# Undergraduate Engineering Students Enhance Novel Instrumentation to Detect the Mach Effect

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**Abstract –** Undergraduate electrical engineers performing summer research have enhanced the real-time data collection system of one of their professor's novel detectors to uncover some remarkable results. Over the past two summers at Bucknell University students in engineering have been working on an innovative detector that has repeatedly produced results indicative of a real Machian like reaction force to inertia. Each summer (2018 and 2019) multiple students continued to make electrical enhancements and refinements to this novel instrument and its test protocol at the suggestions of reviewing scientists and their professor. In the most recent version of this instrument, real-time data collection appears to confirm that the Mach Effect is real, directional and electromagnetic in nature. The device is able to observe an electromagnetic interaction of the Mach Effect during incidents of significant local celestial matter alignment (such as the solar eclipse of July 2$^{nd}$ 2019). While some of these scientific results have been reported in multiple IEEE publications, this paper goes into detail as to the role that the students (undergraduate engineers) have played in the research and their work to use and refine the instrument as well as developing innovations to the protocol of the sensor array instrumentation. As a team, they helped their professor successfully continue the hunt to answer the query of whether a Mach Effect (inertial reaction force) is actually detectable. Due partly to their efforts the science around this instrument is now quite robust and this novel device provides consistent, replicable and predictable results. During the summer research, the students got to apply much of their theoretical electrical engineering training to a real-world application in sensor arrays and instrumentation.

## Background and Motivation

The roles that our undergraduate engineers played in this research during the summer of 2018 was written up in a recent (2019) ASEE Zone 1 conference publication. [1] That paper focused primarily on the students' activities, their feedback, evaluation of their research experience and the National Academy of Engineering (NAE) grand challenge known as "Engineering the Tools of Scientific Discovery". It is worth rehearsing here a brief quote from the NAE website describing part of that challenge: "missions of exploration always need engineering expertise to design the tools, instruments, and systems that make it possible to acquire new knowledge about the physical and biological worlds. In the century ahead, engineers will continue to be partners with scientists in the great quest for understanding many unanswered questions of nature.… All things considered, the frontiers of nature represent the grandest of challenges, for engineers, scientists, and society itself."[2] While the previous ASEE publication described the research team's early involvement with this technology, this paper is devoted to their 2019 summer research and documents the revisions they have made to the device that made it possible for them to make some exemplary empirical observations during that summer. This team of three engineering students (a rising sophomore, junior and senior) built upon the previous year's work on the technology and its associated research protocols and empirical investigations previously completed by others [3]. Prior to this point in time, key scientific reviewers of this controversial work suggested many ways to improve the technology in order that the device and the experiments completed with it might be considered more robust science. The student team made multiple important enhancements to the scientific apparatus (described below) and then they were able to complete their own new empirical investigations (during a major eclipse event) which validated the previously discovered scientific anomalies [4-7]. Their work also provided new insights into what may be happening to generate inertia in the bodies of matter on earth.

While inertia is defined as a physical characteristic of bodies that is proportional to their rest mass, our research tests the hypothesis of Mach that inertia might actually be something more. "According to E. Mach, physical processes are determined by the relations of bodies with each other in the world. Since unmediated action at a distance is excluded by physicists today, then mediation must be assumed in order to carry this idea through. One way is to be seen in the effect of the "inertial field". We observe that matter is subject to it as is likewise a closely connected field of light [Lichtschreitungen]. Thus, in the sense of Mach, one may consider the foundation of the world [Weltuntergrund], which is given by the inertial field in connection with the field of light, to be other than "space" and "time". We must represent it, rather, as somewhat corporeal [but] possessing spatial and temporal characteristics, and according to the mores of physics the fitting name would be "aether"." [8] Literature suggests that there is more to discover about inertia than how it is perceived and described presently. "Concerning the problem of the relativity of inertia, B. Friedlaender further notes that inertia, i.e. the resistance to changes in the velocity, is not an internal property of a single body but rather a consequence of the influence of all the other bodies of the universe." [9] Previous scientific research raised significant interest in E. Mach's thoughts about how inertia is influenced by all matter [10-12]. According to most widely accepted theory, inertial properties are equal against any force from any direction since the universe is isotropic in matter distribution at large scales, and hence it would be nearly impossible to test this theory because of the difficulty of detecting any differences in inertial reactions from different directions [13]. Our research team wanted to test the viability of Mach's theory by attempting to detect differences that only arise prominently and become measurable when there is an asymmetry in local mass distributions (while the universe remains symmetric when viewed from a larger scale).

**The Summer Research Challenges**

The 2019 summer student engineering research team was charged with many diverse tasks including: primary research, engineering, testing, procurement and construction. Like the previous summer team (of 2018), the majority of those tasks were based upon the input of serious reviewers who had seen the Mach Effect research in its early stages and had substantive ideas of how the work could be made more compelling. At the kick-off of the summer research project the professor worked in collaboration with the students to review the comments and critiques we had received to date and challenged them to seriously consider which of the refinements and modifications to the device, protocol and data acquisition system we could seriously attempt in one summer. This was the goal of their summer work; to complete as many refinements as possible to the device and research protocol. By way of background the scientific apparatus and the protocol used for experimentation and control runs were substantially consistent to that previously published on this research [3-7] and will not be described again in detail here due to space limitations. But interested readers are encouraged to review those disseminations of the work for greater detail regarding the device's construction and operation. In Fig. 1, we have provided a photograph of the device in a typical lamp control experiment. The other referenced publications [3-7] provide great detail on each component of the scientific instrument and share the simplicity of its construction and operation to encourage others to replicate the observations we have made, but is not required to describe the student work and important observations of last summer.

