A proposal for the

Doctor of Philosophy Degree

in

Mechanical Engineering with Specialization in Intelligent Energetic Systems

at the

New Mexico Institute of Mining and Technology

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Executive Summary

Doctor of Philosophy Degree in Mechanical Engineering with Specialization in Intelligent Energetic Systems at New Mexico Institute of Mining and Technology

The Department of Mechanical Engineering at New Mexico Institute of Mining and Technology (NMIMT) proposes a new Ph.D. program in Mechanical Engineering with Specialization in Intelligent Energetic Systems. The Ph.D. program is aimed at addressing educational needs of emerging markets in intelligent mechanical systems, explosives engineering, and national security. The purpose of the proposed program is to provide graduate education and training in the mechanical engineering discipline focusing on research, development and practical applications of intelligent systems, energetic materials, and state-of-the-art security practices in private industry and governmental entities. The program explores system engineering thinking, knowledge of energetics, use of innovative design techniques, and cross-disciplinary analysis of system elements for applications in explosives engineering, smart systems and intelligent structures. It is due to the fact that all modern energetic or explosive systems incorporate some form of intelligence and real time analytics that this program represents technological innovation and the next step in explosives science and engineering.

Need for the program comes from diversity of New Mexico business enterprises and growing interest in national security, energetics, and intelligent systems in general. There is no in-state and out-of-state duplication due to specific interconnection between intelligent systems and energetics. In this respect, the program is uniquely positioned to serve students interested in engineering smart/intelligent/adaptronic systems and explosives science.

It is anticipated that the main clientele of the program will consist of recent bachelor or master engineering degree graduates, qualified working professionals, as well as qualified staff members of national laboratories and other governmental entities. Projected full-time and part-time student enrollment for the first 5 years of the Ph.D. program is 14 students. Students will be supervised by a growing number of mechanical engineering faculty with involvement of faculty from other departments and adjuncts. Financial support of the Ph.D. students will mainly come from faculty research and scholarships provided by industry, government, and foundations. Availability of high quality Ph.D.-level students could augment faculty teaching contributions by providing highly skilled TA's. The Ph.D. students will also enhance faculty research allowing for more complex topics to be approached. Procedures already implemented for assessment of the existing M.S. program in Mechanical Engineering will be used to evaluate operation and impact of the proposed Ph.D. program.

The program will be administered by the Department of Mechanical Engineering. In addition, it is projected that other departments and NMIMT divisions (e.g. EMRTC) will contribute to program operation. The Mechanical Engineering Ph.D. program is well aligned with NMIMT's strategic plan and current educational/research directions.

A Purpose of the Program

The Department of Mechanical Engineering at New Mexico Institute of Mining and Technology (NMIMT) proposes a new Ph.D. program in *Mechanical Engineering with Specialization in Intelligent Energetic Systems* (MENG-IES). The Ph.D. program is aimed at addressing educational needs of emerging markets in intelligent mechanical systems, explosives engineering, and national security.

A.1 The Primary Purpose of the Proposed Program

The purpose of the proposed Ph.D. program in *Mechanical Engineering with Specialization in Intelligent Energetic Systems* is to provide graduate education and training in the mechanical engineering discipline focusing on research, development and practical applications of intelligent systems, energetic materials, and state-of-the-art security practices in private industry and governmental entities.

The uniqueness of the program is that it explores system engineering thinking, knowledge of energetics, use of innovative design techniques and cross-disciplinary analysis of system elements for applications in explosives engineering, intelligent structures, energetic effects and smart systems. It is due to the fact that all modern energetic or explosive systems incorporate some form of intelligence and real time analytics that this program represents technological innovation and the next step in explosives science and engineering

Modern engineering systems are truly multidisciplinary. They feature synergistic integration of chemical and mechanical functions with electronic components, embedded computational cores, information inference algorithms, and communication links for real-time autonomous functionality. The demand for intelligent engineering systems is dynamically expanding as government and consumers alike consider buying a new generation of systems and products with microcontrollers and sensors structurally integrated to enable unprecedented performance, reliability, and safety. Examples of these household technological innovations include advanced garden irrigation systems adaptable to weather conditions, programmable house climate control devices, and other products with mechanical functionality enhanced by ability to sense and adapt to operation environment. However, intelligent mechanical systems are not only consumer oriented. Governmental organizations and industry have well-documented use and increasing need of mechanical systems with built-in intelligence. Such systems enable mankind to expand the scientific exploration beyond the planet to the Moon and Mars and permit broader use of alternative, including nuclear, energy sources. It is intelligent systems that assist in defending this country and promoting free societies.

The defense-related applications require an extensive knowledge of energetic materials and shock physics. These subjects are the core of explosives science. However, to design and build energetic systems for both civic and defense applications, knowledge of mechanical engineering is crucial as it implies achieving a concerted operation of mechanical, electrical, software and energetic components – i.e. system level intelligence. It is difficult to find a successful engineering system lacking integration of mechanical actions, electronic control, information processing and decision making at least at some level. This is especially true for energetics.

As these smart, adaptronic, and self-sustainable devices grow in complexity and in the levels of civic, scientific and defense tasks they perform, it is of paramount importance to educate a new generation of mechanical engineers on a broad spectrum of issues pertaining to the design, realization, maintenance and safe retirement of such systems. This is the primary purpose of the proposed Ph.D. program in Mechanical Engineering with Specialization in Intelligent Energetic Systems.

A.2 Consistency of the Proposed Program with the Role and Scope of the Institution

The Doctor of Philosophy program in Mechanical Engineering with Specialization in Intelligent Energetic Systems is consistent with NMIMT's mission and strategic plan[1]. The NMIMT's mission indicates the following central aspects pertaining to the role and scope of the institute:

"New Mexico Tech serves the state and beyond through education, research, and service, focused in science, technology, engineering, and mathematics. Involved faculty educate a diverse student body in rigorous and collaborative programs, preparing scientists and engineers for the future. Our innovative and interdisciplinary research expands the reach of humanity's knowledge and capabilities. Researchers, faculty, and students work together to solve real-world problems. Our economic development and technology transfer benefit the economy of the state and create opportunities for success. We serve the public through applied research, professional development, and teacher education, benefitting the people of New Mexico."

The NMIMT mission emphasizes science, technology, engineering, and mathematics, which constitute the core of the Ph.D. program in Mechanical Engineering with Specialization in Intelligent Energetic Systems. Design and development of modern mechanical engineering systems prepares students to tackle "real-world problems" requiring the integration of multifaceted mechanical, electronic, bio, structural, or energetic components into one system. Complying with the NMIMT mission, the program will develop an inclusive multi-disciplinary learning environment focused on "preparing

[1] Excerpt taken from the NMIMT 2015-2020 strategic plan: http://www.nmt.edu/images/stories/presidentsofficepages/NMT_Strategic_Plan_2015-2020_final.pdf

scientists and engineers of the future". Therefore, the Ph.D. program in Mechanical Engineering with Specialization in Intelligent Energetic Systems is well aligned with the mission of the institute as is indicated in the NMIMT governing documents.

A.3 Priority of the Institution for the Proposed Program

The strategic plan of the New Mexico Institute of Mining and Technology states: "New Mexico Tech aspires to be a preeminent *community of scholars* dedicated to research, education, and innovation – advancing science, technology, engineering, and mathematics – to meet the challenges of tomorrow. We will drive innovation and education through transdisciplinary collaborations." The Ph.D. program in Mechanical Engineering with Specialization in Intelligent Energetic Systems is well aligned with this vision and is intended to support its practical realization. Institutional priority for establishing the ME-IES Ph.D. is reflected in a broad spectrum of the institute's activities including:

(a) Traditional focus of NMIMT Mechanical Engineering department on multi-disciplinary research including such areas as Mechatronics, Smart Structures, Traditional/Renewable Energy, and Explosives Engineering.

(b) Establishing an M.S. degree program in Mechanical Engineering with specializations in: Explosives Engineering, Mechatronics Systems and Robotics, Fluid and Thermal Sciences, Solid Mechanics. In addition, the B.S. Minor in Explosives Engineering was established in 2007, which is one of two undergraduate explosives programs in the nation.

(c) Establishing in 2001 a Distance Education Master of Science Degree program with annual enrollment of approximately 35 mechanical engineering students.

(d) During years 2006-2015 engineering departments has hired 15 tenure-track faculty members in areas closely matching the scope of the Ph.D. program in Mechanical Engineering with Specialization in Intelligent Energetic Systems. One additional hire focusing on explosives chemistry is anticipated this year at the Chemistry department which will collaborate on ME-IES Ph.D. program.

(e) The NMIMT administration has allocated space and other resources to establish additional research labs (11), teaching labs (4), plus 3 Living Learning Communities for freshman students.

(f) In 2014 NMIMT administration expressed ideas during a Board of Regents meeting of allocating a whole building to house the Mechanical Engineering Department with associated offices, laboratories and teaching auditoriums.

(g) A number of NMIMT departments have established a partnership with NMIMT's Energetic Materials Research and Testing Center (EMRTC) on a number of

national and international projects within the scope of the Ph.D. program in Mechanical Engineering with Specialization in Intelligent Energetic Systems.

(h) In 2015 strategic plan, the establishment of a Ph.D. in Mechanical Engineering with Specialization in Intelligent Energetic Systems is listed as the top priority related to the goal to "grow graduate enrollment to become Ph.D.-granting institution in 7 to 10 years", as part of the strategic priority to "Ensure Intentional and Planned Quality Growth". The NMIMT administration, including the Vice President for Research and Economic Development and the Vice President for Academic Affairs, has indicated the institute's priority for the ME-IES Ph.D. program in a number of public speeches to various audiences.

A.4 Curriculum

The Curriculum for the proposed Ph.D. program in Mechanical Engineering with specialization in Intelligent Energetic Systems is detailed below. The majority of the coursework will be based on courses currently listed in the catalog.

The prospective doctoral candidate should develop a strong background in energetics, intelligent systems, and fundamental aspects of mechanical engineering. Candidates will also develop the ability to integrate aspects of these fields and apply them to cutting-edge research. Upon completion of the program the student shall exhibit: a) an ability to apply advanced knowledge of mathematics, science, and engineering, b) an ability to identify, formulate, and solve engineering problems, c) an ability to design, document, and conduct experiments, as well as to analyze and interpret data, d) an ability to analyze requirements, propose design and evaluate practical realization of an engineering system, e) an ability to communicate effectively, f) an understanding of professional and ethical responsibility, g) the broad education necessary to understand the impact of engineering solutions in a global and societal context, h) a recognition of the need for, and an ability to engage in life-long learning, i) a knowledge of contemporary (within the profession) issues, j) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

Specific programs of study are developed by the student and their advisory committee, subject to the requirements listed below.

