Humanitarian Engineering

Degrees
- Graduate Certificate in Humanitarian Engineering and Science

Program Description
The MS degrees in Humanitarian Engineering and Science (HES) are a professional MS (non-thesis) and a thesis-based MS. These degrees are targeted to recent graduates or mid-career professionals with a BS in science and engineering who are interested in careers, research opportunities, and/or acquiring skills that will help them work effectively with communities. The degrees include a core HES curriculum plus an approved track of related courses in a science or engineering discipline.

The HES graduate certificate is designed for professionals seeking to attend school part-time or students who are seeking degrees in other departments at Mines but still desire graduate training in humanitarian engineering and science. It consists of four courses.

In both the master's degrees and graduate certificate, a unique mix of social science, applied science, and engineering perspectives prepares students to apply knowledge about the earth to promote more sustainable and just uses of water, energy, and other earth resources and to understand and mitigate potential hazards.

To achieve the Master of Science (MS) degree, students may elect the Non-Thesis option, based exclusively upon coursework and a practicum, or the Thesis option. The thesis option is comprised of coursework in combination with individual research performed under the guidance of two faculty advisors and presented in a written thesis approved by the student's committee. HES students have academic advisors from both the Engineering, Design & Society Department and their disciplinary track (Environmental Engineering, Geological Engineering, or Geophysics). The thesis-based MS usually takes two years to complete, while the non-thesis MS can often be completed in one year.

For more information on program curriculum please refer to the HES website: https://humanitarian.mines.edu/mshes/.

PRIMARY CONTACT
Jessica Smith
303.384.3944
jmsmith@mines.edu

Graduate Certificate Program Requirements
The Humanitarian Engineering and Science (HES) certificate is an online or residential program designed for working professionals as well as graduate students who are enrolled in other degrees at Mines but wish to gain knowledge in humanitarian engineering and science. To obtain a graduate certificate, students must complete a minimum of 9 credits of the following courses. Students may not double-count courses from their undergraduate degrees. Students who have already taken one of the classes as undergraduates must find a suitable replacement, to be approved by the HES Director. Students are encouraged to take 12 credits of coursework if possible, adding an elective from the Approved HES electives list below.

Required HES certificate courses (9 credits):

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>EDNS577</td>
<td>ADVANCED ENGINEERING AND SUSTAINABLE</td>
<td>3.0</td>
</tr>
<tr>
<td></td>
<td>COMMUNITY DEVELOPMENT</td>
<td></td>
</tr>
<tr>
<td>EDNS479</td>
<td>COMMUNITY-BASED RESEARCH</td>
<td>3.0</td>
</tr>
<tr>
<td>EDNS590</td>
<td>RISKS IN HUMANITARIAN ENGINEERING AND SCIENCE</td>
<td>3.0</td>
</tr>
</tbody>
</table>

Total Semester Hrs: 9.0

Master of Science (MS) Program Requirements
The MS degrees in Humanitarian Engineering and Science (HES) are a professional MS (Non-Thesis) and a Thesis-based MS. These degrees are targeted to recent graduates or mid-career professionals with a BS in science and engineering who are interested in careers, research opportunities, and/or acquiring skills that will help them work effectively with communities. The degrees include a core HES curriculum plus an approved track of related courses in a science or engineering discipline. A unique mix of social science, applied science, and engineering perspectives prepares students to apply knowledge about the earth to promote more sustainable and just uses of water, energy, and other earth resources and to understand and mitigate potential hazards.

Master of Science (Non-Thesis)
To obtain the 30 credits required for the MS (Non-Thesis), students must satisfy the following program requirements: (1) 12 credits of required HES courses; (2) 3 credits of elective HES courses approved by Engineering, Design & Society; and (3) 15 credits of courses (400 or 500+ level) approved by the affiliated Department (see the 6 Tracks detailed below).

