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Cover Sheet for In-State Institutions
New Program or Substantial Modification to Existing Program

Institution Submitting Proposal	University of Maryland, College Park

Each action below requires a separate proposal and cover sheet.

- (•) New Academic Program
- ( ) New Area of Concentration
- ( ) New Degree Level Approval
- ( ) New Stand-Alone Certificate
- ( ) Off Campus Program
- ( ) Substantial Change to a Degree Program
- ( ) Substantial Change to an Area of Concentration
- ( ) Substantial Change to a Certificate Program
- ( ) Cooperative Degree Program
- ( ) Offer Program at Regional Higher Education Center

Payment Submitted: ( ) Yes (•) No

Payment Type: ( ) R*STARS (•) Check

Date Submitted:

Department Proposing Program	Electrical and Computer Engineering	
Degree Level and Degree Type	Bachelor of Science	
Title of Proposed Program	Embedded Systems and Internet of Things	
Total Number of Credits	121	
Suggested Codes	HEGIS:	CIP: 14.0999
Program Modality	(•) On-campus ( ) Distance Education (*fully online*) ( ) Both	
Program Resources	(•) Using Existing Resources ( ) Requiring New Resources	
Projected Implementation Date	(•) Fall ( ) Spring ( ) Summer	Year: 2020
Provide Link to Most Recent Academic Catalog	URL: https://academiccatalog.umd.edu/	
Preferred Contact for this Proposal	Name: Romel D. Gomez	
	Title: Professor and Assoc. Chair, Electrical and Computer Engineering	
	Phone: (301) 405-7755	
	Email: rdgomez@umd.edu	
President/Chief Executive	Type Name: Wallace D. Loh	
	Signature: Wallace D Loh Date: 11-27-2018	
	Date of Approval/Endorsement by Governing Board:	

Revised 6/13/18

A. Centrality to the University's Mission and Planning Priorities

Description. As a society, we are currently within an era of the "Internet of People": Facebook, YouTube, Instagram and Twitter, along with myriad other social networking sites are ubiquitous and omnipresent. These social media platforms have revolutionized how people communicate and interact with each other, and their impact is felt in nearly all facets of human enterprise, including commerce, entertainment, health and politics. Yet despite its current importance, the Internet of People will soon give way to the "Internet of Things". In a few years, our human senses to "see, hear, touch, smell and taste" and our ability to rearrange our environment will be supplemented with inanimate sensors and actuators that collect information, communicate with one another. These devices will be rigidly managed by a control algorithm that will analyze voluminous data and perform appropriate actions to achieve a mission.

At the foundation of an Internet of Things (IoT) infrastructure are the microelectronic circuits that perform data acquisition, signal processing and communications within the device. These are performed by integrated circuits and microcontrollers that are incorporated within the device, commonly referred to as "embedded systems". On the other end are the data analytics and control systems that process the information and implement applications. In between lies the computing platforms, protocols and gateways that seamlessly connect these devices, and process the data into actionable information while providing security that all is trustworthy and safe.

With the rapid pace of growth in new products and applications, there is a pressing need in industry and government for engineers with special skills in hardware and software design and who are well-versed with both analog and digital electronics and information systems. The Bachelor of Science in Embedded Systems and the Internet of Things will provide students with a solid foundation in key emerging technologies of IoT, the ability to integrate devices into complete IoT systems, and an understanding of how IoT fits within the wider context of information and communications technology, including data analytics and cloud computing. It is expected that graduates will be in high demand in such occupational areas as computer developers, computer systems analysts, network architects and administrators, information security analysts, information systems analysts and computer programmers.

Relation to Strategic Goals. The proposed major in Embedded Systems and the Internet of Things (BSES) relates to UMD's strategic goals by adding to its STEM program offerings, most specifically at the Universities at Shady Grove (USG). UMD states the following undergraduate education objective in its *Mission and Goals Statement*: "Increase the number of STEM graduates by creating new programs."

The BSES program is one of several UMD programs planned for delivery specifically at the Universities at Shady Grove to contribute to workforce development in the state and most specifically in the Montgomery County region, taking advantage of the robust partnership with Montgomery College. USG's mission is *"to support and expand pathways to affordable, high-quality public higher education that meet the distinctive needs of the region and are designed to support workforce and economic development in the state; to achieve these goals through partnerships and collaborations with*

academic, business, public sector and community organizations that promote student success, high academic achievement and professional advancement." This program contributes directly to the goals of access and affordability, to high quality programming, and to regional and state capacity building, as articulated in USG mission statement.

Funding. Resources for the new program will be drawn from the University System of Maryland's Workforce Development Initiative that was approved by the State Legislature beginning in FY19. Funds were specifically directed to increasing the number of undergraduate degree offerings in STEM areas at the Universities at Shady Grove.

Institutional Commitment. The program will be administered by the Department of Electrical and Computer Engineering within the A. James Clark School of Engineering. Each of UMD's USG programs has an on-site program director. In addition, two staff members are currently in residence at USG to support the program directors in admissions decisions and to provide academic operational support such as recruiting, outreach to community colleges, access to training, and to act as a liaison to academic services on the College Park campus. The University of Maryland (UMD) is also the managing institution for USG, and in that role supports many administrative services for the operation of USG.

B. Critical and Compelling Regional or Statewide Need as Identified in the State Plan

Need. A report by McKinsey[1] , Inc. in 2017 has projected that the number of connected 'things' will grow from 10 billion today to 30 billion devices by 2020, or about 3 billion new devices per year. It further cites an estimate that the global impact of IoT can be as high as $6.2 trillion by 2025, or roughly 23% of the US GDP projected by the Congressional Budget Office. Graduates of this program will be suitable for the high demand occupational areas as computer developers, computer systems analysts, network architects and administrators, information security analysts, information systems analyst and computer programmers.

The proposed Bachelor of Science in Embedded Systems and Internet of things will train future engineers who are cognizant of the latest trends in circuits and hardware-oriented software that are capable of immediate contribution to the private and public sector institutions in which they will work. It is intended to be the first of its kind in the U.S. from a major research university. This program will draw students from community colleges and will admit students who have completed their sophomore-level courses in any engineering or allied area, and who satisfy the admission requirements of the A. James Clark School of Engineering. Students graduating from the program can successfully compete for jobs in the information technology, cyber-security, software engineers and analysts, in addition to the specialized jobs in Internet of Things.

State Plan. The proposed program aligns with the *Maryland State Plan for Postsecondary Education* in different ways. First, the program aligns with the state's emphasis on career training and research.

[1] https://www.mckinsey.com/industries/semiconductors/our-insights/the-internet-of-things-sizing-up-the-opportunity) Disruptive technologies: Advances that will transform life, business, and the global economy.

Strategy 7 of the *Maryland State Plan* is "Enhance career advising and planning services and integrate them explicitly into academic advising and planning."[2] Career advising will not only be integrated with student advising, it will also be incorporated in the program coursework. All of the core courses for the program will help students achieve this outcome

C. Quantifiable and Reliable Evidence and Documentation of Market Supply and Demand in the Region and State

The field of IoT is projected by some experts (Forbes, Dec. 2017) to have a global market value of $457B by 2020 with a Compound Annual Growth Rate of 28, and the need for trained workforce to fuel this growth is essential. The proposed curriculum is a synthesis of some of the core concepts in electrical engineering, computer engineering, computer science, information technology and telecommunications.

From the USBLS Occupational Outlook Handbook (https://www.bls.gov/ooh/computer-and-information-technology/home.htm), computer and information technology occupations is projected to grow 13 percent from 2016 to 2026 in the US, faster than the average for all occupations. These occupations are projected to add about 557,100 new jobs. Demand for these workers will stem from greater emphasis on cloud computing, the collection and storage of big data, and information security. For the State of Maryland (http://www.dllr.state.md.us/lmi/iandoproj/maryland.shtml), the combined job demand for software systems and applications developers is expected to be around 40,000 in 2024, up by more than 34% from 2014. Similarly, on a very short time frame, the job search site http://www.indeed.com, there are 570 job listings under the category of internet of things in the zip code 20850 (Universities at Shady Grove.)

D. Reasonableness of Program Duplication

Several universities within the state of Maryland offer programs in electrical engineering, given the high demand for graduates in this area. A program that is focused on embedded systems – developing deep expertise in both analog and digital circuits along with the required software skills, would be unique to the region.

E . Relevance to Historically Black Institutions (HBIs)

Of the four historically black institutions in Maryland, the two that offer bachelor's programs in electrical engineering are the University of Maryland, Eastern Shore and Morgan State University. Overall engineering enrollment at UMES has been stable at close to 300 students, drawing largely from Prince Georges County. Morgan State University's undergraduate program has seen steady growth since 2011, consistent with national trends, and is now at about 550 students and is comparable in size to UMCP's program in electrical engineering. This new option at the Universities at Shady Grove is

[2] Maryland Higher Education Commission. (2017). *Maryland State Plan for Postsecondary Education.* (p. 60). Retrieved October 29, 2018 from: http://www.mhec.state.md.us/About/Documents/2017.2021%20Maryland%20State%20Plan%20for%20Higher%20Education.pdf.

expected to serve an expanding demand, particularly in central Maryland, and given the expected size we do not expect that it will impact existing EE programs.

F. Relevance to the identity of Historically Black Institutions (HBIs)

The proposed program would not have an impact on the uniqueness or institutional identity of any Maryland HBI, since this program would be a unique offering in the state.

