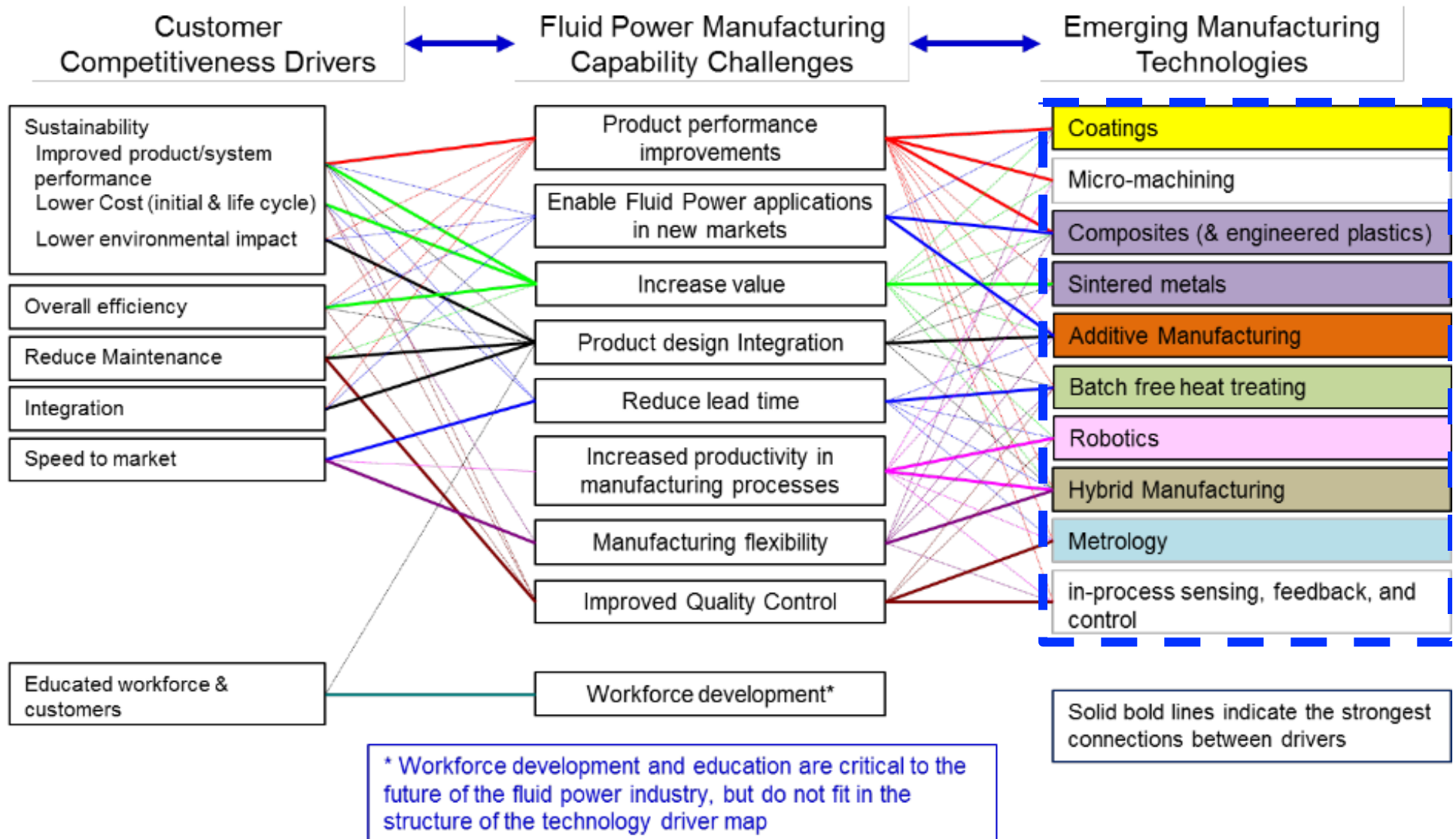
At least (4) CCEFP university proposals are planned.

