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On the Fly: The Development of a Hands-On, Projects-Based Aerospace Engineering Major at West Point

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Abstract

West Point has included limited aeronautical sciences in its curriculum since 1921, graduating leaders who would play foundational roles in both the Army Air Corps (later US Air Force) and NASA. Today, the increasing integration of air, space, and ground domains has given West Point the impetus to expand its aerospace engineering curriculum. The faculty at West Point in the Department of Civil and Mechanical Engineering are currently in the process of developing the Academy's first Aerospace Engineering major and find themselves in a unique position of building it "on the fly." To create a major from inception while simultaneously enrolling the first graduating class (2028) into the program, they must develop and gain approval for each subsequent year's curriculum only a year ahead of the students taking the courses. This paper will be the first in a series documenting and exploring the development of the new Aerospace Engineering major at West Point over the next four years. It will provide a brief history of aerospace engineering at West Point and summarize the current program within the Mechanical Engineering major. It will define the current 47-month core cadet experience and highlight its unique constraints on the available credit hours for the aerospace engineering curriculum. It will discuss how and why the faculty converged on the final Aerospace Engineering Curriculum informed by benchmarking against peer institutions. It will explore how the fledgling department will leverage both new aerospace engineering courses and existing mechanical engineering courses for curriculum and faculty optimization. The desired end state is a program that both satisfies ABET Accreditation requirements and maximizes high-quality instruction with projects-based, hands-on learning leveraging flight laboratories in the department's aircraft, a new wind tunnel (under construction), summer internships with DoD and industry partners, and culminating in a sponsored capstone design project.

Key words: Aerospace Engineering, education, curriculum development, program development

Introduction/Motivation

According to STEM education data from the U.S. National Science Foundation from 2002-2012, Aerospace Engineering had the largest percentage change of engineering fields,, while the number of bachelor's degrees in aerospace engineering more than doubled during that 10-year period [1]. The U.S. Bureau of Labor Statistics' Occupational Outlook Handbook forecasts that the demand for aerospace engineers will continue to increase, with a projected job growth of 6% between 2023 and 2033 [2]. Such data supports trends that are easily observable with the growth of the airline industry, commercial space races with companies such as Blue Origin and SpaceX, and the proliferation of drone technology. As a result, several universities have inaugurated aerospace engineering programs. Notably, the University of California, Berkeley, launched an aerospace engineering program in the fall of 2002 [3], and Michigan Technological University is prepared to launch its program in the fall of 2025 [4].

Air and space growth is not limited to the civilian sector, as recent conflicts have demonstrated an increased reliance on the air and space domains to support ground combat operations, communications, and navigation. As of 2023, the U.S. Army already operates a fleet of 21 different types of aircraft with over 3900 crewed aircraft, including the world's largest helicopter fleet with over 3700 helicopters. In addition, the Army operates over 700 large uncrewed aircraft systems (UAS), accounting for 61% of the DoD's inventory [5]. Combat trends indicate that these numbers will only increase, particularly with small UAS (sUAS) or "drones." Of the Army's six modernization priorities, aerospace engineering directly or indirectly supports four (future vertical lift, long-range precision fires, network technologies, and air and missile defense) [6]. Yet, unlike its sister service academies, the Army's premier leader development institution lacks an internal way to create Aerospace Engineers.

By directive of the Dean of the Academic Board, Brigadier General Shane Reeves, and with the approval of the Secretary of the Army and the United States Congress, West Point is now creating an undergraduate aerospace engineering major for the first time in its 200+ year history. The faculty at West Point in the Department of Civil and Mechanical Engineering are currently in the process of developing the Academy's first Aerospace Engineering major and find themselves in a unique position of building it "on the fly." Their task is to create a major from inception, with the first classes taught in fall 2025. They must simultaneously enroll the current freshmen into the program and develop and gain approval for each subsequent year's curriculum only a year ahead of the students taking the courses. They will graduate the first students in 2028 and seek initial ABET accreditation in 2029.

A Brief History of Aerospace Engineering at West Point

Officially established in 1802 by Thomas Jefferson as a military academy to train cadets in the study of artillery and engineering, West Point first gained accreditation in 1925 and began granting general Bachelor of Science degrees in 1933. It was not until 1985 that cadets could declare academic majors. Since 1985, West Point has not offered a major in Aerospace Engineering; rather, it offered electives, concentrations, and a minor in Aerospace Engineering as part of its Mechanical Engineering Major [7].

When the Wright brothers first took flight in 1903, math, science, and engineering constituted 68% of a cadet's four-year curriculum [8]. A little over a decade later, World War I clearly demonstrated the important role that airplanes and the air domain play in land warfare; the character of war was forever changed. The war served as an impetus for the inclusion of aeronautical sciences in the West Point curriculum, which started in 1917 when the Head of the Department of Natural & Experimental Philosophy, Lieutenant Colonel C.C. Carter, added elements of aerodynamics to the Academy's Mechanics course [8].

But simple exposure to elements of aerodynamics was insufficient in the view of an officer in the Technical Section of the Division of Military Aeronautics, Colonel Thurman H. Bane. In a 1918 memorandum to the Superintendent of West Point (then Brigadier General Douglas MacArthur), Bane wrote, "With the great and constantly increasing importance of aviation, it is essential that there should be a permanent group of officers who are aeronautical engineers [9]." Despite an attempt by Carter to develop a course in collaboration with the Massachusetts Institute of Technology, West Point rejected the curriculum proposal. Due to the ongoing war, cadets' studies at the time were compressed to three years instead of four. Hence, it was the Academy's position that "it was not feasible to teach Aerodynamics because there was insufficient time to teach the cadets all of the required pre-requisite subjects in sufficient depth [8]."

By 1920, with the war over, the academy returned to a four-year curriculum, and a request was again made to the Superintendent to incorporate aerodynamic studies, this time by Chas T. Menoher, the Chief of the Air Service. In 1921, Brigadier General Douglas MacArthur authorized the inclusion of aerodynamic topics into the existing Mechanics course to "broaden the curriculum so as to be abreast of the best modern thought on education, and to bring West Point into a newer and closer relationship with the Army at large [10]." The curriculum was comprised of 18 lessons ranging from sustentation (lift) to aircraft performance and stability [11]. In a subsequent memorandum to the Air Service, MacArthur noted that "…instruction is made as practical as possible by using charts, graphs, models, results of wind tunnel tests, lantern slides, films, lectures, and actual demonstrations of an airplane [12]."

