2022-2024 ESRs
Space Systems Engineering
Subspecialty 5500
Curriculum 591

1. Curriculum Number: 591.

2. Curriculum taught at Naval Postgraduate School.

3. Curriculum Length in Months: 21.

4. APC Required: 323.

5. The officer must understand the fundamental concepts and be familiar with the basic functional areas of Space Systems Engineering within the Department of the Navy (DON) and the Department of Defense (DoD) including the below numbered ESRs.

6. ESR-1. ORBITAL MECHANICS AND SPACE ENVIRONMENT:

a. Graduates will examine the basic physics of orbital motion, and calculate and distinguish the parameters used in the description of orbits and their ground tracks.

b. Graduates will examine the design of orbits and constellations, and analyze how they are achieved, maintained, and controlled; to include spacecraft maneuver and orbit transfer calculations.

c. Graduates will examine the fundamentals of spacecraft tracking and command/control from a ground station.

d. Graduates will examine the various orbital perturbations, including those due to non-spherical earth and due to atmospheric drag, and interpret their effects.

e. Graduates will analyze the relationship between various orbital characteristics and the satisfaction of mission requirements, including the advantages and disadvantages of various orbits.

f. Graduates will design and optimize mission orbits through the analysis of common performance measures such as access, coverage, and revisit; and will employ appropriate tools to conduct these analyses.

g. Graduates will examine the physical behavior of the upper atmosphere, ionosphere and space environment under the influence of both natural and artificial phenomena such as solar activity, geomagnetic and magnetospheric effects, and man-made disturbances.

h. Graduates will apply this understanding of how the space environment impacts spacecraft parts, materials, and operations to spacecraft and mission design.

7. ESR-2. NATIONAL SECURITY SPACE SYSTEMS:

a. Graduates will examine the nature of space warfare (theory, history, doctrine, and policy); distinguish how space operations as discussed in JP 3-14 enable joint force capabilities; and interpret how current and planned space capabilities contribute to the satisfaction of mission objectives.

b. Graduates will examine the roles, responsibilities, and relationships of National and DoD organizations in establishing policies, priorities, and requirements for National Security Space systems; and in the design, acquisition, operation, and exploitation of these systems.

c. Graduates will examine the role of the Services / Agencies in establishing required space system capabilities, and will translate these capabilities into end-to-end, system-of-systems performance requirements.

d. Graduates will examine: current and planned Intelligence, Surveillance, and Reconnaissance (ISR) capabilities; how space systems contribute to these capabilities; the intelligence collection and analysis process; and how war-fighters access information from these sources.

e. Graduates will examine concepts of employment, space tactics and CONOPS. The graduate will consider end-to-end capabilities and system-of-systems architectures that enhance, support, and integrate into military operations to include resiliency concepts in a contested environment.

f. Graduates will identify how proposed space-related capabilities / doctrine transition from concept to real-world implementation through experimentation.

g. Graduates will examine the capabilities of unclassified DoD and commercial space systems, and how those systems relate to National Space Systems to include potential overlaps and leverage opportunities.

8. ESR-3. PROJECT MANAGEMENT AND SYSTEM ACQUISITION:

a. Graduates will examine project management and DoD system acquisition methods and procedures to include contract management, financial management and control, and the Planning, Programming, Budgeting and Execution (PPBE).

b. Graduates will recognize the role of the Defense Acquisition University and the acquisition courses and qualifications available.

c. Graduates will examine system acquisition organizational responsibilities and relationships (e.g., Congress, DoD, Services, Resource Sponsor, Systems Commands, Operating Forces) as they pertain to the acquisition of systems for DoD, Naval, and civilian agency users.

d. Graduates will examine the unique nature of space acquisition programs and plan a notional space system acquisition program.

