JOHNS HOPKINS
WHITING SCHOOL
of ENGINEERING

Space Systems Engineering

Graduate Student Handbook

Dear Students,

Welcome to the Space Systems Engineering master's degree program of the Johns Hopkins University, Whiting School of Engineering, Engineering for Professionals. This is the nation's premier program to educate, prepare, and advance the careers of engineers involved in the development and operation of complex space missions. I am thankful that you have selected our rigorous yet rewarding program and placed your educational trust in us.

This Student Handbook is developed to assist you in planning your coursework, creating a time frame for graduation, and designing an educational path based on your career needs and aspirations.

We are releasing this edition in support of the 2024-2025 academic year.

Our entire staff are committed to improving the quality and increasing the quantity of courses that we offer to our students. We contine to add to our elective offerings which currently includes over twenty courses spanning many areas of technical interest. Our most current and accurate set of available electives will always be found on our web site . As always, your best source of consultation and support is your academic advisor who can be found through your SIS account.

As a working professional, completing your master's degree in Space Systems Engineering will require commitment and a lot of hard work, as you would expect from Johns Hopkins University. I think you will equally enjoy collaborating with fellow students, engaging with highly experienced faculty, and expanding your knowledge.

I wish you the best of luck and welcome you to reach out to me at any time.

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Whiting School of Engineering
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Note: This handbook is not a substitute for communcation with your advisor.

Contents

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ACADEMIC REGULATIONS

Following are the general requirements governing study in the Engineering for Professionals program at Johns Hopkins. Students are expected to be familiar with these requirements and with the specific regulations set forth in the sections relevant to particular programs of study.

Requirements for degree and certificate programs described in the EP catalog are subject to change. When this occurs, students may choose the requirements from the year they were admitted or any subsequent year's requirements.

Note that only graduates who complete degree requirements prior to the ceremony date will be allowed to participate in Commencement activities.

ADVISORS AND PROGRAM COURSE PLANNING

Students are assigned an advisor when accepted. The advisors name and contact information are contained in the welcome letter. Students are strongly encouraged to contact their advisors prior to registration. Students are encouraged to use the SSE Academic Planning checklist (https://ep.jhu.edu/current-students/student-forms/ep-student-academic-planning-checklists/) for planning. Advisors have access to a degree worksheet that can help track the path to graduation along with any waivers granted.

ACADEMIC STANDING/CODE OF CONDUCT

The university reserves the right to exclude, at any time, a student whose academic standing or general conduct is deemed unsatisfactory. JHU students must abide by the JHU Code of Conduct. The Code of Conduct can be found at https://studentaffairs.jhu.edu/policies-guidelines/student-code/.

MASTER'S DEGREE CANDIDATES

Only one C-range grade (C+, C, or C–) can count toward the master's degree. GPA is not calculated nor does EP have a Dean's List.

Academic Probation: Any student receiving either one grade of D+, D, or F or two grades of C (+/–) during their program of study will be placed on academic probation. Students placed on probation are permitted to retake any graduate course in which they have earned a grade of C+ or below. Students may attempt no more than two retakes during their program of study at JHEP; this may be on the same course or two different courses. If a grade of B– or above is earned in the repeated course, the probationary status will be removed. Please note that not all courses are offered every term. If an additional grade below B– is received before the course is repeated and successfully completed, the student will be dismissed. Dismissal appeals may be submitted to the JHEP Student Services Office.

There are circumstances described below where students will not be placed on probation but will be immediately dismissed from the program.

Academic Dismissal—The following are causes for dismissal from the program:

- Students already on probation receiving an additional grade of C+ or below
- Students with a grade of C(+/–) and a subsequent D+, D, or F
- Students receiving three grades of C(+/–)
- Students receiving two grades of D+, D, or F
- Students receiving grades of D+, D, or F and C(+/–) in the same term

Applicants who have been dismissed or suspended by any college or university, including Johns Hopkins, within the past four years are not eligible for admission.

PROGRAM REQUIREMENTS

ADMISSION REQUIREMENTS

Applicants must meet the general requirements for admission to graduate study. The applicant's prior education must include an undergraduate or graduate degree in a quantitative discipline (e.g., engineering, computer science, mathematics, physics, or equivalent) from a regionally accredited college or university. Applicants must show competency in (1) calculus, (2) physics, and (3) computer programming, which must be demonstrated through undergraduate or graduate coursework or equivalent work experience. In addition to this requirement, applicants will typically have earned a grade point average of at least 3.0 on a 4.0 scale (B or above) in the latter half of their undergraduate studies. When reviewing an application, the candidate's academic and professional background will be considered. As part of the admission process, the chair or the program manager may interview candidates to better evaluate their application.

DEGREE REQUIREMENTS

A total of ten courses (at least three at the 700-level) must be completed within five years. The curriculum consists of five core courses and five others chosen by the student in consultation with their advisor. The curriculum is designed to provide maximum flexibility to students, enabling them to customize their five non-core classes based on their educational needs and career goals. Only one C-range grade (C+, C, or C–) can count toward the master's degree. All courses in the Space Systems Engineering program may be completed remotely (online or via virtual-live), except for the program capstone (675.710), which includes a requirement that students attend a specified residency weekend in the Baltimore, MD area to complete the laboratory component.

