

**FY19-21 EDUCATIONAL SKILLS REQUIREMENTS (ESRs)  
SYSTEMS ENGINEERING  
5801P, 5802P, 5803P, 5804P  
Curriculum 580**

1. Curriculum Number: 580
2. Curriculum taught by NPS resident and non-resident. Resident and non-resident active duty Navy and Marine Corps students are fully funded.
3. Curriculum Length in Months: 21  
Month the program starts:

September or March

Refresher quarter: July or January

4. APC Required 323
5. Officers entering into the Systems Engineering curriculum will be offered the necessary preparatory level courses to enable them to satisfy the equivalent of a baccalaureate degree in Engineering. By the time they complete the curriculum, they shall meet, as a minimum, the requirements set forth by the Accreditation Board for Engineering and Technology (ABET). In the context of systems engineering, the term “systems” shall be used to include both systems and systems-of-systems (SoS). At the graduate level, the officer will acquire the competence to effectively contribute as a systems engineer to naval systems research, design, development, maintenance and acquisition. The officer will gain the ability to effectively integrate future technological, engineering, and acquisition approaches with existing practice through a combination of core systems engineering courses, specialization studies, and project/thesis research. An officer will meet the below-listed ESRs through the completion of a program of study determined by the officer, the program officer and the academic associate. Individual programs and how they support the officer’s attainment of the ESRs will be specifically designed to meet the needs of the Navy and the officer’s interests.

a. **ESR-1: [UNDERGRADUATE MATHEMATICS AND BASIC SCIENCES]**

Understand and apply baccalaureate-equivalent coding, mathematics and physics. For mathematics, this includes single and multi-variable differential and integral calculus, ordinary differential equations, probability, and statistics. Coding includes the logic and application of programming languages. This ESR can be met by the appropriate undergraduate work.

b. **ESR-2: [CAPABILITY ENGINEERING]** Model and analyze military operations in order to identify capability needs and derive system requirements. Use modeling and simulation to analyze the operational effectiveness and performance of existing systems, emerging technological concepts, and planned systems. Consider the joint warfighter environment, technology readiness levels, effectiveness, cost, and risk in the analysis. Select the appropriate modeling tools to include back-of-the-envelope spreadsheet modeling, analytical modeling, discrete-event simulation, and continuous simulation modeling. Analyze cost and perform suitability analysis considering the entire life cycle.

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d. **ESR-3: [SYSTEM ARCHITECTING]** Perform system architecting, applying and integrating methods for both software and hardware applications. Construct feasible system functional and physical architectures that represent a balanced approach to meeting stakeholder needs and expectations; stated, implied, and derived system requirements; cyber-resiliency objectives; and suitability objectives such as being open, modular, extensible, maintainable, and reusable. Understand system architecture frameworks and their role in architecture development. Use model-based systems engineering techniques to create, define, and develop system architectures. Develop, analyze, and compare alternative architectures against appropriate, system-level evaluation criteria.

e. **ESR-4: [ENGINEERING DESIGN ANALYSIS]** Understand and apply core qualitative and quantitative methods to analyze and select hardware and software system designs. Methods should include problem formulation, alternatives development, alternatives modeling and evaluation, alternatives comparison, optimization, decision analysis, failure analysis, risk analysis, and futures analysis.

f. **ESR-5: [SYSTEM INTEGRATION AND DEVELOPMENT]** Apply the core skills of system integration and development to include integrating relevant technological disciplines that bear on the system effectiveness and cost. Understand system realization methods and processes necessary to transition from design to production, including prototyping, design for producibility, and production methods.

g. **ESR-6: [SYSTEM VERIFICATION & VALIDATION]** Apply the fundamental verification and validation principles of system test and evaluation to confirm if the capability needs and system requirements are met by the designed system. V&V principles are to include inferential statistics methods such as design of experiments (DOE) and analysis of variance (ANOVA), and testing methods such as functional simulation, analysis, examination, software in the loop, hardware in the loop, full system testing, and operational testing; in order to verify that the hardware matches the simulations in the earliest available environment and continuing during the entire life-cycle.

h. **ESR-7: [HUMAN SYSTEMS INTEGRATION]** Address human factors during requirements definition, as well as workload, safety, training, operability and ergonomics during design. Conduct functional analysis and allocation to human elements, performing cost-risk-effectiveness trade-offs among hardware, software, and human elements. Evaluate proposed designs for man-machine integration, human performance testing, and usability during development test and evaluation. Understand basic human biology as applied to human systems.

