Section 1: Project Administrative Detail

Project Title	Development of Energy Efficient Fluid Power for Vehicles
Topic	Vehicle Technologies

Laboratory	Argonne National Laboratory	
Principal Investigator	Name: George Fenske	E-mail: gfenske@anl.gov

Proposed Budget	$863K ($325K from DOE and $538K from CCEFP & Affiliates)	
Period of Performance	Start: Jan 1st, 2019	End: Dec 31st, 2020

Section 2: Project Plan

2.0 Executive Summary

Argonne National Laboratory (Argonne) and its partner CCEFP (Center for Compact and Efficient Fluid Power, and its affiliate companies) are pleased to submit this proposal in response to the FY 2018/2019 Technologist-in-Residence Call for Proposals. In the proposed program, technologists from Argonne and from CCEFP and thirteen of its affiliates will concentrate on the development of collaborative R&D projects which apply the unique expertise and capabilities that exist within DOE's national lab complex to overcome challenges and barriers industry has identified that are related to the development of energy-efficient fluid power systems. The partners propose a 24-month program with a total budget of $863K, of which $538K will come from CCEFP and its affiliates, and $325K will come from the Department of Energy.

The mobile off-road fluid power market comprises construction, agriculture, material handling, oil and gas, and mining sectors. Combined, these markets consume up to 1.8 quads[1] of energy per year in the United States, corresponding to approximately 6.5% of the total energy consumed in the transportation sector in 2016. Consequently, there is strong motivation within the hydraulic fluid industry to improve the efficiency, productivity, and reliability of systems that rely on hydraulic power.

CCEFP brings together multidisciplinary teams of researchers from over 30 industrial and academic institutions to develop broad and diverse solutions to improve the performance of hydraulic systems. CCEFP recognizes the value that the DOE national lab complex can bring to their teams in low TRL R&D activities related to big data, new technologies and architectures, materials, fluids, and manufacturing, and are working closely with DOE to develop support to overcome critical barriers.

2.1 Relationship Between CCEFP and National Laboratories

2.1.1 Additionality of Proposed Work

The proposed TIR project will clearly bring additionality to existing collaborative interactions between CCEFP, its affiliates, and national labs. The CCEFP Technologist will raise awareness within the CCEFP community of researchers of DOE/federally funded research and research capabilities. We anticipate the TIR effort will also build stronger ties between national labs and

[1] Lauren A. Lynch and Bradley Zigler, 'Estimating Energy Consumption of Mobile Fluid Power in the United States,' NREL/TP-5400-70240, November, 2017

industrial affiliates of CCEFP. This activity will be accomplished by embedding the Industry and Laboratory Technologists in each other's organizations through hosted visits, participation in biannual summit meetings, and periodic teleconferences. Initial activities will focus on Argonne/CCEFP teams, and later shift to Argonne/affiliate teams to define a list of high-priority challenges and barriers for specific follow-on project development.

In addition to benefiting industrial affiliates, the national lab (and DOE/EERE/VTO) teams will develop a better comprehension of industry's challenges and barriers that will enhance the ability of the labs to develop tools and technologies relevant to fluid power. Until recently, interactions between industry and national labs have been limited and not coordinated. CCEFP, which was successful in coordinating joint development efforts between academia and industry, is now turning its attention to developing collaborations between national labs and its affiliates to address critical barriers in fluid power. Several rounds of fluid power funding opportunities have been announced by DOE/EERE/VTO and research is underway on development of energy-efficient systems; however, opportunities still exist to further strengthen collaborations between the national labs and industry. The outcomes of collaborations will be improved by informing the labs and industry affiliates of the challenges and barriers that industry needs to overcome, and the capabilities that the labs can apply to overcoming these challenges.

The pairing of Argonne and CCEFP will be a start to this endeavor – partnerships will be selectively developed and pursued between Argonne (and other national labs) and CCEFP affiliates to identify specific technology topics they want to pursue. Industry partners will include vehicle/platform affiliates such as [redacted] and [redacted]; hydraulic equipment manufacturers such as [redacted], and [redacted] and companies involved in the formulation and blending of hydraulic fluids such as [redacted].

2.1.2 Previous CCEFP Collaborations with National Laboratory Complex

While direct collaborations between the CCEFP and national labs have been limited, Argonne and other labs, such as ORNL, have a strong track record of collaborations with CCEFP affiliates (both industrial and academic). Experience gained during these collaborations, some of which are ongoing, increases the probability of success of the proposed TIR project. Examples of collaborations between Argonne and CCEFP affiliates include:

[redacted], a subsidiary of [redacted], is an international company and world leader in the manufacture, marketing, and distribution of petroleum products including hydraulic fluids. Argonne and [redacted] have an ongoing collaboration with Argonne, ORNL, and PNNL to supply reference fluids for a multilab DOE project on hydraulic fluids.

[redacted], headquartered in [redacted], is an international leader in design, manufacture, and marketing of mining and construction equipment and hydraulic fluid components, and has a rich history of collaborating with national labs including Argonne and ORNL. Recent examples of Argonne/[redacted] collaborations include development of lightweight cast iron alloys,

tribological assessment of engineered surfaces, virtual engine design, and fuel injection spray visualization.

[redacted], headquartered in [redacted] a subsidiary of the [redacted], is a world leader in the design, manufacture, and marketing of hydraulic and electronic control systems for mobile applications. Argonne and [redacted] have participated in the development of joint DOE FOA (DE-FOA-0001815) proposals on advanced hydraulic systems, and have an active collaboration on fluid power components.

