AN OFF-ROAD EQUIPMENT MINOR

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ABSTRACT: The Department of Agricultural and Biological Engineering at Penn State began offering an Off-Road Equipment (OFFRD) minor in the fall of 2002. This article reviews the rationale for the minor, the content of the minor, and the impact on students and course enrollments. With 52 students enrolled in the minor in four years, the formation of the minor has increased exposure of ABE and ASM courses to students in other majors and other colleges. The OFFRD minor has helped several students launch careers in a variety of off-road equipment industries. The course requirements for the minor are matched to specific learning objectives which include understanding engines, power transmission systems, sensors and controls, off-road equipment application challenges, vehicles as integrated systems, ergonomics, fluid power, and safety.

Keywords. Education, Electronics, Engines, Equipment, Hydraulics, Machinery, Off-road, Power, Safety.

Academic programs around the world commonly use the terms major and minor to indicate a level of study or focus which are relatively well-defined by the institution and accepted at other institutions. A minor field of study typically incorporates 18 to 21 credits of focused study in a topic area. The Pennsylvania State University approved an Off-Road Equipment (OFFRD) minor in July, 2002. The purpose of this article is to give information regarding the rationale, content, and impact of the OFFRD minor.

Academically, students can often choose between emphasis areas, focus areas, options, cognates, areas of specialization, or similarly named “sub-topics” of an academic major. These “sub-topics” often complement a major field of study with a related, or sometimes unrelated, minor field of study. An advantage of a minor over a “sub-topic” is that the minor is identifiable as a collection of courses and normally appears on the academic transcript. While emphasis areas or options vary widely among institutions, minors are relatively consistently quantified and recognized among institutions. Most potential employers know what having a minor entails, but may be unclear about the meaning of “option,” “cognate,” or “emphasis area.” A study of numerous course catalogs and advising information from a wide variety of universities suggests the following.

From the student perspective, reasons for obtaining a minor might include:

• Providing better counsel to students with a pre-packaged recommendation
• Increased recognition of courses in the department, college, and university
• Increased enrollment in courses being offered

Topically, off-road equipment has several things in common: engines, drive trains, safety needs, electronics, operator interfaces, ergonomics, power transmission, and usually hydraulics. These common elements are present in machines from apple harvesters to zambonis; understanding these topics is important to people selling, servicing, or designing equipment ranging in size from lawn mowers to dozers or excavators. Therefore, the learning objectives and course selections for the OFFRD minor focus on these topics.

The content and marketing of this Off-Road Equipment Minor grew out of faculty observations of student interests, alumni career paths, and industry need; while there were no formal surveys, department faculty agreement (and subsequently Agriculture and Engineering Colleges, and University) on the details of the minor structure was very strong. While it is not an engineering science/design minor, it is a technical minor which complements several engineering, agricultural, and mining majors. The minor strengthens the academic program for students who have machinery interests by exposing them to the technical aspects of off-road equipment.

The off-road equipment industries (e.g., turfgrass, agriculture, construction, landscaping, forestry, mining, military) are located worldwide. These industries have steadily increased in magnitude with both economic and cultural impact. With value of equipment shipments increasing from $27.7 to $40.5 billion per year, the combined farm, lawn and garden, and construction machinery industries of the United States grew an average of 7% per year from 1998 to 2005 (U.S. Census Bureau, 2007a, 2007b). These industries employ graduates from many disciplines in a wide variety of job roles. With the OFFRD minor, graduates interested in a career with companies serving off-road industries could develop specific technical expertise to complement their chosen major making them more employable and productive early in their career.
CONTENT OF THE OFFRD MINOR

The Penn State Off-road Equipment Minor has one prescribed course and other courses from relatively short selection lists (Penn State, 2005b). Each course requirement or short course list satisfies a learning objective as outlined in table 1. Additionally, Penn State has a policy that in order for a course to apply towards a minor, a grade of C or better must be earned.

By necessity, this minor has prerequisites of introductory calculus and physics (algebra-based or calculus-based) which, unfortunately, intimidated some interested students from some agricultural or non-technical majors. Most engineering students [Agricultural and Biological Engineering (ABE) included] and Agricultural Systems Management (ASM) students have the necessary prerequisites from their major field of study to pursue the OFFRD minor. Each course meeting the categorical learning objectives (table 1) is discussed briefly below.

ENGINE POWER

Because of the prerequisite list, non-engineers would take Combustion Engines for Mobile Equipment. This course has prerequisites of Power Transmission in Agriculture, also required for the minor, and a course which covers application of engineering principles to agricultural structures and machinery. Combustion Engines for Mobile Equipment covers internal combustion engine operation, performance, selection, and maintenance of engine systems in mobile equipment. This course has a blend of theory and practical application that also makes it attractive to engineering students. This course is offered with two lecture periods and a double period laboratory each week.

