



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 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 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 first edition in support of the 2020-2021 academic year.

I am committed to improving the quality and increasing the quantity of courses that we offer to our students. Over the past 18 months we have created and released 11 new electives that are available to you today, and we are creating and have plans to release another 10 new electives over the next 18 months. 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 with 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.

A handwritten signature in blue ink that reads "Patrick Binning". The signature is written in a cursive, flowing style.

Patrick Binning, Ph.D.
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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 fulfill any set of requirements in force during their time in the program.

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

ADVISORS AND DEGREE AUDIT

Students are assigned an advisor when accepted. In addition, students are strongly encouraged to contact their advisors prior to registration. Logging of course and program completion as well as viewing of approvals and exceptions approved by a student's advisor can be tracked through degree audit viewable through SIS.

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. It 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 receiving 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 coordinator 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 at the APL campus 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		
<u>ELECTIVE 1</u>			
<u>ELECTIVE 2</u>			
<u>ELECTIVE 3</u>			
<u>ELECTIVE 4</u>			
<u>ELECTIVE 5</u>			
675.701	Applications of Space Systems Engineering		
675.710	Small Satellite Development and Experimentation		

(Signature)

(Date)

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

NAME: _____

First Semester: _____

Planned Final Semester: _____

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

(Signature)

(Date)

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/files/scheduleplan-sse.pdf>

SSE Program Contact Information

Patrick Binning, Program Chair

patrick.binning@jhu.edu

Will Devereux, Program Coordinator

Will.Devereux@jhuapl.edu

240-228-6509

Jolena Arcuri, Education Specialist

Jolena.arcuri@jhuapl.edu

240-592-2925

Anne Zylinski, Program Admission Coordinator

azyilins1@jhu.edu

410-516-7904

If you experience technical problems and need additional assistance, please e-mail 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.

FREQUENTLY ASKED QUESTIONS:

Question: How do students request a leave of absence or an extension to the five-year time limit for completing a degree?

Answer: For students who are unable to complete their degree within the five-year-limit, a formal request for an extension needs to be made to, and approved by, the Program Chair. An explanation of the student's circumstances resulting in the request needs to be included. Once approved, the advisor must send an extension request (Gerald) Doug Bulkley at gbulke1@jhu.edu

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

Answer: Submit a writing request, official transcript and course description to program coordinator. Refer to https://ep.jhu.edu/student-services/academic-services/academic-regulations#transfer_courses

Question: Can I waive a pre-requisite?

Answer: Contact the instructor to obtain permission to take the course without having completed the pre-requisite. Have the instructor send their approval to your advisor. The advisor will review and send their recommendation to the Space Systems Engineering Chair for approval. You advisor will set a waiver in SIS.

Question: Can I waive a CORE course?

Answer: You will need to submit an online waiver request via SIS. The system will send an email to your advisor, who will review your request. If your advisor approves, they will send the approval to Space Systems Engineering Chair. Even if waivers are granted, you still must take 10 courses.

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

Answer: Their advisor must first approve the course. The student should send an email to Doug Bulkley (gbulke1@jhu.edu) or ep.registration@jhu.edu to request an Interdivisional Registration (IDR). Other divisions of the JHU may hold up the IDR to give their own students priority so notification of enrollment may be delayed. Tuition rates may also vary.

Question: Do we note "Honors" acknowledgements on the transcript?

Answer: Students who earn A's 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: How do students request a leave of absence or an extension to the five-year time limit for completing a degree?

Answer: For students who are unable to complete their degree within the five-year-limit, a formal request for an extension needs to be made to, and approved by, the Program Chair. An explanation of the student's

circumstances resulting in the request needs to be included. Once approved, the advisor must send an extension request (Gerald) Doug Bulkley at gbulke1@jhu.edu

Question: If a student has a question about their student account or financial aid, to whom should they direct their questions?

Answer: Students should direct financial-aid questions to fin_aid@jhu.edu and student account questions to homewoodstudentaccounts@jhu.edu.

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

Answer: No. 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. Many online courses do conduct optional, weekly live office hours. These office hours are usually scheduled on a specific day and time each week. These office hours are recorded and uploaded to the course site so 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 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 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. However, 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 thru the program and may find one that you'd 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.

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

Question: The SSE electives seem to cover a broad range of technical subject areas. If I wanted to see the courses grouped by general subject area, what would that look like?

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

Spacecraft Design

675.622	Spacecraft Hardware Design Considerations
675.640	Satellite Communications Systems
675.731	Spacecraft Propulsion Systems
675.753	Spacecraft Avionics and Power Systems
675.754	Flight Software for Space Systems
675.756	Antenna Design for Space Systems
675.769	Space Mechanical Systems Design and Analysis
675.xxx	Thermal Design and Analysis of Space Systems (Course in development)
675.xxx	Materials for Space Systems (Course in development)

Space Systems Analysis

675.621	Space Environment and Effects
675.650	Mathematics for Space
675.751	Space Weather and Space Systems
675.752	Attitude Determination and Control of Space Systems
675.771	Space Mission Design and Navigation
675.xxx	Space Control (Course in development)

Remote Sensing

675.691	Electro-Optical Space Systems
675.741	Passive Emitter Geo-Location
675.757	Space-Based Radar Systems

Mission and Spacecraft Systems Engineering

675.711	Ground System Engineering and Mission Operations
675.712	Space Mission Formulation (Course in development)
675.713	Fault Management and Autonomy: Improving Spacecraft Resilience
675.740	Assuring Success of Aerospace Programs
675.761	Reliability Engineering and Analysis for Space Missions
675.768	Spacecraft Integration & Test
675.772	Verification and Validation of Space Systems

SSE COURSES AND DESCRIPTIONS

Core Courses

675.600 Systems Engineering for Space - Online

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 – Online

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.

