2017 UPDATE TO NFPA TECHNOLOGY ROADMAP

# RESEARCH CHALLENGE BRIEFING MATERIALS

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# CCEFP Research Strategy Summary

The Center for Compact and Efficient Fluid Power (CCEFP) is transforming fluid power. The CCEFP research strategy has catalyzed the fluid power industry and research community. The fluid power research strategy is based on multiple sources including industry needs identified through the NFPA Technology and Manufacturing Roadmaps. A comprehensive review results in key technical barriers that fluid power must overcome to grow and prosper. The significant technical barriers facing fluid power are:

1. Efficient Components and Systems
2. Efficient Control
3. Efficient Energy Management
4. Compact Power Supplies
5. Compact Energy Storage
6. Compact Integration
7. Safe and Easy-to-Use
8. Leak-free
9. Quiet

Of these, three technical barriers are transformational: efficient components and systems, compact power supplies, and compact energy storage, which provide the largest benefits in mobile applications. As a result, mobile hydraulics has been the dominant research focus for CCEFP since its inception.

Fluid power manufacturing can be typically described by the making of high precision components coupled with multiple product configurations and small order sizes. This results in its own unique set of challenges. These challenges can be best overcome by focusing pre-competitive research on ten emerging manufacturing technologies, including:

1. Coatings
2. Micro-machining
3. Composites and 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 seeks to address these technology and manufacturing barriers. The research strategy calls for support and coordination of pre-competitive research in three strategic areas:

- *Off-Highway Vehicles* – addressing the technical barriers associated with increasing the energy efficiency of fluid power components and systems, as well as efficient control and energy management through fluid power.
- *Human Scale Systems* – addressing the technical barriers associated with compacting or integrating power supplies, energy storage devices, and other components while making fluid power safer and easier-to-use.
- *Fluid Power Manufacturing* – addressing the barriers associated with enabling single piece flow (batch size of one), increased production rates, meeting quality levels that are matched to real world requirements and environmentally friendly processes.

