



# **NFPA Technology Roadmap Roadmapping Session Report**

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**April 6, 2017**

# Participants and Working Groups



The following people participated in the session and volunteered for the following working groups.

Hydraulic Mobile Markets	Hydraulic Industrial Markets	Pneumatic Markets
Wiley Abner, Netshape Technologies Marty Barris, Donaldson Shubhamita Basu, Lubrizol Mark Bokorney, Sun Hydraulics Eric Bretey, Danfoss Enrique Busquets, Bosch Rexroth Celine Cabana, FD Groups America Michael Crosby, Parker Hannifin Aleksander Egelja, Caterpillar Michael Freisleben, CNH Industrial Rick Hill, Gates Hudson Keyler, Gates Gilles Lemaire, Poclain Hydraulics Scott Lane, Linde Hydraulics Kevin Lingenfelter, Danfoss Gunter Matt, Bobcat Randy Van Dyken, Kawasaki Howard Zhang, Parker Hannifin	Greg Kuhlman, Iowa Fluid Power Randy Nobles, Womack Machine David Raymond, Womack Machine Brian Rhode, Afton Chemical Marcus Royal, Deltrol Fluid Products Ramnik Singh, Gamma Technologies Mike Sprengel, Czero	Mike Gust, Innotronics Bob Hammond, Deltrol Fluid Products Jim Kaas, Iowa Fluid Power Kent Sowatzke, Bimba Manufacturing

All were informed of and agreed to abide by NFPA's anti-trust guidelines.

# Discussion – Trends in Customer Markets

As part of an open discussion, the following trends in fluid power's customer markets were identified. Participants focused on changes that may have occurred within the last two years, or since the time of the last refresh of the NFPA Technology Roadmap.

- Oil prices have changed, making energy savings less of a customer driver than it was two years ago. The availability of natural gas may have tempered this trend somewhat, but that affects on-highway more than off-highway vehicles.
- Emission regulations have tightened and are expected to get even tighter, but the current political climate makes that a wild card.
- FDA regulations on food processing and food handling have changed, requiring changes in the materials being used on these machines.
- Industry 4.0 (the widespread use of sensors, connected systems and products, and big data analytics) has arrived.
- There is an increased drive for the electrification of drive systems, control systems, and actuation technologies. This is partially driven by the rise of machines with remote, automated, and/or driverless functionality.
- There is a greater emphasis on worker safety.

# Customer Drivers

Customer drivers are the business or technology objectives of fluid power customers. They help them serve the needs of their own customers, or end-users, and are not necessarily connected to their use of fluid power. The 2015 NFPA Technology Roadmap identified four customer drivers as common to all fluid power customer markets:

- Increased productivity and performance
- Increased availability/up-time
- Lower total and life cycle costs
- Increased ease/predictability of maintenance

In reviewing the identified trends in fluid power's customer markets, and in discussing what end-user needs they might reflect, these four customer drivers were seen as still valid for all fluid power customer markets. Two new drivers were added:

- Quieter machines
- Machines that are compliant with safety regulations

It was proposed that the 2017 NFPA Technology Roadmap be built on the foundation of these six customer drivers.

# Worksheet – Trends in Fluid Power Capabilities



In their working groups, participants then ranked how well hydraulics or pneumatics were currently meeting the customer drivers in their market segments.

How well does fluid power currently meet each customer driver?				
Customer Driver	Hydraulic Mobile Markets	Hydraulic Industrial Markets	Pneumatic Markets	Weighted Averages
Increased productivity and performance	1	2.5	2	1.625
Increased availability/up-time	2	2	1	1.750
Lower total and life cycle costs	2	3	1	2.000
Increased ease/predictability of maintenance	3	1	2	2.250
Quieter machines	3	3	3	3.000
Machines that are compliant with safety regulations	2	3	1	2.000
<b>1 = Fluid power is the technology of choice for meeting this customer driver</b> <b>2 = Fluid power holds its own among viable competing technologies in meeting this customer driver</b> <b>3 = Fluid power is seldom chosen over competing technologies for meeting this customer driver</b>				

The weighted averages reflect the relative fluid power product sales volumes in each market segment (50% mobile hydraulics, 25% industrial hydraulics, and 25% pneumatics). Based on those averages, fluid power's strongest advantage is in helping customers deliver increased productivity, performance, availability and up-time to the end-user. Its strongest disadvantage is in delivering machines that are quiet and which have easy or predictable maintenance.

