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Beyond STEM Attrition

Quantifying the Flow of U.S. Air Force Academy Cadets between Academic Majors to Improve STEM Persistence

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Abstract

In increasingly technological civilian and military worlds, professionals in science, technology, engineering, and mathematics (STEM) are essential. To what extent postsecondary institutions are providing quality support to STEM majors is subject to debate, but the consensus is that STEM attrition at the college level is problematic. This study examines how cadets enrolled at the U.S. Air Force Academy (USAFA) moved from initially declared majors to their final graduation majors. The sample consisted of 6,110 cadets, of which 739 (12%) switched majors at least once. These switches included within-STEM changes (38%), STEM departers (28%), within non-STEM changes (28%), and STEM arrivers (6%). Researchers noted a strong flow of cadets away from majors with more mathematics requirements. Academic disciplines that were the sources of most major changes and STEM departers were identified. Recommendations to reduce STEM attrition include changing generic "undeclared" categories to meta-majors or similar alternatives that are division-specific to better track early major flow trends, broadening the cadets' core quantitative skills by requiring at least four mathematics courses for all degree majors, providing dual credit opportunities for USAFA-accepted high school seniors interested in STEM, and performing focus

groups with STEM departers to obtain firsthand insights into their reasons for their switch.

The decision of which college major and career to pursue is, for many students, a process fraught with indecision (Brown & Rector, 2008; Choi et al., 2012; Feldt et al., 2011). For decades, higher education scholars have studied persistence in a major and major switching to help students make the best decision possible based on their specific situation (Beggs et al., 2008; Ferrare & Lee, 2014; Reardon et al., 2015). Switching majors is common. An estimated 30%–50% of students change majors at least once, 10%–25% change majors multiple times, and more than 40% do so as juniors or seniors (Kramer, 1994; National Center for Education Statistics, 2017; Peterson, 2006). Many of these changes occur within the same broad disciplinary groupings, like sciences, social sciences, or humanities (Smart et al., 2000).

Researchers have learned that students' choice of college major involves a multifaceted decision process (Beggs et al., 2008; Malgwi et al., 2005; Peterson, 2006). The relative weight of these factors is a source of academic debate. For instance, Peterson's (2006) proposed major choice is influenced by three factors: extrinsic (e.g., expected future earnings), intrinsic (e.g., academic preparedness, learning styles), and experiential factors (e.g., involved faculty, departmental culture). He also notes that, for students who changed majors, intrinsic and experiential reasons are more important in choosing the new major. Beggs et al. (2008) and Malgwi et al. (2005) suggested four main factors associated with major selection: (a) sources of information and influence, (b) job characteristics, (c) fit and interest in the subject, and (d) characteristics of the major or degree.

Regardless of the number and relative importance of factors, keeping the most competitive GPA possible is critical. When students discover they struggle in prerequisite or major-specific coursework, some may reconsider their major choice. For example, Sjoquist and Winters (2015) studied college students receiving a state-sponsored, GPA-based scholarship. They found scholarship holders switched from their original majors to those perceived to be less difficult as their GPA approached the minimum GPA required to maintain the scholarship. Wright (2018) agreed, stating most major switches could be grouped into three categories, one of which is where students realize they are unable to successfully complete coursework at a sufficient level and risk not graduating on time or not meeting scholarship GPA requirements. The other categories include the students gaining additional major information (knowledge of new majors that they had not previously known about or updated information about their original major that made them view it differently) and personal self-discovery that leads students to change their values or interests.

At the U.S. Air Force Academy (USAFA), there is a strong "carrots and sticks" incentive for cadets to keep excellent GPAs. Unlike universities where a student can lose a scholarship but remain enrolled, USAFA is unique in that every student has a four-year scholarship inextricably tied with their enrollment. If a cadet withdraws or loses their enrollment

status due to deficient academic performance as juniors or seniors, cadets can be responsible for approximately $50,000 per completed semester (Belasco, 2022). Repayment can be financial or by serving the military as an enlisted airman. Alternatively, the higher a cadet's GPA, the greater the access to opportunities and benefits, such as career preferences, base preferences for pilot training, scholarships for graduate studies programs, USAFA military leadership positions, and specialized programs like airmanship.

Another factor strongly contributing to students changing majors is mathematics preparation coming from high school and performance in college mathematics (Daugherty & Lane, 1999; Nuñez-Peña et al., 2013; Perry, 2004). Bressoud (2021) argued there is a "tremendous disparity across the [U.S.] in what [mathematics] courses are offered and how teachers are prepared to teach these courses" (p. 521), including calculus, resulting in many students unprepared for college-level mathematics. Introductory calculus tends to be the biggest cause of attrition in the STEM major undergraduate pipeline, regardless of school type, student preparedness, or class size (Chen, 2015; Cohen & Kelly, 2020).

The change in college majors from STEM to non-STEM disciplines is known as STEM attrition (Ferrare & Lee, 2014; National Science Foundation, 2018). Because STEM attrition has been reported to be as high as 30%–50% nationwide (Chen, 2013; National Science Board, 2018), it has become a subject of intense study (Brewer et al., 2021; Chen,

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2015; Laskey & Hetzel, 2011; Seymour & Hunter, 2019; Shedlosky-Shoemaker & Fautch, 2015; Sithole et al., 2017; Xu, 2018). The literature has identified several potential factors for STEM attrition, including high school background in mathematics and science, academic performance in prerequisite math and science coursework, prerequisite course design, time management, study habits, self-efficacy, and fear of failure, among others (Dwyer et al., 2020).

Given the rapid pace of technological advancement, reducing STEM attrition among cadets is key to maintaining military superiority (Air Force Research Laboratory, 2022). The U.S. Department of Defense has identified a STEM workforce as essential for a strong military and an evolving and increasingly complex national and international security environment (National Academies of Sciences, Engineering, and Medicine, 2015; National Research Council, 2010, 2012a, 2012b, 2014).

Military postsecondary institutions like USAFA, which recruit and enroll cadets with outstanding academics and leadership skills, also experience STEM attrition. A previous study showed that, after cadets are accepted into USAFA but before they start their first coursework sequence, about two-thirds of them were likely to pursue STEM degrees. Four years later, less than half of them received a bachelor's in a STEM discipline. According to Dwyer et al (2020), this rate of STEM attrition seems related to their experience with Calculus I, Physics I, and Chemistry I. Another study also explored related factors associated with STEM attrition at USAFA using data from academic years 2019–20 and 2020–21 (O'Keefe et al., 2022). The researchers found five factors were individually associated with an increased likelihood of STEM departure: (a) USAFA preparatory school attendance, (b) scholars program nonparticipation, (c) low GPA, (d) low SAT mathematics scores, and (e) low SAT reading and writing scores. Of the factors studied, GPA emerged as the strongest factor associated with cadets leaving STEM (O'Keefe et al., 2022).

