MORGAN STATE UNIVERSITY
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Provost and Senior Vice President for Academic Affairs

May 16, 2022

The Honorable Dr. James D. Fielder, Jr.
Maryland Higher Education Commission
6 N. Liberty Street, 10th Floor
Baltimore, MD 21201

Dear Dr. Fielder,

On behalf of Morgan State University, please find attached a proposal to establish the "*Doctor of Philosophy (Ph.D.) in Industrial Engineering with a pass-through (En Passant) Master of Science (M.S.) in Industrial Engineering"* which was approved by the Board of Regents on May 3, 2022.

If additional information is required, please contact me at hongtao.yu@morgan.edu or (443)885-3350.

Sincerely,

Hongtao Yu, PhD
Provost and Senior Vice President for Academic Affairs, Morgan State University

cc: Dr. David Wilson, President, Morgan State University
Dr. Phyllis Keys, Interim Associate Vice President for Academic Affairs, MSU
Dr. Oscar Barton, Dean, School of Engineering, MSU
Dr. Emily Dow, Assistant Secretary for Academic Affairs, Maryland Higher Education Commission

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Office Use Only: PP#

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

Institution Submitting Proposal	Morgan State University

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 # Payment Amount: $850 Date Submitted: 5/15/2022

Department Proposing Program	School of Engineering	
Degree Level and Degree Type	Ph.D. with a pass-through M.S.	
Title of Proposed Program	Industrial Engineering	
Total Number of Credits	60	
Suggested Codes	HEGIS: 913.00	CIP: 14.3501
Program Modality	(●) On-campus ( ) Distance Education (*fully online*)	
Program Resources	( ) Using Existing Resources (●) Requiring New Resources	
Projected Implementation Date	(●) Fall ( ) Spring ( ) Summer	Year: 2023
Provide Link to Most Recent Academic Catalog	URL: catalog.morgan.edu	
Preferred Contact for this Proposal	Name: Dr. Phyllis Keys	
	Title: Interim Associate Vice President for Academic Affairs	
	Phone: (443) 885-3350	
	Email: Phyllis.Keys@morgan.edu	
President/Chief Executive	Type Name: Dr. Hongtao Yu, Provost & Senior Vice President for Academic Affairs	
	Signature: [signature]	Date: 05/16/2022
	Date of Approval/Endorsement by Governing Board:	05/03/2022

Revised 1/2021

Morgan State University

School of Engineering

Proposed

Doctor of Philosophy (Ph.D.) in Industrial Engineering with a pass-through (e*n passant*) Master of Science (M.S.) in Industrial Engineering

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A. Centrality to Institutional Mission and Planning Priorities:

A.1. Program Description

In this proposal, Morgan State University (MSU) proposes an academic program "**Doctor of Philosophy (Ph.D.) in Industrial Engineering**" with *en passant* (pass-through) Master of Science (MS) in Industrial Engineering, in the Department of Industrial and System Engineering at the Clarence M. Mitchell, Jr School of Engineering (SOE). The SOE has offered the following graduate programs since 1998: Doctor of Engineering and Master of Engineering in Industrial Engineering, Civil Engineering and Electrical Engineering, which focus more on applied research and industrial careers for students. This proposed Ph.D. (with a pass-through MS) in Industrial Engineering program will cover and focus more on the fundamental, theoretical, and original research in industrial engineering, which will benefit students in seeking academic careers.

This proposed program will provide a graduate curriculum for study and research in industrial engineering, such as the areas of operations efficiency, systems engineering, production systems and manufacturing, quality and reliability, *etc.* The program will require a minimum of 60 graduate credit hours of study beyond a B.S. degree (the M.S. degree will be granted after the successful completion of 30 credits of study), or a minimum of 36 graduate credits of study for the student who already has a master's degree. The required credit hours include a maximum of 18 dissertation-related research credit hours. The maximum time for the student to complete this Ph.D. program will be seven years. A typical program for a full-time student to earn this Ph.D. degree will be about 4 years beyond a B.S. degree with a roadmap as follows (the student will be granted a master's degree after successfully completing at least 30 credit hours):

First Year: 9 credits of coursework for each semester.
Second Year: 9 credits of coursework for each semester.
Third Year: 6-9 credits of coursework and/or dissertation research per semester.
Fourth Year: 6 credits of dissertation research per semester or IEGR 997 dissertation guidance
Thereafter, the student will continue in IEGR 997 until the successful dissertation defense (IEGR 998).

A typical program for a full-time student to earn this Ph.D. degree beyond a master's degree will be about 3 years with a roadmap as follows:

First Year: 9 credits of coursework for each semester.
Second Year: 6-9 credits of coursework and/or dissertation research for each semester.

Third Year: the student will register for IEGR 997 dissertation guidance until the successful dissertation defense (IEGR 998).

Based on the faculty's research expertise, the program will also provide the study and research concentration guidance in the following concentration areas. Under the guidance of the faculty adviser, the student will select the courses from the course list in Section G 4.5 for the plan of study, which can enhance the dissertation research capability in the respective area.

- Reliability and Quality Engineering
- Manufacturing and Production Systems
- Energy Systems and Industrial Technology
- Ergonomics and Human Factor
- Systems Engineering and Information

A.1. 1. Program of Study

The program will utilize the courses currently available in the inventory of WebSIS at Morgan State University. Section G4.5 of this proposal gives all graduate-level industrial engineering courses available in the inventory at Morgan State University, together with the course descriptions. The following categories in the tables below summarize the curriculum requirements for this **Ph.D. in Industrial Engineering beyond a B.S. degree (Table A1) or beyond a master's degree (Table A2)**:

Table A1: Credit breakdown for students pursuing a Ph.D. directly from bachelor's degree (60 credits required beyond a bachelor's degree).

Core Courses (4)	12 credits
Foundation Elective Courses or Research Courses (9) *	27 credits
Graduate Seminar (1)	3 Credits
Dissertation Research (5)	15 credits
Dissertation Defense IEGR 998 (1)	3 Credits
Total	**60 credits**

(* No more than 3 research courses)

Table A2: Credit breakdown for students pursuing a Ph.D. beyond a master's degree (36 credits required beyond a master's degree).

Foundation Elective Courses *or* Research Courses (5) **	15 credits
Graduate Seminar (1)	3 credits
Dissertation Research (5)	15 credits
Dissertation Defense IEGR 998 (1)	3 Credits
Total	**36 credits**

(** No more than 3 research courses; the core courses should be included if they were not taken when the student pursued the master's degree)

The further descriptions of the course requirements are given below:

1) **Core Courses**
   IEGR 512 Advanced Project Management (3 credits)
   IEGR 530 Advanced Simulation (3 credits)
   IEGR 535 Engineering Experimental Design (3 credits)
   IEGR 550 Human Performance Engineering (3 credits)

2) **Foundation Elective Courses**
   Foundation Elective Courses are from the available course list of IEGR 5xx/IEGR 6xx, and the research courses are from the available list of IEGR 7xx/IEGR 8xx in the course inventory, or equivalent graduate courses from other departments and schools. The courses from the non-IE department must be approved by the adviser and graduate program coordinator or departmental chairperson. These courses should enhance the student's preparation for dissertation research and/or career development. The student should take more IEGR 5xx/6xx elective courses than non-IE 5xx/6xx elective courses.

3) **Dissertation Research Courses**
   The student will become a Ph.D. candidate after passing Examination A: Admission to Doctorate Candidacy. Then, the student can take dissertation research courses of IEGR 905, IEGR 910, IEGR 915, IEGR 920, IEGR 925 as given in Section G4.5. After completing these 15 credits of dissertation research, the student should maintain the doctorate candidacy by taking IEGR 997, until the successful dissertation defense.

4) **Dissertation Defense (IEGR 998)**
   The student will defend the dissertation research (Examination B) and receive 3 credits of IEGR 998 Dissertation Defense in the final semester.

The doctoral student should complete a plan of study in the first year of study with the academic adviser and get approval from the graduate program coordinator/departmental chairperson. The student may be required to take more than the minimum credits of requirement if his/her undergraduate degree and/or master's degree is not in industrial engineering or a closely related field.

A.2. Strategic Goals Support and Affirmation

This proposed Ph.D./M.S. program is strategically aligned with the university's mission statement. MSU's current mission is to offer a comprehensive array of undergraduate programs and graduate programs to a broad cross-section of students in a supportive environment that encourages research and service toward the needs of underserved communities. The vision embedded in the current plan is for MSU to be recognized statewide and nationally for demonstrating both student access and success in higher education. As the premier public urban research university and the largest HBCU in Maryland, MSU endeavors to meet and serve the needs of a significant segment of the state's population with its mission and vision.

Morgan State University's vision and mission statements as well as it's core institutional values are consistent with the University's Carnegie Foundation classification as a doctoral research university and are intended to direct Morgan's strategic growth over the next decade. As a premier public urban research university in Maryland, known for its excellence in teaching, intensive research, effective public service, and community engagement, Morgan prepares diverse and competitive graduates for success in a global, interdependent society. The mission of Morgan State University is to serve the community, region, state, nation, and the world. As an intellectual and creative resource, MSU supports, empowers, and prepares high-quality, diverse graduates to lead the world. The university offers innovative, inclusive, and distinctive educational experiences to a broad cross-section of the population in a comprehensive range of disciplines at the baccalaureate, master's, doctoral, and professional degree levels. Through collaborative pursuits, scholarly research, creative endeavors, and dedicated public service, the University gives significant priority to addressing societal problems, particularly those prevalent in urban communities.

The core values of Morgan State University guide the promotion of student learning and success, faculty scholarship and research, and community engagement at Morgan, which consist of:

1) ***Excellence*.** Excellence in teaching, research, scholarship, creative endeavors, student services, and in all aspects of the University's operations is continuously pursued at Morgan to ensure institutional effectiveness and efficiency.
2) ***Integrity*.** At Morgan, honest communications, ethical behavior, and accountability for words and deeds are expected from all members of the University community.
3) ***Respect*.** Each person at Morgan is to be treated with respect and dignity and is to be treated equitably in all situations.
4) ***Diversity*.** Broad diversity of people and ideas are welcomed and supported at Morgan as essential to quality education in a globally interdependent society. Students will have reasonable and affordable access to a comprehensive range of high-quality educational programs and services.
5) ***Innovation*.** Morgan encourages and supports its faculty, staff, and students in all forms of scholarship including the discovery and application of knowledge in teaching and learning and in developing innovative products and processes.
6) ***Leadership*.** Morgan seeks to provide rigorous academic curricula and challenging co-curricular opportunities to promote the development of leadership qualities in students and to facilitate leadership development among faculty, staff, and students.

Morgan State University (MSU), as Maryland's Preeminent Public Urban Research University under the leadership of President Wilson, has achieved the *Research 2 (R2) status: Doctoral Universities - High Research Activity* according to the Carnegie Classification of Institutions of Higher Education, which was the goals set in our current 10 years (2011-2021) strategic plan. Among 107 HBCUs in the country, MSU is one of the 11 HBCUs that has achieved R2 status.

At the spring 2020 Faculty Institute on January 15, 2020, President Wilson presented to all MSU faculty and staff the highlights of our next 10-year strategic plan (2021-2031). A goal in this next 10-year strategic plan is to achieve the status of R1, which currently none of the HBCUs in the country has reached. In addition, President Wilson received an invitation on January 15, 2020, from the Director of the Board on Higher Education and Workforce of *National Academies of Sciences, Engineering, and Medicine,* to attend a one-day meeting for the Presidents of R2 HBCUs

in early fall 2020. The *National Academies of Sciences, Engineering, and Medicine* wishes to convene the 11 Presidents of R2 HBCUs for this one-day meeting in Washington DC with the purposes quoted from the invitation:

a. Consider evidence-based practices and strategies to enhance the quality of science, STEM-based research, and workforce development on their campuses.
b. Enable their engagement with NSF, NIH, DoD, and other federal agency officials; members and staff of Congress; leadership of the Office of Science and Technology Policy; the National Science Board; and private foundations to increase understanding of the different motivations, incentives, and needs around STEM research.
c. Begin to outline a strategic plan for collaboration among the institutions toward a comprehensive strategy for strengthening the research enterprise at these HBCUs.

President Wilson has committed to the attendance of this important meeting and discussion, to well pursue our goal of R1 status in the next 10 years.

The Department of Industrial and Systems Engineering at MSU has the only ABET-accredited Industrial Engineering program in the State of Maryland. Our department has very qualified and experienced faculty resources in the industrial engineering field. In addition, with our experience in running the Doctor of Engineering program with a concentration in Industrial Engineering since 1998, we are committed to developing a high-quality Ph.D./M.S. program in Industrial Engineering at Morgan State University, especially to serve the underrepresented minority students in the state, in the region, and the country. In particular, the Ph.D./M.S. program in Industrial Engineering addresses the following aspects of MSU's mission:

- Providing quality teaching, research, and service for the citizens of the state, with a special emphasis on meeting the needs of culturally diverse and multi-ethnic populations living in Baltimore as well as in other centers within the state and the nation.
- Enrolling an academically diverse student population, increasing the number of minorities in the industrial engineering field in which they are underrepresented, at the Ph.D. level.
- Training the workforce of Baltimore City and Maryland in professions essential to the economic, political, educational, social, and/or cultural well-being of the city, state, and nation.

Industrial Engineering offers employment opportunities in a wide variety of industries, public and private organizations, including manufacturing and engineering consulting firms, service and health care industries, colleges/universities, as well as public agencies at all levels of government. The demand for well-trained industrial engineers continues to grow, especially after this COVID-19 Pandemic, the demand for efficient manufacturing and manufacturing of essential medical supplies will significantly grow. The core values of industrial engineering include efficiency, productivity, and high quality. The MSU motto indicates “grow the future, lead the world.” To deal with the global challenges in low-cost, high-quality, and more efficient manufacturing and production system, it is necessary to train more IE professionals at the Ph.D. level. Based on our IE faculty resources and our experiences in running the IE program at the graduate level, our department is the most qualified and appropriate academic unit in Maryland to establish a Ph.D. program in industrial engineering. This proposed Ph.D./M.S. program in Industrial Engineering is

well aligned with MSU's strategic plan and mission. The rationale for the proposed program is threefold:

1) Improvement on an effective, pre-existing baccalaureate, master's, and a doctorate program in Engineering (B.S., M.Eng, and D.Eng). The Clarence M. Mitchell, Jr. School of Engineering currently awards B.S. degrees (ABET-accredited since 1992), Master of Engineering, and Doctor of Engineering. Since the inception of the MSU graduate program in the Industrial Engineering Department over 22 years ago, more than 100 people (mostly African Americans) have received their Master of Engineering and Doctor of Engineering with an emphasis in Industrial Engineering, and nearly all of them are currently employed with manufacturing firms, private and public sectors.
2) The second rationale for the proposed program is its importance to minority achievement in Engineering at both national and state levels. Morgan leads all other campuses in Maryland in the number of bachelor's degrees awarded to African Americans in Engineering and consistently ranks among the national leaders in the production of African Americans receiving their degrees in Engineering. Especially, Morgan is the only institution in the State of Maryland offering an undergraduate degree and graduate degree in industrial engineering.
3) Morgan is prepared now to offer a Ph.D./M.S. in Industrial Engineering, not only because of the specific needs of minorities in the region but also because of the strength of its faculty resource in industrial engineering and the outcomes of its current programs. The Clarence Mitchell School of Engineering has very qualified industrial engineering faculty, especially in the State of Maryland. All faculty members hold terminal degrees with most of them being in industrial engineering. The IE faculty are actively involved in high-level research and national/international professional activities. In addition, the department benefits from the interdisciplinary strength of a diverse faculty in the School of Engineering, several of whom are known scholars in their fields.

A.3. Five Year Funding Plan

The proposed Ph.D./M.S. in Industrial Engineering program moves the university forward in achieving two initiatives toward the goal to enhance student success in its strategic plan: (a) increasing student enrollment by developing unique high demand degree programs and (b) enhancing students' educational experiences by expanding the curriculum to include more credits for prior learning and work experiences as well as an interdisciplinary courses and degree programs.