[redacted] an international company, headquartered in [redacted] with North American operations headquarters in [redacted] is a world leader in specialty chemicals (additives) used in hydraulic fluids. [redacted] and Argonne have ongoing collaborations (NDAs, CRADAs, SPPs) on wind turbine lubricants and hydraulic fluids.

Academia

The Argonne Tribology program routinely collaborates with academia through a number of DOE-sponsored university programs including internship programs (graduate and undergraduate level), visiting scientist programs, thesis research programs, sponsored research, and funding opportunity announcements. We have been fortunate to have hosted well over 150 students over the past three decades, some of them from universities associated with CCEFP (Georgia Tech, Purdue, Iowa State, and Milwaukee School of Engineering). We see the Argonne/CCEFP TIR project as a venue to further strengthen these relationships. For example, we note that Argonne teamed with [redacted] on two proposals recently submitted to a DOE FOA on Fluid Power (DE-FOA-0001815).

2.2 Project Approach

To address the TIR goal/mission of "…building deeper relationships between industry and DOE's national laboratories that result in high-impact collaborative early stage research and development…'[2], the Argonne/CCEFP TIR program will establish an approach to maximize contact between the Technologists to exchange information on the needs of CCEFP and its affiliates, and capabilities available at Argonne and its sibling labs. This will be accomplished through a series of site visits to CCEFP operations at the University of Minnesota, affiliate member R&D facilities, and key national labs, followed by detailed one-on-one discussions with key affiliates to develop agreements to perform R&D on specific topics of interest on fluid power. Activities will include participation in CCEFP biannual Summit meetings, trade meetings (NFPA, FPIC, Mining, Agriculture, and Construction meetings), site visits (at national labs and Industry/Academic affiliates).

The work plan for the TIR project will include the following major tasks:

[2] Technologist-in-Residence Program Laboratory Call for Proposals Fiscal Year 2018/2019 Advanced Manufacturing Office - https://www.energy.gov/eere/amo/downloads/tir-laboratory-call-proposals

1. Initial Coordination Visits – During the initial three-month period of the TIR, technologists from Argonne and CCEFP will identify national labs, national lab personnel, affiliates, and affiliate personnel who have relevant experience to the topics identified below in the Technical Scope section. We envision this will entail attendance to CCEFP Spring/Fall Summit Meetings, and NFPA meetings, and weekly teleconferences to establish connections within specific affiliates. A report documenting key contacts at labs and affiliate companies and details on topical areas to be pursued will be prepared.
2. Follow-On Visits & Embedding – Pursuant to Task 1, follow-on visits will take place to embed Technologists at selected labs and affiliates to identify specific areas for collaboration. We expect this will involve engaging vehicle-, equipment-, and hydraulic fluid-OEMs affiliated with CCEFP. Potential areas of interest include autonomous vehicles, simulation, big data, architecture, and materials and fluids. A report on each group (vehicle-, equipment-, or hydraulic fluid-OEMs) will be issued detailing opportunities and capabilities. Group 1 activities will focus on vehicle-level system topics; group 2 activities will address fluid power equipment/hardware architecture topics, and group 3 activities will address fluids and material related topics.
3. Affiliate Agreements – The Technologists will develop strategic partnership agreements that will govern the collaborations between the national labs and each specific affiliate. The agreements will be sufficiently broad to cover general subject areas (e.g. 'tribology', 'vehicle simulation', etc.) with adequate flexibility to specify individual tasks / statements of work as identified during the project. Using this 'broad yet specific' approach enables IP rights to be negotiated upfront, thus avoiding lengthy renegotiation for each specific task identified. The agreements will follow current CRADA and SPP rules agreed upon by DOE and the national lab contracts.
4. Statement of Work Development – Drawing on information accumulated during site visits to participating labs and affiliates, the technologists will develop a set of work statements for future collaboration between participating labs (e.g., Argonne) and affiliates. We anticipate establishing one agreement/SOW per quarter. The SOW development will focus on technical broad topics related to fluid power as discussed in Section 2 on technical scope.
5. Metrics Documentation – Throughout the project, technologists will collect and compile metrics as specified in Section 2.5.

Together, these five tasks will achieve the goals and expectations of the TIR program, namely:

- Identify the participating company's (or companies') technical priorities and challenges, and the resources and capabilities across all of DOE's national laboratories that may be highly suitable to address them;
- Propose collaborative R&D efforts to develop science-based solutions to the company's (or companies') most strategic scientific, technological, and business issues; and
- Develop a general framework agreement and begin developing specific scopes of work for the proposed collaborative R&D efforts. The proposed R&D will then take place outside of the program and will not use TIR program funds.

2.3 Technical Scope

Overview

The technical scope of the Argonne CCEFP TIR project is fluid power, which encompasses a wide range of applications including manufacturing, agriculture, construction, mining, and transportation. We have chosen to narrow the project to focus on mobile fluid power applications due in part to the recent interest of EERE/VTO in off-road applications. The VTO activity on Off-Road Fluid Power started in FY 2017, was in the FY 2018 DOE budget, and is currently in the President's and Congressional budgets for FY 2019. One of the key concerns identified by CCEFP is the necessity for better coordination of CEEFP affiliate programs with national labs - they recognize the value the DOE national labs can bring to the achievement of their missions and goals and need support to navigate the broad and diverse capabilities of the labs to identify appropriate partners.