G. Adequacy of Curriculum Design, Program Modality, and Related Learning Outcomes

Curricular Development. The curriculum was developed by faculty of ECE department in consultation with industrial partners in the hardware (Texas Instruments) and software/data analytics (Microsoft) spaces. The contents are outside the scope of any of the two traditional disciplines of electrical engineering and computer engineering, making it unique and customized for the anticipated needs of this emerging technology.

All of the undergraduate programs within the A. James Clark School of Engineering are "limited enrollment programs", due to high demand and finite capacity. Students who meet the School's LEP Admissions requirements and who have completed the required basic math/sciences courses and lower level General Education requirements are eligible for the program. The first two years prior to admissions into the program, students can complete these requirements through an associate's degree in Engineering or other STEM Program (e.g. A.S. or A.A.) from a Maryland public community college. Once students are admitted to the program, they will be able to complete their baccalaureate degree in two years.

The program will be offered exclusively at the Universities at Shady Grove. All undergraduate programs at USG are years 3 and 4 only. Expectations for lower-level coursework will be established through articulation agreements with the Maryland community colleges or taken at College Park prior to admission to the School of Engineering and Embedded Systems major. Students will take four or five courses per semester, covering 11 foundational courses, two capstone design lab courses, six advanced technical electives, and Professional Writing. In addition to course work, students will have the opportunity to be engaged in undergraduate research led by faculty mentors. In their junior years, they will receive training that satisfies the following foundational course objectives.

Students will be able to have knowledge and skills in:

1. Computer coding and software development, including C and Javascript programming languages;
2. Foundations of analog circuits and digital logic;
3. Introduction to microelectronics;
4. Introduction to computer networks;
5. Introduction to computer organization;
6. Foundations of discrete mathematics;
7. Introduction to Internet of Things;

8. Introduction to computing algorithms in Python programming language.

In their senior year, students will have the option of taking elective courses with concentrations in devices, communication and protocols, cyber security, data analytics and computing. They will also be required to complete a two-semester capstone design course dedicated to the design and building of a functional IoT system in real world applications in manufacturing, healthcare, transportation, security and commerce applications.

Faculty Oversight. The faculty within the department of Electrical and Computer Engineering will provide academic direction and oversight for the program. Appendix A contains a list of the ECE tenured and tenure-track faculty.

Educational Objectives and Learning Outcomes. Within 3 to 5 years from graduation, a graduate of BS in Embedded Systems and Internet of Things will have engaged in life-long learning and will have attained any of the following program educational objectives (the language used here is consistent with requirements for ABET accreditation):

PEO #1. Gainful employment and advancement to a leadership position in a reputable industry or government institution.
PEO #2. Successful innovator and/or entrepreneur in embedded systems, information technology or related space.

Student Learning Outcomes (SLO a-i)
The program must enable students to attain, by the time of graduation:
(a) An ability to apply knowledge of computing and mathematics appropriate to the program's student outcomes and to the discipline;
(b) An ability to analyze a problem, and identify and define the computing requirements appropriate to its solution;
(c) An ability to design, implement, and evaluate a computer-based system, process, component, or program to meet desired needs;
(d) An ability to function effectively on teams to accomplish a common goal;
(e) An understanding of professional, ethical, legal, security and social issues and responsibilities;
(f) An ability to communicate effectively with a range of audiences;
(g) An ability to analyze the local and global impact of computing on individuals, organizations, and society;
(h) Recognition of the need for and an ability to engage in continuing professional development;
(i) An ability to use current techniques, skills, and tools necessary for computing practice.

Institutional assessment and documentation of learning outcomes. Undergraduate programs complete annual assessments, with each learning outcome evaluated at least once in a four-year cycle. Programs report findings each fall in summary form following a template structure and are informed by a "best practices" guide and a rubric. Assessment summary reports for each college are collected by the College Coordinator, who works to promote high standards through support and guidance to programs and with continuous improvement practices.

Assessments of the courses in this program are based on well-defined rubrics that form the basis for course improvement within our curriculum. Every course has an associated rubric for each performance indicator. Some student outcomes are directly related to the aforementioned SLO (a-i) student learning outcomes, while others are generated by faculty Course Disciplinary Committees. Most of these are technical and focus on the key concepts needed that will enable students to engage in the field long after they graduate. The collection of assessment data follows the ABET process which the ECE department has implemented from as of 2001 ABET self-study. At the end of the semester, every faculty member is encouraged to fill out assessment sheets in which they assign a number (1-4) for each student corresponding to his/her level of achievement - 1 (undeveloped) to 4 (mastery).

Course requirements.

FIRST & SECOND YEAR

Prior to being admitted to the Embedded System major, students should have completed the Engineering LEP gateway courses, basic math/science courses, and lower-level General Education requirements.

Course	**Title**	**Cr**
MATH 140	Calculus I	4
MATH 141	Calculus II	4
ENGL 101	Academic Writing	3
CHEM 135	General Chemistry for Engineers	3
PHYS 161	General Physics: Mechanics and Particle Dynamics	3
PHYS 260	General Physics: Vibration, Waves, Heat, Electricity and Magnetism	3
PHYS 261	General Physics: Vibrations, Waves, Heat, Electricity and Magnetism (Laboratory)	1
ENES 100	Introduction to Engineering Design	3
MATH 246	Differential Equations	3
MATH 240	Linear Algebra	4
GenEd Courses	General Education Requirements	29
	Total Credits	**60**

JUNIOR & SENIOR YEARS AT SHADY GROVE

Junior Year 1st Semester

Course	**Title**	**Cr**
ENEE 302	Analog Circuits	4
ENEE 344	Introduction to Digital Circuits	4
ENEE 354	Discrete Mathematics and Applications	3

ENEE 340	Programming Concepts for Engineers (C/C++)	2
ENEE 341	Introduction to Internet of Things	3
	Total Semester Credits	**16**

Junior Year 2nd Semester

Course	Title	Cr
ENEE 304	Microelectronics and Sensors	3
ENEE 352	Introduction to Networks and Protocols	3
ENEE 353	Computer Organization	3
ENEE 355	Algorithms in Python	3
ENGL 393	Technical Writing	3
	Total Semester Credits	**15**

Senior Year 1st Semester

Course	Title	Cr
ENEE 408x	Capstone Design Lab I	3
ENEE454	Embedded Systems	3
ENEE4xx	Senior Level Electives (based on track)	9
	Total Semester Credits	**15**

Senior Year 2nd Semester

Course	Title	Cr
ENEE408x	Capstone Design Lab II	3
ENEE443	Hardware/Software Security for Embedded Systems	3
ENEE4xx	Senior Level Electives (based on track)	9
	Total Semester Credits	**15**

TOTAL DEGREE CREDITS	**121**

PROGRAM TRACKS

Students in the Embedded Systems major will be required to choose one of three program tracks available in the major. Each track will have its specific senior level course required course(s) and electives.

Hardware Track (18 credits)

Status	Course	Title	Cr
Required	ENEE 444	Operating Systems for Embedded Systems	3
Required	ENEE 455	Advanced FPGA System Design Using Verilog	3

Elective	ENEE 453	Web Based Application Development	3
Elective	ENEE 451	Network Security	3
Elective	ENEE 345	Probability and Statistical Inference	3
Elective	ENEE 459Q	Machine Learning Tools	3
Elective	ENEE 459D	Database	3

Computational/Data Management Track (18 credits)

Status	Course	Title	Cr
Required	ENEE 444	Operating Systems for Embedded Systems	3
Required	ENEE 453	Web Based Application Development	3
Required	ENEE 345	Probability and Statistical Inference	3
Required	ENEE 459Q	Machine Learning Tools	3
Required	ENEE 452	Advanced Software for Embedded Systems-Connected Systems	3
Elective	ENEE 455	Advanced FPGA System Design Using Verilog	3
Elective	ENEE 451	Network Security	3

Network Security Track (18 credits)

Status	Course	Title	Cr
Required	ENEE 453	Web Based Application Development	3
Required	ENEE 345	Probability and Statistical Inference	3
Required	ENEE 459Q	Machine Learning Tools	3
Required	ENEE 452	Advanced Software for Embedded Systems-Connected Systems	3
Elective	ENEE 455	Advanced FPGA System Design Using Verilog	3
Elective	ENEE 451	Network Security	3
Elective	ENEE 444	Operating Systems for Embedded Systems	

See Appendix B for course descriptions.

General Education. Students will complete their science and mathematics general education requirements by way of fulfilling major requirements. Students who transfer to UMD with an Associate's degree from a Maryland community college are deemed to have completed their General Education requirements with the exception of Professional Writing, which is typically taken in their third year of study.

Accreditation or Certification Requirements. As with other undergraduate Engineering degree programs at UMD, the Clark School of Engineering will seek to have this program accredited by the Accreditation Board of Engineering and Technology (ABET).

121 Credit Total. Because of ABET accreditation requirements for engineering undergraduate programs, this program, as with other engineering programs, requires more than 120 credits. This total is still lower than many engineering programs and is, by design, in line with the existing electrical engineering and computer engineering programs offered on the College Park campus, which have minimum requirements of 123 and 125 credits, respectively. For additional context, a recent survey of Big 10 electrical engineering programs found that most programs required more than 123 credits, with Ohio State, Michigan, Michigan State, and Illinois each requiring 128 credits.

