



University of Pittsburgh

Training the Next Generation of Electric Power Engineers: A 15 Year Strategic Partnership Between Pitt Swanson Engineering and Eaton

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Associate Professor

Director, Electric Power Technologies Lab

Associate Director, Energy GRID Institute

Co-Director, AMPED Consortium

Department of Electrical and Computer Engineering

University of Pittsburgh

Swanson School of Engineering





Outline of Discussion

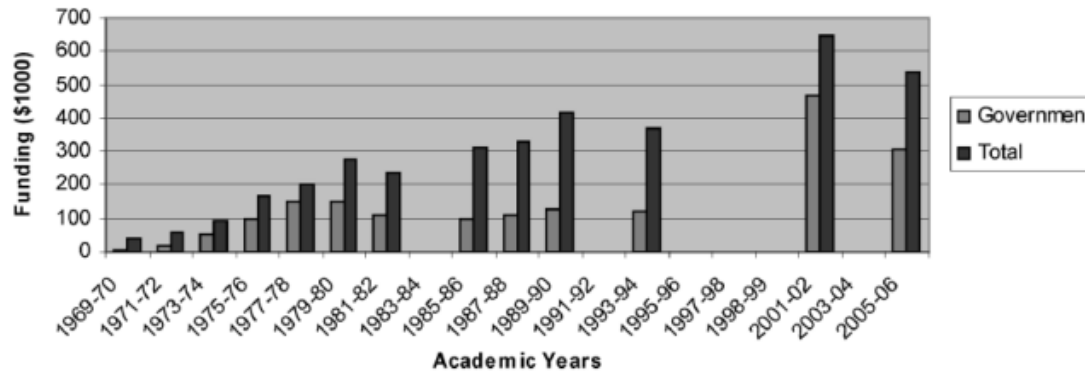
- **Introduction: Where are all the electric power engineers at?**
- **Education: Modernized Classes in Power Systems and Power Electronics - Undergraduate**
- **Education: Modernized Classes in Power Systems and Power Electronics - Graduate**
- **Facilities: Modernized Teaching Laboratories for Education and Research**
- **The Pitt Electricity Center: Further Facility Development for R&D and Training**
- **Workforce: How do you get access to the talent?**
- **Give Me the Numbers: Was Eaton's Investment Worth It?**
- **Acknowledgments**



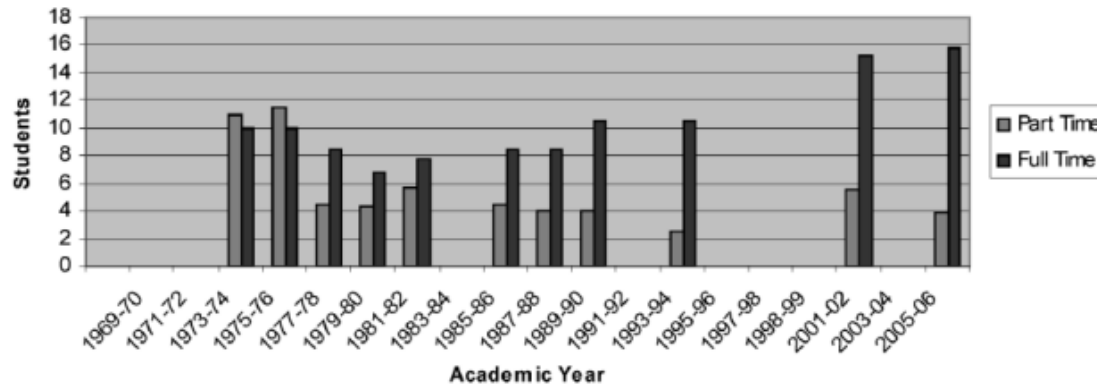
Introduction:

Where are all the electric power engineers at?

Little to No Investment in Electric Power R&D throughout the 1990s !



Institution and Average Funding from Government and All Sources – 115 U.S. and 10 Canadian Schools



Average Number of Graduate Students per Institution – 115 U.S. and 10 Canadian Schools



Eaton-Pitt Partnership in Electric Power Engineering

• 8 Key Initiatives Summary:

- 1) **Electric Power Systems Engineering Laboratory**
- Facility dedicated January, 2014, Benedum Hall
- 2) **Undergraduate Capstone Senior Design Projects**
- 75 EE and ME completed projects to-date (+150 students), many conducted at the Eaton Power Systems Experience Center
- 3) **Power System Engineering Curriculum Support**
- New course developments, adjunct professor support, numerous guest lecturers, lab section developments
- 4) **Joint Research Program Developments**
- Collaboration with business groups, innovation center
- 5) **Professional Society Contributions**
- IEEE, ASEE, others -- joint papers, panels, trade shows
- Pitt EPIC participant -- sponsor, exhibitor, keynotes, etc.
- 6) **Community Service and Outreach**
- K-12 STEM activities, EPIC sponsorship, volunteerism
- Various local and national media events
- 7) **Student Recruiting**
- 329 total: co-ops (141), interns (96), FTE's (92) since 2011
- Leadership training, seminars, job fairs, campus events, etc.
- 8) **GRID Institute at Energy Innovation Center**
- \$3M of design efforts and equipment discounts



