2017-18 NFPA Fluid Power Vehicle Challenge

Overview, Rules and Awards

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INTRODUCTION

The NFPA Fluid Power Vehicle Challenge is a unique engineering design/build competition that embeds in the capstone design course at participating universities. It strives to promote original thinking in a competitive setting by combining two technology platforms that are not normally associated with one another—human-powered vehicles and fluid power.

The first, as exemplified by the bicycle, is recognized as extremely efficient in terms of input vs. output. The second presents more of a challenge in terms of efficiency, especially at low speeds. A fluid powered vehicle, then, presents undergraduate engineers with a familiar yet challenging platform for change. By combining this unlikely pair, the Vehicle Challenge hopes to create an environment that results in uncommon connections and breakthroughs, while supporting learning and the growth of fluid power industry knowledge.

The Vehicle Challenge supports the education of next generation engineers by exposing them to the design challenges associated with a fluid powered vehicle, and teaching them the value of fluid power components, circuits, and systems. In addition, the program provides these students with first-hand experience in working as an engineering team on a timeline to design, simulate, build, test, qualify, and compete with their concepts. Added benefits for the industry that supports this program through its donations to the NFPA Education and Technology Foundation include the potential development of new breakthrough technologies for motion control and the identification of high-performing students to hire into the fluid power industry.

PROGRAM OBJECTIVES

1. Stimulate education in fluid power components, circuits, and systems, incorporating them into a systems engineering experience.

2. Provide students with experience in real world engineering under a strict timeline of designing, simulating, ordering, building, testing and demonstrating their designs.

3. Stimulate innovative thinking for designing and testing potential new fluid power technologies or concepts integrated into a vehicle platform.

4. Provide an industry recruitment opportunity for high potential engineering seniors by engaging directly with practitioners in the fluid power industry.

BACKGROUND

The Vehicle Challenge is based on the Chainless Challenge program, pioneered and managed by Parker Hannifin from 2004 through 2016. The first program under the Vehicle Challenge name was held in 2017. Schools that have participated in past years have been:

- California Polytechnic State University, San Luis Obispo
- Cleveland State University
- Illinois Institute of Technology
- Kent State University
- Milwaukee School of Engineering

- Murray State University
- Northwestern University
- Purdue University
- University of Akron
- University of California, Irvine
- University of Cincinnati
- University of Illinois, Urbana-Champaign
- University of Michigan
- University of Minnesota
- Western Michigan University

Many of these schools have built a knowledge base in the design of fluid powered vehicles, and are able to pass that knowledge to the next group of students. A record of the designs and vehicles that have been built is available on the following website: http://nfpahub.com/fpc/vehicle-challenge/

Teams are encouraged to review and improve upon these designs for the 2017-18 Vehicle Challenge. Teams from universities that have previously participated in the program, in fact, are required to make significant changes from designs of previous years. This experimentation has resulted in vehicle designs that have varied from two, three, and four-wheels, upright and recumbent, using hydraulic and pneumatic components.

The Vehicle Challenge encourages universities to participate in the context of their senior capstone design courses, but student teams in other configurations are welcome. Either way, students are required to design and build the drive system for their vehicles, as well as participate in the Final Competition Event. They can utilize either off-the-shelf components provided by the program's Official Parts and Fluids Suppliers, from other suppliers and resources, or design their own.

The Final Competition Event includes judging criteria for a straight sprint race, an efficiency challenge, and an endurance challenge. In addition, teams will present on their design process and decisions, and demonstrate the safe function of their vehicles. The Event will be conducted over a two-day period at a location hosted by one of the major donors to the NFPA Education and Technology Foundation. For the 2017-18 program, the event host will be Danfoss Power Solutions in Ames, IA. Travel funds are provided by the program to offset the transportation and accommodations costs of the participants. Cash awards are given to the winning teams in several specified categories.

This document, and others, will define the requirements of the design of the human-assisted, fluid powered vehicle, provide the design review timeline, describe the Final Competition Event and rules, and special award categories.

PROJECT OVERVIEW

Design Team

One team per university will be funded through the program. Additional teams may be supported by the university, but only one team will receive program support from NFPA.

- Team members may have participated in previous year(s).
- One faculty advisor and up to five students will be eligible to receive travel funds to the Final Competition Event.
- Maximum of seven students per team. Can be graduate and/or undergraduate.