9. ESR-4. COMMUNICATIONS:

a. Graduates will examine the basic principles of communications systems engineering to include both the space and ground segments.

b. Graduates will examine digital and analog communications architecture design, including such topics as frequency reuse, multiple access, link design, repeater architecture, source encoding, waveforms/modulations, and propagation media.

c. Graduates will calculate and analyze link budgets to assess communication system suitability to support mission requirements, and to translate mission requirements into communications system design characteristics.

d. Graduates will differentiate, compare, and contrast the characteristics and capabilities of current and future communications systems in use or planned by naval operating and Joint forces afloat and ashore.

e. Graduates will examine how current and planned space communications systems should be used to meet Joint communications requirements across the spectrum of operations.

f. Graduates will differentiate signal processing techniques, both digital and analog, as applied to missions such as spacecraft communications, surveillance, and signals intelligence.

g. Graduates will examine spacecraft vulnerabilities in an electronic warfare context.

10. ESR-5. COMPUTERS: HARDWARE AND SOFTWARE

a. Graduates will understand the fundamentals of digital logic and digital system design of simple digital computer subsystems.

b. Graduates will examine the design of current and planned computer hardware and software architectures for space-based applications to include their potential to support service life extensions and enable incremental capabilities of cyber and platform resiliency.

c. Graduates will examine the use of computers in complex systems such as guidance, signal processing, communications, and control systems.

d. Graduates will examine the fundamentals of electronic component design, fabrication, reliability, and testing (to include radiation hardening), with an emphasis on parts, materials, and processes.

e. Graduates will examine modern Information Technology capabilities and their applications for space systems ground processing, data storage, information sharing, and network design.

11. ESR-6. SPACECRAFT DYNAMICS, GUIDANCE, AND CONTROL

a. Graduates will analyze spacecraft dynamics, guidance, and control to include topics such as linear control, coordinate transformations, rotational kinematics, three-axis stabilization design, sources of and response to disturbance torques, and selection of attitude determination and associated sensors and actuators.

b. Graduates will apply these techniques to the analysis and design of resilient spacecraft guidance and control systems.

12. ESR-7. SPACECRAFT STRUCTURES AND MATERIALS

a. Graduates will examine the engineering and design of space structures, perform simplified sizing calculations, and analyze the dynamics of these structures.

b. Graduates will understand the use of materials for space structures and the associated trade space in spacecraft design.

13. ESR-8. PROPULSION SYSTEMS

a. Graduates will examine the operating principles (fluid mechanics, thermodynamics, electricity and magnetism) and propulsion devices used in current and proposed space applications.

b. Graduates will analyze and choose appropriate propulsion systems for spacecraft applications to include launch, orbit transfers, and spacecraft maneuvering with the potential for on-orbit serviceability.

14. ESR-9. SPACECRAFT THERMAL CONTROL

a. Graduates will examine the principles of heat transfer and how surfaces and materials are manipulated in spacecraft thermal control.

b. Graduates will examine the design, analysis, and applications of current active and passive thermal control devices (including heat pipes, louvers, and materials).

c. Graduates will examine the sources of heat in space (solar, terrestrial, reflected solar, internal vehicle generation) and their variation as a function of vehicle orbit, and apply this knowledge to thermal subsystem analysis and design.

15. ESR-10. SPACECRAFT POWER

a. Graduates will examine the principles and operating characteristics of major power generating systems for spacecraft, including the performance of photovoltaic sources in the natural and artificial radiation environment.

b. Graduates will examine the principles and operating characteristics of energy storage devices in power systems design to include the potential to support associated service life extensions.

16. ESR-11. REMOTE SENSING AND PAYLOAD DESIGN

a. Graduates will examine principles of active and passive sensors in current or planned use, to include analysis of electromagnetic wave propagation and design of optics, detectors, and antennae.

b. Graduates will examine the effects of the space, atmospheric, and terrestrial environments (including countermeasures) on sensor performance.

c. Graduates will assess and conduct tradeoffs among various sensors and platforms, evaluating how each satisfies mission requirements such as access area, resolution, timeliness, and capacity.

d. Graduates will examine the design of current and planned space-based mission payloads (e.g., ISR, Communications, PNT, SIGINT).

e. Graduates will analyze mission capabilities and conduct associated trades in order to develop associated payload design requirements.