HES MS (Non-Thesis) Core Courses (15 credits):

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>EDNS577</td>
<td>ADVANCED ENGINEERING AND SUSTAINABLE</td>
<td>3.0</td>
</tr>
<tr>
<td></td>
<td>COMMUNITY DEVELOPMENT</td>
<td></td>
</tr>
<tr>
<td>EDNS479</td>
<td>COMMUNITY-BASED RESEARCH</td>
<td>3.0</td>
</tr>
<tr>
<td>EDNS590</td>
<td>RISKS IN HUMANITARIAN ENGINEERING AND SCIENCE</td>
<td>3.0</td>
</tr>
<tr>
<td>EDNS580</td>
<td>HUMANITARIAN ENGINEERING AND SCIENCE</td>
<td>3.0</td>
</tr>
<tr>
<td></td>
<td>CAPSTONE PRACTICUM</td>
<td></td>
</tr>
</tbody>
</table>

TOTAL SEMESTER HRS: 15.0

Approved HES Electives:

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>EDNS430</td>
<td>CORPORATE SOCIAL RESPONSIBILITY</td>
<td>3.0</td>
</tr>
<tr>
<td>EDNS475</td>
<td>ENGINEERING CULTURES IN THE DEVELOPING WORLD</td>
<td>3.0</td>
</tr>
<tr>
<td>EDNS478</td>
<td>ENGINEERING AND SOCIAL JUSTICE</td>
<td>3.0</td>
</tr>
<tr>
<td>EDNS480</td>
<td>ANTHROPOLOGY OF DEVELOPMENT</td>
<td>3.0</td>
</tr>
<tr>
<td>CEEN401</td>
<td>LIFE CYCLE ASSESSMENT</td>
<td>3.0</td>
</tr>
<tr>
<td>CEEN472</td>
<td>ONSITE WATER RECLAMATION AND REUSE</td>
<td>3.0</td>
</tr>
<tr>
<td>CEEN475</td>
<td>SITE REMEDIATION ENGINEERING</td>
<td>3.0</td>
</tr>
<tr>
<td>CEEN477</td>
<td>SUSTAINABLE ENGINEERING DESIGN</td>
<td>3.0</td>
</tr>
<tr>
<td>CEEN479</td>
<td>AIR POLLUTION</td>
<td>3.0</td>
</tr>
<tr>
<td>CEEN556</td>
<td>MINING AND THE ENVIRONMENT</td>
<td>3.0</td>
</tr>
<tr>
<td>CEEN570</td>
<td>WATER AND WASTEWATER TREATMENT</td>
<td>3.0</td>
</tr>
</tbody>
</table>
CEEN573  RECLAMATION OF DISTURBED LANDS  3.0
CEEN580  CHEMICAL FATE AND TRANSPORT IN THE ENVIRONMENT  3.0
CEEN581  WATERSHED SYSTEMS MODELING  3.0
CEEN595  ANALYSIS OF ENVIRONMENTAL IMPACT  3.0
EBGN553  PROJECT MANAGEMENT  3.0
HASS425  INTERCULTURAL COMMUNICATION  3.0
HASS525  ENVIRONMENTAL COMMUNICATION  3.0
HASS526  INTERCULTURAL COMMUNICATION  3.0
HASS527  RISK COMMUNICATION  3.0
HASS565  SCIENCE, TECHNOLOGY, AND SOCIETY  3.0
HASS568  ENVIRONMENTAL JUSTICE  3.0
MNGN482  MINE MANAGEMENT  3.0
MNGN503  MINING TECHNOLOGY FOR SUSTAINABLE DEVELOPMENT  3.0
MNGN510  FUNDAMENTALS OF MINING AND MINERAL RESOURCE DEVELOPMENT  3.0
MNGN565  MINE RISK MANAGEMENT  3.0
MNGN567  SUSTAINABLE DEVELOPMENT AND EARTH RESOURCES  3.0
MNGN571  ENERGY, NATURAL RESOURCES, AND SOCIETY  3.0
PEGN530  ENVIRONMENTAL LAW AND SUSTAINABILITY  3.0

Disciplinary Tracks

Track 1: Geophysics (GPGN) (15 credits):

Degree candidates should have an undergraduate degree in geophysics, physics, quantitative earth sciences and engineering, or equivalent coursework. In addition, candidates will need to complete necessary prerequisite courses for the graduate courses.

In addition to the Core HES MS (Non-Thesis) curriculum (15 credits) detailed above, MS (Non-Thesis) students following the Geophysics track must take one required course (3 credits) and at least 12 credits of approved elective courses, as shown below. Courses not listed below that align with the student’s practicum can be substituted in consultation with the degree advisor.

