



NFPA Roadmap Committee

Meeting Report on Capability Improvements

March 2, 2023

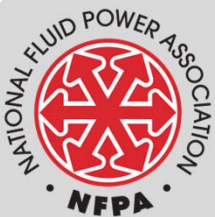
NFPA Technology Roadmap

The NFPA Technology Roadmap describes an industry-wide consensus regarding the pre-competitive research and development needs associated with improving the design, manufacture, and function of fluid power components and systems.

The research and development agenda it describes is focused on advancements that will help the fluid power industry meet the future needs of its customers, expand into new markets, and attract the best and brightest students to the field.

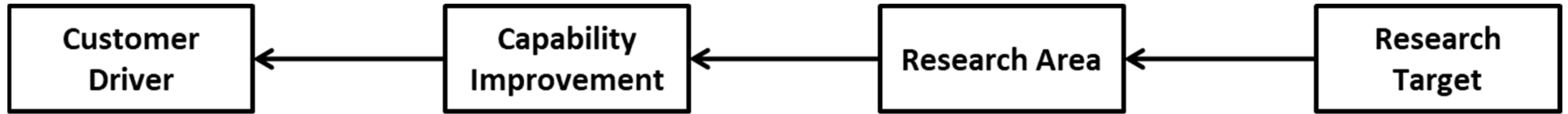
It is used by the NFPA and its academic partners to guide their research efforts, by NFPA members and other industry players to inform decisions about research partnerships and product development, and by academic, government, and other organizations that wish to pursue research and development projects of importance to the fluid power industry.

It is updated every two years under the guidance and leadership of the NFPA Roadmap Committee.



Roadmap Elements

The NFPA Technology Roadmap is comprised of the following four elements, each linked to the one preceding in an interdependent chain.



Customer Drivers are the business or technology objectives of fluid power customers. They help them serve the needs of their own customers, and are not necessarily connected to their use of fluid power.

Capability Improvements describe the ways in which fluid power systems must improve if they are to meet or better meet the customer needs described by the Customer Drivers.

Research Areas are the broad areas of pre-competitive investigation that could assist in bringing about the Capability Improvements.

Research Targets are the objectives that quantify or otherwise describe successful strategies for pursuing the Research Areas.



2023 Roadmap Process and Timeline

The NFPA Roadmap Committee is following this process and timeline for the 2023 update to the NFPA Technology Roadmap. This is the report from its meeting on March 2, 2023 to discuss, define and prioritize capability improvements.

Phase 1 – Customer Drivers

- | | |
|--------|---|
| Dec 1 | Present Roadmap Process and Timeline at NFPA/FPIC Regional Conference
Launch of survey on customer drivers |
| Dec 22 | Deadline to respond to survey on customer drivers |
| Jan 12 | Virtual committee meeting to discuss, define and prioritize customer drivers |

Phase 2 – Capability Improvements

- | | |
|--------|--|
| Jan 26 | Meeting report sent with prioritized customer drivers and setting the stage for fluid power alignment and capability improvements
Launch of survey on fluid power alignment and capability improvements |
| Feb 16 | Deadline to respond to survey on fluid power alignment and capability improvements |
| Mar 2 | Virtual committee meeting to discuss, define and prioritize capability improvements |

Phase 3 – Research Areas and Targets

- | | |
|---------|--|
| Mar 16 | Meeting report sent with prioritized capability improvements and setting the stage for research areas and targets, including process for defining working groups for each capability improvement
Launch of survey on research areas and targets |
| Apr 6 | Deadline to respond to survey on research areas and targets |
| Apr/May | Virtual working group meetings to discuss and prioritize research areas and targets for each capability improvement |
| Jun 1 | Virtual committee meeting to review and harmonize research areas and targets for each capability improvement |

Phase 4 – Final Roadmap Document

- | | |
|--------|--|
| Jun | Draft Roadmap document written |
| Jun 29 | Draft Roadmap document sent for review and comment |
| Jul 20 | Deadline to return comments on draft Roadmap |
| Aug 16 | Final Roadmap document presented at NFPA IEOC |