COURSE PLANNING GUIDE - For taking one course per semester

NAME: ___________________________________ First Semester: ___________________

Planned Final Semester: ____________

COURSE #	COURSE NAME	SEMESTER	YEAR
675.600	Systems Engineering for Space		
675.601	Fundamentals of Engineering Space Systems I		
675.602	Fundamentals of Engineering Space Systems II		
ELECTIVE 1			
ELECTIVE 2			
ELECTIVE 3			
ELECTIVE 4			
ELECTIVE 5			
675.701	Applications of Space Systems Engineering		
675.710	Small Satellite Development and Experimentation		

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(Signature)

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(Date)

Note: This handbook is not a substitute for communcation with your advisor.

COURSE PLANNING GUIDE – For taking 2 or more courses per semester

NAME: ____________________________________

First Semester: ____________________

Planned Final Semester: _____________

COURSE #	*COURSE NAME*	*SEMESTER*	*YEAR*
675.600	Systems Engineering for Space		
ELECTIVE 1			
675.601	Fundamentals of Engineering Space Systems I		
ELECTIVE 2			
675.602	Fundamentals of Engineering Space Systems II		
ELECTIVE 3			
675.701	Applications of Space Systems Engineering		
ELECTIVE 4			
675.710	Small Satellite Development and Experimentation		
ELECTIVE 5			

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(Signature)

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(Date)

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IMPORTANT INFORMATION

New Student Orientation and Information
https://ep.jhu.edu/student-services/new-student-orientation

How to set up your JHU email
https://ep.jhu.edu/student-services/new-student-orientation/e-mail-set-up
All official communications – including class assignments – will be sent to your JHU email

EP Student Orientation Course Information
https://ep.jhu.edu/student-services/new-student-orientation/ep-student-orientation-course

Helpful page for information on degree audit, graduation, and refund policy
https://ep.jhu.edu/current-students

SSE Program course offering
https://ep.jhu.edu/student-services/academic-services/course-planning/

SSE Program Contact Information

Patrick Binning, Program Chair
patrick.binning@jhu.edu

William Devereux, Program Manager, Academics
will.devereux@jhu.edu
240-228-6509

Kristin Fretz, Program Manager, Advising and Admissions
kristin.fretz@jhu.edu
240-228-5386

Nicholas Rotunda, Program Manager, Outreach Programs
nicholas.rotunda@jhu.edu
240-228-8376

Sally Kamen, Program Coordinator
skamen2@jhu.edu
443-535-1410

Anne Zylinski, Admissions Coordinator
azylins1@jhu.edu
410-516-7904

If you experience technical problems and need additional assistance, please e-mail the support staff at ep-help-desk@jhu.edu. Staff is available from 8:00 a.m. to 4:00 p.m. ET, Monday through Friday.

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FREQUENTLY ASKED QUESTIONS:

Question: How do I request a leave of absence?

Answer: Leave of Absence (LOA) - Students who do not plan to enroll in classes for a period of more than one year must request a leave of absence for a specified period of time. If granted, the duration of the Leave of Absence will not be counted against a student's 5-year time limit for completing their degree. A Leave of Absence request should be submitted to the EP Student Academic Success Office at ep-studentsuccess@jhu.edu. Your academic advisor should be copied on the request.

Question: How do I transfer a course from another institution?

Answer: To request the transfer of a course, submit a written request (to include the equivalent SSE course), official transcript, course description to the Program Coordinator. Refer to https://ep.jhu.edu/student-services/academic-services/academic-regulations#transfer_courses

Question: Can I waive a prerequisite?

Answer: The course instructor must approve any request to either a waive a prerequisite or concurrent course enrollment with the prerequisite. If approved, the student should submit their request and a copy of the instructor approval via a SEAM ticket (https://support.sis.jhu.edu/case-home).

Question: Can I waive a CORE course?

Answer: CORE courses have been designated as essential foundational elements of the program. These courses, as a matter of practice, are not eligible for a waiver.

Question: How do I register for other JHU courses outside of EP?

Answer: Students will need to obtain advisor approval to have a non-EP JHU course count towards their degree. Students should complete the Interdivisional registration form (IDR) for WSE (Whiting School of Engineering) from the Office of the University Registrar (https://registrar.jhu.edu/idr/ along with their advisor's approval. Enrollment notification may be delayed as other divisions of JHU may give registration priority to their students. Tuition rates may also vary.

Question: Are "Honors" acknowledgements on the transcript?

Answer: Students who earn A grades in all coursework taken for their SSE degree will graduate with "Honors" and have it noted on their transcripts This is also noted in the graduation ceremony program.

Question: Who do I contact with questions about my student account or financial aid?

Answer: Student questions regarding their account should be submitted to the Student Enrollment and Account Management Team (SEAM) at https://support.sis.jhu.edu/case-home.

Question: Do I have to log into my course on a specific day or time?

Answer: One of the major advantages of online instruction is the ability to access the course materials 24/7. You can log in to the course site whenever and wherever it is most convenient for you. Online courses, designated with a .8X course number suffix, do not require synchronous participation. With respect to virtual live courses (those with a .XVL suffix), courses are presented at a set day/time each week. Each individual instructor establishes student participation requirements. The SSE program can be completed virtually with the exception of course EN.675.710 Small Satellite Development and Experimentation which requires in-person attendance for a weekend residency project.

Question: Do Instructors hold virtual Office Hours?