**Required Course**

GPGN577  HUMANITARIAN GEOSCIENCE  3.0

**At least four courses of the following:**

GPGN520  ELECTRICAL AND ELECTROMAGNETIC EXPLORATION  3.0
GPGN570  APPLICATIONS OF SATELLITE REMOTE SENSING  3.0
GPGN574  ADVANCED HYDROGEOPHYSICS  3.0
GPGN590  INSTRUMENTAL DESIGN IN APPLIED GEOSCIENCES  3.0
GEGN532  GEOLOGICAL DATA ANALYSIS  3.0

Track 2: Environmental Engineering (CEEN) (15 credits):

A BS degree in a science or engineering discipline is required. Pre-requisites include two semesters of college calculus, one semester of college physics, two semesters of college chemistry, and one semester of college statistics.

In addition to the Core HES MS (Non-Thesis) curriculum (15 credits) detailed above, MS (Non-Thesis) students following the Environmental Engineering track must take three required courses (9 credits) and at least two courses (6 credits) of approved elective courses, as shown below. Courses not listed below that align with the student’s practicum can be substituted in consultation with the degree advisor.

**Required Courses:**

GPGN577  HUMANITARIAN GEOSCIENCE  3.0
CEEN550  PRINCIPLES OF ENVIRONMENTAL CHEMISTRY  3.0
CEEN580  CHEMICAL FATE AND TRANSPORT IN THE ENVIRONMENT  3.0

**At least two courses of the following:**

**Environmental Microbiology**

CEEN560  MOLECULAR MICROBIAL ECOLOGY AND THE ENVIRONMENT  3.0
CEEN562  ENVIRONMENTAL GEOMICROBIOLOGY  3.0
CEEN566  MICROBIAL PROCESSES, ANALYSIS AND MODELING  3.0

**Treatment**

CEEN472  ONSITE WATER RECLAMATION AND REUSE  3.0
CEEN570  WATER AND WASTEWATER TREATMENT  3.0
CEEN575  HAZARDOUS WASTE SITE REMEDIATION  3.0
MNGN556  MINE WATER AND ENVIRONMENT  3.0

**Hydrology**

CEEN555  LIMNOLOGY  3.0
CEEN581  WATERSHED SYSTEMS MODELING  3.0
GEGN582  INTEGRATED SURFACE WATER HYDROLOGY  3.0
GEGN584  FIELD METHODS IN HYDROLOGY  3.0

Track 3: Geological Engineering (GEGN) (15 credits):

Degree candidates should have an undergraduate degree in engineering or the equivalent coursework. In addition, candidates will need to complete necessary prerequisite courses for the graduate courses, including engineering geology, ground-water engineering, soil mechanics, and rock mechanics.

In addition to the Core HES MS (Non-Thesis) curriculum (15 credits) detailed above, MS (Non-Thesis) students following the Geological Engineering track must take two required courses (6 credits) and at least three courses (9 credits) of approved elective courses, as shown below.

**Required Courses:**

GEGN532  GEOLOGICAL DATA ANALYSIS  3.0
GPGN577  HUMANITARIAN GEOSCIENCE  3.0

Candidates must also take at least three of the following courses. The student and the instructor will work together to develop humanitarian themes in the project assignments within each course.

GPGN577  HUMANITARIAN GEOSCIENCE  3.0
CEEN550  PRINCIPLES OF ENVIRONMENTAL CHEMISTRY  3.0
CEEN580  CHEMICAL FATE AND TRANSPORT IN THE ENVIRONMENT  3.0

**At least two courses of the following:**

**Environmental Microbiology**

CEEN560  MOLECULAR MICROBIAL ECOLOGY AND THE ENVIRONMENT  3.0
CEEN562  ENVIRONMENTAL GEOMICROBIOLOGY  3.0
CEEN566  MICROBIAL PROCESSES, ANALYSIS AND MODELING  3.0

**Treatment**

CEEN472  ONSITE WATER RECLAMATION AND REUSE  3.0
CEEN570  WATER AND WASTEWATER TREATMENT  3.0
CEEN575  HAZARDOUS WASTE SITE REMEDIATION  3.0
MNGN556  MINE WATER AND ENVIRONMENT  3.0