Department of Energy

Results from a DOE sponsored a study[1] and a workshop[3] on mobile fluid power identified key barriers to improving efficiency:

- Large variations in mobile fluid power equipment in off-road markets and unique fluid power architectures, end applications, versatility, and operating conditions necessitate application-specific solutions to improving system efficiency – no single solution will fit all applications. Consequently, the cost of improving fleet-wide efficiency where each architecture and operating condition is unique will require significant resources.
- The diverse range of applications and variation in use of equipment utilizing fluid power make it difficult to standardize testing as well as to compare and measure performance of different fluid power systems and components: there is a lack of standardized test protocols and drive/duty cycles.
- Off-road systems are regulated in terms of emissions, but not for efficiency: consequently, there is no regulation-driven incentive to develop and adopt technologies to increase efficiency. There is also end-user resistance to adoption of new technologies (perceived reliability and durability risks for being the first to adopt).

From these, opportunities and topics for collaborative research between industry, labs, and academia were identified in the following areas:

- Data Needs
  - Characterization of duty cycles
  - Definition and measurement of performance and efficiency
  - Development and definition of standardized equipment level test methods
- New Technologies and Architectures
  - New technologies to increase power density of stored energy
  - New architectures to recover and apply stored energy
  - New technologies to reduce fluid power system losses
  - New architectures to level and reduce peak system load requirements

[3] Mobile Fluid Power Workshop, https://www.nrel.gov/transportation/mobile-fluid-power-workshop.html, NREL, Golden, CO, Sept. 12, 2017

- Optimization and Integration of Fluids and Materials
  - Hydraulic fluid development and evaluation
  - Component design
  - Integration of fluids into advanced component designs

CCEFP Technical Challenges

Through its affiliates, the CCEFP has developed a broad research strategy addressing key technical barriers in three thrust areas:

- Efficiency – addressing barriers associated with increasing energy efficiency of fluid power components and systems, including efficient control and energy management through fluid power
- Compactness – addressing barriers related to design of compact power supplies, energy storage devices, and other fluid power devices.
- Effectiveness – addressing barriers related to making fluid power safer, easier to use, and pollution-free (leakage and noise).

From these, the CCEFP identified opportunities and established technology-based strategies that address the following topics:

- Mobile – adoption of new designs in hydraulic hardware to improve efficiency of mobile systems.
- Human-Scale – expansion of the use of hydraulic powered systems for medical applications, e.g., self-powered tools and exoskeletons with a focus on compact and efficient components.
- Manufacturing – design light, robust, and inexpensive hydraulic/pneumatic tools for use in manufacturing.
- Fluids and Tribology – design of fluids and materials that are improve reliability and durability, exhibit high viscosity index properties, are shear stable, and enable functionality under extreme conditions.

From these barriers, challenges, and lab capabilities, the TIR team will establish collaborative topics in the following areas:

1. Autonomous Vehicles – connected and autonomous transportation innovations for intelligent, efficient integrated implementation of hydraulic-fluid powered systems.
2. Vehicle Simulation – modeling of off-road vehicles environment using whole-vehicle simulation codes such as Autonomie
3. Data – handling and sharing of big data-sets for real-time monitoring of system performance, definition of duty cycles, and integration with GPS for autonomous operation.
4. Materials and Fluids – development of reliable, robust materials, coatings, surface treatments, and fluids.
5. Architecture – design and integration of novel system hardware into efficient hydraulic systems.

6. Manufacturing – development of advanced (e.g., additive manufacturing) to accelerate development/implementation of new designs, and fabrication of new control concepts.

2.4 Risks, Challenges, and Mitigation

Risk/Challenge: Both the CCEFP and DOE have expressed the need for greater collaboration between the fluid power sector and the national labs to resolve critical issues related to energy efficiency. The challenge and risk to greater collaboration is the lack of awareness of the issues, barriers, and capabilities that each can bring to the table.
Mitigation: Through the TIR project, Argonne, and national lab personnel with broad knowledge in relevant disciplines will participate in meetings and summits organized by CCEFP, NFPA, and FPIC as well as in one-on-one meetings with affiliate companies to understand detailed challenges and barriers. Complementary to the lab activities, key personnel from CCEFP and affiliate companies will network with lab PIs to obtain a firm grasp of capabilities.

Risk/Challenge: Difficulty to access lab capabilities and establish suitable agreements.
Mitigation Plan: Argonne and a few of the labs mentioned above currently have agreements in place (e.g., non-disclosure agreements) that address many of the terms and conditions that would be relevant in future interactions. Our strategy will initially focus on lab/industry pairs that have past or current agreements in place to simplify upfront agreement negotiations.

Risk/Challenge Inability to enlist personnel from other labs to collaborate jointly with industrial affiliates.
Mitigation Plan: Argonne and its sibling labs are experienced in the development of multilab teams; Argonne, ORNL, and PNNL are currently collaborating on a DOE/VTO Fluid Power Project with two CCEFP affiliates. Argonne, ORNL, PNNL, and NREL just concluded a separate DOE VTO lubrication project involving multiple vehicle OEMs, additive suppliers, and major oil companies. Argonne, ORNL, INL, and NREL are partners on multiple DOE/BETO AOPs, and SPP projects related to tribology.