# Research Challenges



Research challenges are the broad areas of attention that must be addressed if fluid power is to meet or better meet the customer needs described by the drivers. Participants first reviewed the six research challenges that were identified on the 2015 NFPA Technology Roadmap.

- 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 fluid 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

The participants then split into their working groups and ranked the degree to which improvements in each of these areas of research challenge would increase the ability of hydraulics or pneumatics to meet the customer drivers in their market segments. The results of each individual exercise and the calculated weighted averages are shown on the next several slides.

# New Areas of Research Challenge

Recognizing that new Customer Drivers may be best met by new areas of Research Challenge, the participants in each working group discussed other areas where improvements would increase the ability of hydraulics or pneumatics to meet the customer drivers in their market segments.

The working group on **Mobile Hydraulic Markets** suggested the following new areas of Research Challenge:

- **Quieter components.** Lowering the noise of fluid power systems is already encompassed in the Research Challenge focused on “Reducing environmental impact.” Therefore, this suggestion is better positioned as a Research Target or Objective under that Research Challenge.
- **Fast and accurate control.** This is a discrete area of Research Challenge, separate from the existing six. Therefore, it should be added as a new Research Challenge.
- **Miniature and cost effective sensors.** Sensors are a clear enabling technology for the Research Challenge focused on “Building ‘smart’ components and systems.” Therefore, this suggestion is better positioned as a Research Target or Objective under that Research Challenge.

The working group on **Industrial Hydraulic Markets** suggested the following new areas of Research Challenge:

- **Understand noise creation and propagation in hydraulic systems.** Lowering the noise of fluid power systems is already encompassed in the Research Challenge focused on “Reducing environmental impact.” Therefore, this suggestion is better positioned as a Research Target or Objective under that Research Challenge.

The working group on **Pneumatic Markets** suggested the following new areas of Research Challenge:

- **New materials.** This is a discrete area of Research Challenge, separate from the existing six. Therefore, it should be added as a new Research Challenge.

The participants in the cited working groups also ranked the degree to which improvements in each of these new areas of research challenge would increase the ability of hydraulics or pneumatics to meet the customer drivers in their market segments.

# Worksheet – Areas of Needed Improvement



## HYDRAULIC MOBILE MARKETS

Would improvements in these areas of research challenge increase fluid power’s ability to meet these customer drivers?

CUSTOMER DRIVERS	RESEARCH CHALLENGES							
	Increase Energy Efficiency	Improve Reliability	Reduce Size	Build “Smart” Components and Systems	Reduce Environmental Impact	Improve Energy Storage Capabilities	Fast and Accurate Control	New Materials
Increased productivity and performance	1	1	2	1	2	1	1	--
Increased availability/up-time	3	1	2	1	1	2.5	2	--
Lower total and life cycle costs	1	1	1	2	2	2	2	--
Increased ease/predictability of maintenance	3	1	3	1	3	3	3	--
Quieter machines	2	3	2	2	1	2	2	--
Machines that are compliant with safety regulations	3	1	3	1	1	3	2	--
<b>Straight Averages</b>	<b>2.167</b>	<b>1.333</b>	<b>2.167</b>	<b>1.333</b>	<b>1.667</b>	<b>2.250</b>	<b>2.000</b>	<b>--</b>

**1 = YES, improvements in this area of research challenge WILL increase fluid power’s ability to meet this customer driver**

**2 = MAYBE, improvements in this area of research challenge MIGHT increase fluid power’s ability to meet this customer driver**

**3 = NO, improvements in this area of research challenge WILL NOT increase fluid power’s ability to meet this customer driver**

The straight averages provide equal weight to each of the six customer drivers. Based on those averages, the greatest focus for mobile markets should be on improving hydraulic reliability and on building “smart” hydraulic components and systems. The least focus should be on improving hydraulic energy storage capabilities.