i. **ESR-8: [SYSTEM DESIGN]** Understand and demonstrate the system design process in a holistic context, applying and integrating methods for both software and hardware aspects of a design. The end-to-end design process should include: identifying capability need; defining requirements; conducting functional analysis and allocation to hardware, software, and human elements; creating a system functional design; designing a system; deriving and defining requirement specifications; allocating requirement specifications to sub-systems (for hardware,

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software, and human elements); designing for suitability, including reliability, availability, maintainability, operability, and logistical supportability; performing a system assessment by conducting trade-off studies, evaluating system design alternatives against system capability need expressed as military effectiveness; estimating and analyzing the system cost and risk, including risk mitigation strategies; integrating human elements into the system design; and analyzing and planning for system testing and evaluation.

j. **ESR-9:** [PROJECT MANAGEMENT] Work as a team member or leader on a military systems engineering project. Demonstrate an understanding of project management principles. Demonstrate competence in the planning and management of complex projects. Understand the principles of and apply current industry approaches and technology to manage systems design, integration, test, and evaluation for large engineering projects.

k. **ESR-10:** [SPECIALIZATION] Demonstrate in-depth understanding of the principles, technologies, and systems used in at least one major specialty area. These areas can be specific warfare areas, such as combat systems, total ship systems, EW, IW, avionics, undersea warfare, or net-centric systems, a single traditional engineering specialty, such as mechanical, electrical, software, aerospace engineering, or naval architecture, or specialized disciplines such as human factors, availability, or safety. Demonstrate in-depth understanding of the scientific and engineering principles of the respective specialty, such as sensors, weapons, C4I systems, information systems, ship structures, hydrodynamics, power systems, and reliability. Demonstrate broad understanding of systems context of the specialization. Apply that understanding to the design of system components, sub-systems, and interfaces in the holistic context of the engineering of systems.

There will be four tracks of specialization resulting in differing P – Codes:

1. 5801 - Total Ship Systems Design Specialization
2. 5802 - Combat Systems specialization
3. 5803 - System of Systems Engineering and Integration
4. 5804 - Naval Air Systems Specialization

l. **ESR-11\*:** [CYBER] Understand and apply the fundamentals of the underlying principles of cyber infrastructure and systems; inherent vulnerabilities and threats, including industrial control systems; and defensive security procedures. (\* ESR required for 14XX designators only)

m. **ESR-12:** [THESIS] Conduct independent analysis and research in the area of Systems Engineering, and show proficiency in presenting the results in writing and orally by means of a thesis and command-oriented briefing appropriate to this curriculum.

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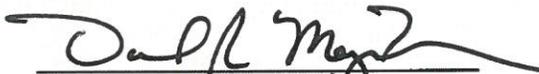
Approved:

  
VADM Johnny Wolfe,  
Director, Strategic Systems Program

27 NOV 18  
Date

  
VADM Ronald Route (Ret.), President,  
Naval Postgraduate School

DEC 14 2018  
Date

  
Director, TFMTER, (OPNAV M2)

4 FEB 2019  
Date

**FY19-21 SAMPLE MATRIX  
SYSTEMS ENGINEERING 580**

**SHIP SYSTEMS TRACK - 5801P**

Start Dates: October (Fall Qtr) & March (Spring Qtr)