The Ph.D./M.S. in IE also advances the statewide goal that 55% of adult Marylanders will hold a degree by 2025. Likewise, the State Plan for Postsecondary Education, Maryland Ready, established deliverables that include increasing college enrollments and completion. The IE Ph.D./M.S. is consistent with the Maryland Higher Education Commission's (MHEC) One Step Away State Grant Program (OSA) which provides funds to support public and independent nonprofit two-year and four-year institutions' efforts to identify, re-engage, re-enroll, and graduate near-completer students.

The Ph.D./M.S. program in IE addresses the statistically documented needs of both the nation and the state, the financial support required is minimal. Although administrative leadership and other professional staff will be secured to staff and operate the ISE’s programs, the overall academic program delivery rests upon capitalizing on existing academic programs and will utilize

available seats in our courses. In a corporate sense, this Ph.D./M.S. program can be viewed as intersecting subsidiaries of a corporation, rather than the more costly process of conceiving a completely new academic program. This Ph.D./M.S. program in IE is primarily undergirded by existing university academic programs such as DEng and MEng programs.

This enhancement will require the hiring of additional faculty in the existing academic programs. Currently, the department is authorized by the university to hire three more tenure-track or tenured faculty and the advertisements are listed in the university website. However, a cursory look at the potential tuition income generated in comparison to the possible cost of additional faculty and administrative staff quickly reveals that in a short time horizon this Ph.D./M.S. program will pay for itself.

Morgan has committed sufficient resources to 1) recruit faculty to teach both online and face-to-face courses; and 2) enhance the research stature of the university via research grants/contracts, journal papers, and technical presentations. Currently, this program is supported by seven full-time faculty of the Industrial and Systems Engineering (ISE) department, and several -part-time adjunct faculty. Faculty searches are underway to hire additional faculty with research interests well aligned with the program.

The Department of Industrial and Systems Engineering has faculty with extensive experience to prime the pipeline for the program, a portion of new enrollments in the current Doctor of Engineering program will be considered for admission into the Ph.D./M.S. in Industrial Engineering program. If necessary, these students would utilize currently available funding mechanisms, such as financial assistance and Scholarships from the School of Graduate Studies, to cover program tuition costs. Additional students will be supported through current and new research funding. Our faculty have established research collaborations and strategic partnerships with NSF, NASA, DOD, DOE, Navy and Army, as well as industrial partners.

A.4. Morgan Commitment

This Ph.D./M.S. in Industrial and Systems Engineering has received full support from Morgan State University President, Dr. David Wilson, and the Provost and Senior Vice President for Academic Affairs Dr. Hongtao Yu. President Wilson has articulated an emerging vision for Morgan focusing on urban sustainability and applied research. As a part of the University's strategic plan, the President has charged the University community to focus on intractable challenges facing the local community and communities around the globe as that will elevate Morgan's current Carnegie classification from R2 to R1, high research activity. This program is well-aligned to address the challenges through fundamental research conducted by the program's faculty.

Morgan State University will support the Ph.D./M.S. in Industrial and Systems Engineering with seven full-time faculty, with a potential for additional new tenure-track faculty members in the near future. Laboratory facilities within the School of Engineering are well equipped to support associated research and the inclusion of approximately 10 graduate student researchers.

In alignment with Morgan's mission statement and its planning priorities, this proposal for a Ph.D. in the Industrial and Systems Engineering Department is consistent with Morgan's current mission of serving "the community, region, state, nation, and the world as an intellectual and creative resource by supporting, empowering and preparing high-quality, diverse graduates to lead the world," which is firmly grounded in enhancing student success, the first goal of Growing the Future, Leading the World. To realize its institutional mission, its legislative designation as Maryland's Preeminent, Public, Urban, Research Institution and its strategic planning goals, and Carnegie R1 designation goal, Morgan has focused on developing unique high demand degree Programs to offer both in traditional classroom face-to-face settings as well as online.

This new program will benefit our students, our institution, and the State. Our institution can increase graduation rates, expand its engaged graduate alumni base, collect additional tuition revenues, and better recognize the return on institutional investments in these students. The State benefits from an increased pool of more-educated, credential-bearing workers with the skills needed to support its growing knowledge-based economy. State investment in higher education is more fully realized when students complete a degree.

Morgan State University serves the community, region, state, nation, and the world as an intellectual and creative resource by supporting, empowering, and preparing high-quality, diverse graduates to lead the world. The University offers innovative, inclusive, and distinctive educational experiences to a broad cross-section of the population in a comprehensive range of disciplines at the baccalaureate, master's, doctoral, and professional degree levels. Through collaborative pursuits, scholarly research, creative endeavors, and dedicated public service, the University gives significant priority to addressing societal problems, particularly those prevalent in urban communities.

Recently, the University has made special efforts to improve both retention and graduation rates. The commitment to this endeavor is evidenced in the establishment of a centralized Office of Student Success and Retention, which provides dedicated staff members for each academic school and the college of liberal arts. These staff members are responsible for maintaining positive retention and graduation rates through several strategic initiatives and activities. Students are monitored, advised, mentored, engaged, and encouraged to support and ensure their success and retention through graduation. The University continues to invest in software application platforms that allow the office to assess student academic statuses in real-time.

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

B.1. Program Demand and Need

The Department of Industrial and Systems Engineering offers a B.S. degree in industrial engineering (IE) which has been accredited by ABET since 1992 and is the only accredited IE degree in the state of Maryland. The department also offers a Doctor of Engineering degree and Master of Engineering degree with an emphasis in Industrial Engineering since 1998. Recently,

we have received many inquiries about a potential Ph.D. program study in industrial engineering from potential students, especially underrepresented minority students. As the only accredited Industrial Engineering program in Maryland with valuable IE faculty resources, the ISE department is inspired and dedicated to proposing and establishing this Ph.D./M.S. program in Industrial Engineering at Morgan State University to help the state and regional needs for Ph.D. level talents in industrial engineering, especially the talents from under-represented minority communities.

As an HBCU, we are proposing this Ph.D./M.S. program in Industrial Engineering at Morgan State University to accommodate the needs of African Americans for Ph.D. level education in industrial engineering and to enhance workforce diversity and improve the under-represented minority status. With our very qualified faculty resources in industrial engineering (nearly all regular faculty holding a Ph.D. in industrial engineering or a closely related area), our department can help Maryland, a state with many federal research centers and top manufacturing companies, to end the embarrassing situation of zero Ph.D. degree awarded in industrial engineering in history. This new Ph.D./M.S. program in industrial engineering can also help strengthen the research capability of our department, our engineering school, and Morgan State University, recognized by the University's Carnegie Foundation classification as a doctoral research university, by the state as the premier public urban research university in Maryland. Our new program can help the minority and educationally disadvantaged students from the Baltimore area, from Maryland to pursue a Ph.D. in industrial engineering at an affordable cost.

B.1.a) The need for the advancement and evolution of knowledge

It is important to the United States and the State of Maryland to bring manufacturing back to the country or maintain a leading role in manufacturing in the world. Especially after this COVID-19 outbreak, the demand for efficient manufacturing enterprises and manufacturing of essential medical supplies and personal protection equipment will significantly increase. The core values of industrial engineering include operation efficiency of humans, machines, energy, productivity, and high quality, etc. To maintain and increase the competitiveness of American manufacturing industries, the demand for well-trained industrial engineers is expected to grow. More than 10 years ago, a senior faculty from our department worked at Goddard Space Flight Center as a NASA Administrator’s Fellow with Space Technology 5 (ST-5) program for several years for manufacturing cost reduction for the space mission. He witnessed the shortage and need for industrial engineering talents to maintain efficient and low-cost space missions at governmental agencies. There are similar needs and shortages of industrial engineering talents at management levels for manufacturing and service industries.

B.1.b) Societal needs, including expanding educational opportunities and choices for minority & educationally disadvantaged students at institutions of higher education

Industrial Engineering offers employment opportunities in a wide variety of industries, public and private organizations, including manufacturing and engineering consulting firms, service and health care industries, colleges/universities, public agencies at all levels of government. The demand for well-trained industrial engineers continues to grow, and especially after this COVID-19 Pandemic, the demand for efficient manufacturing and manufacturing of essential medical supplies will significantly grow. The core values of industrial engineering include efficiency,

productivity, and high quality. MSU's motto indicates “grow the future, lead the world”. To deal with the global challenges in low-cost, high-quality, and more efficient manufacturing and operations systems, it is necessary to train more IE professionals at the Ph.D. level.

B.1.c) Need to strengthen and expand the HBCU capacity in Industrial Engineering

This proposed Ph.D./M.S. in Industrial Engineering program will not only create desirable synergies with the existing degree programs in industrial engineering, but it will also extend the reach of the Mitchell School of Engineering with its interdisciplinary focus on manufacturing, social, environmental, economic, and policy issues that draw on other closely related fields at Morgan State University. This improvement will serve as a resource center for addressing timely cross-cutting issues of the community. This proposed Ph.D./M.S. program will support the Department of Industrial and Systems Engineering, the School of Engineering, and thereby, enhance Morgan's position of leadership in industrial engineering education and research, as an HBCU in the country.

Morgan leads all other campuses in the State of Maryland in the number of bachelor's degrees awarded to African Americans in Engineering and consistently ranks among the national leaders in the production of African Americans receiving their degrees in Engineering. Especially, Morgan is the only institution in the State of Maryland offering an undergraduate degree and graduate degree in Industrial Engineering.

B.2. Compliance with State Postsecondary Education Plan

The Ph.D./M.S. in Industrial Engineering is consistent with the three primary goals outlined in the State Plan, including access, success, and innovation.

- **Access**

  In addition to its well-established array of baccalaureate (45), Master's (38), doctoral and professional degrees (17), Morgan has also established a robust online presence through the establishment of the office of Morgan Online, an administrative unit for oversight of the new innovative online degree and certificate programs offered by the University. The intent of establishing these online programs is, in no small measure, an effort by the University to fulfill its access mission by providing agile degree programs on campus and online to expand educational opportunities for traditional and non-traditional students. As noted in the State Plan, non-traditional students comprise most post-secondary students who delay initial enrollment or are returning, part-time, are financially independent of parents, have families to support, or work full-time. These students have needs and expectations that are often quite different from those of the traditional high school-to-college student. The Ph.D./M.S. in Industrial Engineering is consistent with Morgan's access mission in that by offering the degree on campus and online to more students, especially non-traditional students. They will have the opportunity to earn a degree in a unique, high-demand STEM-based program. Offering the Ph.D./M.S. in Industrial Engineering at Morgan helps to improve student access in this discipline and career pathway.

- **Success**

  Morgan has several well-established initiatives to increase the educational success of underserved populations. A key aspect of student success at Morgan is the 50 by 25 Campaign,

which aims at raising the six-year graduation rate to 50% by 2025. The President reported to the General Assembly: Beginning with the entering class of 2010, the University has significantly increased its freshman and sophomore retention rates. Second-year retention rates are above 70% for the past nine years. Third-year retention rates are at 60%. Fourth-year retention rates have risen to 56%. Our six-year graduation rates have increased from 31% for the fall 2009 cohort to 43% for the fall 2013 cohort. In summary, the Ph.D. in Industrial Engineering degree integrates with an ongoing set of strategic initiatives focused on ensuring student success. The University has a storied history of success in graduating African Americans, particularly women, and other underrepresented minorities with undergraduate and graduate degrees in most of the STEM disciplines.

• **Innovation**

In March (2019), Morgan celebrated its 6th annual "Innovation Day" in Annapolis, MD. at the Miller Senate Office Building. Morgan Innovation Day has the goal of taking the lead in innovation and providing a pipeline to new technologies, consistent with our historic mission of preparing a diverse student body. The Ph.D. program in Industrial Engineering enhances Morgan's tradition of providing unique, high-demand, and innovative academic programs. No higher education institution in Maryland offers a Ph.D./M.S. program in Industrial Engineering. Through the collaboration with academic, industry, and government stakeholders, the Ph.D. program in Industrial Engineering can provide maximum and flexibility to graduate students, working professionals as well as non-traditional students to acquire instruction skills, and competencies in a leading-edge career pathway essential to meet the workforce demand in the State and the nation. In summary, the proposed Ph.D./M.S. in Industrial Engineering program is unique in Maryland and does not duplicate any other Ph.D. degrees offered by any other university in Maryland.

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

C.1. Industry or industries, employment opportunities, and expected level of entry for graduates of the proposed program

Our department has awarded Master of Engineering degrees and Doctor of Engineering degrees in Industrial Engineering for more than 20 years and awarded ABET-accredited B.S. degrees to the students from the State of Maryland and the country, and from the World for about 30 years. Nearly all graduates were able to secure employment with manufacturing industries, service industries, and governmental agencies, such as Lockheed Martin, Northrop Grumman, UPS, etc. Every year, our alumni come back to the MSU campus to represent their companies to recruit new graduates from our department. We have not observed any case that an IE graduate had serious difficulty in securing his/her employment. For this Ph.D./M.S. in Industrial Engineering program, the expected entry-level of employment will be an entry-level faculty position for educational institutions, a mid-level management position in a manufacturing or service industry, mid-level at research institutions or governmental agencies, as well as senior-level at consulting firms.

C.2. Employment Opportunities for the Ph.D. in Industrial Engineering

In addition to the faculty positions in educational institutions, the recipients of the Ph.D. in Industrial Engineering also have good opportunities to be hired as scientists for national research institutions and public sectors, as senior engineers, or managers in industries for product development to enhance reliability and quality. Graduates might also be able to become a senior industrial engineering consultant, director of ergonomists, senior quality engineer, operations analyst or industrial engineer manager. Previous work history can play a role in the career students qualify for after graduation.

Industrial Engineers typically do the following:

- Review production schedules, engineering specifications, process flows, and other information to understand methods that are applied and activities that take place in manufacturing and services
- Figure out how to manufacture parts or products, or deliver services, with maximum efficiency
- Develop management control systems to make financial planning and cost analysis more efficient
- Enact quality control procedures to resolve production problems or minimize costs
- Design control systems to coordinate activities and production planning in order to ensure that products meet quality standards
- Confer with clients about product specifications, vendors about purchases, management personnel about manufacturing capabilities, and staff about the status of projects

Industrial engineers apply their skills to many different situations, from manufacturing to healthcare systems to business administration. For example, they design systems for:

- Moving heavy parts within manufacturing plants
- Delivering goods from a company to customers, including finding the most profitable places to locate manufacturing or processing plants
- Evaluating job performance
- Paying workers.

Some industrial engineers, manufacturing, or process engineers, focus entirely on the automated aspects of manufacturing processes. They design manufacturing systems to optimize the use of computer networks, robots, and materials. Industrial engineers focus on how to get the work done most efficiently, balancing many factors, such as time, manpower, available technologies, actions to be taken, achieving the optimal process operation with concern about worker's safety, environment, and cost.

The versatility of industrial engineers allows them to engage in activities that are useful to a variety of businesses, governments, and nonprofits. For example, industrial engineers engage in supply chain management to help businesses minimize inventory costs, conduct quality assurance activities to help businesses keep their customer bases satisfied, and work in the growing field of project management as industries across the economy seek to control costs and maximize efficiencies.

C.3. Salaries of Industrial Engineering Professionals

Employment of industrial engineers is projected to grow 14 percent from 2020 to 2030, faster than the average for all occupations. Many of those openings are expected to result from the need to replace workers who transfer to different occupations or exit the labor force, such as to retire.

According to the U.S. Bureau of Labor Statistics, the national demand for industrial engineers is high, and especially in the State of Maryland, the annual mean wage of industrial engineers is $99,480-$113,920 according to the statistical data collected in May 2020 (see Figure C1 below). The independent studies on the demand for industrial engineers in 2016 also revealed about 10% increase of industrial engineer jobs in the next 10 years from then 257,899 industrial engineers (source: https://www.careerexplorer.com/careers/industrial-engineer/job-market/). There are four cities where the typical salary for an Industrial Engineering job is above the average in Maryland. Topping the list is Baltimore, with Frederick and Salisbury close behind in second and third. Salisbury beats the Maryland average by 5.7%, and Baltimore furthers that trend with another $8,347 (11.2%) above the $74,299. Significantly, Baltimore has a very active Industrial Engineering job market as there are several companies currently hiring for this type of role.

