

Ph.D. in Electrical Engineering

The following resolution is presented to the committee for approval and recommendation to the Board of Trustees for appropriate action:

RESOLUTION 16-

WHEREAS, Wright State University is proposing a new Ph.D. program within the Department of Electrical Engineering and the College of Engineering and Computer Science; and

WHEREAS, establishing a Ph.D. in Electrical Engineering will better serve the Electrical Engineering doctoral students and is a natural next step in the growth of doctoral engineering programs at Wright State University and consistent with national, state, and regional drives to increase education in the STEM fields; and

WHEREAS, the program has been approved by the Faculty Senate and the Provost; therefore be it

RESOLVED that the Ph.D. in Electrical Engineering, as submitted to this meeting be, and the same hereby is endorsed.

I offer this motion:

Do I have a second?

Roll call vote:

PROPOSAL

Doctor of Philosophy in Electrical Engineering

Corresponding to Specializations Currently Offered

in the Existing Degree

Doctor of Philosophy in Engineering

**Prepared by
Department of Electrical Engineering
Wright State University
February 2015**

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Executive Summary

This proposal seeks to establish an independent Ph.D. in Electrical Engineering within the Department of Electrical Engineering of the College of Engineering & Computer Science at Wright State University. Faculty in electrical engineering currently advise students within the interdisciplinary Ph.D. in Engineering program. This program was established less than 20 years ago and has flourished under the leadership of Dr. Ramana Grandhi. As a natural next step in the growth and evolution of doctoral studies in engineering at Wright State University, the faculty in electrical engineering seek to establish an independent Ph.D. program to better serve their doctoral students and continue to grow the volume of doctoral-level study and research at the university.

1 Degree Proposal and Motivation

Wright State University proposes to establish a new Doctor of Philosophy in Electrical Engineering that a number of faculty from 3 of the 7 focus areas under the existing multi-disciplinary Doctor of Philosophy in Engineering degree. The focus areas to be drawn from are as follows:

- Controls & Robotics
- Electronics, Microwave, VLSI, & Nanotechnology
- Sensor Signal & Image processing

Faculty within each of these focus areas will likely remain from other departments with specialties in Mechanical Engineering, Materials Engineering, Biomedical Engineering, Industrial Engineering, or Human Factors Engineering. The existing Ph.D. in Engineering degree would continue to operate unaffected over all existing focus areas, and we would expect no change in the above three focus areas, unless so chosen by the remaining faculty.

The existing Ph.D. in Engineering produced its first graduate in 1999, and since that time, it has produced a total of 141 with 47 of those graduates advised by faculty in Electrical Engineering. The Ph.D. in Engineering program averages roughly 100 active students per year with 41 students currently active under the advisement of faculty in Electrical Engineering. Hence, the proposed program is already thriving under the current multi-disciplinary degree, and establishing it as an independent degree program would have the following benefits:

- enhancement of our marketing of the degree to students,
 - Enrollment in the Ph.D. in Engineering program for electrical engineering faculty is dominated by students that have earned earlier degrees at WSU and by local students. Both of these populations are aware of the program by virtue of proximity. Lack of an electrical engineering brand on the Ph.D. program makes it difficult to market to students outside of the Dayton region. Furthermore, we observe that the WSU Department of Electrical Engineering is not featured in the attached NRC rankings, owing in part to lack of our own independent Ph.D. program, despite our research output relative to peers.*
- permit the development of program requirements and curriculum that is more responsive to student needs, and
 - The Ph.D. in Engineering program currently requires core engineering courses outside the field of electrical engineering that are largely of no use to students seeking doctoral-level study in electrical engineering. The Ph.D. in Engineering program also requires 3 semester hours of a seminar course, comprising all focus areas and implying that most of the presented seminars will be for advanced research in areas that are inaccessible to doctoral students in electrical engineering. The proposed program will eliminate these requirements and refocus the curriculum on doctoral-level preparation in electrical engineering.*
- provide graduating students a degree that is more easily marketed to employers.
 - The value of a "Ph.D. in Engineering" is not readily apparent to employers, requiring graduating students to explain that their course content and dissertation work largely mimic a Ph.D. in Electrical Engineering. Lacking the opportunity for this explanation students will may be disadvantaged in some employment pursuits or may take the liberty to represent their degree as a "Ph.D. in Electrical Engineering" on the resumes.*