<b>Refresher</b>	<b>SE1001</b>	<b>SE2003</b>	<b>SE1002</b>	<b>SE2101</b>	
Winter	<b>Math I for SEA</b>	<b>Fundamentals of Mechanical Systems</b>	<b>Math II for SEA</b>	<b>Fundamentals of Electromagnetic Systems</b>	
15-7	(4-2)	(4-2)	(3-1)	(4-2)	
<b>QTR 1</b>	<b>SE3100</b>	<b>SE2440</b>	<b>OS3180</b>	<b>SE 3112</b>	<b>SE3811</b>
Spring	<b>Fundamentals of Systems Engineering</b>	<b>Intro to Scientific Programming</b>	<b>Probability and Statistics for SE</b>	<b>Combat Sys Engineering I (Sensor Fund.)</b>	<b>Critical Thinking</b>
16-7	(3-2)	(3-2)	(4-1)	(4-2)	(2-0)
<b>QTR 2</b>	<b>SE3400</b>	<b>SE 3250</b>	<b>SE 3011</b>	<b>SE 4112</b>	<b>SE3812</b>
Summer	<b>Engineering Project Management</b>	<b>Capabilities Engineering</b>	<b>Engineering Cost Estimation</b>	<b>Combat Sys Engineering III (Sensor Tech)s</b>	<b>Engineering Ethics</b>
15-6	(3-2)	(3-2)	(3-0)	(4-2)	(2-0)
<b>QTR 3</b>	<b>SE3302</b>	<b>SE4150</b>	<b>TS3000</b>	<b>SE 3113</b>	<b>SE3813</b>
Fall	<b>Systems Suitability</b>	<b>System Architecting and Design</b>	<b>Electrical Power Engineering</b>	<b>Combat Sys Engineering II (Weapons)</b>	<b>Technical Writing I</b>
15-8	(3-2)	(3-2)	(3-2)	(4-2)	(2-0)
<b>QTR 4</b>	<b>SE 4115</b>	<b>SE4354/OA4603</b>		<b>TS 3001</b>	<b>SE3814</b>
Winter	<b>Combat Systems Integration</b>	<b>Test &amp; Evaluation</b>	<b>Track Elective</b>	<b>Fundamentals of Naval Architecture</b>	<b>Technical Writing II</b>
16+?-4+?	(4-2)	(4-0)	(?-?)	(3-2)	(2-0)
<b>QTR 5</b>	<b>OS 4680</b>	<b>SE 0811</b>	<b>TS4001</b>	<b>SE 3121</b>	<b>SE3000</b>
Spring	<b>Naval Systems Analysis</b>	<b>Thesis Research</b>	<b>Integration of Naval Systems Engineering</b>	<b>Introduction to C4ISR</b>	<b>SE Colloquium</b>
11-10	(4-0)	(0-8)	(3-2)	(3-0)	(1-0)
<b>QTR 6</b>	<b>EO 2701</b>	<b>SE 0811</b>	<b>SE 0811</b>	<b>TS4002</b>	<b>SE3000</b>
Summer	<b>Introduction to Cyber Systems</b>	<b>Thesis Research</b>	<b>Thesis Research</b>	<b>Ship Design Integration</b>	<b>SE Colloquium</b>
7-22	(4-2)	(0-8)	(0-8)	(2-4)	(1-0)
<b>QTR 7</b>			<b>SE 0811</b>	<b>TS4003</b>	<b>SE3000</b>
Fall	<b>SE Elective</b>	<b>SE Elective</b>	<b>Thesis Research</b>	<b>Total Ship Systems Engineering</b>	<b>SE Colloquium</b>
9+?-12+?	(?-?)	(?-?)	(0-8)	(2-4)	(1-0)

Foundation Skills
SE Core
SE Electives
Track Courses
Thesis Slots
Project Sequence
Graduate Success/ Professional Development

**FY19-21 SAMPLE MATRIX  
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**COMBAT SYSTEMS TRACK - 5802P**

Start Dates: October (Fall Qtr) & March (Spring Qtr)

<b>Refresher</b> Summer/Winter 15-7	<b>SE1001</b> <b>Math I for SEA</b> (4-2)	<b>SE2003</b> <b>Fundamentals of Mechanical Systems</b> (4-2)	<b>SE1002</b> <b>Math II for SEA</b> (3-1)	<b>SE2101</b> <b>Fundamentals of Electromagnetic Systems</b> (4-2)		
<b>QTR 1</b> Fall/Spring 16-7	<b>SE3100</b> <b>Fundamentals of Systems Engineering</b> (3-2)	<b>SE2440</b> <b>Intro to Scientific Computing</b> (3-2)	<b>OS3180</b> <b>Probability and Statistics for SE</b> (4-1)	<b>SE 3112</b> <b>Combat Sys Engineering I (Sensor Fund.)</b> (4-2)	<b>SE3811</b> <b>Critical Thinking</b> (2-0)	<b>Foundation Skills</b>
<b>QTR 2</b> Winter/Summer 15-6	<b>SI3400</b> <b>Engineering Project Management</b> (3-2)	<b>SE 3250</b> <b>Capabilities Engineering</b> (3-2)	<b>SE 3011</b> <b>Engineering Cost Estimation</b> (3-0)	<b>SE 4112</b> <b>Combat Sys Engineering II (Sensors Tech)</b> (4-2)	<b>SE3812</b> <b>Engineering Ethics</b> (2-0)	<b>SE Core</b>
<b>QTR 3</b> Spring/Fall 15-6	<b>SE3302</b> <b>Systems Suitability</b> (3-2)	<b>SE4150</b> <b>System Architecting and Design</b> (3-2)	<b>SE 3121</b> <b>Introduction to C4ISR</b> (3-0)	<b>SE 3113</b> <b>Combat Sys Engineering II (Weapons)</b> (4-2)	<b>SE3813</b> <b>Technical Writing I</b> (2-0)	<b>SE Electives</b>
<b>QTR 4</b> Summer/Winter 15+?-6+?	<b>SE 4115</b> <b>Combat Systems Integration</b> (4-2)	<b>SE4354/OA4603</b> <b>Test &amp; Evaluation</b> (4-0)	<b>Track Elective</b> (?-?)	<b>SE3201</b> <b>Engineering Systems Conceptualization</b> (2-4)	<b>SE3814</b> <b>Technical Writing II</b> (2-0)	<b>Track Courses</b>
<b>QTR 5</b> Fall/Spring 10-14	<b>OS 4680</b> <b>Naval Systems Analysis</b> (4-0)	<b>SE 4113</b> <b>Unconventional Weapons (CBNRE)</b> (3-2)	<b>SE0811</b> <b>Thesis Research</b> (0-8)	<b>SE3202</b> <b>Engineering Systems Design</b> (2-4)	<b>SE3000</b> <b>SE Colloquium</b> (1-0)	<b>Thesis Slots</b>
<b>QTR 6</b> Winter/Summer 7-22	<b>EO 2701</b> <b>Introduction to Cyber Systems</b> (4-2)	<b>SE0811</b> <b>Thesis Research</b> (0-8)	<b>SE0811</b> <b>Thesis Research</b> (0-8)	<b>SE3203</b> <b>Engineering Systems Implementation</b> (2-4)	<b>SE3000</b> <b>SE Colloquium</b> (1-0)	<b>Project Sequence</b>
<b>QTR 7</b> Spring/Fall 7+? - 16+?	<b>SE Elective</b> (?-?)	<b>SE Elective</b> (?-?)	<b>SE0811</b> <b>Thesis Research</b> (0-8)	<b>Track Elective</b> (?-?)	<b>SE3000</b> <b>SE Colloquium</b> (1-0)	<b>Graduate Success/ Professional Development</b>