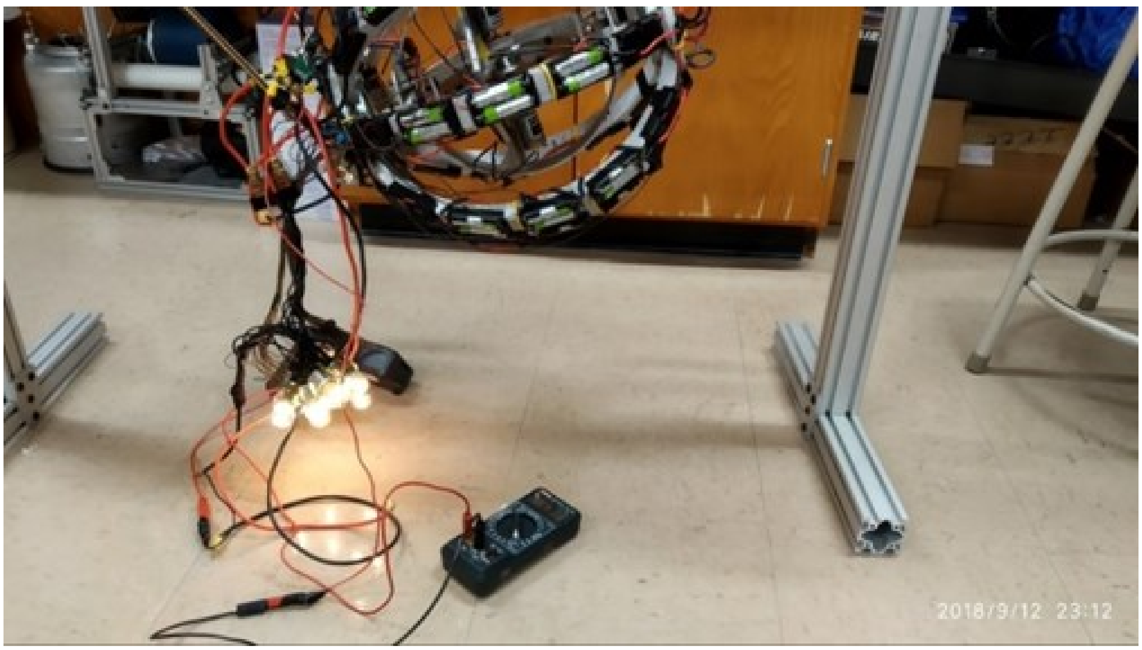


Fig. 1 - MJFD in Lamp Control Experiment

The team's approach to running trials over the summer was to test whether or not our suggested hypothesis holds (i.e., running experimental trials when there is a mass distribution asymmetry, significant local celestial mass alignment will yield regular results). The team also expanded our control trials database where the device batteries were loaded with comparable electrical demand and energy from its DC drive motors using solely resistive lamps (as shown in Fig. 1). This suggestion was offered by colleagues at Dresden University during a presentation of the results at Aerospace Corporation in California [view Ref. 7 Youtube presentation]. These controls enabled us to have more accurate statistics and to reinforce a solid understanding of batteries discharge behavior in a control (or more normal) setting. The list below (in Table 1) is a subset of all the challenges identified but highlights the actual accomplishments of the team.

Table 1 – Student Research Progress / Activities over the Summer of 2019

1. Nickel Cadmium Batteries
    a. Created a new battery log that:
        i. Includes the new batteries added recently and batteries with same/different naming in the old log
        ii. Includes the battery pack and the trials for each experiment a battery was used in
        iii. Calculates the number of uses for each battery highlighting batteries with +25 uses
        iv. Includes the details of all retired batteries
    b. Wrote a research conclusion on the memory effect for the Ni-Cad batteries
    c. Searched for and suggested a few alternatives for batteries to experiment with
    d. Created a protocol for battery retirement that:
        i. Initially used battery impedance to decide appropriate time for retirement
        ii. Later, bought a battery analyzer to test batteries capacity for retirement
2. Device Design Modifications
    a. Created a design for the electrical system of one MJFD on Multisim
    b. Designed and 3D printed a lamp holder on Solidworks and the Mooney Lab
3. Prospective Systems Supporting the New Modular MJFD
    a. Communications with the BU Project Development Lab about the progress of the new modular devices
    b. Searched and listed a few types of ribbon cable that can be used to wire them
    c. Created a design/simulation for the futuristic modular device system on Simulink, MATLAB
    d. Initiated a design for sensing system (with probably ADC and op-amps)
    e. Built the code and system for RPM and Temperature sensors that will send data over WiFi
    f. Started wiring new devices but it was not completed successfully
4. Lists of Supporting Data
    a. Purchases
    b. Tasks to undertake and accomplish over the summer
    c. Potential experimental trial dates in the summer and fall of 2019
    d. Inventory of all scientific research equipment in the Lab
5. Experimental Protocols (Present & Future)
    a. Initiated a protocol for the futuristic modular device system
    b. Created a protocol for running motors (start-up) after a long time of inactivity
    c. Standardized protocol for Other Experimenters
6. Trials (Controls and Experiments)
    a. Conducted 19 experiments (most in July 2019)
    b. Conducted 10 control trials (half in July and half in August 2019)
    c. Data/analyses collected/included for each trial
        i. Pre/post voltage per battery
        ii. Real-time voltage graph for top 2 and bottom 4 batteries combined respectively
        iii. Voltage, current, power, RPM, motor temperature for most of the trials
        iv. Stellarium [14] snapshots of local space in front of and behind Earth (with respect to location of experimentation "_____________")
    d. Wrote thorough analyses for the trials done and tried to come up with helpful conclusions
7. Created New Files
    a. one that calculates the standard deviations for all of the lamp experiments
    b. a PowerPoint file to show experimenters how to tilt the devices in the summer and winter day and night time
    c. a spreadsheet that confirms the hits from previous experiments
    d. Set of instructions for operating the digital, more advanced, and auto- DC power supply
    e. Created a folder of instructions on how to use the DC Supply with drivers to run it using LabVIEW