The combination of these benefits should lead to increased student enrollment and improved student outcomes. Faculty and students in this program would already be engaged with a wide variety of research sponsors and employers, for example: AFRL, NASIC, MacAulay-Brown, SAIC/Leidos, Matrix Research & Engineering, Etegent, Defense Research Associates, Defense Engineering Corporation, Northrop Grumman, SET Associates, Raytheon, Boeing, Systems Technology Research, National Science Foundation, Army Research Lab, UDRI, HPTI, Ohio Supercomputer Center, Ohio State University, Alphatech, ATK-Mission Research, and Wright Brothers Institute. Establishing an independent Ph.D. in Electrical Engineering would improve our brand recognition and expand our reach and impact in the local community and nationally.

2 Curriculum Requirements

2.1 Current Program Requirements

The contents of this subsection are excerpted from the web site for the Ph.D. in Engineering program.

To obtain the Ph.D. in Engineering degree, a student must complete an approved Program of Study that contains at least 90 semester graduate credit hours beyond the bachelor's degree in engineering or an equivalent degree, or 60 graduate semester credit hours beyond a Master's degree in engineering.

To meet the 90 semester graduate credit hours required for the Ph.D. in Engineering degree, a student must:

- Complete at least three interdisciplinary core courses and earn a minimum grade of "B" in each course. The core courses are
 - EGR-7010, Applied Linear Techniques
 - EGR-7020, Systems Engineering and Analysis
 - EGR-7030, Computation Engineering Analysis
 - EGR-7040, Design Optimization
 - EGR-7050, Design and Analysis of Engineering Experiments
- Complete 18 semester credit hours of major courses (7000-level and above) in electrical engineering, biomedical engineering, human factors engineering, mechanical engineering, materials science and engineering, or in a focus area
- Complete at least 9 semester credit hours of research focus area courses, i.e., graduate courses (6000-level and above). This may include core courses and courses used to satisfy graduate course requirements
- Complete at least 6 semester credit hours of breadth courses, i.e., graduate courses (6000-level and above) outside the research focus area
- Complete at least 6 semester credit hours of graduate (6000-level and above) courses in mathematics (MTH) or statistics (STT).
- Complete 3 semester credit hours of EGR 8910, Ph.D. Seminar
- Take no more than 3 semester credit hours of independent study (Course number 7900)
- Complete between 30-40 semester credit hours of dissertation research
- Complete the requirements of the Program Qualification
- Complete the Candidacy Examination satisfactorily
- Complete the Research Proposal Defense satisfactorily
- Present a 50-minute dissertation seminar during an EGR 8910 course meeting
- Submit at least one manuscript to a peer-reviewed journal
- Complete the Dissertation Defense satisfactorily
- Complete the final dissertation satisfactorily, as judged by the student's Dissertation Committee and the Graduate School

Students having non-engineering backgrounds are required to successfully complete the equivalent of the relevant math and science sequences required for an undergraduate engineering degree appropriate for their focus area. These courses cannot be used to satisfy degree requirements.

2.2 Proposed Program Requirements

To obtain the Ph.D. in Electrical Engineering degree, a student must complete an approved Program of Study that contains at least 90 semester graduate credit hours beyond the bachelor's (BS) degree in electrical engineering or an equivalent degree, or 60 graduate semester credit hours beyond a Master's (MS) degree in electrical engineering or a related area. These requirements are consistent with national norms.

In addition to meeting graduate credit hour requirement for the Ph.D. in Electrical Engineering degree, a student must do the following.