Answer: Yes, virtual office hours are held weekly. Student attendance is optional. These office hours are usually scheduled on a specific day and time each week and are recorded and uploaded to the course site. If the student is unavailable to attend the live session, they can listen to the recorded session.

Question: How much time can I expect to spend in an online course?

Answer: Online courses are designed to meet the 135-hour minimum requirement for a 3-credit graduate course. On average, a student should expect to spend approximately 10 hours a week participating in the course and completing all course assignments.

Question: What opportunity exists for networking with other students in an online course?

Answer: Surprisingly, you will get to know your fellow online students fairly well. Online students typically are asked to introduce themselves the first week of the course through the discussion forum. Many of EP's online courses require team-based projects. These projects serve as a way to get to know and learn from your classmates. Students often comment on the highly collaborative nature of online learning and the professional connections made through these collaborations. The student population of an online course tends to be fairly diverse; it may include regional, national and international students. The potential for establishing new professional connections is very high.

Question: Can you tell me more about the Directed Studies course, 675.800?

Answer: In this course, qualified students are permitted to investigate possible research fields or to pursue problems of interest through reading or non-laboratory study under the direction of faculty members. You are highly encouraged to begin this process by first communicating with your advisor. The burden falls on the student to find an instructor to work with and to define the subject matter, activities, products, and deliverables of the course. You will be getting to know instructors as you go through the program and may find one that you would like to work with. If needed, your advisor or one of your instructors can help you make a connection with one of the other SSE program instructors best matched to your interests. This is an independent studies course driven by the student, but the instructor is there to ensure the student plans a body of work worthy of a graduate course and then executes to that plan. A Directed Studies course can be successfully completed using distance learning methods. Program Chair approval is required for all Directed Studies courses.

Question: The SSE electives seem to cover a broad range of technical interest areas. Is there a way to categorize these by general subject area?

Answer: SSE electives can be grouped into 4 interest areas. These groupings only serve as an aid to students in planning their course schedules. They do not appear on a student's transcript or diploma. 675.800 Directed Studies could fall within any of these depending on the specific course topic.

Course interest areas (to aid in course planning):

Systems Engineering

675.600 *[Core Course]* Systems Engineering for Space
675.701 *[Core Course]* Applications of Space Systems Engineering
675.613 The Bold Science Motivating and Enabled by our Engineering
675.617 The Intersection of Space Systems Engineering and International Public Policy
675.641 Space Systems Cybersecurity
675.711 Ground System Engineering and Mission Operations
675.712 Space Mission Formulation
675.713 Fault Management and Autonomy: Improving Spacecraft Survivability
675.740 Assuring Success of Aerospace Programs
675.761 Reliability Engineering and Analysis for Space Missions

Spacecraft Design and Development

675.601 *[Core Course]* FESS I (Fundamentals of Engineering Space Systems I)
675.602 *[Core Course]* FESS II (Fundamentals of Engineering Space Systems II)
675.710 *[Core Course]* Small Satellite Development and Experimentation
675.622 Spacecraft Hardware Design Considerations 675.702 Materials for Space Systems
675.702 Materials for Space Systems
675.731 Spacecraft Propulsion Systems
675.732 Advanced Topics in Spacecraft Hardware Design
675.752 Attitude Determination and Control of Space Systems
675.753 Spacecraft Avionics Systems
675.754 Flight Software for Space Systems
675.756 Antenna Design for Space Systems
675.768 Spacecraft Integration & Test
675.772 Verification and Validation of Space Systems

Systems Analysis

675.621 Space Environment and Effects
675.650 Mathematics for Space
675.733 Spacecraft Rendezvous and Proximity Operations
675.734 Fundamentals of Celestial and Orbital Mechanics
675.751 Space Weather and Space Systems
675.771 Space Mission Design and Navigation

Payloads and Instruments

675.691 Electro-Optical Space Systems
675.792 Scientific Instruments for Space

SSE COURSES AND DESCRIPTIONS

Core Courses

675.600 Systems Engineering for Space

This course introduces students to the fundamental principles of systems engineering and their particular application to the development of space systems. It describes how the systems engineering viewpoint differs from that of the engineering specialist, as well as the essential role that systems engineering plays across the mission design life cycle. Topics include requirements analysis, trade studies, concept definition, interface definition, system synthesis, and engineering design. Techniques and analysis methods for making supportable quantitative decisions will also be explored, along with risk assessment and mitigation planning. The importance of thorough systems engineering from the initiation of the project through launch and flight operations will be emphasized. This is intended as the first course in the Space Systems Engineering program curriculum so that the student establishes a firm grasp of the fundamentals of systems engineering as applied to space programs. Examples will be presented from real space missions and programs, with assignments, special topics, and a team project focused on typical space systems engineering problems and applied methods of technical problem resolution.

675.601 Fundamentals of Engineering Space Systems I

The effective development of space systems is predicated on a firm understanding of the foundational technical and systems engineering components necessary to both comprehend the design task and formulate an appropriate solution. For engineers and technical managers seeking to develop this working knowledge and associated skills, this course will provide an overview of the key elements comprising space systems and an analytic methodology for their investigation. With a strong systems engineering context, topics will include fundamentals on astrodynamics, power systems, communications, command and data handling, thermal management, attitude control, mechanical configuration, and structures, as well as techniques and analysis methods for remote sensing applications. In addition, a number of supplemental topics will be included to provide further breadth and exposure. This is the first course of a two-semester sequence that features a combination of instruction from practitioner subject matter experts, and a team design project.
Course prerequisite(s): Completion of 675.600 Systems Engineering for Space or with approval of the instructor.