As can be observed in this table, there was a significant amount of research and scientific work completed by the three (3) undergraduate engineers during the single summer research project. The volume and quality of work shows how commendable the student efforts were given they only had an eight (8) week summer research period. The standard test protocol for the experiment is to attach the DC motors powering the central inertial wheel to a gradually increasing (simple voltage step increases) voltage from an external power supply. After a few specified minutes of time (in the test protocol) the wheel reaches the desired range of a few thousand rpm and the external voltage source is disconnected and the powering of the inertial wheel is then transferred to the array of eight (8) parallel strings of 1.2V Ni-Cad batteries (each comprised of six batteries in a series string). The batteries power the wheel for an additional four (4) minutes when the team via our data acquisition system seeks to observe any anomalies in the battery discharge patterns. The data acquisition system is a product of DATAQ Instruments, model DI-1110. This device is a general-purpose data logger that can be reconfigured to suit many applications. It is compatible with our real-time voltage measurement purposes as it can read up to 8 analog differential channels simultaneously with frequency up to 160 kHz. The input scale is ±10 V with a 12-bit resolution. In addition to its compatibility with .NET Classes for Visual Studio, the model comes with a ready-to-run WinDaq software from which we exported measured data to excel files for processing. [14] A typical plot of voltages for the batteries in a lamp control experiment (from Table 1 – part 6(b) above) is provided in Fig. 2. It is obvious that this system of DC batteries normally behave as one would expect. Initial voltage is flat, then when placed under the loading of the DC motors to maintain the inertia of the central wheel the voltages drop significantly, with a steady decline for the four (4) minutes of the experiment. When the motor load is removed at that time, the voltage rebounds and gradually settles to a new (lower) voltage representative of the energy that was transferred from the batteries to the wheel to overcome its normal windage and friction.

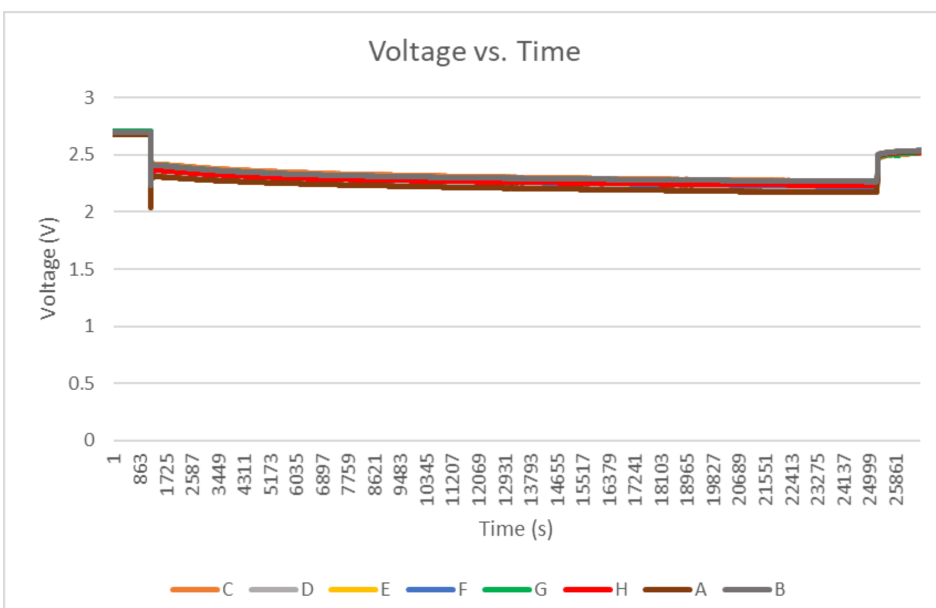


Fig. 2 – Typical Discharge Pattern for Batteries in Lamp Control Experiment

**The Empirical Results of The Investigations**

Experimental trials are conducted at all times of the year but of particular interest are those times when a local mass alignment arises in proximity to the Earth. A solar eclipse is considered an ideal event for an experimental run. Six experiments were conducted: three on July 1 and three on July 2 when the full solar eclipse occurred in the southern hemisphere [15]. Those experiments were a milestone in our research from the 2019 summer, as they completely captured the voltage fluctuations of all the battery packs in real-time. On July 1, the mass alignments above the Earth were Venus with Moon, Sun, and Mars with Mercury (see Fig. 3). The arm pointing upward is Alpha and the three Earth arms are D, E, and F (E being the middle Earth arm, pointing to the center of the Earth). H arm was in the direction of the most local mass above (i.e.: all the mentioned alignments). Please note how all these observations can be made by inspecting Fig. 3 which has been captured from Stellarium program [16]. Figs. 4 and 5 which follow show the real-time voltage fluctuations in the upper and lower battery packs of the arms of the device. Looking closely one can observe that for Figs. 4 and 5 the voltages that swing wildly away from the standard pattern are in fact mirror images of each other. This is due to the same voltage reference location being used between the series string battery packs. The actual impact is most likely on one battery.