Partnership Signing Ceremony – March 10, 2009



EPSSL Dedication Ceremony– January 9, 2014



Dave Bucklew Recognition – October 15, 2018

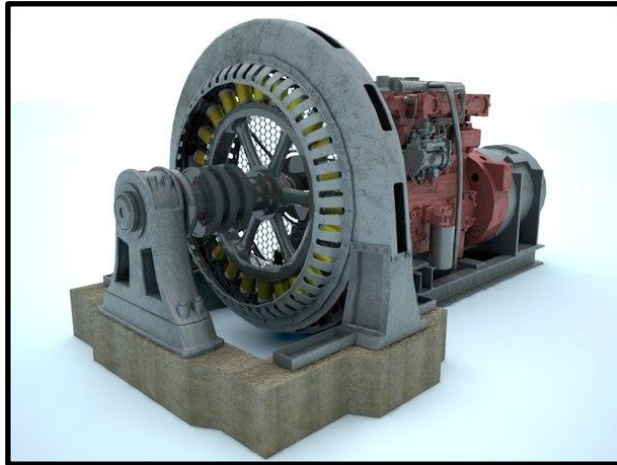


Education:
**Modernized Classes in Power Systems and
Power Electronics**

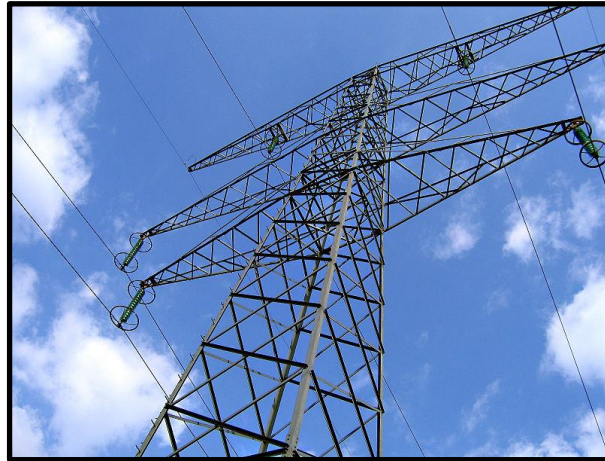
Undergraduate

A New Era in Electric Power Engineering Education

This is what most students think of when you mention power engineering because most programs only have one or two courses at their local university.



Generator



Transmission



Substation

A New Era in Electric Power Engineering Education



All Electric Aircraft



Electric Vehicle Charging,
Machines, and Drives



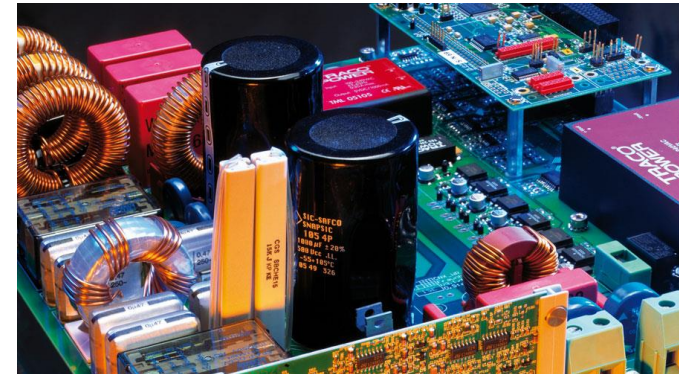
All Electric Ships



Cybersecurity, Digital Twins,
and Machine Learning



Bulk Power System
Management



Power Electronics, Magnetics,
and Semiconductors

Power engineering is a like an onion. There are so many layers to get involved with and this needs to be communicated.



Undergraduate Electric Power Concentration

- **Required Course:**

ECE 1701 Fundamentals of Power Engineering (Required for all EE Students)

- **Three additional elective to be selected from the following options:**

ECE 1673 Linear Control Systems (Required for all EE Students)

ECE 1710 Electric Distribution Engineering and Smart Grids (Summer)

ECE 1750 Power Electronics Conversion Theory (Spring)

ECE 1771 Electric Machines (Fall)

ECE 1773 Power Generation, Operation, & Control (Spring)

ECE 1774 / 2774 Advanced Power Systems Analysis (Spring)

ECE 1775 Power Quality with Laboratory (Spring)

ECE 1776 / 2776 Microgrid Concepts and Distributed Generation Technologies

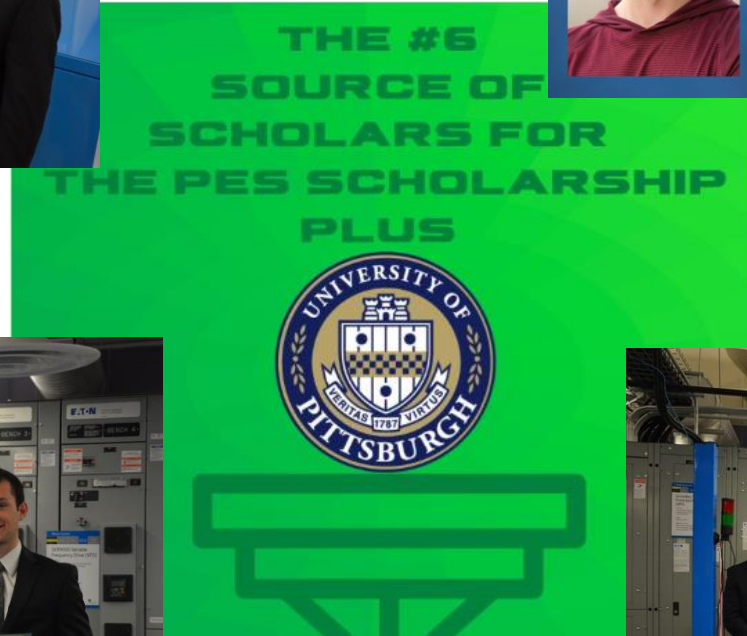
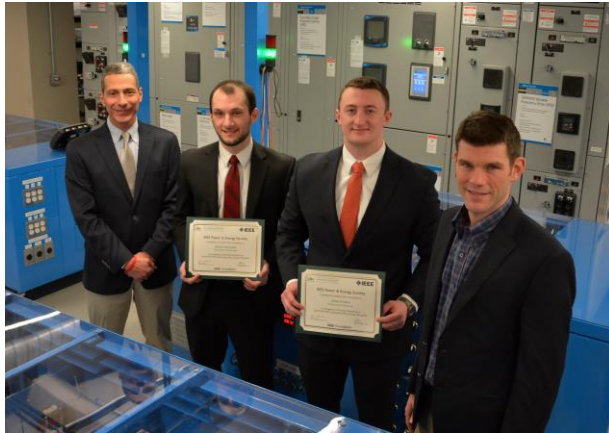
ECE 1XXX: Electrical Wiring Fundamentals for Electrical Engineers (**Planning**)

ENGR 1281 Clean Energy Grid Engineering: Scandinavia (Int'l – Summer)

Yes, these courses continuously run all year. Approximately 1/3 of all EE students obtain the power concentration in the department.



IEEE PES Scholarship Initiative – Ranked #6 in the USA !