Other Institutions or Organizations. The department will not contract with another institution or non-collegiate organization for this program.

Student Support. Shady Grove students will receive academic advising and support from the academic adviser at Shady Grove who will report to the Director, Office of Undergraduate Studies in Electrical and Computer Engineering at UMCP. This advising includes the usual scheduling of classes, evaluation of progress towards the degree, and identification of resources, as well as separate meetings with a cohort, as needed. In addition, the ECE department will maintain an office at Shady Grove during the times when classes are in session. An ECE faculty member will be designated as the Associate Chair of the Shady Grove Program. The Associate Chair will spend a one to two days per week at the Shady Grove facility to address the concerns of students, faculty and instructors. In addition, we will hire a lab technician to maintain the labs at Shady Grove and part-time IT specialist. These personnel will report to the corresponding group leaders in the ECE department at UMD. The ECE undergraduate office will conduct mid-semester surveys or roundtable discussions for student feedback. Students evaluate courses and faculty through the on-line course evaluation system for UMD courses.

Marketing and Admissions Information. The ECE office of external relations in collaboration with the undergraduate office will produce marketing materials and will conduct recruitment events at various times in the year.

H. Adequacy of Articulation

Montgomery College is expected to be the largest feeder, although students who have completed two years in any engineering program in a Maryland Community College will be eligible for admission. The Clark School's requirements for transfer students are articulated with Montgomery College's Associate of Science in Engineering. In 2009, the Maryland Higher Education Commission approved a statewide articulation in electrical engineering that creates a smooth pathway between the state's associate and baccalaureate degrees in electrical engineering and we anticipate that this articulation will satisfy the new degree program as well.

I. Adequacy of Faculty Resources

Program faculty. Appendix A contains a full list of ECE department faculty.

Faculty training. For the learning management system, faculty teaching in this program will have access to instructional development opportunities available across the College Park campus, including those offered as part of the Teaching and Learning Transformation Center. For online elements of the coursework, instructors will work with the learning design specialists on campus to incorporate best practices when teaching in the online environment.

J. Adequacy of Library Resources

The University of Maryland Libraries has conducted an assessment of library resources required for this program. The assessment concluded that the University Libraries are able to meet, with its current resources, the curricular and research needs of the program.

K. Adequacy of Physical Facilities, Infrastructure, and Instructional Resources

Required classroom facilities are spaces for four lecture classes/semester of 50-75 students each, and space for hosting a microelectronics lab, an FPGA lab/embedded microcontroller lab, and a software lab. In year two, a general purpose lab for the capstone projects will also be required. We estimate each lab will need a room of about 400 sq. ft. in area. These spaces are expected to be available (for rent) within the new Biomedical Sciences and Engineering (BSE) Building at the Universities at Shady Grove. The BSE building is scheduled to open in spring 2019.

L. Adequacy of Financial Resources

Resources for the program will come from tuition revenue and from the Governor's Workforce Development Initiative funds that were specifically directed towards implementation of STEM degree programs at the Universities at Shady Grove. Students in this program will represent new enrollment at UMD the tuition revenue associated with this enrollment will be directed towards program needs. Tuition revenue alone is not adequate to support the program; UMD, USG and USM have articulated a memorandum of understanding to maintain funding for the program, beyond revenue expected from tuition. See Tables 1 and 2 for anticipated resources and expenditures.

M. Adequacy of Program Evaluation

Formal program review is carried out according to the University of Maryland's policy for Periodic Review of Academic Units, which includes a review of the academic programs offered by, and the research and administration of, the academic unit (http://www.president.umd.edu/policies/2014-i-600a.html). Program Review is also monitored following the guidelines of the campus-wide cycle of Learning Outcomes Assessment (https://www.irpa.umd.edu/Assessment/LOA.html). Faculty within the department are reviewed according to the University's Policy on Periodic Evaluation of Faculty Performance (http://www.president.umd.edu/policies/2014-ii-120a.html). Since 2005, the University has used an online course evaluation instrument that standardizes course evaluations across campus.

The course evaluation has standard, university-wide questions and also allows for supplemental, specialized questions from the academic unit offering the course.

Important changes to the curriculum, such as introduction or deletions of courses, curriculum and pedagogical approaches are approved by the chair of the department, upon recommendation from the associate chair of undergraduate education and vetting by the General Academic Affairs Committee (GAAC) in accordance with the department bylaws. The Undergraduate Affairs Committee (UAC) is tasked with the oversight of all matters related to undergraduate education, including the overall curriculum for both the regular electrical and computer engineering programs and the departmental honors program.

N. Consistency with Minority Student Achievement goals

An important aspect of this program is to draw upon students in the community colleges, which have traditionally large numbers of African and Latino Americans, and thereby improving the numbers of underrepresented minorities in STEM education. This will be a factor in student recruitment.

O. Relationship to Low Productivity Programs Identified by the Commission

N/A

P. Adequacy of Distance Education Programs

N/A

Tables 1 and 2: Resources and Expenditures

TABLE 1: RESOURCES

Resources Categories	Year 1	Year 2	Year 3	Year 4	Year 5
1.Reallocated Funds	$900,000	$900,000	$900,000	$900,000	$900,000
2. Tuition/Fee Revenue (c+g below)	$251,275	$517,627	$1,066,311	$1,372,875	$1,696,873
a. #FT Students	25	50	100	125	150
b. Annual Tuition/Fee Rate	$10,051	$10,353	$10,663	$10,983	$11,312
c. Annual FT Revenue (a x b)	$251,275	$517,627	$1,066,311	$1,372,875	$1,696,873
d. # PT Students	0	0	0	0	0
e. Credit Hour Rate	$476.00	$490.28	$504.99	$520.14	$535.74
f. Annual Credit Hours	16	16	16	16	16
g. Total Part Time Revenue (d x e x f)	$0	$0	$0	$0	$0
3. Grants, Contracts, & Other External Sources	$0	$0	$0	$0	$0
4. Other Sources	$0	$0	$0	$0	$0
TOTAL (Add 1 - 4)	**$1,151,275**	**$1,417,627**	**$1,966,311**	**$2,272,875**	**$2,596,873**

Tuition revenue is based on AY2018-19 rates for the A. James Clark School of Engineering. It does not include mandatory fees or laboratory fees. Reallocated funds assume support from the States Workforce Development Initiative targeted towards programs to be delivered at the Universities at Shady Grove.

TABLE 2: EXPENDITURES

Expenditure Categories	Year 1	Year 2	Year 3	Year 4	Year 5
1. Faculty (b+c below)	$465,500	$616,455	$846,598	$871,996	$898,156
a. #FTE	3.5	4.5	6.0	6.0	6.0
b. Total Salary	$350,000	$463,500	$636,540	$655,636	$675,305
c. Total Benefits	$115,500	$152,955	$210,058	$216,360	$222,851
2. Admin. Staff (b+c below)	$325,850	$335,626	$493,849	$813,863	$1,047,849
a. #FTE	3.5	3.5	5.0	8.0	10.0
b. Total Salary	$245,000	$252,350	$371,315	$611,927	$787,856
c. Total Benefits	$80,850	$83,276	$122,534	$201,936	$259,993
3. Total Support Staff (b+c below)	$166,250	$171,238	$176,375	$181,666	$187,116
a. #FTE	2.5	2.5	2.5	2.5	2.5
b. Total Salary	$125,000	$128,750	$132,613	$136,591	$140,689
c. Total Benefits	$41,250	$42,488	$43,762	$45,075	$46,427
4. Equipment	$50,000	$25,000	$25,000	$25,000	$25,000
5. Library	$5,000	$5,000	$5,000	$5,000	$5,000
6. New or Renovated Space	$0	$0	$0	$0	$0
7. Other Expenses: Operational Expenses	$465,000	$465,000	$515,000	$515,000	$515,000
TOTAL (Add 1 - 7)	**$1,462,600**	**$1,603,318**	**$2,046,822**	**$2,397,525**	**$2,663,121**

Notes: The “admin staff” category includes graduate assistants to support laboratory instruction. Other expenses include tuition remission for graduate assistants, lab equipment and maintenance ($200K), materials and supplies, program outreach, travel related to the program, and $75K per year in scholarships.

Appendix A: Faculty in the Electrical and Computer Engineering Department

All ECE faculty hold doctoral degrees in a field relevant to the discipline. Faculty biographies and research interests can be found in the ECE department web site faculty listings. All faculty listed are full-time.