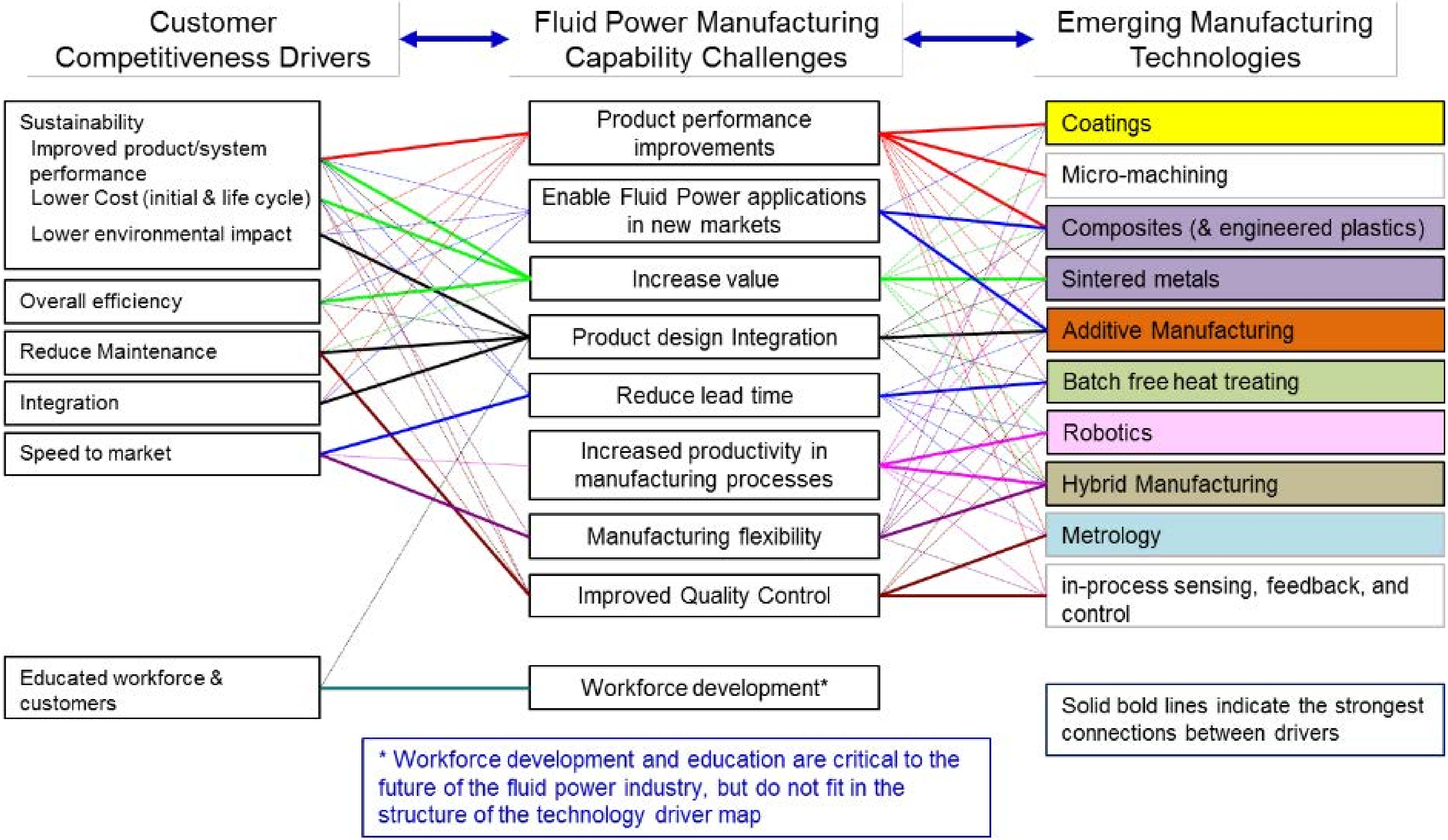
The underlying research needs of making fluid power leak-free, quiet, and cost effective permeates all three strategic areas.

CCEFP recognizes the value in a systems-based approach to addressing these technical barriers. CCEFP encourages the use of research test beds to the greatest extent possible. Ideally, the results of individual research projects should be validated on test beds in a systems environment so that student researchers can develop a systems-level approach to solving technical challenges. These skills are highly desirable in a modern day workforce. In fact, it is universally accepted by key CCEFP stakeholders that the training of the next generation of fluid power leaders and technical workforce is the most significant outcome of executing the CCEFP research strategy.

# Fluid Power Manufacturing Roadmap
# Summary

as presented March 9, 2017

# Roadmap Schematic



# Cross Cutting Themes

- High precision coupled with multiple product configurations and small orders sizes present unique challenges
- Single piece flow (batch size of one)
- Increased production rates
- Meet quality levels that are matched to requirements that reflect real world operation
- Environmentally friendly processes

# Coatings – Research Needs

- Coatings that are cost effective
- Easy to apply including shapes that are difficult to coat
- Improved substrate interface strengths, including inter-coating bonds
- Improved anti-friction, anti-wear and corrosion resistant properties
- Environmentally friendly processes (replace hexavalent chrome)

# Micro-Machining – Research Needs

- Increased through-put without affecting accuracy or statistical process control (SPC)
- Reduced cost of capital (includes machining centers, tooling and fixturing)
- Reduced setup time
- Improved Takt time (German word for pulse or baton)

# Composites/Engineered Plastics – Research Needs

- Better simulation modeling and predictive tools to eliminate uncertainty from manufacturing processes and tooling design
- Increase in the number and complexity of net shape components produced via molding
- Lower cost
- Decrease weight using components with material properties that allows replacement of metals and castings