Pitt-Ohio Express Harmar – DC Microgrid

- Renewable DC Energy (Solar/Wind) and Storage System
- First all-DC Renewable Integration Project in the U.S.





Executive Summary of Undergraduate Program

- Undergraduate Electric Power Engineering Concentration
 - BS degree in EE with EPE Concentration – requires 4 power electives (out of 9 BS power specific courses)
 - 33% of all graduating EE's are completing the EPE Concentration
 - Strong enrollments – e.g., avg. of 45 students in ECE-1769 each fall term
 - National IEEE PES scholarships
 - Award winning undergraduate research projects and papers
 - Industry participation – senior design projects, co-op assignments, internships
 - 100% job placement – in the power/energy sector or graduate school

Stabilize the undergraduate curriculum and growth first when building a new program. This will generate a continuous pipeline for a graduate program.



Education:
**Modernized Classes in Power Systems and
Power Electronics**

Graduate

Electric Power Graduate Assessment and Direction

Core Question: Do you enjoy **big picture thinking** or do you want to drill down into a **piece of equipment**? This differentiates a system person (utility or consulting) and an equipment designer.

Course Selection for Equipment Student: He or she is required to take courses in the following areas with more emphasis on the first three buckets.



Power Electronics &
Magnetics



Control Theory



Machines & Drives



A System Class

If you are going to design equipment, you need to know the system constraints associated with the installation.

If you are going to design systems, you need to know what is going on inside the “green or gray boxes”.



Graduate Program Electric Power Curriculum

• Power Engineering Focused Courses:

MSE 2033 Power Magnetic Devices

ECE 2250 Fundamentals of Power Electronics

ECE 2774 Advanced Power System Analysis

ECE 2775 Advanced Machines and Drives

ECE 2776 Microgrid Concepts and Distributed Generation Technologies

ECE 2777 Power System Transients

ECE 2778 Advanced Power Electronics (FACTS & HVDC Systems)

ECE 2780 Renewable & Alternative Energy Systems

ECE 2781 Smart Grid Technologies and Applications

ECE 2795 Electrical Distribution System Engineering & Analysis II

ECE 2795 Protective Relaying and Substation Automation

ECE 3776 Power System Stability

ECE 3777 Power Electronics Conversion II

ECE 3783 Modern Control and Optimization for Energy & Complex Engineering Systems

ECE 3779 High Frequency Power Electronics

ECE 3795 Cyber-Physical Power Systems

In planning/development stages:

ECE 2795 Software Based Finite Element Analysis for Electrical Engineers

ECE 3XXX: Advanced Modelling and Control of Power Electronic Systems

ECE 2XXX: Wide Bandgap Semiconductor Course

ECE 2XXX: Electric Vehicle Machine Design



Electric Power Program Constituents

MITSUBISHI ELECTRIC POWER PRODUCTS, INC.

EATON
Powering Business Worldwide

Richard King Mellon Foundation

HILLMAN FAMILY FOUNDATIONS

UNIVERSAL
ELECTRIC CORPORATION

SIEMENS

Dominion

ABB

DLC
DUQUESNE LIGHT CO.

PA pennsylvania DEPARTMENT OF COMMUNITY & ECONOMIC DEVELOPMENT

Ben Franklin Technology Partners 25TH ANNIVERSARY

arpa.e

NSF

FirstEnergy

NETL
NATIONAL ENERGY TECHNOLOGY LABORATORY

CITY OF PITTSBURGH OFFICE OF THE MAYOR

PITTOHIO
SUPPLY CHAIN • GROUND • LTL • TL

U.S. DEPARTMENT OF ENERGY

Science & Engineering Ambassadors
A Program of the National Academy of Sciences and the National Academy of Engineering

DEPARTMENT OF COMMERCE UNITED STATES OF AMERICA

EMERSON
Process Management

ANSYS

THE HEINZ ENDOWMENTS
Howard Heinz Endowment • Vira I. Heinz Endowment

Westinghouse

Sargent Electric Company

Typhoon HIL

APL JOHNS HOPKINS APPLIED PHYSICS LABORATORY

DEPARTMENT OF DEFENSE
UNITED STATES OF AMERICA

GE

WindStax™
Wind Power Systems

AMETEK

JPL
Jet Propulsion Laboratory
California Institute of Technology

DRANETZ™
THE STANDARD FOR ENERGY & POWER MEASUREMENT



AMPED Program Constituents

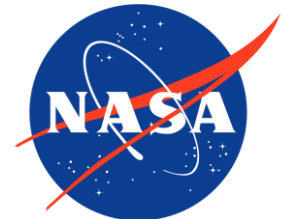
Charitable Contributors



L3HARRIS



Full Participants





Executive Summary of Graduate Program

- Graduate Electric Power Engineering Program
 - M.S. and Ph.D. degrees offered with EPE Concentration
 - Student demographics are approximately 50%-50% full-time students and part-time industry students – great classroom environment!
 - New course developments each year – renewable energy, power electronics, smart grids, etc.; with plans for more in future terms --- total of 17 MS/PhD level courses
 - Strong enrollments – averaging 20 students in many courses



Faculty Contributors and Researchers at Pitt

- Brandon Grainger*** Associate Professor: Power electronics, wide bandgap semiconductor utilization (GaN and SiC), medium voltage converter design, solid state transformers, electric motor drives
- Robert Kerestes*** Associate Professor: Distribution circuit analysis, wide-area control, smart grids (IoT, Machine Learning, Digital Twins)
- Alexis Kwasinski*** Associate Professor: Microgrid technologies and systems, power electronics, power system reliability and resiliency, cyber-physical security
- Masoud Barati*** Assistant Professor: Optimal power flow, system resiliency, optimization, smart grid, system protection
- Paul Ohodnicki Jr.*** Associate Professor: Power magnetics (transformers and inductors), optical sensing, optimization routines for electrical components, solid state transformers, machine design
- New Hire Coming*** Full Professor
- Zhi-Hong Mao*** Full Professor, Advanced control (adaptive, optimal), optimization, multi-agent systems



Adjunct Faculty and Key Education Collaborators

Dan Carnovale Program Collaborator (Eaton)
- Electric Power System Lab Support and Senior Design Project Advisor