Fluid Power Vehicle Challenge Phone App

NFPA launched a phone app to help teams stay informed about program updates, schedules and to provide open communication between students and industry supporters. NFPA suggests students download the app and participate.

- Upon completion of the initial registration, participants will be provided a username and password using their non-university email address. Download the ConferenceBeat Event App to your phone using either the App Store or Google Play.
    - Click Current Events
    - Search for NFPA Fluid Power Vehicle Challenge
    - To open the event, click the Go to Event button at the bottom
    - To access it on a desktop http://app.resultsathand.com/fpvc2017

Vehicle Requirements

All vehicles must abide by the following technical requirements, and must be approved through the Verification Review process in order to be cleared for safety and usability at the Final Competition Event.

- Vehicle propulsion must be accomplished through fluid power (hydraulics or pneumatics) with human power serving as the prime mover in the system. No internal combustion, electric drive motor, chains, belts, or other modes of propulsion are permitted. Gears, chains or belts are allowed in order to transfer power to the fluid power pump/compressor, but a fluid link (oil or air) is required between the pump/compressor and the motor.
- Vehicle designs must include an energy storage device.
    - Gas pre-charging systems will be available at Final Event location. Energy shall be stored in the device at the start of each race. The total accumulator pressure including the fluid and/or nitrogen gas charge cannot exceed the safe working limits of the storage device and system components. After pre-race pressurization, additional pressurization can only be supplied as a result of the design, i.e., supplied by the rider and/or the course (braking or gravity).
- Vehicle designs must include at least two fluid power circuits – one for direct propulsion and the second for regenerative braking. There is no requirement for the method of switching between the circuits, i.e., electronic or manual.
- Vehicles must use environmentally-friendly fluids.
- Vehicle design must be for a single rider. The rider must be able to enter, exit, start and stop the vehicle unassisted.
- Style of vehicle design is open. There are no requirements for the number of wheels or for either a standard, recumbent, or multi-wheel drive.
- Maximum weight of the vehicle is 210 pounds without rider if a team intends to ship the vehicle. No weight limit if not shipping.

Components

Parts Supplier will furnish a menu of fluid power components that will work well with most vehicle designs, including pumps, motors, accumulators, valves, pressure gauges, hoses, fittings, etc. Based on their specific needs, teams will be able to order parts from this list, up to $1,500 in total value.

- Fluid Supplier will furnish a 5-gallon pail of environmentally-friendly fluid, as specified.
- Reservoirs will need to have adequate sealing and venting capability. There is zero-leak tolerance in the system.

- Components must be ordered on or before December 1, 2017, to enable adequate delivery time for building and testing prototypes. Lead times will be provided.
- Some tools will be provided at the Final Competition Event, but it is expected that teams will bring necessary tools and equipment.

Safety & Rules

- All designs must comply with safety policies.
- All vehicles must be judged by the Technical Liaison prior to operation. Vehicles deemed unsafe will either be repaired before competition or disqualified.
- Zero leak tolerance. No pipe thread except for low pressure circuits.
- All vehicles must have multiple, fully active, independent brakes that provide a failsafe braking condition. Brakes should be able to hold the vehicle at a stop under the full charge of the accumulator.
- If shipping to the final event, vehicles are to be void of hydraulic fluid pressure and no more than 50 PSI of gas charge. Vehicles are to be shipped at least 10 days before the Event. Vehicles can weigh no more than 210 pounds. Instructions will be provided.
- Each rider must wear a helmet. The helmet must comply with a nationally recognized standards organization. All bicycle helmets must carry a CPSC sticker. The burden of proof of meeting this guideline will rest with the participant.
- Guards are required to protect the rider from moving components, where deemed necessary for safety reasons.
- Vehicles will be disqualified for any of the following reasons:
    - Insufficient braking capability
    - Lack of stability
    - Poor visibility
    - Dangerous protrusions
    - Unsafe design features
- During the competition, any participant demonstrating unsportsmanlike conduct will be disqualified from the Challenge and forfeit any and all awards. Driving under the influence is automatic elimination. Same rules apply as driving a motor vehicle on the highway.

PROGRAM CADENCE

The Vehicle Challenge will be divided into five phases.