From that time until the present, the aerospace curriculum at West Point and the degree to which it has been included varied widely. The Department of Natural & Experimental Philosophy and the Engineering departments eventually morphed into the current Department of Physics and Nuclear Engineering (PANE) and the Department of Civil and Mechanical Engineering (CME). However, practical teaching methodologies have continued to be a mainstay of CME's teaching philosophy. Since 1970, West Point has used military-owned, general aviation, single-engine fixed-wing aircraft and military helicopters to conduct Flight Laboratories as an essential part of the aeronautical curriculum within Mechanical Engineering. Fixed-wing flight labs have been and continue to be flown by Army aviators within the department, serving as instructors or professors, while helicopter flight labs are flown by West Point's 2nd Aviation Detachment with oversight and onboard instruction by department's aerospace faculty. A 2005 paper presented by the flight section within the department [13] succinctly articulates the five main goals of the program:

> *1. To provide students with quality, hands-on instruction one-on-one with their instructor in an actual aircraft.*
> *2. To build technical understanding of the aerodynamics and performance of airplanes and helicopters for both students and instructors.*

3. To validate theory presented in the classroom through hands-on application.
4. To reinforce the test and experimentation aspect of engineering.
5. To excite students about aerospace engineering and to inspire in them the desire for continued learning.

Beginning in 2017, select mechanical engineering students had the opportunity to pursue a minor in aeronautical engineering consisting of a three-course sequence: *ME387: Introduction to Applied Aeronautics, ME388: Helicopter Aeronautics, and ME481: Aircraft Performance and Stability*. All these courses include class trips to defense and commercial manufacturers, flight laboratories, and demonstrations using physical models and the AEROLAB Educational Wind Tunnel (EWT). These courses are also available to other Mechanical Engineering students as electives.

Initial SWOT Analysis

The first step in the development required a SWOT analysis to determine how to build on what we have within the constraints to satisfy stakeholders' (DoD, cadets/students, research sponsors, graduate programs, etc.) requirements. This analysis allowed us to understand and consider the key factors (strengths, weaknesses, opportunities, and threats) involved.

Strengths:

- Existing Curriculum: Like UC Berkeley and Michigan Tech, West Point aerospace engineering is evolving from an existing minor within a larger nationally ranked mechanical engineering program.
- Existing Talent: West Point's Mechanical Engineering program is tied for #6 with the U.S. Air Force Academy in the 2025 U.S. News and World Report Rankings for schools not offering a doctorate degree [14].
- Academic Flight Program: The existing Academic Flight Laboratory program and associated Aeronautical Instructors who are also pilots and can bring realism and operational experience to the classroom. The program has modern aircraft with advanced diagnostics, instrumentation, and data collection opportunities.
- Existing Resources: There are existing undergraduate laboratories and hands-on experiences for overlapping topics.
- Established Research and Design Curriculum: The department also has an established two-semester capstone and a robust independent study program.
- Academy Structure: The Academy enforces small class sizes and a high faculty-to-student ratio. There is already an existing vibrant interest at West Point in Aviation, Aeronautics, and Space as demonstrated by existing cadet activities, clubs, and research.

Weaknesses:

- Curricular Constraints: A West Point cadet's 47-month experience differs vastly from that of their civilian undergraduate counterparts; all cadets must take 24 common courses (ranging from military history to physics) as part of the core USMA Academic Program (Table 1). While cadets currently declare a major in the second semester of their plebe (freshman) year, their first year is standardized. They do not take courses within their major until their second year, and even then, only one or two per semester. Additionally, cadets (with rare exceptions) must graduate in four years, so they have a highly constrained schedule. While these constraints are limiting, they are not insurmountable; there are already seven different engineering majors available.
- Aero-Specific Faculty: The department has limited aerospace engineering faculty, and a majority are junior rotators (active-duty military who earn an M.S. in Aerospace Engineering from a civilian school, teach for three years at West Point, and return to the operational Army). There are only two permanent military professor positions with PhDs in aerospace engineering in the department. Faculty growth is limited to the hiring of two additional civilian PhD associate professors and one civilian instructor (M.S. or PhD). Finally, there is a current lack of fully developed aerospace research facilities (research-grade wind tunnel, rocket test stands, etc.).

Opportunities:

- Collaboration: A new aerospace major will broaden the opportunities for collaboration with programs from other academies and universities to include graduate programs for technical scholarships or graduate degrees for returning faculty.
- Modernized Facilities: The academy is building a new 136,000-square-foot state-of-the-art Cyber and Engineering Academic Center (CEAC) to enable and inspire collaboration across engineering disciplines [15]. Completion is scheduled for 2026. While this building was designed and planned prior to approval of the aerospace engineering major, it included improved facilities for the aeronautical engineering minor to include space for low- and high- speed wind tunnels, a rocket test stand, and a high bay for sUAS testing.
- Interdisciplinary Study: The interdisciplinary nature of aerospace offers new opportunities for collaboration with Electrical Engineering and Computer Science (EECS), Systems Engineering (SE), and PANE.