CCEFP ARM Robotics Proposal(s)

- ARM research proposal funding begins this fall.
- CCEFP ARM participating universities and companies should band together to increase chances of funding success.
- Shoulder/arm exoskeleton for assembly line MFGT support is a planned proposal.
- **A demonstration site such as a manufacturing assembly line is needed.**



NIST AMTech Manufacturing Roadmap



10 Enabling Technologies – Mapping suggests significant opportunities in coatings, composites, and additive

Key enabling technologies

1. Coatings
2. Micro-machining
3. Composites & engineered plastics
4. Sintered metals
5. Additive Manufacturing
6. Batch free heat treating
7. Robotics
8. Hybrid manufacturing
9. Metrology
10. In-process sensing, feedback and control

CCEFP FP Manufacturing Strategy



- CCEFP leadership reviewed the (10) key enabling technologies identified in the FP manufacturing roadmap and concluded that the best candidate for government funding is a research program on **tribology, fluids and coatings**.
- CCEFP leaders are planning a trip to meet with Department of Defense (DOD) agencies this fall. SMI is organizing the discussions.
- The CCEFP strategy is to convince the DOD that CCEFP researchers can help with mission oriented needs.
- For fundamental research, a Multidisciplinary University Research Initiative (MURI) is needed.
- Goal is to have this area included in the 2018 MURI call for proposals and then form an academic team to win an award.

Coatings as a Manufacturing Strategy - Example



- Challenges
 - Depending on the test environment, temperature and sliding conditions, the performance, toughness, and durability of tribological and solid lubricant coatings differ significantly.
- Opportunities
 - Exploring new coating architectures having multi-layers, micro-surface texturing, nano-structures and/or composites that allow for enhanced property tailoring
 - Exploring key enabling technologies for coating simple to highly complex shapes or components that are cost effective and scalable
- Industry members are invited to collaborate on (not limited to):
 - Developing new materials, especially water soluble, for each layer, which has a specific property
 - Guiding specific property combinations and key constraints

Upcoming CCEFP Events

Fall Meeting of the Vibro-Acoustics Consortium

November 2, 2017
University of Minnesota
Mechanical Engineering Building (Room ME 1130)
111 Church St. S.E.
Minneapolis, MN 55455

8:00 a.m. Coffee and Pastries

8:30 a.m. Morning Session

- Introductions
- Introduction to the Center for Compact and Efficient Fluid Power

Tutorial Review of ISO-15086 – Testing and Characterization of Hydraulic Silencers
Flow Noise in Exhaust Systems

- Continuing Work on Muffler Insertion Loss Flow Rig
- Acoustic FEM of Perforated Tubes Including the Effect of Flow
- Measurements of Flow Noise Generation

Using Simulation to Solve NVH Problems

- Diesel Particulate Filter and Catalyst Transmission Loss Validation Study
- Benchmark Examples for Acoustic FEM
- FEM Simulation and Scale Modeling of Acoustic Scattering
- Simulation of Panel Transmission Loss using Structural / Acoustic FEM

12:00 p.m. Lunch

1:00 p.m. Afternoon Session

Tutorial Review of ISO-10864 – Determination of Isolator Properties
Source Identification

- Panel Contribution Analysis Applied to an Interior Acoustic Problem
- Source Identification of a Single Cylinder Internal Combustion Engine
- Microphone Array Design for Patch Contribution Analysis

Sound Absorbing Materials

- Continuing Research on Sound Absorptive Fabrics
- Development of Excel Spreadsheet for Sound Absorptive Treatments

Applications

- Continuing Work on Scale Modeling of HVAC Ducts
- Development of an Isolator Test Rig
- Characterization of a Small Reverberation Room using Acoustic FE
- Review of the Mic-W for use with PDA

5:00 p.m. Adjourn

-

UK Vibro-Acoustics Consortium
(<http://www.engr.uky.edu/vac/>)
provides complimentary NVH
research capabilities.
Contact Prof Herrin for
additional info.

Contact Prof David Herrin
david.herrin@uky.edu or
mjgust@umn.edu or
alyssa@umn.edu for details.

Fall Meeting Attendees



Name	Company
James Kim	3M
Ron Gerdes	3M
Thomas Herdtle	3M
Seungkyu Lee	3M
Pingfan Wu	3M
Jon Alexander	3M
Cuneyt Uyker	Active Exhaust
Ray Cheng	Aero Systems Engineering
Brian Rhode	Afton Chemical
Charlie Moritz	Blachford
Jennifer Shaw	Blachford
Shashikant More	Cummins Power Generation
Jundong Li	Cummins Power Generation
Jeffrey Watt	Daikin Applied
Jinghao Liu	Deere and Company
Sam Suh	Deere and Company

Michel Beyer	Eaton Corp.
Eric Klopp	Federal Foam
Dennis Fall	Federal Foam
Sean Stephens	Federal Foam
Paul Pederson	Harley Davidson
Dan Lehrbaum	Harley Davidson
Bill Rockwood	Ingersoll Rand
Steve Gleason	Ingersoll Rand
Vaibhav Lidbide	Ingersoll Rand
Roger Albert	Kohler
Michael Gust	University of Minnesota
David Herrin	University of Kentucky
Keyu Chen	University of Kentucky
Kangping Ruan	University of Kentucky
Jonathan Chen	University of Kentucky