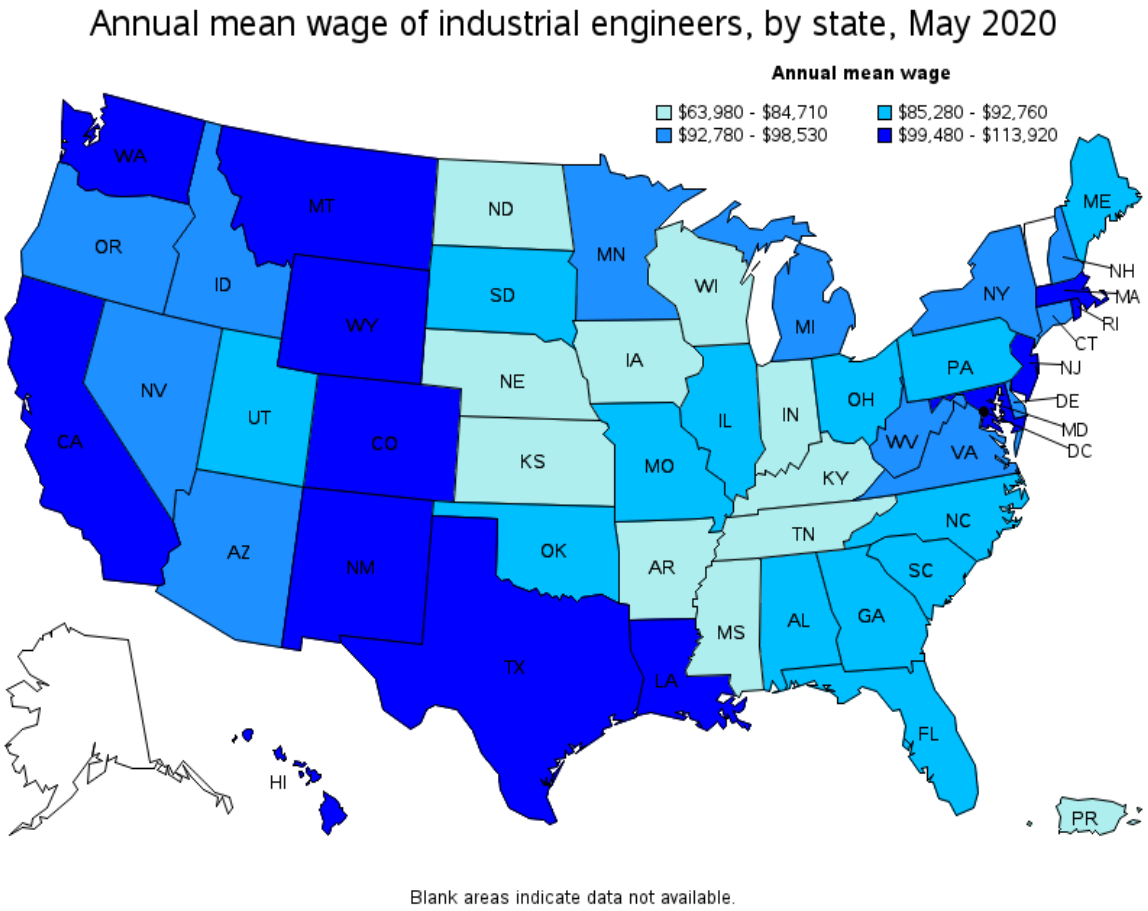

Figure C1 Annual mean wage of industrial engineers by state, May 2020 (source: https://www.bls.gov/oes/current/oes172112.htm#ind)

There are at least 5 jobs related to the Industrial Engineering job category that pay more in Maryland than a typical Industrial Engineering salary. Top examples of these roles include Mechanical Engineering Supervisor, Industrial Engineering Director, and Mechanical Engineer IV (Table C1).

Table C1. Five additional higher-level or more experienced jobs related to industrial engineering

Job Title	Annual Salary	Monthly Pay	Weekly Pay	Hourly Wage
Mechanical Engineering Supervisor	$106,812	$8,901	$2,054	$51.35
Industrial Engineering Director	$101,687	$8,474	$1,956	$48.89
Mechanical Engineer IV	$98,928	$8,244	$1,902	$47.56
Industrial Engineering Management	$95,067	$7,922	$1,828	$45.71
Manufacturing Engineer III	$91,462	$7,622	$1,759	$43.97

Source: https://www.ziprecruiter.com/Salaries/Industrial-Engineering-Salary--in-Maryland

According to the statistics by PayScale, the average base salary for PhD in IE recipients is $112k (https://www.payscale.com/research/US/Degree=Doctor_of_Philosophy_(PhD)%2C_Industrial_Engineering_(IE)/Salary). The typical job titles and respective salaries are summarized in Table C2.

Table C2. Typical job positions for PhD in Industrial & Systems Engineering recipients

S/N	Related Positions	Salary (in USD)
1	Industrial Engineer	61k – 130k
2	Data Scientist	80k – 135k
3	Senior Data Scientist	96k – 159k
4	Research Scientist	74k – 149k
5	Operations Research Scientist	72k – 163k
6	Senior Process Engineer	103k – 155k
7	Human Factors Engineer	77k – 143k
8	Research Analyst, operations	54k – 93k
9	Risk Manager	69k – 122k
10	Senior Industrial Engineer	78k – 106k
11	Systems Engineer (Computer Networking/ IT)	63k – 102k
12	Chief Systems Engineer	125k – 238k

(Additional references: Doctor of Philosophy (PhD), Industrial Engineering (IE) Salary - Page 5 | PayScale, https://www.forbes.com/sites/andrewdepietro/2020/10/31/heres-how-much-money-industrial-engineers-earn-in-every-us-state/?sh=3eb9aacb7058, https://www1.salary.com/Salaries-for-Industrial-Engineer-V-with-a-JD-MD-PhD-or-Equivalent).

According to a report by Forbes, Maryland is one of the top 10 states where Industrial Engineers earn the most money with average salary of $101,710, and the median salary for an Industrial Engineer V with a JD, MD, PhD or Equivalent is $130,183 - $138,138.

C.4. Current and Projected Supply of Prospective Graduates

Congressional Research Service (CRS) analysis of Bureau of Labor Statistics 22 employment projections indicate that the science and engineering workforce will grow from 7.3 million to 8.2 million jobs between 2016 and 2026, an increase of 853,600 (11.7%) jobs over the ten years (1.1% CAGR). This growth rate is higher than the growth rate projected for all occupations (0.7% CAGR) during this period. Figures C2 and Table C3 show the science and engineering occupations with the most projected job openings due to growth, labor force exits, and occupational transfers, respectively. Industrial Engineers are listed as one of the most projected job openings annually.

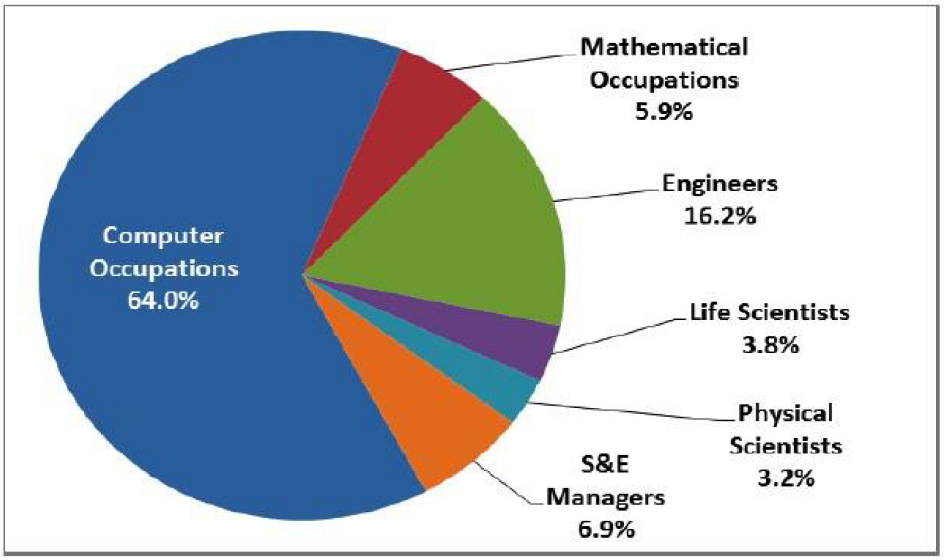

Figure C2 the most projected job openings in science and engineering

Table C3: The most projected job openings

Rank	S&E Occupation	Projected Average Annual Job Openings
1	Software developers, applications	85,500
2	Computer user support specialists	55,400
3	Computer systems analysts	44,800

4	Software developers, systems software	32,700
5	Computer and information systems managers	32,500
6	Civil Engineers	27,000
7	Operations research analysts	25,900
8	Computer occupations, all other	22,300
9	Mechanical Engineers	21,200
10	Industrial Engineers	19,700

D. Reasonableness of Program Duplication

This new program will be the first Ph.D. program in Industrial Engineering in the State of Maryland. Thus, there is no duplication concern. With our very qualified faculty resource in industrial engineering (all faculty have doctoral degrees and the majority hold degrees in Industrial Engineering), our department currently is the most qualified academic unit to propose and implement this Ph.D./M.S. in Industrial Engineering program in the State of Maryland.

E. Relevance to High-demand Programs at Historically Black Institutions (HBIs)

E1. Program's potential impact on the implementation or maintenance of high-demand programs at HBI's.

To date, there are no equivalent programs at any of the State's HBIs, including Bowie State University, Coppin State University, and the University of Maryland Eastern Shore (UMES). The Ph.D./M.S. program in Industrial Engineering will not have any negative impact on the State's HBIs. Furthermore, this program will enhance Morgan's reputation across the country since there is a need nationwide for such a program. Indeed, this program will be in high demand and benefit Morgan State University substantially.

As one of the noted HBIs or HBCUs and Maryland's Preeminent Public Urban Research University, Morgan State University (MSU) has achieved the Research 2 (R2) status: Doctoral Universities – High Research Activity according to the Carnegie Classification of Institutions of Higher Education, which was of the goals set in our current 10 years (2011-2021) strategic plan. Out of 107 HBCUs in the country, MSU is one of the only 11 HBCUs and the only HBCU from the State of Maryland that has reached R2 status. In addition, MSU has the only ABET-accredited Industrial Engineering program in the State of Maryland. We keep offering high-quality education in industrial engineering to the residents of Maryland State, especially to the under-represented minority in higher education. We have received many inquiries from prospective and current students about the possibility to pursue a Ph.D. degree in Industrial Engineering. This new Ph.D./M.S. in Industrial Engineering can also help MSU's next 10-year strategic plan to achieve R1 status.

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

Morgan is the largest and most comprehensive among the four HBIs in the state. In 2017, Morgan was designated by the General assembly as Maryland's Preeminent Public Urban Research University. Morgan was also elevated from a Carnegie research classification to a high-research kind in 2019. Morgan's undergraduate and graduate student populations are roughly 80% African Americans. Morgan is committed to the academic success and achievement of all students. None of the other HBIs have a Ph.D. program in Industrial Engineering in Maryland, DC, and Virginia, and even the M id-Atlantic region. For reasons previously discussed, the proposed program is essential in supporting Morgan's mission and identity as an HBI.

G. Adequacy of Curriculum Design, Program Modality, and Related Learning Outcomes (as outlined in COMAR 13B.02.03.10)

G1. Program Establishment and Oversight

This program is well-aligned with the university vision established by Dr. David Wilson, President of Morgan State University and Provost Hongtao Yu. In addition, Dr. Oscar Barton, Dean of the Clarence M. Mitchell, Jr. School of Engineering, encouraged the establishment of this program and is enthusiastically supportive. The program is established upon our current graduate programs and graduate courses offered in the Department of Industrial and Systems Engineering (ISE) since 1998 and encompasses the research expertise/capabilities and graduate courses taught by the ISE faculty. It leverages most of the existing courses within the Doctor of Engineering program and introduces new courses designed to integrate contemporary knowledge across industrial and systems engineering fields. The program will be offered by the ISE Department. Since 1998, the ISE Department has offered graduate studies for Doctor of Engineering (D.Eng) degree and Master of Engineering (M.Eng) degree. The D.Eng and M.Eng programs focus more on applied and industrial research. Recently, we have received many inquiries about potential Ph.D. program study in industrial engineering from potential students, especially underrepresented minority students. Since we have the only accredited industrial engineering program in Maryland and have valuable and very qualified IE faculty resources, we are responsibly proposing to establish this Ph.D. program in Industrial Engineering at Morgan State University to help the state and regional needs for Ph.D. level talents in industrial engineering, especially the talents from under-represented minority communities. This new Ph.D. in Industrial Engineering program will benefit our graduate students, especially from under-represented communities, in pursuing academic careers in educational and research institutions.

The graduate program coordinator/director Dr. Chen will oversee the program, with his more than 31-year experience in industrial engineering education and research, as well as his experience in recruiting graduate students, with duties of reporting to the departmental Chairperson, scheduling graduate classes, data gathering, program assessment, student orientation and registration, retention, recruitment, marketing the program and program development. He will be supported by the departmental chairperson Dr. Bardhan and other experienced and very qualified ISE faculty: Dr. Lee, Dr. Bronner, Dr. Salimian and Dr. Talley. Most of our ISE faculty have their doctoral degrees in Industrial Engineering and have more than 20-years teaching and research experiences in Industrial Engineering, such as Dr. Chen has been an IE faculty since 1990 and he was an NASA Administrator Fellow in 2002-2004 and worked full-time for one year with NASA

Space Technology 5 (ST-5) Team at Goddard Space Flight Center on systems engineering and reliability during the design stage of three ST-5 microsatellites in 2002-2003.

G2. Program Educational Objectives and Learning Outcomes

The Program mainly targets highly motivated students who have already obtained the bachelor's or master's degree and wish to pursue academic careers in research and educational institutions, as well as consulting or management positions. Upon completion of the Program, students will have gained a broad technical and interdisciplinary background that will allow them to identify and tackle critical problems related to industrial engineering and systems that require efficient usage of manpower, material, energy, time, and other resources for high-quality and efficient operations. Specifically, upon completing the Program, students will be expected to:

1) Demonstrate a breadth of knowledge in optimal product and production system design, including service industry, for high quality and low cost.
2) Master fundamental concepts in mathematical system theory, principles of engineering, planning and management in solving complex engineering problems.
3) Conduct independent research and disseminate research results through peer-review and publication.
4) Communicate difficult technical concepts both orally and in writing as well as function on an interdisciplinary team, particularly in a laboratory setting; and
5) Teach and mentor other students in classroom or directed research activities under faculty supervision.

G3. Program Evaluation

The assessment of this program will be administered by the University's Office of Assessment which supports the strategic initiatives of Morgan State University by directing the implementation of the Comprehensive Assessment Plan and the General Education Program. By using software systems Searchlight and Starfish, the Office works with University Divisions to collect, analyze, report on and use data related to institutional effectiveness, accreditation, student success, satisfaction and retention, and campus performance against key benchmark indicators.

G 4. Course Descriptions & Program Requirements

G.4.1. Admission Requirements

The Program welcomes exceptional students with at least a 3.0 cumulative GPA (on a scale of 4.0) for all undergraduate and graduate work completed. Other requirements include a resume or curriculum vitae documenting current and previous professional activities, achievements, planned career goals, a statement of research interest, and three letters of recommendation from professors or supervisors who are familiar with the applicant's academic background. All application materials must be sent directly to the School of Graduate Studies through the application system for preliminary screening. Eligibility to be a student within the School of Graduate Studies is a prerequisite for admission into the Program.

G.4.2. General Requirements

Students enrolled in the Program will be required to satisfy the following requirements:

1. Form a doctoral advisory committee by the end of the first year after admission, comprising of four members, among whom at least three of them should be tenured or tenure-track faculty members. The chair of the committee must be a member of the graduate faculty and the ISE department. A minimum of two ISE faculty must serve on the committee. The students form an advisory committee no later than the end of the first year. The committee approves the student's program of study and guides the student's research activities.
2. Complete a minimum of **36** graduate credit hours (including 18 hours of dissertation-related research) of study beyond the master's degree or complete a minimum of **60** graduate credit hours of study beyond the bachelor's degree (including 18 hours of dissertation-related research).
3. Pass a written qualifying exam within the first two years of study (one attempt within the first year), doctoral candidacy examinations (no sooner than a year of passing qualifying exam), administered by the dissertation committee, on the foundation course subjects.
4. Develop and defend a dissertation proposal.
5. Complete and successfully defend a dissertation based on timely and original research in Industrial Engineering.
6. The dissertation committee chair must determine the original contribution of the dissertation.