Meeting Participants

Committee Vice Chair

- Steven Meislahn, Sun Hydraulics

Committee Members

- Ed Danzer, 6K Products
- Benjamin Moses, Association for Manufacturing Technology
- Bill Shepard, BDI
- Cory Geers, BDI
- Jon Frey, Bosch Rexroth Corporation
- Christian Eitel, Bucher Hydraulics
- Todd Harmon, Canfield Industries
- Dominic Catanzarite, Daman Products
- Matthew Giloth, Daman Products
- Mike Betz, Danfoss
- Jason Palmer, Delta Computer Systems
- David Yale, Delta Power Company
- Ivan Sheffield, Des-Case
- Adam Livesay, Elevat
- Jonathan Gamble, Enfield Technologies
- Matt Loeffler, FORCE America
- Tom Miklos, Galland Henning Nopak
- Russell Evans, HYDAC
- Mark Bokorney, Hydra-Power Systems
- Narendra Gupta, Hyster-Yale Group

- Joe Jackan, JARP Industries
- Jeff Bauer, John Deere
- Paul Marvin, John Deere
- Tom Vander Meulen, Kawasaki Precision Machinery
- Michael Miles, KersTech, Inc.
- Roy Schmoutz, Komatsu
- Dave Geiger, Moog
- Bob Mosey, Mosey's Production Machinists, Inc.
- Larry Wesley, Muncie Power Products, Inc.
- Ron Hibbler, Proportion-Air
- Jay Dalal, ROSS Controls
- Scott McCambridge, SMC Corporation of America
- Jeff Andrasik, Smithers
- Zeke Metzler, Texcel
- Furat Al-Saleem, Trelleborg Sealing Solutions
- John McLaughlin, Trelleborg Sealing Solutions
- Michael Cook, Trelleborg Sealing Solutions
- Trevor Combs, Trelleborg Sealing Solutions

NFPA Staff

- Eric Lanke



Customer Drivers and Strategies

The NFPA Roadmap Committee met on January 12, 2023, to review survey data, discuss, and determine the Customer Drivers and Strategies that would help frame the 2023 refresh of the NFPA Technology Roadmap.

The chosen Customer Drivers and Strategies, and the primary connections between them, are shown at right.

CUSTOMER DRIVERS

Top Level Machine Performance Objectives

Increased availability and up-time
Generally defined as the robustness of the machine, its ability to work continuously.

Increased productivity and performance
Generally defined as the efficiency of the machine, its ability to do more work in less time.

Lower total cost of ownership
Includes capital and/or operating costs.

Compliance with regulations
Such as those pertaining to environmental, safety, or other concerns.

CUSTOMER STRATEGIES

Machine-Level Objectives and Technologies That Help Achieve Performance Objectives

Autonomy
Either semi- or fully-autonomous functions and/or operations.

Compactness
Increasing power density and/or reducing weight and/or size.

Connectivity
Expanding the use of data, such as intelligence for cloud-based condition monitoring, integration with site management systems, and/or communicating machine status for other value-added purposes.

Electrification
Decarbonizing prime movers through a variety of strategies. Currently connected to regulations; likely connected to productivity in the future.

Energy Efficiency
Increasing it; and including strategies to improve battery life and/or charging and to use less energy and/or reduce emissions.

Maintenance
Making it easier; and including strategies to ease the serviceability of the machine and to increase the availability of repair and replacement parts.

Materials
Use of conflict and/or environmentally friendly materials in strategic ways to better comply with regulations.

Noise
Reducing perceived noise levels and/or improving noise pulsation. Connected to productivity when operators are more comfortable and able to work in "new" areas.



Capability Improvements

The Committee next reviewed the Capability Improvements that were defined as part of the 2021 NFPA Technology Roadmap.

Capability Improvements describe the ways in which fluid power systems must improve if they are to meet or better meet the customer needs described by the Customer Drivers and Strategies.

In the 2021 NFPA Technology Roadmap, the following seven Capability Improvements were identified as those of highest importance for the fluid power industry to pursue in order to meet or better meet customer needs.