**Hydrology**

CEEN555  LIMNOLOGY  3.0
CEEN581  WATERSHED SYSTEMS MODELING  3.0
GEGN582  INTEGRATED SURFACE WATER HYDROLOGY  3.0
GEGN584  FIELD METHODS IN HYDROLOGY  3.0
of approved elective courses, as shown below. In addition to earning a track must take four required courses (12 credits) and at least 3 credits detailed above, MS (Non-Thesis) students following the Data Science track must take four required courses (12 credits) and at least 3 credits of approved elective courses, as shown below. Courses not detailed above, MS (Non-Thesis) students following the Interdisciplinary track must take three required course (9 credits) and at least 3 credits of approved elective courses, as shown below. Courses not detailed above, MS (Non-Thesis) students following the Humanitarian Engineering track must take three required courses (9 credits) and at least 3 credits of approved elective courses, as shown below. Courses not listed below that align with the student's practicum can be substituted in consultation with the degree advisor.

**TRACK 4: humanitarian robotics (15 CREDITS):**

Degree candidates should have an undergraduate degree in computer science, mechanical or electrical engineering, or robotics, or equivalent coursework. In addition, candidates will need to complete necessary prerequisite courses for the graduate courses.

In addition to the Core HES MS (Non-Thesis) curriculum (15 credits) detailed above, MS (Non-Thesis) students following the Humanitarian Robotics track must take three required course (9 credits) and at least 6 credits of approved elective courses, as shown below. Courses not listed below that align with the student's practicum can be substituted in consultation with the degree advisor.

**Required Courses:**

- CSCI532 ROBOT ETHICS 3.0
- CSCI536 HUMAN-ROBOT INTERACTION 3.0
- CSCI573 HUMAN-CENTERED ROBOTICS 3.0

At least two courses from the following:

- CSCI404 ARTIFICIAL INTELLIGENCE 3.0
- CSCI507 INTRODUCTION TO COMPUTER VISION 3.0
- CSCI534 ROBOT PLANNING AND MANIPULATION 3.0
- CSCI575 ADVANCED MACHINE LEARNING 3.0
- EENG517 THEORY AND DESIGN OF ADVANCED CONTROL SYSTEMS 3.0
- EENG519 ESTIMATION THEORY AND KALMAN FILTERING 3.0
- MEGN540 MECHATRONICS 3.0
- MEGN544 ROBOT MECHANICS: KINEMATICS, DYNAMICS, AND CONTROL 3.0
- MEGN545 ADVANCED ROBOT CONTROL 3.0

**TRACK 5: DATA SCIENCE (DSCI) (15 CREDITS):**

Degree candidates should have an undergraduate degree in computer science, mathematics or data science, or equivalent coursework. In addition, candidates will need to complete necessary prerequisite courses for the graduate courses.

In addition to the Core HES MS (Non-Thesis) curriculum (15 credits) detailed above, MS (Non-Thesis) students following the Data Science track must take four required courses (12 credits) and at least 3 credits of approved elective courses, as shown below. In addition to earning the HES MS (Non-Thesis) degree, they will also earn the Data Science Statistical Learning Graduate Certificate.

**Required Courses**

- DSCI403 INTRODUCTION TO DATA SCIENCE 3.0
- DSCI530 STATISTICAL METHODS I 3.0
- DSCI560 INTRODUCTION TO KEY STATISTICAL LEARNING METHODS I 3.0
- DSCI561 INTRODUCTION TO KEY STATISTICAL LEARNING METHODS II 3.0

At least one course of the following:

- MATH432 SPATIAL STATISTICS 3.0
- MATH437 MULTIVARIATE ANALYSIS 3.0
- MATH498 SPECIAL TOPICS (TIME SERIES) 3.0
- MATH536 ADVANCED STATISTICAL MODELING 3.0

**TRACK 6: interdisciplinary (15 CREDITS):**

In addition to the Core HES MS (Non-Thesis) curriculum (15 credits) detailed above, MS (Non-Thesis) students following the Interdisciplinary track will work with their advisor to choose an additional 15 credits that best match their intellectual interests. As with our other tracks, at least 12 of these credits need to be engineering or applied science courses. Students seeking this Track are required to identify their desired focus area when applying and identify possible courses upon matriculation. They will then work with their advisor to ensure that the student meets the course pre-requisites and that the courses are offered on an appropriate timetable according to their anticipated graduation date.