The qualifying exam is at the level of advanced undergraduate courses and introductory graduate-level courses. To maintain good academic standing and remain in the Program, the student may not have course grades lower than B in any of the required foundation courses and must maintain a cumulative GPA of 3.0. Failure to meet these requirements will lead to academic probation for one academic year.

G.4.3. Program of Study

The required minimum coursework for the Ph.D. in Industrial Engineering is 60 graduate credits beyond a bachelor's degree (Table G1) or 36 graduate credits beyond a master's degree Table G2). Up to four courses (12 credits) from other accredited institutions may be accepted for transfer towards the Ph.D. degree if the student did not use transfer courses to satisfy the academic requirements of the former program. Transfer courses at a grade of B or above are approved by the department. The acceptable master's degree programs that can be considered for the 36-credit Ph.D. in Industrial Engineering are listed in Table G3.

Table G1: Credit breakdown for students pursuing a Ph.D. directly from a bachelor's degree (60 credits required beyond a bachelor's degree).

Core Courses (4)	12 credits
Foundational Elective Courses or Research Courses (9) *	27 credits
Graduate Seminar (1)	3 Credits
Dissertation Research (5)	15 credits
Dissertation Defense IEGR 998 (1)	3 Credits
Total	**60 credits**

(*No more than 3 research courses)

Table G2: Credit breakdown for students pursuing a Ph.D. beyond a master's degree (36 credits required beyond a master's degree).

Foundational Elective Courses *or* Research Courses (5) *	15 credits
Graduate Seminar (1)	3 credits
Dissertation Research (5)	15 credits
Dissertation Defense IEGR 998 (1)	3 Credits
Total	**36 credits**

(*No more than 3 research courses)

Table G3. List of approved master's degree programs for admission to the Ph.D. program in Industrial Engineering *

Master's in Industrial Engineering, Manufacturing and Mechanical Engineering
Master's in Systems Engineering, Information Systems, Engineering Management
Masters in Operations Research, Production Systems, Management

(* If a student with a master's degree not in the above areas is interested/eligible for the Ph.D. study in IE, the student will be required for additional 9 credits or one additional semester of full-time study. The requirement for this student will be 45 credits (36+9) beyond a master's)

The further descriptions of the course requirements are given below:

1) The Core required courses (4 courses, 12 credits)
   - IEGR 512 Advanced Project Management (3 credits)
   - IEGR 530 Advanced Simulation (3 credits)
   - IEGR 535 Engineering Experimental Design (3 credits)
   - IEGR 550 Human Performance Engineering (3 credits)

2) Foundation Elective or Research Courses from the available course list of IEGR 5xx/IEGR 6xx/IEGR 7xx in our course inventory listed in Section G4.5 and/or equivalent graduate courses from other departments or schools as approved by the advisor. The courses from the non-IE department must be approved by the adviser and graduate program coordinator or departmental chairperson and the courses should enhance students' preparation for dissertation research and/or career development. The student should take more IEGR 5xx/6xx/7xx elective courses than non-IE 5xx/6xx elective courses.

3) Dissertation Research Courses. The student will become a Ph.D. candidate after passing Examination A (Admission to Doctorate Candidacy). Then, the student can take dissertation research courses of IEGR 905, IEGR 910, IEGR 915, IEGR 920, IEGR 925 as given in Section G4.5. After completing these 15 credits of dissertation research, the student should maintain the doctorate candidacy by taking IEGR 997, until the successful dissertation defense.

4) Dissertation Defense (IEGR 998)
   The student will defend the dissertation research (Examination B) and receive 3 credits of IEGR 998 Dissertation Defense in the final semester.

The doctoral student should complete a plan of study in the first year of study with the academic adviser and get approval from the graduate program coordinator/departmental chairperson. The student may be required to take more than the minimum credits of requirement if his/her undergraduate degree and/or master's degree is not in industrial engineering or a closely related field. In addition to taking IEGR 5xx/6xx courses in our course inventory, the students may take no more than three research-based courses from the research course list in Table G4 to fulfill the elective course credit requirement before achieving a Ph.D. Candidacy:

Table G4. Research-Based Courses before Ph.D. Candidacy

Course Code	Course Title	Credits
IEGR 790	RSCH IN DESIGN & MANUFACTURING	3
IEGR 791	INDEP STUDY IN INDUSTRIAL ENGR	3
IEGR 792	DIRECTED RSCH IN INDUST ENGR	3
IEGR 805	Pre-Candidacy Research I	3
IEGR 810	Pre-Candidacy Research II	3
IEGR 815	Pre-Candidacy Research III	3

After the student is advanced to Ph.D. Candidacy, the student should take 15 credits of dissertation research of IEGR 905 – IEGR 925 listed in Table G5, and then continue to register for IEGR 997 thereafter. After the dissertation defense is completed, the final IEGR 997 will be converted to IEGR 998 dissertation defense. Three credits of IEGR 998 can be used for the minimal credit hour requirement.

Table G5. Dissertation Research Courses Including Dissertation Defense

Course Code	Course Title	Credits
IEGR 905	Dissertation Research I	3
IEGR 910	Dissertation Research II	3
IEGR 915	Dissertation Research III	3
IEGR 920	Dissertation Research IV	3
IEGR 925	Dissertation Research V	3
IEGR997/998	Dissertation Guidance/Defense	3

Note: the student is eligible to take the Dissertation Research courses listed in Table G5 only after he/she has passed the Dissertation Proposal Exam (A), and advanced to candidacy. Before this, the research courses in Table G4 must be used. A student who has completed all required course credits but has not been advanced to Ph.D. candidacy should register for the IEGR 993 (Pre-Candidacy course). The Independent Research courses (IEGR 790, IEGR 791, and IEGR 792) listed in Table G4 can be used either in the Pre-Candidacy or Dissertation phase of the Research course. Students are expected to submit at least three articles for publication, and the Ph.D. program will be completed with IEGR 997/998 (Dissertation-Guidance/Defense).

Residency Requirements: All candidates must satisfy eighteen (18) credit hours of residency requirements in one of the following ways: enrolling in nine credit hours per semester for two consecutive semesters or part-time candidates must register for six credit hours per semester for three consecutive semesters.

Upon achieving Doctoral Candidacy and completing 15 credits of dissertation research, the student will continuously register for IEGR 997 (Dissertation-Guidance) until the Dissertation is completed and submitted to the School of Graduate Studies for review. The course is used only when the curriculum has been completed, candidacy has been achieved, and the student is completing the research and writing of the Dissertation. The IEGR 997 course registration maintains the student status as a matriculated, full-time student (student is registered for 3 credit hours and the system reports a full-time 9 credit hour load).

After the Intent to Defend the Dissertation form has been received by the School of Graduate Studies, this course registration will be converted to IEGR 998 (Dissertation Defense) in the final semester for 3 credit hours of curricular coursework. The grade for IEGR 998 is "P/F" (Pass/Fail).

G.4.4. Example Plans of Study

Below are two examples of study plans for a Ph.D. in Industrial Engineering.

Plan I: For students holding a B.S. degree pursuing a Ph.D. in Industrial Engineering (60 credits)

Table G6. 60-credit Plan for students with a B.S. degree pursuing a Ph.D. in Industrial Engineering

		First Semester	Credits		Second Semester	Credits
YEAR 1	IEGR 787	Graduate Seminar	3	IEGR xxx	Core Course	3
	IEGR xxx	Core course	3	IEGR xxx	Core course/foundation elective	3
	IEGR xxx	Core Course/foundation elective	3	IEGR xxx	Foundation Elective	3
	TOTAL		**9**	**TOTAL**		**9**
YEAR 2	IEGR xxx	Foundation Elective Course	3	IEGR xxx	Foundation Elective Course	3
	IEGR xxx	Foundational Elective Course	3	IEGR xxx	Foundation Elective Course	3
	IEGR xxx	Foundational Elective Course	3	IEGR xxx	Foundational Elective or Research Course	3
		TAKE QUALIFYING EXAM				
	TOTAL		**9**	**TOTAL**		**9**
		After successful completion of all credits outlined in Years 1 and 2, the student is awarded the MS degree				
YEAR 3	IEGR xxx	Foundation Elective or Research Course	3	IEGR 905	Dissertation Research I	3
	IEGR 8xx	Foundational Elective or Research Course	3	IEGR 910	Dissertation Research II	3
		CANDIDACY PROPOSAL EXAM (A)		IEGR 915	Dissertation Research III	3
		SUBMIT PAPER # 1			*SUBMIT PAPER # 2*	
	TOTAL		**6**	**TOTAL**		**9**

YEAR 4	IEGR 920 IEGR 925	Dissertation Research IV Dissertation Research V *SUBMIT PAPER # 3*	3 3	IEGR 997/998	Dissertation Guidance/Defense ***Dissertation Defense Exam (B)*** Complete & Submit Dissertation	3
	TOTAL		**6**	**TOTAL**		**3**
	BS –>	Ph.D. in Industrial Engineering			**TOTAL CREDIT HOURS**	**60**

First Semester (9 Credits)

- Graduate Seminar 3 credits
- Core Course/Foundation Elective 6 credits

Second Semester (9 Credits)

- Core Course/Foundation Elective 9 credits

Third Semester (9 Credits)

- Foundation Elective Course 9 credits
- *Take Qualifying Exam (Q Exam)*

Fourth Semester (9 Credits)

- Foundation Elective 6 credits
- Foundation Elective / Research Course 3 credits

Fifth Semester (6 Credits)

- Foundation Elective / Research Course 6 credits
- *Submit Paper 1*
- *Take Candidacy Exam (A Exam)*

Sixth Semester (9 Credits)

- Dissertation Research 9 credits
- *Submit Paper 2*

Seventh Semester (6 Credits)

- Dissertation Research 6 credits
- *Submit Paper 3*

Eighth Semester (3 Credits)

- Dissertation Defense (997/998) 3 credits
- *Take Dissertation Defense Exam B*

Total Credits = 60

Plan II: For students with a M.S. degree pursuing a Ph.D. in Industrial Engineering (36 credits)

Table G7. 36-credit Plan for students with a master's degree pursuing a Ph.D. in Industrial Engineering

		First Semester	Credits		Second Semester	Credits
YEAR 1	IEGR 787	Graduate Seminar	3	IEGR xxx	Foundation Elective *Or* Research Course	3
	IEGR xxx	Foundation Elective *or* Research Course	3	IEGR xxx	Foundation Elective *Or* Research Course	3
	IEGR xxx	Foundation Elective *or* Research Course	3	IEGR xxx	Foundation Elective *Or* Research Course	3
		Take Qualifying Exam			***Candidacy Proposal EXAM (A)***	
	TOTAL		**9**	**TOTAL**		**9**
YEAR 2	IEGR 905	Dissertation Research I	3	XEGR 920	Dissertation Research IV	3
	IEGR 910	Dissertation Research II	3	XEGR 925	Dissertation Research V	3
	IEGR 915	Dissertation Research III	3		*Submit Paper # 2*	
		Submit Paper # 1				
	TOTAL		**9**	**TOTAL**		**6**
YEAR 3	IEGR 997/998	DISSERTATION GUIDANCE/DEFENSE	3			
		DISSERTATION DEFENSE EXAM (B)				
		Submit Paper # 3				
		COMPLETE & SUBMIT DISSERTATION				
	TOTAL		**3**			
	MS –>	**Ph.D. in Industrial Engineering**			**TOTAL CREDIT HOURS**	**36**

First Semester (9 Credits)

- Graduate Seminar 3 credits
- Foundation Elective/Research Course 6 credits
- *Take Qualifying Exam (Q Exam)*

Second Semester (9 Credits)

- Foundation Elective/Research Course 9 credits
- *Take Candidacy Proposal Exam A*

Third Semester (9 Credits)

- Dissertation Research 9 credits

Fourth Semester (6 Credits)

- Dissertation Research 6 credits

Fifth Semester (3 Credits)

- Dissertation Defense IEGR 997/998 3 credits
- *Take Dissertation Defense Exam B*

Total Credits = 36

G.4.5. Course Descriptions

The list of Industrial Engineering Graduate Courses (approved and currently available in MSU course inventory or WebSIS) is given below:

IEGR 500 MATHEMATICAL PROGRAMMING, 3 credits: Introduction to the construction of deterministic mathematical models. Mathematical techniques such as linear programming, dynamic programming, integer programming, and game theory. Applications are made to production, transportation, assignment, and resource allocation problems.

IEGR 501 INTRO TO ADV SYSTEMS ENG, 3 credits: This course provides an understanding of the advanced concepts and principles of both the theory and practice of the discipline of System Engineering. In particular, students will learn the application of these principles to the design, development, and production of complex systems. The course enables the student to become familiar with System Engineering and demonstrate an understanding of inter-relationships among System Engineering artifacts.

IEGR 502 - OBJECT-ORIE ANALY & DESIGN, 3 credits: Systems engineering focuses on the analysis of entire systems. In this course, students will obtain a strong foundation in system analysis and design. This includes a structured problem-solving approach using object-oriented and analysis techniques. Also, students will be introduced to systems methodology and management. There will be an introduction to selected techniques in systems and decision sciences, including mathematical modeling, decision analysis, risk analysis, and simulation modeling. An overview of contemporary topics will be presented such as reengineering and total quality management. Elements of systems management include decision styles, human information processing, organizational decision processes, and information system design for planning and decision support. The course will emphasize relating theory to practice via written analyses and oral presentations and case studies.

IEGR 503 - ADV QUANT METH IN SYSTEMS ENG, 3 credits: Introduction to the principles of Object-Oriented Analysis and Design (OOAD) applied to Software Engineering. Introduction to systems analysis and design theory by using object-oriented methodologies. The OQAD methodology in conjunction with use-case methods, and analysis, model, and simulation of software applications.

IEGR 505 - INDUSTRIAL ENGINEERING PRIN I, 3 credits: Introduction to principles and concepts of Industrial Engineering for non-bachelor degreed graduate students. This is the first course to learn applied statistics and quality control, engineering economics, ergonomics/human factors, process analysis, and other advanced quantitative topics at the graduate level. This course is required for graduate students without an undergraduate degree in Industrial Engineering.

IEGR 506 - INDUSTRIAL ENGINEERING PRIN II, 3 credits: Introduction to principles and concepts of Industrial Engineering for non-bachelor degreed graduate students. This is a second course to learn the fundamentals of operations research, simulation, productions systems, and other quantitative methods in industrial engineering at the graduate level. This course is required for graduate students without an undergraduate degree in Industrial Engineering.

IEGR 510 - PROD SEQUENCING & SCHEDULING, 3 credits: Analysis of sequencing and scheduling activities. Static and dynamic scheduling problems applied to single and multi-machine models, heuristic models, rule-based models and simulation studies of priority dispatching rules, priority queuing models.

IEGR 511 - ADV ENGINEERING ECONOMY, 3 credits Topics include measuring economic worth, economic optimization under constraints, analysis of economic risk and uncertainty, foundations of utility theory, and econometric models.

IEGR 512 - ADV PROJECT MGMT, 3 credits: This is a study of project management theory and practices, emphasizing strategic management for engineering activities. The concept of project planning and organization project life cycle project scheduling, organizational forms, and conflict resolution will be addressed. The use of cost and time value of money, schedule and technical planning and control methods such as WBS, and network models as AOA, AON, CPM/PERT will be stretched. Proposal writing and the use of project management software tools for creating a typical project plan will be explored.

IEGR 514 - ADV RISK ASSESS & SYS REL, 3 credits: This course covers risk assessment and reliability modeling/estimation when conducting system design and development. It will address the identification and quantification of the risk and its consequences, as well as the reliability requirement of a system by using life cycle analysis and reliability engineering.

IEGR 515 - ENGR OPTIMIZATION, 3 credits: Introducing and developing the practical aspects of optimization methods focusing on techniques and strategies useful in engineering design, operations, and analysis. Survey of the important families of optimization methods. Topics include functions of single and several variables, constrained optimality criteria, transformation methods, constrained direct search, linearization methods for constrained problems, direction generation methods, quadratic approximation methods, structured problems, comparison of constrained optimization methods, strategies for optimization studies. Case studies include the optimal design of a compressed air energy storage system, design of the natural gas pipeline, and optimization of ethylene glycol-ethylene oxide process.