Academic Program	Credit Hours
Mathematics	19.5
Chemistry	4
Physics	8
Engineering	55.5
Information Technology	3
Literature and Writing	6
Physical Geography	3
Philosphy and Law	6
History	9
Foreign Languages	8
Psychology and Leadership	9
Political Science and International Relations	6
Economics	3
Academic Program Total	140
Military Program	**Credit Hours**
Military Science	4.5
Physical Program	**Credit Hours**
Physical Education / Heath and Wellness	5.5
4 Year Cadet Experience Total	**150**

Table 1: Standard 4-Year Cadet Curriculum

Threats:

- Disciplinary Depth: 100 years have passed since the first introduction of aeronautics at West Point, but history has a funny way of repeating itself. Both incidents were motivated by the importance of air (and now space) in ground combat. But more interestingly, similarly to the reason the inclusion of the material was initially rejected in 1918 (three years was insufficient for the breadth and depth of required topics), the new major must fit into a different three-year constraint while satisfying ABET requirements. The high core course load makes the depth of studies more difficult.
- Constraints to Growth: West Point faculty are likely in a zero-growth phase; an inability to hire the additional three civilian personnel could put the development and execution of the curriculum at risk. The program will limit enrollment to 40 cadets (two sections) for the inaugural class, but it must meet the minimum requirements for the curriculum.
- Facility Availability: Extended delays in the construction of the CEAC or the wind tunnels could impact instruction of the first class and impact ABET accreditation. Because ABET evaluation and accreditation require students to have graduated from the program, the initial four student year groups enrolled

(2028, 2029, 2030, 2030) will commit to the major on the assumption that the program will be accredited in 2029.

The SWOT analysis identified a path forward: the new aerospace program nests within and leverages existing complementary programs to the maximum extent possible to satisfy math and basic sciences credit hours and engineering topics (ET) requirements while leveraging the breadth of expertise required for curriculum development and instruction.

Benchmarking

West Point requires that all engineering programs be ABET-accredited. Hence, the proposal and initial planning for the major were built based on ABET's general and program criteria from the outset. The current ABET aerospace program criteria provide three options. Programs can either be aeronautical, astronautical, or aerospace in nature. For accreditation of an Aeronautical Engineering undergraduate degree, the program must contain sufficient depth in the topics of aerodynamics, aerospace materials, structures, propulsion, flight mechanics, and stability and control. For an astronautical program, there must be sufficient depth in the topics of orbital mechanics, space environment, attitude determination and control, telecommunications, space structures, and rocket propulsion. Aerospace programs provide a blend of both disciplines and must cover all six topic areas from either aeronautical or astronautical engineering and at least two topic areas from the other [16]. Based on the guidance from the Dean's analysis teams, our proposal focused on an aerospace program to cover both aeronautical and astronautical topics (Table 2).

The proposal team made the decision to cover six topic areas in aeronautical engineering and two from astronautical engineering for two reasons. First, the existing mechanical engineering and aeronautical engineering courses at the academy made this approach the least risky in terms of accreditation. West Point was closest to achieving the aeronautical requirements based on coursework in ME and the existing aeronautical electives. Therefore, to go further and satisfy the aerospace engineering degree, space topics could be easily incorporated into the current ME and AE courses, included in the development of new courses, and/or leveraged in at least two courses in the PANE Space Sciences major with space engineering topics incorporated. Second, historical enrollment and a recent survey of cadets indicated a greater level of interest in aeronautical topics than astronautical.

A team of faculty members from the Academy with aerospace engineering backgrounds conducted two rounds of benchmarking. The first round consisted of an analysis of two other service academies the United States Naval Academy (USNA) and the United States Air Force Academy (USAFA) as well as aspirant Aerospace Engineering programs throughout the country to determine the relative size and scope of those programs. The aspirant schools included Stanford, MIT, the University of Maryland, Georgia Tech, and Penn State.

Course(s)	Aeronautical	Astronautical	Course(s)
AE481	Aerodynamics	Orbital Mechanics	SP471
MC380	Aerospace Materials	Space Environment	SP472
AE364	Structures	Attitude Determination and Control	N/A
AE354	Propulsion	Telecommunications	EE477
AE287, AE473	Flight Mechanics	Space Structures	AE364
AE473	Stability and Control	Rocket Propulsion	AE354

Table 2: ABET Topic Coverage (Green=sufficient depth, Yellow = insufficient depth)

The proposal West Point faculty created was comparable to the aspirant schools in terms of math and science credits. However, they all have fewer core requirements than West Point and the other service academies. Hence, their programs can cover the aerospace program criteria in greater depth. Many of the programs have both an introductory course and an advanced course in several of the criteria topics, whereas our program can only afford to have a single course in each topic. All the programs have a comparable number of courses and credits dedicated to the design and capstone process. All the other programs also have greater opportunities for technical electives, with up to three required to complete the degree, compared to the one technical elective in our proposal. While this difference will not affect the accreditation efforts, it does limit the amount of specialization or focus a student can take. Due to the need to satisfy eight topic areas required for an aerospace major, the major will be largely prescriptive, with only one introductory and one technical elective option. If the program criteria are relaxed in future ABET requirements, that structure could change to allow for additional electives. Ultimately, it is desirable to have a small (3-4 course) elective track that is modular and would allow the major to stay relevant with current technology and provide cadets the opportunity to achieve more depth in topic areas such as unmanned systems, autonomous flight, satellite design, rotorcraft, and hypersonics.

The other major difference between our proposal and the other schools is that most of the other programs feature labs and experimentation in a separate course. At West Point, the labs are typically integrated into the appropriate course with an additional 0.5 credit hours. Finally, the biggest difference was the significant emphasis on hands-on experiences at West Point, to include the academic flight program. This is an important feature that will continue to make our program unique. Given the nature of what our graduates will do after graduation compared to aspirant institutions, the decision was to retain it within the program.

During the second round of benchmarking, the team focused on the programs offered at USAFA and USNA, primarily because they operate under similar constraints with a high number of required courses in the core curriculum. USNA's aerospace engineering program provided the best model for this proposal. In contrast, USAFA offers both aeronautical and astronautical programs, but not a single aerospace program like the Naval Academy. Thus, the current proposal was modeled on USNA's. Their chair, Dr. Chris Pettit, and one of their professors, Dr. Jin Jang, were particularly helpful in providing information on their courses and structure as well as feedback during this process.

In its current form, the program proposal is comparable to the aerospace program at USNA in terms of course count and topics reflected in the ABET program criteria. The largest difference between the programs is the number of credit hours devoted to materials and structures (USNA has more) and design (USMA has more). Figures 1 and 2 are sample products used to benchmark West Point's existing ME major with AE minor against the USAFA aeronautical engineering major and the USNA aerospace major, respectively.