Capability Improvements

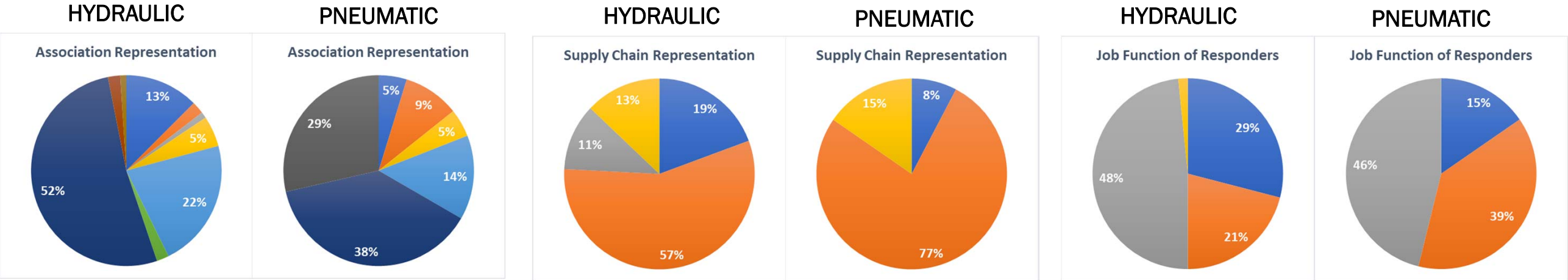
In order to better meet the needs of our customers, fluid power should seek to:

- Improve fluid power control systems (including through electrification)
- Monitor, gather and use data generated from working fluid power products to add value
- Improve fluid power's reliability and durability
- Increase fluid power's energy efficiency
- Increase fluid power's power density
- Reduce the environmental impact of fluid power components and systems
- Reduce lead time for fluid power components and their control elements



Survey on Capability Improvements

The Committee next reviewed the results of two February 2023 surveys conducted by NFPA to assist in determining fluid power’s current ability to meet the customer needs described by these Customer Strategies, in assessing the usefulness of these Capability Improvements in helping fluid power meet them, and in determining if any new Capability Improvements had emerged since the time of the 2021 NFPA Technology Roadmap. One survey asked about hydraulic capabilities; the other about pneumatic capabilities. Together, the surveys received responses from 75 individuals across the fluid power supply chain, including a large percentage from the NFPA Roadmap Committee.



- AEM - Association of Equipment Manufacturers
- AHTD - Association for High Technology Distribution
- AMT - Association for Manufacturing Technology
- FPDA - FPDA Motion and Control Network
- IFPS - International Fluid Power Society
- NAHAD - Association for Hose and Accessories Distribution
- NFPA - National Fluid Power Association
- NTMA - National Tooling & Machining Association
- PMMI - Packaging Machinery Manufacturers Institute
- PTDA - Power Transmission Distributors Association

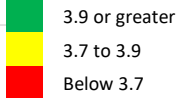
- SUPPLIER to the fluid power industry
- MANUFACTURER of fluid power components
- Fluid power DISTRIBUTOR or system integrator
- MACHINE BUILDER that uses fluid power technology
- USER of machines that use fluid power technology

- Executive Management
- Sales or Marketing
- Engineering
- Human Resources

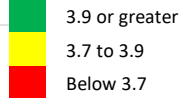


Alignment with Hydraulics and Pneumatics

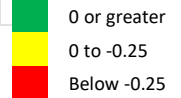
CUSTOMER STRATEGIES	N	HYDRAULICS		
		IMPORTANCE	FREQUENCY	GAP
Autonomy	55	3.709	3.473	-0.236
Compactness	50	3.720	3.780	0.060
Connectivity	47	3.979	3.511	-0.468
Electrification	44	4.000	3.614	-0.386
Energy Efficiency	43	3.884	3.767	-0.116
Maintenance	43	3.977	3.907	-0.070
Materials	43	3.326	3.349	0.023
Noise	43	3.721	3.698	-0.023
All Responses	368	3.788	3.633	-0.155



3.9 or greater
3.7 to 3.9
Below 3.7

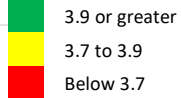


3.9 or greater
3.7 to 3.9
Below 3.7




0 or greater
0 to -0.25
Below -0.25

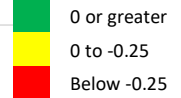
CUSTOMER STRATEGIES	N	PNEUMATICS		
		IMPORTANCE	FREQUENCY	GAP
Autonomy	9	3.444	3.222	-0.222
Compactness	9	3.556	3.222	-0.333
Connectivity	8	3.750	3.500	-0.250
Electrification	8	3.625	3.250	-0.375
Energy Efficiency	8	3.250	3.000	-0.250
Maintenance	8	4.125	4.125	0.000
Materials	8	3.500	3.250	-0.250
Noise	8	3.500	3.250	-0.250
All Responses	66	3.591	3.348	-0.242



3.9 or greater
3.7 to 3.9
Below 3.7



3.9 or greater
3.7 to 3.9
Below 3.7



0 or greater
0 to -0.25
Below -0.25

Survey participants were asked how important each of the Customer Strategies were to the technology and performance objectives of the machine builders in their marketplace, and they were asked how frequently hydraulics or pneumatics were included as part of each strategy. The scoring scale was: 5 = Extremely important or Always; 4 = Very important or Usually; 3 = Somewhat important or Sometimes; 2 = Not so important or Rarely; 1 = Not at all important or Never.