**ESR TO COURSE CROSSWALK  
SYSTEMS ENGINEERING 580**

Curriculum Number	580			
Subspecialty Codes:	5801P - Total Ship System Design Specialization 5802P - Combat Systems Specialization			
Degree Awarded	MS SE			
<b>ESR</b>	<b>LEVEL</b>	<b>Course #</b>	<b>Course Name</b>	
1 Mathematics and Basic Sciences	1000	SE1001	Math I	
	2000	SE1002	Math II	
		SE2003	Fundamentals of Mechanical Systems	
		SE2101	Fundamentals of EM Systems	
		SE2440	Intro to Scientific Computing	
	3000	OS3180	Probability /Statistics	
2 Capability Engineering	3000	SE3100	Fund of Systems Engineering	
		SE3250	Capabilities Engineering	
3 System Architecting	3000	SE3100	Fund of Systems Engineering	
	4000	SE4150	Systems Architecting and Design	
4 Engineering Design Analysis	3000	SE3202	Engineering System Design	
		SE3302	Systems Suitability	
	4000	SE4115	Combat Systems Integration	
		OS4680	Naval Systems Analysis	
5 System Integration and Development	3000	SE3100	Fund of Systems Engineering	
	4000	SE4115	Combat Systems Integration	
6 System Verification and Validation	3000	SE3100	Fund of Systems Engineering	
		SE3250	Capabilities Engineering	
	4000	SE4354	Test & Evaluation	
7 Human System Integration	3000	OS3401	Human Factors in System Design	
		SE3302	Systems Suitability	
8 System Design	3000	SE3201	Engineering Systems Conceptualization	
		SE3202	Engineering System Design	
		SE3203	Engineering Systems Implementation	
	4000	SE4150	Systems Architecting and Design	
9 Project Management	3000	SI3400	Engineering Project Management	
		SE3011	Engineering Cost Estimation	
10 Specialization	3000	SE3112	CS Engineering I (Sensor Fund.)	
		SE3113	CS Engineering III (Conv. Weapons)	
		SE3121	Introduction to C4ISR	
		SE4112	CS Engineering II (Sensor Tech)	
		YYXXX	SE Elective #1 (indicate course)	
		YYXXX	SE Elective #2 (different course)	
		<i>for Ship Systems Track (5801P) also include:</i>		
		TS3000	Electrical Power Engineering	
		TS3001	Naval Architecture	
		<i>for Combat Systems Track (5802P) also include:</i>		
SE4113	Unconventional Weapons (CRNRE)			
SEXXX	Track Elective			
11 Cyber		EO2701	Introduction to Cyber Systems	
12 Thesis		SE0811	Thesis Research (x4)	