Craig Gob Program Collaborator (Eaton)
- Chair, Eaton Steering Committee / Eaton Representative on Center for Energy Advisory Board

Adam Sparacino Program Collaborator (Mitsubishi Electric)
- Instructor for ECE 2777 – Electrical Transients

John Paserba Program Collaborator (Mitsubishi Electric)
- Mitsubishi Electric Representative on Center for Energy Advisory Board

Elizabeth Cook Adjunct Professor (Duquesne Light)
- Grid Modernization Initiatives



Facilities:
**Modernized Teaching Laboratories for
Education and Research**

The Electric Power Systems Laboratory

Benedum Engineering Hall – 8th Floor



- AC/DC Microgrid facility
- 480-V, 200-A, 75-kW maximum capacity
- Mix of Generation: PV, Gas, Wind, Grid
- Customized workbenches
- Variable system strength
- Integrated laboratory workbenches
- Motor Control Centers
- Advanced controls
- UPS and Datacenter
- Power factor correction
- Sag/Surge generators
- 6 MHz metering
- Multi-media capabilities
- Industry sponsorship (Eaton)

Facility Dedicated January, 2014



The Electric Power Systems Laboratory

Dedication Ceremony – January 9, 2014





The Electric Power Systems Laboratory

Video Tour:

<https://www.youtube.com/watch?v=N7A7Lqa8l18&list=PL8XobqCtN9Z9zmxXF91EJpX2k8FjdRIEb&index=84>





The Pitt Electricity Center

Further Facility Development for R&D and Training



University of Pittsburgh Advanced Research Facilities at the Energy Innovation Center

Electric Power Technologies Lab

- Dr. Brandon Grainger – ECE
- Medium-Voltage/High-Power AC Grid Facility

Advanced Magnetics for Power & Energy Development (AMPED)

- Dr. Paul Ohodnicki – MEMS
- Dr. Brandon Grainger – ECE
- Magnetic Materials Processing and Manufacturing

Energy Storage Technologies Lab

- Dr. Prashant Kumta – BioE, ChemE
- Nano-Materials for Conversion and Energy Storage

High-Temperature Corrosion Testing Lab

- Dr. Brian Gleeson – MEMS
Harsh-Environment, High-Temperature Materials Testing

Energy-Related University Incubator Space

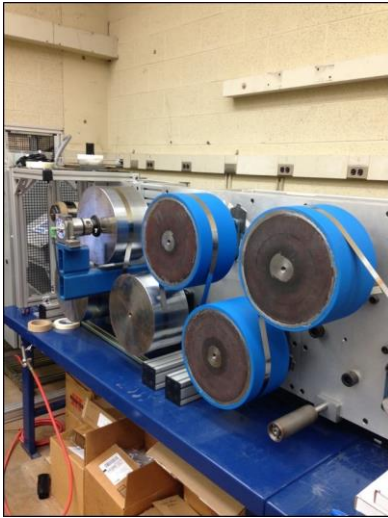
- Lab Spaces for Start-up/Commercialization Activities



Energy Innovation Center –
Downtown/Lower Hill District, Pittsburgh

Allows INDUSTRY to work COLLABORATIVELY on product research, development, demonstration, & early-STAGE deployment