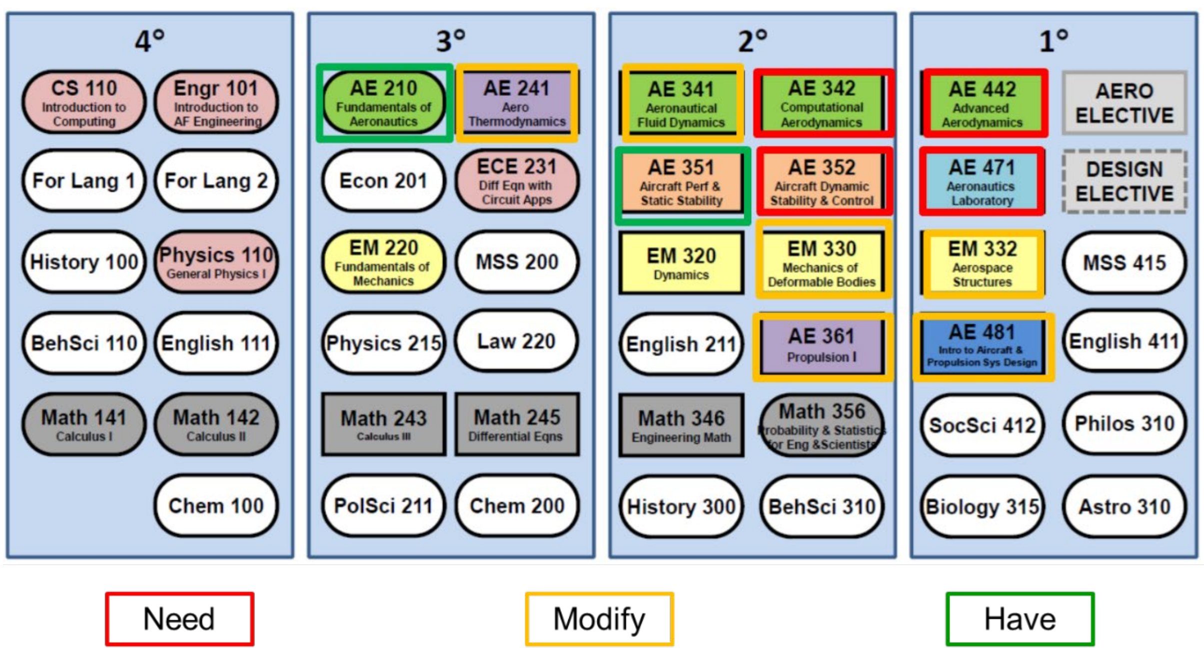

Figure 1: USAFA Benchmarking

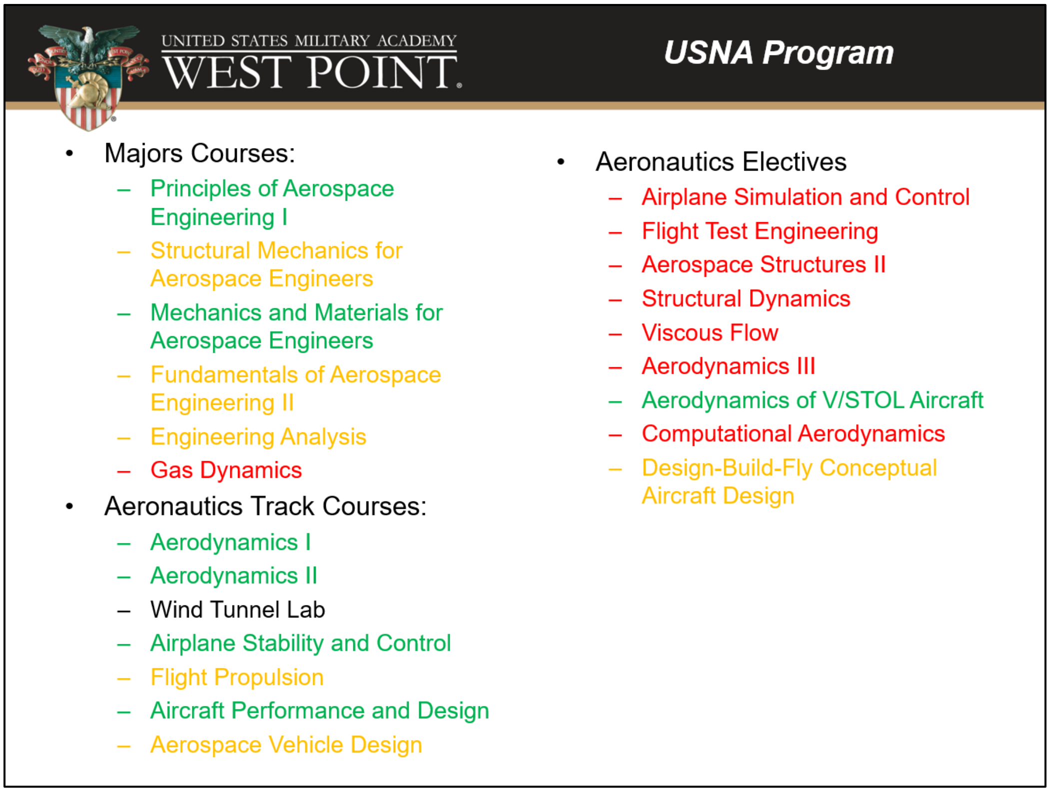

Figure 2: USNA Benchmarking. Courses designated in Red represent gaps in our curriculum, amber are courses for which similar courses exist but must be modified, and green are courses which exist in similar form.

Course Selection and Mapping

As part of the benchmarking, detailed comparisons were conducted by course/subject matter. Table 3 shows an example of a lesson-by-lesson comparison of *EA322: Structural Mechanics for Aerospace Engineers* (USNA) to an existing mechanical engineering course at USMA, *MC364: Mechanics of Materials*. Comparisons were conducted for each of the ABET topic areas from Table 2 using course materials (both open source and provided by those programs) for a variety of courses from aspirant programs, USAFA, and USNA.