**Master of Science (Thesis)**

To obtain the 30 credits required for the MS (Thesis), students must satisfy the following program requirements: (1) 9 credits of required HES Core courses; (2) 3 credits of elective HES classes approved by Engineering, Design & Society; (3) 12 credits of approved Disciplinary Track classes (400 or 500+ level); and (4) 6 credits of MS Thesis research on a thesis topic approved by HES faculty in the Engineering, Design, & Society Division and the affiliated disciplinary track.

**HES MS (Thesis) Core Courses (12 credits):**

- EDNS577 ADVANCED ENGINEERING AND SUSTAINABLE COMMUNITY DEVELOPMENT 3.0
- EDNS479 COMMUNITY-BASED RESEARCH 3.0
- EDNS590 RISKS IN HUMANITARIAN ENGINEERING AND SCIENCE 3.0
- ELECTIVE 3 credits of approved HES electives from list below 3.0

**Approved HES Electives:**

- EDNS430 CORPORATE SOCIAL RESPONSIBILITY 3.0
- EDNS475 ENGINEERING CULTURES IN THE DEVELOPING WORLD 3.0
- EDNS478 ENGINEERING AND SOCIAL JUSTICE 3.0
- EDNS480 ANTHROPOLOGY OF DEVELOPMENT 3.0
- CEEEN401 LIFE CYCLE ASSESSMENT 3.0
- CEEEN472 ONSITE WATER RECLAMATION AND REUSE 3.0
- CEEEN475/575 SITE REMEDIATION ENGINEERING 3.0
Disciplinary Tracks

Track 1: Geophysics (GPGN) Courses and Thesis (18 credits):

Degree candidates should have an undergraduate degree in geophysics, physics, quantitative earth sciences and engineering, or equivalent coursework. In addition, candidates will need to complete necessary prerequisite courses for the graduate courses.

In addition to the Core HES MS (Thesis) curriculum (12 credits) detailed above, MS (Thesis) students following the Geophysics track must take one required course (3 credits), at least three courses of the following: GPGN520, GPGN570, GPGN574, and at least three courses of the following: GPGN577, GPGN578, GPGN580, GPGN590, and at least three courses of the following: GPGN600, GPGN610, GPGN620, GPGN630. Courses not listed below that align with the student’s thesis can be substituted in consultation with the degree advisor.

Required Course:
GPGN577 HUMANITARIAN GEOSCIENCE 3.0

At least three courses of the following:
GPGN520 ELECTRICAL AND ELECTROMAGNETIC EXPLORATION 3.0
GPGN570 APPLICATIONS OF SATELLITE REMOTE SENSING 3.0
GPGN574 ADVANCED HYDROGEOPHYSICS 3.0
GPGN590 INSTRUMENTAL DESIGN IN APPLIED GEOSCIENCES 3.0

And:
GPGN707 GRADUATE THESIS / DISSERTATION RESEARCH CREDIT 6.0

Track 2: Environmental Engineering (CEEN) (18 credits):

A BS degree in a science or engineering discipline is required. Prerequisites include two semesters of college calculus, one semester of college physics, two semesters of college chemistry, and one semester of college statistics.

In addition to the Core HES MS (Thesis) curriculum (12 credits) detailed above, MS (Thesis) students following the Environmental Engineering track must take one required course (3 credits), at least two courses (6 credits) of approved elective courses, and 6 credits of independent thesis research, as shown below. Courses not listed below that align with the student’s thesis can be substituted in consultation with the degree advisor.

Required Course:
CEEN550 PRINCIPLES OF ENVIRONMENTAL CHEMISTRY 3.0

At least three courses of the following:
CEEN550 PRINCIPLES OF ENVIRONMENTAL CHEMISTRY 3.0
CEEN557 WATER AND WASTEWATER TREATMENT 3.0
CEEN558 HAZARDOUS WASTE SITE REMEDIATION 3.0
MNGN556 MINE WATER AND ENVIRONMENT 3.0

Environmental Microbiology
CEEN560 MOLECULAR MICROBIAL ECOLOGY AND THE ENVIRONMENT 3.0
CEEN562 ENVIRONMENTAL GEOMICROBIOLOGY 3.0
CEEN566 MICROBIAL PROCESSES, ANALYSIS AND MODELING 3.0

