2020 Proposed REU Project Descriptions

The purpose of this list is to provide 2020 POETS REU applicants with a preview of potential REU projects they could be assigned. The REU program coordinators will use the REU applicants' Statement of Purpose and answers to the additional questions to match students to a Research Advisor's research group. It is to the REU applicant's benefit to mention particular projects/advisors of interest.

Project Number: 1
REU Project Title: Dynamic Modeling and Validation of a Hybrid-Electric UAV System
Research Advisor(s): Andrew Alleyne (lead) and Cyril Rybicki
REU Project Title Description: An REU is sought to perform dynamic modeling and model validation for complex electro-thermal systems. A hybrid-electric Class-2 UAV propulsion, power and thermal system is under development within the POETS testbeds. We require dynamic models of this system including all of its subsystems. The REU student will utilize a previously developed MATLAB/Simulink toolbox to create models of the engine, power conversion, battery storage, motors, thermal management, and loads. The student will also validate these models using test data taken of the test stand. At the end of the project, the student will be able to run models of the hybrid-electric UAV under varying load conditions that match well with the test data. These models will be used for real-time system simulation as well as for controller design done by graduate students and post-docs. This project is suitable for students interested in control systems related to aerospace applications.

Project Number: 2
REU Project Title: Modeling and Validation of a Hybrid Electric UAV
Research Advisor(s): Andrew Alleyne (lead), David Huitink, and Fang Luo
REU Project Title Description: An REU is sought to perform dynamic modeling and model validation for complex electro-thermal systems. A hybrid-electric Class-2 UAV propulsion, power and thermal system is under development within the POETS testbeds. We require dynamic models of this system including all of its subsystems. The REU student will utilize a previously developed Matlab/SIMULINK toolbox to create models of the engine, power conversion, battery storage, motors, thermal management, and loads. The student will also validate these models using test data taken off of the test stand. At the end of the project, the student will be able to run models of the hybrid-electric UAV under varying load conditions that match well with the test data. These models will be used for real-time system simulation as well as for controller design done by graduate students and post-docs. This project is suitable for students interested in control systems related to aerospace applications.

Project Number: 3
REU Project Title: Characterization of GaN-based Magnetic Field Sensors within Dynamic Motor Environments REU
Research Advisor(s): Andrew Alleyne (lead), Greg Salamo, Alan Mantooth, Kiruba Haran, and Debbie Senesky
Project Title Description: Electric transportation systems of the future (e.g., aircraft, UAVs, automobiles) require advanced electronics (e.g., sensors) to monitor the state of the complex motor systems. Data from these electronics can be used to actively, control, protect and diagnose safety critical motors. The POETS center is developing Hall-effect sensors that can remotely detect magnetic field and electrical current within motor assemblies. For example, the Hall-effect magnetic field sensors (solid-state devices) can be used for sensing position, velocity or directional movement within motors during the start-up phase and during flight. This is especially important for monitoring the position of crank shaft or motor in moving objects. They also offer advantages over other sensors due to their non-contact wear free character and their comparatively low maintenance. Due to packaging they can also be less subject to error due to vibrations. In this project the student will investigate the effectiveness of packaging to reduce error due to vibrations which can cause small changes in the magnitude of the magnetic field that is sensed and therefore introduce error in the positioning data. The student will learn about high power electronics, Hall-effect sensors, and performance analysis as well as develop creativity by proposing explanations for observed data that the student will take under vibration circumstances and techniques to make improvements.

Project Number: 4
Research Advisor(s): Andrew Alleyne (lead), Kai James, Mehdi Asheghi, and Nenad Miljkovic
REU Project Title: Design and Control of a Reconfigurable Electro-Thermal Testbed
REU Project Title Description: This project will design, fabricate and control a modular scale thermal management testbed representative of an automotive system for electric and hybrid vehicles as depicted in the figure. The system will consist of pumps, flow valves, piping, heat exchangers, and heaters. The system will operate on a breadboard with quick connections to allow for re-configurability. A data acquisition and control (DAQ) command center (to be supplied) will be used to program thermal loading profiles akin to vehicle drive cycles. Additionally, the DAQ will be used to control the multiple cooling systems and record system performance. This is a good project for students interested in design and control of hardware systems. Additionally, it would suit Mechanical or Aerospace Engineers interested in electrified transport.