Course Requirements:

The student is required to take 72 graduate credit hours beyond the Bachelor's degree (or equivalent):

- 27 credit hours of core courses (3 courses from each core segment)
- 9 credit hours of elective courses, as approved by the graduate advisory committee
- 3 credits of Graduate Seminar (MENG 585)
- 9 credits maximum of Directed Study (MENG 581 or related 581, must be graded)
- 24 credits minimum of Dissertation research

A student with a Master's degree in Mechanical Engineering (or closely related discipline) must complete the following minimal requirements of 48 credits beyond the Master's degree:

- 18 credit hours of core courses (3 courses from Energetics and 3 courses from Intelligent Systems core segments)*
- 3 credits of Graduate Seminar
- 3 credits maximum of Directed Study (MENG 581 or related 581, must be graded)
- 24 credits minimum of Dissertation research

Energetics core segment: MENG 545 Introduction to Explosives Engineering, MENG 546 Detonation Theory, MENG 549 Wave Propagation, MENG 550 Advanced Explosives Engineering, MENG 552 Explosives Technology and Applications, MENG 589 Impact Dynamics, ME 548 Rock Fracturing and Fragmentation by Explosives, CHEM 540 The Chemistry of Energetic Materials.

Intelligent Systems core segment: MENG 544 Modern Control Theory, MENG 548 Manipulator based Robotics, MENG 567 Smart Engineering Systems, MENG 570 Advanced Mechatronics, MENG 572 Sensor Technology, MENG 574 Electrical Measurements of Non-Electrical Quantities, EE 551 Discrete-Time Signal Processing, Filtering, and Estimation, CSE 568 Intelligent Systems.

Fundamental Science and Engineering core segment: MENG 515 Theory of Elasticity, MENG 575 Advanced Engineering Mathematics, MENG 577 Advanced Fluid Mechanics, MENG 578 Advanced Thermodynamics, MENG 579 Advanced Heat Transfer, MATE 530 Design and Analysis of Experiments, PHYS 509 Methods of Theoretical Physics.

Qualifying Examination:

Core competency in mechanical engineering fundamentals must be demonstrated. The qualifying exam will also assess a student's ability to rationally approach novel problems and apply engineering analytical tools. The student will take written exams in three of the following topic areas as selected by the student with approval of the academic advisor.

Exam Topic areas:

- Control theory
- Dynamics
- Thermodynamics
- Fluid dynamics
- Heat transfer

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* In the case of a student who has completed equivalent courses in the energetics and/or intelligent systems core segments as part of their M.S. degree, the distribution of credits within the core segments may be adjusted (including credits from the Basic Science and Engineering core segment) as determined by the Graduate Advisory Committee.

- Mechanics of Materials
- Structural Analysis

The exam questions will be written and graded by department faculty members. These exams will be used to evaluate the student's knowledge of mechanical engineering topics at the undergraduate level and their ability to a) apply advanced knowledge of mathematics, science, and engineering, b) identify, formulate, and solve engineering problems.

The exam will be offered shortly after the end of each spring semester. The exam must be first taken before the beginning of the 3rd semester and is subject to the following:

- Students must take exams from three selected topics at first exam attempt.
- A student who does not pass a topic exam may retake that topic exam (or another topic exam with advisor approval) at the next offering; they do not need to retake exams that they have passed.
- A student who has not passed exams in three topics by the completion of their second exam attempt does not advance, and will leave the program. The student will be able to pursue a M.S. in Mechanical engineering subject to those degree requirements.

Candidacy Examination:

- Written dissertation proposal
- Presentation of written proposal and oral exam on the proposal and related IES coursework
- Must be taken no fewer than 12 months after passing the qualifying exam
- Three possible outcomes:
    - Pass: Student advances to Candidacy
    - Pass with conditions: 6 month window to correct minor deficiencies; Student advances to Candidacy only after the Graduate Advisory Committee determines deficiencies have been corrected.
    - Fail: Student does not advance to Candidacy and will leave the program.

Publication of Research:

- The student must demonstrate dissemination of research results by publishing at least one article in a peer-reviewed science or engineering journal.

Dissertation & Defense:

- Written Dissertation
- Oral presentation with public and private (committee only) Q&A
- Defense must take place no fewer than 12 months after passing the Candidacy Examination
- Possible outcomes:
    - Pass
    - Pass with conditions: Student must correct minor deficiencies. Note that the deficiencies should be minor and not require a second defense.

- Fail: Student has not satisfactorily presented/defended their dissertation and will leave the program.

B Justification for the Program

B.1 State and Regional Need

Over the past decade there is an increasing need of engineering professionals in national defense and energy sectors. New government initiatives had a direct impact on number and specialization of professionals entering Sandia National Laboratories, Los Alamos National Laboratory, Space Vehicles and Directed Energy Directorates Air Force Research Laboratory-Kirtland (AFRL-Kirtland), and White Sands Missile Range. Strong connection to national laboratories through joint projects, information exchange and on campus seminars allows NMIMT to be at the forefront of research in areas critical to national interest and intrinsically understand skills and expertise needed for professionals working in such areas. NMIMT has established collaborative programs with the national laboratories that provided students with opportunities not only to visit and to participate in cutting-edge research, but also to understand high levels of professional expertise required for government employees. These efforts have resulted in a substantial number of NMIMT graduates hired by national laboratories and industry closely associated with the labs. For example, needs of the Space Vehicles Directorate of AFRL have prompted collaborative work with NMIMT in the area of smart structures and mechatronics. This lead to a number of internships awarded to mechanical engineering students and a subsequent hire by Space Vehicles Directorate. It should be also mentioned that a number of engineering students were hired by industrial partners of the Space Vehicles Directorate.

NMIMT's undergraduate program in Mechanical Engineering is well known for a rigorous sequence of design courses in which each team of students is working on a project assigned by industry or a national laboratory. This approach to design courses is, perhaps, one of the best ways to understand needs of local New Mexico business. Appendix IV lists current projects initiated by the Mechanical Engineering department with local business. These close ties have resulted in many NMIMT Mechanical Engineering graduates finding employment by a wide spectrum of New Mexican companies ranging from large enterprises to small business.

With emergence of commercial space transportation, NMIMT is at the forefront of educating professionals to this new industry. With one of first national spaceports, Space Port America, New Mexico is a leader providing commercial space services. NMIMT Mechanical Engineering is among few educational institutions selected to participate in the Federal Aviation Administration (FAA) National Center of Excellence for Commercial Space transportation (CST). In this center, NMIMT has focused on tasks involving smart mechatronics systems and explosives engineering for improving safety and reliability of commercial space vehicles. Through these efforts, for the first time ever, active ultrasonic measurements in near-space and space environment were conducted by students and

faculty. NMIMT research also helps FAA to establish guidelines for propellant safety procedures through associated testing at explosives facility in EMRTC. Over past few years, the department has instrumented two payloads flown on two commercial spaceflights from Space Port America. As New Mexico space activities grow in number and magnitude, NMIMT views itself as one of key state educators of professionals in energetic systems and intelligent structures entering new commercial space industry.

Testimonials from employees at national laboratories and testing facilities help to articulate their interest in supporting a doctoral program in *Mechanical Engineering with specialization in Intelligent Energetic Systems* at NMIMT and underscore the fact that such a program would offer unique education opportunities not offered elsewhere in the state.

"The mission of the NASA/White Sands Test Facility is propulsion systems testing and energetic/hazardous materials evaluation. The addition of a Ph.D. program in Mechanical Engineering at NMIMT capitalizes on unique capabilities and academic knowledge that directly support the site and NASA's mission. This also opens significant opportunities for advanced collaboration in testing and research on energetic materials." – *Mark R. Leifeste, Jacobs Technology Inc. NASA/White Sands Test Facility*

"Sandia National Laboratories is always interested in students from New Mexico Tech. In the current capacity NMIMT Mechanical Engineering is only able to provide students at the Master's level. If a Ph.D. were available Sandia would gladly draw from NMIMT due to their students' proven track record." – *Leroy Garley, Sandia National Laboratories*

"A Ph.D. program that included a focus in explosives and energetic systems would greatly benefit our research initiatives here at Los Alamos National Laboratories." – *Matthew N. Rush, Los Alamos National Laboratories*

B.2 Duplication

In-State

In the state of New Mexico both University of New Mexico (UNM) and New Mexico State University (NMSU) offer degrees of Doctor of Philosophy in Engineering with variety of concentrations. These two degree programs are similar in that they are based in the fundamental discipline of engineering. However, none of the New Mexico universities offer a graduate program with specialization in *Intelligent Energetic Systems*. The only graduate program related to this field is MS Mechanical Engineering program with concentrations in Explosives Engineering and Mechatronic Systems & Robotics offered by NMIMT. With the proposed Ph.D. program, NMIMT extends its established expertize and educational services into the Ph.D. level. It is the specialized nature and associated areas of study that differentiate the proposed Ph.D. in Mechanical Engineering with specialization in Intelligent Energetic Systems from other Mechanical Engineering Ph.D. programs in the state. The proposed NMIMT's Ph.D. program specializes exclusively in *Intelligent Energetic Systems* and does not offer any other Mechanical Engineering specializations.

University of New Mexico (UNM) grants Ph.D. degrees in Engineering with several concentrations. Four core classes (math, thermal, solids, dynamics) are required and then supplemental courses to meet needs of research. As of March 2015 the current Mechanical Engineering Ph.D. enrollment is 25-30 students, and the capacity in program is 55-60 students (4-5 students per faculty member).

New Mexico State University (NMSU) grants Ph.D. degrees in Engineering with several concentrations. No core curriculum exists, only courses that are related to a student's chosen area of study. As of March 2015 the current Mechanical Engineering Ph.D. enrollment is 3 students, and has ranged from 2-5 students over the past 5 years. The estimated capacity in program is 13 students (assuming 1 student per faculty member).

The Ph.D. Mechanical Engineering with specialization in Intelligent Energetic Systems (MENG-IES) program at NMIMT is built on the unique and renowned strength of NMIMT in Explosives Engineering and Mechatronics Systems Engineering. In this respect, the Ph.D. in MENG-IES program proposed by NMIMT does not duplicate the other Ph.D. programs available in the state of New Mexico. Furthermore, this new program compliments the other programs and opens a broad spectrum of collaborative educational and research initiatives between the universities and colleges located within the state. The new NMIMT Ph.D. program is a natural extension of the existing Master of Science in Mechanical Engineering program, which encompasses four areas of specialization (Explosives Engineering, Mechatronics Systems and Robotics, Fluid and Thermal

Sciences, and Solid Mechanics) and has no analogous M.S. program in the state of New Mexico. Current enrollment in the Mechanical Engineering M.S. program at NMIMT is more than 50 students. This number demonstrates outstanding potential and need for the Ph.D. program as a notable number of students in the M.S. program expressed interest in advancing their education to Ph.D. level.

Out of State

The NMIMT's Ph.D. program in Mechanical Engineering with specialization in Intelligent Energetic Systems has no formal out of state counterparts. The proposed program is unique in that it is a synergistic integration of various branches of mechanical engineering, systems engineering thinking, and knowledge of energetics aimed at addressing growing interest in intelligent systems, explosives engineering, and related national security applications. Separately (but not collectively), some aspects relevant to the program are emphasized as separate degree programs at few out of state universities. However, as it is shown below, focuses of the existing out of state programs are noticeably different from the NMIMT's MENG-IES Ph.D. program.