Treatment
CEEN472 ONSITE WATER RECLAMATION AND REUSE 3.0
CEEN570 WATER AND WASTEWATER TREATMENT 3.0
CEEN575 HAZARDOUS WASTE SITE REMEDIATION 3.0
MNGN556 MINE WATER AND ENVIRONMENT 3.0

Hydrology
CEEN555 LIMNOLOGY 3.0
CEEN581 WATERSHED SYSTEMS MODELING 3.0
GEGN582 INTEGRATED SURFACE WATER HYDROLOGY 3.0
GEGN584 FIELD METHODS IN HYDROLOGY 3.0

And:
CEEN707 GRADUATE THESIS / DISSERTATION RESEARCH CREDIT 6.0

Track 3: Geological Engineering (GEGN) (18 credits):

Degree candidates should have an undergraduate degree in engineering or the equivalent coursework. In addition, candidates will need to complete necessary prerequisite courses for the graduate courses, including engineering geology, ground-water engineering, soil mechanics, and rock mechanics.

In addition to the Core HES MS (Thesis) curriculum (12 credits) detailed above, MS (Thesis) students following the Geological Engineering
track must take two required courses (6 credits), at least two courses (6 credits) of approved elective courses, and 6 credits of independent thesis research, as shown below.

**Required Courses:**

<table>
<thead>
<tr>
<th>Course</th>
<th>Description</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>GEGN532</td>
<td>GEOLOGICAL DATA ANALYSIS</td>
<td>3.0</td>
</tr>
<tr>
<td>GPEN577</td>
<td>HUMANITARIAN GEOSCIENCE</td>
<td>3.0</td>
</tr>
</tbody>
</table>

At least two of the following courses:

<table>
<thead>
<tr>
<th>Course</th>
<th>Description</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>GEGN563</td>
<td>APPLIED NUMERICAL MODELLING FOR GEOMECHANICS</td>
<td>3.0</td>
</tr>
<tr>
<td>GEGN570</td>
<td>CASE HISTORIES IN GEOLOGICAL ENGINEERING AND HYDROGEOLOGY</td>
<td>3.0</td>
</tr>
<tr>
<td>GEGN573</td>
<td>GEOLOGICAL ENGINEERING SITE INVESTIGATION</td>
<td>3.0</td>
</tr>
<tr>
<td>GEGN575</td>
<td>APPLICATIONS OF GEOGRAPHIC INFORMATION SYSTEMS</td>
<td>3.0</td>
</tr>
<tr>
<td>GEGN580</td>
<td>APPLIED REMOTE SENSING FOR GEOENGINEERING AND GEOSCIENCES</td>
<td>3.0</td>
</tr>
<tr>
<td>GEGN671</td>
<td>LANDSLIDES: INVESTIGATION, ANALYSIS &amp; MITIGATION</td>
<td>3.0</td>
</tr>
<tr>
<td>GEGN673</td>
<td>ADVANCED GEOLOGICAL ENGINEERING DESIGN</td>
<td>3.0</td>
</tr>
</tbody>
</table>

And:

<table>
<thead>
<tr>
<th>Course</th>
<th>Description</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>GEGN707</td>
<td>GRADUATE THESIS / DISSERTATION RESEARCH CREDIT</td>
<td>6.0</td>
</tr>
</tbody>
</table>

**TRACK 4: HUMANITARIAN ROBOTICS (18 CREDITS):**

Degree candidates should have an undergraduate degree in computer science, mechanical or electrical engineering, or robotics, or equivalent coursework. In addition, candidates will need to complete necessary prerequisite courses for the graduate courses.

In addition to the Core HES MS (Thesis) curriculum (12 credits) detailed above, MS (Thesis) students following the Humanitarian Robotics track must take three required course (9 credits), at least 3 credits of approved elective courses, and 6 credits of independent thesis research, as shown below. Courses not listed below that align with the student's thesis can be elective courses, and 6 credits of independent thesis research, as shown below. Courses not listed below that align with the student's thesis can be elective courses, and 6 credits of independent thesis research, as shown below.