Project Number: 5
REU Project Title: System-of-systems optimized electric machine design and validation for integrated electrified powertrains**.**
Research Advisor(s): James Allison (lead) and Kiruba Haran
REU Project Description: The objective of this project is to develop a framework to design electric machines for electrified powertrains with a more holistic systems view. This includes detailed modeling of the electric machine, drives, and cooling system in a *system-of-systems* design optimization framework. This will be achieved by applying a multi-disciplinary design optimization (MDO) strategy in a hierarchical fashion to capture design coupling between the electric machine and associated powertrain components. MDO methods have been utilized to optimize electrified-powertrains for both ground and air vehicles to several levels of complexity. At one end of the spectrum, system-of-systems design optimization has been performed to size many aspects of an airplane. The electric machine in these studies is captured as a simple parameter. At the other end of the spectrum, the electric machine can be designed in detail with many physics considerations. System-level characteristics, however, are often ignored. Here we target a strategy that lies in between these two extremes: the detailed design of the electric machine can be performed while considering design coupling to the drive and cooling subsystems. Models that account for electro-thermal interactions will be used along with design optimization techniques. Helpful background for undergraduate students interested in applying for this project include: technical and hands-on experience with design/fabrication/testing of electric machines/motors, use and development of dynamic system/state space models, electromagnetic theory, heat transfer, numerical methods (specifically optimization and numerical solution of differential equations), and any experience with electrical or thermal system modeling and design.

Project Number: 6
REU Project Title: Radical New Density Levels for Passive LC Networks via Integrated S-RuM Components and System-Driven Freeform Multiphysics Design Optimization
Research Advisor(s): James Allison (lead) and Xiuling Li
REU Project Description: This project focuses on the design of a new type of configuration for inductors and capacitors, integrated into a dense LC network. Planar geometric designs are self-assembled into a rolled-up configuration, including multiple inductors and capacitors in a single component. This new concept provides many advantages from an electromagnetic and density perspective, and offers new opportunities in terms of design flexibility. This project focuses on design optimization methods for exploring new geometries for these LC networks, as well as development and testing of multi-physics models that are appropriate for design optimization studies. This project will build a foundation for future physical prototyping and testing within POETS testbeds. Desirable background for students contributing to this project include topics such as electromagnetics, finite element analysis, power electronics, and numerical methods (especially optimization and numerical solutions for differential equations).

Project Number: 7
REU Project Title: High-Power Density 3D Stacked Silicon Carbide Power Module Integrated with Busbar Interposer using Embedded Cooling REU Project
Research Advisor(s): Simon Ang (lead)
REU Project Title Description: This project proposes collaborative optimization concept to reduce the overall parasitic inductance of inverter system by integrating power module with its busbar system

Project Number: 8
REU Project Title: Testing of Electric Drive Traction Systems for Electric Vehicles
Research Advisor(s): Juan Balda (lead), Yue Zhao, and Nenad Miljkovic
REU Project Description: The REU student will develop an application for the User Manual of Testbed 2 to make sure that a third party not familiar with the Testbed 2 operation can use it without major difficulties. The REU student will be guided by Mr. Chris Farnell, who is the NCREPT test engineer, doctoral students, and a master student.

Project Number: 9
REU Project Title: Chain alignment of conjugated polymers for enhanced thermal conductivity
Research Advisor(s): Paul Braun (lead) and David Cahill
REU Project Description: Conjugated polymers have alternating single and double carbon-cabon bonds along the polymer backbone. This chemical structure produces high electrical conductivity that is important for applications in electronic devices and potentially also produces high thermal conductivity that would be of great use in the management of heat. In this project, the undergraduate research assistant will study methods for creating aligned, conjugated polymers with a goal of enhancing their thermal conductivity. The undergraduate assistant will gain experience in the materials processing and the characterization of materials microstructure by optical spectroscopy and x-ray diffraction.

Project Number: 10
REU Project Title: Fabrication and Testing of High Temperature Rechargeable Batteries and Supercapacitors at the University of Illinois
Research Advisor(s): Paul Braun (lead) and Thomas Searles
REU Project Title Description: In this project, the student will fabricate high temperature rechargeable batteries and supercapacitors. The energy storage devices will be fabricated in either coin cell or swagelok configurations and tested at both room temperature and the higher temperatures present within many electro-thermal systems. The student will perform post-mortem analysis of cells using optical microscopy and scanning electron microscopy.

Project Number: 11
REU Project Title: Narrow Diameter Vertically-Aligned Carbon Nanotubes for Rechargeable Battery Applications at Howard University
Research Advisor(s): Thomas Searles (lead) and Paul Braun
REU Project Title Description: In this project, the student will fabricate narrow diameter (< 2 nm) vertically-aligned carbon nanotubes for high temperature rechargeable batteries using a new method for nonmetallic catalyst growth. A key result of this study will be the influence of diameter and packing density of the carbon nanotube forest anodes directly related to the proposed POETS project. The student will perform analysis of the nanotube forests with Raman spectroscopy, UV-Vis, SEM and then work towards integration of these forests as anode materials in coin-cells to be fabricated at Howard.

