SPACE RESOURCES (SPRS)

SPRS501. SPACE RESOURCES FUNDAMENTALS. 3.0 Semester Hrs.
(I,II) This course provides an overview of the space resources field, including the current knowledge of available resources in the Solar System, extraction and utilization systems under development, economic and technical feasibility studies, legal and policy issues, and space exploration architectures that may be enabled by utilizing extraterrestrial resources in the near future. The course will build broad knowledge and develop confidence in problem solving in the space resources field. This is an 8-week online course. Prerequisite: Working knowledge of physical sciences, engineering fields, or economics at an advanced undergraduate level, with basic numerical analysis skills using a programming language or spreadsheet calculations.
Course Learning Outcomes

- 1. Students will demonstrate knowledge of space resource exploration, resource availability, and technologies associated with their recovery, extraction, processing, and utilization
- 2. Students will exhibit understanding of current technological, economic, and policy challenges in space resources
- 3. Students will develop the ability to evaluate quantitatively and design a space-resource technology plan

SPRS502. SPACE SYSTEMS ENGINEERING. 3.0 Semester Hrs.
(I,II) This course conveys the fundamentals of the systems engineering process as applied to large, complex space systems. It is intended for graduate students with various backgrounds. The students will become familiar with full scope of the systems engineering process from requirements definition, system design, system analysis through system verification. The process will be illustrated with real-world examples from current space systems with an emphasis on systems relevant to the development of space resources. This is an 8-week online course. Prerequisite: SPRS501.
Course Learning Outcomes

- 1. Understand the logic steps of the systems engineering process for space systems
- 2. Understand the detailed objectives of each step in the process and become familiar with some of the standard industry tools.
- 3. Understand the wide range and applicability of analysis disciplines in assessing space systems.
- 4. Gain familiarity and develop intuition with the complex interactions among system elements and how proper operation can be verified.

SPRS503. SPACE RESOURCES SEMINAR. 1.0 Semester Hr.
(I, II) The Space Resources Seminar will engage students in the program with current research and developments related to space resources. Students will assess the importance and relevance to the space resources field in the near-, medium-, or long-term of topics covered in lectures presented by technical experts from a variety of disciplines. They will report and analyze events, news, and research publications and develop scientific, technical, and economic arguments for their impact and relevance to the space resources field, while also responding thoughtfully and critically to other students' contributions. Students will synthesize the information presented during the course in a final report with an analysis of the most important developments in the science, technology, economics and policy of space resources during the course period. This is an 16-week online seminar course.
Course Learning Outcomes

- Gain in-depth exposure to current research and development pertaining to space resource.
- 2. Develop student’s skills at professional communication through giving their own presentation and evaluating those of others.
- 3. Understand professional expectations for technical experts in the space resources field through assessing industry, government, and academic opportunities.

SPRS504. ECONOMICS OF SPACE RESOURCES. 3.0 Semester Hrs.
(I,II) This course provides an overview of economics and business topics that are commonly found in the space industries. Students will build a basic knowledge of economics, finance, and business issues that are relevant to space resource markets and industries. The big picture is to help provide perspective on what investors or the financial officers at companies are investing in and planning for in or around the space industry. Prerequisite: SPRS501.
Course Learning Outcomes

- Interpret and assess basic economic intuition and lingo so that one can contribute to projects on the business side
- Evaluate and critique standard investment analysis techniques
- Describe common market structures for natural resource commodities and theorize its impact on firm behavior
- Name the location of basic data on natural resource price, production, and consumption and demonstrate its evolution over time
- Design a presentation for the business community that provides a clear value proposition
- Execute an "elevator pitch" (concise and persuasive speech to spark interest) about a Space Resource topic

SPRS505. SPACE OPERATIONS. 3.0 Semester Hrs.
(I,II) This course explores the people, events, missions, operations, and basic system principles that have shaped the space industry. It is intended for graduate students with various backgrounds. Students will become familiar with space operations principles through work in orbital mechanics, space environments analysis, as well as mission and spacecraft design. Students will evaluate a broad range of existing missions and architectures from different perspectives through various case studies and discussions and will apply these concepts to the preliminary design of a space mission. Eight-week online course with asynchronous web content and no on-campus lectures, but with two synchronous, one-hour videoconferencing sessions per week. Prerequisite: SPRS501.
Course Learning Outcomes

- 1. Analyze the influence of policy, politics, physics on the history and evolution of the space industry
- 2. Integrate and outline characteristics, operations, and suitability of launch systems and spacecraft missions
- 3. Calculate and estimate preliminary spacecraft subsystem parameters and architecture
- 4. Articulate a space mission motivation and objectives that support space resources
- 5. Apply design principles to iterate and optimize across multiple subsystem interactions and top-level requirements

- 6. Develop an integrated preliminary spacecraft mission and bus design solution that synthesizes learning

SPRS506. INTERNATIONAL SPACE LAW & POLICY. 3.0 Semester Hrs.
(II) This course will familiarize students with the fundamentals of international space law, and train students to think critically about issues of space law and policy as human utilization of space continues to grow and change. Students will be exposed to new ways of thinking-spotting issues and applying what is learned in order to analyze issues of space law. It is intended for graduate students with various backgrounds. This is an 8-week online course. Prerequisite: SPRS501.
Course Learning Outcomes