For example, very few universities in the nation offer Ph.D. degrees related to explosives engineering. The list of universities includes: University of Kentucky, Missouri University of Science and Technology, Virginia Tech, and Colorado School of Mines. Traditionally, explosives programs were established at mining departments, which defined the scope and focus of the curriculum. For example, Colorado School of Mines has several explosives related courses offered through their mining engineering program, but all of these courses are specifically focused on mining and blasting applications. In 2014, Missouri University of Science and Technology established a separate Ph.D. program in explosives engineering, but this too grew out of the mining engineering program. A similar trend is observable in most of Ph.D. programs offered by the universities listed above, The MENG-IES Ph.D. program proposed here takes a significantly different approach. This program leverages the diverse range of NMIMT faculty expertise to provide students with a unique approach to engineering energetic systems that will be applicable to more than just the mining industry.

There are very few universities in the U.S. that offer formal education related to intelligent systems. The Certificate Program in Robotics and Intelligent Systems is opened to juniors and seniors at Princeton University. As it is evident from the description of the program, it is designed for undergraduate students. The University of Pittsburgh offers a Doctor of Philosophy degree in Intelligent Systems Program with a General Intelligent Systems Track Curriculum. The program is heavily focused on computer science/engineering aspects of intelligent systems and lacks coverage of mechanical system integration. University of California, San Diego (UCSD) offers a Ph.D. in Intelligence Systems, Robotics & Control. Although this program features courses relevant to electrical, mechanical, and computational algorithms design for intelligent system, it is noticeably distinct from NMIMT's Ph.D. in Mechanical Engineering with specialization in Intelligent

Energetic Systems, which provides substantial coverage of energetics and structures. Therefore, the Ph.D. in Mechanical Engineering with specialization in Intelligent Energetic Systems program proposed by NMIMT is a unique graduate program not only within the state of New Mexico, but also nationwide.

WICHE

The Western Interstate Commission for Higher Education (WICHE) seeks to leverage educational resources located in the western region to provide residents with opportunities that extend beyond the borders of their home state. We have examined existing programs in neighboring states that participate in WICHE for duplication.

There are Ph.D. programs available in Mechanical Engineering from Colorado School of Mines, Colorado State University, the University of Colorado at Boulder, the University of Utah, Utah State University, and Arizona State University. These programs are structured with emphasis in the typical areas of the discipline: solid mechanics, thermal/fluids, and dynamics and control systems. Doctoral programs with an aerospace emphasis are offered through the University of Arizona, Arizona State University, and the University of Colorado at Boulder. A program at the Ph.D. level with a systems engineering emphasis is available at Arizona State University, although this program has an emphasis on transdisciplinary approaches involving earth and environmental science. None of these programs has an emphasis (or even courses available) on energetic materials or explosives.

The Western Regional Graduate Program (WGRP) run via the Western Interstate Commission for Higher Education (WICHE) currently has no programs that grant Ph.D. in Mechanical Engineering with specialization in Intelligent Energetic Systems. The WGRP offers two programs that feature a few aspects marginally related to intelligent energetic systems, but still lacking unique emphasis of NMIMT's program in the areas of explosives engineering and intelligent structures. These programs include Industrial and Systems Engineering and Engineering Systems. The first program primarily deals with human/machine systems and provides students with a practical knowledge in facilities planning, operations planning and control, economic and decision analysis, and project management. As can be seen from this short description, the scope of this program is quite different from the proposed NMIMT's Ph.D. in MENG-IES program. This WICHE program is an M.S., not a Ph.D. program. The second WICHE program in Engineering Systems is a Ph.D. program with some themes relevant to intelligent systems, but without opportunities to integrate knowledge of energetics and practices in explosives engineering. Educational opportunities in intelligent energetic systems are not currently available through the WICHE initiative.

As a result, proposed NMIMT's Ph.D. program does not duplicate nor substitute for any existing program in neighboring WICHE states. Furthermore, Graduate educational opportunities in Intelligent Energetic Systems are not currently available through the WGRP initiative, indicating potential regional need for the proposed program.

B.3 Inter-Institutional Collaboration and Cooperation

The proposed Ph.D. program in Mechanical Engineering with specialization in Intelligent Energetic Systems will involve a broad spectrum of collaborative activities with other institutions in the state of New Mexico as well as with programs from other states. On one hand, there is no analogous degree program in the state and in the nation. On the other hand, it is believed that collaboration with other institutions will broaden student experiences and benefit the program. Below are some examples of collaborative activities. This list; however, will be broadened every semester as the collaboration with other institutions is expanded.

UNM collaborative activities: Collaboration with UNM is planned along two avenues: delivery of courses via distance education facilities and joint research projects. It is believed that certain courses taught at UNM will benefit the NMIMT's Ph.D. in MENG-IES program. These courses are intended to be delivered via distance education in similar fashion to the existing sharing of courses between NMIMT and departments at UNM. For Example, Students from UNM have taken our Biomedical Mechatronics course (MENG 576) via distance education. The following courses might be the first ones to be available to the students of both schools via distance education program: Fundamentals of Nanotechnology, Advanced Nanotechnology, Self-repairing Materials. The Mechanical Engineering Departments of NMIMT and UNM already collaborated in several proposals to NASA and NSF. One proposal to DOE is pending. Since 2006 the faculty and students of both departments regularly visit each other's facilities, give seminars, and discuss possibilities to collaborate in research and education.

NMIMT students and faculty actively participate in seminar/conference activities organized by UNM. Especially, NMIMT contributes to local (i.e. state wide) events such as the Rio Grande Annual Symposium on Advanced Materials (RGSAM).

Dr. Hargather gave a seminar at UNM as part of the Mechanical Engineering Department seminar series March 27, 2015. Based on the discussions after the seminar, increased collaborations are expected, especially with Dr. Vorobieff and Dr. Truman. Dr. Hargather has also attended two seminars hosted by the AIAA professional society chapter based at UNM, and has interacted with UNM faculty and students at the associated social hours. Dr. Zagrai has also participated in UNM seminar series and is a member of New Mexico's AIAA chapter.

As a junior faculty member, Dr. Mousavi has recently submitted a pre-proposal to NASA EPSCOR in collaboration with UNM and is developing a graduate level course in which students will attend the lectures at NMIMT or via distance education technology and benefit from laboratory instruction in the cleanroom facilities at UNM's Manufacturing Technology Training Center (MTTC). This opportunity will not only provide a chance to share facilities and courses between the two schools, but it is also aimed to help the two schools complement and benefit from each other's facilities and specialties.

Dr. Grow has a joint appointment at UNM as an Adjunct Assistant Professor in the Department of Orthopaedics, School of Medicine. He has twice taught MENG 576, Biomedical Mechatronics with students enrolled at UNM through the Center for Biomedical Engineering. Dr. Grow also has coauthored proposals with multiple faculty from UNM and NMSU and currently has a funded project at UNM.

Dr. Bakhtiyarov has collaborated as an IPA with DoD US Air Force HQ, NASA HQ, DoE, EPA, SNL, LANL, JPL on Mars Science Lab project (2011-2014). In addition he has submitted a collaborative proposal entitled "New Mexico - Columbia Univ. and Penn State Univ. MRSECs Partnership: Synergistic Partnership for Integrated Research and Education on Multifunctional Materials and Composites" to NSF PREM Program. Duration: 5 years. Total Cost requested from NSF: $2,765,619 and is preparing to submit a collaborative proposal with NMSU entitled "Undergraduate Spaceflight Center – NM HSI Perspective" to NASA MUREP Program. Duration: 3 years. Total Cost requested from NSF: $701,097.

Dr. Ghosh has initiated a number of collaborations including a proposal with Dr. Ram K. Tripathi, a Senior Research Scientist at NASA Langley Research Centre and Dr. Ming Tang, Technical staff, Los Alamos National Laboratory focused on A Novel Multi Functional Composite Material for Radiation Protection for NASA Spacecraft and Astronauts. This proposal was funded for $56,750. An Education Partnership Agreement (EPA) was signed by AFRL [Point of contact (POC) as John E. Higgins] and NMIMT [with POC as A. K. Ghosh] during 2004 and is still in operation. This EPA provides an opportunity for NMIMT students to work in a technology rich area with excellent employment prospects. With AFRL/RV, Dr. Ghosh conducted acoustic testing on fluid-filled, porous media in a four-microphone transmission loss tube. The outcome of the effort has been a patent disclosure submitted by NMIMT and a journal article.

NMSU collaborative activities:

A collaboration already exists between NMSU and NMIMT to teach courses in the undergraduate aerospace engineering program. This program was initiated and is financially supported by the State of New Mexico. NMIMT has established an undergraduate minor degree program in Aerospace Engineering within the existing NMIMT mechanical engineering B.S. program. The current NMSU/NMIMT collaborative plan is for each university to offer, via distance education, one or more undergraduate courses per year in aerospace engineering, available to undergraduate students at both universities. NMSU taught the course Aerodynamics I via distance education. This course was taken by both NMSU and NMIMT students. In several Fall semesters NMIMT's Orbital Mechanics course was available to NMSU students, and NMSU's Flight Dynamics course was available to NMIMT students. NMSU's Aerodynamics II course was also available to NMIMT students. NMIMT offers a Compressible Fluid Flow course that is available to both graduate and undergraduate students at NMSU. At the same time NMSU

offers Astrodynamics. The NMSU/NMIMT collaboration at the undergraduate level is functioning well and will be expanded to include graduate courses.

NMIMT and NMSU established a strong collaboration in the research. In 2007 NMSU and NMIMT received a joint grant from NASA EPSCoR in the amount of $1.5M for three years. Another joint proposal submitted to DOE is pending ($5M for five years). Each year, in collaboration with NMSU, NMIMT participates in NASA EPSCoR and other NASA proposals. All of these proposals include graduate assistants and resources to conduct graduate level research.

Northern NM College collaborative activities:

Since 2008 NMIMT and NNMC established a strong collaboration in research and education. The faculty of both schools submitted several joint proposals to NSF, NASA and DOE. More collaboration is expected in the near future by providing distance education classes in the renewable energy area.

University of Texas at El Paso collaborative activities:

Since 2012, NMIMT and UTEP have established a strong collaboration in research and education. The faculty of both schools submitted joint proposals to NSF and DOE. These proposals include graduate assistants and resources to conduct graduate level research.

Missouri University of Science and Technology collaborative activities: In 2012, a MOU was established between Missouri University of Science and Technology (MST) and NMIMT in order to expand the explosives engineering education curriculum at MST as part of their Ph.D. in Explosives Engineering. The MOU allows credits to transfer between the two institutes in a few selected explosives classes. Students who have been under this MOU have been exposed in an engineering/science side of explosives application, and are greatly affected by the uniqueness of the program that NMIMT provides.