# Worksheet – Areas of Needed Improvement



## HYDRAULIC INDUSTRIAL MARKETS

Would improvements in these areas of research challenge increase fluid power’s ability to meet these customer drivers?

CUSTOMER DRIVERS	RESEARCH CHALLENGES							
	Increase Energy Efficiency	Improve Reliability	Reduce Size	Build “Smart” Components and Systems	Reduce Environmental Impact	Improve Energy Storage Capabilities	Fast and Accurate Control	New Materials
Increased productivity and performance	1	1	1	1	1	1	--	--
Increased availability/up-time	3	1	3	1	2	2	--	--
Lower total and life cycle costs	1	1	1	2	2	2	--	--
Increased ease/predictability of maintenance	3	1	3	1	3	3	--	--
Quieter machines	2	3	3	2	1	1	--	--
Machines that are compliant with safety regulations	3	2	3	1	2	1	--	--
<b>Straight Averages</b>	<b>2.167</b>	<b>1.500</b>	<b>2.333</b>	<b>1.333</b>	<b>1.833</b>	<b>1.667</b>	--	--

**1 = YES, improvements in this area of research challenge WILL increase fluid power’s ability to meet this customer driver**

**2 = MAYBE, improvements in this area of research challenge MIGHT increase fluid power’s ability to meet this customer driver**

**3 = NO, improvements in this area of research challenge WILL NOT increase fluid power’s ability to meet this customer driver**

The straight averages provide equal weight to each of the six customer drivers. Based on those averages, the greatest focus for industrial markets should be on building “smart” hydraulic components & systems and on increasing hydraulic reliability. The least focus should be on reducing the size of and on increasing the energy efficiency of hydraulic components and systems.

# Worksheet – Areas of Needed Improvement



## PNEUMATIC MARKETS

Would improvements in these areas of research challenge increase fluid power’s ability to meet these customer drivers?

CUSTOMER DRIVERS	RESEARCH CHALLENGES							
	Increase Energy Efficiency	Improve Reliability	Reduce Size	Build “Smart” Components and Systems	Reduce Environmental Impact	Improve Energy Storage Capabilities	Fast and Accurate Control	New Materials
Increased productivity and performance	1	1	3	1	2	1	--	1
Increased availability/up-time	3	1	3	1	3	3	--	3
Lower total and life cycle costs	1	1	2	2	2	2	--	1
Increased ease/predictability of maintenance	3	1	3	1	3	3	--	3
Quieter machines	1	3	3	3	1	2	--	1
Machines that are compliant with safety regulations	3	1	2	1	3	3	--	3
<i>Straight Averages</i>	<b>2.000</b>	<b>1.333</b>	<b>2.667</b>	<b>1.500</b>	<b>2.333</b>	<b>2.333</b>	--	<b>2.000</b>

**1 = YES, improvements in this area of research challenge WILL increase fluid power’s ability to meet this customer driver**

**2 = MAYBE, improvements in this area of research challenge MIGHT increase fluid power’s ability to meet this customer driver**

**3 = NO, improvements in this area of research challenge WILL NOT increase fluid power’s ability to meet this customer driver**

The straight averages provide equal weight to each of the six customer drivers. Based on those averages, the greatest focus for pneumatic markets should be on improving pneumatic reliability and on building “smart” pneumatic components & systems. The least focus should be on reducing the size of pneumatic components and systems.

# Worksheet – Areas of Needed Improvement



## WEIGHTED AVERAGES

Would improvements in these areas of research challenge increase fluid power’s ability to meet these customer drivers?