675.602 Fundamentals of Engineering Space Systems II

This course will build on the foundational elements introduced in 675.601 Fundamentals of Engineering Space Systems I, expanding on the breadth and depth of prior subject matter treatment, as well as their integrated application. Classes will again feature a combination of instruction from subject matter experts and a team design project.
Course prerequisite(s): Completion of 675.600 Systems Engineering for Space and 675.601 Fundamentals of Engineering for Space Systems I, or with approval of the instructor.

675.701 Applications of Space Systems Engineering

The ability to effectively apply knowledge and skills to new problems and situations is critical in the development of space systems. Building upon the foundational systems engineering and technical skills developed through prior coursework, this course will introduce further topics related to areas of active exploration and investigation, as well as practical details pertaining to mission formulation and assessment. Classes will be structured to include both information exchange led by subject matter experts from across the community and active group discourse. In addition, a number of topical case studies will be worked by students in both individual and group formats. Students will be asked to explore, in depth, various advanced areas of space systems engineering challenges and share information with each other in online discussions.

Course prerequisite(s): Completion of 675.600 Systems Engineering for Space, 675.601 Fundamentals of Engineering for Space Systems I, and 675.602 Fundamentals of Engineering for Space Systems II or with approval of the instructor.

675.710 Small Satellite Development and Experimentation

Online w/end of semester in-person Capstone Project in the Baltimore area

The capstone course in the Space Systems Engineering Program will introduce practical methods and tools used for evaluating the design and implementation of space systems—with a particular focus on small satellites and CubeSats. This will be principally achieved through a significant experimentation laboratory component intended to reinforce analytical experience with empirical exposure and insight. The laboratory will build on prior foundational understanding of spacecraft subsystem design and performance, through a structured series of experiments and investigations to be conducted both individually and in small student teams. It will utilize tabletop satellite simulator kits that are especially designed for hands-on educational purposes, while drawing heavily on the analysis methods and tools developed in the Fundamentals of Engineering Space Systems I/II sequence. All work is aimed at preparing for and executing a single long-residency-weekend exercise, nominally held during the final quarter, typically within the last three weekends of the semester in the Baltimore area. The lab component will have a mandatory set of core hours. The residency-lab will meet the Friday (4p-8p) and Saturday (9a-8p). Students are responsible for their own travel and accommodations, as required. Following residency weekend, only final laboratory deliverables and any remaining assignments are due per provided instructions.
Course prerequisite(s): Completion of 675.600 Systems Engineering for Space, 675.601 Fundamentals of Engineering for Space Systems I, and 675.602 Fundamentals of Engineering for Space Systems II or with approval of the instructor.

Electives

675.613 The Bold Science Motivating and Enabled by our Engineering

This course will introduce students to the connection between innovative space engineering and the most significant scientific breakthroughs that have resulted from it. This course will first explore the early generation of engineering tools that were turned to the night sky due to curiosity, and the discoveries that were made. These tools fundamentally changed our understanding of what our place in the Universe was, and the exploration led to a new framework for how engineers and scientists partner together to advance space exploration. A long line of observatories, both on the ground and in space, followed and have brought the wonders of the cosmos to humanity. The latest marvel of engineering in this line of engineering tools, a tennis-court sized "eye" in space called the Webb Telescope, was just launched and has revealed the Universe to us in unimaginable ways. It took 20,000 engineers and scientists working over 20 years to enable this mission. The course will explore how these engineering marvels were motivated and built, how they are used, the challenges that were encountered along the way, and how we plan to move forward to chase down even bolder pursuits (e.g., a new generation of robotic engineering experiments to detect life on alien moons in the Solar System). This course is also being given during an era in which space exploration is one of the most exciting, fast-paced, and rapidly growing industries. The increased competition from hundreds of private companies that are entering space is resulting in incredible reductions in the cost to access to space, and has led to an explosion in the number of launches and space-based assets. Lessons in the course will challenge students to explore the modern capabilities of the space industry and how these innovations will power future scientific pursuits.
Course prerequisite(s): Completion of 675.600 Systems Engineering for Space

675.617 The Intersection of Space Systems Engineering and International Public Policy
This course straddles the boundary between engineering and public policy related to space. It presents space policy and the effects that policy has on engineering decisions. It presents the underlying space systems engineering principles that necessitate space policy. Space is a highly technical and nonintuitive domain. Professionals working in any space-related field should have a basic understanding of the relationship between engineering and international public policy. EP students have the opportunity to enroll in this one-of-a-kind course which was developed in partnership with the JH School of Advanced International Studies (SAIS). This course focuses on the intersection of space systems engineering and policy, and will be offered for credit as an elective in both the EP SSE Program and SAIS. Students have the option to attend in-person at the Bloomberg Center in Washington, D.C. or synchronously online.