Generally speaking, the Customer Strategies were rated as more important in the hydraulic marketplace, and hydraulics was seen as better aligned with them. For hydraulics, the biggest negative gaps between importance and frequency were in Connectivity and Electrification. For pneumatics, they were in Electrification and Compactness.



Importance of Hydraulic Capability Improvements

CUSTOMER STRATEGIES	N	CAPABILITY IMPROVEMENTS						
		Improving hydraulic control systems	Improving ability to monitor, gather, and use data generated from hydraulic products and/or systems	Improving the reliability and/or durability of hydraulic products and/or systems	Increasing the energy efficiency of hydraulic products and/or systems	Increasing the power density of hydraulic products and/or systems	Reducing the environmental impact of hydraulic products and/or systems	Reducing the lead time for hydraulic products and their control elements
Autonomy	54	4.074	4.204	3.907	3.667	3.407	3.185	3.519
Compactness	48	3.667	3.542	3.833	4.104	4.188	3.167	3.396
Connectivity	46	3.978	4.522	3.826	3.478	3.043	3.065	3.283
Electrification	43	4.023	4.047	3.651	4.116	3.581	3.256	3.302
Energy Efficiency	42	4.119	4.071	3.667	4.476	3.833	3.333	3.286
Maintenance	42	3.571	4.357	4.524	3.262	3.024	3.143	3.452
Materials	41	2.927	2.902	3.707	3.244	3.244	3.488	3.146
Noise	42	3.738	3.429	3.524	3.571	3.333	3.262	2.976
All Responses	358	3.777	3.899	3.832	3.743	3.464	3.232	3.304

5.000 - 4.500
 4.499 - 4.000
 3.999 - 3.500
 3.499 - 3.000
 2.999 - 2.500
 2.499 - 2.000


Survey participants were then asked to rank how important each of the 2021 Capability Improvements would be in increasing the use of hydraulics in each Customer Strategy. The scoring scale was: 5 = Extremely important; 4 = Very important; 3 = Somewhat important; 2 = Not so important; 1 = Not at all important.

These results show the three capability improvements with the greatest potential impact on the use of hydraulics are improving the use of data, improving reliability/durability, and improving control systems.



Importance of Pneumatic Capability Improvements

CUSTOMER STRATEGIES	N	CAPABILITY IMPROVEMENTS						
		Improving pneumatic control systems	Improving ability to monitor, gather, and use data generated from pneumatic products and/or systems	Improving the reliability and/or durability of pneumatic products and/or systems	Increasing the energy efficiency of pneumatic products and/or systems	Increasing the power density of pneumatic products and/or systems	Reducing the environmental impact of pneumatic products and/or systems	Reducing the lead time for pneumatic products and their control elements
Autonomy	9	3.556	3.778	3.667	2.889	3.111	2.778	3.667
Compactness	9	3.444	3.444	3.667	3.222	3.222	2.778	3.333
Connectivity	8	4.000	4.375	3.750	3.250	3.125	2.750	3.750
Electrification	8	3.625	3.250	2.875	3.125	3.250	2.750	3.375
Energy Efficiency	8	3.500	3.125	3.375	4.000	3.000	3.250	3.750
Maintenance	8	3.500	4.125	4.250	3.125	2.500	2.875	3.500
Materials	8	2.500	2.500	3.125	2.500	2.625	3.375	2.750
Noise	8	3.500	2.625	3.500	2.875	2.500	2.625	3.125
All Responses	66	3.455	3.409	3.530	3.121	2.924	2.894	3.409



5.000 - 4.500

4.499 - 4.000

3.999 - 3.500

3.499 - 3.000

2.999 - 2.500

2.499 - 2.000

Survey participants were then asked to rank how important each of the 2021 Capability Improvements would be in increasing the use of pneumatics in each Customer Strategy. The scoring scale was: 5 = Extremely important; 4 = Very important; 3 = Somewhat important; 2 = Not so important; 1 = Not at all important.