Pitt Advantage with Facilities



Materials
Science



Electrical Product
Development



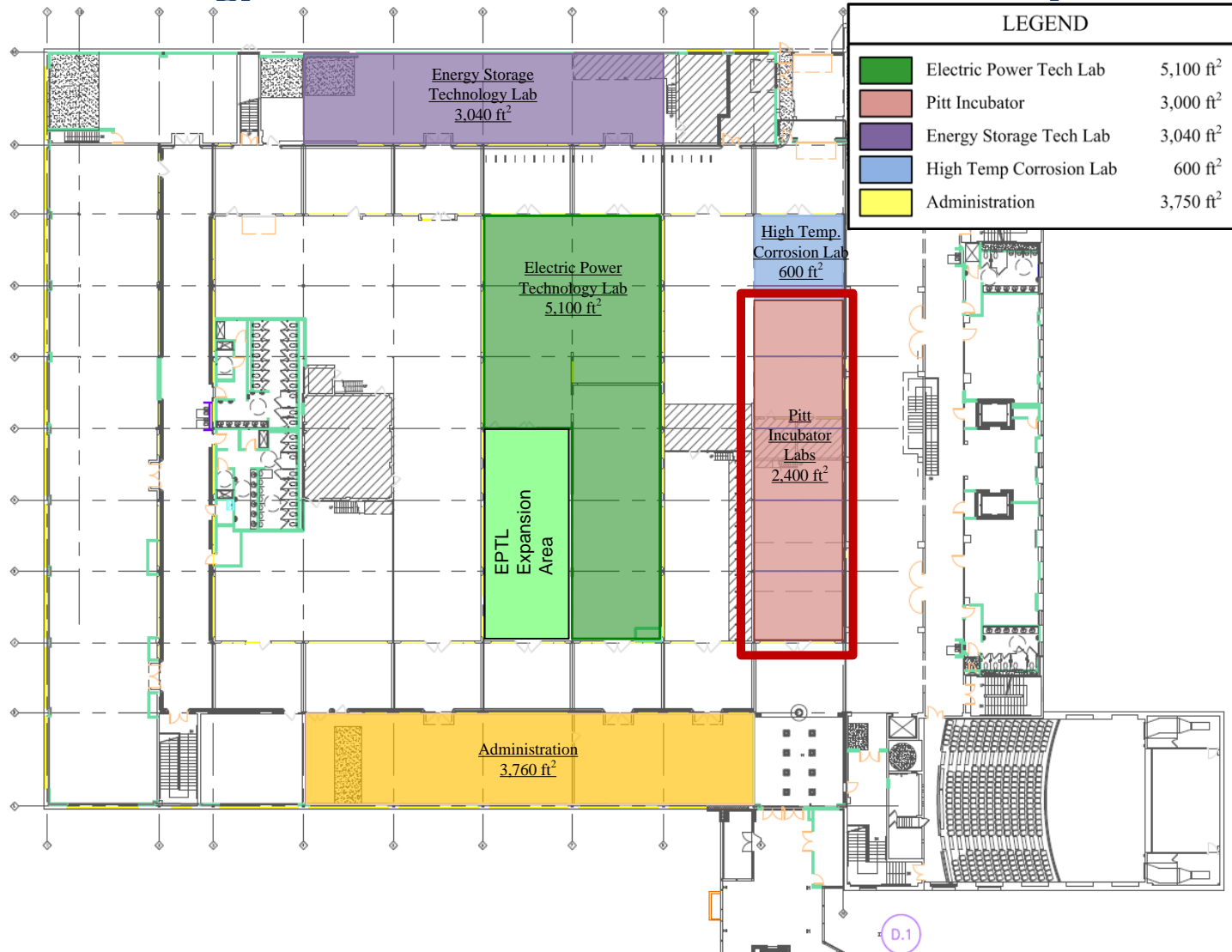
High Power Testing

Multidisciplinary ecosystem between materials science and electrical engineering to develop and test medium voltage electrical products.

Recall the Battelle consulting study that launched the Center for Energy in 2012 that showcased that Pitt could develop strengths in harsh environment materials and electric power engineering.

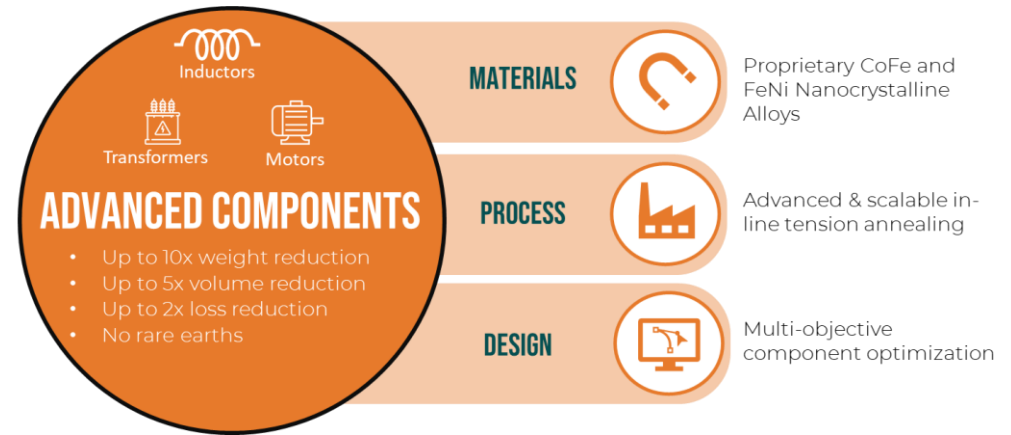


University of Pittsburgh, Center for Energy/ GRID Institute Energy Innovation Center – Facilities Layout



Materials: CorePower Magnetics – Redefining the Limits of Electronic components

- Formed: June 2020
- Spin-Out from Carnegie Mellon University
- >20 Granted or Pending Patents
- Location: Energy Innovation Center, Pittsburgh PA
- Commercial revenue (past 12 months): \$300k



Lead Team

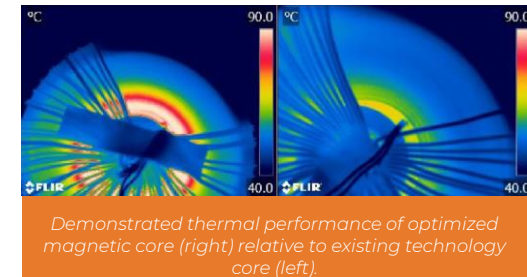
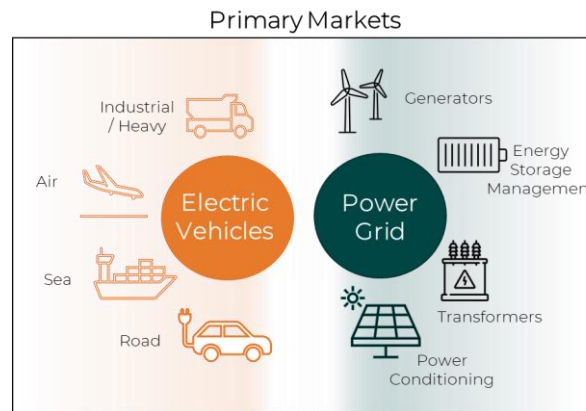
DR. SAM KERNION
CEO

DR. PAUL OHODNICKI, JR.
CTO

LEAH OHODNICKI
COO

DR. MICHAEL MCHENRY
Chief Scientist

KEVIN BYERLY
Lead Engineer





Utility: Duquesne Light is establishing a presence at the Energy Innovation Center for evaluating products and working closely with Pitt faculty and students.