675.621 Space Environmental and Effects
This course will introduce and explore design and verification methods for the space environment in general and radiation and plasma environments in particular. Intended as a practical complement to 675.751, Space Weather and Space Systems, this course will focus on mission requirements definition, design features, analyses and ground testing, state-of-the-art engineering models / tools, and national / international standards associated with the design and operation of modern high reliability space systems. Design and operational impacts will consider Total Ionizing Dose (TID), Total Non-Ionizing Dose (TNID), Single Event Effects (SEE), spacecraft charging, material outgassing, atomic oxygen, and Micrometeoroids / Orbital Debris (MMOD). All phases of a program lifecycle will be discussed – from environment definition through operational anomalies and anomaly attribution. Lectures, journal reading, and homework assignments will prepare engineers to quantify and assess risk as well as mitigate space environmental effects. A final project will consider a more detailed analysis of a system of interest to the student.
Course prerequisite(s): Completion of 675.600 Systems Engineering for Space.

675.622 Spacecraft Hardware Design Considerations
This course will focus on the engineering of hardware systems that will reliably perform in the harsh environment of space. This course will cover design considerations, terrestrial based manufacturing, storage, launch and on-orbit performance of successful hardware systems, as well as failure modes and mitigations for the design engineer, systems engineer or aerospace program manager. Design and manufacturing concerns covering electrical, electronic and electromechanical components including part selection, materials considerations, radiation ratings and test, packaging, and manufacturing will be covered. The course will also cover the unique environments from terrestrial based to exo-atmospheric driving design and handling considerations relative to spacecraft hardware.

675.641 Space Systems Cybersecurity
Our space systems are under attack. Cyberattacks are among the most prevalent threats to space assets. They are often stealthy, inexpensive and highly effective at achieving an adversary's goal – be it data corruption, IP theft or physical destruction of the satellite. Given space systems are complex, composing ground stations, communications and satellites the surface area of attack is vast and considering the constrained computing capacity of space systems, many traditional security mechanisms are not applicable. This course provides an introduction to how an adversary would approach attacking a satellite, opportunities for systems engineers to develop cyber-resilient assets and relevant policies and best practices to support space system cybersecurity.
Course prerequisite(s): Completion of 675.600 Systems Engineering for Space and 675.601 Fundamentals of Engineering for Space Systems I, or with approval of the instructor.

675.650 Mathematics for Space Systems

This course is designed to teach Mathematical Methods commonly employed for engineering Space Systems. The course will provide a solid technical foundation in mathematics so the students can apply this knowledge to broad field. Topics will include select, applicable methods from vector calculus, linear algebra, differential equations, transform methods, complex variables, probability, statistics, and optimization. Various applications to real problems related to space systems and technical sub-disciplines will be used during the semester. No prior knowledge of advanced mathematics is assumed and important theorems and results from pure and applied mathematics are taught as needed during the course. Examples and relevant applications will be utilized throughout the course to further clarify the mathematical theory.

Course prerequisite(s): The course requires prior knowledge of college calculus and algebra, or approval of the instructor.

675.691 Electro-Optical Space Systems

The goal of this course is to engage the student with multiple design studies of subsystems of space-based electro-optic systems. The technical and scientific elements necessary to be successful with these studies will be presented during the lectures. The concepts and technologies behind elements such as photon detectors, imaging elements over many spectral bands, optical elements and systems typically used in space sensors, and active optical sources will be described. These concepts and technologies will be the fundamental elements used to describe the various sensor types and modalities used in space electro-optical systems.

Course prerequisite(s): An undergraduate or graduate degree in a quantitative discipline (e.g., engineering, computer science, mathematics, physics, or equivalent), or with approval of the instructor.

675.702 Materials for Space Systems

Through online lectures and mini cohorts, this course illustrates the fundamental applications of materials to spacecraft design for a systems engineering perspective. Topics include the environments of dynamics, vacuum, thermal, reactive chemicals, radiation, and electrostatics relating to material selection; applications in the material classes of metals, ceramics, polymers, and composites to spacecraft design; design considerations from preliminary design through product verification, launch, and mission operations; and considerations for environment impacts, commons issues encountered, and lessons learned. The course is not intended to cover materials analysis that is taught specific to individual engineering domains, rather it instructs the application of the materials to the space environment with specific industry examples.

Course prerequisite(s): Completion of 675.600 Systems Engineering for Space and 675.601 Fundamentals of Engineering for Space Systems I, or with the approval of the instructor

675.711 Ground System Engineering and Mission Operations

This course will focus on the critical functions performed by ground systems and mission operations throughout the space systems life-cycle and their integrated application. Course topics will include planning and sequencing, uplink and control, testing, real-time operations, communications, data management, data analysis, and assessment. Students will learn about end-to-end best practices that pertain to most missions and how ground systems and mission operations concepts are tailored across a diversity of missions. Examples will be presented from real space missions and programs, with assignments, special topics, and a team project focused on typical ground system engineering problems, mission operations challenges, and applied methods of technical problem resolution.

Course prerequisite(s): Completion of 675.600 Systems Engineering for Space and 675.601 Fundamentals of Engineering Space Systems I, or with approval of the instructor.

675.712 Space Mission Formulation
This course covers the creative and generative side of space mission engineering. Highly successful space science and exploration missions are the result of close collaboration between scientists who define the highest-level goals and the engineers who provide the means to make the measurements necessary to achieve those goals. In addition, mission formulation teams must understand the external strategic environment that supports a mission, specifically the government sponsors, their funding capabilities, how their priorities get set, and the cycles they go through. This course will help the student develop an understanding of that external environment, the process of collaboration between the scientists and the engineers and their sponsors, and how to frame mission goals and requirements in terms that lead to mission success. The instructors will provide insight into the formulation of scientific investigations, the process of crafting a compelling and accurate narrative for a mission proposal. Topics also include: derivation of mission requirements, launch vehicle capabilities and selection; mission architecture elements; and project flow from pre-proposal through mission confirmation.
Course prerequisite(s): Completion of 675.600 Systems Engineering for Space and 675.601 Fundamentals of Engineering Space System, or with approval of the instructor.