The current policy at USAFA is that "cadets may declare a major as soon as they desire," though it is encouraged for cadets to wait at least until their second semester. The deadline for declaring a major is "the registration deadline of their third semester" (U.S. Air Force Academy [USAFA], 2021, p. 111). However, academic and nonacademic reasons may result in a small number of cadets unable to complete their chosen program. In this case, USAFA provides an alternate path to their eight-semester graduation requirements where cadets may earn a bachelor of science without any major.

Purpose and Research Questions

The purpose of this study is to better understand the flow of cadets into and out of individual majors to specifically examine the effects of STEM majors. The research questions guiding this study were as follows:

- To what extent are cadets who change their original STEM major remaining within STEM as persisters or becoming STEM departers?
- To what extent are cadets who change their original non-STEM major staying within non-STEM as persisters or becoming STEM arrivers?
- Which STEM majors experience the most and least attrition, by sheer numbers and as percentages of total initial enrollment?
- Which factors contribute to STEM attrition?

The answers to these research questions are important for USAFA departments so they may perform additional major flow analyses and brainstorm potential interventions to reduce attrition (National Science Board, 2018).

More broadly, reducing STEM attrition at USAFA is an urgent matter. Since the mid-1990s, less than half of the Air Force officer corps is commissioned with STEM undergraduate degrees, and the inventory of officers with STEM master's degrees fell from about 7,000 in 1989 to just over 5,000 currently. To meet Air Force needs, it is estimated that about 10,000 officers with *graduate* STEM credentials are needed (Air Force Research Laboratory, 2022). Achieving this goal is only possible if more *undergraduates* with STEM degrees are produced, whether through USAFA or other commissioning sources.

Methodology

This study relied on data from the Office of Student Academic Affairs and Academy Registrar collected during academic years 2019–20, 2020–21 and 2021–22. Although numerous variables were present in the data, this analysis used (a) CODE ID (a random code assigned to each cadet to maintain confidentiality); (b) cadet MAJOR, the main variable of interest; and (c) DATE to keep track of when cadets switched majors, if any, over their time at USAFA. A total of 505 freshmen cadets from academic year 2021–22 were classified as undeclared (they did not declare a major within the time frame of the study) and were removed from the dataset. The researchers coded each combination of major switching, from those cadets who declared a major and never switched, to cadets who switched multiple times. Finally, the dataset was classified by each major and Sankey diagrams were prepared to visually illustrate cadet flow by major.

The data was categorical in nature, so analyses consisted of descriptive statistics and Chi-Square tests when appropriate. Because of the exploratory nature of the study, minimum statistical significance was assigned a probability (p) value of 0.05 or less to balance the risks of Types I and II errors.

To simplify the graphical representation of the findings, several abbreviations were used in the Sankey diagrams. These include the following:

- **noSwitch:** cadets remaining in their original major.

- **SwitchSTEM:** cadets who switched from their original major to STEM majors.
- **SwitchNONSTEM:** cadets who switched from their original major to non-STEM majors.
- **Final STEM:** cadets who switched major multiple times with STEM as the final major.
- **Final NONSTEM:** cadets who switched major multiple times with non-STEM as the final major.
- **Back to:** cadets who left a major but eventually returned to it.

Due to the Sankey diagram's size limitations and the variety of majors, USAFA majors and abbreviations are listed in the Table.

Results

Demographics

The sample consisted of 6,110 cadets with major history on file. Of these, 4,361 (71.4%) were male and 1,749 (28.6%) were female. This included 3,905 (63.9%) Caucasian, 642 (10.5%) Asian, 622 (10.2%) Hispanic, 559 (9.2%) Black, 200 (3.3%) "unknown," 123 (2.0%) Hawaiian/Pacific Islander, and 59 (1.0%) Native American.

The dataset included cadets from several graduation years: five cadets from 2019, 995 from 2020, 1,071 from 2021, 1,101 from 2022, 1,062 from 2023, 1,081 from 2024, and 795 from 2025 (which had many undeclared cadets). Because of the exploratory nature of the study, it is worth pointing out that three years' worth of data were examined, meaning some cadet cohorts had longer data collections than others. For example, there is only one year's worth of data for cadets who graduated in 2020 or who will graduate in 2025, two years for cadets who graduated in 2021 or will graduate in 2024, and three years for cadets who graduated in 2022 or will graduate in 2023.

Cadet Flow for All Major Switchers

Out of 6,110 cadets in the dataset, 5,371 (87.9%) never switched majors and 739 cadets (12.1%) switched majors. Of these, about two thirds (n = 491) were STEM majors, compared with non-STEM majors (n = 248). STEM switchers split somewhat evenly between STEM persisters (n = 269, 54.7%) and STEM departers (n = 222, 45.2%). In contrast, the proportion of non-STEM switchers was more than to 5:1 between non-STEM persisters (n = 210, 84.6%) and STEM arrivers (n = 38, 15.3%). Using a 2x2 Chi-square test revealed this difference in discipline persistence versus departure was statistically significant, $X^2(1, n = 739) = 105.7$, $p < 0.00001$.

Of the cadets who switched majors, 63 did so multiple times, including 46 cadets (73%) originally in STEM majors and 17 cadets (26.9%) originally in non-STEM ma-