These detailed comparisons served several purposes. First, they allowed the team to look both externally and internally to determine if efficiencies could be gained by leveraging existing courses within West Point CME, PANE, and EECs while satisfying the ABET requirements to the same breadth and depth as other programs without creating new courses. Second, if it was determined that existing course content was insufficient and modification of an existing course to satisfy the requirements was not possible nor desirable, it justified the creation and prioritization of new course development. Third, if the necessity to create a new course existed, it provided a means to recommend what concepts should be included in the new course. Fourth, it allowed the team to draft initial course descriptions for provisional approval by the curriculum committee and the Dean's office. Fifth, it allowed a pre- and co-requisite mapping (Figure 3) necessary to sequence the courses into the cadets' rigid 8-term academic plan (8TAP) (Figure 4). Lastly, these course comparisons will be used to develop each course and all subsequent materials (including textbook selection) for approval by the curriculum committee on the prescribed timeline.

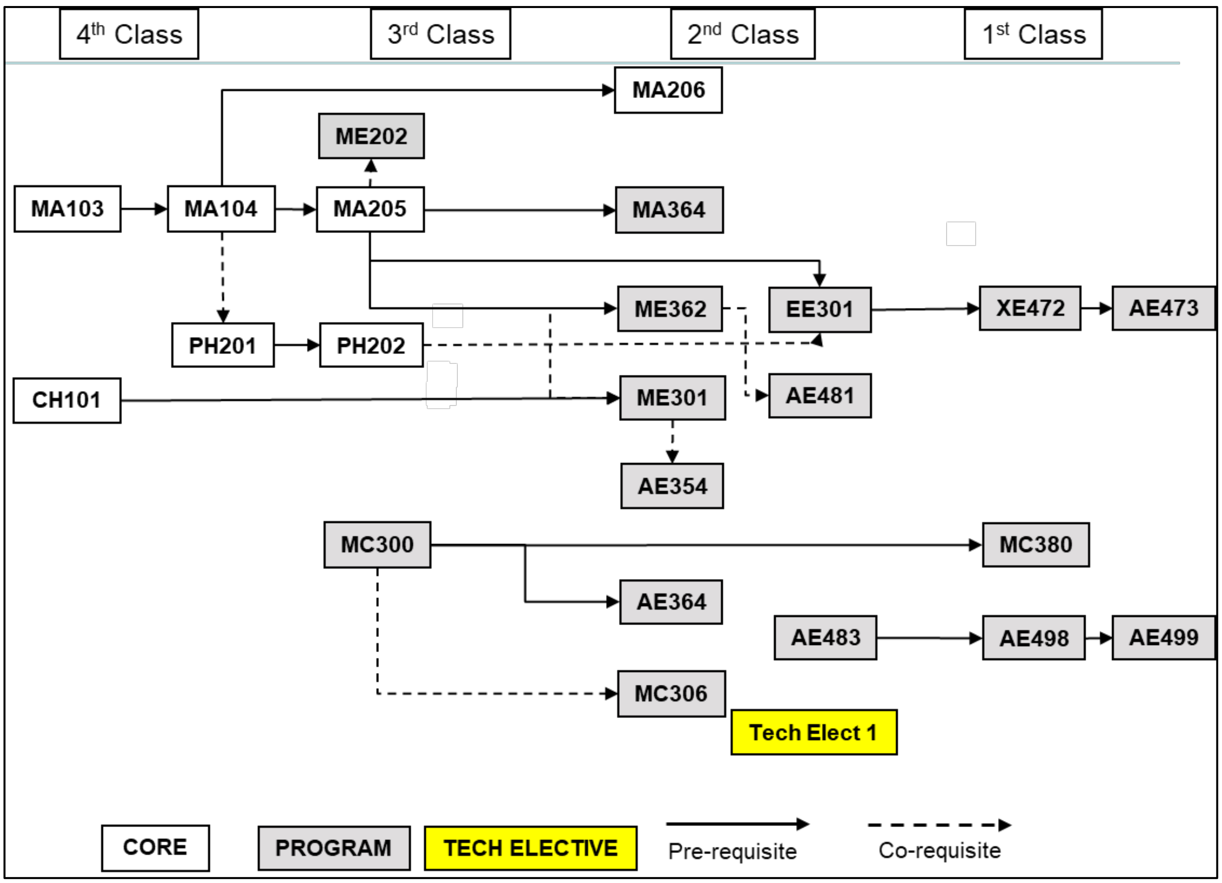

Figure 3: Pre- and Co- Requisite Mapping

Comparison of EA322 and MC364

EA322 Lesson #	Summary of EA322 Topics	MC364 Lesson #
1	Course Intro & EA222 Review	
2	Aircraft Structures & Materials	
3	Loads on Aerospace Structures	
4	Quiz on EA222 Review	
5	Load Paths & Types in Aerospace Structures	
6	Displacement and Strain	
7	Stress	22
8	Stress Components & Vector, Eqns of Equil	23
9	Principal Stresses and Max Shear Stress	24
10	Quiz 1 & Stress Transformation	23
11	Generalized Hooke's Law	26
12	Plane Elasticity	
13	Torsion (Arbitrary or Circular)	9, 10
14	Torsion (Narrow Rectangular)	
15	Torsion (Closed, Single-Cell, Thin-Wall)	
16	Torsion (Multi-Cell, Thin-Wall)	
17	BEBT Beam Bending & Flexural Shear	12-20
18	BEBT (Cont.)	12-20
19	Quiz 2 & Structural Idealization	
20	Transverse Shear	
21	Transverse Shear (Cont.)	
22	Saint Venant's Principle	
23	Failure Modes: Structural & Material; Failure - Ductile	33
24	Failure - Ductile (Cont.)	33
25	LEFM: SCF & Crack Growth	
26	LEFM: SCF & Crack Growth (Cont.)	
27	LEFM: SIF & Fracture Toughness	
28	Crack Tip Plasticity & Fracture Toughness	
29	Fatigue	
30	Euler Buckling of Beam	4
31	Column Buckling w/ Lateral Supports	
32	Buckling of Thin-Wall Structures	
33	Quiz 4 & Buckling Problems	
34	Safety Margins and Factors	33,34
35	Joining of Structures & Manufacturing	
36	Joining of Structures & Manufacturing (Cont.)	
37	Joining of Structures & Manufacturing (Cont.)	
38	Fuselages	
39	Wing Spars	
40	Quiz 5	

LEGEND
Covered (at least in part) in MC364.
Also recommended for AE364.
Not recommended for AE364.