In addition to the collaborative relationships established with other universities, NMIMT has ties to New Mexico's two prominent national laboratories. These ties have helped impact our curricula and are described below.

Sandia National Laboratories (SNL) collaborative activities:

The current M.S. degree with specialization in explosives engineering was initially started through contact with several adjunct faculty members from the nearby national labs. This kind of collaboration with the national labs has been well established as a practice for over a decade now. Currently, in every single semester, the program continuously invites professionals from the national labs (Sandia National Laboratory, Los Alamos National Laboratory) or other research/consulting organizations with a wealth of experience as a guest lecturer or an adjunct professor in every areas of subject. This activity has been

successfully accomplished, and based on this activity along with the proposed Ph.D. program, more wide ranges of research/consulting collaboration with those organizations are expected.

Los Alamos National Laboratory (LANL) collaborative activities: Collaboration with LANL includes: delivering graduate courses to LANL staff, a teaching seminar series by LANL researchers, delivering invited lectures by LANL personnel, and establishing joint research directions, some of which would lend themselves well to long-term Ph.D.-level research. Additionally, NMIMT students participate in the Structural Dynamics School organized by the LANL Engineering Institute.

Cross-campus Collaborations

The faculty and students collaborate with the research scientists at on-campus research centers at New Mexico Tech including the Energetic Materials Research and Testing Center (EMRTC), the Petroleum Recovery Research Center (PRRC), and the Institute for Complex Additive Systems Analysis (ICASA). In addition, a faculty member has a current project in conjunction with the state Bureau of Geology, housed on the NMIMT campus. Engineering faculty participate in the research of these centers as PIs, Co-PIs, and collaborators, because of the close alignment of faulty research interests and the center foci. Graduate and undergraduate students benefit from these collaborations through campus jobs and research assistantships, while broadening their education through applications. These collaborations would be strengthened through the creation of this Ph.D. program and new opportunities for student research projects will be developed.

EMRTC is the largest of the research divisions of New Mexico Tech. EMRTC performs research and testing of energetic materials for customers including the federal government, defense contractors, and private companies that develop explosives or explosive-related systems for a range of applications. The EMRTC facilities include over 10,000 square feet of office and traditional laboratory space in addition to over 40 square miles of field laboratory testing space.

Collaboration between EMRTC and university departments is frequent and ongoing. Four professors in the Mechanical Engineering department (Grow, Hargather, Kimberley, Lim) have joint appointments with EMRTC, which allows these faculty members to perform testing in the EMRTC facilities and to easily participate as Co-PIs or subject matter experts on EMRTC funded projects. One faculty member, Dr. Hargather, has his research laboratory in an EMRTC building to facilitate direct collaboration. Dr. Hargather and Dr. Lim both have currently-funded research programs that they are PI on that directly involve research and testing at EMRTC. These funded research efforts are directly supporting graduate students toward Masters of Science degrees and would support Ph.D. students in the future. In the period of 2008-2015 24 students graduated with M.S. degrees in Mechanical Engineering that were directly involved with EMRTC in some capacity.

Each year EMRTC directly supports a noticeable number of science and engineering students through student jobs, research assistantships, and scholarships. In some departments, an average of two graduate students are supported on research assistantships or scholarships through EMRTC each year allowing them to complete their thesis and coursework. These students participate in EMRTC funded research and are mentored by joint-appointed faculty and EMRTC senior engineers. In the Mechanical Engineering alone, EMRTC hires approximately 10 undergraduate students each year for jobs ranging from field work to student engineers. Many of these undergraduates continue to graduate school; especially remaining at New Mexico Tech because of the research they were exposed to at EMRTC.

PRRC is a research center dedicated to improved oil and gas recovery research for independent hydrocarbon producers throughout the state of New Mexico. PRRC performs research and development that is funded by organizations including the Department of Energy and by private corporations. Research is performed on campus and at sites throughout the southwest.

Collaboration between the university departments and PRRC includes collaborative research proposals and funded projects supporting students pursuing graduate degrees. These research projects include research connected to the fluid-thermal sciences and energetic materials.

Dr. Ghosh has initiated a project with the state Bureau of Geology, housed on the NMIMT campus. This project involves collaborating with the Bureau of Geology Director and Hydrogeology Program Manager in transitioning the water desalination technology to the market.

ICASA performs research in computer science, mathematics, engineering, and management for government and private sector customers, and is co-located with EMRTC on the New Mexico Tech campus. A robotics faculty, Dr. Grow, has collaborated with ICASA for development of robot control algorithms to define the operation space for a particular customer robot. This research included support for a graduate student who completed his graduate degree in 2014, based on the work performed at ICASA.

In addition to collaborations with the on-campus research centers, the Department of Mechanical Engineering has established collaborative activities with other academic departments on campus. In recent years Mechanical Engineering faculty have co-authored funding proposals with faculty members of the following departments: Mathematics, Physics, Earth and Environmental Science, Chemistry, Biology, Civil Engineering, Electrical Engineering, Materials Engineering, Mineral Engineering. For example, Dr. Hargather has submitted several proposals related to the development of novel energetic materials with Dr. Henneke of Materials Engineering. Dr. Kimberley has been a co-investigator on an NSF proposal to study blast induced rock fragmentation with faculty members of Mineral Engineering. Dr. Grow has submitted proposals with Electrical

Engineering faculty to NFS National Robotics Initiative dealing with cooperative robotic–human interfaces. Dr. Ghosh has collaborated with Faculty from materials Engineering and Chemistry to submit a proposal to NSF to investigate the use of carbon nanotubes as flow sensors. The Department of Mechanical Engineering has also engaged in offering graduate courses listed or cross-listed in other departments. Specific examples from recent semesters include: Materials Engineering (MATE 445, MATE 530) and Mineral Engineering (ME 520, ME 549)

C Clientele and Projected Enrollment

C.1 Clientele

(a) The students to be served by the proposed Ph.D. in Mechanical Engineering with specialization in Intelligent Energetic Systems program are primarily:

i. Recent bachelor or master degree graduates, who obtained their degrees in science, engineering, technology, or another closely related discipline and who are interested in advancing their education, training, and expertise to compete for high level employment positions in industry, academia, and governmental entities.

ii. Qualified working professionals who have encountered a need to strengthen their professional capabilities.

iii. Qualified staff members of national laboratories and other governmental entities who wish to continue their professional education.

It is anticipated that the majority of students in the program will be accommodated on a full-time basis. However, due to specifics of national laboratories and other governmental/private entities, their staff members will be likely involved as part-time students.

(b) The following guidelines are proposed for admission of students into the Ph.D. program in Mechanical Engineering with specialization in Intelligent Energetic Systems:

i. Admission to NMIMT's Ph.D. in MENG-IES program will be consistent with general admission requirements set by the NMIMT graduate school. These requirements, among others, include GRE (domestic and international students) and TOEFL or IELTS (most of international students) tests.

ii. Candidates for admission into the Ph.D. MENG-IES program must possess a bachelor or master degree in science, engineering, technology, or other closely related discipline from an accredited institution of higher learning.

iii. Candidates for admission into the program must indicate completeness of the pre-requisite courses and/or proof of competency in basic science and engineering subjects.

iv. A minimal grade point average (GPA) of 3.3 on a 4.0 scale or other proof of satisfactory academic standing if the GPA is not available is recommended for candidates for admission into the Ph.D. in MENG-IES program. In addition, three letters of recommendation for admission into the program are required.

v. Depending on the candidate's background, additional course work may be recommended to ensure meeting the pre-requisite courses and competency requirements. While completing pre-requisite courses and competency requirements for admission into the Ph.D. in MENG-IES program, a student may be allowed to enroll with provisional status.

(c) The New Mexico Institute of Mining and Technology is qualified as a *Hispanic-Serving Institution* by the U.S. Department of Education (see the attached letter in Appendix VIII).

For Fall 2014 semester, New Mexico Institute of Mining and Technology Male-to-Female Ratio: 68 % male 32 % female.

The following NMIMT services are available that are aimed at increasing the higher educational opportunities for the underrepresented groups:

- Office for Student Learning (OSL) – The office facilitates the development of quality advising relationships between faculty and students as well as providing a wide spectrum of academic support services to help students explore their life goals, interests, abilities and values.

- Academic Referral Program – An early intervention program designed to identify and help students when they show signs of academic difficulty. The teaching faculty is asked to refer students to the OSL or Graduate Dean for assistance during the third week of the semester.

- Academic Counseling – Individual and group counseling is offered to help students identify their learning style and develop academic success skills such as time and stress management, study skills, and adaptive choice-making.

- Counseling and Disability Services, which mission is to support the emotional, intellectual and social development of students at NMIMT. This service helps individuals resolve existing problems, prevent potential problems, and develop new skills that will enrich their lives. NMIMT provides accessible programs, services, and reasonable accommodations for any student with a documented, qualifying

disability as defined by Section 504 of the Rehabilitation Act of 1973, as amended, and by the Americans with Disabilities Act of 1990.

- Advising Resources for Faculty – A seminar for new faculty members on utilizing the theory and techniques of developmental advising, mentoring, as well as orientation to academic policies, services and resources on campus and in the community.

- Instructional Training – Teaching training is provided to all new faculty and teaching assistants. This training is provided by the Center for Graduate Studies and addresses all aspects of teaching practice.

- STEM Communication Fellows – Partial TA-ships intended to improve communication within academic departments and to assist in written and oral communication tutoring at the graduate level through the Writing and Oral Presentation Center.

- Writing and Oral Presentation Center – Provides writing and presentation assistance to students of all levels and from all disciplines. Multiple resources are available for students to consult or borrow. Technology in this center includes recording of presentations that students can view via web link.

- Student Research Symposium a (SRS) is a campus-wide co-curricular event open to all New Mexico Tech students and organized by faculty, students, administrators, and staff. The mission of the Student Research Symposium is to provide a forum for students to voluntarily share knowledge with their peers, faculty, community, guests, and reviewers through oral or poster presentations and extended abstracts of their research/design projects. Students are encouraged to develop professional oral presentation, writing, and document design skills to communicate their research/design to a multidisciplinary audience.

- Research @ Tech Day – New Mexico Tech invites prospective students and their families to explore cutting-edge research on campus.

- State Science & Engineering Fair – The Science and Engineering Fair program encourages students to explore their environment in a systematic, logical manner. Participation in the science fair stimulates students' interest in science and technology while simultaneously promoting the development of the life skills of communication, decision making, evaluation of alternative solutions, and critical thinking.

- Supercomputing Challenge, Project G.U.T.S. – Summer Teacher Institute on the NMIMT campus training high school and middle school teachers to learn programming and then instruct and mentor their own students involved in these

national events. NMIMT also hosts the kickoff event in October with approximately 400 students and teachers coming to campus to attend.

C.2 Projected Enrollment

Projected enrollments for the first five years of the Ph.D. program in Mechanical Engineering with specialization in Intelligent Energetic Systems are listed in Table 1 below. The number of enrolled students assumes that we will have two new full time students per year, and one new part time student per year. Of the full time students, it is expected that one student graduate in 4 years (entering program with M.S.) and the other will graduate in five years (entering with a B.S.). After this initial ramp-up, a steady state of nine full-time students will be achieved and we expect two full-time students to graduate each subsequent year.