<table>
<thead>
<tr>
<th>Course</th>
<th>Description</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>CSCI404</td>
<td>ARTIFICIAL INTELLIGENCE</td>
<td>3.0</td>
</tr>
<tr>
<td>CSCI507</td>
<td>INTRODUCTION TO COMPUTER VISION</td>
<td>3.0</td>
</tr>
<tr>
<td>CSCI534</td>
<td>ROBOT PLANNING AND MANIPULATION</td>
<td>3.0</td>
</tr>
<tr>
<td>CSCI575</td>
<td>ADVANCED MACHINE LEARNING</td>
<td>3.0</td>
</tr>
<tr>
<td>EENG517</td>
<td>THEORY AND DESIGN OF ADVANCED CONTROL SYSTEMS</td>
<td>3.0</td>
</tr>
<tr>
<td>EENG519</td>
<td>ESTIMATION THEORY AND KALMAN FILTERING</td>
<td>3.0</td>
</tr>
<tr>
<td>MEGN540</td>
<td>MECHATRONICS</td>
<td>3.0</td>
</tr>
</tbody>
</table>

**Track 5: Data Science (DSCI) (18 Credits):**

Degree candidates should have an undergraduate degree in computer science, mathematics or data science, or equivalent coursework. In addition, candidates will need to complete necessary prerequisite courses for the graduate courses.

In addition to the Core HES MS (Thesis) curriculum (12 credits) detailed above, MS (Thesis) students following the Data Science track must take four required courses (12 credits) and 6 credits of independent thesis research, as shown below. In addition to earning the HES MS (Thesis) degree, they will also earn the Data Science Statistical Learning Graduate Certificate.

<table>
<thead>
<tr>
<th>Course</th>
<th>Description</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>DSCI403</td>
<td>INTRODUCTION TO DATA SCIENCE</td>
<td>3.0</td>
</tr>
<tr>
<td>DSCI530</td>
<td>STATISTICAL METHODS I</td>
<td>3.0</td>
</tr>
<tr>
<td>DSCI560</td>
<td>INTRODUCTION TO KEY STATISTICAL LEARNING METHODS I</td>
<td>3.0</td>
</tr>
<tr>
<td>DSCI561</td>
<td>INTRODUCTION TO KEY STATISTICAL LEARNING METHODS II</td>
<td>3.0</td>
</tr>
</tbody>
</table>

And:

<table>
<thead>
<tr>
<th>Course</th>
<th>Description</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>MATH707</td>
<td>GRADUATE THESIS / DISSERTATION RESEARCH CREDIT</td>
<td>6.0</td>
</tr>
</tbody>
</table>

**TRACK 6: INTERDISCIPLINARY (18 CREDITS):**

In addition to the Core HES MS (Thesis) curriculum (12 credits) detailed above, MS (Thesis) students following the Interdisciplinary track will work with their advisor to choose an additional 12 elective credits that best match their intellectual interests, and take 6 credits of independent thesis research. The 12 elective credits need to be engineering or applied science courses. Students seeking this Track are required to identify their desired focus area when applying and identify possible courses upon matriculation. They will then work with their advisor to ensure that the student meets the course pre-requisites and that the courses are offered on an appropriate timetable according to their anticipated graduation date.

**Mines' Combined Undergraduate / Graduate Degree Program**

Students enrolled in Mines' combined undergraduate/graduate program may double count up to six hours of credits which were used in fulfilling the requirements of their undergraduate degree at Mines, towards their graduate program. Any courses that count towards the graduate degree requirements as either "Required Coursework" or "Elective Coursework", as defined above, may be used for the purposes of double-counting at the discretion of the advisor (MS Non-Thesis) or thesis committee (MS Thesis or PhD.). These courses must have been passed with a "B-" or better and meet all other University, Department, Division, and Program requirements for graduate credit.

<table>
<thead>
<tr>
<th>Course</th>
<th>Description</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>MEGN544</td>
<td>ROBOT MECHANICS: KINEMATICS, DYNAMICS, AND CONTROL</td>
<td>3.0</td>
</tr>
<tr>
<td>MEGN545</td>
<td>ADVANCED ROBOT CONTROL</td>
<td>3.0</td>
</tr>
<tr>
<td>And:</td>
<td>CSCI707 GRADUATE THESIS / DISSERTATION RESEARCH CREDIT</td>
<td>6.0</td>
</tr>
</tbody>
</table>
EDNS479. COMMUNITY-BASED RESEARCH. 3.0 Semester Hrs.
Engineers and applied scientists face challenges that are profoundly socio-technical in nature, and communities are increasingly calling for greater participation in the decisions that affect them. Understanding the diverse perspectives of communities and being able to establish positive working relationships with their members is therefore crucial to the socially responsible practice of engineering and applied science. This course provides students with the conceptual and methodological tools to conduct community-based research. Students will learn ethnographic field methods and participatory research strategies, and critically assess the strengths and limitations of these through a final original research project. Prerequisite: HASS100 or graduate student standing. Co-requisite: HASS200 or graduate student standing.