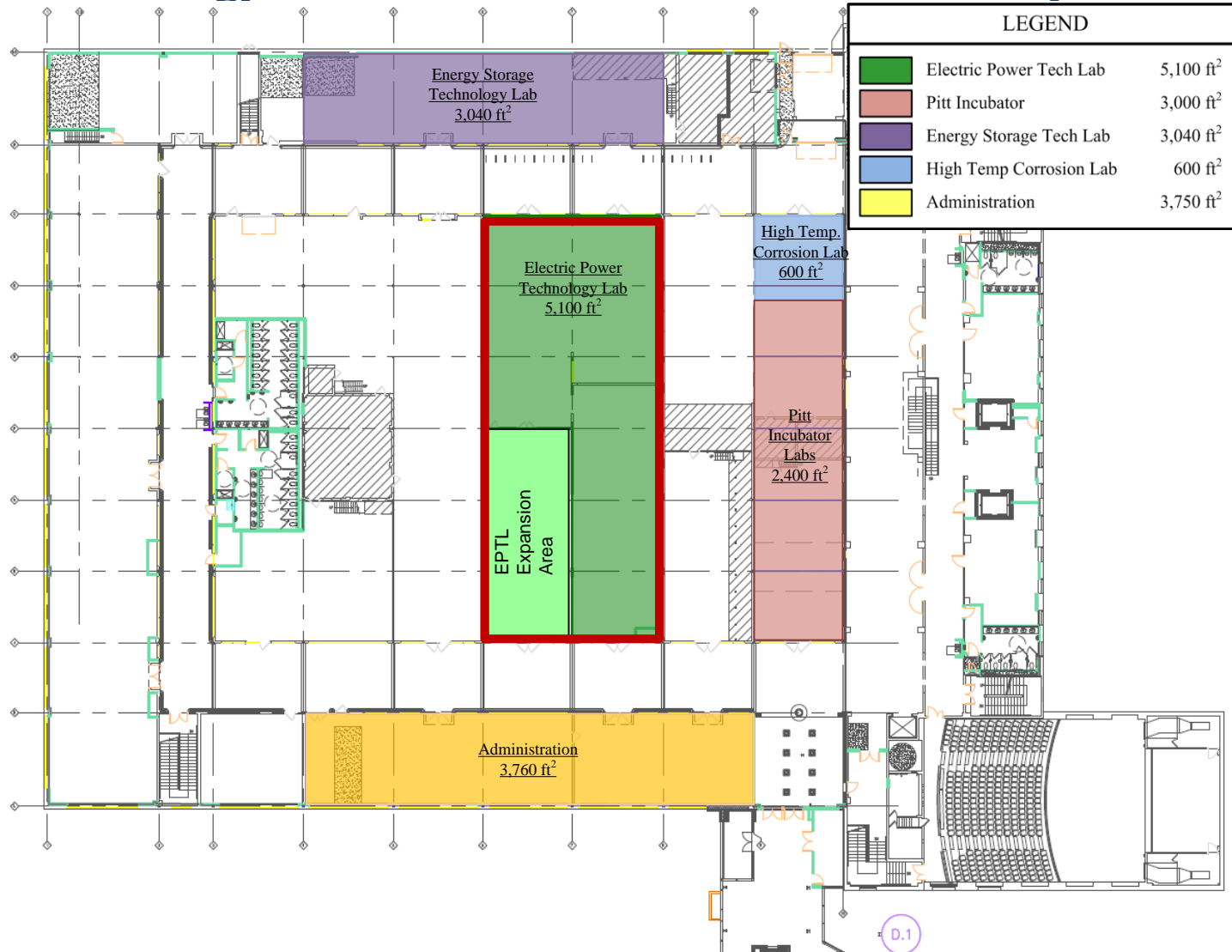


Pittsburgh, January 04, 2022

PARTNERING FOR A POWERFUL FUTURE

Pitt Energy GRID Institute Partners with Duquesne Light Co. to Modernize Electric Grid and the Workforce that Maintains It

University of Pittsburgh, Center for Energy/ GRID Institute Energy Innovation Center – Facilities Layout



Electric Power Technologies Laboratory Layout Plan, Features, and Capabilities

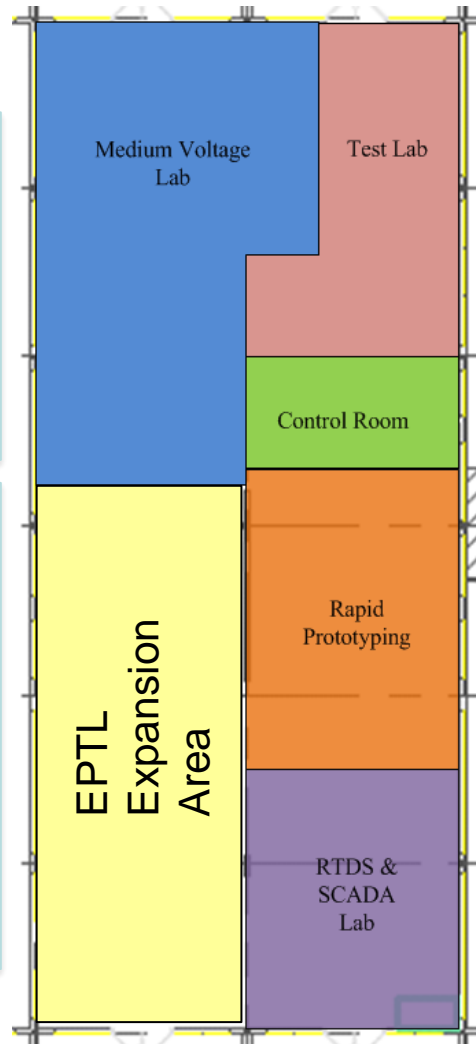
EPTL Layout

Power Distribution Areas

- **MV Grid Lab:** Reconfigurable lab for traditional projects. Designed using Eaton utility-grade distribution equipment.
- **Test Lab:** Isolated testing facility for safe testing of industry technologies, and EPTL research projects.
- **AC Flexibility:** Flexible power architecture capabilities through Eaton reclosers