Table

STEM and Non-STEM Majors and Their Abbreviations

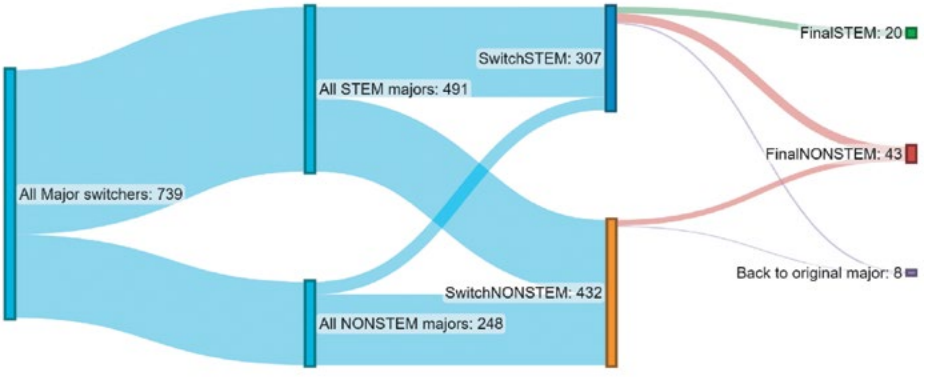
STEM Majors	Non-STEM Majors
• Aeronautical Engineering (AeEn) • Astronautical Engineering (AsEn) • Basic Sciences (BasS) • Biology (Biol) • Chemistry (Chem) • Civil Engineering (CiEn) • Computer Engineering (CoEn) • Computer Science (ComS) • Cyber Sciences (CybS) • Data Science (DatS) • Electrical and Computer Engineering (ElCoEn) • General Engineering (GeEn) • Mathematics (Math) • Mechanical Engineering (MeEn) • Meteorology (Mete) • Operations Research (OpsR) • Physics (Phys) • Space Operations (SpaO) • Systems Engineering (SyEn)	• Behavioral Science (Beha) • Economics (Econ) • English (Engl) • Foreign Area Studies (FAS)- • Geospatial Sciences (GeoS) • History (Hist) • Humanities (Huma) • Legal Studies (Lega) • Management (Mana) • Military and Strategic Studies (MSS) • Philosophy (Phil) • Political Science (PolS) • Social Science (SocS)

jors. For STEM multi-switchers, 26 (51%) departed STEM and 25 (49%) remained in STEM, including five cadets who returned to their original STEM major of record. For non-STEM multi-switchers, 20 (100%) remained in non-STEM, including three cadets who returned to their original major. Figure 1 summarizes overall flows for all major switchers.

To evaluate the role of mathematics, described in the literature as a strong indicator of major switching, original and final majors were combined into groups based on required mathematics courses. Each cadet also takes a course in statistics, taught by either the math or behavioral sciences departments, and these statistics courses are not included in the discussion of required math courses. The resulting categories included the following:

- **13 courses:** Mathematics
- **6 courses:** Aeronautical Engineering, Astronautical Engineering, Mechanical Engineering, Operations Research, Physics

Figure 1
Cadet Flow for All STEM and Non-STEM Major Switchers



- **5 courses:** Civil Engineering, Data Science
- **4 courses:** Basic Sciences, Computer Science, Cyber Science, Electrical and Computer Engineering, Meteorology, Space Operations
- **3 courses:** Biology, Chemistry, Economics, General Engineering, Systems Engineering
- **2 courses:** Behavioral Sciences, English, Foreign Area Studies, Geospatial Science, History, Humanities, Legal Studies, Management, Military & Strategic Studies, Philosophy, Political Science, Social Sciences

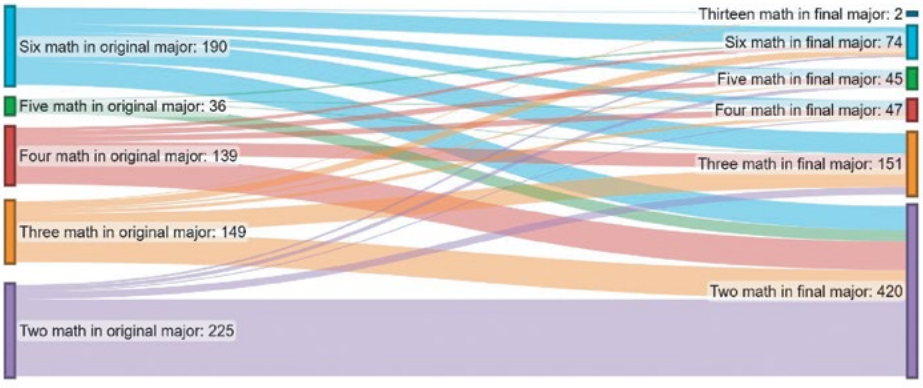
Major flow from all regrouped original and final majors can be seen in Figure 2.

For this case, the total number of cadets who switched majors was 739. The number of cadets in majors requiring six math courses decreases from 190 (25.7%) to 74 cadets (10%). The cadets in majors requiring four math courses decreases from 139 (18.8%) to 47 cadets (6.4%). In contrast, the cadets in majors requiring two math courses almost doubled, from 225 cadets (30.4%) to 420 cadets (56.8%). Interestingly, for majors requiring five and three math courses, the number of cadets remained similar, hovering around 5%–6% and 20%, respectively. A 2x5 Chi-square test comparing the number of cadets in original and final majors by the number of required math courses revealed a statistically significant difference, $X^2(4, n = 1{,}476) = 156.4$, $p < 0.00001$.

Because non-STEM majors have fewer mathematics requirements, it is unclear whether mathematics versus new career goals based on an emerging interest in non-STEM majors are driving STEM attrition. One way to untangle these interacting variables is to modify the Sankey diagram by focusing on major flow between courses requiring only four, five, or six mathematics courses, since they are all STEM majors. Figure 3 shows the results. A 2x3 Chi-square test comparing the number of cadets in original and final majors by the number of required math courses revealed

Figure 2

Cadet Major Flow as a Function of the Number of Required Math Courses Within Majors



a statistically significant flow of cadets from majors requiring more to fewer math requirements, $X^2(2, n = 240) = 23.4$, $p < 0.00001$.

Although the statistical test showed a trend in cadets seeking majors with fewer required mathematics courses, it would not be appropriate to infer an exclusively causal link. Factors like curriculum changes, course structure, and coursework pace could also be associated with STEM attrition.

Cadet Flow for All STEM Departers

The percentage of departures by STEM major was calculated by dividing the number of STEM departers by the original number of within-major cadets. This percentage ranged from 1.5% (mathematics) to 44.4% (space operations). Three majors with higher levels of STEM attrition, cyber science, data science, and computer science, were all related to computers. A few majors such as general engineering and basic sciences had low enrollments (six cadets or fewer) and showed no STEM departures, likely because they were seniors who could not meet the requirements of their original majors and did not have time or the proper prerequisites to switch into anything else. Enrollment values were added to Figure 4 to contextualize the STEM attrition rates.

More than half of all STEM departers originated from four majors: biology, computer science, aeronautical engineering, and systems engineering. The number of STEM departers from other STEM majors are presented in Figure 5. The percentages are calculated using the total number of STEM departers.