675.713 Fault Management and Autonomy: Improving Spacecraft Survivability
This course introduces students to the fundamental principles of fault management engineering as it pertains to space systems. It describes how the fault management engineering viewpoint differs from that of systems engineers and engineering specialists, as well as the role that fault management plays throughout the mission design life cycle. Fault management is a systems engineering function that defines the functional requirements distributed throughout the spacecraft (hardware, software, and autonomy) and ground/mission operations that enable the detection, isolation, and recovery from events that upset nominal operations. Students will learn about the principles of fault management architecture (i.e., driving requirements, redundancy concept, safing and modes concept, ground intervention concept, and critical sequences) and how those principles inform the fault management design, the analytical techniques used for fault analysis, trade studies, and requirements allocation, and the role of the fault management engineer from the initiation of the project through design, integration and test, launch, and flight operation. Examples will be presented from real space missions and programs to emphasize the different implementations of fault management systems given the technical, cost, and schedule constraints.
Course prerequisite(s): Completion of 675.600 Systems Engineering for Space and 675.601 Fundamentals of Engineering Space System, or with approval of the instructor.

675.731 Spacecraft Propulsion Systems
The intent of this class is to teach the basics of propulsion such that you will be able to make informed decisions about which sort of system would be best for a particular application. To do this, the class starts with a basic primer on the physics of propulsion and then covers key elements of the various types of propulsion systems that are typically used on spacecraft, including chemical and electric systems, and also some types of system not typically used now, but that might be available in the future (e.g., nuclear propulsion, matter/antimatter propulsion). In the class, you are introduced to how a propulsion subsystem is used and how it interacts with the rest of the spacecraft, so it can be seen from a system perspective and not just from the subsystem view. Key pros and cons of each type of system presented are discussed, as well as key constraints and failure modes. Subsystem components and performance characteristics are introduced and then used in examples from actual spacecraft to explain why these systems were selected for flight. Then, you are shown how to specify propulsion subsystem and trade various subsystem types against each other, how to size them, how to integrate and test them, and ultimately how to fly them.
Course prerequisite(s): Completion of 675.600 Systems Engineering for Space and 675.601 Fundamentals of Engineering Space Systems I, or with approval of the instructor.

675.732 Advanced Topics in Aerospace Hardware
This course focuses on spacecraft hardware topics to include current and emerging technologies including hardware in system configurations such as constellations and for sensing and communication applications. The course is grounded in a hardware and software design understanding of materials and operations in the space environment (design rules, material and component considerations, safe life versus fail safe designs, environmental considerations, among other hardware guidelines). Specific topics in hardware addressed in these studies include Instruments and Detectors (Optical, Radio Frequency, Imagers…), Low Earth Orbit Commercial Constellations and Swarms, Geostationary (GEO) and GEO Transfer Comm and Remote Sensing, Flagship Missions, Cislunar, In Situ Resource Utilization, Landers and Samplers, Subsystem specifics, Hardware, Firmware and Software Interfaces and Launch vehicles.
Course prerequisite(s): Completion of 675.600 Systems Engineering for Space and 675.601 Fundamentals of Engineering Space Systems I, EN.675.622 Spacecraft Hardware Design Considerations or with approval of the instructor.

675.733 Spacecraft Rendezvous and Proximity Operations
The objectives of this course are to develop the general principles governing spacecraft proximity operations, rendezvous, and docking, and analyze the challenges associated with their operational implementation. Students will be introduced to topics such as near and far range rendezvous, natural motion circumnavigation (NMC), autonomous rendezvous guidance, and relative navigation using GPS and relative motion sensors. Practical mission constraints, including passive safety, collision avoidance, and sun illumination will be discussed. Applications from emerging areas including on-orbit servicing, in-space manufacturing/assembly/refueling, formation flying, active debris removal, close inspection, and logistics resupply to a cislunar human habitat will also be studied.
Notes: Students are expected to be comfortable in programming with Matlab, Python or similar simulation platforms, and must have been exposed to the mathematical topics of Linear Algebra, Differential Equations, Calculus, and elementary Probability through prior coursework.
Course prerequisite(s): EN.675.600 Systems Engineering for Space; EN.675.601 Fundamentals of Engineering Space Systems I and EN.675.602 Fundamentals of Engineering Space Systems II, or with approval of the instructor.

675.734 Fundamentals of Celestial and Orbital Mechanics
This course will focus on the study of orbital and celestial mechanics, using many of the methods that are covered in a traditional advanced mechanics course. This is foundational and necessary information for the study of advanced astrodynamics. We will look primarily at closed form and approximation methods (as opposed to numerical solutions) in a wide variety of problems in orbital and celestial mechanics. Students who take this class will be well-versed in fundamentals that can then be leveraged in more advanced future space applications such as spaceflight mechanics, navigation and control, geodesy, maneuver design, orbit determination rendezvous and proximity operations, and others. Topics will include Newtonian Mechanics, Newtonian Gravitation, Central Force Orbits (with a focus on Keplerian Orbits), Orbital & Interplanetary Maneuvers, Non-inertial Reference Frames, the Lagrangian Formalism, Rigid Body Rotation, the Three Body Problem, Approximation Methods for Orbits, Spherical Harmonic Representation of the Earth's geoid, and Lunar Motion. Discussions will include the historical figures who contributed significantly to the topics discussed.