2.5 Metrics and Milestones

Argonne and CCEFP will track the following project metrics:

- Number of national labs visited to build relationships, explore ideas, and evaluate resources
- Time spent by the Laboratory Technologist embedded in industry
- Time spent by the Industry Technologist embedded in national labs
- Number of ideas and resources identified at the Laboratory Technologist's facility
- Number of ideas and resources identified at additional national labs
- Meetings with leadership and staff from either national labs or industry to brief and consult about proposed potential ideas for R&D
- Number of statements of work (SoWs) developed for R&D collaborations
- An assessment of how much a change (from lab-push to commercial-needs pull) the partnership effected in the proposed R&D collaborations

- Number of scopes of work for proposed collaboration that have moved to contract negotiation or execution

Argonne / CCEFP project milestones include:

1. Identification of initial group affiliates (month 5)
2. Group 1 (vehicle OEMs) visits and framework identification (month 9)
    a. Groups 2 (equipment OEMs) visits/framework identification (month 13)
    b. Group 3 (Hydraulic fluid OEMs) visits/framework identification (month 17)
3. Framework Partnership Agreement Developed
    a. Group 1 (month 12)
    b. Group 2 (month 15)
    c. Group 3 (month 18)
4. SoW Documents Developed (months 15, 18, 21)
5. Metrics Collection Complete (month 24)

Section 3: Team and Resources

3.1 Team Members and Abilities

Lab Technologist

The Lab Technologist will be Dr. George Fenske of Argonne National Laboratory who will commit approximately 1,000 hours to the project over its 24-month duration.

Dr. George Fenske is a senior materials scientist in the Applied Materials Division of Argonne. He is the senior project leader for tribology. His forty-five years of research have focused on synthesis, performance testing, and characterization of materials under extreme conditions in automotive, manufacturing, nuclear, and biomass energy sectors. He was instrumental in establishing the Argonne Tribology group and has managed activities in surface engineering, performance testing, and characterization using advance surface analytical tools. He developed unique out-of-pile experimental system to simulate and investigate nuclear fuel behavior during severe nuclear accident conditions. He has authored or co-authored over 200 technical papers in the areas of tribology and nuclear materials, and has developed and led multi-laboratory teams investigating fuel-efficient lubricants and hydraulic fluids.

Industry Technologist

The Center for Compact and Efficient Fluid Power (CCEFP) is an engineering research center established by the National Science Foundation in 2006. Although its 10-year grant ended in 2016, CCEFP has evolved into an industry consortium supported by companies which recognize that fluid power innovation is critical to improved business outcomes. The consortium members represent a wide spectrum of the value chain including OEMs, manufacturers, suppliers, associations, and academic partners. CCEFP leads the nation's fluid power research strategy to improve existing applications and to identify new markets. The CCEFP Leadership Team includes Professor and Director Zongxuan Sun, Professor and Director Emeritus Kim Stelson, Industry Relations Director Michael Gust, and Administrative Director Alyssa Burger.

Zongxuan Sun is a Professor in Mechanical Engineering at the University of Minnesota and Director of the CCEFP. Before joining the University of Minnesota, Dr. Sun served as a Staff

Researcher at the General Motors Research and Development Center. Dr. Sun's research interests include dynamic systems and control, tracking control and disturbance rejection, nonlinear and time-varying control, mechatronics, fluid power, and applications to automotive and off-highway propulsion systems.

Kim Stelson is a College of Science and Engineering Distinguished Professor of Mechanical Engineering at the University of Minnesota and Director Emeritus of the CCEFP. Dr. Stelson's research interests include fluid power transmissions for wind power applications and optimized control of fluid power systems in off-highway applications.

Michael Gust, Industry Relations Director, and Alyssa Burger, Administrative Director, have served in leadership, management, and programmatic functions for the CCEFP since its inception in 2006. Mr. Gust has over twenty years of industry experience and has held senior engineering management positions at Eaton (Global Engineering Director for Hydraulics) and Daikin (VP of HVAC Engineering-Americas), leading hydraulic and HVAC component and system providers. Mr. Gust has strong expertise in all areas of product and technology development and extensive exposure to construction, agriculture, aerospace, industrial, and automotive markets and applications. Ms. Burger is a research program administrator responsible for the facilitation and execution of CCEFP activities. Mr. Gust and Ms. Burger collaboratively lead the industry engagement functions of the Center.

Other Team Members

As part of the TIR project, we will consult with Argonne staff on multiple levels – from individual scientists and engineers involved in technology discovery, innovation, process development, modeling and computing, to technology commercialization, licensing, and strategic partnering. While the specific PIs will depend on the areas identified during initial exploratory visits, we expect to involve experts from major involved in major Argonne initiatives on materials, processing, simulation, computing, transportation, chemistry, and material characterization. From the onset, we will coordinate activities closely with Argonne's business development teams to ensure timely development of business agreements and work statements. We expect its affiliates to embrace this project; within the past few weeks, CCEFP has identified thirteen of its affiliates (Donaldson, CNH, Evonik, Linde, Parker, Bobcat, NFPA, Poclain, Lubrizol, Afton, Eaton, FD-Groups, and CZERO) who are interested in joining the CCEFP/TIR project.

3.2 Commitment to Project

Argonne is strongly committed to the TIR program – its senior management recognizes our capabilities and obligations to work with industry on critical challenges and barriers. Per the attached budget, Argonne will devote approximately 30% of the time of one of its key personnel to the project over the 24-month duration.

CCEFP and its affiliates are strongly committed to the TIR project and the value it brings to their future – in particular in providing access to unique capabilities, tools, expertise, and technologies available at DOE's national labs. The attached letters-of-commitment attest to their interest in establishing strong ties with the DOE national lab complex - with an overall commitment of $538K - nearly double the funds requested from DOE.

Both Argonne and CCEFP have agreed to commit other resources to support the project. Argonne and CCEFP legal personnel will work with technologists to develop a partnership agreement, and will further commit lab technical staff to the development of SoWs. CCEFP and Argonne will commit to providing awareness opportunities at twice-yearly Summit meetings.