Figure 3

Cadet Major Flow for Majors Requiring Four, Five, or Six Mathematics Courses

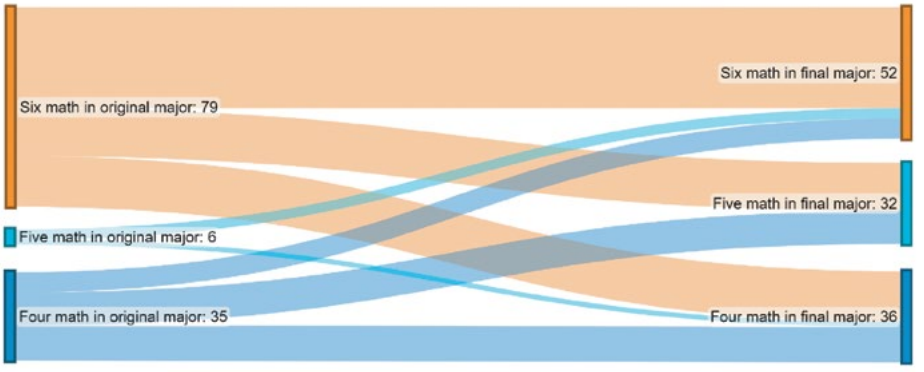


Figure 4

Original Enrollment and Percentage of STEM Departers by Major

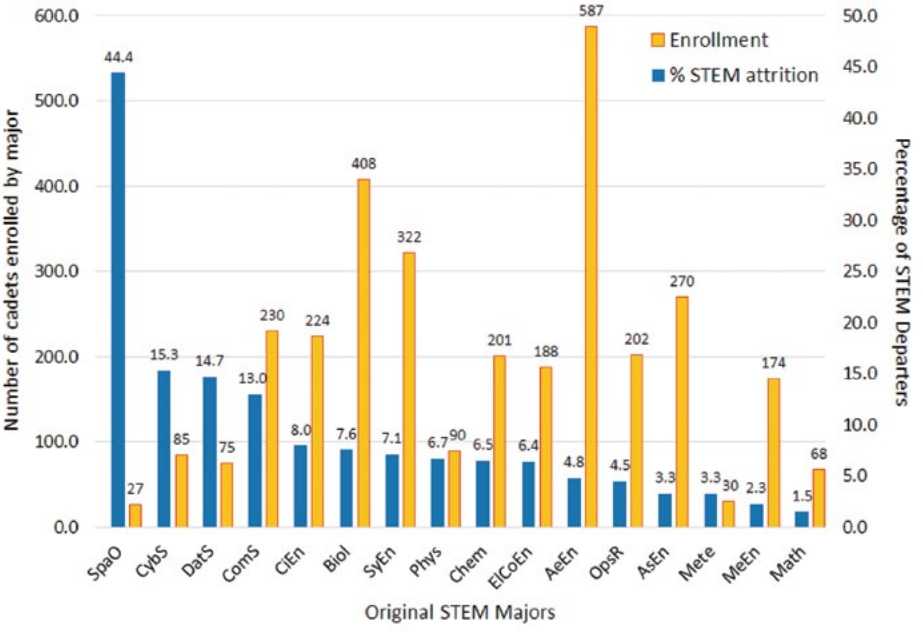


Figure 6 compares the number of cadets who switched to STEM and non-STEM majors. The diagonal represents a ratio of 1:1, cadets changing majors evenly between STEM and non-STEM majors. Seven majors had more cadets switching

from STEM to non-STEM: biology, space operations, civil engineering, computer science, cyber science, data science, and systems engineering. Of particular concern were civil engineering, space operations, and biology, which had non-STEM/STEM switching ratios of 6:1, 4:1, and 3:1, respectively. Ratios may be interpreted using slopes from the origin to major in Figure 6.

Pairwise Chi-square tests were used to compare the proportion of cadets who remained in their original STEM major, switched to another STEM major, and switched out of STEM. These tests complement Figure 5 because they account for cadets who remained in their original major. The results are displayed in the chord diagrams (Figure 7). The thicker the connecting lines between two majors, the more similar the major flows are.

The diagrams confirm biology and civil engineering are similar in their high major flow of STEM departers (top-left). Data science, computer science, and cyber science share a similar cluster of relatively high major flow (top-center and top-right). In the region of moderate flow there are two clusters centered around aeronautical engineering, which tie both to operations research and systems engineering on one end (bottom-left), and physics, chemistry and electrical, and computer engineering on the other (bottom-center). Finally, astronautical engineering and mechanical engineering share a similar, low flow of STEM departers (bottom-right). Mathematics, space operations, and meteorology are not in the chord diagrams because of low sample sizes in a category needed to perform the Chi-square tests.

Management received almost a third of all STEM departers, with four other majors receiving another third: military and strategic studies, behavioral science, legal studies, and foreign area studies. Additionally, geospatial science, economics, and English received a sizable number of STEM departers. Figure 8 displays destination majors for STEM departers.

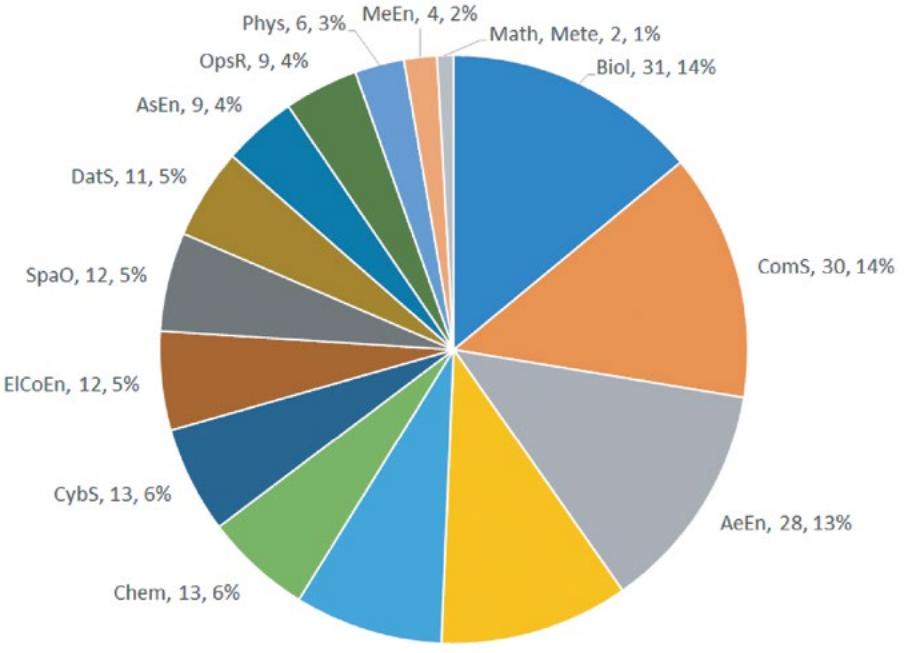
Cadet Flow by STEM Major

Although Sankey diagrams for cadet major flow were prepared for all STEM majors, only those corresponding to the seven majors identified in Figure 6 are presented due to the concerning number or rate of STEM departures. The diagrams (Figures 9–15) are divided into four main regions:

- **Left:** the number of cadets and their original major.
- **Center-left:** cadet split between those who remained in the major (noSwitch), who changed majors to a different STEM one (SwitchSTEM), and who departed STEM (SwitchNONSTEM).
- **Center-right:** the number of cadets and their destination majors.
- **Right:** the number of cadets who switched major multiple times and their final destination discipline. Cadets who returned to the original major are noted.