Phase 1 – Kickoff | September – October

<u>Activities</u>

- University Student Teams confirm participation and register by September 22nd, 2017.
- Supporting documents provided by Program Manager.
- Teams attend a Kick-Off Webinar lead by Program Manager.
- Technical Liaison assists teams in identifying project objectives and setting a plan.
- Universities receive $1,000 from Program Manager for support of Student Team activities.

Phase 2 – Design and Specification Midway Review | October – December

<u>Activities</u>

- Coinciding with the university's senior capstone design course, students gain knowledge in fluid power components, circuits, and systems, and their use in controlling force and motion.
- Educational webinar offered by Technical Liaison and Parts Supplier, along with data sheets and instructions for ordering components.
- Student Team creates initial design and mechanical drawings to illustrate the fluid power control circuits that will be created for the vehicle.
- Student Team simulates design and performs dynamic, fluid flow, expected performance, and other relevant analyses on it.
- Program Manager schedules and conducts a Design and Specification Midway Review Webinar where the Student Team presents their project objectives and design specifications to the Program Manager, Technical Liaison, Industry Judges and other volunteers. Program Manager coordinates scoring of the presentations.
- Universities receive $1,000 from Program Manager for support of Student Team activities.
- Student Team chooses and orders components to use on their vehicle from the Parts Supplier and Fluids Supplier. Teams may supplement new components with equipment from previous years.
- Student Team receives ordered components for Parts Supplier.
- Student Team begins to construct vehicle prototypes.

Phase 3 – Build and Test | December – March

Activities
- Student Team builds, tests, and makes adjustments to their vehicle.

Phase 4 – Verification Review | March

Activities
- Student Team sends final design drawings and video of vehicle in operation to Program Manager.
- Program Manager confirms entry into Final Competition Event and sends specific instructions for vehicle shipping and Student Team travel and accommodations.
- Student Team prepares final presentation of design project and vehicle operation, and sends to Program Manager no later than seven days prior to departing for Competition Event.

Phase 5 – Final Competition Event | April

Before the Event Activities
- Student Team builds transport crate (if shipping)
- Student Team makes arrangements for vehicle shipping.
- Student Team makes travel and accommodation arrangements.

Day 1: Travel Day
- All team members, advisors travel to the Final Competition Event
- Evening event to welcome and introduce teams to judges and program sponsors

Day 2: Prep and Presentation
- Morning

    - Student Team unpacks vehicle and ensures system integrity and readiness to operate under the guidance of the Program Manager, Technical Liaison and Final Event staff.
    - Other participants and guests arrive for afternoon presentation session and evening banquet
- Afternoon, Early Evening
    - Student Team presentations begin, conclude prior to reception and dinner
    - Networking reception and dinner with guest presentations

Day 3: Final Competition

- Morning
    - Student Teams, advisors, marshals, program managers, and judges arrive to Event site
    - Student Teams participate in the sprint race, the efficiency challenge, and the endurance challenge.
    - Vehicles are judged for the determination of several awards.
    - Student Team repacks vehicle and arranges for shipping or transport back to university.
- Afternoon, Early Evening
    - Final scores are tabulated
    - Networking reception, banquet and award ceremony for all attendees.

Day 4: Travel Day

- All team members, advisors travel to back to universities

CONSIDERATIONS: Design and Specification Midway Review & Final Competition

Design and Specification Midway Review

The Design and Specification Midway Review prepared and presented by Student Team will be evaluated and scored by the Technical Liaison and Industry Judges. Refer to the FPVC Scoring Rubric for more information on the assessment criteria. A presentation outline and template will be provided. All presentations submitted throughout the FPVC will be posted on the website after the Final Competition. Teams will be evaluated on:

- Design objectives
- Vehicle design
- Fluid power circuit design
- Selection of hardware
- Results and incorporation of analyses (e.g., finite element analysis)
- Stage of prototype built to date

For teams from returning universities, the minimum requirement will be to use all new components on the same vehicle frame, or to reuse components on a new vehicle frame. You will need to describe changes at your Midway Review.