General Areas of Map

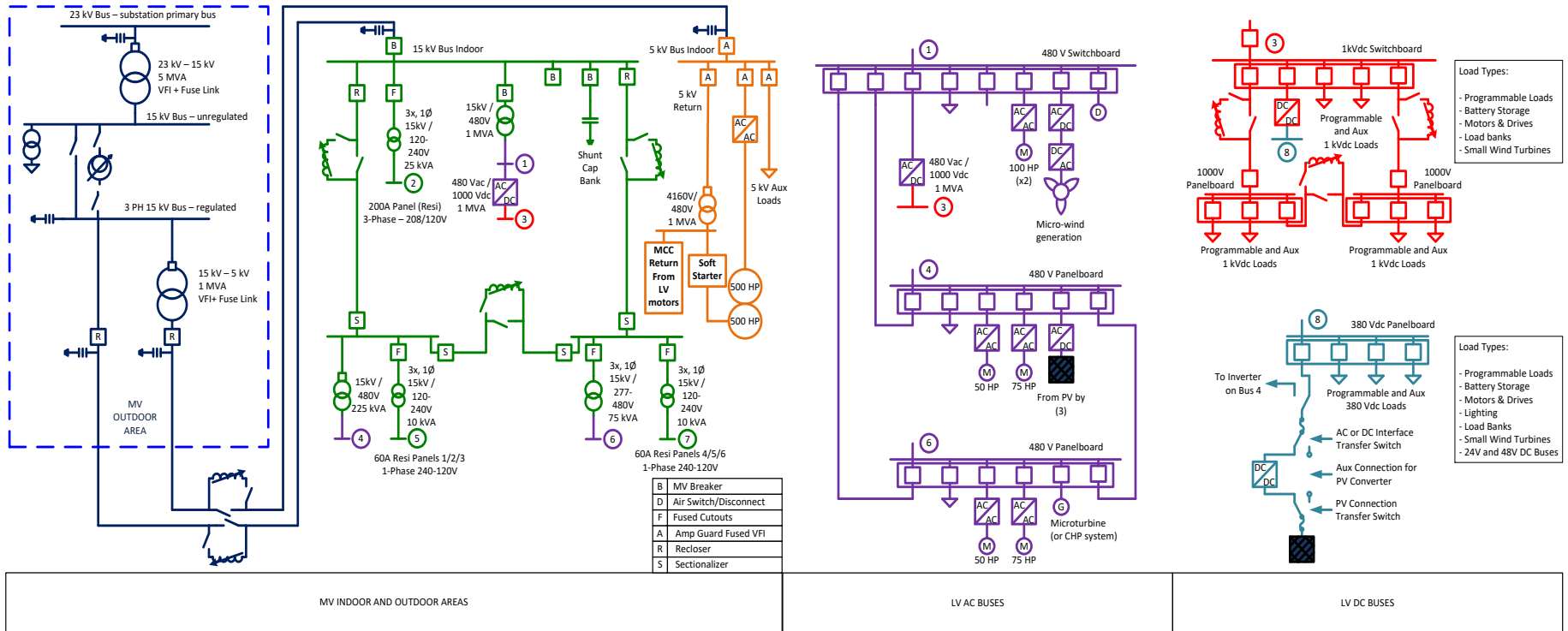
- **Rapid Prototyping:** Advanced machine shop for development of professional grade components and projects (Planning)
- **SCADA Center:** Automation, metering, and control for distribution network.
- **Relaying and Controls:** Protective relaying technologies and advanced control
- **RTDS Center:** Real-Time Digital Simulator and hardware in the loop capabilities – research and testing on industry leading equipment.



Laboratory Ratings and Features

- 15 kV-ac, 5 MVA capacity
- Microgrid Environment at Electric Utility Distribution Level
- Distributed Energy Resource and Load Integration
- Renewable Technologies (50kW Solar PV)
- Energy Storage, Electric Vehicle-2-Grid
- Real Time Digital Simulator (RTDS)
- SCADA and Systems Operations through Emerson Ovation Platform
- Protective Relaying and Substation Automation (Schweitzer and ABB Products)
- Advanced Control and Communications
- Modeling, Simulation, and Analysis through ANSYS
- FACTS and HVDC Control Systems (Planned)
- Medium Voltage Power Electronics Converters (and other power technologies development, prototyping, and testing -- e.g., IEEE 1547 certification)
- Technology testing and certification

Electric Power Technologies Laboratory Electrical One-Line Diagram



**Electric Power Technologies Lab: One-Line Diagram
(AC network: 23-kV/15-kV/4.16-kV/480-V > system)**

GRID – Outside of the EIC



Eaton MITS Substation

23kV to 13.8kV and 5kV



Electric Power Technologies Laboratory

Medium Voltage Features



- 13.8kV, 4.16kV, 480V, and 208V AC voltage rails.
- Rated to handle 5MVA of power capacity.
- System is reconfigurable through Eaton reclosers to isolate parts of the lab OR create a ring architecture.

Notable Equipment Provided In-Kind

- Eaton MITS, MV circuit breakers, reclosers, power transformers, 500HP motor drive, LV motor drives, and ground fault indicator (**Donated by Eaton**).
- **Emerson Ovation** platform communicates with all major equipment.
- All equipment installed by **Sargent Electric**.





Virtual Tour of Medium Voltage Lab

<https://my.matterport.com/show/?m=p85qmPtaFx>



AMPED Consortium wins a NSF Industry-University Cooperative Research Center planning grant.




Advanced Magnetics for Power and Energy Development (AMPED)
First "In-Person" Workshop
10/7/2021, Energy Innovation Center

Dr. Paul R. Ohodnicki, Jr.
 Director, Engineering Science Program
 Director, AMPED (Pitt)
 Contact Information: pro8@pitt.edu, 412-973-4416

Prof. Brandon Grainger, Co-Director, AMPED (Pitt)
Prof. Michael McHenry, Director, AMPED (CMU)
Prof. Maarten deBoer, Co-Director, AMPED (CMU)
Prof. Subhashish Bhattacharya, Director AMPED (NCSTU)
Dr. Richard Beddingfield, Co-Director AMPED (NCSTU)

Pittsburgh, February 08, 2022

AMPED CONSORTIUM RECEIVES NSF IUCRC PLANNING GRANT





Workforce:
How do you get access to the talent?



What Defines a Corporate Champion?

University of Pittsburgh

PittChronicle

Newspaper of the University of Pittsburgh

March 2, 2009

Swanson School, Eaton Corp. Form Partnership To Train Students in Electric Power Engineering

By: Sharon S. Blake

Financial Investment in Programs



Investment in Collaborations with Other Companies



Guest Lectures



Graduate Internships



Be Apart of the Student Community

Students DO NOT care about the company brand anymore. They care about company impact and culture.



What Does Eaton Do Yearly to Recruit?

Key Events

Career Fairs

Power Systems
Experience Center
Tour

Mock Resume &
Interview Workshops

In Person
Presentations/Panels

University Hosted
Networking Nights

Eaton Day on
Campus

Student Organization
Events &
Sponsorship

Excel Scholars
Program

On Campus
Interviews



What Does Eaton Do Yearly to Recruit?

Eaton Day



11am-1pm
Fun & Games
William Pitt Union Bigelow Lawn (near 5th Ave/Bigelow Blvd)
First 300 attendees receive free Insomnia Cookies!