Figure 5

Number and Percentage of STEM Departers by Their Original Major



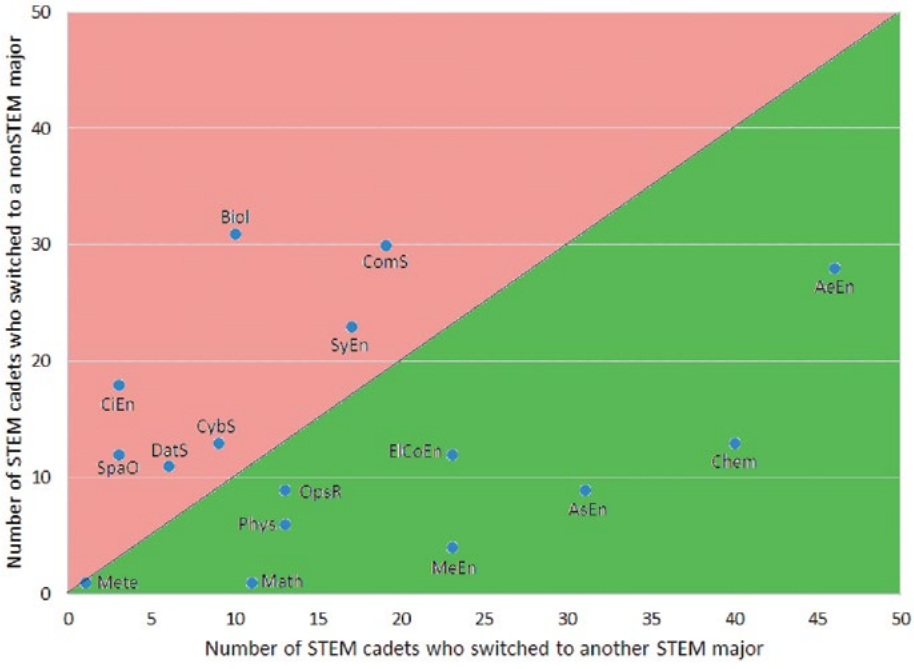
Discussion and Recommendations

At first glance, the pattern of major switching at USAFA compares favorably with previous publications in the literature. For instance, the percentage of cadets who switched majors multiple times (10%) is within the 10%–25% range that the extant literature has reported by Kramer (1994), Peterson (2006), and others. About two-thirds of cadets who switched majors remained in their broad STEM or non-STEM disciplines, consistent with the findings of Smart et al. (2000). Even the overall percentage of cadets who change majors at USAFA (12%) and the number of STEM departers (28%) is much lower than the national average (30%–50%), which can be explained by USAFA's highly selective criteria for admission and recommendation for cadets to not declare a major until after the first semester of class.

However, previous studies with USAFA cadet data have reported that cadets are weighing options and changing their minds regarding which major they plan to declare while in the "undeclared" status, especially after completing quantitative core courses (Dwyer et al., 2020; O'Keefe et al., 2022). In fact, the latest data on cadet career preferences from a basic science division survey, completed in the summers of 2021 and 2022,

Figure 6

Ratio of Non-STEM to STEM Switching for All Cadets With an Original STEM Major



and prior to their first semester, showed 57% of cadets considered majoring in STEM very likely or likely, 32% considered majoring in non-STEM very likely or likely, and about 11% had no stated preference (Lt. Col. David Meier, personal communication, 22 July 2022). Unfortunately, there is a knowledge gap spanning many months, from the time cadets report their planned major in the basic science division survey to the time cadets declare, and the researchers hypothesize there may be significant attrition during this period. It is recommended for USAFA to replace the generic "Undeclared" major category with ones reflecting the division the cadet is planning to join, as follows:

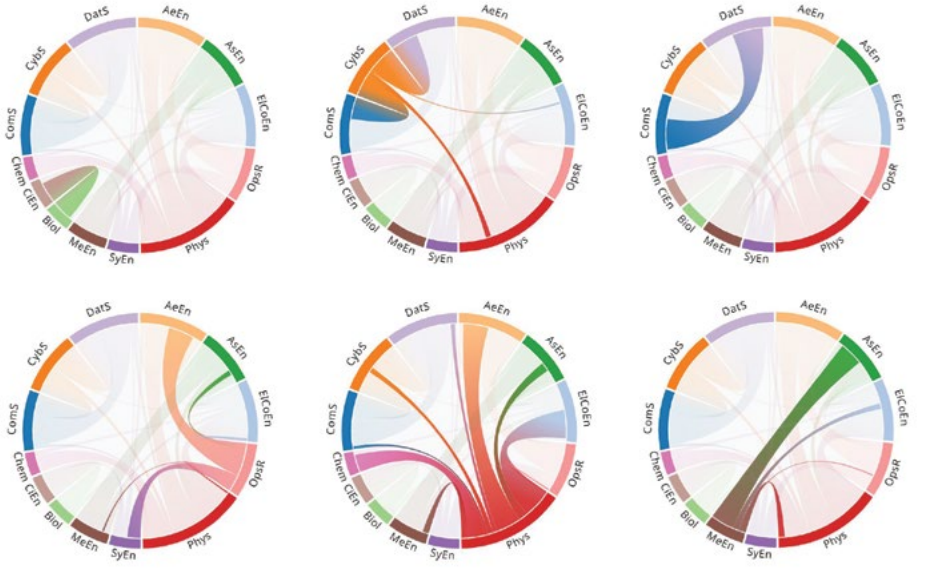
- Undeclared-Basic Sciences (BS)
- Undeclared-Engineering (E)
- Undeclared-Humanities (H)
- Undeclared-Social Science (SS)

For example, a cadet who is "Undeclared-BS" is considering majoring in biology, chemistry, mathematics, physics, or meteorology, while another cadet who is "Undeclared-H" is planning to study languages, fine arts, international studies, history, or philosophy.