3.3 Additional Information

Argonne will establish an advisory panel of senior managers to provide oversight of the TIR project. The panel will consist of Suresh Sunderrajan - Interim Associate Lab Director of Energy and Global Security, Gregory Krumdick - Interim Division Director of Applied Materials Division, and David McCallum - Manager, New Opportunity Development Group. The panel will meet quarterly to review progress and provide guidance as needed.

Section 4: Proposed Project Timeline and Budget

Deliverables and milestones for the proposed TIR project are shown in Table 1 below. A Gantt chart showing proposed timeline is presented in Figure 1.

Table 1: Proposed Budget & Milestones

Deliverable/Milestone	Period of Performance
Technical Priorities Identified and Industry Alliances Developed	Months 1-4
Framework Partnership Model Agreement Developed	Months 2-4
Group 1 Affiliates – Vehicle-level OEMs	Months 5-9
Group 2 Affiliates – Equipment-level OEMs	Months 9-13
Group 3 Affiliates – Hydraulic Fluid OEMs	Months 13-17
Metric Collection	Months 22-24
DOE Funding $325,000	
Non-DOE CCEFP Funding $113,369	
Non-DOE CCEFP Affiliate Funding $424,800	
Total Funding $863,169	

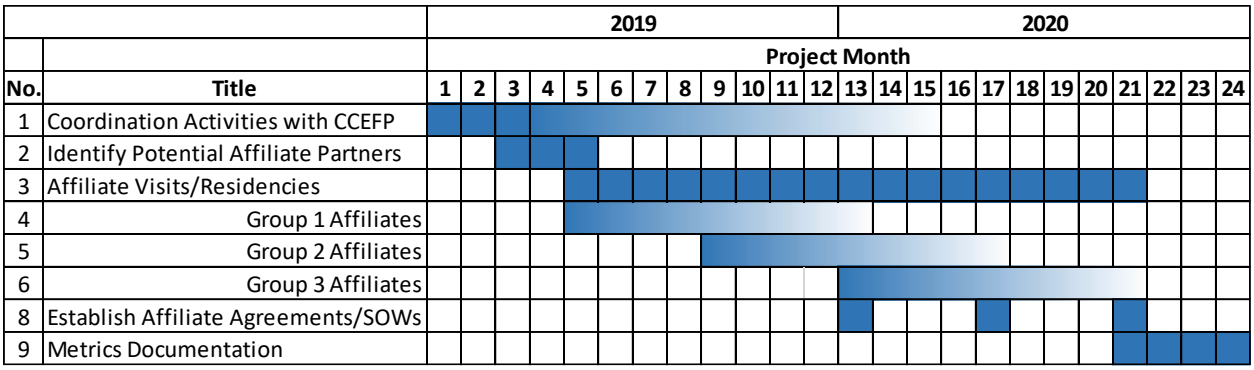

Figure 1: Gantt chart showing timeline of proposed activities.

Appendices

A: Argonne Technologist Resume: George Fenske

B: CCEFP Technologist Resumes:
1. Michael Gust
2. Kim Stelson
3. Zongxuan Sun
4. Alyssa A. Burger

C: CCEFP Letter-of- Commitment ($113,369)

D: CCEFP Affiliate Letters-of-Commitment
1. [redacted] Architecture/components
2. [redacted] Vehicle OEM
3. [redacted] Fluids
4. [redacted] Architecture/components
5. [redacted] Architecture/components
6. [redacted] Vehicle OEM
7. [redacted] Vehicle OEM, Architecture, Fluids
8. [redacted] Architecture/components
9. [redacted] Fluids
10. [redacted] Fluids
11. [redacted] Architecture/components
12. [redacted] Architecture/components
13. [redacted] Architecture/components

Appendix A: Resume of George R. Fenske

George R Fenske
Senior Materials Scientist and Tribologist
Argonne National Laboratory
Applied Materials Division
Argonne, IL 60439

Dr. George Fenske is a senior materials scientist in the Applied Materials Division of Argonne National Laboratory. He is the senior project leader for tribology. His forty-fives of research have focused on synthesis, performance testing, and characterization of materials under extreme conditions in automotive, manufacturing nuclear, and biomass energy sectors. He helped establish the Argonne Tribology group and managed activities in surface engineering, performance testing, and characterization using advance surface analytical tools. He developed unique out-of-pile experimental system to simulate and investigate nuclear fuel behavior during severe nuclear accident conditions. He has authored/co-authored over 200 technical papers in the areas of tribology and nuclear materials, and has developed/led multi-laboratory teams investigating fuel efficient lubricants and hydraulic fluids.

Education and Training

University of Illinois – Urbana/Champaign, Nuclear Engineering Ph.D., 1979
University of Illinois – Urbana/Champaign, Nuclear Engineering, M.S., 1975
University of Illinois – Urbana/Champaign, Mechanical Engineering, B.S., 1972

Research and Professional Experience

2018 to present	Senior Program Leader – Tribology (Argonne)
1995 to 2018	Manager of Argonne's Tribology Section (Argonne)
1987 to 1995	Principle investigator (PI) in Tribology Section (Argonne) On assignment to DOE as technical detailee for DOE's PNGV Program
1987 to 1994	Leader for DOE's Surface Engineered Interface Tribology Task (Argonne)
1979 to 1987	PI in Argonne's Ceramic Section responsible for hot-cell studies on the transient behavior of nuclear fuels (Argonne) PI in Ceramic Section responsible for establishing national DOE Tribology Program (Argonne)
1975 to 1979	Intern/Thesis Research Studies at Argonne National Lab – Physics Division