# Sintered Metals – Research Needs

- Better simulation modeling and predictive tools to eliminate uncertainty from manufacturing processes and tooling design
- Increase in the number and complexity of net shape components produced via pressing of sintered metals
- Lower cost
- Improved prediction of material properties, especially fatigue strength

# Additive Manufacturing – Research Needs

- High pressure (350 bar) capability without leaks or weeping
- Material strength standards, including fatigue
- Increased printing speeds without compromising part complexity, strength or surface finish
- Improved finishing techniques and processes
- Lower cost
- Improved design tools

# Batch-Free Heat Treating – Research Needs

- Investigate alternative energy sources including lasers, electron beam, induction, friction, etc., for shafts, rotating groups and thrust plates
- Investigate fluidized sand bed for castings
- Process models and design tools
- Low distortion heat treating
- Heat treating at the work center

# Robotics – Research Needs

- Integrated sensor networks with low-cost non-contacting sensors

- Intrinsically safe co-bot (cooperative robot) HMIs (human machine interfaces)

- Lightweight and efficient fluid power components and systems

- Big data and analytics

# Hybrid Manufacturing – Research Needs

- Defined as combination of subtractive, additive and secondary processing (machining, welding, brazing, inspection, heat treating and coatings) in one setup
- Develop guidelines for identifying candidate parts for hybrid manufacturing
- Methods for stress relief, flaw detection, and distortion correction
- Better understanding of process interactions

# Metrology – Research Needs

- Automated and digital metrology systems that can be integrated by simple connectivity tools such as Wi-Fi or Bluetooth
- Methods to define inspection and quality plans that leverage connected and digital metrology capabilities
- Better coordinate metrology and non-contacting systems that generate large quantities of digitized data
- Real-time and big data feedback connected to the cloud for rapid information delivery and utilization (this ties in well with automation and sensors)
- Statistical and other types of models to be formulated such that the data can be used in real-time, or near real-time
- Expand metrology to include more than just dimensions such as material characteristics, residual stress, internal structures, etc.

# In-Process Sensing, Feedback & Control – Research Needs

The desired future state is intelligent adaptive control (IAC) as described below:

- Ability to interface with any controller, whether proprietary (e.g., Haas) or generic (e.g., Siemens and Fanuc)
- Have physics-based kernel that allows them to make intelligent changes to the process so that the outcome of the change is known with precision
- Physics-based software with access to the Cloud, specifically big data in the Cloud; include tooling information from cutting tool companies to further enhance predictive nature

# IMPROVING THE DESIGN AND FUNCTION OF FLUID POWER COMPONENTS AND SYSTEMS

## RESEARCH CHALLEGES AND OBJECTIVES

### Research Challenges

The 2015 NFPA Technology Roadmap identifies the following six broad areas of research challenge for the fluid power industry to tackle in order to meet the future needs of its customers, expand fluid power into new customer markets, and attract the best and brightest students to field.

- Increasing the energy efficiency of fluid power components and systems
- Improving the reliability of fluid power components and systems (e.g., increasing up-time, reducing maintenance requirements, making fuid power safe and easy to use)
- Reducing the size of fluid power components and systems while maintaining or increasing their power output
- Building “smart” fluid power components and systems (i.e., ones that perform self-diagnostics and troubleshooting and that integrate easily with “plug and play” functionality)
- Reducing the environmental impact of fluid power components and systems (e.g., lowering noise, eliminating leaks)
- Improving and applying the energy storage capabilities of fluid power components and systems

Organizations that wish to pursue projects of importance to the fluid power industry should seek alignment with these Challenges.

### Research Objectives

For each of the Research Challenges described above, a specific set of targeted Research Objectives has also been identified. Research organizations that wish to pursue projects aligned with a specific Research Challenge should focus their activities on the objectives described below.

<u>Increasing the energy efficiency of fluid power components and systems</u>

- Increase the energy efficiency of fluid power systems through improvements at the component & system level.
- Reduce energy consumption of fluid power systems through improvements at the component & system level.
- Reduce power consumption of fluid power systems through improvements at the component & system level.