Generally speaking, the importance of these capability improvements was ranked lower for pneumatics than it was for hydraulics. These results show the three capability improvements with the greatest potential impact on the use of pneumatics are improving reliability/durability, improving control systems, and improving use of data.



Suggestions for New Capability Improvements

Customer Strategies	Suggested Hydraulic Improvements	Suggested Pneumatic Improvements
Autonomy	<ul style="list-style-type: none"> • Availability of all the hydraulic component manufacturers all over the world to make use of technology efficiently. • Better match hydraulics with electronics directly. • More general knowledge of the benefits and basics of hydraulics. Too many times I hear that it leaks, is noisy or generates too much heat. Too many people sell systems without engineering them properly. • Ease of integration...software, hardware, UI interface. • Availability of capable machine controllers. • Making hydraulic systems more plug and play. • Use of more built-in brain (on board processors) for hydraulic components. • Better, lower cost and easier to learn simulation tools. The simulation tools need to provide a better way to create and share digital twin information. • This goes along with monitoring and reliability but reducing contamination sources and ensuring filtration is reaching out to all components in a system or circuit. • In built multi purpose sensors. • Having systems learn how become self-aware of potential breakdown issues and be able to diagnose and schedule their own maintenance. • More research and education democracy across the industry. We need to work more together if we want to be best in class for the future. Working with competitors on projects that create new industries should be the norm. 	<ul style="list-style-type: none"> • Better sales support. • Provide better products to replace medium sized, highly reliable systems. Specifically, 3/4" NPT systems.
Compactness	<ul style="list-style-type: none"> • Compactness increases the machine's aesthetic as well as weight to facilitate efficiency of final product working. • Developments in high pressure fluid connector/conductor options in a sub 1/4" world • Increased pressure ratings to increase power density. • Use of new technology such as AI to help reduce needed controls and in the end, help reduce number of components needed. • Use of higher strength materials for reduced sizes for the same force. 	<ul style="list-style-type: none"> • Come up with modular solutions that utilize a smaller cast/mold profile.

In addition to ranking the importance of the existing Capability Improvements, participants were also asked to suggest any additional Capability Improvements that they would suggest to increase the use of hydraulics or pneumatics in each of the Customer Strategies. A summary of the responses received is shown at left.

Many of these suggestions would require market-based rather than technology-based improvements in order to be effective, and therefore may not be appropriate for incorporation into a technology Development roadmap.



Suggestions for New Capability Improvements

Customer Strategies	Suggested Hydraulic Improvements	Suggested Pneumatic Improvements
Connectivity	<ul style="list-style-type: none"> Standards on electrohydraulic control schemes, auto sensing i/o, auto calibration routines, data outputs. Use local computers on components and AI for advance connectivity and troubleshooting. Having an ISO communication language and use low code or no code programming to reduce errors and allow for updating as the product goes from cradle to grave. 	<ul style="list-style-type: none"> Better knowledge of options available to the market Implement on-board EtherCAT or related opensource strategy that provides real-time control over a single comm cable.
Electrification	<ul style="list-style-type: none"> Power density must remain the industry's value proposition in power transmission...once this is lost fluid power will decline. Reducing hydraulic noise is becoming more important with electrification. Complete self-contained units that have the motor, pump, actuator, etc. all tied together in one unit. In my experience, maximizing hydraulic efficiency isn't usually the main goal. Most companies I work with are targeting hours of operation to make it through a shift. If a shift is 10 hrs and the machine can make it that long with the current hydraulic efficiency, increasing the efficiency does not add any additional value to the customer. In addition, many customers are looking for packaged solutions such as electric motors and hydraulic pumps being integrated together. The two technologies today have developed separately and are not easily combined. I believe the hydraulics industry would be well served to work with the electric industry to create designs and standards that would allow customers to more easily combine electric and hydraulic components. Energy recovery systems for prime movers. 	<ul style="list-style-type: none"> Use available technology to produce the most efficient end product.