Faculty Name	Highest Degree Earned- Field and Year	Rank
Babadi, B.	Engineering Sciences, 2011	Assist Prof
Dachman- Soled,D.	Computer Science, 2011	Assist Prof
Dumitras, T.	Electrical Engineering, 2010	Assist Prof
Papamanthou, C.	Computer Science, 2011	Assist Prof
Rotkowitz, M.	Aeronautics & Astronautics, 2005	Assist Prof
Franklin, M.	Computer Science, 1993	Assoc Prof
Hafezi, M.	Theoretical Physics, 2009	Assoc Prof
Horiuchi, T.	Computation and Neural Systems	Assoc Prof
Khaligh, A.	Electrical Engineering, 2006	Assoc Prof
Martins, N.	Electrical Engineering and Computer	Assoc Prof
Munday, J.	Physics, 2008	Assoc Prof
Papamarcou, A.	Electrical Engineering, 1987	Assoc Prof
Abed, E.H.	Electrical Engineering, 1982	Prof
Abshire, P.	Electrical Engineering, 2002	Prof
Antonsen, T.	Electrical Engineering, 1977	Prof
Barg, A.	Electrical Engineering, 1987	Prof
Barua, R.	Electrical & Computer Engineering, 2000	Prof
Bhattacha ryya, S.	Electrical & Computer Science,1994	Prof
Blankensh ip, G.	Electrical Engineering, 1971	Prof
Chellappa, R.	Electrical Engineering, 1981	Prof
Dagenais, M.	Physics, 1978	Prof
Davis, C.	Physics, 1970	Prof
Ephremid es, A.	Electrical Engineering, 1971	Prof
Espy- Wilson, C.	Electrical Engineering, 1987	Prof
Ghodssi, R.	Electrical Engineering, 1996	Prof
Goldhar, J.	Physics, 1976	Prof
Goldsman, N.	Electrical Engineering, 1989	Prof
Gomez, R.	Physics, 1990	Prof
Iliadis, A.	Electrical Engineering, 1980	Prof
Jacob, B.	Computer Science & Engineering, 1997	Prof
JaJa, J.	Applied Mathematics, 1977	Prof
Krishnaprasad, P.	Engineering 1977	Prof
La, R.	Electrical Engineering, 2000	Prof
Lawson, W.	Electrical Engineering, 1985	Prof
Liu, K. J.	Electrical Engineering, 1990	Prof

Makowski, A.	Mathematics, 1981	Prof
Marcus, S.	Electrical Engineering, 1975	Prof
Mayergoyz, I.	Electrical Engineering, 1968	Prof
Milchberg, H.	Astrophysica l Sciences, 1985	Prof
Murphy, T.	Electrical Engineering, 2001	Prof
Nakajima, K.	Computer Science, 1980	Prof
Narayan, P.	Electrical Engineering, 1981	Prof
Newcomb, R.	Electrical Engineering, 1960	Prof
Oruc, A.	Electrical Engineering, 1983	Prof
Ott, E.	Electrophysics, 1967	Prof
Qu, G.	Computer Science, 2000	Prof
Shamma, S.	Electrical Engineering, 1980	Prof
Shayman, M.	Applied Mathematics, 1981	Prof
Simon, J.	Physics, 1990	Prof
Sprangle, P.	Physics, 1973	Prof
Srivastava, A.	Computer Science, 2002	Prof
Tits, A.	Electrical Engineering, 1980	Prof
Ulukus, S.	Electrical and Computer Engineering, 1998	Prof
Vishkin, U.	Computer Science, 1981	Prof
Waks, E.	Electrical Engineering, 2003	Prof
Wu, M.	Electrical Engineering, 2001	Prof
Yeung, D.	Electrical Engineering, 1998	Prof
Beaudoin, B.	Electrical Engineering, 2011	PTK
Mogul, N.	Science and Technology Studies, 2002	PTK
Picozzi, S.	Physics, 1987	PTK
Romero, D.	Physics, 1999	PTK

Appendix B: Course Descriptions

Some courses will be new to this program; they will be approved through the university's standard course approval process prior to delivery.

ENEE 302 Analog Circuits
Foundations of circuits, focusing on applications including signal amplification, power amplification, instrumentation and filters. Prerequisite: MATH246 and PHYS260/261.
Ref: Practical Electronics for Inventors 3rd ed, Paul Scherz

ENEE 344 Introduction to Digital Circuits
Hands on approach to learning foundations of digital circuits, including input/output, logic gates, Karnaugh maps, latches, flip-flops and state-machines. Ref: Learn Digital Design with PSoC, a bit at a time, Van Ess. The adoption of PSoC is suggested. Appropriate tutorial on C programming will be supplemented if needed. Co-requisite: ENEE340.

ENEE 354 Discrete Mathematics for Information Technology
Foundations of dscrete math for information technology. Topics include sets, relations, functions and algorithms, proof techniques and induction, Number theory, Counting and combinatorics and Graph theory (Suggested text: Discrete Mathematics and Its Applications, 7th ed., Kenneth Rosen).

ENEE 340 Programming Concepts for Engineers C/C++ with hardware applications
Description: Principles of software development, high level languages, input/output, data types and variables, operators and expressions, program selection, repetition, functions, arrays, strings, introduction to algorithms, software projects, debugging, documentation. Target hardware: ARM-based evaluation or development kit, e.g., Atmel AVR.

ENEE 341 Introduction to Internet of Things
Description: The course begins by covering the fundamentals of IoT, including devices, applications and business models. The course will include basic tools for networking, protocols and gateways. Introduction to data analytics and cloud computing platform.

ENEE 304 Microelectronics and Sensors
The course covers the basics of analog amplifier design starting from single-stage to multiple stage units. The four basic single stage configurations (common-source/common-emitter, follower, cascade and differential pair) are stressed, as are the bias networks that go along with them. Mid-band gains and impedances are derived and the concepts of frequency and time domain analysis are presented. Topics on introductory power electronics will be included. Prerequisite: ENEE302.

ENEE352 Introduction to Networks and Protocols
Description: An overview of design issues and the important industry standards for digital communications networks. This includes protocols, data communications technologies, error correction and detection, congestion control, traffic routing, Local Area Network (LAN) protocols,

TCP/IP, and some security issues. . It covers layered architectures for the construction of networks, following a simplified OSI reference model. This includes error detection, protocols for retransmission, data link control protocols, medium access control protocols, and both intradomain and interdomain routing. In addition to detailed study of TCP/IP networks, SONET, ATM, and WDM are considered. Both wired and wireless local area networks are studied.

ENEE353 Computer Organization for Embedded Systems
Description: This course covers the basics of computer organization and design. The topics include assembly and machine instructions, datapath and controller design, pipelining and memory hierarchy. Prerequisite: ENEE344 and ENEE340.

ENEE351 Algorithms in Python
Description: A study of Python programming language and its use in some algorithms related to sorting, graphs and trees, combinatorics. Suggested text: Python Algorithms: Mastering Basic Algorithms, Magnus Lie Hetland. Prerequisite: ENEE354 and ENEE340.

ENGL393 Technical Writing
The writing of technical papers and reports. This course teaches students how to make the technologies they work with understandable to many different types of readers. (Offered by the English department)

ENEE 453 Web-based Applications Development
Description: Introduction to computer programming in the context of developing full featured dynamic web sites. Uses a problem-solving approach to teach basics of program design and implementation using JavaScript; relates these skills to creation of dynamic web sites; then explores both the potential and limits of web-based information sources for use in research.

ENEE 455 Advanced FPGA System Design using Verilog
Description: This is a project-oriented course to on digital system design using Verilog hardware description language (HDL) in an industry-standard design environment. Students will implement real-world designs in field programmable gate arrays (FPGAs) as well as test and optimize the FPGA-implemented systems. Prerequisite: ENEE344 and ENEE340.

ENEE 454 Embedded Systems
Description: This course will provide students with the essential knowledge base that will enable them to tackle complex problems encountered in embedded systems design. In addition to the overview of associated hardware components and software methodologies and tools used in the development of modern embedded systems, and theory behind them, the course will include a a carefully selected collection of hands-on Lab exercises that would help students get a sense of how the presented theoretical concepts connect with the real-world embedded systems applications.

ENEE 444 Operating System for Embedded Systems
The course will present the theory, design, implementation and analysis of computer operating systems. Through classroom lectures, homework, and projects, students learn the fundamentals of

concurrency, process management, interprocess communication and synchronization, job scheduling algorithms, memory management, input-output devices, file systems, and protection and security in operating systems. Optional topics may include communications protocols, computer security, and real-time operating systems.

ENEE 451 Network Security
This course covers the foundations of modern cryptography and the current efforts from both academia and industry in building trustworthy computing. We will focus on the technology advances, industrial standards, and law enforcements that have been or have to be made to establish trust in four key areas to establish the trust in computing: security, privacy, reliability, and business integrity.

ENEE 345 Probability and Statistical Inference
Simplest tests of statistical hypotheses; applications to before-and-after and matched pair studies. Events, probability, combinations, independence. Binomial probabilities, confidence limits. Random variables, expected values, median, variance, standard distributions, moments, law of large numbers, tests based on ranks, normal approximation, central limit theorem. Sampling methods, estimation of parameters, testing of hypotheses.

ENEE 408x Capstone Design (Two Semester Capstone Design Course)
This focuses on a culminating design experience with specific attention to real world requirements in terms of constraints and component selection, optimization, security and integration into systems.

ENEE 452 Advanced Software for Embedded Connected Systems
Description: This course focuses on the hardware and software foundations, evaluation and validation, application mapping, optimization and testing of cyber-physical systems connected via the web. Emphasis is placed on the tow basic technologies of ICT systems, namely, embedded systems and communication technologies.

References:
Embedded System Design; Embedded Systems Foundations of Cyber-Physical Systems – Peter Marwedel 2ed (2010); Computer Organization and Embedded Systems, 6th ed. by Hamacher, Vranesic, Zaky and Manjikian. McGraw Hill, 2011; Test Driven Development for Embedded C. James Grenning. The Pragmatic Bookshelf, 2011. Embedded System Design: A Unified Hardware/Software Introduction. Vahid and Givargis. Wiley, 2001.