IEGR 516 - APPLIED DECISION ANALYSIS, 3 credits: Bayes Theorem, Bayesian estimators, utility functions, loss functions, risk analysis, minimax strategies, game theory, multiple criteria decisions making. Problems in social and public decision making, values and preferences,

subjectivity measurement, and Pareto optimality, group decision analysis, social decision processes, and strategy of conflicts.

IEGR 520 - DSTRBTD INTLLGNT AGNT SYS, 3 credits: Distributed Intelligent Agent Systems are the next major advancement in-network computing architectures beyond Object-Oriented technology. This course is an introduction to intelligent agent-based technology that views large complex systems as societies of independent communicating agents working together to meet the goals of the system.

IEGR 530 - ADVANCED SIMULATION, 3 credits: An up-to-date treatment of all the important aspects of the simulation study, including modeling, simulation languages, validation, and output data analysis. Topics include selecting input probability distribution, random number generators, generating random variables, output data analysis, statistical techniques for comparing alternative systems, validation of simulation models, variance reduction techniques, and experimental design and optimization.

IEGR 531 - QUAL MGMT & STAT PROC CONTROL, 3 credits: Introduce the important concept of quality management; Learn basic quality management approaches including online and offline quality activities, such as TQM, SPC, six sigma, etc; Get familiar with international quality standards like ISO 9000; Prepare students ready for managing and controlling the quality of the manufacturing companies or service industries; Learn contemporary quality concepts.

IEGR 534 - ENGINEERING STAT & MODELING, Sampling distributions, estimation, maximum likelihood estimation, confidence intervals, regression, the goodness of fit, correlation, tests of hypotheses, nonparametric statistics, introduction to the analysis of variance (ANOVA), and design of experiments.

IEGR 535 - ENGR EXPERIMENTAL DESIGN, 3 credits: Analysis and application of standard experimental design, including factorials, randomized block, Latin square, confounding, and fractional replication multiple comparisons. Fractional factorials, analysis of unbalanced data, and covariance models. Introduction to response surface methodology.

IEGR 539 - ROBUST DESIGN BY QUALITY ENGR, 3 credits: System design, parameter design, and tolerance design. Quality loss function, orthogonal arrays. Quality improvement by design. Making products insensitive to manufacturing variations, environmental variations, and deterioration over time. Introduction to TQM, QFD, JIT.

IEGR 550 - HUMAN PERFORMANCE ENGR, 3 credits: Engineering acceptable performance, human limits, and differences, sensing, cognitive processing and performance, perception, problem-solving and decision-making, memory, motivation. Basic design and human factors, human-machine interface, human-human interface, human-computer interfaces. Supporting human performance and evaluating performances and preferences.

IEGR 555 - ARTIFICIAL INTEL PROGRAMMING, 3 credits: Introduction to Lisp programming, early Al programs that use rule-based pattern matching techniques advance Al programs. Topics include building software tools, symbolic mathematics, logic programming, object-oriented programming, knowledge representation and reasoning, expert systems, and natural languages.

IEGR 560 - ASSEMBLY AUTO & PROD DESIGN, 3 credits: Analysis of the product design for ease of automatic assembly, automatic assembly transfer systems, automatic feeding, and orienting-vibratory feeders, automatic feeding and orienting-mechanical feeders, feed tracks, escapements, parts-placement mechanisms, performance and economics of assembly systems, design for manual assembly, product design for high-speed automatic assembly and robot assembly, printed circuit board assembly, and feasibility study for assembly.

IEGR 562 - RAPID PROTOTYPING, 3 credits: Fundamental concepts in the development of computational algorithms for the design of machine components and assemblies, and other engineering systems. Methodologies of idea generation and refinement; Computer-assisted Rapid Sketching methods; general-purpose computer programs for engineering analysis and design; Solid modeling techniques and parametric modeling for manufacturing; Analysis of trajectory from idea-generation to prototype production; representation of the design process as a network of decision tables and logical flags; introduction to stereo-lithography.

IEGR 563 - NONTRAD MANUFACTURING PROCESS, 3 credits: This course is designed to provide an assessment of the state of the art in the design tools and techniques in non-traditional manufacturing. The students will be exposed to practical applications of non-traditional manufacturing, including the use of wire electro-discharge machining and computer-assisted numerical control programming.

IEGR 570 - ADV INSTRUMENTATION TECHNIQUES, 3 credits Pressure and sensors; laser holography; laser doppler velocimetry; anemometry signal conditioning, use of amplifiers with shielding and grounding techniques; digital techniques; signal multiplexing, use of microcomputers; sampling techniques, error analysis, and data handling; data acquisition methods; hardware and software review.

IEGR 571 - ADV INTERNAL COMBUSTION ENGINE, 3 credits: Main phases of Otto cycle, Spark-ignition internal-combustion engine, Combustion, and detonation; Carburetion and fuel injection, application of reciprocating piston engine, optimal design of triangular rotor (or rotary piston), the optimal arrangement of intake, exhaust, and ignition mechanisms, exhaust emissions, fuel economy, and reliability.

IEGR 572 - DESIGN & ANALY OF ENERGY SYST, 3 credits: Elements in the design analysis of energy systems, system designs involving heat reservoirs and work reservoirs, selection of fluid flow equipment, heat exchange design options, availability analysis, system flow sheeting, economic evaluation/cost estimation, optimal design techniques, and energy systems simulation.

IEGR 573 - APPL THERMODYN & COMBUST, 3 credits: In-depth analysis of power and refrigeration cycles. Flow-through nozzles and blade passages. Impulse and reaction turbines. Blade diagrams and efficiency. Production of thermal energy. Chemical reactions and reactive mixtures. Combustion process and analysis of the products for the fossil-fuel systems.

IEGR 574 - HVAC & ENERGY CONSER SYSTEMS, 3 credits: Air conditioning and environmental control, heat transmission in building structure, space heat load, and cooling load, room and building air distribution, Principal of psychometrics, mass transfer and measurement of humidity, direct contact heat/mass transfer, refrigeration, renewable/inexhaustible energy sources,

energy conservation/legislation, cogeneration/heat reclamation, Design, installation, and operation computer-controlled Energy Management Systems Automation.

IEGR 575 - COMPUTER INTEGRATED MANUFACT, 3 credits: Overview of the functions, processes, and disciplines of computer-integrated manufacturing. Topics include automation and computer integrated manufacturing, computer-aided process planning, group technologies, hierarchical computer control, information systems and processing, computer communications systems and software, computer networks, design, assembly, machining, and control nodes. Current issues, emerging technologies, and future developments in computer integrated manufacturing.

IEGR 576 - PRIN OF MANUFAC INFO SYSTEMS, 3 credits: Introduction to the theory and concepts of information for manufacturing organization and management of information within a manufacturing enterprise, database systems, information-based planning and management tools, electronic data interchanges. Design of manufacturing systems such as MRP, SERS, CAD/CAM, etc. Concerns of integration machine interface in manufacturing systems.

IEGR 577 - COMPUT HEAT & FLUID ENGR, 3 credits: Engineering applications of computational heat and fluid engineering, computational methodology for the closed/open systems, heat balance and loss in circular pipes, variation of atmospheric by in-viscid flows are outlined and the relevant numerical methods are introduced.

IEGR 585 - OCCUPATIONAL SAFETY ENGR, 3 credits: Design and modification of machinery and products to eliminate or control hazards arising out of mechanical, electrical, thermal, chemical, and motion energy sources. Application of retrospective and prospective hazard analysis, systems safety performance and measurement, accident prevention philosophies, expert systems, and accident reconstruction methodologies. Case studies include industrial machinery and trucks, construction and agriculture equipment, and automated manufacturing systems and processes.

IEGR 590 - ADVNCD TPCS IN IND ENG, 3 credits: Advanced topics in industrial engineering areas will be selected and taught including manufacturing & production systems, reliability & quality engineering, and ergonomics & human factors engineering, energy systems, and information engineering.

IEGR 595 - ENGINEERING FOR PROFIT, 3 credits: This is an interdisciplinary course in the development and application of tools, methods, and resources to provide engineering students with an entrepreneurial look at the business side of the engineering profession.

IEGR 601 - SYS ENG: THEORY, TREND & APP, 3 credits: This course provides an understanding of the advanced concepts and principles of both the theory and practice of the discipline of System Engineering. The applications of SE principles to the design, development, and production of complex systems are explored. A familiarity of System Engineering development trends and understanding of inter-relationships among System Engineering artifacts are emphasized. The key principles are taken from NASA's Systems Engineering Handbook & the International Council on Systems Engineering Handbook v3.7 and the Systems Engineering.

IEGR 603 - SUPPLY CHAIN/LOGISTIC MGMT, 3 credits: An in-depth study on the discipline and philosophy of logistics and supply chain management with the high-level strategy design and concepts utilizing the analytical and mathematical tools to solve simultaneous cost reduction and service enhancement problems. Within the strategic framework of supply chain and logistics management, topics like inventory, transportation information, and facilities-oriented philosophies and techniques will be explored as knowledge integration of logistics and supply chain methodologies.

IEGR 605 - INTEGER PROG & NETWORK MODELS, 3 credits: Network flow models and applications. Algorithms for the shortest path, minimum cost flow, and maximum flow problems. Integer programming models and formulation. The computational complexity of integer programming problems. Lagrangean duality theory, branch, and bound techniques, cutting planes, and hybrid algorithms. Application of these methods to facility location and traveling salesman problems. Study of special techniques for selected topics such as vehicle routing, set covering, and network design problems.

IEGR 606 - STRUCT & INFO SECURITY, 3 credits: This is a course suitable for students that need an understanding of information security and its critical role in business - technical and non-technical alike. Those students that might be contemplating a career in information security will find this course to be well worth their while. Topics to be covered include Developing and implementing an information security education program, Developing and implementing information security policies and Developing procedures for assessing and controlling risk, Factors that drive the need for information security, Identifying and assessing risks, Legislative/legal aspects of information security, Risk management, and Technical and administrative controls.

IEGR 615 - ADV ENGINEERING OPTIMIZATION, 3 credits: Techniques and strategies are useful in engineering design, operation, and analysis. This course introduces and develops the practical aspects of optimization methods at a level suitable for engineers.

IEGR 617 - TOPICS IN COMP AIDED DESIGN, 3 credits: A study of advanced topics in Computer-Aided Design (CAD) theory that are applied to translate and interoperate the design, manufacturing, and production intents as constraints, design history, and parameterization. Advanced theories and practices of geometrical modeling will be addressed. The application and theories of tolerancing in designing, manufacturing, and inspection will be approached including ANSI Y14.5M standards on Geometric Dimensioning and Tolerancing (GD&T). Developments in the standards of interpretability between CAD systems including ISO 10303+, STEP, ENGEN as extensions of PART 42 of ISO standards will be explored.

IEGR 620 - NONLINEAR PROGRAMMING, 3 credits: Theoretical development of solution methods in nonlinear programming including manifold suboptimization, convex simplex, reduced gradient, gradient projection, feasible direction, cutting plane, and penalty function methods. Investigation of convergence of algorithms. Methods of solution for integer programming problems including cutting plane methods, enumerative techniques, and dynamic programming methods.

IEGR 625 - STOCHASTIC PROCESS, 3 credits: A survey course of stochastic processes with an emphasis on applications in engineering, management science, and physical sciences. Topics covered include random walk, Markov and Poisson processes, renewal theory, and stationary processes, illustrated with examples in queuing theory, inventory control, time series, and random noise.

IEGR 635 - ADVANCED ROBUST DESIGN, 3 credits: This course will provide useful techniques for product and manufacturing process design. It has three basic steps: system design, parameter design, and tolerance design. Quality can be built into product into products through design. The methodology is based upon quality loss function, experimental design, and orthogonal arrays, etc.

IEGR 636 - TIME SER ANALY & FORECAST SYS, 3 credits: Time and frequency domain aspects of time series are developed in a mutually reinforcing fashion. Behavior patterns of time series are examined with a view toward model identification and forecasting. The statistical procedures for model estimation are presented and employed. Multiple time series concepts and problems are introduced. The Box-Jenkins approach is emphasized.

IEGR 640 - RELIABILITY, 3 credits: Probabilistic models underlying reliability and life testing analysis. Structural and reliability properties of coherent systems, exact system reliability and approximation, parametric families of life distribution and their characterizing models, homogeneous and non-homogeneous Poisson processes, mixtures of distributions, competing risk and multiple failure mode models, accelerated life testing models, regression and partial likelihood models, types of censoring, multiple failure mode analysis. Inference procedures, including graphical analysis for various parametric models for complete and censored samples. Applications in engineering, biometry, and actuarial science

IEGR 659 - WRK PHYSIOLOGY, 3 credits: The study of cardiovascular, pulmonary, and muscular responses to industrial work including aspects of endurance, strength, fatigue, recovery, and energy cost of work. Utilization of physical capacity and job demand for task design, personnel assignment, and assessment of work-rest scheduling.

IEGR 660 - OCCUPATIONAL BIOMECHANICS, 3 credits: Introduction of the mechanical behavior of the musculoskeletal system as related to physical work activities in the industry. Fundamentals of human body mechanics, physical fatigue, and musculoskeletal injury mechanism with an application to the design of physical work activities.

IEGR 662 - RAPID PROTOTYPING II, 3 credits: Students, individually or in groups, develop a small-scale rapid prototyping team to address the need for a rapid prototype of a component or set of components relevant to an engineering subject. Students are given a fixed budget and a target time for the completion of the prototype. Problem identification, ideation, and refinement; problem analysis; decision processes; advanced sketching and computer-aided design; applications of advanced solid-modeling, using a robust parametric modeler; introduction to graphical file transfer protocols for sharing design information arnung4eam members; advanced prototype production methods; production of prototypes using as stereolithography system.

IEGR 663 - NONTRAD MANUFACTURING PROCESS, 3 credits: Analysis of the processes, sensors, machine tools, and control systems in nontraditional manufacturing processes. Processes include abrasive jet machining, water jet machining, abrasive water jet machining, abrasive flow machining, ultrasonic machining, ultrasonic welding, high energy rate forming, electrochemical machining, electrochemical grinding, electrochemical discharge machining, electro stream drilling, shaped-tube electrolytic machining, chemical machining, electrical discharge machining, electrical discharge wire cutting, electrical discharge grinding, electron beam welding, electron beam machining, laser processing, plasma arc cutting, and thermal energy (deburring) method.

IEGR 670 - ADV PROD & OPERATIONS MGMT, 3 credits: An advanced study of production management techniques applied to control the operation of production and manufacturing systems. Advanced theories and practices of forecasting and inventory control including definitive, statistical, and mixed behavior. The planning process will be approached at the aggregation of a master production schedule will be intensively explored including the unique approach of MRP. Methods of Operation sequencing and scheduling techniques under resource constraints including BHR&S. The future of production analysis and control with the use of recent developments in FMS, ASIRS, AGVS theories, and applications.

IEGR 678 - ENGINEERING DESIGN PROCESS, 3 credits: Definition of design, the design process, and its considerations, managing design projects, modeling and simulation, design analysis for material selection, economic analysis in design, optimization in design, statistical decisions, design for reliability, safety and environmental protection, engineering ethics characterization.

IEGR 680 - ADVANCED PRODUCT DESIGN, 3 credits: This course will provide a determination of the feasibility of design ideas and decision processes for choosing better design alternatives. Case studies will include the planning and creation of successfully engineered designs.

IEGR 686 - INDUST ENGR APPL IN HEALTH SYS, 3 credits: Description of the health care system and its resource components, accessibility, availability, distribution, and cost. Health system inputs, processes, and outputs. Applications of industrial engineering to health care management problem. Hospital management, forecasting, managerial control, facility planning, resource allocation, and information systems.

IEGR 690 - ENTERPRISE RESOURCE PLANNING, 3 credits: The various topics include MRP (Material Requirements Planning), MRP II (Manufacturing Resources Planning), and Flow Manufacturing, Time as a competitive weapon (TCW) Theory, Just-In-Time Principles, Inventory Management, and Theory of Constraints (TOC) philosophy. Prerequisite: IEGR 512 and EEGR 505 or consent of instructor.