- Complete at least three EE breadth courses by choosing one course from each of at least three focus areas and earn a minimum grade of "B" in each course along with any associated laboratory component. None of these courses can be duplicative of courses already taken at the undergraduate level. Students originally enrolled in the Ph.D. in Engineering may count engineering core courses, which were completed in spring 2015 or earlier, towards the breadth requirement. Breadth courses must be at the 7000-level or above, although courses at the 6000-level may be permitted with approval from Director of Graduate studies. The Ph.D. in Electrical Engineering focus areas include the following.

VLSI	Electronics	RF & Microwave
Signal Processing	Communications	Controls

- Complete 20 semester credit hours of courses numbered 7000-level and above in electrical engineering. Core breadth courses may be included in the 20 semester hours.
- Complete at least 6 semester credit hours of graduate (6000-level and above) courses in mathematics (MTH) or statistics (STT).
- Take no more than 3 semester credit hours of independent study (EE 7900).
- Complete between 30-45 semester credit hours of dissertation research.
- Pass the Program Qualification Exam.

Upon completion of the coursework students are required to pass a qualifier where problem solving and independent research comprehension skills are thoroughly examined by a Ph.D. committee comprised of subject matter experts.

- Pass the Research Proposal Defense.

Upon passing the qualifier, a student is required to survey the literature to master the current state of the art in the student's intended area of research. Based on this study, the student is required to independently develop a novel research plan that proposes to push the envelope of current state of art in research in specific areas in a significant way. The novelty in the research proposal is reviewed, examined and approved by the subject matter experts in the Ph.D. committee.

- Present a seminar based on their dissertation research during an open meeting or conference.
- Submit at least one manuscript to a peer-reviewed (IEEE quality) journal.
- Pass the oral Dissertation Defense and satisfactorily complete the written Dissertation Document

A student is required to submit a comprehensive written report on the new research findings, which must be approved by the dissertation committee. Furthermore, the student is required to give an oral presentation to defend the findings in the written report to a Ph.D. dissertation committee comprised of subject matter experts in the field.

If needed, students are required to successfully complete any prerequisite material at the undergraduate

level. These courses cannot be used to satisfy Ph.D. degree requirements.

3 Degree administration

The proposed Ph.D. in Electrical Engineering would be administered by the Department of Electrical Engineering within the College of Engineering & Computer Science at Wright State University. The curriculum would be established, assessed, evaluated, and maintained by the department's Graduate Studies Committee, which is chaired by the Director of Graduate Studies. The Department of Electrical Engineering already has the largest graduate student population at the university with 393 students enrolled in the Master of Science in Electrical Engineering as of fall semester 2014. Therefore, the department will assign a 1/2-time administrative assistant to help support the Ph.D. program, and no administrative support will be sought from the Ph.D. in Engineering program. In addition, all students enrolled in the Ph.D. in Electrical Engineering would be required to have a dissertation advisor, who would naturally assume much of the responsibility in advising a student on defining their program of study and completing degree requirements.

4 Evidence of need

Establishing an independent Ph.D. in Electrical Engineering is a natural next step in the growth of doctoral engineering programs at Wright State University. This is consistent with national, state, and regional drives to increase education in the STEM fields at all levels. The Ohio 3rd Frontier program annually cites technology focus areas for investment in the state of Ohio. The list for 2014 included the following topics that would be impacted by a Ph.D. in Electrical Engineering: advanced materials, aeropropulsion power management, fuel cells & energy storage, medical technology, sensing & automation, and situational awareness & surveillance. Research within the Department of Electrical Engineering has historically touched on all of these areas, and establishment of an independent Ph.D. in Electrical Engineering would facilitate growth of student enrollment in these and supporting technology areas and would facilitate the attraction of faculty and industry partners in these areas.

We also note the close proximity of Wright-Patterson Air Force Base, the largest employer in Ohio, which houses the Air Force Research Laboratory, the National Air & Space Intelligence Center, and several major program offices. These government facilities have attracted and sustained a surrounding ecosystem of support contractors. The combined government and private employers have substantial historical and ongoing needs for students trained in electrical engineering with advanced degrees. This is demonstrated by the large number of graduates from the Ph.D. in Electrical Engineering that are employed in the local community as listed in the table below.