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Suggestions for New Capability Improvements

Customer Strategies	Suggested Hydraulic Improvements	Suggested Pneumatic Improvements
Energy Efficiency	<ul style="list-style-type: none"> • Components should have certified efficiency ratings...volumetric, mechanical, and overall efficiencies should be a requirement to meet a standard. • Research new components and compounds and fluids to help reduce frictional losses in order to increase efficiency. • Better simulation tools. A better way to create a digital twin from test results. A test standard for digital twin test data collection over a wide temperature range and with different viscosity fluids. 	
Maintenance	<ul style="list-style-type: none"> • Do more failure analysis over a longer time frame. Extend warranties. • Hydraulic seal manufacturers do not typically state intervals due to the wide variety of variables, more focus should be put on this to inform customers of maintenance intervals, i.e., seal life ratings vs. contamination or temp variations. 	
Materials	<ul style="list-style-type: none"> • Do more failure analysis over a longer time frame. Extend warranty time for seals and other components. Be willing to try new designs. 	
Noise	<ul style="list-style-type: none"> • Lowering hydraulic noise in systems is becoming more important when discussing electrification projects. Without the diesel engine, the hydraulics tend to be the next loudest system. Reducing sound power is important but so is improving the sound quality (frequencies) which is less annoying to the operator. 	

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Discussion of 2023 Prioritized Capability Improvements

In discussing which Capability Improvements to prioritize for the 2023 Roadmap, the Committee considered the items shown at right.

First, a ranked order of 2021 Capability Improvements was reviewed, relying on a weighted average of the scores received from both the hydraulic and pneumatic surveys.

Then, noting that many of the additionally suggested Capability Improvements could be nested as possible Research Areas under one of the 2021 Capability Improvements, a list of newly-suggested Capability Improvements was created.

The Committee then proceeded to discuss each of these items in turn, and determined which items would be positioned as 2023 Capability Improvements, and how each would be connected to the Customer Strategies.

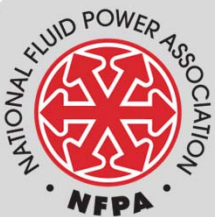
The outcome of that discussion is shown on the next page.

Ranked Order of 2021 Capability Improvements

- 3.850 Improving ability to monitor, gather, and use data generated from fluid power products and/or systems
- 3.802 Improving the reliability and/or durability of fluid power products and/or systems
- 3.746 Improving fluid power control systems
- 3.681 Increasing the energy efficiency of fluid power products and/or systems
- 3.410 Increasing the power density of fluid power products and/or systems
- 3.315 Reducing the lead time for fluid power products and their control elements
- 3.198 Reducing the environmental impact of fluid power products and/or systems

Suggestions for New Capability Improvements

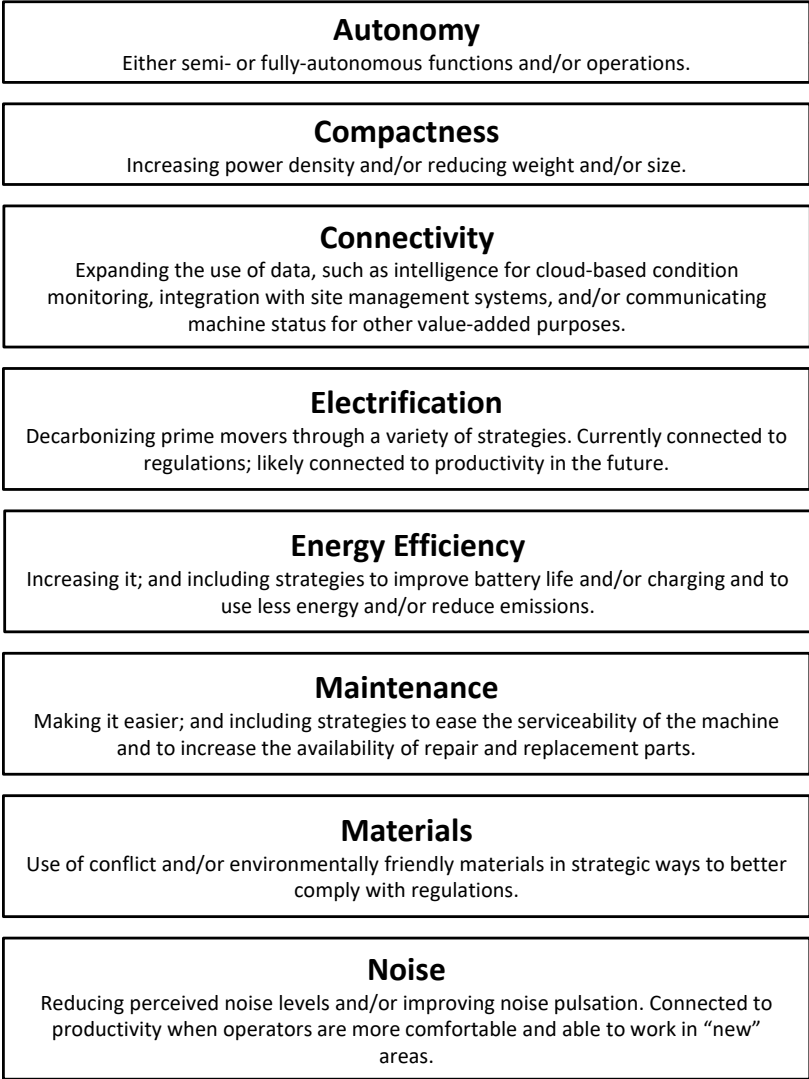
- Ease of use and ease of application of technology (putting systems together)
 - Improving communication protocols and data management strategies
 - Training (more knowledge of fluid power benefits, workforce development)
- Reduced noise (level and quality)
- Increasing safety