Table 1: Projected student enrollment for the NMIMT's Ph.D. program in Mechanical Engineering with specialization in Intelligent Energetic Systems

	Year 1 2016-2017	Year 2 2017-2018	Year 3 2018-2019	Year 4 2019-2020	Year 5 2020-2021
New Students, Full-time	2	2	2	2	2
New Students, Part-time	1	1	1	1	1
Returning students Full-time	0	2	4	6	7
Returning Students Part-time	0	1	2	3	4
Total Full-time Students	2	4	6	8	9
Total Part-time Students	1	2	3	4	5
Program Graduates	0	0	0	1	2
Total Credit Hours Generated	75	150	225	300	345

D Institutional Readiness for the Program

In recent years, several NMIMT Mechanical Engineering departments have experienced an unprecedented growth. The growth is seen in practically all areas: number of enrolled students, number of newly hired faculty, number of research laboratories, amount of allocated resources, etc. For example, according to recent institutional research data shown in Table 2 & Table 3, Mechanical Engineering leads a list of NMIMT departments with the largest undergraduate student enrollment (22.7%) as shown in and the second largest graduate student enrollment (20.7%). The total numbers of students served by the department as of Fall 2015 is approximately 350 undergraduate (B.S.) students and 50 graduate (M.S.) students. Figure 1 below demonstrates the number of NMIMT Mechanical Engineering undergraduate degrees awarded for the past decade. A stable increasing pattern is noticeable. Undergraduate students provide clientele to the Mechanical Engineering graduate (M.S.) program and may consider enrolling in the MENG-IES Ph.D. program if available.

Table 2. Bachelor's degree program enrollment, sorted by descending enrollment percentages

Rank	Program Code	Program Name	Total Enrollment	Percentage of Enrollment
1	MENG	Mechanical Engineering	338	22.7%
2	PETR	Petroleum Engineering	192	12.9%
3	CSE	Computer Sci. & Engr.	153	10.3%
4	CHE	Chemical Engineering	120	8.1%
5	EE	Electrical Engineering	117	6.6%
6	BIOL	Biology	99	5.6%
7	PHYS	Physics	84	4.4%
8	CE	Civil Engineering	65	4.3%
9	MATE	Materials Engineering	48	3.2%
10	CHEM	Chemistry	37	2.5%
10	MATH	Mathematics	37	2.5%
10	ERSC	Earth Science	37	2.5%
13	ENVE	Environmental Engineering	30	2.0%
14	ME	Mineral Engineering	26	1.7%
15	TC	Technical Communications	22	1.5%
16	0000	Undecided	19	1.3%
17	PSY	Psychology	16	1.1%
18	IT	Information Technology	15	1.0%
19	MGMT/MGTT	Management	12	0.8%
20	ENVS	Environmental Science	10	0.7%
21	BS	Basic Science	5	0.3%
22	EUND	Engineering Undecided	5	0.3%
23	GS	General Studies	2	0.1%
		TOTAL	305	100.0%

Table 3. Master's degree program enrollment, sorted by descending enrollment percentages

Degree Awarded	Program Code	Program Name	Men	Women	Total Enrollment	Percentage of Enrollment
MST	ST	Science Teaching	19	46	65	21.3%
MS	MENG	Mechanical Engineering	51	12	63	20.7%
MS	PETR	Petroleum Engineering	17	7	24	7.9%
MS	GEOL	Geology	10	11	21	6.9%
MEM	MEM	Engineering Mgmt.	13	6	19	6.2%
MS	HYD	Hydrology	12	6	18	5.9%
MS	ME	Mineral Engineering	14	2	16	5.2%
MS	MATH	Mathematics	10	3	13	4.3%
MS	CSE	Computer Sci. & Engr.	6	5	11	3.6%
MS	EE	Electrical Engineering	10	1	11	3.6%
MS	CHEM	Chemistry	5	3	8	2.6%
MS	MATE	Materials Engineering	6	2	8	2.6%
MS	ENVE	Environ. Engineering	4	3	7	2.3%
MS	BIOL	Biology	2	4	6	2.0%
MS	GEOP	Geophysics	4	2	6	2.0%
MS	GEOC	Geochemistry	2	3	5	1.6%
MS	PHYS	Physics	2	2	4	1.3%
		TOTAL	187	118	305	100.0%

NOTE: One graduate student seeking a Post-Baccalaureate Certificate is not included on this table

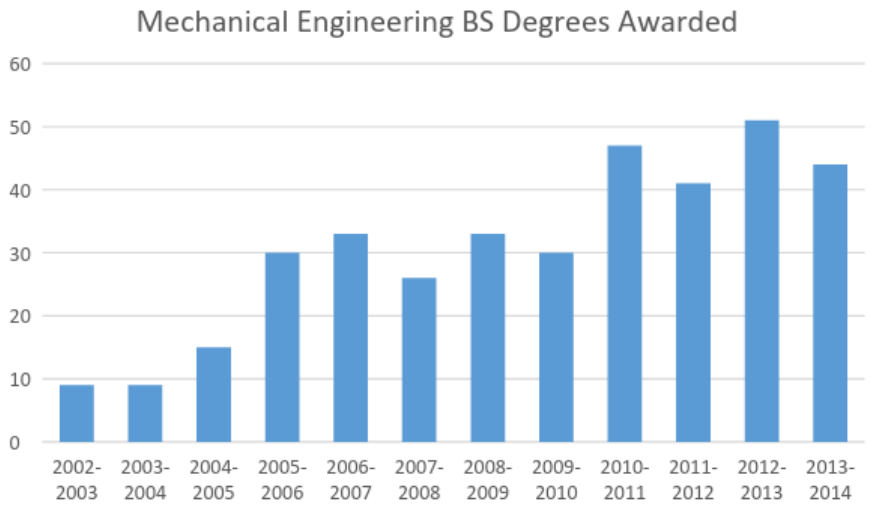

Figure 1: Annual accounting of Mechanical Engineering B.S. degrees awarded.

D.1 Teaching faculty

The Department of Mechanical engineering includes 13 full-time, tenured or tenure-track faculty members. These faculty members, with their areas of specialization, are listed in Appendix II. Each of these faculty members teaches an average of two, three-credit courses per semester. In addition, approximately 8 adjunct faculty appointments are anticipated per year, with each adjunct teaching an average of one, three-credit course per year. The adjunct faculty that have taught graduate courses during the past 4 semesters (Fall 2015- Spring 2014) are also listed in Appendix II. The current staffing of the department with full-time and adjunct faculty is sufficient to initiate this proposed Ph.D. program and teach all required graduate and undergraduate courses in the department. We also expect the program to be enriched by faculty course offerings from other departments, but the program is not dependent upon those offerings.

The development of this Ph.D. program will create the possibility of using graduate student assistants that can assist with teaching undergraduate mechanical engineering courses. It is anticipated that some graduate teaching assistants will be used to teach laboratory courses, but no full classes will be taught with graduate assistants. The department prides itself in the excellence of teaching provided by the faculty and is not looking to change the general teaching structure used at the undergraduate level.

Overall, a successful transition from the M.S. program to the Ph.D. program through a more efficient course catalog and better rotation of class offerings on a two-year cycle is anticipated. With this careful planning, the current teaching resources will be sufficient to support the new Ph.D. program.

D.2 Library and other academic resources

NMIMT Skeen Library has a rich offering of science and engineering resources to support the proposed Ph.D. program in Intelligent Energetic Systems. The library maintains subscriptions to electronic journals and research databases that are available to NMIMT faculty, staff and students. These resources are also available off-campus by using the library's EZProxy system or the NMIMT Computer Center's VPN server. The library currently subscribes to many prominent electronic research collections including: IEEE/IET Electronic Library, VDE Verlag Conference Proceedings, ACM Digital Library, ASME, Elsevier's ScienceDirect, Springer, IOP, AIP and ACS. Related research databases include Compendex, Web of Science, Computer Database, Computers & Applied Sciences Complete and CSA Materials Research Database. The library's book collection is substantial with 93,000 printed books and over 350,000 eBooks available for immediate download 24/7. Some articles from non-subscribed journals and books not available in the NMIMT library can be obtained via Interlibrary Loan. NMIMT Skeen Library and other academic resources including computer services and distant education support are sufficient to initiate the Ph.D. in Mechanical Engineering with specialization in Intelligent Energetic Systems.

D.3 Physical facilities

Mechanical Engineering occupies a large portion of Weir Hall. Recent expansion of the department resulted in the presence of Mechanical Engineering facilities in most buildings on the university campus. The faculty-led Space Utilization Committee is considering consolidating department facilities in a few buildings.

D.4 Equipment and technological resources

An important aspect of the Ph.D. Program is availability of resources to conduct research. Mechanical Engineering faculty supervise research laboratories within their area of expertise. A list of laboratories is provided below.

Laboratory for Intelligent Systems and Structures (LISS) conducts research in sensors, intelligent systems, dynamics, and structural health monitoring areas. The laboratory occupies approximately 318 sq. ft. The laboratory is well equipped with a complete line of analog and digital equipment includes a number of analog function and pulse generators, oscilloscopes, signal amplifiers, and a programmable power supply. Digital instruments are realized via a broad spectrum of National Instruments (NI) DAQ and signal generation cards, NI signal conditioning units, and a 4 channel Tektronix 200 MHz digital oscilloscope. The equipment covers a broad frequency range allowing for both high frequency ultrasonic testing and low frequency structural dynamic analysis. A conventional HP4142A impedance analyzer is available in the lab for broadband impedance measurements. In addition, to expand research capabilities in ultrasonics, the state-of-the-art RAM-5000 acoustic testing system has been acquired from Ritec Inc. The system is capable of delivering dual-channel high power (up to 7 kW) high frequency (up to 20 MHz) RF bursts for driving EMAT or piezoelectric transducers. RAM-5000 incorporates a broadband receiver and allows for complete signal synchronization for up to 80 MHz. The laboratory research is supported with a wide range of sensors including 2 and 3 axis accelerometers, strain gauges, Hall effect sensors, infrared sensors, LVDTs, and light and temperature sensors. Noncontact measurement of vibration velocity can be achieved using the Polytec's single-point laser Doppler vibrometer (LDV). Piezoelectric active sensors of various shapes and sizes are being fabricated in the laboratory from the piezoceramic sheets supplied by Piezosystems Inc. Several sets of commercially produced piezoelements are available that cover a wide range of dimensions and spectral characteristics.