IEGR 780 - MSU/JHU ENGINEERING EDUC STUDY, 3 credits: This course will facilitate educational exchange between students at Morgan State University and Johns Hopkins University.

IEGR 788 - SEMINAR I, 3 credits: The course is designed to provide a multidisciplinary approach to the integration of engineering disciplines and technologies. The primary objective is

to demonstrate to the students how important it is, in the professional world, to work together as a team in terms of solving practical engineering problems. The students will be exposed to practical applications that focus on their academic interests but are tempered by ideas coming from other disciplines. This will be accomplished by having guest speakers, special assignments, project-oriented discussions, and self-study activities.

IEGR 789 - SEMINAR II, 3 credits: The course is designed to provide a multidisciplinary approach to the integration of engineering disciplines and technologies. The primary objective is to demonstrate to the students how important it is, in the professional world, to work together as a team in terms of solving practical engineering problems. The students will be exposed to practical applications that focus on their academic interests but are tempered by ideas coming from other disciplines. This will be accomplished by having guest speakers, special assignments, project-oriented discussions, and self-study activities.

IEGR 790 - RSCH IN DESIGN & MANUFACTURING, 3 credits: Introduce the graduate students to the research topics in the important design and manufacturing area. Through this course, the students can conduct timely and topic engineering research, perform industrial design and analysis.

IEGR 791 - INDEP STUDY IN INDUSTRIAL ENGR, 3 credits: A program of research consisting of directed reading and laboratory work under the direction of a graduate faculty member. In accordance with an agreed-upon plan and culminate in a report paper.

IEGR 792 - DIRECTED RSCH IN INDUST ENGR, 3 credits: A research topic was conducted by the guidance of a graduate faculty member. In accordance with an agreed-upon plan and culminate in a report paper.

IEGR 793 - MASTER'S PRE-CANDIDACY, 3 credits: This course conveys full-time status to a master's graduate student engaged in the study before the achievement of master's candidacy. Students preparing for comprehensive examinations, or a thesis proposal defense enroll in this course. Additionally, students needing additional time to complete a master's Project enroll in this course after initial enrollment in the appropriate Master's Project course. This course is non-curricular and cannot be used as a program credit requirement. The student registers for 3 credit hours and the registration reports the full-time status of 9 graduate credit hours.

IEGR 795 - PROJECT REPORT, 3 credits: Project Report allows the students to learn how to prepare a real project. The course provides the student with the opportunity to formulate and develop a professional engineering project under the guidance of a faculty advisor. This course emphasizes the analysis and the design of a specific engineering problem, and the student must address advanced professional engineering issues, which may include analysis, design, synthesis, feasibility, development of alternatives, standards, and codes, and other relevant issues. Technical writing skills will be developed, and the course culminates in a final report. Each student completing this course is expected to submit a technical report on their research project that is suitable for publication in a peer-reviewed conference or journal. Students should also prepare a conference-ready or journal-ready paper for submission by the end of the semester. This course should be taken in the final semester.

IEGR 796 - PROJECT REPORT II, 3 credits: Project report II is to let students learn how to conduct a real project. This course emphasizes the analysis and the design of a specific industrial engineering problem under the guidance of a faculty advisor. Each student taking IEGR 796 is expected to have published or submitted (at least) a paper on the research project to a professional journal or a refereed conference proceeding.

IEGR 799 - THESIS DEFENSE, 3 credits: This course allows master's students the opportunity to defend their thesis for approval by the student's thesis chairperson and committee after the thesis has been completed. After gaining approval from the thesis chairperson and committee, the thesis is submitted to the School of Graduate Studies for final processing and approval. This course is a curricular course and is counted as 3 credit hours of the overall program credit requirement. The student registers for 3 credit hours and the registration reports the full-time status of 9 graduate credit hours.

IEGR 805 - Pre-Candidacy Research I, 3 Credits. This course is intended as a rotational research opportunity for students. Students will conduct research driven by the instructor/PI to advance a research objective. The course will work through research issues and solutions utilizing current research projects being undertaken by the faculty. In addition, this course will enable a PhD student to develop a scholarly research plan of heir own in consultation with the student's dissertation committee chairperson. This course aims for the student to experience various research methods/techniques while developing their plan of action for completion of the dissertation

IEGR 810 - Pre-Candidacy Research II, 3 Credits. This course is intended as a rotational research opportunity for students. Students will conduct research driven by the instructor/PI to advance a research objective. The course will work through research issues and solutions utilizing current research projects being undertaken by the faculty. In addition, this course will enable a PhD student to develop a scholarly research plan of their own in consultation with the student's dissertation committee chairperson. This course aims for the student to experience various research methods/techniques while developing their plan of action for completion of the dissertation.

IEGR 815 - Pre-Candidacy Research III, 3 Credits. This course is intended as a rotational research opportunity for students. Students will conduct research driven by the instructor/PI to advance a research objective. The course will work through research issues and solutions utilizing current research projects being undertaken by the faculty. In addition, this course will enable a PhD student to develop a scholarly research plan of their own in consultation with the student's dissertation committee chairperson. This course aims for the student to experience various research methods/techniques while developing their plan of action for completion of the dissertation.

IEGR 905 - Dissertation Research I, 3 Credits. This course enables a PhD candidate to execute the scholarly research plan (previously developed in the pre-candidacy phase) in consultation with the student's dissertation chairperson and committee. A student can only take this dissertation course after passing the A-Exam and being advanced to candidacy.

IEGR 910 - Dissertation Research II, 3 Credits. This course enables a PhD candidate to execute the scholarly research plan (previously developed in the pre-candidacy phase) in consultation with the student's dissertation chairperson and committee. A student can only take this dissertation course after passing the A-Exam and being advanced to candidacy.

IEGR 915 - Dissertation Research III, 3 Credits. This course enables a PhD candidate to execute the scholarly research plan (previously developed in the pre-candidacy phase) in consultation with the student's dissertation chairperson and committee. A student can only take this dissertation course after passing the A-Exam and being advanced to candidacy.

IEGR 920 - Dissertation Research IV, 3 Credits. This course enables a PhD candidate to execute the scholarly research plan (previously developed in the pre-candidacy phase) in consultation with the student's dissertation chairperson and committee. A student can only take this dissertation course after passing the A-Exam and being advanced to candidacy.

IEGR 925 - Dissertation Research V, 3 Credits. This course enables a PhD candidate to execute the scholarly research plan (previously developed in the pre-candidacy phase) in consultation with the student's dissertation chairperson and committee. A student can only take this dissertation course after passing the A-Exam and being advanced to candidacy.

IEGR 993 - DOCTORAL PRE-CANDIDACY, 3 credits: This course conveys full-time status to a doctoral student as a full-time student engaged in the study before the achievement of doctoral candidacy. Students studying for comprehensive examinations or preparing for a proposal defense enroll in this course. This course is non-curricular and cannot be used as a program credit requirement. The student registers for 3 credit hours and the registration reports the full-time status of 9 graduate credit hours.

IEGR 997 - DISSERTATION GUIDANCE, 3 credits: This course enables a doctoral student to develop and execute an approved scholarly research agenda in consultation with the student's dissertation chairperson and committee. Students who register for this course continue to maintain enrollment until the student has completed the dissertation. This course is non-curricular and is not considered a program credit requirement. The student registers for 3 credit hours and the registration reports the full-time status of 9 graduate credit hours.

IEGR 998 - DISSERTATION DEFENSE, 3 credits: This course allows doctoral students the opportunity to defend their doctoral dissertation for approval by the student's dissertation chairperson and committee after the dissertation has been completed. After gaining approval from the dissertation chairperson and committee, the dissertation is submitted to the School of Graduate Studies for final processing and approval. This course is a curricular course and may be considered as 3 credit hours of the overall program credit requirement. The student registers for 3 credit hours and the registration reports the full-time status of 9 graduate credit hours.

G5. General Education Requirements

General education requirements do not apply to this Program.

G6. Specialized Accreditation or Graduate Certification Requirements

There are no specialized accreditation or graduate certification requirements for this program and its students.

G7. Morgan-JHU Memorandum of Understanding

Students will be able to participate in courses related to Mechanical or Systems Engineering at John Hopkins University (JHU) and transfer the courses to Morgan to fulfill the elective credits requirement. A copy of the Memorandum of Understanding (MOU) between Morgan and John Hopkins University follows.

G8. Program Assurances

Morgan provides students with all the necessary information at various levels in the table below, services, and assistance for success.

Table G8. Information for program assurances

Academic Unit	Document
University	University Catalog
School/College	School/College Catalog
Program	Program Handbook, Program Brochure
	Course Description Sheets
	Suggested Curriculum Sequence Sheets
Course	Course Syllabus and Course Outline
Help	Office All kinds of help
Academic Advisor	All kinds of academic advising

Documents in digital form are posted on Morgan website and copies in paper form can be found in the University Library, School/College, and Department Offices.

G9. Advertising, Recruiting, and Admissions Material

The ISE Department has Offices/Services to support Advertising, Recruiting, Admission. Program materials are also provided by the department. These materials are written by faculty members of the program for distribution. The program will also be advertised in media formats such as IE publications, and Chronicles of Higher Education.

H. Adequacy of Articulation

There are no articulation agreements in place.

I. Adequacy of Faculty Resources

I.1. Program Faculty

The Department of Industrial and Systems Engineering has distinguished and experienced faculty with backgrounds and expertise in industrial engineering, quality, reliability, production systems and manufacturing, operations research, simulation, robotics, energy system, information system, human factors, and ergonomics. Seven full-time faculty in the ISE department are affiliated with the Program and they are listed below:

LeeRoy Bronner. Ph.D., PE, Associate Professor of Industrial Engineering. He received the following degrees:

- Ph.D., Systems Engineering, Case Western Reserve University, 1973
- M.S., Electrical Engineering, Northeastern University, 1966
- B.S., Electrical Engineering, University of Akron, 1963

Dr. Bronner has an academic specialty and interest in System Engineering, Object-Oriented Analysis and Design, Big Data, Cloud Technology, and Conceptual Modeling and Analysis.

Dr. Bronner has 30 years of experience in System Engineering at International Business Machines (IBM) Corporation (1963-1993). During this time at IBM, he worked in all phases of the software industry research, software development and marketing (i.e., Thomas J. Watson Research Center, Operating Systems, Large System Capacity Planning, Desktop Computer Software Development, Advanced Word Processing Software, Marketing IBM products at the Branch Office level). In the academic arena, Dr. Bronner has taught at Morgan State University for the past 23 Years. He taught System Engineering courses at the undergraduate and graduate levels producing a number of master's and doctoral students (i.e., 20 students). In addition, Dr. Bronner has been a Registered Professional Engineer in the State of Ohio for the past 56 years.

Tridip K Bardhan. Ph.D., CEng, CMfgE, CEMP, Associate Professor of Industrial Engineering, and Chairman (Interim). He received the following degrees:

- Ph.D. in Industrial Engineering, Wichita State University, Wichita, Kansas, 1997.
- M.S. in Engineering Management Science, Wichita State University, Wichita, Kansas, 1989.
- B.S. (Cum-Laude) in Industrial Engineering, Wichita State University, Wichita, Kansas, 1986.
- B.Sc. (First Class, First) in Industrial Arts, Dhaka University, Dhaka, Bangladesh, 1992.

Dr. Bardhan has an academic specialty in industrial engineering ranged from Manufacturing and Production Control to Engineering Management. During his graduate studies, Dr. Bardhan worked for industrial organizations like Koch Industries, Central Industries, and Boeing. After receiving his Ph.D., he worked as a Research Scientist at the National Institute of Standards and Technology, US Department of Commerce for two years. He has worked as a faculty member at Wichita State University, Catholic University of America, and Morgan State University. During his tenure with these institutions, he supervised and co-supervised nine doctoral students in Industrial Engineering and Engineering Management. Dr. Bardhan also supervises the first doctorate degree reception in Industrial Engineering from any Maryland institute. He has a publication list of above 75. Royal Engineering Institute registers Dr. Bardhan as Chartered Engineer. He is also registered as Certified Manufacturing Engineer and Certified Engineering Management Professional.

Guangming Chen. Ph.D., Professor of Industrial Engineering, and graduate program coordinator. He received the following degrees:

- Ph.D. in Industrial Engineering, Wayne State University, Detroit, MI, 1990.
- MS in Systems Engineering, Shanghai Jiao Tong University, Shanghai, China, 1984.
- BS in Electrical Engineering, Shanghai Jiao Tong University, Shanghai, China, 1982.

Dr. Chen has an academic specialty and interest in reliability and quality, experimental design and robust design, systems engineering and operations research. He was a NASA Administrator's Fellow (Sept 2002- Aug 2003) at Goddard Space Flight Center, working full-time at Goddard Space Flight Center with NASA ST-5 Project Team on three microsatellites during the critical design and testing stages. He was also a Guest Scientist at Brookhaven National Laboratory, Upton, NY, 6/1/1994-8/12/1994, doing research on Risk Assessment and Reliability of Nuclear Reactors. He was also an adjunct faculty with Florida Institute of Technology, Graduate Center at Aberdeen Proving Ground (1995-1996). He was a Reliability Engineer with A-LINE Plastics, Inc., Plymouth, MI (8/1990–11/1990), responsible for the

quality and reliability of the auto parts produced by the company and he was a lecturer at Guilin Institute of Electronic Technology (now Guilin University of Electronic Technology), China (2/1985 – 9/1986). Dr. Chen's other academic credentials include two awards received from NASA Administrators Charles Bolden Jr. and Sean O'Keefe and serving as an associate director for Maryland Space Grant Consortium. He was an ASEE summer faculty fellow at Goddard Space Flight Center (summer 1999 and summer 2000). Dr. Chen has an academic publication record of over 100 papers and served on the editorial boards for three international journals. He has served as PI or Co-PI for more than 20 research grants.

Seong W. Lee. Ph.D., Professor of Industrial Engineering. He received the following degrees:

- Ph.D. in Mechanical Engineering (The Catholic University of America, Washington, DC, 1989)
- MS in Mechanical Engineering (The Catholic University of America, Washington, DC, 1986)
- MS in Mechanical Engineering (Pusan National University, Pusan, South Korea, 1981)
- BS in Mechanical Engineering (Pusan National University, Pusan, South Korea, 1979)

Dr. Lee has an academic specialty and interest in efficient and clean biomass process systems. He also worked on efficient energy storage technology, nutrient reduction technology, micro-combined heat and power system, particulate materials science, spray and atomization characteristics (e.g. particle droplet size, concentration, and velocity distribution using the laser-based diagnostic methods). In addition, he conducted renewable energy research (fuel cell, solar, photovoltaic, wind modules/testing) micro-liquid and biodiesel fuel and engine system testing & analysis, building energy systems design, indoor air quality (IAQ) modeling & simulation, emissions, and environmental control technologies. He additionally worked on feed-back-control system, autonomous vehicle technology, and modeling statistical analysis and optimization, numerical modeling of heat transfer & combustion & fluid-thermal systems computational fluid dynamics (CFD) simulation. Dr. Lee was named a 2015 Innovator of the Year by The Daily Record having been recognized for his Cycloburn Combustion System ™, an innovative system that produces energy from waste biomass, in particular poultry litter. Dr. Lee is one of 28 honorees who was recognized at the awards event in October in Baltimore. This marks his second Innovator of the Year Award. He also received the honor back in 2010. He has a well-equipped lab and several graduate students work with him on different projects.

Masud Salimian, Ph.D., Professor of Practice in Industrial Engineering. He received the following degrees:

- Ph.D. in Industrial Engineering, The University of Oklahoma, Norman, OK, 1987.
- M.S. in Industrial Engineering, The University of Oklahoma, Norman, OK, 1986.
- B.S. in Industrial Engineering, The University of Oklahoma, Norman, OK, 1984.