675.602 Fundamentals of Engineering Space Systems II – Online

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.

675.701 Applications of Space Systems Engineering – Online

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.

675.710 Small Satellite Development and Experimentation – Online with end of semester Capstone Project at APL

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 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 the 10th week of the semester at the Johns Hopkins University Applied Physics Laboratory. In lieu of meeting during normal class time during the 10th week, the lab will meet the Friday, Saturday,

and Sunday immediately following the normal class date. The lab component will have a mandatory set of core hours during a time period running from Friday at 5 p.m. through Sunday at 12 p.m.; students are responsible for their own travel and accommodations, as required. An optional tour of APL space facilities is planned for 4 p.m. on Friday. There will be no further classes following the residency weekend, with only final laboratory deliverables due per provided instructions.

Electives

675.621 Space Environmental and Effects – Virtual Live

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 and 675.601 Fundamentals of Engineering for Space Systems I, or with approval of the instructor.

675.622 Spacecraft Hardware Design Considerations - Online

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.

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.

675.640 Satellite Communications Systems – Online

This course presents the fundamentals of satellite communications link design and an in-depth treatment of practical considerations. Existing commercial, civil, and military systems are described and analyzed, including direct broadcast satellites, high throughput satellites, VSAT links, and Earth-orbiting and deep space spacecraft. Topics include satellite orbits, link analysis, antenna and payload design, interference and propagation effects, modulation techniques, coding, multiple access, and Earth station design. The impact of new technology on future systems in this dynamic field is discussed. *Note: This course is cross-listed with 525.640*

Prerequisite(s): 525.616 Communication Systems Engineering or equivalent, or with approval of the instructor.

675.650 Mathematics for Space Systems – Online

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.

Prerequisite(s): The course requires prior knowledge of college calculus and algebra,

675.691 Electro-Optical Space Systems – Online

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.

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.

675.711 Ground System Engineering and Mission Operations - Online

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.

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 – Virtual Live

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 Resilience– Virtual Live

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 – Virtual Live

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): 675.600 Systems Engineering for Space and 675.601 Fundamentals of Engineering Space Systems I, or with approval of the instructor.

675.740 Assuring Success of Aerospace Programs – Available Fall 2020 - Online

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): 675.600 Systems Engineering for Space and 675.601 Fundamentals of Engineering Space Systems I, or with approval of the instructor.

Course Note(s): This course is cross-listed with EN.595.740

675.741 Passive Emitter Geo-Location – Online

This course covers the algorithms used to locate a stationary RF signal source, such as a radar, radio, or cell phone. The topics covered include a review of vectors, matrices, and probability; linear estimation and Kalman filters; nonlinear estimation and extended Kalman filters; robust estimation; data association; measurement models for direction of arrival, time difference of arrival, and frequency difference of arrival; geo-location algorithms; and performance analysis. Most of the course material is developed in planar Cartesian coordinates for simplicity; however, the extension to WGS84 coordinates is provided to equip the students for practical applications. Homework consists of both analytical problems and problems that require computer simulation using software such as MATLAB.

Course prerequisite(s): 525.614 Probability and Stochastic Processes for Engineers

Course Note(s): This course is only offered in the fall. An undergraduate course in linear algebra/matrix theory, and familiarity with MATLAB are required. This course is cross-listed with 525.744.

675.751 Space Weather and Space Systems – Online

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.

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 – Virtual Live

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.

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 and Power Systems – Virtual Live

This course will focus on the engineering development and operations of the spacecraft Avionics and Power systems. Course topics for Avionics will include spacecraft avionics systems overview, requirements, key parts identification for processors, volatile and non-volatile memories, and field-programmable gate arrays (FPGA). Onboard spacecraft command and telemetry data flow architectural trade-offs will be evaluated against reference design scenarios. Avionics topics such as hardware development, integration and test and inflight support will be used to illustrate the concepts. (Power systems portion to be added by co-instructor to be appointed)

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 – Online

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.

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 – Virtual Live

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.

Prerequisite(s): An undergraduate- or graduate-level introductory antenna systems course, or with approval of the instructor.

675.757 Space-based Radar Systems – Online

Radar systems launched in and used in space are utilized in a number of applications including navigation, intelligence, maritime domain awareness, ocean ice monitoring, meteorology, disaster recovery, and lunar and planetary science. This course will begin with radar fundamentals before covering the scientific requirements that drive the engineering decisions that go into designing a space-based radar system, the data processing that must occur, and how that data is then exploited. Emphasis will be on Synthetic Aperture Radar, but other techniques and technologies will also be

included. Case studies of historic, existing, and future systems will be done. Students will select a particular mission of interest and then design a space radar system that would be capable of executing the chosen mission.

Course prerequisite(s): Completion of 675.600 Systems Engineering for Space, 675.601 Fundamentals of Engineering Space System, and 675.650 Mathematics for Space, or with approval of the instructor.

675.761 Reliability Engineering and Analysis for Space Missions – Virtual Live

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.

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 – Online

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.

Prerequisite(s): 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 – Online

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.

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 – Virtual Live

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): 675.600 Systems Engineering for Space and 675.601 Fundamentals of Engineering Space Systems I, or with approval of the instructor.

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. Note: *This course is open only to candidates in the MS Space Systems Engineering program.*

Prerequisite(s): [The Independent Study/Project Form](http://ep.jhu.edu/student-forms) (ep.jhu.edu/student-forms) must be completed and approved prior to registration.