The final presentation must be received by the Program Manager no later than seven days before the final event. These final presentations shall be submitted in electronic PDF format only. A presentation outline and template will be provided. Final presentations will be given at the final event and evaluated and scored by the Technical Liaison and Industry Judges. Refer to the FPVC Scoring Rubric for more information on the assessment criteria. Teams will be evaluated on:

- Summary of Midway presentation
    - Design objectives

    - Vehicle design
    - Fluid power circuit design
    - Selection of hardware
    - Results and incorporation of analyses (e.g., finite element analysis)
- Vehicle construction
- Vehicle testing and improvements
- Final vehicle brought to competition
- Lessons learned and conclusions

Final Competition
Will include a safety inspection, design assessment, sprint race, efficiency challenge, endurance challenge and presentation

- Each team starts with storage device void of hydraulic fluid pressure. Maximum 10 minutes allowed to manually pressurize the storage device. Team can only use one person and method of pressurizing at a time.
- No mechanical, hydraulic, or pneumatic failures are allowed due to poor design or application of components. Vehicle failures during the Sprint Race and Efficiency Challenge will result in elimination.
- Reservoirs, components, and plumbing must meet reasonable industry standards. No duct tape or other examples of insufficient workmanship. There is zero-leak tolerance in the system.
- Be sure to include instrumentation (pressure gauge).
- The size of the accumulator must be easy to read. If air is used, the size of the receiver and pressure must be known.
- All course competitions will begin with a standing start.
- The vehicle system configuration does not need to remain the same for all races. Teams may modify the configuration as long as there is no loss of oil during the change-over, other than a few drops.
- Drivers must maintain a safe speed and adhere to all instructions from the course marshals. Failure to comply will result in penalties or disqualification.
- The decisions of the judging panel are final. This includes tie breaking decisions. All ties will be broken based on adherence to the design criteria and performance.

Sprint Race
This event will demonstrate the ability of the vehicle to move a distance where the weight of the vehicle is proportional to the human propulsion.

- Heats of multiple bikes at a time on a 600 ft course.
- Standing start, one rider on vehicle, no pushing.
- Each team is allowed up to two attempts, and must use the same rider in both attempts.
- Best time for places 1st, 2nd, and 3rd.
- Timing in Minutes: seconds: tenths of seconds: hundredths of seconds.

Efficiency Challenge
This event will demonstrate the ability of the vehicle to effectively store and most efficiently use the smallest amount of stored energy to propel the unassisted vehicle the greatest distance proportional to the vehicle's weight.

- The vehicle that goes the farthest is NOT necessarily the most efficient. Similarly, the most stored energy does not automatically indicate the winner either.
- The vehicle must travel a minimum distance of 100 ft. Braking is not required. Vehicle will go as far as it can before coming to a complete stop.
- The vehicle, rider, and safety gear will be weighed at the track, immediately before starting the event.
- Each team is allowed up to two attempts, and must use the same rider in both attempts.
- Standing start, one rider on vehicle. There can be no assistance in making the machine move on its own. No windshields or wiggling of handlebars is allowed. Rider must remain on the vehicle for the entire event. If a foot touches the ground, this distance will be measured from the starting point.
- Rider will not be allowed to operate the pedals or any other mechanical input device from the start of the event until the vehicle comes to rest. Braking is allowed for energy recovery, but not required.
- The vehicle's pre-charge pressure used in the calculation below will be the pre-charge that is requested by the team and deployed by approved Technical Liaison only.
- The volume of the storage device used in the calculation will be as stated on the vessel by the manufacturer (Pressure storage devices manufactured other than by Parts Supplier, must be approved by the Technical Liaison).
- The winner will be the determined by the following parameters and equation:
    - L = total distance traveled from starting point in inches.
    - W = weight of the vehicle and rider in pounds.
    - P = gas pre-charge pressure in pounds per square inch (PSI) (Note: The minimum accumulator gas pre-charge pressure during filling will be 100 PSI)
    - V = gas volume of storage device in cubic inches.
    - Scoring Ratio = [(W x L)/(P x V)]
- This calculation is a dimensionless ratio and will provide an objective measurement to judge vehicle/system efficiency. It quantifies the winning vehicle as providing the most work with the smallest amount of stored energy.
- In the simplest terms, the vehicle that completes the challenge with the least amount of energy per pound of weight, wins.

Endurance Challenge

This event will demonstrate the reliability, safety, replicability, and durability of the fluid power system design and assembly.