Recent Project Involvement at Argonne

1. Fluid Power – Project lead for multilab DOE/EERE/VTO project on Fluid Power (Argonne/lead, ORNL, PNNL)
2. Lubrication – Project lead for multilab DOE/EERE/VTO project on Fuel Efficient Lubricants (Argonne/lead, ORNL, PNNL, NREL)
3. Wear Modeling – Argonne project lead for DOE/EERE/BETO AOP projects on wear and tribology of materials and components used in biomass conversion processes

4. Vehicle Lubrication – Project lead on multiple multiyear DOE/EERE/VTO annual operating projects on lubricants & additives, materials & coatings, characterization, and tribological phenomena
5. Parasitic Friction Loss Modeling – Project lead on multiyear DOE/EERE/VTO projects on modeling and verification of parasitic friction losses in vehicles.
6. Co-Coordinator of DOE Panel/Workshop on Lubrication Stakeholders Report - ENGINE AND DRIVELINE LUBRICANTS IN FUEL EFFICIENCY SUMMARY REPORT
7. Manager – Argonne tribology and Thermo-Mechanics Section

Appendix B1: Resume of Michael J. Gust

Michael J. Gust
Industrial Liaison Director, Center for Compact & Efficient Fluid Power
University of Minnesota (2013 – present)

Summary

Senior industry executive with over twenty years progressive responsibility in Global Product Engineering & Technology Management within the manufacturing, aerospace and automotive sector markets. Demonstrated skills include:

- Strategic Engineering Leadership
- Strong Manufacturing, Marketing & Sales/Customer Exposure
- Team Building and Problem Solving
- Global Engineering Organizational Knowledge
- Exceptional industry and academic network
- Lean Enterprise/Six Sigma Champion
- Eaton Business Excellence (akin to Malcolm Baldridge) Examiner
- Product Development & Technology Roadmaps
- Acquisition Integration
- Program Management Expertise

Relevant Experience

Vice President Engineering – Americas, McQuay International (Daikin Group) Dec 2011 to Feb 2013
Engineering leader of the Americas region for the world's largest HVACR (heating-ventilation-air conditioning & refrigeration) company. Key responsibilities included setting future product and organizational strategies; identifying, implementing and improving key engineering processes and standards; establishing and implementing a new product development phase-gate process, improving product development test throughput and productivity; introduction of reliability/test validation; and ramping up low cost country engineering support.

Industry Liaison Director, Center for Compact and Efficient Fluid Power 2006 – Nov 2011
Responsible for all industry related activities associated with the recently formed Engineering Research Center headquartered at the University of Minnesota and backed by the NSF that is focused on revolutionizing the fluid power industry through innovation. Other major US universities included in the Center are Purdue University, University of Illinois, Georgia Tech, Vanderbilt University, Milwaukee School of Engineering and North Carolina A&T. Recently resumed this role in February 2013 to present.

Engineering Director, Eaton Corporation, Hydraulics Operations 1999 to 2006
Global engineering and technology manager for a leading fluid power component and system provider. Primary focus was strategic, technology related initiatives including creation of technology and product roadmaps. Help identify and champion all subsequent technology and product development activities necessary to realize these critical initiatives for the entire operation including product design, supplier sourcing, lab durability and field test evaluation.

Education

Eaton Corporate Executive Development Program Graduate - 2004
B.S., Mechanical Engineering, University of North Dakota - 1984

Appendix B2: Resume of Kim A. Stelson

Kim A. Stelson
College of Science and Engineering
University of Minnesota

Professional Preparation

Stanford University	Mechanical Engineering	B.S., 1974
Massachusetts Institute of Technology	Mechanical Engineering	S.M., 1977
Massachusetts Institute of Technology	Mechanical Engineering	Sc.D., 1982

Appointments

2015-present	College of Science and Engineering Distinguished Professor, Department of Mechanical Engineering, University of Minnesota
2001-2002	Visiting Professor, Department of Mechanical Engineering, University of Bath
1996	Visiting Associate Professor, Department of Mechanical Engineering, University of Auckland
1994-2015	Professor, Department of Mechanical Engineering, University of Minnesota
1992-1993	Visiting Senior Lecturer, Hong Kong University of Science and Technology
1987-1994	Associate Professor, Department of Mechanical Engineering, University of Minnesota
1981-1987	Assistant Professor, Department of Mechanical Engineering, University of Minnesota

Products

Publication

[1] Groepper, C., P. Y. Li, T. Cui and **K. A. Stelson** (2017). "MEMS Pressure-Flow-Temperature (PQT) Sensor for Hydraulic Systems," in D. Zhang and B. Wei (eds.), *Advanced Mechatronics and MEMS Devices – II (Microsystems and Nanosystems)*, Springer Verlag.

[2] Frosina, E., A. Senatore, D. Buono, and **K. A. Stelson** (2017). "A Modeling Approach to Study the Fluid-Dynamic Forces Acting on the Spool of a Flow Control Valve," *ASME Journal of Fluids Engineering,* Vol. 139, no. 1.

[3] Ramdan, M. I. and **K. A. Stelson** (2016). "Optimal Design of a Hydro-Mechanical Transmission Power-Split Hybrid Hydraulic Bus," *Proceedings of the Institution of Mechanical Engineers, Part D: Journal of Automobile Engineering*, Vol. 230, no. 12, pp. 1699-1718.