CUSTOMER DRIVERS	RESEARCH CHALLENGES							
	Increase Energy Efficiency	Improve Reliability	Reduce Size	Build “Smart” Components and Systems	Reduce Environmental Impact	Improve Energy Storage Capabilities	Fast and Accurate Control	New Materials
Increased productivity and performance	1.000	1.000	2.000	1.000	1.750	1.000	1	1
Increased availability/up-time	3.000	1.000	2.500	1.000	1.750	2.500	2	3
Lower total and life cycle costs	1.000	1.000	1.250	2.000	2.000	2.000	2	1
Increased ease/predictability of maintenance	3.000	1.000	3.000	1.000	3.000	3.000	3	3
Quieter machines	1.750	3.000	2.500	2.250	1.000	1.750	2	1
Machines that are compliant with safety regulations	3.000	1.250	2.750	1.000	1.750	2.500	2	3
<b>Straight Averages</b>	<b>2.125</b>	<b>1.375</b>	<b>2.333</b>	<b>1.375</b>	<b>1.875</b>	<b>2.125</b>	<b>2.000</b>	<b>2.000</b>

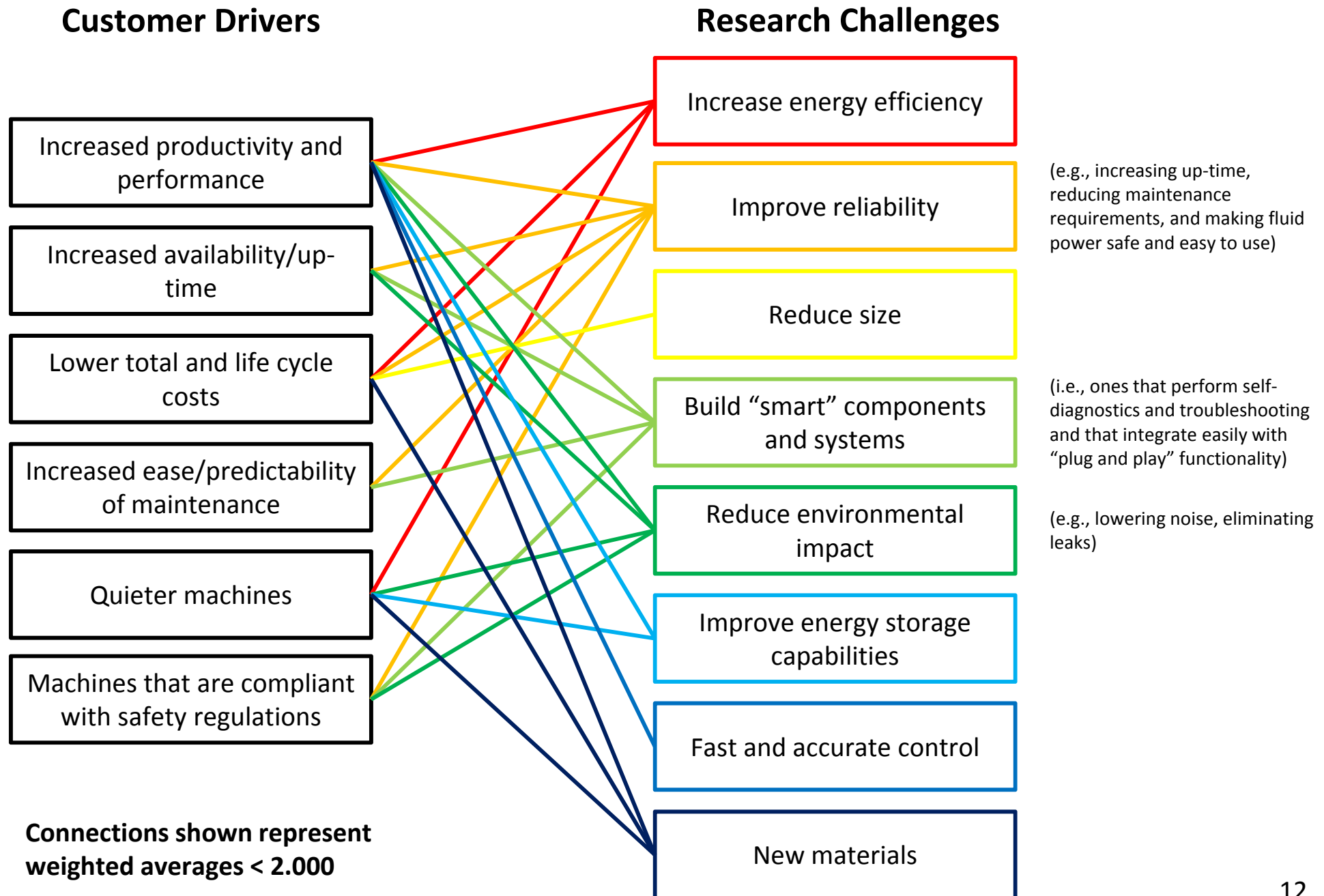
**1 = YES, improvements in this area of research challenge WILL increase fluid power’s ability to meet this customer driver**