- Two bikes leave every two minutes.
- The course may consist of laps in a slalom fashion and will total no more than 1 mile. Maximum time to complete will be 30 minutes. Specific course will be determined and communicated prior to the Competition Event.
- To test the regenerative braking circuits of the vehicles, the course will require at least one stop and restart of the vehicle.
- Standing start, one rider on vehicle, no pushing.
- Teams are allowed up to two drivers, as an option, although not a requirement to complete the course. Driver changes will only be allowed in a designated area. For safety sake, vehicle will come to a complete stop to change drivers, no pushing.
- If vehicle breaks down during the Endurance Challenge, it must be moved to a safe distance from the track. The team will have 15 minutes to repair. The clock is not stopped for repairs.
- Best time for places 1st, 2nd, and 3rd. Timing in minutes: seconds: tenths of seconds.

PROCEDURES FOR STIPEND, TRAVEL and AWARD PAYMENTS

Detailed below are the procedures for stipend payments, prize awards issued, and requests for reimbursement for travel expenses incurred to participate in the Fluid Power Vehicle Challenge and attend the Final Competition. One team per university will be funded through the program. Additional teams may be supported by the university, but only one team will receive program support from NFPA. Complete documentation is required to be submitted to VehicleChallenge@nfpa.com no later than 30 days after the Final Competition

FOR UNIVERSITIES:

University advisors are required to submit a W9 in the initial team registration form.

STIPEND PAYMENTS

In support of the Student Team activities upon completion of the Kick-Off Webinar, Design and Specification Midway Review and Final Presentation given at the NFPA Fluid Power Vehicle Challenge Final Competition, teams are allocated a $1,000 stipend in three separate disbursements. The Final Presentation stipend payment may be lumped into any prize awards issued to the university at the Final Competition.

PRIZE AWARDS

Based on the decisions of the Judging Committee following the Final Competition, awards will be issued to the university as specified.

TRAVEL

NFPA will reimburse up to $4,000 for travel and allowable expenses directly related to the Fluid Power Vehicle Challenge for one faculty advisor and up to five students, participating in the Final Competition event. Advisors will be required to fill out the Travel Reimbursement form and submit a PDF of all relevant receipts to VehicleChallenge@nfpa.com.

Reimbursable budget items:

- Team Accommodations
    - NFPA suggests that students share hotel rooms
- Team Travel
    - Trailer rental
    - Vehicle shipment
    - Airfare
    - Personal vehicle
        - IRS mileage rate covers gas, other expenses and wear and tear
    - Auto rental
        - Gas will be reimbursed
    - Food
        - Excludes meals provided by the Vehicle Challenge host or NFPA
- Miscellaneous
    - Taxi, Uber, Tollways, Parking, etc.

INDIVIDUAL TEAM PARTICIPANTS

Based on the decisions of the Judging Committee, awards will be issued to individual team members as specified. Recipients should consult a tax professional about reporting awards.

- Advisors are required to identify the recipient(s) of the prize award(s) and how much is to be issued by filling out the Award Recipient form.

- Each recipient is required to submit documentation to collect payment from NFPA in the form of a W-9 for U.S. Citizens or a W-8BEN for non-U.S. Citizens.
- All checks issued to individual team participants will be mailed to the address listed on the W-9 or W-8BEN.

AWARDS

The Judging Committee, Marshals, Timekeepers, and program leaders determine final award winners based on the overall assessment of the Design and Specification Midway Review, the competition results and final presentations. The decisions of the judging panel are final.

AWARD	PRIZE	CONSIDERATIONS
Overall Champion 1st place 2nd place 3rd Place	 $3,000 $2,000 $1,000	Will not be eligible to be the winner of more than one Event race. Funds will be distributed directly to team participants.
Best Presentations	$2,000	Midway review score to be included in evaluating winning presentation. Funds will be distributed directly to team participants.
Sprint Race	$1,000	Top three scores to be considered for placement. Final 1st place will be determined by a number of factors, including Overall Champion.
Efficiency Challenge	$1,000	Top three scores to be considered for placement. Final 1st place will be determined by a number of factors, including Overall Champion.
Endurance Challenge	$1,000	Top three scores to be considered for placement. Final 1st place will be determined by a number of factors, including Overall Champion.
Best Design	$500	To be considered for award, the innovative, uniqueness and originality of the design. Selected by Student Teams.
Best Reliability and Safety	$500	To be considered for award, sufficient steps taken to prevent injuries from hardware and surpass a 1-year warranty.
Best Workmanship	$500	Best workmanship
Best Teamwork	$500	Best attitude and cohesiveness of team
11 Awards	$13,000	