2023 Prioritized Capability Improvements

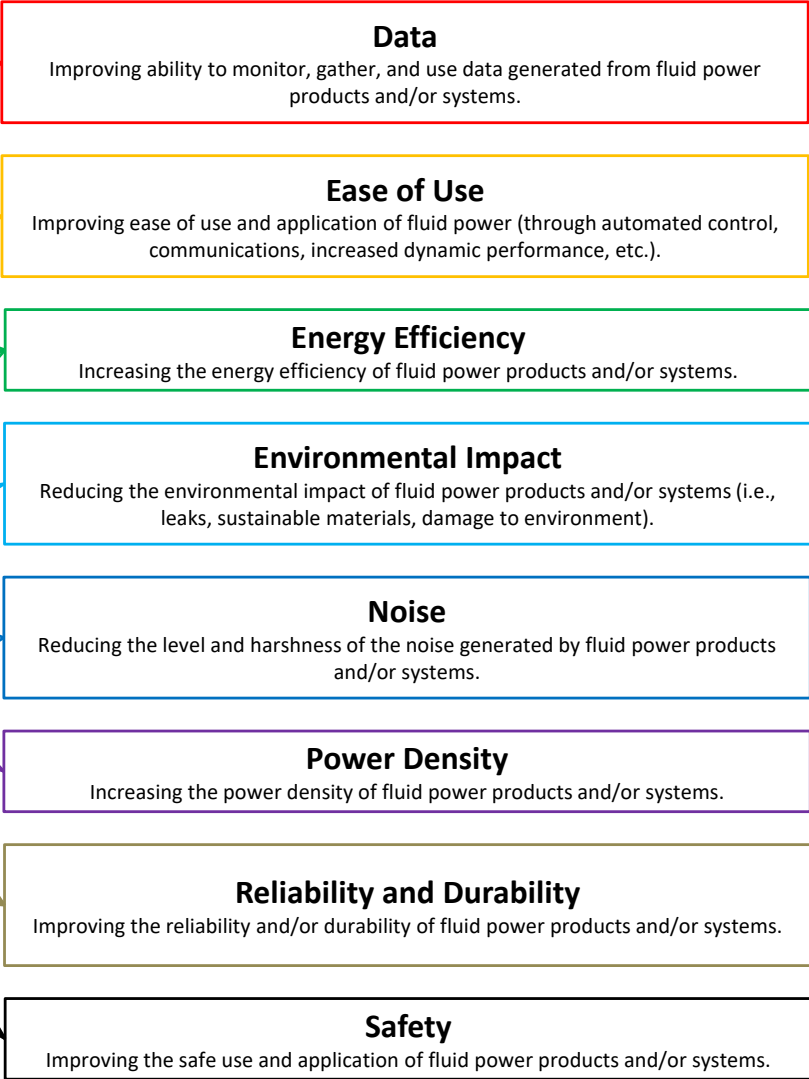
CUSTOMER STRATEGIES

Machine-Level Objectives and Technologies That Help Achieve Performance Objectives



CAPABILITY IMPROVEMENTS

Improvements to Fluid Power Systems to Increase Their Use in Customer Strategies



← Connections flow this way
Capability Improvement supports Customer Strategy



Wrap-Up and Next Steps

The Committee meeting closed with a review of the next steps on the process and timeline for the 2023 update to the NFPA Technology Roadmap, including the survey on research areas and targets and the launch of virtual working groups for each Capability Improvement.

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