Admittedly, there are a number of other Ph.D. in Electrical Engineering programs within the state of Ohio system, including at the University of Dayton within our own regional community. However, we note that, under our present means of operation under the umbrella Ph.D. in Engineering program, we have found a useful niche to serve within the Ohio doctoral education community. We prevalently serve local students within the Dayton-WPAFB ecosystem, and our faculty have found areas of research emphasis (e.g., sensor exploitation, VLSI, power electronics) that are distinct from the University of Dayton's own areas of strength. Owing to the relatively small size of the Electrical Engineering faculty at both institutions, it seems that they have easily found room to coexist and even collaborate, for example on the IDCAST program from several years ago.

Advisor	Year	First	Last	Employer	Location (city, state)
Dr. Brown	2014	John	Catnar	Air Force Research Laboratory	Fairborn, OH
Dr. Brown	2014	John	Middendorf	Mound Laser and Photonics Center	Kettering, OH
Dr. Chen	2007	Kiranraj	George	California State University	Fullerton, CA
Dr. Chen	2007	Mingzhan	Wang	Science and Technology of China	Chengdu, China
Dr. Chen	2008	Kumar	Yelamarthi	Central Michigan University	Mount Pleasant, MI
Dr. Chen	2009	Yu-Heng	George Lee	RBS Technologies, LLC	Beavercreek, OH
Dr. Delbel	2012	Satya	Ganti	Alfred University	Alfred, NY
Dr. Emmert	2011	Harish	Gopalakrishnan	ANSYS-Apache Design Inc	San Diego, CA
Dr. Garber	2002	Michael	Bryant	Matrix Research	Beavercreek, OH
Dr. Hong	1999	Erik	Biasch	Air Force Research Laboratory	Rome, NY
Dr. Hong	2002	Shi	Shen		
Dr. Hong	2005	Joseph	Anderson		
Dr. Hong	2005	Shunguang	Wu		
Dr. Hong	2008	Peter	Hilnomaz		
Dr. Hong	2010	Arunesh	Roy		
Dr. Hong	2011	Nicholas	Gale		
Dr. Hong	2012	Andrew	Kondrath		
Dr. Hong	2012	Wu	Yang		
Dr. Kazimierczuk	2004	Brad	Bryant	Dayton-Phoenix Co	Dayton, OH
Dr. Kazimierczuk	2004	Karl	Gudmundsson	Iceland University	Reykjavik, Iceland
Dr. Kazimierczuk	2005	Donald	Kessler	Dayton-Research Inst	Dayton, OH
Dr. Kazimierczuk	2005	Richard	Kleinmit	Wright State University	Dayton, OH
Dr. Kazimierczuk	2009	Gregory	Cazzell	WPAFB	Dayton, OH
Dr. Kazimierczuk	2010	Robert	Fitch	WPAFB	Dayton, OH
Dr. Kazimierczuk	2010	Nisha	Kondrath	Villanova University	Philadelphia, PA
Dr. Kazimierczuk	2010	Dakshina	Murthy Bellur	Cummins Power Generation	Minneapolis, MN
Dr. Kazimierczuk	2010	Simon	Trischler	Wright State University	Dayton, OH
Dr. Kazimierczuk	2012	Veda Prakash	Galligekere	Lear Co	Southfield, MI
Dr. Kazimierczuk	2012	Julia	Lee	Emerson Co.	Cleveland, OH
Dr. Kazimierczuk	2012	Rafal	Wojda	ABB	Cracow, Poland
Dr. Petkie	2014	Ryan	Hamilton	Wright State University	Dayton, OH
Dr. Rattian	2004	James	Adams	Lockhead Martin	Boulder, CO
Dr. Rattian	2013	Nicholas	Baine	Grand Valley State University	Allendale, MI
Dr. Rattian	2013	Pratikumar	Desai	Imbus, Inc	San Francisco, CA
Dr. Ren	2013	Christopher	Benedik	MacAulay-Brown	Dayton, OH
Dr. Rigling	2008	Philip	Hanna	AFRL	Dayton, OH
Dr. Rigling	2009	Lee	Patton	Matrix Research	Dayton, OH
Dr. Rigling	2011	Orelie	Fogle	Wright State Research Institute	Dayton, OH
Dr. Rigling	2012	Andrew	Lingg	Elegant Technologies	Dayton, OH
Dr. Shaw	2008	Vasu	Chakravarthy	Air Force Research Laboratory	Dayton, OH
Dr. Sifard	2000	Khalid	Abed	Jackson State University	Jackson, MS
Dr. Sifard	2008	Michael	Myers	Local Contractor, AFRL, WPAFB	Dayton, OH
Dr. Sifard	2008	Saiyu	Ran	Wright State University	Dayton, OH
Dr. Wu	2012	Ruolin	Zhou	Western New England University	Springfield, MA
Dr. Wu	2013	Xue	Li	Samsung America	San Diego, CA
Dr. F. Zhang	2013	Qi	Zhang	IGATE Corporation	Bridgewater, NJ
Dr. Xue	2012	Piyush	Shah	FMI Technologies, Inc.	Dayton, OH