This recommendation follows the literature on implementing meta majors to reduce college attrition. Using students' interests as a starting point, meta majors organize aca-

Figure 7

Chord Diagram of Major Flow by STEM Major



demic programs broadly, creating general areas of interest that allow students to complete coursework in these areas before they decide on a more specific major or program of study (Schudde et al., 2020; Waugh, 2016). For USAFA, having additional insight into cadet major intentions fills knowledge gaps and may help track STEM-interested cadets beginning to struggle in quantitative courses and who may never declare STEM.

On a related topic, although discouraged, USAFA cadets can declare a major at any point during their first year or the first semester of their sophomore year and can switch majors at any time. In fact, the researchers noted several multi-switchers over a single semester. USAFA may consider a restricted timeline for declaring and switching majors similar to the U.S. Naval Academy, where cadets declare majors in March of their freshman year and should not switch majors until after the drop date in November of their third semester, except on a case-by-case basis (Dr. Carl E. Mungan, personal communication, 27 July 2022; U.S. Naval Academy, 2022). This strategy assures cadets complete some sophomore-level courses in their original major before switching and avoids impulsive major changes.

A strong flow of cadets from majors with more required mathematics courses to majors with fewer ones was identified in the dataset, consistent with findings by Bressoud (2021), Daugherty and Lane (1999), Nuñez-Peña et al. (2013), and Perry (2004). Despite an attempt to separate the role of mathematics and non-STEM courses in STEM attrition via various Sankey diagrams, it is difficult to determine whether the identified major flow is a