Jessye Talley. Ph.D., Assistant Professor of Industrial Engineering. She received the following degrees:

- Ph.D. in Industrial & Systems Engineering (North Carolina Agricultural & Technical State University, 2016)
- MS in Industrial & Systems Engineering (North Carolina Agricultural & Technical State University, 2011)
- BS in Industrial Engineering (North Carolina Agricultural & Technical State University, 2008)

Dr. Talley's has an academic specialty and interest focuses on problems that identify vulnerabilities and disruptions that occur within supply chains to develop intervention or mitigation strategies that optimize the total system. She uses the following methods for her research: stochastic and deterministic modeling, simulation, stochastic programming, Markov chains, differential equations, linear programming, and queueing theory. Dr. Talley is focused on two main application areas. (1) Agricultural and (2) Humanitarian. Under agriculture she considers 4 areas (1) Food Supply Chain Optimization, (2) Food Contamination (Risk), (3) Supply Chain Traceability, (4) Food Waste. She is PI on a National Science Foundation (NSF) grant to look at microgreen optimization entitled: "Excellence in Research/Collaborative Research: Smart Technology-enabled Nutrient Lifecycle and Supply Chain Management for Microgreens. She is also Co-PI on a grant centered on Sustainable Food Systems entitled: SRS RN: Multiscale RECIPES (Resilient, Equitable, and Circular Innovations with Partnership and Education Synergies) for Sustainable Food Systems. She works with undergraduate and graduate students in the Risk Optimization Management and Evaluation (R.O.M.E) Lab.

The ISE department also has the following adjunct faculty affiliated with the Program:

Kayenda T. Johnson, Ph.D., adjunct professor, part-time. She received the following degrees:

- PhD, Industrial and Systems Engineering, Virginia Tech, 2008.
- MS, Industrial and Systems Engineering, Virginia Tech, 2002.
- BS, Industrial Engineering, Morgan State University, 1999.

Garfield Jones, D.Eng., adjunct faculty, part-time. He received the following degrees:

- Doctor of Engineering, Industrial Engineering, Morgan State University, May 2019.
- M.S. in Engineering/Technical Management, The Johns Hopkins University, May 2006.
- B.S., Industrial Engineering, Southern Illinois University, Edwardsville, IL, Dec 2002.

Wa-Muzemba A. Tshibangu, DEng., adjunct professor, part-time. He received the following degrees:

- Doctor of Engineering, Industrial Engineering, Morgan State University 2003
- M.S., Engineering Management, University of Johannesburg, 1998
- BSc, Mechanical Engineering, University of Kinshasa, 1986

J. Adequacy of Library Resources

J. 1. Library Resources

J.1.1. Morgan Library

The Earl S. Richardson Library at Morgan State University has an extensive collection of books, journals, and magazines on industrial engineering and related subjects to meet the needs of teaching and research in this proposed Ph.D. program. The students will have access to Morgan State University Earl S. Richardson Library (Morgan Library). The Morgan Library offers a range

of resources and services to the Morgan community. Most library **resources (USMAI Catalog, WorldCat MORGAN, Libguides, Collections, etc.) and services can be** accessed remotely.

J.1.2. Required Library Resources

The Ph.D./M.S. program requires modest additional library resources - books and journals related to industrial engineering, operations research, production management, ergonomics and human factors, reliability and quality engineering, supply chains, etc.

J.1.3. Bookstore

Morgan State University's bookstore will sell industrial engineering-related textbooks, journals, and software, as required for the appropriate courses.

K. Adequacy of Physical Facilities, Infrastructure, and Instructional Equipment (as outlined in COMAR13B.02.03.13)

The ISE department has an administrative office, a copy room, and a faculty research office and 10 instructional and research labs to support this **Ph.D./M.S. in Industrial Engineering** program. The details of these office locations and its associated equipment are shown in Table K1.

Classroom space is shared by all departments of SOE. Common features among 7 classrooms: 30-seat capacity, whiteboard, and a data network connection.

The ISE department operates 10 dedicated laboratories. In addition to posted lab times per course syllabus, students have the capacity to schedule additional access depending on the nature of the work and whether close supervision is required.

Table K1. Locations and Equipment of Department Offices

Office	Location	Equipment
Administrative office	SB 322	Windows 10 Intel i7-based computer system, Canon scanner, hp laser and inkjet printer
Copy/break room	SB 342	Departmental reproduction system (model Xerox WorkCentre 5955), fax system, refrigerator, microwave, supply storage
Faculty research office	SB 319	Windows 10 Intel i7-based computer system operated as video production support to faculty, windows system with single licensed specialized software, scanner with ADF, USB microscope, document binding system, large format color printer

1) **Advanced Engineering & Design Center** (SB 103 & SB 104) - Material Testing Laboratory (SB 103) and Rapid Prototyping, and Fabrication and Foundry Laboratory (SB 104).

These two laboratories work in combination: *Advanced Engineering & Design Center and Material Testing Laboratory* and *Rapid Prototyping, and Fabrication and Foundry Laboratory*. The conceptual underpinning of these labs is the ability to go from conception of an idea to fabrication of a prototype. Both labs provide instructional support for research and courses related to:

- Solid Modeling and Design
- Manufacturing Processes
- Multimedia Instructional Design
- Simulation of Industrial Systems
- Operation Research
- Product Design

Equipment Inventory of the SB 103 Lab:

- 8 Intel i5-core based Windows computer systems
- 2 Intel i7-core based Windows computer systems
- 4 older Windows computer systems
- Buehler material test system including:
    - Abrasimatic 2 abrasive Cut-off saw
    - Simplimet 3 Mounting press
    - Automet 3 Polisher/grinders
    - Chemical etcher
    - Micro and macro hardness tester
    - Versamet 3 Image Analyzer
- International Metrology Systems® (IMS) Coordinate Measure Machine (need repairs)
- Starrett® Optical comparator model VB-400
- Ceiling-mounted LCD projector
- AutoCAD® suite software
- Adobe Master Collection® software
- Camtesia® software
- Simio simulation software

Equipment Inventory of the SB 104 Lab:

- Fanuc Wire Electro-Discharging Machining system
- HAAS VH-2 vertical machining center
- Cincinnati Injection molding system
- Johnson Gas Metal foundry system
- Johnson Heat Treating furnace
- MasterCAM software

2) Advanced Instrumentation Laboratory (SB 105) and Industrial Technologies Laboratory (MB 146)

The *Advanced Instrumentation* and *Industrial Technologies Laboratories* provide students with the opportunity to gain a deep insight into the inner workings of selected industrial technologies, and the role that these technologies play in industry. Four main engineering science categories are considered: advanced instrumentation including laser-based diagnostic/optical method, thermo-fluid-based technologies, renewable energy sources and alternative fuels, energy systems design and environmental control technologies and management, and electro-mechanical technologies. The overarching aim of the laboratory is to support students in advanced instrumentation techniques, design, testing, and modification exercises, about these technologies. The SB 105 Lab provides support for research and courses related to:

- Thermodynamics,
- Materials Engineering
- Industrial Safety and Health
- Environmental Management Issues

- Product Design,

Equipment Inventory of the SB 105 Lab:

- Laser-based Particle Image Velocimetry (PIV);
- laser-based Phase Doppler Particle Analyzer (PDPA) system
- Combustion Research Unit
- Advanced Swirling Fluidized Bed Combustors
- Advanced Circulating Fluidized Bed System
- Air Flow Measurement System
- Steam Motor and Energy Test Conversion Test Rig
- Wind Tunnel
- Cross-Flow Heat Exchanger
- Convective Heat Transfer Research Unit
- Industrial Scaled Process Control Unit
- Modular Control System Designer
- Universal Energy Conversion
- HVAC Research System and Components
- Industrial Boiler and Components

3) Human Engineering Laboratory (SB 219)

The *Human Engineering Laboratory* provides learning as well as enriched hands-on experience to students regarding ergonomics, human factors, and safety health principles. The lab provides instructional support for research and courses related to:

- Ergonomics and Workplace Design
- Ergonomics and Human Factors
- Industrial Safety and Health.

Equipment Inventory of the SB 219 Lab:

- Eye Tracking Devices with head tracking apparatus
- Vision Testing Device
- Acoustic Chamber
- Flir® Infrared Camera Model E-60 (new departmental resource)
- Sound Measuring Monitoring Devices
- Johnson Strength Testing system
- Strength Measuring Devices (hand and pinch)
- Physical Work Capacity Assessing Devices
- Low Fidelity Flight and Driving Simulators
- Usability Testing system (multiple computers with webcams) with Morae® software

This laboratory has had a long and close relationship with The Human Research Directorate Laboratory of Army Research Laboratory (ARL) at Aberdeen, Maryland. Joint activities have included research and student support, provided guest speakers and lectures to the School of Engineering and IE department, internship program for Morgan IE students.

4) Information and Systems Engineering Laboratory (SEB307)

The *Information and Systems Engineering Laboratory* provides an experiential-learning environment for the design and development of information and information systems and provides software to apply this knowledge to computer and communication technologies for decision

making. It also acts as an interactive teaching lab for computer intensive course work in support of all IE courses. The SB 307 Lab provides support for research and courses related to:

- Systems Engineering and Analysis
- Software and Database Design
- Information Systems Design
- Quantitative Methods in Systems Engineering
- Multimedia Instructional Design

Equipment Inventory of the SB 307 Lab:

- 4 Microsoft Windows-based servers
- 20 Intel i7-based Windows systems
- Dual Projector multi-screen video and sound presentation capability
- 46" LCD TV with sound bar audio system
- Remote Online Laboratory environment

5) Industrial Robotics and Automated Manufacturing (IRAM) Laboratory (MB 223)

The *Industrial Robotics and Automated Manufacturing Laboratory* supports special projects and several elective courses in manufacturing, automation, and robotics. The MB 223 Lab provides support for research and courses related to:

- Advanced Material Handling Systems
- Industrial Robotics and Automation
- Computer-Aided Manufacturing
- Flexible Manufacturing Systems

Equipment Inventory of the MB 223 Lab:

- State of the art Flexible Manufacturing Cell (FMC) composed of a Yaskawa Motoman HP-3 Performer robot with a linear traverse serving Intelitek® CNC Mill and CNC Turning Center systems which are integrated into a control system with assembly and vision inspection modules (system recently added and upgraded)
- SCORBOT® ER-9 robot with pneumatic end-effector and teach pendant
- Various autonomous mobile vehicles which include:
  - Festo Robotino® robotic system
  - Vex autonomous/remote robot kits
  - Lego® Mindstorms NXT 2.0 robot kits
  - Drones (dji Phantom 4 Pro+, dji Phantom 4 Pro Advanced, Parrot AR Drone, Codrones)
  - FlashForge 3D printer
- Legacy Robotic Equipment include:
  - Amatrol® Automated Storage/Retrieval System
  - SCORBOT® ER-4u robot

6) Manufacturing Processes Laboratory (MEB 250)

The *Manufacturing Processes Laboratory* is a hands-on, all-around workshop which provides research and instructional support related to:

- Materials Engineering (e.g., training of machinery operating utilization, material test specimen preparation, cutting, grinding, welding, fabrication for senior design projects)

- Manufacturing Processes (e.g., for cutting, grinding, welding, casting, rolling, machining, and CNC programming of lathes and mills).
- Project Report

Additionally, all previously mentioned laboratories are used for assigned research projects by instructors of other courses on project-based tasks, as well as the research and design purposes.
Equipment Inventory of the SB 250 Lab

- CNC Dyna 3000 Lathe
- CNC Dyna 2400 Mill
- CNC Boxford 160 Lathe
- 14" Tilting Arbor Table saw
- Metal Cutting Horizontal band saw (7"x12")
- Craftsman 10" Radial saw
- Craftsman 12" Band saw
- 12" Miter saw
- Rockwell combination saw
- Craftsman Floor 12 speed drill press
- 12" Tabletop drill press
- Craftsman 2.5 hp Router
- 12.5" Planer
- Combination sander
- 1"x30" belt sander
- Laser Micrometer LaserMike® model 500
- Arbor press
- 20-ton Shop press (new)
- Assorted hand tools
- Blower Door and assorted Energy Audit tools (new)

7) Quality and Reliability Research Laboratory (SEB 348)

The *Quality and Reliability Research Laboratory* is a hands-on, all-around workshop which provides research and instructional support related to:

- Reliability and Statistics and SPC (e.g., collecting data on quality and reliability projects and performing analysis of the data)
- Design of Experiments
- Quality Control (e.g., experimental design for various projects on quality and reliability, collection of data, analysis of data, etc.)

Equipment Inventory of the SB 348 Lab

- Wacom Cintiq Digitizer used in conjunction with ArtCAM software
- Oculus Rift VR Headset
- Automation Studio: A Complete Project/Product Lifecycle Solution

8) Human Machine Systems & Manufacturing Research Laboratory (SEB 349)

The *Human Machine Systems& Manufacturing Research Laboratory* provides learning as well as enriched hands-on experience to students regarding ergonomics, human factors, and safety health principles a swell as manufacturing of small products. The lab provides research and instructional support related to:

- Ergonomics and Workplace Design

- Manufacturing Processes
- Ergonomics and Human Factors
- Industrial Safety and Health.

Equipment Inventory of the SB 349 Lab

- Dimension BST 3-D Rapid Proto-Typing system
- DynaMite 2400 CNC milling center
- Dyna Mite 3000 CNC turning center
- Boxford 160 Lathe
- CNC Laser Cutter
- MakerBot Digitizer
- MakerBot Replicator 2 3D printer
- MakerBot Replicator 2X 3D Printer
- Portable Oxycon Mobile Oxygen Analyzer
- Landice® L7 Executive Treadmill
- 50" LCD TV on mobile stand with PC system
- Monark Cardio-care 827E Ergo Stationary bicycle
- Diamondback Fitness Model 1260Ef Elliptical Trainer
- Dimension 3D Printer, BST

Computing Resources

1). The Morgan State University Campus Communications Network

The University deploys over 100 miles of 24-strand single mode fiber (smf) to create and support a high-speed 3-tier hierarchical switch star network design infrastructure that radially connects to 45 on-campus buildings, several nearby (less than 1 mile) academic & residence facilities (including the Portage Building and the Morgan View Complex), as well as a tier-2 distribution point (via a private connection provided by Comcast) to a remote research facility locate in St. Leonard, Maryland (the **P**atuxent **E**nvironmental & **A**quatic **R**esearch **L**aboratory – known as P.E.A.R.L.).

Each of the buildings receive their own fiber connections that radiate out from each of the two ultra-high-speed Core Switch/Routers in a redundant dual-homed design to provide maximum availability. The two Tier-1 native-routing Cores (housed in two different buildings) are trunked together to provide a robust 240 Gbps bandwidth switching speed between the two cores, and each individual Core provides separate fiber strands to each building's Distribution switch/router (Tier-2) located in the main distribution frame (MDF) closet of each building. From the centralized distribution switch/router in each building, multi-mode (mmf) fiber risers create an intra-building switch star design to each of the building's intermediate distribution frame (IDF) closets, and each closet contains one or more Access Layer switches (Tier-3) which provide category 5 (or better) UTP cabling to connect user workstations, departmental servers, printers, and other end-node points. The distributed routing bandwidth from the building's centralized MDF switch provides independent switched-routed links to a redundant access layer switch stack at 20 Mbps speed uplinks, and variable node connections of 10/100/1000 Mbps to the desktop.

In addition to the high-speed wired communications network, the infrastructure also provides a comprehensive and resilient wireless network that deploys over 1800 wireless access points (AP)

which deliver high-bandwidth WiFi static and roaming coverage to tens of thousands of campus nodes that are connected to the network using a standard routing internet protocol (ip).
Of the 45 main campus buildings, twelve are student residential buildings which are served from their own Student Network Core switch/router which mirrors the same 3-tier structure as the main administrative network (other 33 buildings). The 3rd Core is connected to the main campus network's dual-homed cores via high-speed Ethernet fiber connections which provides separation from the admin network via high-capacity firewalls. The firewalls between the Admin & Student Cores restrict privileged traffic (that should stay on the admin network) via firewall rules and DNS object definitions.

The university deploys 3 distinct data centers on campus:

- Administrative Computing (Carter-Grant-Wilson) Primary
- Administrative Computing (CEBIS Bldg.) Hot Secondary
- Engineering School Data/Network Ops Center (Mitchell Bldg.)
- Administrative Computing (Bowie State Campus) DR warm site

The university also deploys an ultrafast campus internet 1 connection (10 Gbps) to the main internet, as well as a similar shared 10 Gbps internet 2 connection to facilitate academic and collaborative research.