The Laser Flow Diagnostics and Combustion Engines/Fuels Research Laboratories are used for multi-research and teaching purposes. The Laser Flow Diagnostics Lab is equipped with state of the art Particle Image Velocimetry (PIV) equipment, combustion setups and a low speed wind tunnel and water tunnel. PIV equipment consists of Nd:YAG laser with dual laser cavities, laser light sheet optics, CCD cameras and necessary software. The wind tunnel is equipped with a bench, control panel, wind tunnel including an inlet cone, clear experiment section, outlet cone and screen; manual traverse unit, linear track

with carrier; and main AC circuit breaker. The bench includes a shelf for storage and is mounted on eight casters. The water tunnel is a university desktop water tunnel model 0710 from Rolling Hills Research Corporation. Engine lab capabilities include Engine performance analysis measurements of exhaust gas emissions, in-cylinder pressure-crank angle measurements, testing of biofuels, alcohols, diesel and blended fuels and determination of flash point, heating value, kinematic viscosity, and density of fuels.

The Laboratory for Smart Materials and Structures (LaSMaS) was established with the goal of realizing sustainable structural systems. LaSMaS aims to conduct research on: 1) autonomous composites for self-sustaining structural systems, 2) multifunctional façade for sustainable infrastructures, and 3) resilient structural materials and composites. These goals can be achieved *via* multidisciplinary research spanning materials science, nanotechnology, optoelectronics, and structural engineering. By conducting multidisciplinary research, LaSMaS can build up smart composites and sustainable structural systems by using high-performance and multifunctional materials *via* the "bottom-up" methodology. Research capability of LaSMaS is three-fold: 1) synthesis and functionalization of advanced materials (*i.e.*, functional polymers, carbon nanotubes, and nanoparticles, among many others), 2) scale-up fabrication of multifunctional composites, and 3) multi-physics characterization and validation of the fabricated composites. LaSMaS is capable of materials processing, composites fabrication, and materials characterizations with equipment as follows: ultrasonic-powered materials processor (*i.e.*, ultrasonic bath and high-powered tip sonicator), fume hood, UV-ozone cleaner, spin-coating thin film fabricator, and ultraviolet-visible (UV-Vis) spectrophotometer.

The Shock and Gas Dynamics Laboratory (SGDL) specializes in optical diagnostics of compressible flows. It houses a range of experimental equipment for evaluating and measuring fluid flows across a wide range of flow velocities. The primary measurement techniques employed are optical flow measurement techniques, including schlieren, shadowgraphy, high-speed imaging, and particle image velocimetry. The lab also has computational capabilities including ANSYS/FLUENT and OpenFOAM for performing computational fluid dynamics (CFD) simulations of various flows. The schlieren and shadowgraph techniques are used to visualize flows with refractive disturbances present due to temperature or density gradients in a flow. These techniques are used extensively for high-speed visualizations, including shock waves and compressible jets. For low-speed flows these techniques are useful for identifying thermal or chemical plumes from various sources. The lab has a wide range of schlieren systems ranging in field of view from 0.05-1m in diameter. Several shadowgraph systems are also available with fields of view up to 2x2m square, all of which are portable and can be used in the laboratory or field environment. The laboratory has two high-speed continuous digital video cameras, one Photron SA-X2 and one Phantom v711 (manufactured by Vision Research). These cameras are capable of recording at up to 1 million frames per second and can be integrated with the schlieren and shadowgraph systems as needed and are also used to perform background-oriented schlieren visualizations in the laboratory and field settings.

The MEMS Laboratory is currently being developed by Dr. Mousavi. One of the main pieces of equipment will be his patented Interferometer Microscope which is capable of measuring out of plane motion/deformation of samples as big as 1mmx1mm by a resolution of less than 1Angstrom. This microscope can be used to measure vibrations of MEMS/NEMS up to 2MHz with the current configuration but has the potential of even higher frequencies. The in-plane resolution is limited by light diffraction limit. Other equipment will include different fabrication and characterization tools which will complement the currently available equipment of NMIMT.

The Water Desalination Test Facility. Office of Naval Research (ONR) and Department of Energy (NETL) funding resulted in the development of a market ready water desalination system using Forward Osmosis (FO). The pilot scale, 1000 gallons per day system, desalination system is placed in a mobile and self-contained 33 ft highway-certified commercial trailer. The trailer was taken to fields located at Jal County in South East NM and at Abilene, Texas to demonstrate the technology to possible markets. NMT has filed for a US patent for the "Mechanically Enhanced Circular Raceway" module that was heart of the desalination technology.

The Robotic Interfaces Laboratory (RIL) aims to develop robotic tools that aid humans in performing complex tasks. The RIL is equipped for data acquisition relative to these goals, with instruments including multiple National Instruments data acquisition systems, various force, pressure, acceleration, and acoustic sensors. Large area and multi-body kinematics can be captured using an 8-camera Optitrack systems (Flex 13; 120 fps; 1.3 MP resolution; 4.2 ms latency). The RIL also houses multiple haptic devices (Phantom Omni (3), Phantom Premium, and Entact W5D), which can be programmed to provide between 3-5 degrees of force feedback, with up to 38 N force (peak) or 6 N (continuous) and servo loop rates of up to 2000 Hz. The RIL also has a full complement standard electronic bench equipment and hand tools for construction and testing of custom robotic devices.

The Shock Physics Lab is an explosives test preparation lab with numerical simulation capability focusing on the explosives and shock physics related research and development. Equipment includes VISAR (Velocity Interferometer System for Any Reflector) shock analysis equipment, VISAR data reduction software, a PXI system (data acquisition) with 2Gs/s capability, a high-speed camera with a max recording rate of 16000fps, Ansys Autodyn (simulation software) hydrocode simulation, two 12 core clusters: hydrocode simulation computational systems, and one 18 core cluster: hydrocode simulation computational system. Physical space is approx. 800 sq. ft.

The Lab for Oil Recovery Studies houses pumps and pressure monitoring equipment as well as analytical tools for oil recovery work. Specific equipment includes Ruska positive displacement pump, 10,000 psi, ISCO 500D & LC-5000 pumps, 3700 psi (20), ISCO 1000D pumps, 1250 psi (2), ISCO LC-2600 pumps, 7500 psi, ISCO model 314, 2850 psi, low-pressure utility pumps (2), Welch vacuum pumps (4). Pressure monitoring equipment includes Honeywell ST3000 pressure transducers (44), Honeywell Smart Field

communicators (4), Validyne transducers (10), MC-1-10 carriers (2), MC-1-20 carriers (2), MC-1-3 carrier, assorted pressure gauges, Grove back-pressure regulators (6). Analytical equipment includes Waters 486 tunable absorbance detectors (5), Waters 484 tunable absorbance detectors (2), Shimadzu TOC-5050A total carbon analyzer, spinning drop interfacial tensiometer five-cell, fixed speed, controlled temperature, Orion 520A pH/ion meter (3), Orion SA520 pH/ion meter (2), flow-through pH holders (5), Fisher accumet pH/ion meter, Bausch & Lomb abbe refractometer pH meters (4), Hach Ratio turbidimeter, Klett-Summerson turbidimeter, Standard model zeta-meter, TBI TBS40 high pressure pH probe, Milton Roy Spectronic 20 D spectrophotometer. In addition are multiple viscometers and rheometers, data acquisition and processing equipment, photographics, video and optical equipment.

The Dynamic Deformation and Failure Laboratory (DDFL) at NMIMT focuses on characterizing the mechanical response of materials/structures subjected to extreme dynamics loads. The laboratory houses several dynamic testing set-ups including compression and tension Kolsky (Split-Hopkinson) bars of various diameters. The Kolsky bars can be used to test specimens on the order of 1-25 mm at strain rates in the range of 10^2-10^4 s^{-1}. Diagnostics include a Tektronix 2GHz digital oscilloscope and a HBM Gen-2i 12-bit high speed data acquisition system capable of capturing 4 channels of data at up to 100 megasamples per second. A Vision Research Phantom v711 high speed digital video camera is also available to capture images of deformation and failure processes at frame rates up to 1.4 million frames per second and exposure times as short as 200 ns. Sample preparation facilities are also available in the DDFL including a low speed diamond saw, lapping and polishing machines.

The Computational Fluid Dynamics Laboratory focuses on the numerical simulation of complex fluid flow fields that are relevant to national security and green energy initiatives. The lab features a high performance computing cluster with 20 computing nodes (4-core per node), and a 16-core workstation for data visualization. Relevant software packages include OpenFOAM, Salome, and Paraview.

D.5 Other operating resources

The support staff currently available at the Department of Mechanical Engineering is adequate to start the Ph.D. program and run it for at least five years. The need for additional staff support is anticipated as the program develops into later stages after 5-10 years. We have identified the following long-term needs for the program:

i. Additional office assistant

ii. Lab assistant / technician.

iii. Machine shop supervisor

E Projected Cost of the Program

New Mexico Institute of Mining and Technology places a special emphasis on establishing a strong research component of academic programs. Investment in high-quality research and graduate education allowed the Mechanical Engineering department to secure largest enrollment of undergraduate students and second largest enrollment of graduate students in the whole university. This successful investment implies that the majority of costs associated with a new Ph.D. program have already being covered by the institution and no substantial additional investment is anticipated.

E.1 New Costs for Program Start-Up

NMIMT continues investments in the Mechanical Engineering MS graduate program with several specializations including Explosives Engineering and Mechatronics Systems and Robotics. A new Ph.D. program is built upon a solid foundation of the M.S. program and will require little additional support. It is envisioned that some students currently enrolled (or thinking about enrolling) in the M.S. program will desire to pursue a Ph.D. degree and the total number of Mechanical Engineering graduate students, which is around 50 now, will not change substantially. This means that faculty load and allocation of other necessary resources could be comparable with current investments.

Resources already in place:

(a) Library resources
(b) Facilities, equipment and technological resources
(c) Faculty instructional resources

Resources necessary beyond the current level of support are indicated below.

(a) Five new graduate teaching assistantships are needed to support the program. The current cost of a full (half time) teaching assistantship is approximately $21,000 per year. These new TA positions are proposed to be phased in as the Ph.D. program develops. Due to the recent addition of new faculty and undergraduate enrollment, some departments are moving rapidly towards balancing enrollment by offering senior courses every semester. Such a balance is achieved by increased employment of graduate teaching assistants in primarily laboratory sections of these courses. The Department has already increased a number of teaching assistants and plans to continue increasing them as Ph.D. program grows.

E.2 State Support

The state of New Mexico has recently changed the approach to formula funding. State support projected in accordance with a new formula funding is presented below.