- 1. Define, classify, and apply international law to the law of outer space, its associated fields, and the applicable rules, regulations, and policies
- 2. Explain the role played by the United Nations in creating and maintaining the Outer Space Treaty regime
- 3. Critically analyze the multilateral agreements between States that make up the main body of international space law
- 4. Articulate the principles and evaluate the policy reasoning as well as ethical considerations underlying the past, present, and future uses of space for civil, military, and commercial development, particularly space resource utilization
- 5. Identify, interpret, and examine problems and gaps in international space law with a view to future problem solving
- 6. Apply space law and learn to develop effective policy recommendations when presented with real world or hypothetical scenarios
- 7. Explain the relationship between international space law and domestic space law

SPRS507. ADVANCED PLANETARY GEOLOGY. 3.0 Semester Hrs.
(I,II) This course provides a detailed look at planetary bodies, from atmosphere to surface to interior. The focus is on the geological processes that have formed then transformed these bodies over time, with special attention paid to the formation of space resources. These processes include accretion and differentiation, impact cratering, tectonics, geodynamics, volcanism, erosion and deposition, and chemical weathering, among others. Schedule Type: Eight-week online course with asynchronous web content and no on-campus lectures, but with two synchronous, one-hour videoconferencing sessions per week. Prerequisite: SPRS501.
Course Learning Outcomes

SPRS508. REGOLITH PROPERTIES AND PROCESSING. 3.0 Semester Hrs.
This course provides a detailed look at regolith, the unconsolidated layer of fragmented rock that covers the surface of most terrestrial planetary bodies. The first half of the course focuses on regolith properties, including how regolith forms, its structure and composition on different bodies, and its physical and geotechnical properties. In the latter half, the course explores end-to-end processing methods for regolith including excavation & transport, mineral processing/beneficiation, construction & manufacturing, and oxygen/metal extraction. Prerequisite: Space Resources Fundamentals (SPRS 501); SPRS 507 is recommended but not required; students planning to take both this course and SPRS 507 should take SPRS 507 first.
Course Learning Outcomes

- 1. Develop space resource architectures specific to regolith using knowledge of the source composition and geotechnical properties, and the desired end product(s).
- Critique regolith-focused space resource architectures written by others in terms of their efficiency and realism.
- Evaluate a specific technology's ability to work with regolith in terms of performance and risk.
- Sketch concepts visually or in code to communicate to colleagues and stakeholders.
- Solve quantitative problems related to regolith amounts, resource concentrations, and processing requirements using models and equations.
- Discuss both classic and cutting-edge peer-reviewed research papers by drawing on course materials and outside expertise.

SPRS591. SPACE RESOURCES PROJECT I. 3.0 Semester Hrs.
This course will provide graduate students in the program with directed team-based project learning by exploring the design, planning, and analysis of missions, processes, systems, science, business, and economics for space resources assessment, extraction, and utilization. The course will meet formally online once a week for one hour and include a discussion on relevant design aspects of space mission, processes, and/or systems. In this regard, it will build on content learned in the Space Resources Fundamentals, Space Systems Engineering, and other courses in the Space Resources Program. Students will collaborate in multi-disciplinary teams and will be advised by a course instructor with significant industrial design experience and supported by faculty affiliated with the Space Resources program from relevant disciplines on campus. For teams with students in space resource economics, detailed economic analyses will be incorporated into those projects. Student teams will prepare a preliminary design, planning and analysis report early in the semester, one interim progress report, and a final report and project presentation. This is a 16-week online course. Prerequisite: SPRS501 and SPRS502.
Course Learning Outcomes

- 1. Learn principles and best practices in space systems design, mission, planning, and resource analysis
- 2. Develop student's confidence through practice at design, planning, and analysis for missions,systems, economics, business, and science related to space resources.
- 3. Gain practice in written and oral presentations of design and analysis of space systems.

SPRS592. SPACE RESOURCES PROJECT II. 3.0 Semester Hrs.
This course will provide graduate students in the Masters and PhD programs in Space Resources with an independent design and analysis project. This project will be guided by the course instructor and a technical advisor, and will enable the student to delve deeply into a particular system related to the prospecting, extraction, processing, and utilization of potential space resources, as well as business and economics cases in this field. As much as possible, projects will be coordinated with industrial or government agency partners who are collaborating with the program. The course will involve weekly online meetings where ideas are exchanged and progress discussed within the context of design and analysis principles learned in the prerequisite courses. Students will be partnered with a faculty member affiliated with the Space Resources Program. The student will prepare a final report and presentation to present to industry collaborators, space resources faculty, and other students in the course. The final report and/or presentation as appropriate will be converted to a journal publication,

conference publication and/or research proposal and resources from the program will support student costs for publishing and/or presenting the work. This is a 16-week online course. Prerequisite: SPRS501, SPRS502, SPRS591.

Course Learning Outcomes

- 1. Develop a level of expertise and understanding of a technology opportunity in space resources.
- 2. Raise student's confidence through practice at design, planning, and analysis for missions and systems related to space resources.
- 3. Gain practice in written and oral technical presentations of design and analysis of space systems.

SPRS598. SPECIAL TOPICS IN SPACE RESOURCES. 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: SPRS501. Variable credit: 0 to 6 credit hours. Repeatable for credit under different titles.

SPRS599. INDEPENDENT STUDY IN SPACE RESOURCES. 0.5-6 Semester Hr.

Students can do Individual research or special projects supervised by a faculty member. The student and instructor will agree on the subject matter, content, and credit hours.

SPRS707. GRADUATE THESIS / DISSERTATION RESEARCH CREDIT. 1-15 Semester Hr.

(I, II, S) Research credit hours required for completion of Doctoral dissertation. Research must be carried out under the direct supervision of the student's faculty advisor. Variable class and semester hours. Repeatable for credit. Prerequisite: Instructor approval.