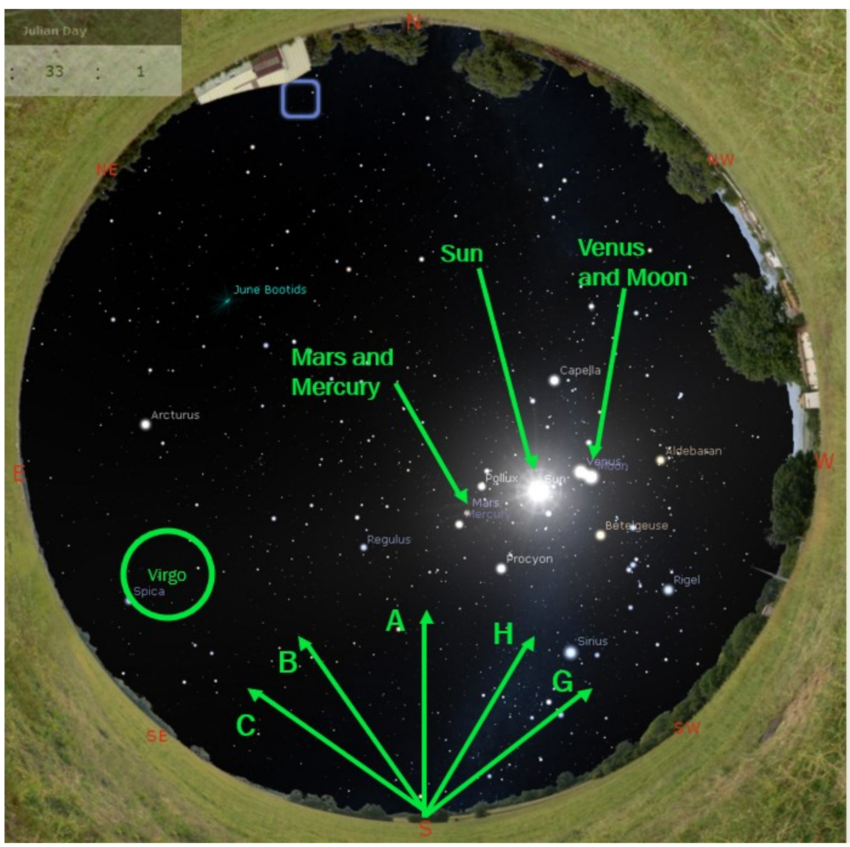


Fig. 3 - Stellarium Front of the Earth image for Exp. 1 - July 1

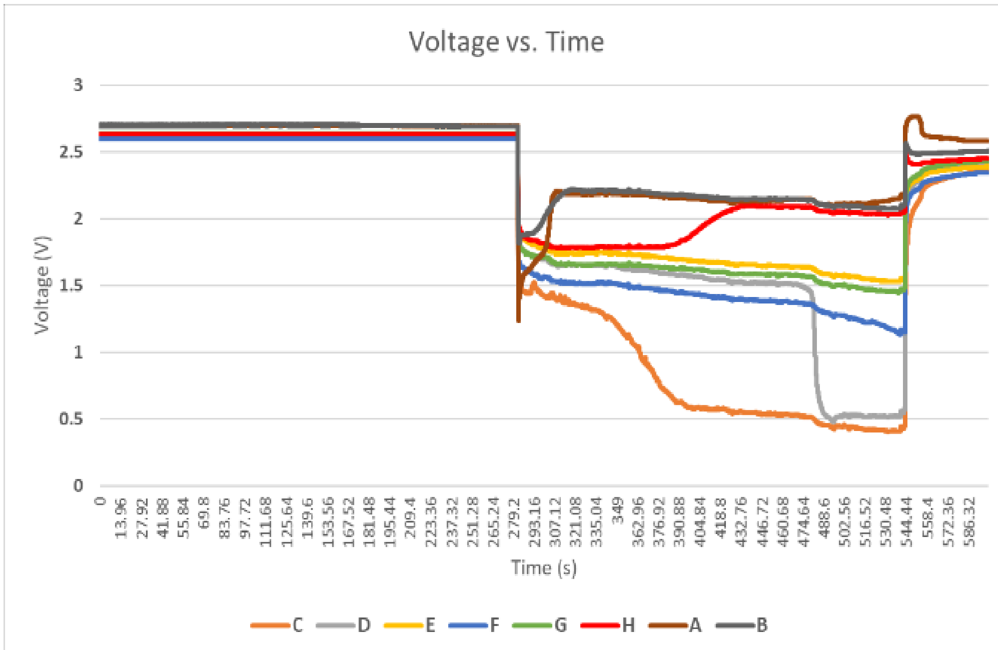


Fig. 4 - Real-time Voltages of Top 2 Batteries – Exp. 1, July 1

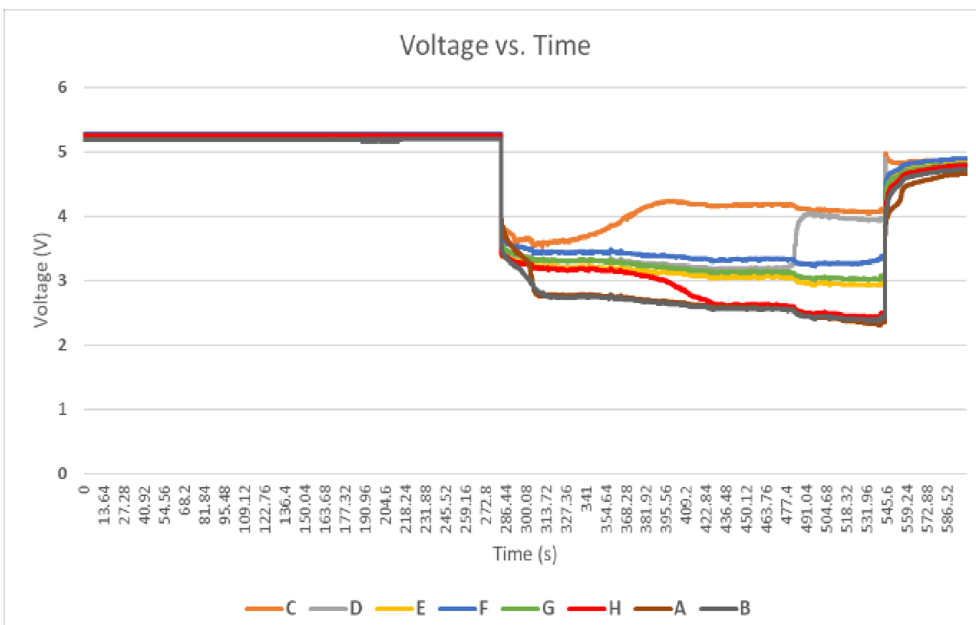


Fig. 5 - Real-time Voltages of Bottom 4 Batteries – Exp. 1, July 1

In order to save the reader time, we have not provided both sets of battery voltages for the remaining five (5) experiments that we conducted. We show one additional Stellarium capture