**2 = MAYBE, improvements in this area of research challenge MIGHT increase fluid power’s ability to meet this customer driver**

**3 = NO, improvements in this area of research challenge WILL NOT increase fluid power’s ability to meet this customer driver**

The weighted averages reflect the relative fluid power product sales volumes in each market segment (50% mobile hydraulics, 25% industrial hydraulics, and 25% pneumatics). These calculations were not conducted for “Fast and Accurate Control” and “New Materials” since not all three working groups evaluated them. The straight averages provide equal weight to each of the six customer drivers. Based on those averages, the greatest focus for all markets should be on improving fluid power reliability and on building “smart” fluid power components & systems. The least focus should be on reducing the size of fluid power components and systems.

# Draft Customer Driver/Research Challenge Map



# Draft Research Targets and Objectives

Research Targets and Objectives seek to quantify or describe successful strategies for pursuing the Research Challenges. The following list is based on the Research Targets and Objectives identified on the 2015 Technology Roadmap, and the new Targets and Objectives suggested at the April 6, 2017, Roadmapping Session.

## **Increase energy efficiency**

- Reduce energy consumption
- Reduce power consumption
- Reduce pressure loss between power source and actuation
- Improve energy recovery methods

## **Increasing reliability**

- Increase up-time
- Reduce maintenance requirements
- Make safer and easier to use
- Increase the intermittent to rated duty cycle ratio
- Identify mean-time-before-failure

## **Reduce size**

- Increase power density
- Reduce size of systems
- Reduce weight of components

## **Build “smart” components and systems**

- Discover new, lower-cost diagnostic modalities
- Develop automatic and adaptive control mechanisms
- Change system configurations and characteristics via electronic controls
- **NEW - Develop miniature and cost effective sensors**

# Draft Research Targets and Objectives, continued

## Reduce environmental impact

- Operate systems and components with environmentally-neutral fluids
- Develop new, affordable, biodegradable, non-hazardous fluids
- Eliminate leaks with disruptive innovations and approaches
- Reduce noise, vibration and harshness
- Reduce pollutants in the air
- Develop environmentally-neutral pneumatic lubricants
- Develop recyclable systems or those made from recyclable materials
- **NEW - Develop quieter components**
- **NEW - Understand noise creation and propagation in hydraulic systems**

## Improve energy storage capabilities

- Increase kilowatt hours per unit volume of energy storage methods
- Increase kilowatt hours per unit weight of energy storage methods
- Decrease cost per kilowatt hour of energy storage methods
- Improve round trip efficiency of storing and re-using energy
- Explore novel uses of wasted energy

## Fast and accurate control

- None yet identified

## New materials

- None yet identified

# Next Steps

Members of the NFPA Roadmap Committee will be organized into eight new working groups, one for each of the eight areas of Research Challenge. Over the course of a conference call, each working group will:

- Review their assigned area of Research Challenge and confirm its connection to the Customer Drivers.
- If necessary, define the area of Research Challenge in greater detail, ensuring that it is distinct from the other seven areas of Research Challenge.
- Review and discuss advances in their area of Research Challenge that have occurred over the past two years.
- Review, discuss, revise, and prioritize the list of Research Targets and Objectives for their area of Research Challenge. Do they all represent fruitful areas of research investigation for this area? Are they stated as specifically as possible, while still maintaining a focus on pre-competitive inquiry? Are they in a priority order that reflects their likelihood of success?

Conference calls will be held between April and July 2017. At their conclusion, a draft of the full Roadmap document will be produced and circulated for additional feedback. A final draft will be presented at the August 2017 NFPA Industry and Economic Outlook Conference.