ENEE 443 Hardware/Software Security for Embedded Systems
Description: The objective is to gain solid understanding of the critical systems level software and hardware issues to be considered when designing industry standard secured embedded systems. Text: Embedded Systems Security: Practical Methods for Safe and Secure Software and Systems Development 1st Edition, David Kleidermacher and Mike Kleidermacher

ENEE 459Q Machine Learning Tools
A broad introduction to machine learning and statistical pattern recognition. Topics include: Supervised learning (Bayesian learning and classifier, parametric/non-parametric learning, discriminant functions,

support vector machines, neural networks, deep learning networks); Unsupervised learning (clustering, dimensionality reduction, auto-encoders). The course will also discuss recent applications of machine learning, such as computer vision, data mining, autonomous navigation, and speech recognition.

ENEE 459D Database

Students are introduced to database systems and motivates the database approach as a mechanism for modeling the real world. An in-depth coverage of the relational model, logical database design, query languages, and other database concepts including query optimization, concurrency control; transaction management, and log based crash recovery. Distributed and Web database architectures are also discussed.

A. Centrality to the University's Mission and Planning Priorities

Description. As a society, we are currently within an era of the "Internet of People": Facebook, YouTube, Instagram and Twitter, along with myriad other social networking sites are ubiquitous and omnipresent. These social media platforms have revolutionized how people communicate and interact with each other, and their impact is felt in nearly all facets of human enterprise, including commerce, entertainment, health and politics. Yet despite its current importance, the Internet of People will soon give way to the "Internet of Things". In a few years, our human senses to "see, hear, touch, smell and taste" and our ability to rearrange our environment will be supplemented with inanimate sensors and actuators that collect information, communicate with one another. These devices will be rigidly managed by a control algorithm that will analyze voluminous data and perform appropriate actions to achieve a mission.

At the foundation of an Internet of Things (IoT) infrastructure are the microelectronic circuits that perform data acquisition, signal processing and communications within the device. These are performed by integrated circuits and microcontrollers that are incorporated within the device, commonly referred to as "embedded systems". On the other end are the data analytics and control systems that process the information and implement applications. In between lies the computing platforms, protocols and gateways that seamlessly connect these devices, and process the data into actionable information while providing security that all is trustworthy and safe.

With the rapid pace of growth in new products and applications, there is a pressing need in industry and government for engineers with special skills in hardware and software design and who are well-versed with both analog and digital electronics and information systems. The Bachelor of Science in Embedded Systems and the Internet of Things will provide students with a solid foundation in key emerging technologies of IoT, the ability to integrate devices into complete IoT systems, and an understanding of how IoT fits within the wider context of information and communications technology, including data analytics and cloud computing. It is expected that graduates will be in high demand in such occupational areas as computer developers, computer systems analysts, network architects and administrators, information security analysts, information systems analysts and computer programmers.

Relation to Strategic Goals. The proposed major in Embedded Systems and the Internet of Things (BSES) relates to UMD's strategic goals by adding to its STEM program offerings, most specifically at the Universities at Shady Grove (USG). UMD states the following undergraduate education objective in its *Mission and Goals Statement*: "Increase the number of STEM graduates by creating new programs."

The BSES program is one of several UMD programs planned for delivery specifically at the Universities at Shady Grove to contribute to workforce development in the state and most specifically in the Montgomery County region, taking advantage of the robust partnership with Montgomery College. USG's mission is *"to support and expand pathways to affordable, high-quality public higher education that meet the distinctive needs of the region and are designed to support workforce and economic development in the state; to achieve these goals through partnerships and collaborations with*

academic, business, public sector and community organizations that promote student success, high academic achievement and professional advancement." This program contributes directly to the goals of access and affordability, to high quality programming, and to regional and state capacity building, as articulated in USG mission statement.

Funding. Resources for the new program will be drawn from the University System of Maryland's Workforce Development Initiative that was approved by the State Legislature beginning in FY19. Funds were specifically directed to increasing the number of undergraduate degree offerings in STEM areas at the Universities at Shady Grove.

Institutional Commitment. The program will be administered by the Department of Electrical and Computer Engineering within the A. James Clark School of Engineering. Each of UMD's USG programs has an on-site program director. In addition, two staff members are currently in residence at USG to support the program directors in admissions decisions and to provide academic operational support such as recruiting, outreach to community colleges, access to training, and to act as a liaison to academic services on the College Park campus. The University of Maryland (UMD) is also the managing institution for USG, and in that role supports many administrative services for the operation of USG.

B. Critical and Compelling Regional or Statewide Need as Identified in the State Plan

Need. A report by McKinsey[1] , Inc. in 2017 has projected that the number of connected 'things' will grow from 10 billion today to 30 billion devices by 2020, or about 3 billion new devices per year. It further cites an estimate that the global impact of IoT can be as high as $6.2 trillion by 2025, or roughly 23% of the US GDP projected by the Congressional Budget Office. Graduates of this program will be suitable for the high demand occupational areas as computer developers, computer systems analysts, network architects and administrators, information security analysts, information systems analyst and computer programmers.

The proposed Bachelor of Science in Embedded Systems and Internet of things will train future engineers who are cognizant of the latest trends in circuits and hardware-oriented software that are capable of immediate contribution to the private and public sector institutions in which they will work. It is intended to be the first of its kind in the U.S. from a major research university. This program will draw students from community colleges and will admit students who have completed their sophomore-level courses in any engineering or allied area, and who satisfy the admission requirements of the A. James Clark School of Engineering. Students graduating from the program can successfully compete for jobs in the information technology, cyber-security, software engineers and analysts, in addition to the specialized jobs in Internet of Things.

State Plan. The proposed program aligns with the *Maryland State Plan for Postsecondary Education* in different ways. First, the program aligns with the state's emphasis on career training and research.

[1] https://www.mckinsey.com/industries/semiconductors/our-insights/the-internet-of-things-sizing-up-the-opportunity) Disruptive technologies: Advances that will transform life, business, and the global economy.

Strategy 7 of the *Maryland State Plan* is "Enhance career advising and planning services and integrate them explicitly into academic advising and planning."[2] Career advising will not only be integrated with student advising, it will also be incorporated in the program coursework. All of the core courses for the program will help students achieve this outcome

C. Quantifiable and Reliable Evidence and Documentation of Market Supply and Demand in the Region and State

The field of IoT is projected by some experts (Forbes, Dec. 2017) to have a global market value of $457B by 2020 with a Compound Annual Growth Rate of 28, and the need for trained workforce to fuel this growth is essential. The proposed curriculum is a synthesis of some of the core concepts in electrical engineering, computer engineering, computer science, information technology and telecommunications.

From the USBLS Occupational Outlook Handbook (https://www.bls.gov/ooh/computer-and-information-technology/home.htm), computer and information technology occupations is projected to grow 13 percent from 2016 to 2026 in the US, faster than the average for all occupations. These occupations are projected to add about 557,100 new jobs. Demand for these workers will stem from greater emphasis on cloud computing, the collection and storage of big data, and information security. For the State of Maryland (http://www.dllr.state.md.us/lmi/iandoproj/maryland.shtml), the combined job demand for software systems and applications developers is expected to be around 40,000 in 2024, up by more than 34% from 2014. Similarly, on a very short time frame, the job search site http://www.indeed.com, there are 570 job listings under the category of internet of things in the zip code 20850 (Universities at Shady Grove.)

D. Reasonableness of Program Duplication

Several universities within the state of Maryland offer programs in electrical engineering, given the high demand for graduates in this area. A program that is focused on embedded systems – developing deep expertise in both analog and digital circuits along with the required software skills, would be unique to the region.

E . Relevance to Historically Black Institutions (HBIs)

Of the four historically black institutions in Maryland, the two that offer bachelor's programs in electrical engineering are the University of Maryland, Eastern Shore and Morgan State University. Overall engineering enrollment at UMES has been stable at close to 300 students, drawing largely from Prince Georges County. Morgan State University's undergraduate program has seen steady growth since 2011, consistent with national trends, and is now at about 550 students and is comparable in size to UMCP's program in electrical engineering. This new option at the Universities at Shady Grove is

[2] Maryland Higher Education Commission. (2017). *Maryland State Plan for Postsecondary Education.* (p. 60). Retrieved October 29, 2018 from: http://www.mhec.state.md.us/About/Documents/2017.2021%20Maryland%20State%20Plan%20for%20Higher%20Education.pdf.

expected to serve an expanding demand, particularly in central Maryland, and given the expected size we do not expect that it will impact existing EE programs.

F. Relevance to the identity of Historically Black Institutions (HBIs)

The proposed program would not have an impact on the uniqueness or institutional identity of any Maryland HBI, since this program would be a unique offering in the state.

G. Adequacy of Curriculum Design, Program Modality, and Related Learning Outcomes

Curricular Development. The curriculum was developed by faculty of ECE department in consultation with industrial partners in the hardware (Texas Instruments) and software/data analytics (Microsoft) spaces. The contents are outside the scope of any of the two traditional disciplines of electrical engineering and computer engineering, making it unique and customized for the anticipated needs of this emerging technology.

All of the undergraduate programs within the A. James Clark School of Engineering are "limited enrollment programs", due to high demand and finite capacity. Students who meet the School's LEP Admissions requirements and who have completed the required basic math/sciences courses and lower level General Education requirements are eligible for the program. The first two years prior to admissions into the program, students can complete these requirements through an associate's degree in Engineering or other STEM Program (e.g. A.S. or A.A.) from a Maryland public community college. Once students are admitted to the program, they will be able to complete their baccalaureate degree in two years.