Table 3: Course Content Comparison by Lesson

Figure 4 depicts the approved Generic USMA Aerospace Engineering Major 8TAP. Note only the last three years are shown since the major does not have any ability to alter the first year of cadet classes.

26-1	26-2	27-1	27-2	28-1	28-2
MA205 Calculus II (4.0)	PY201 Philosophy (3.0)	ME362 Fluid Mechanics (3.5)	EE301 Circuits (3.5)	XE472 Dynamic Modeling and Control (3.5)	AE473 Stability and Control (3.5)
PH202 or PH275 Physics II (4.0)	EV203 Physical Geography (3.0)	ME301 Thermodynamics (3.5)	AE481 Aerodynamics (3.0)	AE380 Aerospace Materials (3.0)	MX400 Officership (3.0)
MC300 Statics/Strengths (3.0)	AE201 Intro to Aerospace Engineering (3.5)	MC306 Dynamics (3.0)	AE354 Propulsion (3.5)	AE498 or XE485 AE Design or Eng. Capstone I (3.5)	HI302 Military Art (3.0)
LXYY3/1/5* Foreign Lang 1 (4.0/4.0/3.0)	LXYY4/2/6* Foreign Lang 2 (4.0/3.0/3.0)	AE364 Aerospace Structures (3.0)	AE483 Aerospace Design (3.0)	SS307 Intl Relations (3.0)	AE499 or XE495 AE Design or Eng. Capstone II (3.5)
AE287 or SP471** Intro to Aeronautics or Astronautics (3.0)	SS202 Political Science (3.0)	PL300 Leadership (3.0)	MA206 Probability and Stats (3.0)	LW403 Law (3.0)	Technical Elective (Choice) (3.0/3.5)
SS201 Economics (3.0)	MA364 Eng. Math (3.0)			AE400 Aerospace Eng Seminar (1.0)	
20/21 credits	**18.5/19.5 credits**	**16 credits**	**16.5 credits**	**17 credits**	**16 credits**

Elective Choices (Choose 1 of 8)

Elective	Title (Term offered, if not both)	Pre-Requisites
AE287	INTRODUCTION TO AERONAUTICS (1)	-
AE388	VTOL AERONAUTICS (2)	AE201 (CO-REQ)
AE389	IND STUDY IN AEROSPACE ENG	-
AE489	ADV IND STUDY IN AEROSPACE ENG	Permission of AE Div Director
EE381	SIGNALS AND SYSTEMS (1)	EE301
ME480	HEAT TRANSFER	ME301, MA364
SP471	ASTRONAUTICS (1)	PH202 or PH275
SP472	SPACE PHYSICS (2)	MA205, PH202 or PH275

Figure 4: Final Templated USMA Aerospace Engineering Major 8TAP

Course Descriptions and Development Plan

This section provides the course descriptions that were presented by the team of aerospace engineering faculty members to the curriculum committee that subsequently received provisional course approval for inclusion in the Academy's official Academic Program Curriculum and Course Descriptions Catalog known as the "Red Book". These course descriptions and the detailed course comparisons will inform course development.

AE201 Intro to Aerospace Engineering: This course provides an overview of the field of Aerospace engineering and an introduction to engineering analysis through modeling, simulation, and experimentation. AE201 introduces structured programming for engineering applications and an overview of solid modeling using Computer Aided Design.

AE354 Propulsion: This course applies the fundamentals of thermodynamics to the study of air-breathing (turbojets, turbofans, and turboprops/turboshafts) and non-air-breathing (rocket) air vehicle propulsion systems. Propulsive forces and performance parameters for these propulsion systems will be explored. Propeller characteristics and performance of electric and hybrid-electric propulsion systems are introduced

AE364 Aerospace Structures: This course covers the introduction of mechanics of materials and introduction to linear elasticity, including stress and strain, generalized Hooke's law, thin-walled pressure vessels, and principal stresses. The course also covers the form and function of aerospace structural components, materials allowable, and factors and margins of safety. Flight and ground loads and the bending of beams having asymmetric cross-sections are covered as they relate to aerospace structures. Shear flow analyses of stress in idealized semi monocoque cross-sections and the elastic buckling of columns and thin-wall structures are introduced.

388 VTOL Aeronautics: The aerodynamics of vertical flight is analyzed for hover, translating, and partial power flight. Theory and experimental results are used to predict aircraft performance. The course analyzes the dynamic response of a rotor system and the performance aspects of the vehicle. This is followed by a design workshop, during which cadets complete the initial sizing of a vertical aircraft to meet specific mission requirements. The course includes one flight lab in a helicopter, a laboratory examining rotor power and thrust utilizing a whirl stand apparatus, and one field trip to a commercial helicopter company.

AE400 Aerospace Seminar: This seminar consists of a series of guest speakers. It will include all cadets majoring in aerospace engineering. Guest Speaker topics will address the concerns of professional aerospace engineers such as engineering ethics, continuing education, engineering economy, social and safety considerations, and professional registration. Guest lecturers will be primarily aerospace engineering practitioners, providing the students with an opportunity to interact with professionals in their major field of interest.

AE473 Stability and Control: This course introduces aircraft static and dynamic stability and control. The course develops and provides the tools required to analyze and design the stability and control attributes of an aircraft in preparation for aircraft design

AE481 Aerodynamics: A course on the fundamentals of incompressible inviscid fluid mechanics and 2-D aerodynamics. Topics include fluid statics, flow kinematics, integral and differential forms of the governing equations, potential flow theory, and thin-airfoil theory. Applications emphasize aeronautics-relevant topics. This course provides knowledge of the fundamentals of fluid mechanics and aerodynamics. Fluid mechanics as applied to the theory of flight prepare students to understand external flows over aircraft including wing design, drag build-up, and viscous phenomena. The course concludes with an introduction to modern computational fluid dynamic tools.