Figure 8

Number and Percentage of STEM Departers by Non-STEM Destination Major

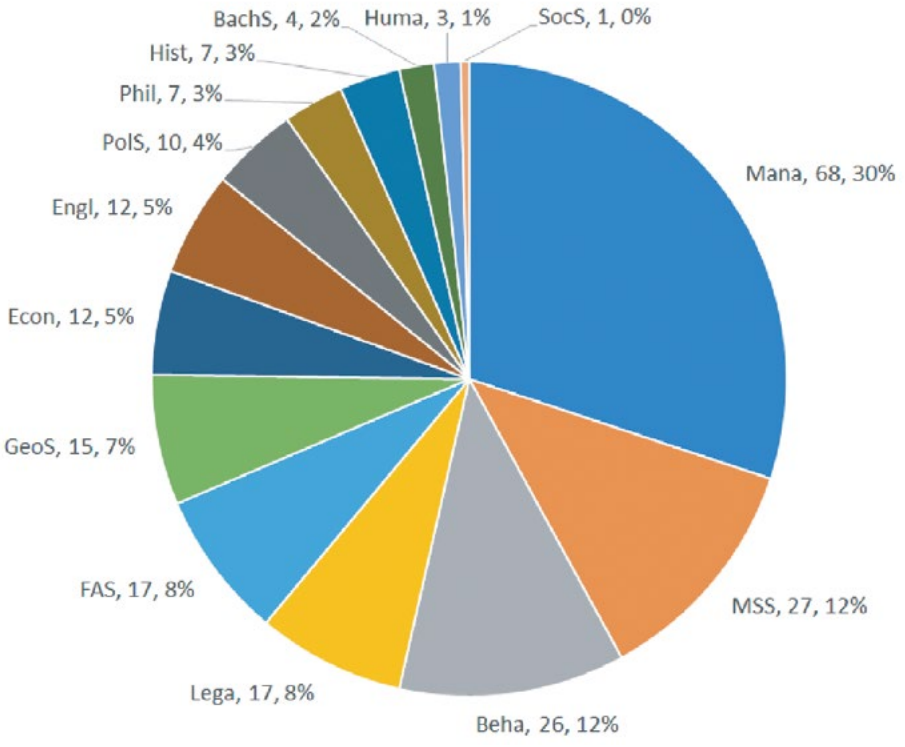


Figure 9

Cadet Flow for Biology Majors

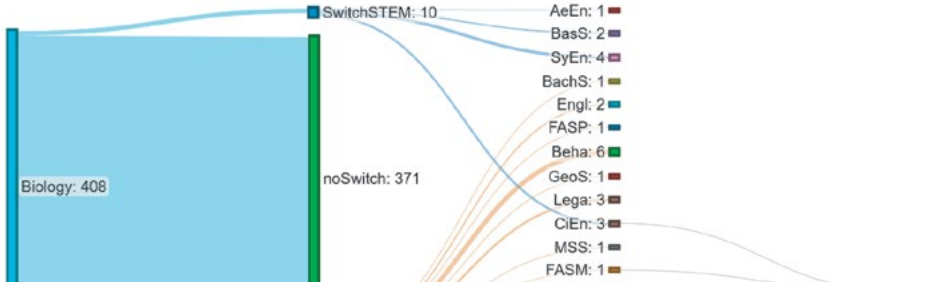


Figure 10

Cadet Flow for Civil Engineering Majors

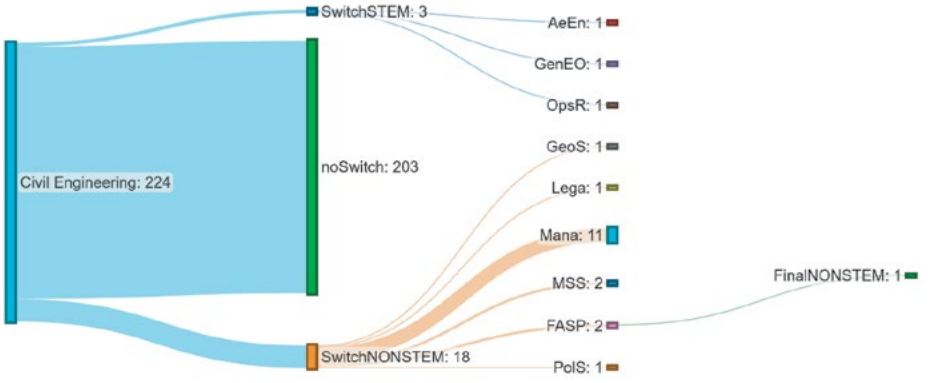


Figure 11

Cadet Flow for Computer Science Majors

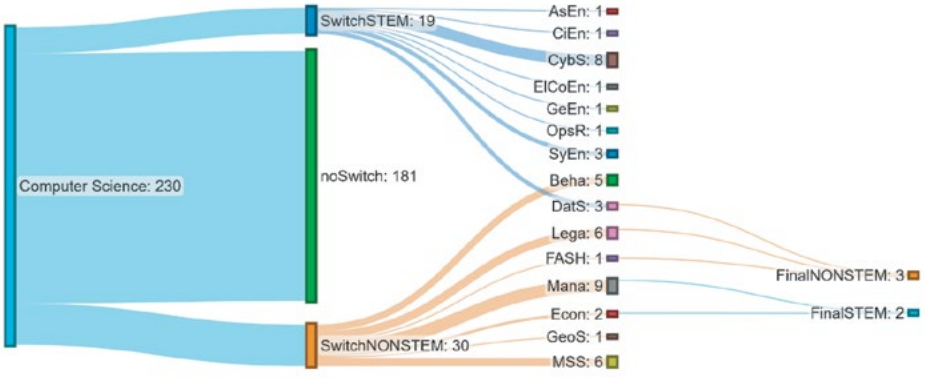


Figure 12

Cadet Flow for Cyber Science Majors

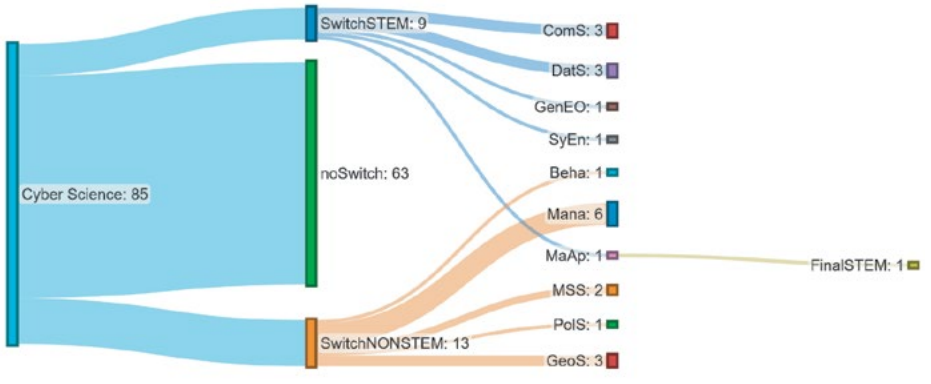


Figure 13
Cadet Flow for Data Science Majors

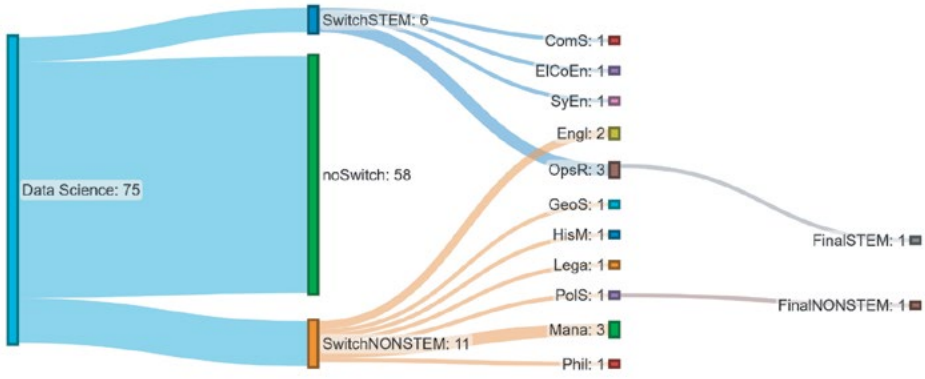


Figure 14
Cadet Flow for Systems Engineering Majors

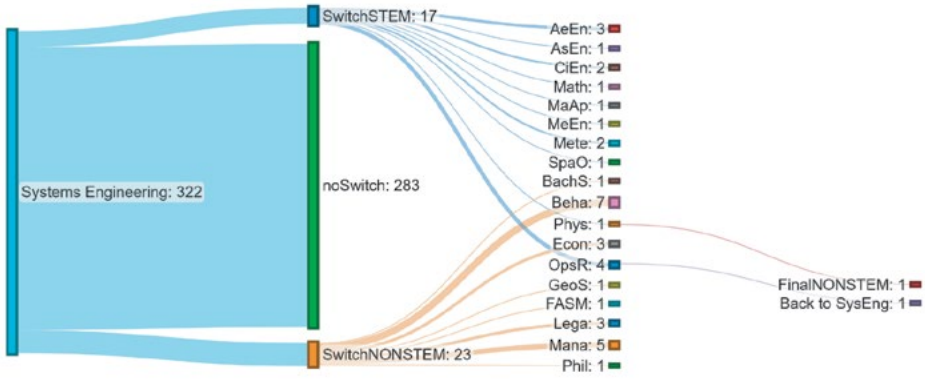
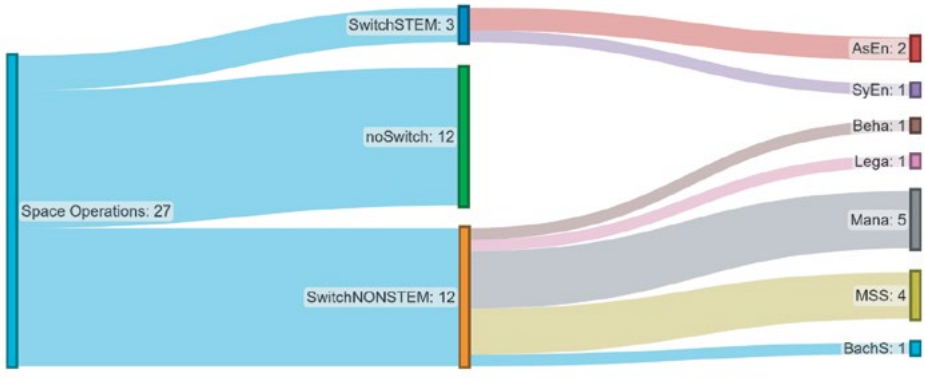


Figure 15
Cadet Flow for Space Operations Majors



causation or a correlation with performance in mathematics, disenchantment with STEM majors, cadets trying to maintain the highest GPA possible, as proposed by Sjoquist and Winters (2015) and Wright (2018), or other factors (Dwyer et al., 2020).