* Not reported – faculty member on leave

4.1 Historical Data

Faculty within the Department of Electrical Engineering have been consistent and strong participants in the Ph.D. in Engineering program, and we expect this level of engagement to only improve with the establishment of an independent Ph.D. in Electrical Engineering that can be more directly tailored to student needs and faculty interests. As shown in the graph below, faculty in electrical engineering advised the first graduate of the Ph.D. in Engineering and continued to actively advise students, at time accounting for more than half of the graduates in a given year, even after the program had become well established.



5 Prospective enrollment

5.1 Target Enrollment

Our initial enrollment plan will be to sustain the current level of student enrollment, which includes 41 students that were actively registered during 2014. Through curriculum improvements, marketing, and outreach, we will seek to reach a target sustained enrollment level that is 50% greater, 60 actively registered students per year.

5.2 Admission Criteria

Students entering the Ph.D. in Electrical Engineering program must have an awarded M.S. degree in Electrical Engineering or a closely related field. Students with M.S. degrees in (non-electrical) engineering fields will frequently begin graduate-level coursework without remediation. Students from other STEM fields (e.g., mathematics, physics, computer science) may be required to complete some remedial coursework before beginning graduate-level studies.

Program admissions will be based on a completed application of background information, submitted transcripts for undergraduate coursework and prior graduate coursework, GRE scores, 3 letters of recommendation, and a written statement of research interests and objectives. International students will also need to submit scores measuring proficiency with the English language (e.g., TOEFL, IELTS).

Students must first satisfy requirements for admission into the Wright State University Graduate School (Graduate GPA ≥ 3.0 , TOEFL ≥ 79 or IELTS ≥ 6.0). Subsequently, admission decisions will be made by the graduate program director based on the complete application package. Admission guidelines for academic criteria will generally be as follows.

1. Student GPA for prior graduate coursework should not be lower than 3.5.

- 2. Student GRE (math) score should not be lower than 155, and the student GRE composite score should not be lower than 300.
- 3. International student test scores for proficiency with the English language should not be lower than 79 for the TOEFL and should not be lower than 6.5 for the IELTS.

Prior work experience may improve an applicant's chances for admission but will not be considered as a substitute for required academic credentials.

5.3 Student recruitment

Enrollment in focus areas of the Ph.D. in Engineering that are associated with electrical engineering are already strong as shown earlier in this proposal. This enrollment is driven by 3 student populations: international, alum of WSU undergraduate programs, and people working in local government and industry, and we expect the same driving populations within the Ph.D. in Electrical Engineering. Thus far, extensive efforts in student recruitment have not been required, as the program is well-known within the local employer community and students in B.S. and M.S. degree programs are already recruited into the Ph.D. program with great frequency. At this time, no special marketing or recruiting effort is planned for the Ph.D. in Electrical Engineering on an ongoing basis. Necessarily, there will be some effort placed in publicity during the initial transition from participation in the Ph.D. in Engineering program.