4-5pm
Engineering Executive Speaker
Benedum Room 102
Nacho bar provided

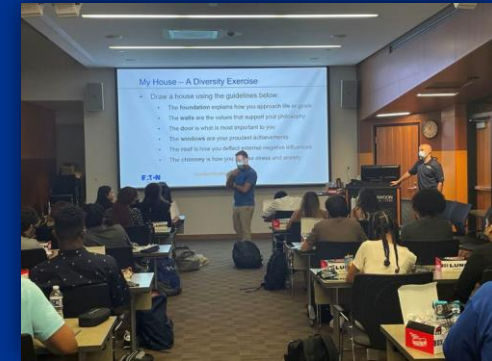
4-5pm
Business Executive Speaker
2650 Sennott Square (Alumni Networking Zone)
Nacho bar provided

5:30-6:30pm
Diversity Talk
William Pitt Union Room 630
Light refreshments & all attendees entered in a drawing for Apple AirPods!



Diversity: Pitt EXCEL x Eaton Summer & Fall 2022 Recap

- Engineering Diversity Student Organizations Planning Meeting
 - June 23, 2022, Eaton met with NSBE, SHPE, SASE, & SWE to discuss the needs of the organizations, and how Eaton could support through various events.
- Summer Engineering Academy (SEA) DEI Event
 - August 11, 2022, Eaton hosted a DEI event that included a team building activity. Introducing SEA First-Year Scholars on how working with a diverse team is essential to success.
- Eaton Luncheon
 - September 14, 2022, Pitt EXCEL hosted their 2nd annual Eaton Luncheon! This event allowed Scholars to network, connect, and learn about Eaton in a safe, casual setting over lunch! The luncheon was a huge success. Scholars said they felt comfortable networking with professionals as they are adjusting to post pandemic events.





Give Me the Numbers

Was Eaton's Investment Worth It ?

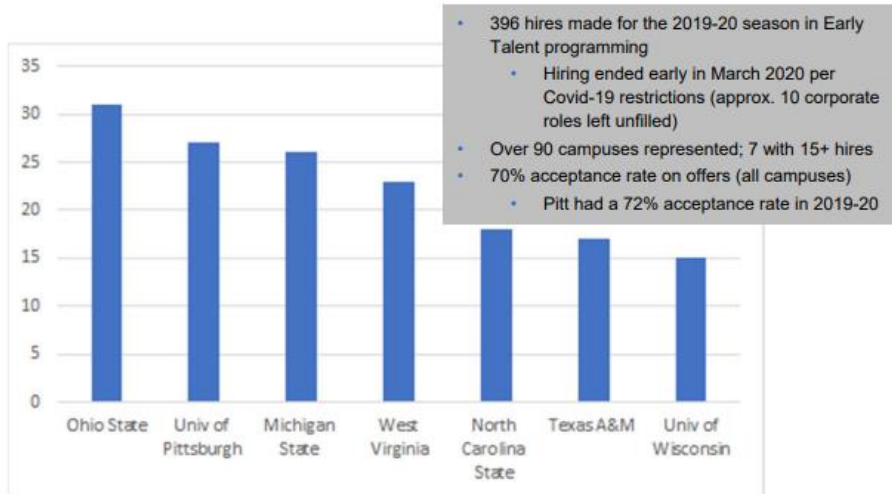


Eaton Gifts and Support / Recruitment Numbers

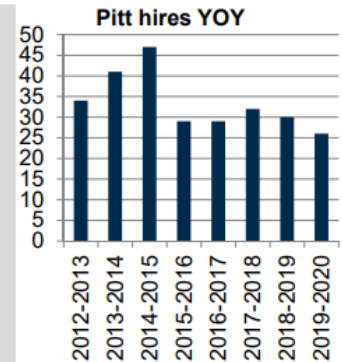
Approx. \$3.8M total gift & non-gift support, including:

- \$520,000 pledge in 2008 established the Partnership and lab in Benedum;
- \$750,000 current gift pledge;
- \$3M approx. value of in-kind equipment and design work support for high voltage lab;
- Career Center partner since 2019 totaling \$45,000;
- AMPED consortium member at \$20,000 level

Total Amount
\$1,781,994.08



- Pitt was the second leading campus in number of hires with 26 for the 2019-2020 season
 - 2019-2020 acceptance rate for Pitt was 72%
 - Eaton overall was 70% for 2019-2020
 - 81% of all hired Pitt students for 2019-2020 came from the Engineering program
- Overall early talent hiring at Eaton has stayed flat over the last 2 years
 - Total for 2019-2020 – 396 – Total for 2018-2019 – 416
 - Total Intern hires 2019-2020 – 215 – Total full-time hires 2019-2020 – 171





Acknowledgments

Students



Acknowledgments: Selection of Former and Current Students



Thomas Cook



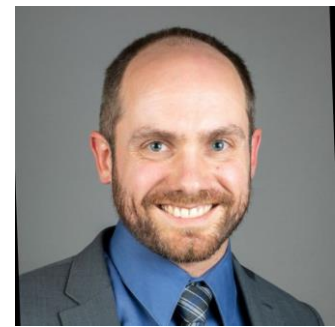
Zachary Smith



Santino Graziani



Thibaut Harzig



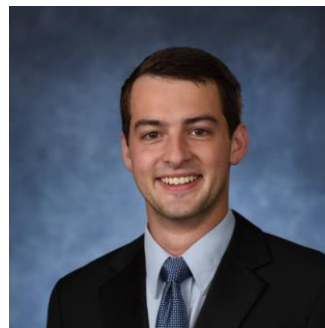
Patrick Lewis



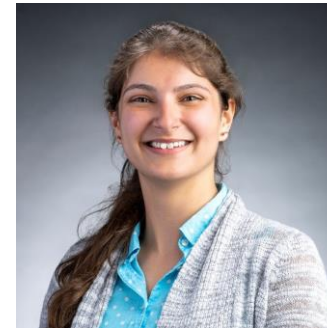
Hashim Al Hassan



Nate Carnovale



Ryan Brody



Sabrina Helbig



Todd Marzec



Maurice Sturdivant



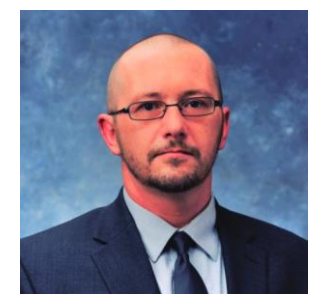
Adam Emes



Aidan Phillips



Nolan Scanlon



Mike Sullivan



Contact Information

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Questions???