Table 4: Expected amount formula funding per each year of the NMIMT's Ph.D. in Mechanical Engineering with specialization in Intelligent Energetic Systems program

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6
			Full-Time Students			
Students enrolled	2	4	6	8	9	9
Graduate credits/student/year	30	30	30	30	30	30
Undergraduate credits/student/year	0	0	0	0	0	0
Credit funding	$85,020	$170,040	$255,060	$340,080	$382,590	$382,590
			Part-Time Students			
Students enrolled	1	2	3	4	5	6
Graduate credits/student/year	15	15	15	15	15	15
Undergraduate credits/student/year	0	0	0	0	0	0
Credit funding	$21,255	$42,510	$63,765	$85,020	$106,275	$127,530
Graduates	0	0	0	0	2	2
Degree funding	0	0	0	0	$6840	$6840
STEM funding	0	0	0	0	$10260	$10260
Total formula funding	$106,275	$212,550	$318,825	$425,100	$505,965	$527,220

E.3 Other Support

It is anticipated that additional support for the Ph.D. program in Mechanical Engineering with specialization in Intelligent Energetic Systems will come from department faculty research grants and contracts. The support will come in the form of research assistantships (RA) for qualified mechanical engineering graduate students enrolled in the Ph.D. program. The Mechanical Engineering Department shows a healthy research funding landscape. Figure 2 demonstrates that the average annual research at the department exceeds $1M, and the average annual funding level per faculty is over $100k. Considering that typical annual graduate student research assistantship is approximately a quarter of faculty's annual funding level, ample opportunities for Ph.D. student research assistantships exist. In addition, funding from research grants received by mechanical engineering faculty is spent on acquiring research equipment, materials, and graduate student travel. Additional graduate student travel support exists through a travel scholarships distributed by the Graduate Student Association in conjunction with the NMIMT Graduate Office.

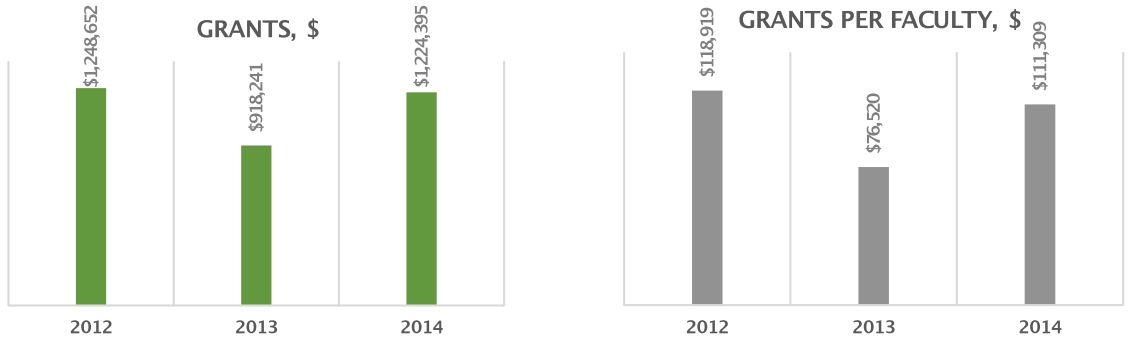

Figure 2: Research grants awarded to the Department of Mechanical Engineering: (a) Total dollar amount per year, (b) Dollar amount per full-time department faculty per year.

Over past several years, mechanical engineering faculty received a considerable number of large (several hundred thousand dollar) grants from NASA, FAA, DHS, ONR, AFOSR and other agencies. Very recent examples of such grants includes – a Defense Threat Reduction Agency Young Investigator award received by Dr. M. Hargather (explosives) and 5 year renewal of FAA funded Center of Excellence for Commercial Space Transportation, where NMIMT participates with tasks ranging from intelligent systems engineering to explosives testing. It is anticipated that financial support received through research funding complemented by teaching assistantships provided by the university, will be sufficient for initiation and operation of the proposed Ph.D. program.

F Quality of the Program

The Ph.D. curriculum in Mechanical Engineering with specialization in Intelligent Energetic System will be built on two existing M.S. level specializations in Explosives Engineering and Mechatronics Systems & Robotics, plus a few relevant graduate courses from other departments. In addition, a number of fundamental graduate courses will be included in the program core to ensure a breadth of graduate education and a solid base in engineering fundamentals. This wide range of course offerings also provides the opportunity for Ph.D. candidates to craft unique interdisciplinary plans of study which serve as the foundation for cutting edge research topics in mechanical engineering related to intelligent energetic systems.

To ensure the Intelligent Energetic Systems focus of the program, but allow for breadth of graduate education and specifics of an individual research topic, the program consists of 27 credit hours of core courses and 9 credit hours of elective courses. The core of the program includes three segments: Energetics, Intelligent Systems, and Fundamental Science and Engineering. Nine credit hours (i.e. 3 courses) must be selected from each core segment. An additional 9 credit hours of elective courses approved by the candidate's advisory committee will be counted towards 36 hours of course work beyond B.S. degree.

General Degree Requirements (note the full curriculum is described in Section A.4)

- 36 credit hours of formal coursework beyond B.S.
- 24 credit hours of dissertation research credit
- 9 credit hours of Directed Study
- 3 credit hours of Graduate Seminar
- Written and/or oral qualifying examination as determined by Graduate Study Committee
- Written dissertation proposal and oral preliminary (Candidacy) examination focused on the presentation of the proposed dissertation topic.
- Publication of one article in a peer-reviewed scientific or engineering journal
- Final defense of the Ph.D. dissertation

These requirements are similar to other programs in NM and the U.S. Table 5 provides a comparison of our proposed curriculum with other programs in the U.S.

Table 5: NMIMT Ph.D. in Mechanical Engineering with specialization in Intelligent Energetic Systems proposed curriculum compared with Mechanical Engineering programs of other institutions.

Institution	Credit Hours Past B.S.	Coursework Credits	Dissertation Credits	Qualifying Exam	Candidacy Exam	Dissertation Defense
New Mexico Inst. of Mining and Tech.	72	36	24	Oral/Written	Oral/Written	Oral
New Mexico State U.	60	36	24	Written	Oral/Written	Oral
U. of New Mexico	72	54	18	Written	Oral	Oral
Michigan Tech.	60	NR	NR	Written	Oral	Oral
Colorado School of Mines	72	42	30	Written	Oral	Oral
U. Texas at San Antonio	90	54	36	Oral/Written	Oral	Oral

The hiring of five (5) new faculty members over the past three years has brought the program roster to a total of thirteen (13) full-time faculty. All of these recent hires have been tenure-track appointments, with the goal of raising the level of externally funded research. Our recent growth has brought new areas of teaching and research expertise to the department, and provided for an increase in the number and diversity of courses offered at the graduate level. Our full-time faculty now represents a critical mass required for a healthy doctoral program. Our strong ties to local research institutions (SNL, LANL, AFRL) has also allowed for the development of a strong adjunct faculty pool. These adjunct faculty enrich both our core and elective course offerings by providing courses in areas relevant to their research expertise.

The majority of engineering Ph.D. programs across the nation require a minimum grade point average in the range of 3.0-3.3 out of 4.0. Most programs require a student to have taken the general Graduate Record Exam (GRE), but do not enforce specific requirements. Other admission requirements include an average of three letters of recommendation. Our university and program requirements are in line with the majority of programs in the U.S.

The Mechanical Engineering department have a number of technology resources currently available to graduate student population. These resources will be made available to graduate students pursuing a doctoral degree as well.

The department is home to several state of the art research and instructional laboratory facilities. These experimental and computational facilities provide the core resources required for the students dissertation research. In addition to research space, the department provides students with office space and individual computer workstations with high-speed access to the campus network and various software analysis packages. Access to the high-performance computing cluster is also available. Also available is a recently acquired graduate student collaborative meeting space.

In addition, technology resources are available at the university level. Our faculty members have strong ties to campus affiliated research centers such as the Energetic Materials Research and Testing Center (EMRTC), (ICASA), Petroleum Recovery Research Center (PRRC). These centers can provide graduate students access to advanced computational and experimental facilities.

Graduate students have access to NMIMT's library resources described in section D.2. Virtually all graduate level Mechanical Engineering courses are taught in classrooms utilizing NMIMT's distance education capabilities. This provides off-campus students access to lectures in real time, as well as an option for on-campus students to review recorded lectures.

The depth and breadth of coursework combined with the focused dissertation research will prepare graduates for employment in areas such as high-level R&D and academia. During their studies, students will be exposed to state of the art experimental and computational resources, providing exposure to technology that may be encountered in their future workplace. The completion of dissertation research will ensure that the graduate is capable of extending core knowledge into new areas of investigation that will serve to benefit humankind. The passing of several oral examinations, and the preparation of the dissertation will ensure that the graduate is capable of communicating in both verbal and written forms. These communication skills are critical for success in any work environment.

The department offers financial support through teaching assistantships and externally funded research assistantships. The Graduate College provides information on other sources of financial support. Several non-financial support programs exist on campus to

assist students in the pursuit of their degree. The Graduate Student Association (GSA) provides a mechanism for identifying and resolving issues that pertain to graduate students (e.g. changes to tuition, or policies that directly affect graduate students). The GSA also provides opportunities for career development by hosting on-campus seminars and providing travel support for students to attend technical conferences. The NMIMT Writing and Oral Presentation Center is another resource that is available to graduate students; providing assistance with the preparation of manuscripts, theses/dissertations, and oral presentations.

Scholarly research is the central focus of the Ph.D. program, and the culmination of years of research under the supervision of the department faculty is the preparation of a dissertation. This dissertation must be successfully defended in a presentation, which is open to the faculty and the general public. Such final examination ensures that the student is capable of producing quality research and can communicate effectively his/her results to a broad audience. The additional requirement of at least one publication in a peer-reviewed technical journal ensures that the graduate's research is of value to the greater scientific community.

Higher Learning Commission (HLC) accreditation will be sought for the Ph.D. program in Mechanical Engineering with specialization in Intelligent Energetic Systems (MENG-IES). We plan to apply for HLC accreditation visit as soon as, potentially, state approval of MENG-IES program is granted. ABET, the accrediting agency for engineering programs, will accredit either the undergraduate or graduate program, not both. All of NMIMT's engineering departments participate in the ABET accreditation process for their undergraduate programs, therefore only HLC accreditation of MENG-IES program will be sought. The MENG-IES Ph.D. program will follow university guidelines for graduate education at NMIMT.

G Assessment of Operations and Impact

Procedures already implemented for assessment of existing M.S. program in Mechanical Engineering will be used to evaluate operation and impact of the Ph.D. program. The program will be assessed annually to ensure the following learning outcomes are demonstrated by mechanical engineering graduate students:

a) an ability to apply advanced knowledge of mathematics, science, and engineering

b) an ability to identify, formulate, and solve engineering problems

c) an ability to design, document, and conduct experiments, as well as to analyze and interpret data

d) an ability to analyze requirements, propose design and evaluate practical realization of an engineering system.

e) an ability to communicate effectively

f) an understanding of professional and ethical responsibility

g) the broad education necessary to understand the impact of engineering solutions in a global and societal context

h) a recognition of the need for, and an ability to engage in life-long learning

i) a knowledge of contemporary (within the profession) issues

j) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

The proposed program will comply with the assessment process implemented by the NMIMT Graduate School.

In particular, operation and impact of the program will be assessed by collecting and analyzing data on:

- Quality of candidates entering the program, retention rates, program completion time, and graduation rates.
- Student academic and professional achievements including GPA, internships, licenses, awards, and scholarships.
- Dissemination of candidates' research results in peer-reviewed publications and presentations at professional meetings.
- Recommendations of candidates' graduate study committee.