Project Number: 12
REU Project Title: 3D integrated power electronics and microfluidic cooling for future electric aircraft.
Research Advisor(s): Ken Goodson (lead), Nenad Miljkovic, Mehdi Asheghi, and Yue Zhao
REU Project Title Description: This project will develop novel 3D integrated power converters and advanced thermal management solutions for future electric aircrafts, enabling radically new aircraft designs with up to 40% fuel savings. REU students will participate in the design (EDA, CAD, CAM), fabrication (soldering, 3D printing, assembly) and testing (electrical wiring, measurements, data analysis) of high power inverters and advanced heatsink designs.

Project Number: 13
REU Project Title: Phase-Change Thermal Switches with Extreme Performance
Research Advisor(s): Ken Goodson (lead), Nenad Miljkovic, and Mehdi Asheghi
REU Project Title Description: This project focuses on thermal characterization of phase change based thermal switches to be integrated with power electronics systems. Characterization will be done with both calorimetry as well as infrared imaging with and without coupling of the thermal switch to electronic devices,

each device dissipating different power levels. The measured temperatures will be analyzed to calculate local heat flux and the thermal performance of the switch. The measurements and analysis will be performed under different cooling conditions and for different switch designs including an all glass switch and a hybrid silicon/glass switch. A key issue to explore is the thermal switch sealing and development, and how well the switch performance over time. The results of this work will be used to develop electro-thermal design guidelines for circuit board layout and the cooling system.

Project Number: 14
REU Project Title: Development of a High Performance µ-cooler for High Power Electronics Modules
Research Advisor(s): Kenneth Goodson (lead) and Debbie G. Senesky
REU Project Title Description: Recent trends towards smaller electronics packaging and high power devices result in increasing power densities which require aggressive thermal management including special consideration for reliability, size, noise and power consumption issues. This project examines cooling strategies for high power electronics devices using chip level-embedded cooling solutions with micro-channels directly fabricated into Si or SiC substrates compatible with fabrication of power electronic devices thus eliminating any thermal interface and decreasing overall thermal resistance. We consider both single and two-phase performance of these systems, characterizing thermal resistance, temperature uniformity, hot spot mitigation as a function of working fluid composition and operating condition as well as micro-channel geometry. Tight integration of advanced microfluidic cooling solutions with heat generating devices offers potential for dramatic improvements in the thermal management of power electronics with attendant gains in performance and efficiency. Specific tasks include but not limited to basic calculation and measurement of temperature and pressure drop in microheat exchangers.

Project Number: 15
REU Project Title: High Frequency Motor and Drive Characterization Test
Research Advisor(s): Kiruba Haran (lead), Nenad Miljkovic, and Fang Luo
REU Project Title Description: Assist graduate students in integrating and testing high-frequency motor and drive with Test-bed 3. Characterize motor resistance, inductance, back-emf, torque coefficient tests at open-circuit and partial load tests. Measure efficiency, loss, and temperature of motor and inverter at various speed and load torque.

Project Number: 16
REU Project Title: High temperature phase change materials for passive electronic temperature control
Research Advisor(s): David Huitink (lead), Simon Ang, Yarui Peng, and Nenad Miljkovic
REU Project Title Description: Phase change materials (PCMs) are materials that can be used to remove or store heat during a transformation between solid and liquid phases. These transitions can passively remove heat without need for pumps or fans, which makes them useful for mobile systems which need to reduce the total system weight and complexity for overall efficiency. Additionally, the relative low spatial requirements for PCMs to be integrated into electronic systems lends itself to opportunity in designing innovative solutions for 3D patterning and integration for applications in electric vehicles, aircraft and spacecraft, where air cooling is not available. In this REU Project, the researcher will partner with graduate students working on Power Electronics for developing next generation PCMs that perform latent heat exchange at temperatures ranging from 150-250C, and develop additive manufactured housings for implementing PCM heat transfer optimization.