[4] Wang, F., M. A. M. Zulkefli, Z. Sun and **K. A .Stelson** (2016). "Energy Management Strategy for a Power-Split Hydraulic Hybrid Wheel Loader," *Proceedings of the Institution of Mechanical Engineers, Part D: Journal of Automobile Engineering,* Vol. 230, no. 8, pp. 1105–1120.

[5] Wang, F. and **K. A. Stelson** (2015). "An Efficient Fan Drive System Based on a Novel Hydraulic Transmission," *IEEE/ASME Transactions on Mechatronics*, Vol. 20, No. 3, pp. 2234-2241.

[6] Deppen, T. O., A. G. Alleyne, J. J. Meyer and **K. A. Stelson** (2015). "Comparative Study of Energy Management Strategies for Hydraulic Hybrids," ASME *Journal of Dynamic Systems, Measurement and Control*, Vol. 137, no. 4.

[7] Dutta, R., F. Wang, B. F. Bohlmann and **K. A. Stelson** (2014). "Analysis of Short-Term Energy Storage for Mid-Sized Hydrostatic Wind Turbine," *Transactions of A.S.M.E., Journal of Dynamic Systems, Measurement and Control*, Vol. 136, No. 1.
*Select publications with co-undergraduate authors (indicated by *)*
[8] Wang, F., M. Bissen*, W. Ward* and **K. A. Stelson** (2014), "Modeling and Design of a Hybrid Bicycle with Hydraulic Transmission," *The Ninth JFPS International Symposium on Fluid Power,* Matsue, Japan.
[9] Wang, F., B. Trietch* and **K. A. Stelson** (2013). "Mid-Sized Wind Turbine with Hydro-Mechanical Transmission Demonstrates Improved Energy Production," in *Proceedings of the Eighth International Conference of Fluid Power Transmission and Control,* Hangzhou, China.
[10] Secord*, T. W., **K. A. Stelson,** and S. C. Mantell (2011), **"**Scaling Analysis and a Critical Thickness Criterion for Thermosetting Composites**,"** *ASME Journal of Manufacturing Science and Engineering,* Vol. 133, no. 1.

Synergistic Activities

Principle Investigator, REU Site: Research Experiences for Undergraduates, (2015-2019).
Director, National Science Foundation Engineering Research Center for Compact and Efficient Fluid Power, (2006-2018).
Associate Technical Editor, *Mechatronics* (2017-present), *ASME Journal of Dynamic Systems, Measurement and Control* (2003-2008), and *ASME Journal of Manufacturing Science and Engineering* (1995-2001).
Director, STEPS Summer Camp for Girls, a program for high school girls that motivates an interest in engineering by building and launching a rocket (2000-2002).
Director of Graduate Studies, M.S. in Manufacturing Systems, a master's degree program for full-time employees in industry, (1997-2001).
Director, Design and Manufacturing Division, Department of Mechanical Engineering, University of Minnesota, (1994-2006).

Appendix B3: Resume of Zongxuan Sun

Zongxuan Sun
Department of Mechanical Engineering
University of Minnesota, Twin Cities Campus

Professional Preparation

Southeast University, China	Automatic Control	B.S. 1995
University of Illinois at Urbana-Champaign	Mechanical Engineering	M.S. 1998
University of Illinois at Urbana-Champaign	Mechanical Engineering	Ph.D. 2000

Appointments

7/2018 – present	Director, NSF Engineering Research Center for Compact and Efficient Fluid Power
1/2014 – 6/2018	Co-Deputy Director, NSF Engineering Research Center for Compact and Efficient Fluid Power
8/2016- present	Professor, Department of Mechanical Engineering, University of Minnesota
8/2012- 8/2016	Associate Professor, Department of Mechanical Engineering, University of Minnesota
8/2007- 8/2012	Assistant Professor, Department of Mechanical Engineering, University of Minnesota
11/2006 – 8/2007	Staff Researcher, Research and Development Center, General Motors Corp.
9/2000-10/2006	Senior Researcher, Research and Development Center, General Motors Corp.
7/1999 – 9/2000	Senior Engineer, Western Digital Corp.

Products

1. Hu, J., Shao, Y., Sun, Z., and Bared, J., “Integrated Vehicle and Powertrain Optimization for Passenger Vehicles with Vehicle-Infrastructure Communication”, Transportation Research Part C, 79, pp.85-102, 2017.
2. Shao, Y., Mohd Zulkefli, A. and Sun, Z., “Vehicle and Powertrain Optimization for Autonomous and Connected Vehicles”, ASME Dynamic Systems and Control Magazine, Vol.5, No. 3, pp.15-19, Sept., 2017.
3. Mohd Zulkefli, A., Mukherjee, P., Sun, Z., Zheng, J., Liu, H. and Huang, P., “Hardware-in-the-Loop Testbed for Evaluating Connected Vehicle Applications”, Transportation Research Part C, 78, pp.50-62, 2017.
4. Mohd Zulkefli, A., Mukherjee, P., Shao, Y. and Sun, Z., “Evaluating Connected Vehicles and Their Applications”, ASME Dynamic Systems and Control Magazine, Vol.4, No. 4, pp.12-17, Dec., 2016.
5. Wang, F., Mohd Zulkefli, A., Sun, Z. and Stelson, K., “Energy Management Strategy for a Power Split Hydraulic Hybrid Wheel Loader”, Proceedings of the IMechE, Part D, Journal of Automobile Engineering, 230(8), pp.1105-1120, 2016.