Engineering students may choose Internal Combustion Engines which covers the thermodynamic aspects of internal combustion engine design and performance with two- and four-stroke cycle, supercharged and non-supercharged, diesel and spark-ignition engines covered. This is a lecture-only course with advanced thermodynamics as a prerequisite.

POWER TRANSMISSION

Power transmission can be studied from the design or application and maintenance perspective. Depending on their major field of study, engineering students may choose from options in ABE or Mechanical Engineering (ME). The 4-credit package of Structural Systems in Agriculture plus Engineering Principles of Agricultural Machines covers topics of engineering analysis and design of structural systems, loads, connectors, analysis and design of structural members and systems, analysis and design of mechanical power transmission systems. These courses have laboratory periods to complement lecture.

Engineering students may, alternatively, take Mechanical Design. This course covers specification of components such as shafts, bearings, and power transformers and optimal designs to meet operational, environmental, and manufacturing requirements. It is a logical choice for ME students in the OFFRD minor since it is required for the ME major.

Non-engineering students would take Power Transmission in Agriculture which covers selection and maintenance of mechanical, hydraulic, and pneumatic power transmission components and systems; this course has two lectures and a double laboratory period each week.

ELECTRONICS AND CONTROLS

Each of the electronics and controls courses has lecture and laboratory periods to maximize learning and application of principles. Electric Power and Instrumentation in Agriculture, one course meeting the electronics and controls category, covers basic principles and applications of electric circuits for power distribution, electric motors, automatic controls, and instrumentation used in agriculture. Sensor

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<thead>
<tr>
<th>Learning Objective</th>
<th>Courses which Satisfy the Minor Requirement (3 credits each unless indicated otherwise)</th>
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<tbody>
<tr>
<td>Understand the generation of power in internal combustion engines</td>
<td>ASM[a] 320 Combustion Engines for Mobile Equipment</td>
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<td>ME 413 Internal Combustion Engines</td>
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<tr>
<td>Understand mechanical power transmission components and systems</td>
<td>ABE 403 Structural Systems in Agriculture (2 cr) and ABE 406 Engineering Principles of Agricultural Machines (2 cr)</td>
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<td></td>
<td>ASM 310 Power Transmission in Agriculture</td>
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<td>ME 51 Mechanical Design</td>
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<tr>
<td>Understand electronic systems used in modern off-road equipment</td>
<td>ABE 405 Agricultural Measurements and Control Systems</td>
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<tr>
<td></td>
<td>ASM 428 Electric Power and Instrumentation in Agriculture</td>
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<td></td>
<td>ME 382 Mechanical Engineering Measurements (4 cr)</td>
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<td>Appreciate the challenges of applications in the off-road environment</td>
<td>AGRO 425 Field Crop Management</td>
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<td>ASM 424 Selection and Management of Agricultural Machinery</td>
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<td>FOR 339 Timber Harvesting Systems</td>
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<td>HORT 408 Landscape Plant Establishment and Maintenance</td>
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<td>HORT 433 Vegetable Crops</td>
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<td>TURF 425 Turfgrass Cultural Systems</td>
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<td></td>
<td>MNG 030 Introduction to Mining Engineering (1 cr) and MNG 401 Introduction to Mining</td>
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<td></td>
<td>Operations (2 cr)</td>
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<tr>
<td>Understand off-road power units as integrated systems for generating and delivering power to the ground for traction and to attachments for other work</td>
<td>ASM 420 Off-Road Power Units</td>
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<tr>
<td>Gain supplemental insight into the operation or design of off-road equipment in a related area of fluid power systems or safety.</td>
<td>ABE 461 Design of Fluid Power Systems</td>
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<td></td>
<td>ASM 426 Management of Safety and Health Issues in Production Agriculture and Related Business</td>
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[a] ASM = Agricultural Systems Management, ABE = Agricultural and Biological Engineering, AGRO = Agronomy, Hort = Horticulture, ME = Mechanical Engineering, TURF = Turfgrass Science, FOR = Forestry, MNG = Mining.
principles are an integral part of the course, but emphasis has gradually shifted from sensors to controls.

*Agricultural Measurement and Control Systems*, another of the course options, covers principles of measurements, instruments/sensors, controls, and data acquisition systems. Mechanical engineering students would take *Mechanical Engineering Measurements*, which, similarly, covers fundamentals of instrumentation and techniques for measurement of temperature, flow, pressure, force, stress, displacement, and acceleration including relevant statistical analysis.

**APPLICATION CHALLENGES**

The purpose of the application challenges course requirement of the OFFRD minor is to give students an appreciation for the working environment and function of off-road equipment. Course choices cover a wide range of application areas including agriculture, forestry, landscaping, turf, and mining.

*Field Crop Management* covers the application of agronomic, ecological, and physiological principles to management systems for the efficient production of the major field crops. The role of machinery in production systems is covered.