6 Effort to enroll and retain underrepresented groups

The College of Engineering & Computer Science has already been long engaged in efforts to recruit underrepresented groups, most notably minorities and women, to engineering programs. The table below shows the current level of engagement of these groups in existing engineering programs. The Ph.D. in Electrical Engineering will continue to engage in college-led activities towards recruiting underrepresented groups to at least maintain this level of engagement.

	Minorities	Women	Total Enrollment
Undergraduate Engineering & Computer Science	384 (16%)	366 (15%)	2408
B.S. in Electrical Engineering	52 (17%)	*	304
Graduate Engineering & Computer Science (M.S.)	52 (6%)	246 (28%)	889
M.S. in Electrical Engineering	15 (22%) (excludes international)	*	393 (includes 325 international)
Ph.D. in Engineering	11 (13%)	*	84

* Not reported

Enrollment in the Ph.D. in Engineering is primarily driven by 3 student populations: international, alum of WSU undergraduate programs, and people working in local government and industry, and we expect the same driving populations within the Ph.D. in Electrical Engineering. Hence, the program's demographics among students from the US will be driven primarily by the local working population and our undergraduate enrollment. As we continue to pursue greater engagement of underrepresented groups in our undergraduate programs, we expect the presence of these groups within the Ph.D. in Electrical Engineering to likewise grow.

As an additional effort to grow engagement of underrepresented groups and recruit from outside the WSU community, we will seek to recruit McNair scholars. McNair Scholars is a U.S. Department of

Education program to increase the enrollment of underrepresented groups in doctoral studies. Every year, the WSU Graduate School receives a list of McNair Scholars from the Council of Graduate Schools. The Electrical Engineering Graduate Studies Committee will look within this list for students interested in electrical engineering to be contacted for recruitment.

7 Faculty and facilities

7.1 Faculty

All faculty within the Department of Electrical Engineering have been awarded terminal degrees. Their degree credentials and research areas are listed below.

- *Josh Ash*, Assistant Professor, Ph.D., The Ohio State University, 2007. Research interests: sensor signal and image processing.
- *Elliott Brown* (joint appointment with Physics), Professor, Ph.D., California Institute of Technology, 1985. Research interests: mmwave and THz mixers made from semiconductor hot-electron bolometers and magnetically-quantized photoconductors.
- *Henry Chen*, Professor, Ph.D., University of Minnesota, 1989. Research interests: VLSI/FPGA/GPU based on demand targeted to CMOS nanotechnologies which includes digital, analog and mixed-signal integrated circuits for signal processing, communication, radar and ultra wideband receivers.
- *Jason Deibel* (joint appointment with Physics), Associate Professor, Ph.D., University of Michigan, 2004. Research interests: terahertz and optical physics.
- *John (Marty) Emmert*, Professor, Ph.D., University of Cincinnati, 1999. Research interests: physical design automation for VLSI, VLSI systems, physical VLSI design, reconfigurable systems, digital CD, VHSIC hardware description language (VHDL), verilog, digital design, VLSI interconnections, analog integrated circuit design, signal processing, digital control systems.
- *Fred Garber*, Associate Professor, Ph.D., University of Illinois, 1983. Research interests: communication systems, target recognition, information theory, and pattern theory.
- *Steve Gorman*, Instructor, Ph.D., University of Kentucky, 1988. Research interest: signal and communication processing related to geolocation of modern signal transmitters including cellular and PC devices.
- *Lang Hong*, Professor, Ph.D., University of Tennessee, 1989. Research interests: computer vision, image processing and pattern recognition, robotic sensing and control, multisensor systems, stochastic systems, system modeling and estimation, and multitarget tracking.
- *Marian Kazimierzuk*, Professor, Ph.D., Technical University of Warsaw, 1978. Research interests: electronic circuit analysis, high-frequency tuned power amplifiers, power electronics, dc-dc PWM and resonant power converters, modelling and control of power converters, magnetic components, and renewable energy sources.
- *Pradeep Misra*, Associate Professor, Ph.D., Concordia University, 1987. Research interests: multivariable control theory, robotics and applied numerical analysis.
- *Doug Petkie* (joint appointment with Physics), Associate Professor, Ph.D., The Ohio State University, 1996. Research: spectroscopy of atmospheric and interstellar related molecules, microwave, mm-wave, and THz sensing and imaging.
- *Teri Platt*, Lecturer, Ph.D., University of Colorado, 1999. Research interests: technical communications, circuits, linear systems, and control systems.