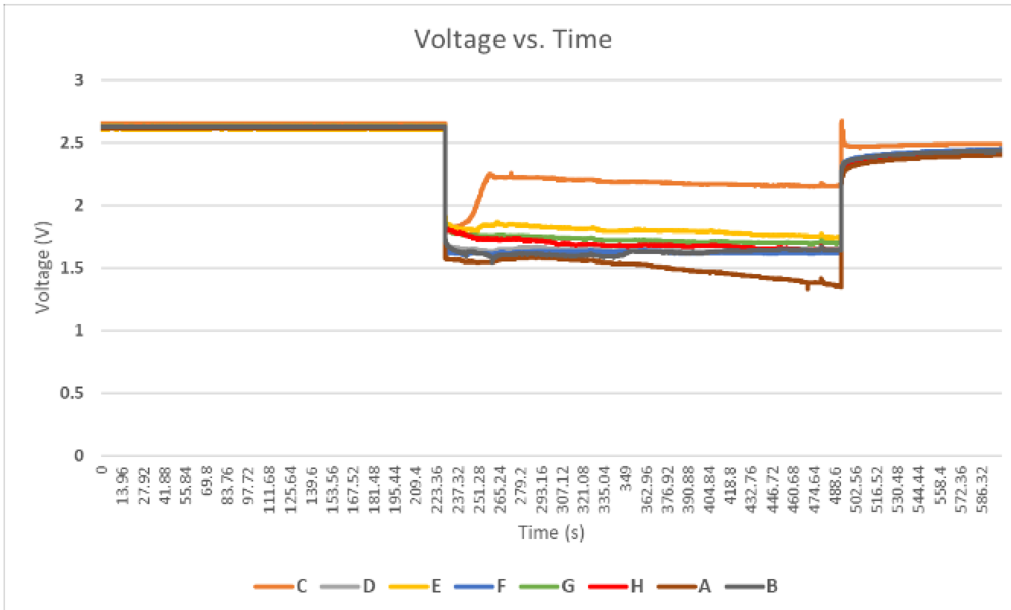


Fig. 6 - Real-time Voltages Top 2 Batteries – Exp. 2, July 1

for the day of the eclipse event (July 2) and only the "Top 2 Batteries" graphs for each trial run. All of the data for the six (6) experimental runs is available for review upon request.

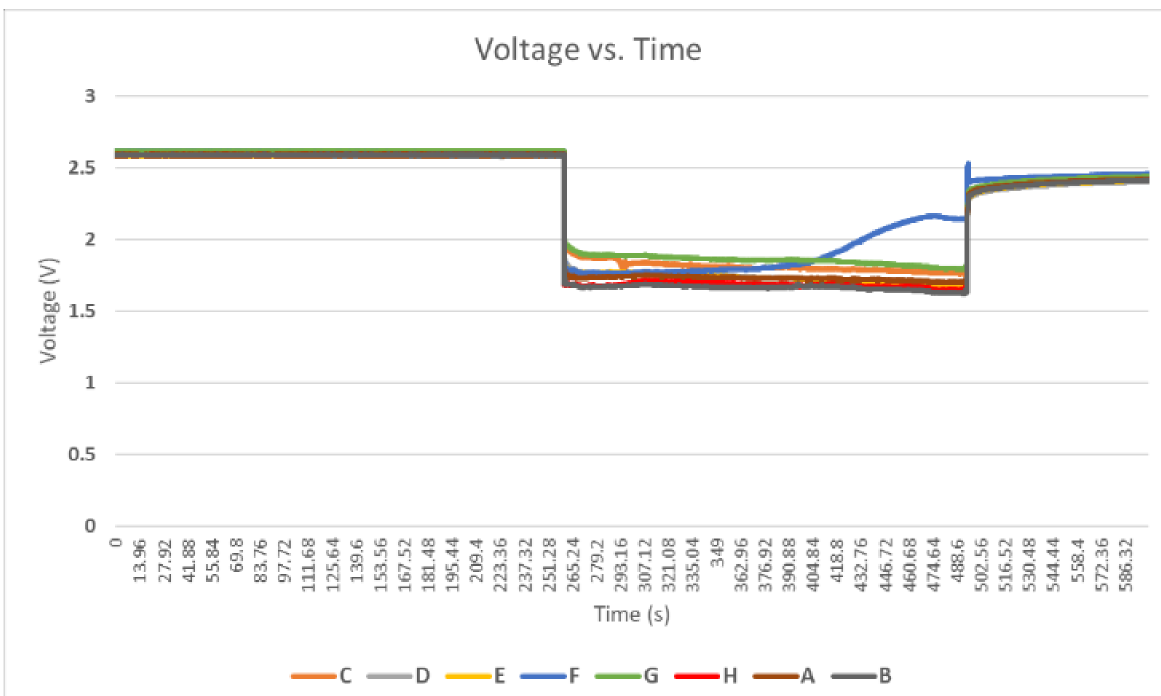


Fig. 7 - Real-time Voltages Top 2 Batteries – Exp. 3, July 1

On July 2 (the eclipse day), the mass alignments are very similar but the moon moved in front of the Sun (see Fig. 8).

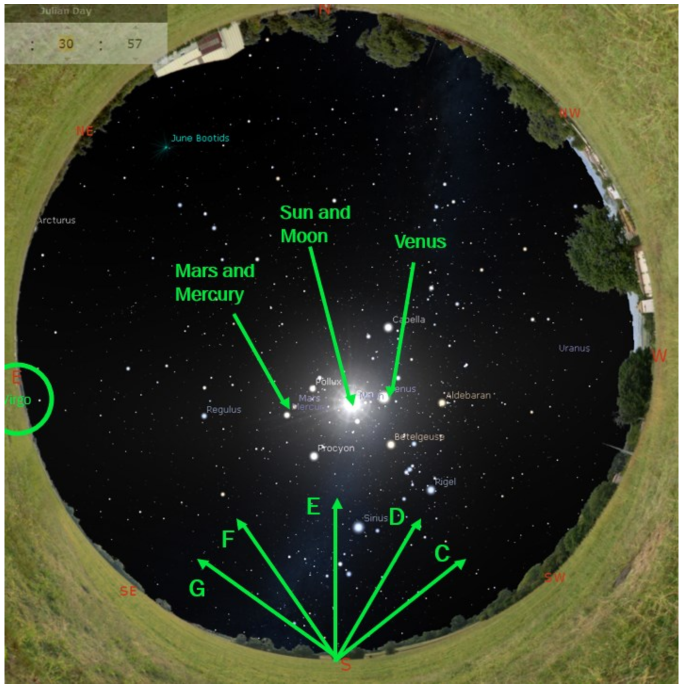


Fig. 8 - Stellarium Front of the Earth Image for Exp. 1, July 2 (Day of Eclipse)