675.740 Assuring Success of Aerospace Programs
Technical managers, systems engineers, lead engineers, and mission assurance professionals will benefit from this course, which focuses on the leadership of system safety and mission assurance activities throughout the life cycle of a project to achieve mission success. This advanced course provides crucial

lessons learned and proven best practices that technical managers need to know to be successful. The integrated application of mission assurance and systems engineering principles and techniques is presented in the context of aerospace programs and is also applicable to other advanced technology research and development programs. Students discuss critical risk-based decision making required from system concept definition and degree auditing through design, procurement, manufacturing, integration and test, launch, and mission operations. Experiences shared by senior aerospace leaders and extensive case studies of actual mishaps explore quality management topics relevant to aircraft, missiles, launch vehicles, satellites, and space vehicles. The course addresses contemporary leadership themes, government policies, and aerospace industry trends in mission assurance requirements, organizational structure, knowledge sharing and communication, independent review, audit, and assessment. Mission assurance disciplines covered include risk management, system safety, reliability engineering, software assurance, supply chain management, parts and materials, configuration management, requirements verification and validation, non-conformance, and anomaly tracking and trending.
Course prerequisite(s): Completion of 675.600 Systems Engineering for Space and 675.601 Fundamentals of Engineering Space Systems I, or with approval of the instructor.

675.751 Space Weather and Space Systems

This course will explore the space environment in the context of its impact on space system operations. Topics include the impacts of ionospheric variability on HF propagation, satellite communications, and GPS; impacts of energetic charged particles on spacecraft; impacts of auroral precipitation on radar and communication systems; and impacts of varying geomagnetic activity on power grids and space situational awareness. Lectures and homework assignments will prepare engineers to quantify and mitigate space weather impacts, and a final project will consist of a detailed analysis on a system of interest to the student.
Course prerequisite(s): An undergraduate or graduate degree in a quantitative discipline (e.g., engineering, computer science, mathematics, physics, or equivalent), or with approval of the instructor.

675.752 Attitude Determination and Control of Space Systems

The Attitude Determination and Control Subsystem, or ADCS, is intimately connected with all the other spacecraft subsystems, and will be studied in the context of the systems engineering of the whole spacecraft and its mission. Students will examine the requirements imposed on the ADCS, and will explore how to meet those requirements. To this end, it starts with a student's understanding of rigid-body dynamics as it relates to spacecraft dynamics and will introduce common and classical approaches to problems encountered in the design of this critical spacecraft subsystem. The course will also include a team design project involving an ADCS for a small spacecraft.
Course prerequisite(s): Completion of 675.600 Systems Engineering for Space, 675.601 Fundamentals of Engineering Space Systems I, and 675.650 Mathematics for Space, or with approval of the instructor.

675.753 Spacecraft Avionics Systems

This survey course will focus on the management, engineering development and operation of the spacecraft Avionics system consisting of hardware topics covering Spacecraft Processing; Command Data Handling and Command Execution; Telemetry Acquisition, Conditioning and Conversion and Telemetry Data Handling; Bulk data storage; Fault Management Support; and Timekeeping Support. The course is grounded in computer and data architecture fundamentals with focus on key electronics such as data interfaces, spacecraft processors, volatile and non-volatile memories, field-programmable gate arrays (FPGA), and analog sensors and circuits. Spacecraft Avionics systems topics will be applied through reference design scenarios to illustrate requirements/implementation trades bound by the constraints of the space environment and spacecraft data resource limitations. Topics such as hardware development,

integration and test and inflight support will be used to illustrate the difficulties inherent to the spacecraft's Avionics system.
Course prerequisite(s): Completion of 675.600 Systems Engineering for Space and 675.601 Fundamentals of Engineering Space System, or with approval of the instructor.

675.754 Flight Software for Space Systems

This survey course reviews the architectures, designs, and implementations of spacecraft flight software systems. The course provides an overview of typical command and data handling software functions and the open-source tools, frameworks, and applications that can implement them. A semester-long programming assignment is provided to build a working flight software system. Special topics include application to resource-constrained Internet-of-Things (IoT) devices, spacecraft security, and space-based networking. Flight software encompasses the complete set of computer instructions running on every processor on a spacecraft.
Course prerequisite(s): Completion of 675.600 Systems Engineering for Space and 675.601 Fundamentals of Engineering Space Systems I, experience programming in C, or with approval of the instructor.

675.756 Antenna Design for Space Systems

This course presents an engineering approach to the design of antennas for space systems. Students will examine antennas for both large and small space-based platforms in earth orbit and beyond. Antenna design is presented in the context of the space environment with particular attention to the flight design and testing cycle, thermal and mechanical considerations, space compatible materials, and high power operation. A primary focus of the course will be single, dual and shaped reflector designs including feed network topologies. Several horn antenna designs including corrugated and multimode horns will be covered as well as feed network components. A variety of other antennas including helices, patches, and arrays will be discussed for applications including: Global Navigation Satellite System (GNSS); Tracking, Telemetry and Command (TT&C); isoflux; smallsat and cubesat antennas.
Course Prerequisite(s): An undergraduate- or graduate-level introductory antenna systems course, or with approval of the instructor.