The program will be offered exclusively at the Universities at Shady Grove. All undergraduate programs at USG are years 3 and 4 only. Expectations for lower-level coursework will be established through articulation agreements with the Maryland community colleges or taken at College Park prior to admission to the School of Engineering and Embedded Systems major. Students will take four or five courses per semester, covering 11 foundational courses, two capstone design lab courses, six advanced technical electives, and Professional Writing. In addition to course work, students will have the opportunity to be engaged in undergraduate research led by faculty mentors. In their junior years, they will receive training that satisfies the following foundational course objectives.

Students will be able to have knowledge and skills in:

1. Computer coding and software development, including C and Javascript programming languages;
2. Foundations of analog circuits and digital logic;
3. Introduction to microelectronics;
4. Introduction to computer networks;
5. Introduction to computer organization;
6. Foundations of discrete mathematics;
7. Introduction to Internet of Things;

8. Introduction to computing algorithms in Python programming language.

In their senior year, students will have the option of taking elective courses with concentrations in devices, communication and protocols, cyber security, data analytics and computing. They will also be required to complete a two-semester capstone design course dedicated to the design and building of a functional IoT system in real world applications in manufacturing, healthcare, transportation, security and commerce applications.

Faculty Oversight. The faculty within the department of Electrical and Computer Engineering will provide academic direction and oversight for the program. Appendix A contains a list of the ECE tenured and tenure-track faculty.

Educational Objectives and Learning Outcomes. Within 3 to 5 years from graduation, a graduate of BS in Embedded Systems and Internet of Things will have engaged in life-long learning and will have attained any of the following program educational objectives (the language used here is consistent with requirements for ABET accreditation):

PEO #1. Gainful employment and advancement to a leadership position in a reputable industry or government institution.
PEO #2. Successful innovator and/or entrepreneur in embedded systems, information technology or related space.

Student Learning Outcomes (SLO a-i)
The program must enable students to attain, by the time of graduation:
(a) An ability to apply knowledge of computing and mathematics appropriate to the program's student outcomes and to the discipline;
(b) An ability to analyze a problem, and identify and define the computing requirements appropriate to its solution;
(c) An ability to design, implement, and evaluate a computer-based system, process, component, or program to meet desired needs;
(d) An ability to function effectively on teams to accomplish a common goal;
(e) An understanding of professional, ethical, legal, security and social issues and responsibilities;
(f) An ability to communicate effectively with a range of audiences;
(g) An ability to analyze the local and global impact of computing on individuals, organizations, and society;
(h) Recognition of the need for and an ability to engage in continuing professional development;
(i) An ability to use current techniques, skills, and tools necessary for computing practice.

Institutional assessment and documentation of learning outcomes. Undergraduate programs complete annual assessments, with each learning outcome evaluated at least once in a four-year cycle. Programs report findings each fall in summary form following a template structure and are informed by a "best practices" guide and a rubric. Assessment summary reports for each college are collected by the College Coordinator, who works to promote high standards through support and guidance to programs and with continuous improvement practices.

Assessments of the courses in this program are based on well-defined rubrics that form the basis for course improvement within our curriculum. Every course has an associated rubric for each performance indicator. Some student outcomes are directly related to the aforementioned SLO (a-i) student learning outcomes, while others are generated by faculty Course Disciplinary Committees. Most of these are technical and focus on the key concepts needed that will enable students to engage in the field long after they graduate. The collection of assessment data follows the ABET process which the ECE department has implemented from as of 2001 ABET self-study. At the end of the semester, every faculty member is encouraged to fill out assessment sheets in which they assign a number (1-4) for each student corresponding to his/her level of achievement - 1 (undeveloped) to 4 (mastery).

Course requirements.

FIRST & SECOND YEAR

Prior to being admitted to the Embedded System major, students should have completed the Engineering LEP gateway courses, basic math/science courses, and lower-level General Education requirements.

Course	**Title**	**Cr**
MATH 140	Calculus I	4
MATH 141	Calculus II	4
ENGL 101	Academic Writing	3
CHEM 135	General Chemistry for Engineers	3
PHYS 161	General Physics: Mechanics and Particle Dynamics	3
PHYS 260	General Physics: Vibration, Waves, Heat, Electricity and Magnetism	3
PHYS 261	General Physics: Vibrations, Waves, Heat, Electricity and Magnetism (Laboratory)	1
ENES 100	Introduction to Engineering Design	3
MATH 246	Differential Equations	3
MATH 240	Linear Algebra	4
GenEd Courses	General Education Requirements	29
	Total Credits	**60**

JUNIOR & SENIOR YEARS AT SHADY GROVE

Junior Year 1st Semester

Course	**Title**	**Cr**
ENEE 302	Analog Circuits	4
ENEE 344	Introduction to Digital Circuits	4
ENEE 354	Discrete Mathematics and Applications	3

ENEE 340	Programming Concepts for Engineers (C/C++)	2
ENEE 341	Introduction to Internet of Things	3
	Total Semester Credits	**16**

Junior Year 2nd Semester

Course	Title	Cr
ENEE 304	Microelectronics and Sensors	3
ENEE 352	Introduction to Networks and Protocols	3
ENEE 353	Computer Organization	3
ENEE 355	Algorithms in Python	3
ENGL 393	Technical Writing	3
	Total Semester Credits	**15**

Senior Year 1st Semester

Course	Title	Cr
ENEE 408x	Capstone Design Lab I	3
ENEE454	Embedded Systems	3
ENEE4xx	Senior Level Electives (based on track)	9
	Total Semester Credits	**15**

Senior Year 2nd Semester

Course	Title	Cr
ENEE408x	Capstone Design Lab II	3
ENEE443	Hardware/Software Security for Embedded Systems	3
ENEE4xx	Senior Level Electives (based on track)	9
	Total Semester Credits	**15**

TOTAL DEGREE CREDITS	**121**

PROGRAM TRACKS

Students in the Embedded Systems major will be required to choose one of three program tracks available in the major. Each track will have its specific senior level course required course(s) and electives.

Hardware Track (18 credits)

Status	Course	Title	Cr
Required	ENEE 444	Operating Systems for Embedded Systems	3
Required	ENEE 455	Advanced FPGA System Design Using Verilog	3

Elective	ENEE 453	Web Based Application Development	3
Elective	ENEE 451	Network Security	3
Elective	ENEE 345	Probability and Statistical Inference	3
Elective	ENEE 459Q	Machine Learning Tools	3
Elective	ENEE 459D	Database	3

Computational/Data Management Track (18 credits)

Status	Course	Title	Cr
Required	ENEE 444	Operating Systems for Embedded Systems	3
Required	ENEE 453	Web Based Application Development	3
Required	ENEE 345	Probability and Statistical Inference	3
Required	ENEE 459Q	Machine Learning Tools	3
Required	ENEE 452	Advanced Software for Embedded Systems-Connected Systems	3
Elective	ENEE 455	Advanced FPGA System Design Using Verilog	3
Elective	ENEE 451	Network Security	3

Network Security Track (18 credits)

Status	Course	Title	Cr
Required	ENEE 453	Web Based Application Development	3
Required	ENEE 345	Probability and Statistical Inference	3
Required	ENEE 459Q	Machine Learning Tools	3
Required	ENEE 452	Advanced Software for Embedded Systems-Connected Systems	3
Elective	ENEE 455	Advanced FPGA System Design Using Verilog	3
Elective	ENEE 451	Network Security	3
Elective	ENEE 444	Operating Systems for Embedded Systems	

See Appendix B for course descriptions.

General Education. Students will complete their science and mathematics general education requirements by way of fulfilling major requirements. Students who transfer to UMD with an Associate's degree from a Maryland community college are deemed to have completed their General Education requirements with the exception of Professional Writing, which is typically taken in their third year of study.

Accreditation or Certification Requirements. As with other undergraduate Engineering degree programs at UMD, the Clark School of Engineering will seek to have this program accredited by the Accreditation Board of Engineering and Technology (ABET).

121 Credit Total. Because of ABET accreditation requirements for engineering undergraduate programs, this program, as with other engineering programs, requires more than 120 credits. This total is still lower than many engineering programs and is, by design, in line with the existing electrical engineering and computer engineering programs offered on the College Park campus, which have minimum requirements of 123 and 125 credits, respectively. For additional context, a recent survey of Big 10 electrical engineering programs found that most programs required more than 123 credits, with Ohio State, Michigan, Michigan State, and Illinois each requiring 128 credits.

Other Institutions or Organizations. The department will not contract with another institution or non-collegiate organization for this program.

Student Support. Shady Grove students will receive academic advising and support from the academic adviser at Shady Grove who will report to the Director, Office of Undergraduate Studies in Electrical and Computer Engineering at UMCP. This advising includes the usual scheduling of classes, evaluation of progress towards the degree, and identification of resources, as well as separate meetings with a cohort, as needed. In addition, the ECE department will maintain an office at Shady Grove during the times when classes are in session. An ECE faculty member will be designated as the Associate Chair of the Shady Grove Program. The Associate Chair will spend a one to two days per week at the Shady Grove facility to address the concerns of students, faculty and instructors. In addition, we will hire a lab technician to maintain the labs at Shady Grove and part-time IT specialist. These personnel will report to the corresponding group leaders in the ECE department at UMD. The ECE undergraduate office will conduct mid-semester surveys or roundtable discussions for student feedback. Students evaluate courses and faculty through the on-line course evaluation system for UMD courses.