The University made a considerable investment 3 years ago to implement a fully converged network design that will allow disparate technologies and protocols to transverse the network via a common and standard ip protocol. The high-speed campus backbone integrates various services within the same bandwidth, and includes such critical services as data (student, admin, and lab systems), voice, video, a robust camera surveillance system, ipTV, Unified Communications (UC), energy management systems, ingress/egress facility locking control and monitoring, as well as high-speed connections to the central ERP systems that support student, staff, finance, and housing management systems.

The current university network architecture is comprised of best-of-breed systems that were installed and are being supported by the Alcatel-Lucent Enterprises organization.
The chosen platform utilizes a comprehensive and state-of-the-art Alcatel-Lucent design for the main 3 tiers, and also integrates an industry leading wireless design that is built on O.E.M. (Aruba) wireless systems, telephone collaborative meeting systems, and their highly rated UC products and features that provides the university with the latest market innovations. The campus network utilizes the following ALE products to facilitate the design and connectivity:

- Alcatel-Lucent OmniSwitch 10K LAN Core Switch/router Chassis and modules
- Alcatel-Lucent OmniSwitch 6900 Stackable Distribution layer Gig-E switch/router
- Alcatel-Lucent OmniSwitch 6450 Stackable Access layer Gig-E LAN switch
- Alcatel-Lucent OmniAccess WLAN high-speed Access Points (AP)
- Alcatel-Lucent OmniVista 2500 Network Management System
- Alcatel-Lucent OmnVista 3600 wireless Air Manager
- Alcatel-Lucent OmniAccess WLAN Controllers
- Alcatel-Lucent Premium DeskPhones

To provide consistently reliable network security, the university deploys the following best-of-breed systems:

- Palo Alto high speed/aggregate network firewalls
- InfoBlox servers

2) Campus Network Diagram

The current design of the university's network infrastructure is illustrated below in Figure K1:

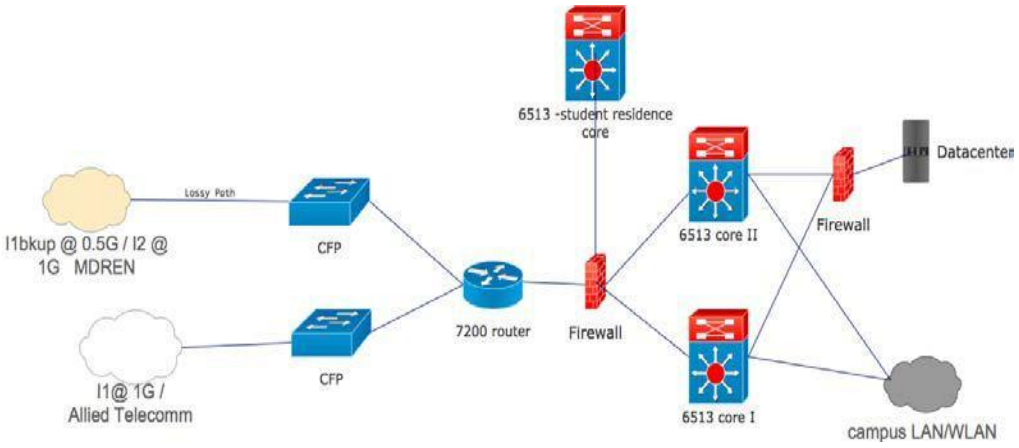

Figure K1. MSU's Network Infrastructure Diagram

L. Adequacy of Financial Resources with Documentation (as outlined in COMAR 13B.02.03.14)

L1. Table L1: Resources and Narrative Rationale.

Resource Categories	Year 1	Year 2	Year 3	Year 4	Year 5
1. Reallocated Funds	0	0	0	0	0
2. Tuition/Fee Revenue (c + g below)	131,964	183,429	222,810	271,611	338,945
a. Number of F/T Students	12	15	18	21	25
b. Annual Tuition/Fee Rate	9,657	10,443	10,445	10,863	11,297
c. Total F/T Revenue (a x b)	115,884	156,645	188,010	228,123	292,425
d. Number of P/T Students	5	8	10	12	15
e. Credit Hour Rate	536	558	580	604	628
f. Annual Credit Hours	6	6	6	6	6
g. Total P/T Revenue (d x e x f)	16,080	26,784	34,800	43,488	56,520
3. Grants, Contracts & Other External Sources	0	0	0	0	0
4. Other Sources (Lab Fees)	0	0	0	0	0
TOTAL (Add 1 – 4)	131,964	183,429	222,810	271,611	338,945

It is projected that 12 fulltime (F/T) students and 5 part-time (P/T) will be enrolled in the first year and the enrollment will grow to 25 F/T and 15 P/T students in Year 5, which will project a total revenue of $131,964 in the first year and grow to $338,945 in Year 5. The detailed calculation for each year is given in above Table L1.

L2. Table L2: Program Expenditures and Narrative Rationale

Expenditure Categories	Year 1	Year 2	Year 3	Year 4	Year 5
1. Faculty (b + c below)	98,100	100,553	103,066	105,643	108,284
a. # FTE	1	1	1	1	1
b. Total Salary	90,000	92,250	94,556	96,920	99,343
c. Total Benefits	8,100	8,303	8,510	8,723	8,941
2. Admin. Staff (b + c below)	0	0	0	0	0
a. # FTE	0	0	0	0	0
b. Total Salary	0	0	0	0	0
c. Total Benefits	0	0	0	0	0
3. Support Staff (b + c below)	34,880	35,752	36,646	37,562	38,501
a. # FTE					
b. Total Salary	32,000	32,800	33,620	34,461	35,322
c. Total Benefits	2,880	2,952	3,026	3,101	3,179
4. Equipment	0	0	0	0	0
5. Library	0	0	0	0	0
6. New or Renovated Space	0	0	0	0	0
7. Other Expenses +	0	0	0	0	0
TOTAL (Add 1 – 7)	**132,980**	**136,305**	**139,712**	**143,205**	**146,785**

It is projected that one fulltime faculty and one support staff will be added to the department with the cost projection details given in above Table L2, from $132,980 in Year 1 to $146,785 in Year 5.

M. Adequacy of Provisions for Evaluation of Program (as outlined in COMAR 13B.02.03.15).

Although there are no accreditation bodies like ABET for the evaluation of Ph.D. curriculum, Morgan's SOE and our Department of Industrial and Systems Engineering have evaluation procedures for administrators (Dean, Department Chair), faculty, students, Programs, and courses that will be used for this program.

Student performance in courses will be evaluated based on graded assignments, tests, quizzes, attendance, etc. Each semester, students will submit online evaluations of their courses and instructors. Each year, the department chair will evaluate faculty and provide feedback for improvement using faculty annual reports, and the SOE Faculty Evaluation Instrument. The Department Chair will also evaluate faculty with respect to their performance in the Program. Subsequently, the dean will evaluate the department chair, and the provost will evaluate the dean, and so on.

Evaluations at each stage are based on specific and well-defined procedures and criteria that are made known in advance, including syllabi, questionnaires, reports, job descriptions, and

evaluation forms. Collecting, managing, and reporting data are time-consuming and very important processes.

The purposes of the evaluations include but not limited to 1) build a stronger school, departments, programs, and courses; 2) track and help improve the performance of administrators, faculty, and students; 3) enhance the rigor of teaching and learning; and 4) promote more effective services.

In case of an overall unsatisfactory evaluation, a Performance Improvement Plan must be developed the next semester or academic year and be approved by the ISE Department Chair and Graduate Coordinator.

M1. Procedures for Evaluating Courses, Faculty and Student Learning Outcomes

At the end of each semester, the ISE Department Chair will evaluate each course, course instructor (peer evaluation), and student performance; meet with the course instructor to go over the evaluation results and to make suggestions for goals and objectives for the new semester. At the end of each academic year, the Department Chair will also evaluate Program performance and meet with the Department Graduate Coordinator to go over the evaluation results and make suggestions and recommendations for program adjustments for the next academic year.

M1.1. Criteria for Course Evaluation

- Course Organization
  - Are the following policies clearly stated in the syllabus?
    - Course objectives
    - Requirements
    - Grading
    - Attendance
  - Is the content taught suited to the stated course objectives?
  - Does the instructor use technology appropriately?
  - Is class time used productively?
  - Does the course use active learning pedagogy?
  - Does the course cater to a variety of learning styles?
- Assignments
  - Are the following appropriate for this course?
    - Homework
    - Technical Writing
    - Projects
    - Tests

        - Textbooks and other assigned reading
    - Do assignments effectively promote positive student learning outcomes?
- Grading
    - Does the instructor provide useful feedback on assignments?
    - Do examinations reflect important aspects of the course?
    - Is the grading system fair and clearly explained at the beginning of the semester?
    - Are assignments graded properly and promptly?
- Communication
    - Does the instructor explain complex ideas well?
    - Does the instructor show and inspire enthusiasm for the subject?
    - Does the instructor answer students' questions clearly?
    - Does the instructor use examples and illustrations to clarify material?
- Interaction with students
    - Does the instructor treat all students respectfully, fairly, and without bias?
    - Does the instructor respond to student communications promptly?
    - Does the instructor encourage student participation in the classroom?
    - Is the instructor open to different points of view?
    - Is the instructor available to provide individual help to students?
    - Does the instructor seem genuinely concerned with students' progress in the course?

M1.2. Criteria for Program Evaluation

The main criteria for Program evaluation are:

- student enrollment
- graduation rate
- student retention
- cost-effectiveness
- assessments of student learning outcomes
- student placement in internships and employment

M1.3. Criteria for Faculty Evaluation

Faculty must satisfy the following criteria:

- Prepare quality syllabus, tests, quizzes, and assignments
- Demonstrate mastery of subject matter and classroom management
- Timely graded material return
- Effective use of university-approved learning management system (e.g., Canvas), pedagogy and student advisement and teaching tools (e.g., Starfish, Degree Works)
- Hold regular office hours

These are the same criteria used for promotion and tenure. Failure to meet any one of these criteria will automatically result in an unsatisfactory teaching rating.

M1.4. Criteria for Student Learning Outcomes Evaluation

The course instructor will tailor assignments to assess students' aptitude against the objectives of the course and the desired student learning outcomes.
After completing the Program, students will have the knowledge and skills needed to successfully:

- Use current hardware and software, lab equipment, tools and methodologies to address engineering grand challenge problems
- Understand and follow trends in industrial and systems engineering
- Function effectively in teaming environments to accomplish a common goal
- Exhibit professional, ethical, legal, security, and social issues and responsibilities
- Communicate effectively both in writing and orally.

N. Consistency with the State's Minority Student Achievement Goals

N1. Minority student Access & Success, and Morgan's Cultural Diversity Goals and Initiatives

The Ph.D. in Industrial Engineering is designed to recruit, retain graduate and place students, especially minority students, in meaningful employment in one of the largest and fast-growing technology sectors in the United States and the world. These goals are

consistent with Morgan State University's goals and initiatives to promote minority student access and success and to recruit diverse, high-quality faculty.

O. Relationship to Low Productivity Programs Identified by the Commission

O1. Relationship to Low Productivity Program

There is no relationship to any low-productivity programs identified by the Commission.

P. Adequacy of Distance Education Programs

P1. Affirmation of Distance Education Eligibility

The Maryland Higher Education Commission (MHEC) has approved Morgan to offer ten (10) online degree and five (5) online post-baccalaureate certificate programs. As of academic year, 2018-2019 two hundred and forty-seven (247) faculty members have been trained through Quality Matters to develop and teach online courses and more than sixty-two hundred (6,200) students have enrolled in the University's online courses.

The Office of Morgan Online was established in 2013 and a full-time Director was hired in 2014 as a function of the President's reorganization of his administration to better realize the 2011 – 2021 Strategic Plan goals. Morgan is a member institution of Maryland Online a consortium of community colleges and senior institutions in the state of Maryland dedicated to championing distance education and enhancing the quality and availability of e-learning in Maryland and worldwide. The Director of Morgan Online is a Vice President of Maryland Online.

In summary, Morgan is fully invested in supporting its online degree and certificate programs. Its faculty are appropriate trained through Quality Matters to develop and teach online courses. The University's Board of Regents has approved a Policy for Online and Hybrid Courses that is published in the Faculty Handbook to establish criteria and guidelines for the development and delivery of high quality online and hybrid courses and online programs.

The Program will be agile in its offering to support both face-to-face and online instruction delivery. Most of the instructional courses, if not all, can be offered online including those that are more project based. However, dissertation research projects requiring specialized instrumentation can be done in a remote laboratory environment. Lastly, the ability for students to obtain certifications is also an anticipated outcome of this Program.

P2. Institutional Compliance with the C-RAC Guidelines

Morgan compiles with the Council of Regional Accrediting Commissions (C-RAC) guidelines - Inter-regional Guidelines for the Evaluation of Distance Education. However, C-RAC Guidelines are not related to this proposed Ph.D. in Industrial Engineering because it's not designed as a distance learning program.

Appendix I. Morgan State University

Morgan is Maryland's preeminent public urban research university, and the only university designated a National Treasure. Founded in 1867, the Baltimore-based HBCU is celebrating its 152nd of excellence in higher education.

For 152 years, Morgan has been an essential part of the higher education system in Baltimore City, the State of Maryland, and the United States of America. Throughout its history, Morgan has served the community with distinction while meeting the educational needs of an increasingly diverse society. Morgan is one of the few historically black institutions nationally to offer a comprehensive range of academic programs from computer science, mathematics, and natural sciences to engineering, business, and education.

Morgan is Maryland's Preeminent Public Urban Research University. Morgan has also recently been elevated from a Carnegie Doctoral Research University (R3) classification to a High Research Activity University (R2).

Morgan has Middle States Association of Colleges and Schools, Commission on Higher Education Accreditation from 01/01/1925. Morgan is comprised of one college and nine schools:

- James H. Gilliam's College of Liberal Arts
- School of Architecture and Planning
- Earl G. Graves School of Business and Management
- School of Community Health and Policy
- School of Computer, Mathematical, and Natural Sciences
- School of Education and Urban Studies
- Clarence M. Mitchell School of Engineering
- School of Global Communication
- School of Graduate Studies
- School of Social Work

Morgan has academic Programs at both undergraduate and graduate levels:

- 45 bachelor's degree Programs
- 10 post-baccalaureate's certificates
- 37 master's degree Programs
- 16 doctoral degree Programs

Morgan has several distinguished faculties in the School of Computer, Mathematical and Natural Sciences, the School of Engineering, and the School of Business and Management who have the background and expertise to deliver the BS in Cloud Computing Program and courses. Morgan enrolls 7,800 students in programs ranging from baccalaureate to doctoral degrees. Morgan attracts students from each state and many foreign countries. Approximately 35% of all students enrolled at Morgan are from outside the state of Maryland. Most matriculating students are from Maryland, New York, New Jersey, and Pennsylvania. Nationally, Morgan is one of the leading institutions for receiving admission applications from African American high school graduates.

Morgan awards more bachelor's degrees to African American students than any other college or university in the state of Maryland. Morgan accounts for large percentages of degrees received

by African Americans from Maryland universities and colleges. Morgan has ranked among the top public universities and colleges nationally in the number of minority graduates receiving doctorates. While Morgan is an HBCU, it has served students of all racial and ethnic backgrounds. Its mission today is to enroll a student body that is diverse in its socioeconomic and academic status and to provide the full range of experiences and services that permit it to serve students with a wide variety of goals and needs.

Appendix II. School of Engineering

The School of Engineering consists of four departments namely:

- Department of Civil Engineering
- Department of Electrical and Computer Engineering
- Department of Industrial and Systems Engineering
- Department of Transportation and Urban Infrastructure Studies

The School of Engineering offers bachelor's degree programs, a Master of Engineering Program, a Doctor of Engineering Program, and post-baccalaureate certificate programs. A complete list of all degree offerings is given below.

- Bachelor of Science in Civil Engineering
- Bachelor of Science in Electrical Engineering
- Bachelor of Science in Industrial Engineering
- Bachelor of Science Transportation and Urban Infrastructure Studies
- Post-Baccalaureate Certificates in Cybersecurity and Transportation
- Master of Engineering (All Departments)
- Doctor of Engineering (All Departments)
- Ph.D. in Transportation