<u>AE483 Aerospace System Design:</u> This course covers the fundamentals of aircraft and spacecraft design. Topics include understanding the mission and payload requirements, sizing methods, understanding design space, and tradeoffs. Students will be introduced to typical design and analysis tools used in the industry.

<u>AE498 Aerospace Engineering Design</u>: This course serves as the first half of the aerospace engineering capstone design experience. Cadets apply the aerospace system design process and their knowledge of math, science, and engineering mechanics to design solutions to real-world engineering problems. They must address public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors. Students begin capstone assignments early in the course and continue their projects with AE499.

<u>AE499 Aerospace Engineering Design II:</u> This course provides experience in the integration of math, science, and engineering principles into a comprehensive engineering design project. Open-ended, client-based design problems emphasize a multidisciplinary approach to total system design providing multiple paths to a few feasible and acceptable solutions which meet the stated performance requirements. Design teams are required to develop product specifications, generate alternatives, make practical engineering approximations, perform appropriate analysis to support the technical feasibility of the design, and make decisions leading to an optimal system design. System integration, human factors engineering, computer-aided design, maintainability, and fabrication techniques are addressed. This course provides an integrative experience in support of the overarching academic program goal and is often interdisciplinary in nature.

Course Development

Table 4 shows an ET credit crosswalk between the USMA AE and ME programs. It also visually depicts which courses need to be created, which require modification, and which are existing and satisfy the requirements. Figure 5 depicts the planning, approval, and execution timeline for the provisionally approved courses for the Aerospace Engineering Major (AEN0). USMA AE and ME faculty will develop courses while simultaneously teaching the previously approved courses, on the fly. These courses, in their entirety, to syllabus, textbook, course objectives, lesson objectives, etc., must undergo review and final approval by the Curriculum Committee no later than 12 months prior to their debut. Once approved and at least 6 months prior to debut, the faculty will then create detailed lesson plans and board notes. Prior to presentation to the committee, courses undergo informal reviews by the Academy's Math, Science, and Engineering (MSE) Committee and an internal Academy ABET Advisor committee.

The department also has four internal faculty ABET-PEVs to provide consultation during course development.

AE				ME		
Course:	ET Credits	Course Count:	Pre/Co Req	Course:	ET Credits	Course Count:
MC300	3.0	1	PH201 Co	MC300	3.0	1
AE201	3.5	2	MA205 Co	ME202	3.0	2
AE287	3.0	3		Tech 1	3.0	3
ME301	3.0	4	CH101, MA205	ME301	3.0	4
ME362	3.5	5	PH201, MA205	ME362	3.5	5
MC306	3.0	6	PH201, MC300 Co	MC306	3.0	6
EE301	3.5	7	MA205, PH202 Co	EE301	3.0	7
AE481	3.0	8	ME362	Tech 2	3.0	8
AE354	3.0	9	ME301	ME403	3.5	9
AE364	3.0	10	MC300	MC364	3.5	10
AE483	3.0	11		ME201	3.0	11
AE498	3.0	12	AE483	ME480	3.5	12
MC380	3.5	13	MC300	MC380	3.5	13
XE472	3.5	14	EE301, MA205	ME404	3.5	14
Tech 1	3.0	15		DS Elect	3.0	15
AE499	3.5	16	AE498	Tech 3	3.0	16
AE473	3.0	17	XE472, MC306	ME496	3.5	17
AE400	1.0			ME400	1.0	

AE	
ET Count:	55.0
Course Count:	17

ME	
ET Count:	55.5
Course Count:	17

Legend
Existing
Modify/Admin
Create

Table 4: USMA AE vs ME ET Credit Crosswalk

Course	24-3	25-1	25-2	25-3	26-1	26-2	26-3	27-1	27-2	27-3	28-1	28-2	28-3	29-1	29-3
AE201	Develop	Submit FEB24	Approve	Course Prep		Debut									
AE287	Develop	ADMIN change	Approve		Debut										
AEX89		Outline	Submit FEB25	Approve				Debut							
AE364	Outline	Outline/ Develop	Develop	Develop	Submit DEC25	Approve	Course Prep	Debut							
AE354	Outline	Outline	Develop	Develop	Develop	Submit MAR26	Approve; Prep	Course Prep	Debut						
AE388						ADMIN change	Approve		Debut						
AE481	Outline	Outline	Develop	Develop	Develop	Submit MAR26	Approve; Prep		Debut						
AE483	Outline	Outline	Develop	Develop	Develop	Submit MAR26	Approve; Prep		Debut						
AE400					Develop	Develop	Develop	Submit DEC26	Approve	Course Prep	Debut				
AE498					Develop	Develop	Develop	Submit DEC26	Approve	Course Prep	Debut				
AE473			Outline			Develop	Develop	Develop	Submit MAR27	Approve; Prep		Debut			
AE499						Develop	Develop	Develop	Submit MAR27	Approve; Prep		Debut			
AME & ABET	PUSMA Selected	Hire x2 T10, 1x Tech	AP Selected	MAE IOC T10 start Tech start	PhD Mil Selected			CEAC Open		MAE FOC	AE Record Year	First Grad	Self Study	ABET Visit	Accred-itation

Not started

Working

Complete

Behind/At Risk

Figure 5: Curriculum Development Timeline

Program Assessment Plan

The program will have a well-documented assessment plan in accordance with the requirements for continuous improvement from ABET and the strong history of assessment in the mechanical engineering program. As courses are refined, the program director will identify direct indicators that will serve as input to assess the attainment of Student Outcomes (SOs). The program's courses will be divided into four threads for continuity purposes. Those threads will be Aerodynamics and Flight Mechanics, Structures and Materials, Propulsion and Design, and Astronautics. For the first three years of the program, the thread leaders will conduct course assessments every academic year to determine the initial attainment of student outcomes and recommend improvements to the courses in those threads. This frequency will continue until the first ABET accreditation visit, most likely in the Fall of 2028. After that point, the thread assessments will occur a minimum of every two years, unless directed more often by the program director. An external ABET Advisory committee will support these efforts. Table 5 identifies how the courses in the major will support the Student Outcomes required of the major and by ABET. If future ABET criteria change to less restrictive as proposed, we are confident that our focus on the previously prescribed topics will allow us to satisfy those new requirements with little modification.