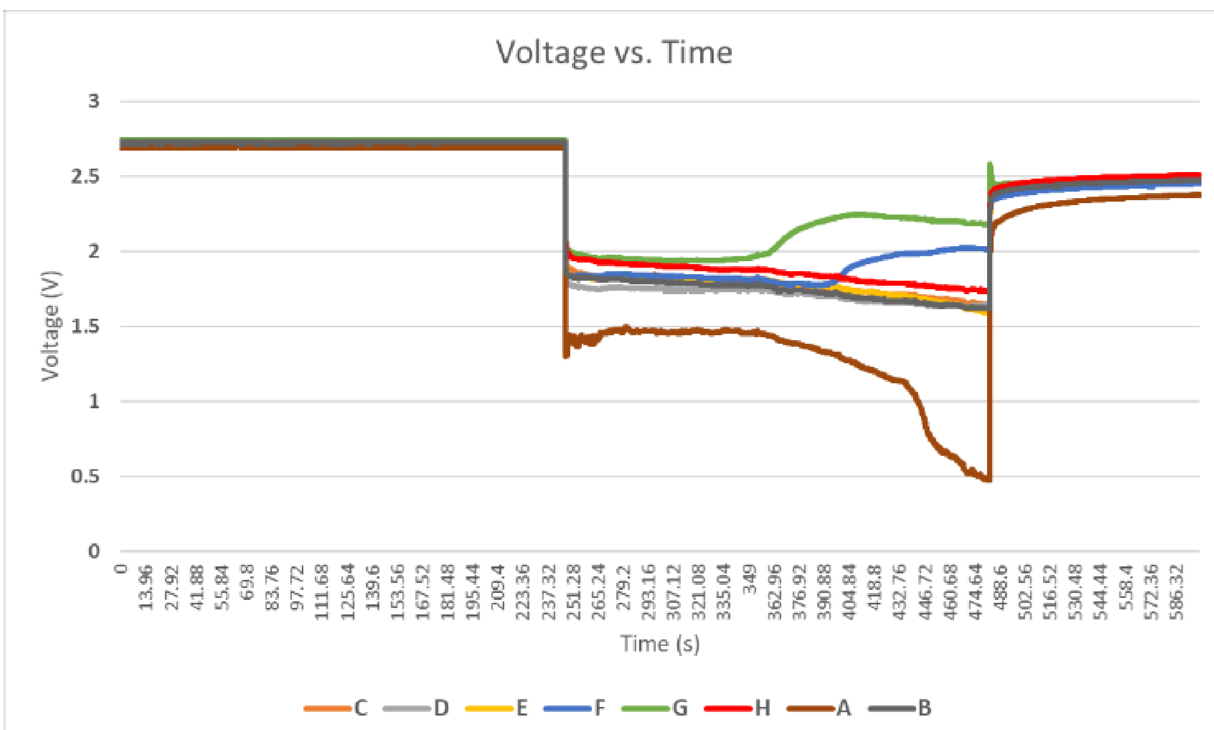


Fig. 9 - Real-time Voltages Top 2 Batteries – Exp. 1, July 2

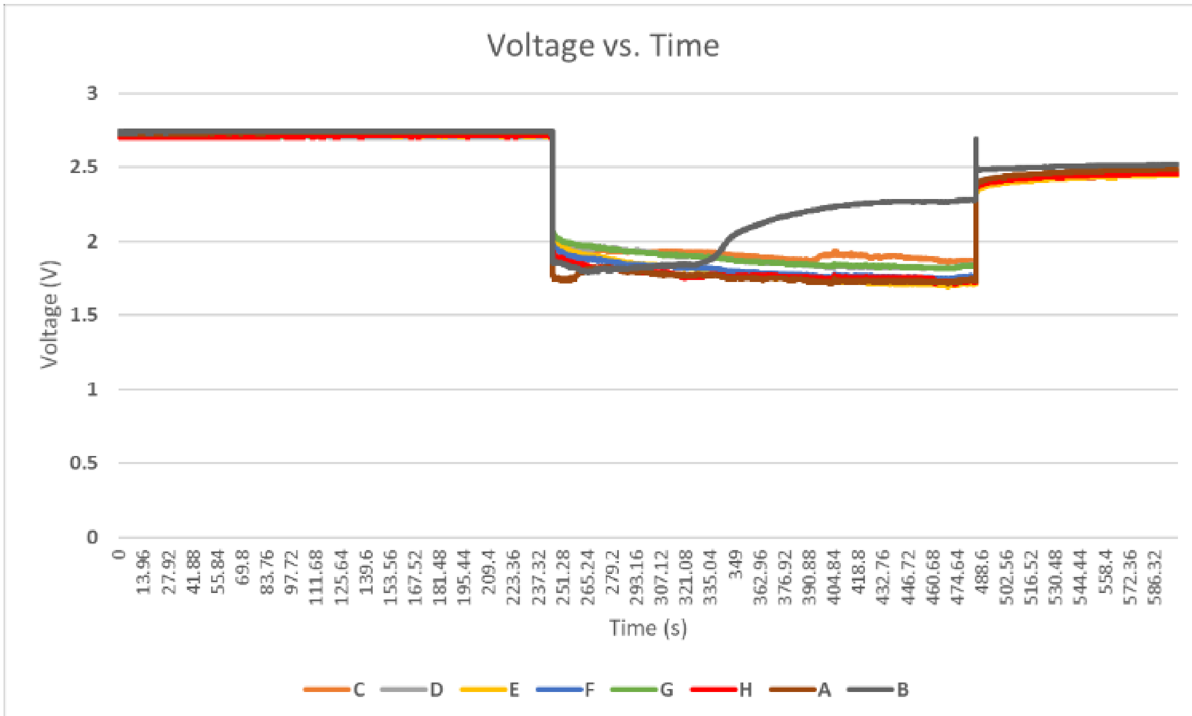


Fig. 10 - Real-time Voltages for Top 2 Batteries – Exp. 2, July 2

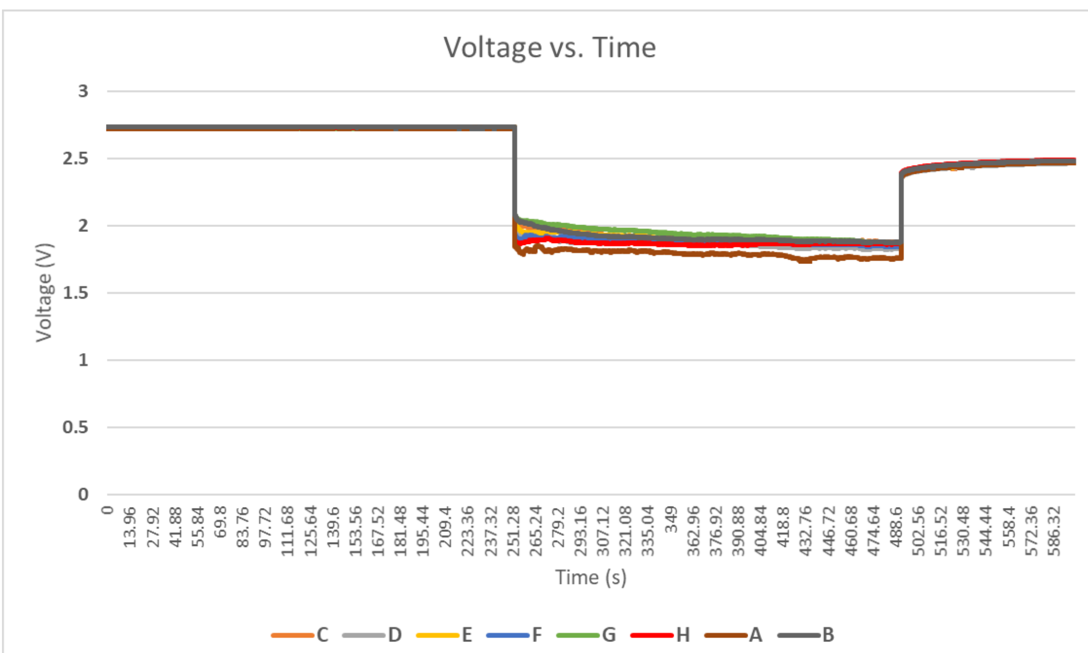


Fig. 11 - Real-time Voltages for Top 2 batteries – Exp. 3, July 2

**Analysis of Results**

The experimental data collected over the summer of 2019 store treasures that can potentially enhance deeper comprehension of the Mach Effect. Whenever there is a slight uneven mass distribution in the region of local space, unusual (extraordinary) patterns in the electromagnetic discharge patterns of our sensor array battery voltages tend to be more pronounced. The real-time voltage discharge graph lines in experiment 1 on July 1 (Fig. 4) appear at first incomprehensible (wild fluctuations in the battery discharge patterns). Batteries voltage discharge graphs are normally more stable than that shown in Fig. 2 or Fig. 11. In Fig. 4, the top pack (of 2 batteries) on arms C and D drops from 1.6 V to 0.5 V which is very odd because the cut-off voltage of these batteries is ~ 0.9 V (for 1.2 V AA rechargeable Ni-Cd). [17] More notably, nearly each arm that shows a peculiar discharge behavior points to a potential mass alignment in the sky. B and C arms are in the direction of Virgo cluster; A, though opposite of E which is the middle Earth arm, does not have a clear target itself. H arm points in the direction of the mass alignment of interest in this experiment and D points through the Earth to the center of the Milky Way. Fully 80% of these arms have targets. We are not attempting to prove causality in this paper (i.e., that these abnormalities of voltage discharge happened because they were directly affected by the celestial masses) but we share the sensor observations since there are uncanny correlations between the extraordinary discharge patterns and celestial bodies. As illustrated in Table 2 below – there is a nearly 92% correlation between the observed voltage fluctuation anomalies with real celestial targets that could be the sources of Machian inertial reaction forces.

<u>Table 2 – Experimental Anomalies vs. Celestial Targets</u>

Extraordinary Real-Time Voltage Fluctuations occurred as follows:

1 Jul Exp. #1 – 80% Correlation with Target Arms (4 of 5)

1 Jul Exp. #2 – 100% Correlation with Target Arms (2 of 2)

1 Jul Exp. #3 – 100% Correlation with Target Arm (1 of 1)

2 Jul Exp. #1 – 100% Correlation with Target Arms (3 of 3)

2 Jul Exp. #2 – 100% Correlation with Target Arm (1 of 1)

2 Jul Exp. #3 – No Obvious Strange Real-Time Voltage Fluctuations