6. Hu, J., Shao, Y., Sun, Z., Wang, M. Bared, J. and Huang, P., "Integrated Optimal Eco-Driving On Rolling Terrain for Hybrid Electric Vehicle with Vehicle-Infrastructure Communication", Transportation Research Part C, 68, pp.228-244, 2016.
7. Mohd Zulkefli, A., Zheng, J., Sun, Z. and Liu, H., "Hybrid Powertrain Optimization With Trajectory Prediction Based On Inter-Vehicle-Communication And Vehicle-Infrastructure-Integration", Transportation Research Part C, 45, pp.41-63, 2014.
8. Wang, Y. and Sun, Z., "Dynamic Analysis and Multivariable Transient Control of the Power-Split Hybrid Powertrain", IEEE/ASME Transactions on Mechatronics, Vol. 20, No. 6, pp.3085-3097, Dec., 2015.
9. Wang, Y., Zhang, H. and Sun, Z., "Optimal Control of the Transient Emissions and the Fuel Efficiency of a Diesel Hybrid Electric Vehicle", Proceedings of the IMechE, Part D, Journal of Automobile Engineering, 227 (11), pp.1546-1561, 2013.
10. Wang, Y., Sun, Z. and Stelson, K., "Modeling, Control and Experimental Validation of a Transient Hydrostatic Dynamometer", IEEE Transactions on Control Systems Technology, Vol. 19, No. 6, pp.1578-1586, 2011.

Synergistic Activities

- Organizer and panelist, Tutorial session, "Model Based Powertrain and Aftertreatment System Control Design and Implementation", The 2015 American Control Conference, Chicago, IL.
- Organizer and panelist, Panel discussion "Engine and Combustion Modeling for Model-Based Control," The 2013 SAE World Congress, Detroit, MI.
- Guest editor, "Active Automotive Safety Systems", IEEE Control System Magazine, 2010.
- Session co-organizer, "HCCI Control", The 2010 SAE World Congress.
- Mentor, for minority summer students, GM Research and Development Center, 2002, 2003.

Appendix B4: Resume of Alyssa A. Burger

Alyssa A. Burger
Department of Mechanical Engineering
University of Minnesota
111 Church Street S.E.
Minneapolis, MN 55455
alyssa@umn.edu

Professional Preparation

University of Minnesota	Kinesiology	B.S., 2003
University of Minnesota	Science Education	M.Ed., 2012
University of Minnesota	Project Management	Certificate, 2016
University of Minnesota	Leadership Essentials	Certificate, 2018

Appointments

2006 – present	Administrator, Industry Relations, and Education Program Director NSF Engineering Research Center for Compact and Efficient Fluid Power University of Minnesota
2015 – 2017	Program Manager National Fluid Power Association, Milwaukee, WI
2017 – present	Board Member Blaisdell YMCA, Minneapolis, MN

Products

1. Developed undergraduate recruitment strategy adopted by CCEFP and the NSF Engineering Research Centers program
2. Developed a program concept for graduate recruitment strategy for the National GEM Consortium (Graduate Degrees for Minorities in Engineering and Science) which is now incorporated into the organization and has doubled the number of “GEM” students
3. Developed technical education and outreach program concept for the National Fluid Power Association to increase the number of high school students entering mechatronics and fluid power technical degrees
4. Contributed to a research study on NSF Engineering Research Centers to determine core objectives across ERC program and platform initiatives

Synergistic Activities

1. Co-PI, NSF REU Site: Fluid Power Research Experiences for Undergraduates Program, 2013-2015 & 2016 - Present
2. Advisor, University of Minnesota AISES Student Chapter and Northstar AISES Alliance, 2008-2014
3. Advisor, CCEFP Student Leadership Council, 2006-2016
4. Lead Personnel, TRIBES-E, Teaching Relevant-Inquiry Based Environmental Science And Engineering Teacher Workshop
5. Lead Personnel, NSF LSAMP North Star Louis Stokes Alliance for Minority Participation

Appendix C: Letter-of-Commitment – CCEFP

CENTER FOR COMPACT AND EFFICIENT FLUID POWER
A National Science Foundation Engineering Research Center

University of Minnesota
111 Church Street S.E.
Minneapolis, MN 55455-0111
www.ccefp.org

October 9, 2018

George R Fenske
Senior Materials Scientist and Tribologist
Argonne National Laboratory
Applied Materials Division
Argonne, IL 60439

Re: Commitment of Effort for Technologist-in-Residence Pilot Program

Dear Dr. Fenske:

I am writing this letter in support of the Argonne/CCEFP proposal entitled "Development of Energy Efficient Fluid Power Vehicles" submitted in response to the Technologist-In-Residence Pilot Program Call for Proposals. This project offers CCEFP the opportunity to partner with Argonne and other national labs to concentrate on the development of collaborative R&D projects which apply the unique expertise and capabilities that exist within DOE's national lab complex to overcome challenges and barriers industry has identified that are related to the development of energy-efficient fluid power systems. A successful collaboration between the National Laboratories, and CCEFP, in technology areas that include vehicle systems and energy storage, will result in the more rapid development of energy-efficient fluid power systems thereby resulting in improved business outcomes for the fluid power industry and more rapid attainment of national goals including the reduction of energy consumption, improved air quality, and economic growth.

CCEFP is very keen to participate as collaborative key personnel in the proposed program. Specifically, CCEFP will pay the salary and travel expenses for its leadership team to plan, develop, and participate in designated meetings and events up to a maximum amount of $113,369.

I look forward to participating in the Technology-in-Residence Pilot Program and to a successful collaboration.

Sincerely,

Professor and CCEFP Director
Zongxuan Sun

Amy Rollinger
Principal Grants and Contracts Administrator
Office of Sponsored Projects Administration