The methods for program evaluation will include:

- Collecting and analyzing individual student data available in the institute's database.
- Collecting and analyzing information reflecting quality of instruction offered to candidates. This includes, but not limited to, assessment of meeting course and program learning outcomes, course evaluations and graduate student surveys (see Appendix VI).
- Analyzing post-graduate surveys completed by former students (see Appendix VII).
- Considering input from the Department of Mechanical Engineering advisory board (current membership of the advisory board listed in Appendix IX).

H Administrative Responsibility for the Program and Institutional Commitment

Department of Mechanical Engineering at NMIMT manages M.S. program with specializations in Explosives Engineering and Mechatronics Systems & Robotics. It is therefore natural for Mechanical Engineering department to assume administrative responsibility for the proposed Ph.D. program in Mechanical Engineering with specialization in Intelligent Energetic Systems. In addition, it is projected that selected divisions of NMIMT, such as EMRTC and ICASA, will present their opinion on the program and contribute to developing and teaching courses and facilitating research in explosives and intelligent systems.

At the departmental level, a *Graduate Study Committee* will be formed to facilitate administration of departmental graduate programs. Responsibilities of the committee will include developing guidelines for the graduate study, approving policies and procedures for departmental graduate programs, and serving as an arbiter in resolving academic disputes and complains. To maintain a sharp focus on recruiting needs of regional employers, the *Graduate Study Committee* will regularly consult the Department of mechanical Engineering external *Advisory Board* consisting of representative of regional business and national laboratories (see Appendix IX for details). Finally, the Dean of Graduate Studies oversees all graduate programs at NMIMT.

Appendix I. NMIMT's Ph.D. in Mechanical Engineering with Specialization in Intelligent Energetic Systems Program Description

1. Admission to Ph.D. program: B.S. or M.S. (or equivalent) in engineering or closely related discipline with a recommended cumulative GPA of 3.3 out of 4.0. Non-engineering degrees may be considered upon review of credentials; additional course work may be required if an applicant demonstrates lack of knowledge in core subjects of the Intelligent Energetic Systems specialization. International students must present results of GRE and TOEFL or IELTS. Under exceptional circumstances requirements for GRE may be waived by faculty if a student shows adequate professional skills.
2. Qualifying (admission to candidacy) examination: Before the beginning of their third semester students are required to sit for and pass written examinations in three of the following areas: Control theory, Dynamics, Thermodynamics, Fluid dynamics, Heat transfer, Mechanics of Materials, Structural Analysis. The exam questions will be written and graded by department faculty members. These exams will be used to evaluate the student's knowledge of mechanical engineering topics at the undergraduate level and their ability to a) apply advanced knowledge of mathematics, science, and engineering, b) identify, formulate, and solve engineering problems.Students failing to pass a subject exam are offered one opportunity to retake that exam at the next offering of the exam. Students that do not pass all three topic exams by the completion of their second attempt do not advance to candidacy, and will leave the program. The student will be able to pursue a M.S. in Mechanical engineering subject to those degree requirements.
3. Possible transfer of credits from a previous academic program or degree is left to discretion of student's Advisory Committee. The transfer must be approved by the department chair and Dean of Graduate Studies.
4. During the first semester after passing the Qualifying (Admission to Candidacy) examination a student's Advisory Committee is formed. A student and faculty suggests minimum of three (3) Mechanical Engineering faculty members and one faculty outside of the program. Faculty participation in the committee is voluntary. A chairman of the committee is typically a student's Academic Advisor. The Advisory Committee must be approved by the Mechanical Engineering Department Chair and the Dean of Graduate Studies.
5. During the first semester after passing the Qualifying (Admission to Candidacy) examination a student must submit his/her program of study. The program of study includes all courses relevant to student's research topic.

At the time of submitting a program of study, student must indicate a tentative title of his/her dissertation and provide a brief description (1-2 paragraphs) of the dissertation research topic. The dissertation research topic must be approved by the student's Advisory Committee.

6. Candidacy examination: This examination may be taken at any time 12 months after passing the Qualifying Exam. The focus of the examination is student's proposed Ph.D. dissertation. The examination consists of written and oral parts. The written part is student's dissertation proposal including statement of a research problem, relevant literature review and outline of the proposed work. The dissertation proposal is communicated to student's Advisory Committee two weeks prior to oral examination. Oral examination is closed to public and consists of 35-40 minutes presentation on the proposed research followed by questions from the advisory committee. Upon reviewing the written and oral portions of Candidacy examination, a committee elects one of the following options: (a) Pass, (b) Pass with conditions: student has 6 months to correct minor deficiencies, (c) Fail: Student does not advance to candidacy and will leave the program.

7. Doctoral dissertation and defense: The dissertation defense must not occur any sooner than 12 months after advancing to candidacy. At least one month prior to the dissertation defense, a student submits a Ph.D. dissertation package on the research topic approved by his/her Advisory Committee. The dissertation package is first submitted to student's advisory committee. The dissertation package includes (a) written dissertation, (b) student's CV with a list of publications on the dissertation topic, (c) copies of any papers published, accepted or submitted for publication in refereed journals acceptable to the doctoral committee (at least one of these papers must be published or accepted for publication in a peer reviewed journal) and (d) evidence of presenting results of the dissertation research at international, national and regional conferences. Some government publications (e.g. national laboratory reports) may be considered in lieu of journal articles if approved by student's Advisory Committee. Dissertation defense is announced 14 days before the actual presentation and is open to public. The defendant delivers 35-40 minutes talk on the results of the dissertation research. A slide discussing broad dissemination of the research results (i.e. through journal publications, conference participation or invited talks) must be included in the presentation. Committee members may ask additional questions during a part of dissertation defense closed to public. Within a week after the dissertation defense, the Advisory Committee submits an evaluation of the defense which may be (a) Pass, (b) Pass with conditions, minor revisions are needed, (c) Fail. In the case (c) Fail, a student will not be granted a Ph.D. in Mechanical Engineering with specialization in Intelligent Energetic Systems.

Appendix II. Intelligent Energetic Systems Specialization Faculty, Fall 2015

Full-time Faculty

Bakhtiyarov, Sayavur Ph.D., DSc Associate Professor	Non-Newtonian Fluid Mechanics, Heat & Mass Transfer, Rheology, Multiphase Flow
Ford, Julie Ph.D., Professor	Written and Oral Communication, Teamwork, Communication Pedagogy
Ghosh, Ashok Ph.D., P.E., Associate Professor	Macro Behavior of Composites, Biomechanics, Finite Element Analysis
Grow, David Ph.D. Assistant Professor	Robotics, Biomedical & Surgical Devices, Haptics, Dynamic Modeling
Hargather, Michael Ph.D. Assistant Professor	Shock & Gas Dynamics, Experimental Fluid Dynamics, High-Speed Gas Dynamics
Kimberley, Jamie Ph.D. Assistant Professor	Solid Mechanics, Impact Studies, Dynamic Behavior of Materials
Lim, Seokbin Ph.D. Associate Professor	Energetic Materials, Linear and Conical Shaped Charges, Explosives Technology
Mousavi, Arash Ph.D. Assistant Professor	Micro/Nano-Electro-Mechanical Systems (MEMS/NEMS), Bio-MEMS, Nanotechnology
Ostergren, Warren Ph.D. Professor	Structural Analysis, Machine Design, Propulsion & Power Systems
Ryu, Donghyeon Ph.D. Assistant Professor	Mechanics of Materials, Smart Materials & Structures, Advanced Sensing Technologies
Wei, Tie Ph.D. Assistant Professor	Thermal-Fluid Science, Wall-Bounded Flow, Flow Instabilities, Turbulent Mixing
Yilmaz, Nadir Ph.D., P.E. Associate Professor	Alternative Fuels, Computational Fluid Dynamics, Combustion & Chemical Kinetics
Zagrai, Andrei Ph.D. Associate Professor	Structural Health Monitoring, Intelligent Systems and Structures, Sensor Networks

Adjunct Graduate Faculty

William Anderson Adjunct Professor	Detonation Physics
Edwin Bryce Adjunct Professor	Geometric dimensioning and tolerancing, engineering design
Lawrence DeChant, Adjunct Professor	Thermal-Fluid Sciences
Michael Fortner Adjunct Professor	Energetic Materials: Initiation, Applications, and Systems
James Kennedy Adjunct Professor	Basic Science and Applications of Explosives, Detonation in Explosives
A. Keith Miller Adjunct Professor	System Dynamics, System Modeling and Simulation, Actuators and Actuator Controls
Wayne Rivera Adjunct Professor	Energetic Materials, Explosives Technology
Jerome Stofleth Adjunct Professor	Instrumentation and Measurements, Explosives Technology

Appendix III. Curricula Vitae of Faculty

Appendix IV. Design Clinic Sponsors from New Mexico

Sponsor	Location	Number of Projects
Honeywell	Albuquerque	1
Holloman Air Force Base	Alamogordo	2
Sandia National Labs	Albuquerque	2
White Sands Research and Developers LLC	Las Cruces	1
Solaro Inc.	Socorro	1
Los Alamos National Labs	Los Alamos	2

Appendix V. Letters of Support

Appendix VI. Example of a Graduate Student Survey

Appendix VII. Example of a Post-Graduate Professional Survey

Appendix VIII. Hispanic Serving Institute Certificate

U.S. Department of Education
Office of Postsecondary Education

April 10, 2012

OPEID: 00265400
New Mexico Institute of Mining & Technology
Socorro, NM

Dear Daniel H. Lopez:

We are pleased to inform you that your recent request for Designation As An Eligible Institution under Title III and Title V programs of the Higher Education Act of 1965, as amended by the Higher Education Opportunity Act of 2008 (HEA) is approved. Subject to the specific program requirements, your institution **may apply for a new grant** under any of the Title III programs and the Title V, Hispanic-Serving Institutions Programs.

As a result of receiving this designation, your institution **is also eligible for a waiver of the non-Federal share matching requirements** under the Federal Work Study Program, the Federal Supplemental Educational Opportunity Grant Program, and the TRIO Student Support Services Program under Title IV of the HEA, as well as the Undergraduate International Studies and Foreign Language Program authorized by Title VI of the HEA. The eligibility for a waiver of the non-Federal share matching requirements applies for a **five-year** period beginning **July 1, 2012**. The offices within the Department that administer those specific programs will handle the waiver of the cost sharing. Accordingly, you do not need to reapply for designation as an eligible institution for five years, unless you wish to apply for a grant under the Title III programs or the Title V, Hispanic-Serving Institutions Programs. You must apply for eligibility designation in each year you wish to participate in a program competition for funding

Please retain this letter as evidence of your eligibility and for an adequate audit trail.

If you have questions concerning this designation, please contact Kelley Harris at kelley.harris@ed.gov or 202 219-7083 or Carnisia Proctor at carnisia.proctor@ed.gov or 202 502-7606.

Sincerely,

Leonard L. Haynes, Ph.D
Senior Director
Institutional Service

Appendix IX. Department of Mechanical Engineering Advisory Board

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