675.761 Reliability Engineering and Analysis for Space Missions

This course covers the principal methods of reliability analysis as it pertains to space systems. These seek to help development teams to anticipate and find design and operational issues. Basic analytical techniques covered include fault tree and reliability block diagrams; Failure Mode and Effects Analysis (FMEA); event tree construction and evaluation; and reliability data collection and analysis. More advanced techniques of risk and reliability modeling of systems include Bayesian methods and applications, estimation of rare event frequencies, uncertainty analysis and propagation methods. These methods and techniques are integrated into quantitative assessments to address hardware, software, and human reliabilities, as well as their dependencies.
Course prerequisite(s): Completion of 675.600 Systems Engineering for Space and 675.601 Fundamentals of Engineering Space Systems I, or with approval of the instructor.

675.768 Spacecraft Integration and Test

This course introduces students to the fundamental principles of developing Integration & Test (I&T) programs for space systems. Topics covered will provide a detailed understanding with practical applications of all phases of Spacecraft I&T starting with the design input/planning phase, staffing/budget phase, subsystem and instrument integration phase, environmental testing phase, and finally the launch campaign phase in the field. Classes will be structured to provide students information exchange sessions with subject matter experts and actual practitioners within the I&T community. Students will learn about all

of the Electrical and Mechanical ground support equipment needed to build a spacecraft and the importance of the paperwork and processes used throughout all phases to manage spacecraft systems I&T.
Course prerequisite(s): Completion of 675.600 Systems Engineering for Space and 675.601 Fundamentals of Engineering Space Systems I, or with approval of the instructor.

675.771 Space Mission Design and Navigation
Critical to the development of space missions is the careful analysis and design of the desired path of the space vehicle (mission design) and the determination of the space vehicle's actual state vector (navigation). This course presents these two topics in an integrated manner, intended to provide space engineering professionals with a technical understanding of these complex subjects. Mission Design topics include kinematics, Kepler's Laws, Newton's Law of gravitation, modeling of several fidelity levels of spacecraft trajectory dynamics, and optimization of objective functions and satisfaction of constraints. Navigation topics include dynamics and measurement model formulations, standard estimation algorithms such as the Kalman filter and batch estimators, and performance analysis. This course will focus on the theory from a mathematical derivation perspective, example problems, and practical implementation considerations. This is an algorithm intensive course and students are expected to be comfortable with the following: MATLAB programming (or equivalent), Linear Algebra, Linear Systems, Differential Equations, basic Probability concepts, and Calculus.
Course prerequisite(s): Completion of 675.600 Systems Engineering for Space, 675.601 Fundamentals of Engineering for Space Systems I, and 675.650 Mathematics for Space, or with approval of the instructor.

675.772 Verification and Validation of Space Systems
A survey course that reviews the specification, verification and validation of spacecraft flight system requirements. The course provides an overview of the requirements gathering process, subsystems allocation, verification methods, typical spacecraft system tests and test events. An overview of the construction of spacecraft comprehensive performance tests and mission scenarios will be part of this course, as well as the development of a requirements verification matrix.
Course prerequisite(s): Completion of 675.600 Systems Engineering for Space and 675.601 Fundamentals of Engineering Space Systems I, or with approval of the instructor.

675.792 Scientific Instruments for Space
This course covers the details for the development of scientific space flight instruments, from the conceptual design phase, all the way to delivery to the space vehicle. The course presents the space environments and the considerations in designing space flight instruments. These design considerations include mechanical, structural, thermal and electrical and how to overcome some of the challenges during the different phases of design, assembly and test of the instruments. Students are introduced to programmatic considerations including budgeting, scheduling, and staffing. The course also covers the importance of identifying, understanding and verifying design requirements at different levels of space flight instrument development. A detailed study of the instrument development cycle is covered during the course, with references to instruments launched to space throughout the history of the space-age.

675.800 Directed Studies in Space Systems Engineering
In this course, qualified students are permitted to investigate possible research fields or to pursue problems of interest through reading or non-laboratory study under the direction of faculty members.
Course Note(s*): This course is open only to candidates in the Master of Science in Space Systems Engineering program.*

Course prerequisite(s): The Independent Study/Project Form (https://ep.jhu.edu/current-students/student-forms/) must be completed and approved prior to registration.

COURSE SCHEDULE

Students should utilize the catalog they have chosen to graduate under (https://ep.jhu.edu/student-services/academic-services/academic-catalogs/) and the Student Academic checklist (https://ep.jhu.edu/current-students/student-forms/ep-student-academic-planning-checklists/) to make sure that they are on track with their program requirements. The most current information on individual courses will be found at the EP Website: https://ep.jhu.edu/programs/space-systems-engineering/courses/

A course planning document can be found under the Space Systems Engineering heading in the Schedule Planning section https://ep.jhu.edu/student-services/academic-services/course-planning/. This document provides the **typical scheduling of courses.** Students should keep in mind that course offering schedules are subject to change and this document is only a general guideline. Students should utilize SIS and the EP Website as the primary sources for each semester's offerings.