Marketing and Admissions Information. The ECE office of external relations in collaboration with the undergraduate office will produce marketing materials and will conduct recruitment events at various times in the year.

H. Adequacy of Articulation

Montgomery College is expected to be the largest feeder, although students who have completed two years in any engineering program in a Maryland Community College will be eligible for admission. The Clark School's requirements for transfer students are articulated with Montgomery College's Associate of Science in Engineering. In 2009, the Maryland Higher Education Commission approved a statewide articulation in electrical engineering that creates a smooth pathway between the state's associate and baccalaureate degrees in electrical engineering and we anticipate that this articulation will satisfy the new degree program as well.

I. Adequacy of Faculty Resources

Program faculty. Appendix A contains a full list of ECE department faculty.

Faculty training. For the learning management system, faculty teaching in this program will have access to instructional development opportunities available across the College Park campus, including those offered as part of the Teaching and Learning Transformation Center. For online elements of the coursework, instructors will work with the learning design specialists on campus to incorporate best practices when teaching in the online environment.

J. Adequacy of Library Resources

The University of Maryland Libraries has conducted an assessment of library resources required for this program. The assessment concluded that the University Libraries are able to meet, with its current resources, the curricular and research needs of the program.

K. Adequacy of Physical Facilities, Infrastructure, and Instructional Resources

Required classroom facilities are spaces for four lecture classes/semester of 50-75 students each, and space for hosting a microelectronics lab, an FPGA lab/embedded microcontroller lab, and a software lab. In year two, a general purpose lab for the capstone projects will also be required. We estimate each lab will need a room of about 400 sq. ft. in area. These spaces are expected to be available (for rent) within the new Biomedical Sciences and Engineering (BSE) Building at the Universities at Shady Grove. The BSE building is scheduled to open in spring 2019.

L. Adequacy of Financial Resources

Resources for the program will come from tuition revenue and from the Governor's Workforce Development Initiative funds that were specifically directed towards implementation of STEM degree programs at the Universities at Shady Grove. Students in this program will represent new enrollment at UMD the tuition revenue associated with this enrollment will be directed towards program needs. Tuition revenue alone is not adequate to support the program; UMD, USG and USM have articulated a memorandum of understanding to maintain funding for the program, beyond revenue expected from tuition. See Tables 1 and 2 for anticipated resources and expenditures.

M. Adequacy of Program Evaluation

Formal program review is carried out according to the University of Maryland's policy for Periodic Review of Academic Units, which includes a review of the academic programs offered by, and the research and administration of, the academic unit (http://www.president.umd.edu/policies/2014-i-600a.html). Program Review is also monitored following the guidelines of the campus-wide cycle of Learning Outcomes Assessment (https://www.irpa.umd.edu/Assessment/LOA.html). Faculty within the department are reviewed according to the University's Policy on Periodic Evaluation of Faculty Performance (http://www.president.umd.edu/policies/2014-ii-120a.html). Since 2005, the University has used an online course evaluation instrument that standardizes course evaluations across campus.

The course evaluation has standard, university-wide questions and also allows for supplemental, specialized questions from the academic unit offering the course.

Important changes to the curriculum, such as introduction or deletions of courses, curriculum and pedagogical approaches are approved by the chair of the department, upon recommendation from the associate chair of undergraduate education and vetting by the General Academic Affairs Committee (GAAC) in accordance with the department bylaws. The Undergraduate Affairs Committee (UAC) is tasked with the oversight of all matters related to undergraduate education, including the overall curriculum for both the regular electrical and computer engineering programs and the departmental honors program.

N. Consistency with Minority Student Achievement goals

An important aspect of this program is to draw upon students in the community colleges, which have traditionally large numbers of African and Latino Americans, and thereby improving the numbers of underrepresented minorities in STEM education. This will be a factor in student recruitment.

O. Relationship to Low Productivity Programs Identified by the Commission

N/A

P. Adequacy of Distance Education Programs

N/A

Tables 1 and 2: Resources and Expenditures

TABLE 1: RESOURCES

Resources Categories	Year 1	Year 2	Year 3	Year 4	Year 5
1.Reallocated Funds	$900,000	$900,000	$900,000	$900,000	$900,000
2. Tuition/Fee Revenue (c+g below)	$251,275	$517,627	$1,066,311	$1,372,875	$1,696,873
a. #FT Students	25	50	100	125	150
b. Annual Tuition/Fee Rate	$10,051	$10,353	$10,663	$10,983	$11,312
c. Annual FT Revenue (a x b)	$251,275	$517,627	$1,066,311	$1,372,875	$1,696,873
d. # PT Students	0	0	0	0	0
e. Credit Hour Rate	$476.00	$490.28	$504.99	$520.14	$535.74
f. Annual Credit Hours	16	16	16	16	16
g. Total Part Time Revenue (d x e x f)	$0	$0	$0	$0	$0
3. Grants, Contracts, & Other External Sources	$0	$0	$0	$0	$0
4. Other Sources	$0	$0	$0	$0	$0
TOTAL (Add 1 - 4)	**$1,151,275**	**$1,417,627**	**$1,966,311**	**$2,272,875**	**$2,596,873**

Tuition revenue is based on AY2018-19 rates for the A. James Clark School of Engineering. It does not include mandatory fees or laboratory fees. Reallocated funds assume support from the States Workforce Development Initiative targeted towards programs to be delivered at the Universities at Shady Grove.

TABLE 2: EXPENDITURES

Expenditure Categories	Year 1	Year 2	Year 3	Year 4	Year 5
1. Faculty (b+c below)	$465,500	$616,455	$846,598	$871,996	$898,156
a. #FTE	3.5	4.5	6.0	6.0	6.0
b. Total Salary	$350,000	$463,500	$636,540	$655,636	$675,305
c. Total Benefits	$115,500	$152,955	$210,058	$216,360	$222,851
2. Admin. Staff (b+c below)	$325,850	$335,626	$493,849	$813,863	$1,047,849
a. #FTE	3.5	3.5	5.0	8.0	10.0
b. Total Salary	$245,000	$252,350	$371,315	$611,927	$787,856
c. Total Benefits	$80,850	$83,276	$122,534	$201,936	$259,993
3. Total Support Staff (b+c below)	$166,250	$171,238	$176,375	$181,666	$187,116
a. #FTE	2.5	2.5	2.5	2.5	2.5
b. Total Salary	$125,000	$128,750	$132,613	$136,591	$140,689
c. Total Benefits	$41,250	$42,488	$43,762	$45,075	$46,427
4. Equipment	$50,000	$25,000	$25,000	$25,000	$25,000
5. Library	$5,000	$5,000	$5,000	$5,000	$5,000
6. New or Renovated Space	$0	$0	$0	$0	$0
7. Other Expenses: Operational Expenses	$465,000	$465,000	$515,000	$515,000	$515,000
TOTAL (Add 1 - 7)	**$1,462,600**	**$1,603,318**	**$2,046,822**	**$2,397,525**	**$2,663,121**

Notes: The “admin staff” category includes graduate assistants to support laboratory instruction. Other expenses include tuition remission for graduate assistants, lab equipment and maintenance ($200K), materials and supplies, program outreach, travel related to the program, and $75K per year in scholarships.

Appendix A: Faculty in the Electrical and Computer Engineering Department

All ECE faculty hold doctoral degrees in a field relevant to the discipline. Faculty biographies and research interests can be found in the ECE department web site faculty listings. All faculty listed are full-time. The specific course assignments have not yet been made, but will be made in time to schedule the courses for the target start term of Fall 2020.

Faculty Name	Highest Degree Earned- Field and Year	Rank
Babadi, B.	Engineering Sciences, 2011	Assist Prof
Dachman- Soled,D.	Computer Science, 2011	Assist Prof
Dumitras, T.	Electrical Engineering, 2010	Assist Prof
Papamanthou, C.	Computer Science, 2011	Assist Prof
Rotkowitz, M.	Aeronautics & Astronautics, 2005	Assist Prof
Franklin, M.	Computer Science, 1993	Assoc Prof
Hafezi, M.	Theoretical Physics, 2009	Assoc Prof
Horiuchi, T.	Computation and Neural Systems	Assoc Prof
Khaligh, A.	Electrical Engineering, 2006	Assoc Prof
Martins, N.	Electrical Engineering and Computer	Assoc Prof
Munday, J.	Physics, 2008	Assoc Prof
Papamarcou, A.	Electrical Engineering, 1987	Assoc Prof
Abed, E.H.	Electrical Engineering, 1982	Prof
Abshire, P.	Electrical Engineering, 2002	Prof
Antonsen, T.	Electrical Engineering, 1977	Prof
Barg, A.	Electrical Engineering, 1987	Prof
Barua, R.	Electrical & Computer Engineering, 2000	Prof
Bhattacha ryya, S.	Electrical & Computer Science,1994	Prof
Blankensh ip, G.	Electrical Engineering, 1971	Prof
Chellappa, R.	Electrical Engineering, 1981	Prof
Dagenais, M.	Physics, 1978	Prof
Davis, C.	Physics, 1970	Prof
Ephremid es, A.	Electrical Engineering, 1971	Prof
Espy- Wilson, C.	Electrical Engineering, 1987	Prof
Ghodssi, R.	Electrical Engineering, 1996	Prof
Goldhar, J.	Physics, 1976	Prof
Goldsman, N.	Electrical Engineering, 1989	Prof
Gomez, R.	Physics, 1990	Prof
Iliadis, A.	Electrical Engineering, 1980	Prof
Jacob, B.	Computer Science & Engineering, 1997	Prof
JaJa, J.	Applied Mathematics, 1977	Prof
Krishnaprasad, P.	Engineering 1977	Prof
La, R.	Electrical Engineering, 2000	Prof
Lawson, W.	Electrical Engineering, 1985	Prof