# COST ANALYSIS SYSTEMS ENGINEERING 580

## NPS Cost Analysis Form

CURRICULUM: Systems Engineering

LENGTH: 8 quarters with refresher

CURRICULUM #: 580

DESIGN: Resident

SUBSPECIALTY: 580X

COURSES: 24 courses with thesis

DEGREE: MS Systems Engineering/MS Engineering Systems

JPME: Yes for URL / No for EDO

NOTE: This table presents a standard cost of a curriculum for one cohort of students based principally on the number of courses contained. Implicit assumptions are that all curriculum courses are provided for the individual curriculum and their costs are attributed separately to it. In practice, courses may be shared by curricula, potentially reducing cost attributable per curriculum. Ongoing costs of curriculum administration and maintenance are included. Overhead costs are assigned using standard rates approximating experience. JPME costs are not reflected. Thesis/capstone project costs are not included in the total number of courses, but thesis/capstone project advising costs are implicit in other program costs.

NPS Cost Elements	Explanation	Examples	Type Cost	Calculation	Annual Cost (\$K)	Program Cost (\$K)	Comment
<b>Refresher Delivery Costs</b>							
Refresher Quarter	Program-level direct course delivery, by student	Faculty cost (faculty cost per student)	Direct	Assumes 25K/1 course and 4 refresher courses/quarter and 20 students per course. Calculation is 5K per student.	\$20	\$20	SE Refreshers are shared with program 308 (SEA program)
<b>Program Delivery Costs</b>							
Program Delivery / Faculty (shared courses)	Direct delivery of program, course sections	Faculty cost	Direct	Assumes \$25K per course 13 section (MOVES has 12 shared courses)	\$163	\$325	SE Combat Systems Track is shared with program 308. SE course courses of SE3201/2/3, SE3100, SI3400, SE3302, and SE4150 are shared with program 308, 311, and/or 312.
Program Delivery / Faculty (curriculum specific courses)	Direct delivery of program, course sections	Faculty cost	Direct	Assumes \$25K per course 15 section (MOVES has 22 curriculum specific courses)	\$188	\$375	
Program Administration	Program-level direct administration, by faculty	Faculty cost	Direct	Assumes 1/2 quarter FTE at \$25K	\$25	\$50	
<b>Prog. Development Costs</b>							
New Course Development	Course research and preparation for first delivery	Faculty cost	Direct	Varies by circumstance. Stnd assumption of 1/2 quarter FTE (\$25K) per course	\$0	\$0	
<b>Program Support Costs</b>							
Student Support	Special prog. support specific to the curriculum	e.g., TAD for student thesis travel. Experience tour.	Direct		\$0	\$0	
Thesis/Project Development	Administration & development of student theses in conjunction with Naval stakeholders, for deliverable output to those stakeholders.		Direct		\$0	\$0	
Technical Support - Lab	Ongoing maintenance of functionality, infrastructure & maintenance support, provided by technicians	e.g., Lab technician	Direct		\$0	\$0	
<b>Prog. Maint/Recap Costs</b>							
Academic Maintenance /Recapitalization	Recapitalization into faculty, discipline, programs	e.g., RIP, 3rd Q, Program development/ initiatives.	Direct	Assumes 1 quarter (4 courses) at \$50K and 50% of courses are staffed by tenure track faculty (Total courses/4/2*\$50K)	\$75	\$150	
Research Program	For programs with a directly-associated research program element	e.g., Funding for research seeding.	Direct		\$0	\$0	
				<b>Direct Costs</b>	<b>\$470</b>	<b>\$920</b>	
<b>Overhead Costs</b>							
Academic Organization	Schools/Departments administrative & overhead	Deans, Chairs, Department staff, Academic Labs staff	Overhead	5% on Direct Costs	\$24	\$46	
Academic Infrastructure	OH related to NPS academic/education mission	Provost, Library, Acad Affairs, Registrar, Ed Technology, Admissions, Research Office, IT	Overhead	20% on Direct Costs	\$94	\$184	
Command Infrastructure	OH related to NPS as Navy command	President, Comptroller, Com Eval, Legal, IT, PAO	Overhead	15% on Direct Costs	\$71	\$138	
				<b>OH Costs</b>	<b>\$188</b>	<b>\$368</b>	
<b>Total</b>				<b>Total</b>	<b>\$658</b>	<b>\$1,288</b>	

NPS TUITION (FY15 per student)		Annual (\$K)	Program (\$K)
Non-Naval Military	Standard Resident	\$20	\$39
Govt Civilian	Standard Resident	\$20	\$39
International	Expected Intl average	\$40	\$79
Contractor	Standard Resident	\$36	\$72

NAVAL COST (FY15 per student)		Annual (\$K)	Program (\$K)
IA: Individuals Acct	(Assumes O-4)	\$154	\$308
Medical			
Other			