17. ESR-12. SPACECRAFT DESIGN, INTEGRATION, AND SYSTEMS ENGINEERING

a. Graduates will develop and assess an overall space system architecture to meet defined mission requirements through the use of systems engineering tools and processes.

b. Graduates will derive system and subsystem performance criteria from stated mission capabilities and conduct trade-offs between payload and other spacecraft subsystems in addressing these capabilities.

c. Graduates will examine a broad spectrum of mission assurance concerns such as reliability, risk management, configuration management, qualification and acceptance testing, proto-flight strategy, spacecraft materials and manufacturing processes, resiliency considerations and cyber vulnerabilities.

d. Graduates will examine various engineering and mathematical definitions of cost functions (revisit time, dwell time, local coverage, etc.) and apply emerging methods and tools to optimizing these utility measures in support of mission objectives.

e. Graduates will examine the basic principles and operational issues of space access to include launch vehicle performance, launch windows, and their impact on military operations.

f. Graduates will examine the capabilities of the various current and planned launch systems, and characterize the issues associated with integrating a spacecraft with a launch vehicle, to include the effects of launch environment.

g. Graduates will perform a trade-off analysis in the selection of a launch vehicle based on mission requirements, performance and design constraints, and business issues involved (e.g., pricing, insurance, policy).

h. Graduates will demonstrate proficiency in design, analysis, and modeling / simulation tools such as NX, MATLAB / Simulink, Systems Tool Kit (STK), and others.

i. Graduates will examine the processes and methods of systems engineering including requirements analysis, functional analysis and allocation, system design, and verification.

18. ESR-13. GROUND SYSTEMS AND SYSTEMS ENGINEERING

a. Graduates will understand the fundamentals of a space-ground system architecture including the system-of-systems that comprise a space-based, end-to-end capability across all mission areas.

b. Graduates will examine Department of Defense Architecture Framework (DoDAF) views of real or notional space network architectures in order to understand necessary internal and external interfaces and domain interactions.

c. Graduates will analyze enterprise and mission-specific frameworks from standard communications infrastructures (C&C, messaging, data, etc.), services, and tools to mission specific T&C, information products and data.

d. Graduates will analyze network and non-network communications within an Information Technology Enterprise Domain context.

e. Graduates will understand application program interface (API) challenges in relation to security requirements, risks and mitigation.

f. Graduates will understand Risk Management Framework integration for cyber security system engineering efforts including information assurance and relevant documentation such as NIST SP800-30, DoDI 8500.1 and 8500.2.

h. Graduates will analyze command and telemetry requirements and capabilities to support mission execution, vehicle operations and anomaly resolution.

i. Graduates will analyze services for access, sharing, processing and external dissemination of information including data management and storage challenges such as "Big Data", open-source implementation and cloud technology applications for Ground Systems.

19. ESR-14. ARTIFICIAL INTELLIGENCE FOR SPACE SYSTEMS

a. Graduates will examine the mathematical foundational principles of artificial intelligence and apply physics-informed machine learning techniques to optimize the design of space systems.

b. Graduates will examine machine learning techniques to address hard problems in national space security.

20. ESR-15. CONDUCT AND REPORT INDEPENDENT RESEARCH

a. Graduates will conduct independent research on a space systems problem, including resolution of the problem and presentation of the results and analysis in both written and oral form, via a Master's thesis.

21. Major Area Sponsor and Subject Matter Experts:

a. Major Area Sponsor: [redacted]

b. Subject Matter Expert: [redacted]

APPROVED: [redacted] [redacted]
Major Area Sponsor [DATE]

APPROVED: [redacted] [redacted]
President, NPS [DATE]

APPROVED: [redacted] [redacted]
Director, OPNAV N[redacted] [DATE]