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- **Kuldip Rattan, Professor Emeritus, Ph.D., University of Kentucky, 1975. Research interests: control theory, robotics, verification and validation of cyber-physical systems (CPS).**
 - **Saiyu Ren, Associate Professor, Ph.D., Wright State University, 2008. Research interests: RF and mixed signal integrated circuit design with applications to wireless transceivers, communications and signal processing.**
 - **Brian Rigling, Professor and Chair, Ph.D., The Ohio State University, 2003. Research interests: sensor signal and image processing, system engineering and modeling.**
 - **Michael A. Saville, Assistant Professor, Ph.D., P.E., University of Illinois at Urbana-Champaign, Illinois, 2006. Research interests: computational and applied electromagnetics, radar measurement and physics-based modeling of sensor signal processing.**
 - **Arnab Shaw, Professor, Ph.D., University of Rhode Island, 1987. Research interests: sensor signal and image processing, automatic target recognition, hyperspectral image processing, high resolution angles of arrival estimation, and vibrometry based target recognition.**
 - **Raymond Siferd, Professor Emeritus, Ph.D., Air Force Institute of Technology, 1977. Research interests: very large scale integrated circuit design, signal processing and analog integrated circuit design.**
 - **Zhiqiang (John) Wu, Associate Professor, Ph.D., Colorado State University, 2002. Research interests: wireless communication and networking, cognitive radio and dynamic spectrum access, cognitive RF, multi-carrier transmission, underwater acoustic communication.**
 - **Jiafeng Xie, Assistant Professor, Ph.D., University of Pittsburgh, 2014. Research interests: cryptographic VLSI.**
 - **Kefu Xu, Associate Professor, Ph.D., Pennsylvania State University, 1987. Research interests: digital image processing, computer vision and special purpose architecture for signal processing.**
 - **Xiaodong (Frank) Zhang, Associate Professor, Ph.D., University of Cincinnati, 2001. Research interests: Fault diagnosis and prognosis, fault-tolerant control and contingency management, intelligent control and adaptive systems, distributed and cooperative control, verification and validation of complex control systems.**
 - **Yan Zhuang, Associate Professor, Ph.D., Johannes Kepler University, Linz, Austria, 2000. Research interests: RF and microwave technology, magnetic materials, nano-composite materials, high speed Si-based electronics, MEMs/NEMs, micro aerial vehicle and sensors.**

7.2 Facilities

The Ph.D. in Electrical Engineering will be supported by resources at the department, college, and university level, unchanged from those leveraged under the Ph.D. in Engineering. These include laboratory spaces assigned on a per faculty member basis by the department, computing and laboratory support provided by the College of Engineering & Computer Science computing staff, dedicated servers and computer labs maintained by the College of Engineering & Computer Science, and on-line and physical library resources, including electronic subscriptions to SPIE Digital Library and IEEExplore.

8 Need for additional facilities and staff

As this degree program is being established based on components of an existing multidisciplinary degree program, and as the Department of Electrical Engineering is already in the practice of supporting a substantial graduate student population, any additional resources required for an independent Ph.D. in Electrical Engineering will be negligible.

9 Projected additional costs

No additional costs are expected to establish the Ph.D. in Electrical Engineering.