EDNS515. INTRODUCTION TO ENGINEERING IN SOCIETY. 3.0 Semester Hrs.
This course engages scholarship on the inextricable link between engineering and the various social contexts within which engineers work. We begin by critically reflecting on the question, What is engineering for? We then explore key conceptual domains in the social scientific study of engineering, including knowledge, agency, and expertise. We will learn from a diverse set of social scientific experts who study and collaborate with engineers. Students will leave the course with a better understanding of how social scientific inquiry can aid in understanding, and practicing, engineering. They will also have a clearer articulation of their individual professional commitments and how those fit with more traditional understandings of engineering.

EDNS577. ADVANCED ENGINEERING AND SUSTAINABLE COMMUNITY DEVELOPMENT. 3.0 Semester Hrs.
Analyzes the relationship between engineering and sustainable community development (SCD) from historical, political, ethical, cultural, and practical perspectives. Students will study and analyze different dimensions of sustainability, development, and "helping", and the role that engineering might play in each. Will include critical explorations of strengths and limitations of dominant methods in engineering problem solving, design and research for working in SCD. Through case-studies, students will analyze and evaluate projects in SCD and develop criteria for their evaluation. 3 hours lecture and discussion; 3 semester hours.

EDNS580. HUMANITARIAN ENGINEERING AND SCIENCE CAPSTONE PRACTICUM. 3.0 Semester Hrs.
(I, II, S) This course allows students to practice the concepts, theories and methods learned in HES courses with the goal of making relevant their academic training to real world problems. This practicum can be achieved through a number of possibilities approved by HES director, including supervision and/or shadowing in HES-related activities, engaging in a social enterprise where they do problem definition, impact gap analysis and layout a business canvas, and designing and carrying out a project or fieldwork of their own, etc. Prerequisite: EDNS570, EDNS479. 3 hours research; 3 semester hours.

EDNS590. RISKS IN HUMANITARIAN ENGINEERING AND SCIENCE. 3.0 Semester Hrs.
(I) This course provides students with opportunities learn about risk and ways of analyzing engineering and scientific projects in relation to risks, and to develop multiple mitigation steps. The students will learn tools to develop their own designs while also evaluating associated risks along multiple dimensions and searching out synergies. 3 hours lecture; 3 semester hours.

EDNS598. SPECIAL TOPICS IN ENGINEERING DESIGN & SOCIETY. 6.0 Semester Hrs.
(I, II, S) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once, but no more than twice for the same course content. Prerequisite: none. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

EDNS599. INDEPENDENT STUDY. 0.5-6 Semester Hr.
Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Variable credit: 0.5 to 6 credit hours. Repeatable for credit under different topics/experience and maximums vary by department. Contact the Department for credit limits toward the degree. Independent Study form must be completed and submitted to the Registrar.

Program Director
Jessica Smith, Associate Professor, Engineering, Design & Society

Department of Civil & Environmental Engineering
Junko Munakata Marr, Associate Professor and Department Head

Department of Engineering, Design & Society
Stephanie Claussen, Research Professor
Juan Lucena, Professor and Director, Humanitarian Engineering Undergraduate Programs

Department of Electrical Engineering
Kathryn Johnson, Professor
Kevin Moore, Professor and Executive Director of Humanitarian Engineering

Department of Geology and Geological Engineering
Paul Santi, Professor

Department of Geophysics
Richard Krahenbuhl, Research Assistant Professor
Jeffrey Shragge, Associate Professor

Department of Humanities, Arts & Social Sciences
Jon Leydens, Professor
Department of Mining Engineering
Nicole Smith, Assistant Professor

Affiliate Faculty
Chris Anderson, Principal of Yirri Global