Since it is difficult to disentangle the roles of mathematics, pressure to keep a strong GPA, and changes in career interests in the dataset, two recommendations are proposed. Cadets, like many college students, may have low self-efficacy associated with their mathematics proficiency and may think the solution is to avoid mathematics. A possible answer may be to do the opposite, by having USAFA help cadets further develop their quantitative reasoning by increasing the required mathematics courses for all majors to at least four, plus two additional quantitative science courses. This would be consistent with sister institutions like the U.S. Naval Academy, which requires Calculus I, II, and III, with a fourth mathematics course that could include differential equations or data science (Dr. Carl E. Mungan, personal communication, 27 July 2022). For USAFA, in addition to Calculus I and II, it is recommended for cadets to complete Calculus III and Differential Equations, as well as Chemistry II and Physics II.

Additionally, increasing the number of required quantitative core STEM courses would help cadets who switch between STEM majors, as sometimes cadets have limited options based on majors' requirements. For instance, civil engineering and biology are the only two STEM majors requiring Chemistry II and Biology (i.e., without the option to take Physics II), and these two STEM majors have also experienced some of the highest ratios of STEM departures. Further, for biology students, the three required mathematics courses would not be enough to transfer to most other STEM majors, so non-STEM might be the cadets' only viable alternative.

Given the previous recommendation, the space operations major deserves a more detailed analysis because, despite requiring Chemistry II, Physics II, and four mathematics courses, including Differential Equations (but not Calculus III), it has the highest percentage of major switches per capita and one of the higher flow ratios out of STEM. It is likely the elevated level of STEM attrition may be attributed to a curriculum misalignment within the space operations major. Since the USAFA course of instruction indicates that "prior completion of Calculus III is strongly recommended" (USAFA, 2021, p. 343) for Differential Equations, space operations should require Calculus III to introduce cadets to multivariate calculus concepts used in Differential Equations.

Furthermore, it is recommended for USAFA faculty to collaborate with those associated with the academy's Scholarship of Teaching and Learning Research Center to develop exit-interview protocols that can be used in short, focus group sessions with cadets who go from "Undeclared-BS," "Undeclared-E," and declared STEM majors to non-STEM majors. By obtaining firsthand knowledge of the reasons why cadets move into non-STEM majors, USAFA can design and implement interventions, such as focusing on academic support in mathematics or career and vocational advising.

Since it is known that STEM-interested first-year cadets may struggle with quantitative core courses, the last recommendation takes advantage of the recent implementa-

tion of virtual course options at USAFA and the emerging opportunities for dual credit in high schools nationwide. For STEM-interested high school students accepted into the academy before December of their senior year, a liaison between the high school and USAFA can coordinate for these students to remotely complete two spring semester USAFA non-STEM courses through learning management systems like Moodle and Blackboard. These courses will be selected so that they also fulfill the high schools' requirements.

The selection of two non-STEM courses for high school dual credit was purposeful. Compared with non-STEM curricula, the heavy course load and fast pace of the first-year STEM curriculum often causes academic struggles, frustration, and discontent for students, especially incoming first-year cadets with significant difficulties with mathematics (Romash, 2019; Seymour & Hunter, 2019). Alternatively, offering one non-STEM class and Math 130 (algebra and trigonometry) as dual credit could be considered to help cadets in reinforcing skills necessary for success in the technical core. Regardless, completing two USAFA courses before cadets arrive at USAFA will result in a reduced course load as freshmen, freeing up extra time to invest in core STEM courses for their expected STEM majors. This recommendation would also apply to military academies or other programs with strict graduation timelines. To ensure that STEM-interested cadets who complete the proposed dual credit opportunity invest their extra time studying for classes, USAFA could require adding a mandatory pass/fail STEM study hall class to its schedule, scheduling extra instruction meetings with instructors, or attending the academy's quantitative reasoning center in the evenings for a certain number of hours. Pushing these courses to virtual delivery for high school students is not without risks, as course structure and delivery might not be conducive for student success; future studies in this area are recommended.

Conclusion

The purpose of this project was to better understand the nature of major switching among cadets, particularly those who switched from STEM to non-STEM majors, as well as those majors where STEM attrition occurs more frequently. This information is critical to addressing STEM attrition at USAFA or other universities.

The first two research questions asked to what extent cadets who change their original major become STEM persisters, non-STEM persisters, STEM departers, and STEM arrivers. Of 738 cadets who changed majors, 38.1% were STEM persisters, 28.3% were STEM departers, 27.5% were non-STEM persisters, and 6.1% were STEM arrivers. The ratio of STEM departers to arrivers is almost 5 to 1.

The third research question inquired which STEM majors experienced the most and least attrition. In terms of the raw number of cadets, the top three STEM majors where cadets switched to non-STEM the most were biology, computer science, and aeronautical engineering. The top three STEM majors where cadets switched to

non-STEM the most per capita were cyber sciences, data science, and computer science. The three STEM majors where cadets switched to non-STEM the least (by raw numbers) were meteorology, data science, and civil engineering. The three STEM majors where cadets switched to non-STEM the least per capita were mechanical engineering, meteorology, and astronautical engineering.

The last research question asked which factors may explain STEM attrition. It was found that most cadets who declared a STEM major either persisted in that major or switched to a different STEM discipline. This is consistent with previous studies showing that STEM attrition occurs the most while cadets have not declared a major and are completing core quantitative courses. Looking at math requirements and major specificity, math requirements appeared to account for a considerable proportion of major flow out of STEM majors. It may be helpful to analyze whether these observed trends are present at other service academies or universities. Further mixed-methods research, like focus groups or surveys, may be able to untangle these variables at USAFA and their association with maximizing GPA.

Several recommendations were proposed to gain insight about undeclared cadets' preference for STEM or non-STEM, strengthen math proficiency across the board, reduce the course load of first-year STEM-interested cadets through virtual instruction prior to matriculation, and interview cadets to obtain first-person accounts of factors that contributed to STEM attrition. These recommendations would apply to other service academies with strict four-year timelines.

One of the limitations of this exploratory study was that it only provided the most complete picture regarding major switching for upperclassmen, who are represented in all three academic years. One new area of research that could expand the literature on STEM attrition at military institutions would be to look at the major flow of cadet cohorts over their four years at USAFA. Another new area of research could be the design, implementation, and evaluation of a pilot dual-credit collaboration with a small number of high schools to measure the impact of a reduced course load of STEM cadets on their GPA and persistence in STEM. This pilot study could also identify and resolve issues related to coursework equivalency and the academic support of incoming cadets while still at their high school of origin.

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