Liu, K. J.	Electrical Engineering, 1990	Prof
Makowski, A.	Mathematics, 1981	Prof
Marcus, S.	Electrical Engineering, 1975	Prof
Mayergoyz, I.	Electrical Engineering, 1968	Prof
Milchberg, H.	Astrophysica l Sciences, 1985	Prof
Murphy, T.	Electrical Engineering, 2001	Prof
Nakajima, K.	Computer Science, 1980	Prof
Narayan, P.	Electrical Engineering, 1981	Prof
Newcomb, R.	Electrical Engineering, 1960	Prof
Oruc, A.	Electrical Engineering, 1983	Prof
Ott, E.	Electrophysics, 1967	Prof
Qu, G.	Computer Science, 2000	Prof
Shamma, S.	Electrical Engineering, 1980	Prof
Shayman, M.	Applied Mathematics, 1981	Prof
Simon, J.	Physics, 1990	Prof
Sprangle, P.	Physics, 1973	Prof
Srivastava, A.	Computer Science, 2002	Prof
Tits, A.	Electrical Engineering, 1980	Prof
Ulukus, S.	Electrical and Computer Engineering, 1998	Prof
Vishkin, U.	Computer Science, 1981	Prof
Waks, E.	Electrical Engineering, 2003	Prof
Wu, M.	Electrical Engineering, 2001	Prof
Yeung, D.	Electrical Engineering, 1998	Prof
Beaudoin, B.	Electrical Engineering, 2011	PTK
Mogul, N.	Science and Technology Studies, 2002	PTK
Picozzi, S.	Physics, 1987	PTK
Romero, D.	Physics, 1999	PTK

Appendix B: Course Descriptions

Some courses will be new to this program; they will be approved through the university's standard course approval process prior to delivery.

ENEE 302 Analog Circuits
Foundations of circuits, focusing on applications including signal amplification, power amplification, instrumentation and filters. Prerequisite: MATH246 and PHYS260/261.
Ref: Practical Electronics for Inventors 3rd ed, Paul Scherz

ENEE 344 Introduction to Digital Circuits
Hands on approach to learning foundations of digital circuits, including input/output, logic gates, Karnaugh maps, latches, flip-flops and state-machines. Ref: Learn Digital Design with PSoC, a bit at a time, Van Ess. The adoption of PSoC is suggested. Appropriate tutorial on C programming will be supplemented if needed. Co-requisite: ENEE340.

ENEE 354 Discrete Mathematics for Information Technology
Foundations of dscrete math for information technology. Topics include sets, relations, functions and algorithms, proof techniques and induction, Number theory, Counting and combinatorics and Graph theory (Suggested text: Discrete Mathematics and Its Applications, 7th ed., Kenneth Rosen).

ENEE 340 Programming Concepts for Engineers C/C++ with hardware applications
Description: Principles of software development, high level languages, input/output, data types and variables, operators and expressions, program selection, repetition, functions, arrays, strings, introduction to algorithms, software projects, debugging, documentation. Target hardware: ARM-based evaluation or development kit, e.g., Atmel AVR.

ENEE 341 Introduction to Internet of Things
Description: The course begins by covering the fundamentals of IoT, including devices, applications and business models. The course will include basic tools for networking, protocols and gateways. Introduction to data analytics and cloud computing platform.

ENEE 304 Microelectronics and Sensors
The course covers the basics of analog amplifier design starting from single-stage to multiple stage units. The four basic single stage configurations (common-source/common-emitter, follower, cascade and differential pair) are stressed, as are the bias networks that go along with them. Mid-band gains and impedances are derived and the concepts of frequency and time domain analysis are presented. Topics on introductory power electronics will be included. Prerequisite: ENEE302.

ENEE352 Introduction to Networks and Protocols
Description: An overview of design issues and the important industry standards for digital communications networks. This includes protocols, data communications technologies, error correction and detection, congestion control, traffic routing, Local Area Network (LAN) protocols,

TCP/IP, and some security issues. . It covers layered architectures for the construction of networks, following a simplified OSI reference model. This includes error detection, protocols for retransmission, data link control protocols, medium access control protocols, and both intradomain and interdomain routing. In addition to detailed study of TCP/IP networks, SONET, ATM, and WDM are considered. Both wired and wireless local area networks are studied.

ENEE353 Computer Organization for Embedded Systems
Description: This course covers the basics of computer organization and design. The topics include assembly and machine instructions, datapath and controller design, pipelining and memory hierarchy. Prerequisite: ENEE344 and ENEE340.

ENEE351 Algorithms in Python
Description: A study of Python programming language and its use in some algorithms related to sorting, graphs and trees, combinatorics. Suggested text: Python Algorithms: Mastering Basic Algorithms, Magnus Lie Hetland. Prerequisite: ENEE354 and ENEE340.

ENGL393 Technical Writing
The writing of technical papers and reports. This course teaches students how to make the technologies they work with understandable to many different types of readers. (Offered by the English department)

ENEE 453 Web-based Applications Development
Description: Introduction to computer programming in the context of developing full featured dynamic web sites. Uses a problem-solving approach to teach basics of program design and implementation using JavaScript; relates these skills to creation of dynamic web sites; then explores both the potential and limits of web-based information sources for use in research.

ENEE 455 Advanced FPGA System Design using Verilog
Description: This is a project-oriented course to on digital system design using Verilog hardware description language (HDL) in an industry-standard design environment. Students will implement real-world designs in field programmable gate arrays (FPGAs) as well as test and optimize the FPGA-implemented systems. Prerequisite: ENEE344 and ENEE340.

ENEE 454 Embedded Systems
Description: This course will provide students with the essential knowledge base that will enable them to tackle complex problems encountered in embedded systems design. In addition to the overview of associated hardware components and software methodologies and tools used in the development of modern embedded systems, and theory behind them, the course will include a a carefully selected collection of hands-on Lab exercises that would help students get a sense of how the presented theoretical concepts connect with the real-world embedded systems applications.

ENEE 444 Operating System for Embedded Systems
The course will present the theory, design, implementation and analysis of computer operating systems. Through classroom lectures, homework, and projects, students learn the fundamentals of

concurrency, process management, interprocess communication and synchronization, job scheduling algorithms, memory management, input-output devices, file systems, and protection and security in operating systems. Optional topics may include communications protocols, computer security, and real-time operating systems.

ENEE 451 Network Security
This course covers the foundations of modern cryptography and the current efforts from both academia and industry in building trustworthy computing. We will focus on the technology advances, industrial standards, and law enforcements that have been or have to be made to establish trust in four key areas to establish the trust in computing: security, privacy, reliability, and business integrity.

ENEE 345 Probability and Statistical Inference
Simplest tests of statistical hypotheses; applications to before-and-after and matched pair studies. Events, probability, combinations, independence. Binomial probabilities, confidence limits. Random variables, expected values, median, variance, standard distributions, moments, law of large numbers, tests based on ranks, normal approximation, central limit theorem. Sampling methods, estimation of parameters, testing of hypotheses.

ENEE 408x Capstone Design (Two Semester Capstone Design Course)
This focuses on a culminating design experience with specific attention to real world requirements in terms of constraints and component selection, optimization, security and integration into systems.

ENEE 452 Advanced Software for Embedded Connected Systems
Description: This course focuses on the hardware and software foundations, evaluation and validation, application mapping, optimization and testing of cyber-physical systems connected via the web. Emphasis is placed on the tow basic technologies of ICT systems, namely, embedded systems and communication technologies.

References:
Embedded System Design; Embedded Systems Foundations of Cyber-Physical Systems – Peter Marwedel 2ed (2010); Computer Organization and Embedded Systems, 6th ed. by Hamacher, Vranesic, Zaky and Manjikian. McGraw Hill, 2011; Test Driven Development for Embedded C. James Grenning. The Pragmatic Bookshelf, 2011. Embedded System Design: A Unified Hardware/Software Introduction. Vahid and Givargis. Wiley, 2001.

ENEE 443 Hardware/Software Security for Embedded Systems
Description: The objective is to gain solid understanding of the critical systems level software and hardware issues to be considered when designing industry standard secured embedded systems. Text: Embedded Systems Security: Practical Methods for Safe and Secure Software and Systems Development 1st Edition, David Kleidermacher and Mike Kleidermacher

ENEE 459Q Machine Learning Tools
A broad introduction to machine learning and statistical pattern recognition. Topics include: Supervised learning (Bayesian learning and classifier, parametric/non-parametric learning, discriminant functions,

support vector machines, neural networks, deep learning networks); Unsupervised learning (clustering, dimensionality reduction, auto-encoders). The course will also discuss recent applications of machine learning, such as computer vision, data mining, autonomous navigation, and speech recognition.

ENEE 459D Database

Students are introduced to database systems and motivates the database approach as a mechanism for modeling the real world. An in-depth coverage of the relational model, logical database design, query languages, and other database concepts including query optimization, concurrency control; transaction management, and log based crash recovery. Distributed and Web database architectures are also discussed.