Project Number: 17
REU Project Title: Additive manufacturing advantages in Electronics Heat Dissipation
Research Advisor(s): David Huitink (lead), Fang Luo, and Sonya Smith
REU Project Title Description: In this project, the REU student will employ additive manufacturing principles to developing novel geometries for heat conduction, convection and associated energy transport, for implementing with electronic assemblies. It will require creative thinking, experience and familiarity with solid modeling tools and heat transfer behavior. The developed designs will be evaluated for performance compared to existing heat sink designs by FEA and experimental techniques. Students will have the opportunity to work across disciplines in delivering innovative cooling technology for electronics packaging designs, and gain valuable experience in additive manufacturing processes as well as electro-thermal co-design of traction inverter systems.

Project Number: 18
REU Project Title: Temperature measurements on thermal switches and power electronics
Research Advisor(s): William King (lead), Nenad Miljkovic, Yue Zhao, and Alan Mantooth
REU Project Title Description: This project focuses on thermal characterization of power electronics systems and the evaluation of novel cooling systems. The electronics are circuit boards with several types of electronic devices, each device dissipating a different power level. The circuit boards are cooled with air blowing over a heat sing. We will use an infrared camera to characterize the microscale temperature distribution on the circuit board. The measured temperatures will be analyzed to calculate local heat flux and the thermal properties of the circuit board. The measurements and analysis will be performed under different cooling conditions and for different circuit board layouts. A key issue to explore is the thermal switch integrated into the circuit board, and how the switch affects the circuit board temperature. The results of this work will be used to develop electro-thermal design guidelines for circuit board layout and the cooling system.

Project Number: 19
REU Project Title: Extreme miniaturization of inductors by self-assembly REU Project Title Description:
Research Advisor(s): Xiuling Li (lead), Paul Braun, Zhendong Yang, and Derek Wood
REU Project Title Description: There is an ever-increasing demand to increase power density and reduce size and cost. Although significant integration of compact active devices in power converters has been made, one of the barriers to ultimately maximize the power density lies in the difficulty to minimize the power inductors. Making inductors with small footprints but large power handling ability often mandates conflicting requirements in designs and processes. To create and fabricate novel passive components for dramatic power density improvement, we explore a 2D for 3D membrane based, scalable, and CMOS compatible technique, strain induced self-rolled-up membrane nanotechnology. REU students will be trained to do fabrication in cleanrooms or electromagnetics modeling.

Project Number: 20
REU Project Title: High Power Density, High Speed motor drive design, control and testing
Research Advisor(s): Fang Luo (lead), David Huitink, and Kiruba Haran
REU Project Title Description: The PI will organize a summer program and help the REU students to get hands-on experiences in highdensity motor drive design and joint-testing tasks. Through this training, the students will get familiar with multi-disciplinary design philosophy and procedures. The PI is already involved in POETS iREU programs. He will further extend his experience in the REU program associate with this proposed project.

Project Number: 21
REU Project Title: High Density Passive Filter Design and Integration
Research Advisor(s): Fang Luo (lead), Xiuling Li, and Morgan Ware
REU Project Title Description: The PI has been involved with POETS iREU program, and will continue to organize iREU summer programs with the focus on passive filter deign, optimization and integration. Students will have a change to access HiDEC for LTCC fabrication training. The PI will elaborate his CAREER award education effort to recruit/involve more under represented and WIE students in this REU project.

Project Number: 22
REU Project Title: Carbon Nanotube Thermal Conduits
Research Advisor(s): Joseph Lyding, Simon Ang, Sonya Smith, and Gang Wang
REU Project Title Description: Carbon nanotube-based composites with thermal conductivity comparable to copper are being integrated with printed circuit boards as well as heatsinks for high-power electronic devices. In addition, free-standing carbon nanotube thermal conduit materials are being developed and will be tested for thermal, electrical and mechanical properties.

Project Number: 23
REU Project Title: User Interface for PowerSynth-Based Standard Power Module Design Flow
Research Advisor(s): Alan Mantooth (lead) and Yarui Peng

REU Project Title Description: The project aims to design a user interface either as a webpage or a standalone tool using Java or the QT library. A power module designs can choose from several existing design templates and packaging options such as DBC or LTCC, with different configurations of device type and rating, substrate size and thickness, and cooling solutions. After gathering the user input, it uses PowerSynth, a power module layout synthesis tool, to create and optimize the layout and export necessary design files to be implemented and manufactured. The designs will then be packaged and tested at HiDEC and NCREPT based on users' requirements. An REU student with interest in computer-aided design, power module layout, power module fabrication and test, and web and software development are encouraged to apply.