*Selection and Management of Agricultural Machines* covers function and operation of field and farmstead machines; aspects of power and energy requirements, quality of work and loss considerations as related to machine design and maintenance are discussed. Approximately two-thirds of the course is devoted to proper selection and utilization of machinery sets with economic analysis. The remaining portion of the course is a primer on the technology of precision agriculture. This course has two lectures and a double laboratory period each week.

*Timber Harvest Systems* deals with principles, concepts, and practices of safe and environmentally sound timber harvesting systems. The course includes machinery/environment and machine/product interactions.

In *Landscape Plant Establishment and Maintenance*, students learn the principles and practices involved in the establishment of plants in the landscape, and their subsequent maintenance.

*Vegetable Crops* covers the cultural requirements of important vegetable crops in conjunction with physiological processes and problems related to commercial production.

*Turfgrass Cultural Systems* provides a detailed study of turfgrass maintenance practices and how their interrelationships can be utilized to develop management systems. Effects of machinery settings and equipment maintenance on turf is included.

A combination of two mining courses, *Introduction to Mining Engineering* and *Introduction to Mining Operations* may also meet the “application challenges” requirement. These courses cover topics including mineral deposits, mining methods, unit operations, mining equipment, fundamentals of explosives, selection of extraction equipment, and relevant auxiliary operations.

**OFF-ROAD POWER UNITS**

*Off-Road Power Units* is the only course required of every student in the OFFRD minor. It covers topics of ergonomics, cabs, tires, traction, power allocation, and electronic systems for tractors and other off-road vehicles. Requirements for machine operation in production agriculture, logging, and construction are discussed. The emphasis of the course is to treat power units and vehicles as systems with integrated engines, power transmission systems, controls, ergonomics, and function. This course includes a laboratory period and students work in teams to become “experts” on a particular machine throughout the semester. They share their insight on topics such as tire selection, transmissions, ergonomics, controls, loads, and machine function with the rest of the class through frequent, but brief, oral reports.

**RELATED AREA**

Depending upon the prerequisite knowledge and desired career path, students may choose one course from two topic areas. In *Design of Fluid Power Systems* students gain depth in topics of open and closed loop hydraulic systems, hydrostatic transmissions, electro-hydraulic control systems and mobile equipment electronic controllers. The course includes design project work and has a laboratory period. Many students who take this course become certified hydraulic specialists by passing a written exam offered by the International Fluid Power Society (IFPS, 2006).

In the alternative course, *Management of Safety and Health Issues in Production Agriculture and Related Businesses* students learn about management of safe workplaces and workers, hazard identification, employee training, legal responsibilities, and program development for farms and related businesses.

**IMPACT TO DATE**

Enrollment in the OFFRD minor has totaled 52 students; these students represent four majors with the following breakdown:

- Agricultural and Biological Engineering 29%
- Agricultural Systems Management 35%
- Civil Engineering 2%
- Mechanical Engineering 35%

The ME students enrolled in the OFFRD minor have taken *Design of Fluid Power Systems, Off-Road Power Units*, and most have taken *Selection and Management of Agricultural Machines* which are courses offered by the ABE department. A few ME students have opted to take the ASM engines course for the minor, even though they may have received credit for the ME engines course in their major. As evidenced by course evaluations and subsequent course registration, the ME students have been, for the most part, extremely satisfied with these courses; this is due largely to the laboratory exercises and hands-on complement to theory and engineering principles. One ME student chose to dual major in ME and ABE after being introduced to these courses through the OFFRD minor. Another student, previously planning on Electrical Engineering, enrolled in ABE after enquiring about the OFFRD minor which led to his comparison of the majors.

Many students in the ASM and ABE majors focus in areas other than machinery systems. Because of this, prior to offering of the minor, two ASM courses (*Off-Road Power Units* and *Selection and Management of Agricultural Machinery*) were offered in alternating years to maximize enrollment per offering. Additionally, *Design of Fluid Power Systems* and *Management of Safety and Health Issues in Production Agriculture and Related Businesses* are not
required for any student which poses a risk of low enrollment. With the minor in place, enrollment has been strong and these courses are now being offered each year with typical enrollments of 15 to 25 per year.

Of the 52 students who entered the OFFRD minor, 35 have graduated with the minor in the first four years. Their placement breakdown has been:

- Agricultural equipment companies 42%
- Industrial and construction equipment companies 24%
- Production agriculture related firms (including farms) 15%
- Other 19%

Job titles of the graduates who received the minor are, as expected, quite variable. The breakdown of job descriptions is:

- Engineering design 38%
- Technical support and analysis, but not design 31%
- Sales and service 15%
- Farming 12%
- Other 4%

**SUMMARY**

The Penn State OFFRD minor has been very successful in the first four years of existence. It has attracted 52 students from four majors. Students seem satisfied with the course offerings and the OFFRD package has boosted enrollment in machinery-related courses offered by the Agricultural and Biological Engineering Department. The minor has given wider exposure of the ABE department and the ABE and ASM majors and courses.

**REFERENCES**