***Overall 11 Target Correlations of 12 Strange Voltage Fluctuations (91.7%)***

If we assume that three (3) of the eight (8) sensor arms might typically point to a target in our experiments, we would expect that a correlation of ~38% could occur purely by random chance. If four (4) arms were pointing to a celestial target in an experiment a random positive correlation could theoretically occur 50% of the time. But these results of very high correlation (91.7%) suggest a real Mach Effect may be at work as indicated by our real-time sensor array response. Earlier peer reviewed manuscripts on these correlations found that >4 and >5 sigma deviations comparing pre- and post-experiment battery voltage deltas had a 100% correlation with celestial targets when magnitudes of the voltage change exceeded 45mV [4].

In experiment 2 on July 1, arms A and C display different discharge patterns (see Fig. 6) compared to the other six (6) arms of the sensor array. Interestingly, A points to the alignment of interest, and C points to the Virgo supercluster (see Fig. 5). In experiment 3 on July 1, arm F, which has a different discharge pattern (Fig. 7), points through the Earth to the Milky Way center. In experiment 1 on July 2, A, F, and G arms express different discharge behavior (see Fig.9). A is the middle Earth arm which points to the Earth's center, G arm points to the Virgo supercluster and F points in the direction of Virgo as well since Virgo is a very distant and gigantic galaxy cluster and it spans an area of 5 by 3 degrees from the local sky [13]. Looking at experiment 2 on July 2, B is the arm with a strange discharge pattern (Fig. 10), and it happens to be the middle Earth arm – pointing to the center of the Earth. Analyzing the last experiment, no arms appear to be of interest.

The working hypothesis of this research is that strange anomalous discharge is expected to take place on arms in the direction of significant celestial mass alignments. Earth is considered the most effective mass because it is the closest to our experimental setting; thus, the Middle Earth arm is believed to be in the direction that contains the largest amount of local matter. Mass alignments in the solar system (i.e.: planets, the sun, and the moon) create unevenness in the local matter level. Virgo supercluster is considered a significant effective mass since it is the driving gravitational center of the supercluster that we, the Milky Way galaxy, are part of. [18-20] Therefore, any arm pointing to Virgo cluster is pointing to the largest amount of matter on the local supercluster level. Table 3 summarizes the observations of the recent solar eclipse for our six (6) experiments and shows how many times each celestial mass appeared as correlated to the sensor arms. Of interest, all sensor arms were involved in the observation of abnormal behavior except for the E arm.