Project Number: 24
REU Project Title: Integration of a Large Footprint μ-cooler and Multi-chip Silicon Carbide Power Module
Research Advisor(s): Alan Mantooth (lead) and Ken Goodson
REU Project Title Description: Recent trends towards smaller electronics packaging and high power devices result in increasing power densities which require aggressive thermal management including special consideration for reliability, size, noise and power consumption issues. This project examines cooling strategies for high power electronics devices using chip level-embedded cooling solutions with micro-channels directly fabricated into Si or SiC substrates compatible with fabrication of power electronic devices thus eliminating any thermal interface and decreasing overall thermal resistance. Tight integration of advanced microfluidic cooling solutions with heat generating devices offers potential for dramatic improvements in the thermal management of power electronics with attendant gains in performance and efficiency. Specific tasks include but not limited to basic calculation and measurement of temperature and pressure drop in microheat exchangers and laboratory fabrication experience with advanced integration techniques.

Project Number: 25
REU Project Title: Water-Based Immersion Cooling of High Power Density Electronics
Research Advisor(s): Nenad Miljkovic (lead), Pingfeng Wang, and Yue Zhao
REU Project Title Description: Immersion cooling with nanoengineered surface coated electronics has the potential to act as an ideal cooling strategy due to the enhanced boiling heat transfer and direct cooling of devices. This REU project will involve the thermal testing of GaN devices coated with a nanoengineered coating using immersion cooling to achieve cooling heat fluxes approaching 200 W/cm^2. The student will be required to learn and use thermal characterization tools such as high-speed imaging, thermography, and LabVIEW electrical control to characterize the integrated device performance. Surface nanostructure fabrication will be learned and utilized prior to testing while thermal and error analysis will be learned and utilized after testing.

Project Number: 26
REU Project Title: Thermal Conductivity of Nanoscale Wide Band Gap Materials
Research Advisor(s): Eric Pop (lead), Debbie Senesky, Xiuling Li, and Greg Salamo
REU Project Title Description: So-called wide band gap (WBG) materials like AlN and h-BN are unique in nature by being electrically insulating but with excellent thermal conductivity. However, the thermal conductivity of these materials is largely unknown in nanoscale (~100 nm) thin films. In this project, we are measuring the thermal properties of these materials in the nanoscale regime, and developing computer models to understand our findings. Please join us if you'd like to learn how to do nanoscale thermal measurements, how to interpret your data and create computer models, while working with a class of important materials that will play a large role in the future of power electronics, autonomous vehicles, and the electric power grid.

Project Number: 27
REU Project Title: Thermal Management of Lithium Ion Battery Packs
Research Advisor(s): Sonya Smith (lead), Paul Braun, and Joe Lyding
REU Project Title Description: The REU student will conduct simulations and optimization of candidate battery pack thermal management designs under the direction of a graduate-student mentor (Damon Gresham-Chisholm). The student will explore the impact of vehicle operating temperature as well as active and passive cooling designs on a small battery pack. The summer student will generate trends and plots

extrapolated from data provided by experiments and computations. The student will also give weekly presentations about their progress.

Project Number: 28
REU Project Title: Numerical Analysis of Hydrophobic Nanostructures in Microchannel Heat Sinks
Research Advisor(s): Sonya Smith (lead) and Kenneth Goodson
REU Project Title Description: The REU student will conduct thermal analysis of high-fidelity heat sink models under operating conditions specified by the peer mentor (Darryl Jennings). The student will explore the impact of hydrophobic nanostructures on microchannel flow. The student will generate trends and plots extrapolated from data provided by the numerical analysis. The student will also give weekly presentations about their progress.

Project Number: 29
REU Project Title: High Temperature Capacitors
Research Advisor(s): Morgan Ware (lead), Fang Luo, and Yue Zhao
REU Project Title Description: We have spent many years developing the growth of III-V semiconductors through molecular beam epitaxy and are focusing on high temperature electronics through the wide bandgap family of III-nitride semiconductors. REU students will gain experience in device development from the most fundamental level of the crystal growth. Materials characterization including, for example, structural, electrical, and optical, through X-ray diffraction, capacitance-voltage measurements, and photoluminescence, respectively, will be heavily relied upon. Specific focus will be on the high temperature response of these characteristics.

Project Number: 30
REU Project Title: Comprehensive Validation of POETS SiC Traction Inverters
Research Advisor(s): Yue Zhao (lead), Juan Balda, and Nenad Miljkovic
REU Project Title Description: The REU student will work closely with the graduated students working on this project to perform comprehensive testing and validation for all the POETS SiC traction inverters including POETS GEN-1, GEN-2 and the preliminary prototypes of Next-GEN. The tests will be performed using vehicle simulator on POETS testbed 2 at UA NCREPT. The REU project will give the REU student hands on opportunities to test the motor drives, collect data, and operate the real-time simulator.