Conclusion/Summary/Takeaway

While West Point's 4-year academic program and its associated constraints can seem wildly different than those of an aspirant college or university, the challenges and requirements faced during the creation of a new aerospace engineering program are universal. Every institution that develops a new program will have constraints, be it time, resources, facilities, faculty, or ABET requirements. It is the authors' intent to share the methodology leveraged at West Point in the hope that it can be useful to other programs.

When developing a new program, establishing, maintaining, and leveraging strong relationships with other departments within the same university and similar programs at other universities is essential. Every single university, professor, or program we contacted offered their assistance and made their course syllabi, assignments, and material readily available for benchmarking. Without their support, the support of West Point, and the monumental efforts of many faculty in CME, PANE, and EECS, we would not be able to build this program –on the fly.

		AE Student Outcomes 1-7 (Identical to ABET Criterion 3 1-7)						
Course	3 = strong relationship 2 = strong to medium relationship 1 = weak relationship blank = very weak or no relationship	Solve complex problems using MSE	Design with constraints	Communication	Professional, ethical	Teams	Experiments	Learning
Required Courses								
AE201	Intro to Aerospace Engineering	2		2	3	2		2
AE287 or SP471	Intro to Aeronautics or Astronautics	3				2	3	2
AE354	Propulsion	3	2			2	2	1
AE364	Aerospace Structures	3	1			1		1
AE400	Aerospace Engineering Seminar	1	2	3	3			3
AE473	Stability and Control	3	2				3	2
AE481	Aerodynamics	3	1	1				
AE483	Aerospace Design	3	3	2	2			1
MC306	Dynamics	3				1		1
MC380	Engineering Materials	3		1	1	2	2	1
ME202	Computer-Aided Design	3	3				3	
ME301	Thermodynamics	3				1		1
ME362	Fluid Mechanics	3		3		2	3	1
XE472	Dynamic Modeling and Control	3		1			1	
CSCs								
EE301	Fund of Electrical Engineering	2						
MA364 or MA365	Engineering or Advanced Engineering Mathematics	2						
MC300	Fund of Engineering Mechanics and Design	2	1	1		1		
Integrative Experience								
AE498 or XE485	Aerospace System Design I or Engineering Capstone I	3	3	3	3	3		3
AE499 or XE 495	Aerospace System Design II or Engineering Capstone II	3	3	3	3	3		3
Science and STEM Depth								
PH202 or PH 275	Physics II or Intro to Space	2						
MA205 or MA255	Calculus II	2						

Table 5: ABET AE Student Outcomes Crosswalk

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30 April 2025

We would like to take the time to thank our reviewers for their time and thoughtful consideration of our Paper *"On the Fly: The Development of a Hands-On, Projects-Based Aerospace Engineering Major at West Point"*. We feel that all the reviewer's comments were reasonable and worthy of consideration for revision. For those that were not incorporated into the paper, we offer our explanation below and will likely discuss many as part of the Conference Proceedings:

Reviewer 1: Timing of Thread Assessments
Historically, thread assessments within the Mechanical Engineering program are conducted annually at the conclusion of the Spring Semester, and we intend to continue this trend. Although only an annual occurrence, the assessments address all courses taught during the year. For courses that are only taught in one semester, this allows assessment once per offering and for courses which are offered twice annually, we believe that an assessment between Fall/Spring semesters would not provide sufficient time to implement substantive changes and could lead to unnecessary churn between semesters.

Reviewer 2: Stakeholder Engagement
In terms of stakeholder engagement, we have continuously sought feedback from DoD agencies both tactical (senior Aviation Officers) and technical (Army Futures Command, Army Research Lab, etc…), research sponsors, graduate programs from aspirant institutions, and current mechanical (aero) cadets and prospective cadets. We thank you for the suggestion of Akinci-Ceylan & Ahn – we acknowledge the need for highlighting communication and technical skills, both of which will be addressed in AE201 and AE400 respectively. Regarding other "soft skills" and job seeking opportunities, we are in a unique position here at USMA in that (1) many of the skills such as leadership, team-building, and communication are addressed through the core and military curriculum and (2) the vast majority of our graduates will not matriculate into professional engineering fields but into military leadership.

Reviewer 2: Challenges in Aerospace Education
We acknowledge that we face all of the challenges addressed Orr et al., and that those challenges are shared among all our STEM majors. The unique admissions process at West Point, in which prospective cadets must attain congressional nominations, ensures that the student body is geographically diverse but continues to struggle with other areas of diversity. We will continue to conduct outreach much like our ME program to bring in as diverse an array of voices as possible, and later work will certainly address our successes/struggles as we are able to collect incoming student data beyond our first recruited class.

Regarding technology, learning practices, etc… those issues are currently being addressed Academy-wide and guidance is forthcoming. Because these considerations are not unique to the Aerospace program, we chose not to include them in the paper.

Reviewer 2: Student Well-Being and Retention
The challenging environment at West Point combined with additional requirements in Physical and Military Education do create unique stressors (although it can also be argued that emphasis on physical health is of benefit), cadets are also provided with several agencies for assistance. For example, the Center for Enhanced Performance offers programs in improving study habits and time management, as well as stress management and emotional regulation. Again, because this is not unique to our program, we chose not to include it as a point of discussion.

Reviewer 2: Insights from Existing Programs

Our initial outreach to existing programs has focused primarily on curricular development, but we acknowledge that the issues raised by the reviewer are relevant and should be considered moving forward.

Reviewer 3:
We thank you for your comments and suggestions for streamlining the paper. We have bulletized the SWOT comments while retaining the narrative so that interested readers can fully engage with any points they feel are cogent to their programs. We have chosen to keep the benchmarking section long as it provides background to the initial decisions regarding our program. In subsequent discussions/papers on the process, this section will be shortened to address major substantive findings.

Once again, we thank you all for your continued consideration – your comments and suggestions have not only improved our paper but have given us much to consider as we continue to develop this exciting program at West Point.

With Kind Regards,

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