- Reduce pressure loss between power source and actuation.
- Improve the energy recovery methods of fluid power systems.

<u>Improving the reliability of fluid power components and systems (e.g., increasing up-time, reducing maintenance requirements, making fuid power safe and easy to use)</u>

- Increase system up-time.
- Reduce system maintenance requirements.
- Make fluid power safer and easier to use.
- Increase the intermittent to rated duty cycle ratio of fluid power components and systems.
- Identify mean-time-before-failure for fluid power components and systems.

<u>Reducing the size of fluid power components and systems while maintaining or increasing their power output</u>

- Increase power density (size to horsepower output).
- Reduce the size of systems.
- Reduce weight of components.

<u>Building "smart" fluid power components and systems (i.e., ones that perform self-diagnostics and troubleshooting and that integrate easily with "plug and play" functionality)</u>

- Discover/experiment with new diagnostic modalities that have the potential to dramatically lower the cost of adding sensor capability throughout a fluid power system, without lowering current performance or durability.
- Develop adaptive control mechanisms that utilize sensor data to monitor conditions and automatically manage system and component performance.
- Explore "programmable" fluid power systems—ways of changing the configuration, control, operation and actuation characteristics of fluid power systems solely through electronic and microprocessor controls, without modifying static fluid power components.

<u>Reducing the environmental impact of fluid power components and systems (e.g., lowering noise, eliminating leaks)</u>

- Develop hydraulic systems and components that operate with environmentally-neutral fluids.
- Develop and adopt new, affordable biodegradable, non-hazardous fluids with traditional performance levels.
- Eliminate leaks using disruptive innovations and approaches.

- Reduce noise, vibration and harshness (NVH).
- Reduce pollutants (e.g., atomized oil) in the air.
- Develop and employ environmentally-neutral lubricants for pneumatics.
- Eliminate the need for lubricants in pneumatic systems.
- Develop systems and components that are recyclable and/or use recyclable materials

Improving and applying the energy storage capabilities of fluid power components and systems

- Increase kilowatt hours per unit volume of storage devices and methods.
- Increase kilowatt hours per unit weight of storage devices and methods.
- Decrease cost per kilowatt hour of energy storage devices and methods.
- Improve the round trip efficiency of storing and re-using energy.
- Explore novel systems for using energy that is currently wasted.

**Top Research Objectives**

The following list of Research Objectives are not sorted by the specific Research Challenges they have been identified to address. Rather, as part of an exercise at an in-person meeting of the NFPA Roadmap Committee, all 29 of the above objectives were combined into a single list and committee members voted on those they believed had the greatest disruptive potential for the increased use of fluid power in its customer markets. The following list of 10 objectives represents the top vote-getters in that exercise.

- Improve the cost effectiveness of fluid power components & systems through disruptive innovation.
- Increase the energy efficiency of fluid power systems through improvements at the component & system level.
- Discover/experiment with new diagnostic modalities that have the potential to dramatically lower the cost of sensor capability throughout a fluid power system, without lowering current performance or durability.
- Increase power density (size to horsepower output).
- Eliminate leaks using disruptive innovations and approaches.
- Develop adaptive control mechanisms that utilize sensor data to monitor conditions and automatically manage system and component performance.
- Reduce noise, vibration and harshness (NVH).
- Improve energy storage through various methods.

- Improve the energy recovery methods of fluid power systems; explore novel systems for using energy that is currently wasted.
- Explore “programmable” fluid power systems—ways of changing the configuration, control, operation and actuation characteristics of fluid power systems solely through electronic and microprocessor controls, without modifying static fluid power components.
- Develop and adopt new, affordable biodegradable, non-environmentally-hazardous fluids with traditional performance levels, and develop hydraulic systems and components that operate with these environmentally-neutral fluids.