Table 3 – Sensor Arms and Celestial Target Frequency

| ***Celestial Target*** | ***Sensor Arms*** | ***Frequency*** |
|---|---|---|
| Virgo Supercluster | B, C, C, F, G | 5 events (45%) |
| Sun-Moon (near eclipse) | A, H | 2 events (18%) |
| Middle Earth Arm | A, B | 2 events (18%) |
| Milky Way Center (via Earth) | D, F | 2 events (18%) |

This makes clear the fact that this is not an electrical error as it can be observed on any sensor arm at any time. It is the orientation of the device that determines which arm is involved in the detection event. The experimental protocol calls for the rotation of the device for different experiments to guard against such false positive results.

## Initial Tentative Conclusions

The research questions, "What is inertia?" and "Is the Mach Effect real or not?" And, if so, "Is it measurable?" challenge many widely held paradigms of how the universe is believed to work. It is our hope in sharing our "real-time" sensor data with the scientific community that others will join in the hunt for answers to these important queries. While this research is still in the infancy of its exploration stage, we believe that our sensor results are beyond intriguing, and actually point to an empirical investigation of the nature inertia that is sure to be "a signpost to new knowledge that underlies the laws of nature." [10] What is potentially even more powerful in these observations is that the professor in charge of the research students gave the team the challenge and set them free to validate (or disprove as the case may be) the results of prior researchers' endeavors. He was not continuously coaching them on how to run these experiments or how to interpret the results. It is becoming increasingly likely that these students observed these amazing relationships because it is potentially the very first time we have looked in the right direction for the interactions and used appropriate sensing equipment.

Given that sometimes multiple arms show odd behavior and that this is clearly a new electromagnetic phenomenon, if it is substantiated by others, we postulate possible alternate natures of the Machian inertial reactions as follows (see Fig. 12 for graphic of these ideas):

1. A wide-range effect reaction field.
2. A point-to-point reaction force / effect.
3. A different type of reaction that affects every piece of matter in proximity, making slight changes in inertia more pronounced.

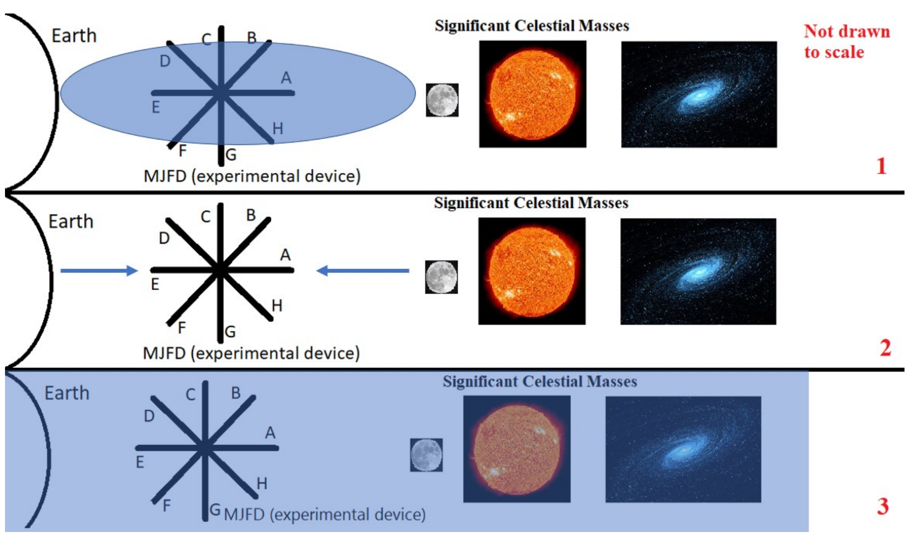


Fig. 12 - Visual Representations of Possible Natures of the Mach Effect Interaction

Our earlier research protocol measured the batteries' voltages difference (pre- and post-experiments) resulting in the need to calculate voltage rebound. This new research experimentation system still requires multiple manual measurements. We are moving to a more automated system where every battery voltage is monitored individually during the entire experiment. It is hoped these new devices will increase our perspective and provide highly reliable data to better direct future research efforts. Our enhancements to real-time data capture has already created opportunities for many more insights into what is happening over the course of an experimental run. We invite the engineering education scientific community to review our work and join us on this important journey in the empirical discovery of knowledge. The tools in the toolkit employed by scientific discovery are many. The roles engineers will play in developing and using those tools in both big scientific endeavors (such as LIGO's observation of gravitational waves [21, 22]) and small science experiments (like those described here) will be diverse and significant. Last year an article in the Harvard Business Review described the dominance of large research teams in how science is performed today "while solitary inventors, researchers, and small teams have all been on the decline." But in stark contrast to that statement, their review of "millions of papers, patents, and software projects… found that while large teams do indeed advance and develop science, small teams are critical for disrupting it." [23] A patent for the detector has been filed by the author and awaits examiner review in the USPTO. [24] Small teams gathering novel empirical data may prove to be one of the least thought of tools for scientific discovery. It is clear that this new data challenges the status quo of science but may that not be what continuous improvement and life-long learning will look like in engineering education when undertaken in earnest? The skills that the students developed over their summer experience are at the foundation of the scientific method and discovery and more importantly invaluable in their holistic engineering education. They learned to understand experimental protocol (and to revise it as needed) and to use and revise new scientific equipment; these skills are applicable to life beyond university in industry, academe or consultancy. Their design and application of new data capture technologies and the significant data analysis and interpretation associated with real world investigations will serve them well in their remaining years as students and their careers beyond. During this research, the student team worked independently, provided regular communications of status and progress and learned how exciting it can be to work on scientific discovery. They know that these experiences helped develop skills that will make them successful in future workplace or research settings. They also demonstrated that they learned the value of continuous improvement. The experiences created in the research environment challenged them to apply their ongoing engineering education, taught them to self-manage and instilled a strong desire to lifelong learning. So many of these and similar learning outcomes are desired in the normal classroom and lab settings, but the opportunities that discovery-driven research experiences provide to students to enhance both the depth and breadth of their learning are multitudinous.

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