University Senate of Michigan Technological University

Bachelors of Science in Aerospace Engineering

Proposal 17-24

1. Basic Program Information

Primary Contact: Jason Blough, Chair
Department of Mechanical Engineering – Engineering Mechanics

Program/Degree Type:BS

Program Title: Bachelors of Science in Aerospace Engineering,

Planned Implementation Date: Fall 2025

Target Student Population: New students; anticipate transfer requests from BSME students

General Description and Characteristics of the Program:

The Bachelors of Science in Aerospace Engineering (BSAE) will prepare students for professional practice in aeronautical and astronautical industries. The BSAE program is being proposed in light of industry needs, student interest, and faculty expertise.

The BSAE four-year curriculum integrates mechanical engineering science and practice courses with theory and practice of aerospace engineering. The curriculum follows the signature hands-on education for which Michigan Tech is known. The addition of this program fills a gap in Michigan Tech's engineering offerings.

The curriculum covers aeronautical and astronautical aspects of aerospace engineering, with an in-depth coverage of space systems and spacecraft engineering. Graduates of the BSAE program have the opportunity to become leaders in the aeronautics industry as well as the rapidly growing space systems sector and the national/international initiatives in planetary exploration. The BSAE program is designed to also provide the stimulus and preparation for students to be successful in pursuit of graduate studies in aerospace engineering.

Rationale:

National and state demand for aerospace engineers

The U.S. Bureau of Labor Statistics, in 2022, projects a 6% growth in aerospace engineering jobs (approximately 3900 new jobs per year) through 2032.[1] This growth is also true for Michigan even though it is not widely recognized as having a significant aerospace industry. Michigan Tech is a member of the Aerospace Industry Association of Michigan (AIAM)[2], which has over 900 member companies. The Michigan Aerospace Manufacturers Association (MAMA)[3] is made up of over 200 manufacturing

[1] https://www.bls.gov/ooh/architecture-and-engineering/aerospace-engineers.htm
[2] https://aiamnow.com/
[3] https://www.michman.org/about/#

companies that focus on aerospace. AIAM and the MAMA reinforce the national and state level need for aerospace engineers.

Interest from students

Currently, Michigan Tech offers a minor in Aerospace Engineering through the Mechanical Engineering Department. Over the last 5 years, 182 students have earned the Aerospace Minor (approximately 13% of all BSME graduates). Two of the major enterprises on campus are directly related to the aerospace industry. The Aerospace Enterprise has 67 students this fall. The Multiplanetary INnovation Enterprise (MINE) has 75 students in Fall 2023 and projects 90 to 100 students enrolled in Spring 2024. A new enterprise will begin in Fall 2024 that encompasses the SAE Aero Team (designs, builds, and flies aircraft in an annual competition) and the elements of the Keweenaw Rocket Club. In 2022, Michigan Tech established a student chapter of the American Institute of Aeronautics and Astronautics (AIAA). This student organization has over 173 students who indicate interest in participating, with 80 members currently registered with Involvement Link.

There is strong interest by prospective students in pursuing Aerospace Engineering. Admissions completed a study in May 2023 on the potential for Aerospace Engineering to increase undergraduate enrollment at Michigan Tech. Some key points from this study are:

- In speaking with our regional team, the most asked about majors that we don't offer are Aerospace Engineering and Nursing
- While students understand that we do offer a lot of opportunities in aerospace, some choose to go elsewhere because we simply do not offer a degree in aerospace
    - Choosing a degree based on minors, research, and enterprise programs is only supportive to an aerospace degree in their mind
- Aerospace Engineering, except for a small median percent decrease in 2017, is the only engineering discipline to show an increase [in enrollment] from 2018 to 2020

The ASEE 2020 Engineering and Engineering Technology By the Numbers reports that "all institutions reported a median percent decrease in freshmen engineering enrollment in Fall" except Aerospace Engineering, which is the only engineering degree with a sustained growth in first year enrollment. Table 4 from that report is included here for reference.

Table 4: Year-to-Year Median Percent Change in Freshmen Enrollment by Engineering Discipline.

Discipline	2017	2018	2019	2020	# Institutions
Aerospace Eng.	-1.5	1.4	8.5	5.0	37
Architectural Eng.	6.5	-4.4	4.1	-18.2	12
Biological Engr. And Agricultural Engr.	-8.5	12.3	-11.8	-6.3	21
Biomedical Eng.	4.3	-4.5	-1.6	-10.2	86
Chemical Eng.	5.6	-5.3	-1.0	-10.4	96
Civil or Environmental Eng.	0.0	0.0	-3.0	-3.6	167
Computer Science (inside engineering)	-7.7	6.9	2.0	-2.2	115
Computer Science (outside engineering)	-5.0	7.3	7.0	6.4	29
Electrical or Computer Eng.	0.0	0.0	-5.6	-9.8	269
Eng. (General)	8.3	-4.7	-7.4	0.0	39
Eng. Management	8.6	-9.2	0.0	0.2	8
Engr. Science and Engr. Physics	0.0	0.0	25.0	-16.7	19
Industrial/Manufacturing/Systems Eng.	0.0	0.0	-5.2	-14.3	63
Mechanical Eng.	1.3	-1.2	-1.3	-5.0	174
Metallurgical and Matrls. Eng.	-8.7	7.7	-3.9	-8.8	32
Mining Eng.	56.3	-23.4	-8.3	-3.8	4
Nuclear Eng.	13.9	-13.6	33.3	-25.0	9
Petroleum Eng.	-3.3	6.0	-3.6	-11.2	10

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Current faculty interest

Michigan Tech is well-positioned to quickly implement a BSAE program. Currently, 26% of MEEM faculty have aerospace degrees and/or significant aerospace background. MEEM currently offers eight technical electives directly related to aerospace alone, those courses support the aerospace minor. The Michigan Tech Aerospace Engineering Research Center (MARC) had $3,846,899 total awarded dollars for aerospace-specific projects from July 1, 2022 to June 30, 2023.[4]

Related Programs (within MTU and at other institutions):

There are no aerospace-specific degree programs at Michigan Tech. There are two aerospace enterprises and a third being developed for Fall 2024 and an Aerospace Minor in mechanical engineering. In Michigan, there are only two other bachelor-level aerospace degree programs; University of Michigan and Western Michigan University. For context, there are 13 BSME programs. In Wisconsin, the only aerospace related program is at the University of Wisconsin, which has an Aerospace Engineering Option as part of the Engineering Mechanics program. In Minnesota, the University of Minnesota and St. Cloud University have aerospace degree programs. To summarize, in the upper Great Lakes region (MI, WI, MN), there are only 4 BSAE programs.

Projected Enrollment:

The long-term projected enrollment is anticipated to be between 400 and 600 students with 100 to 150 students starting each year. This projection is based on the number of current students actively engaged in aerospace studies and national enrollment in BSAE programs as compared to mechanical engineering.

From the 2020 ASEE report (the latest available) the ratio of mechanical engineering students to aerospace engineering students is a factor of 7.6 for BS degrees awarded and 5.4 for enrollment. If we are on the national average with a projected enrollment next year of 1250 BSME students (based on current graduating seniors and a similar first-year enrollment next year) we could expect a steady-state enrollment between 160 and 240 aerospace students based solely on national averages. That said, enrollment in aerospace programs nationally is skewed with a few large programs. The top 20 programs graduate more than 100 students per year. We anticipate moving quickly into the top 20 in BSAE degrees awarded annually (as we have been historically in BSME) , which based on the 2020 ASEE report would be between 100 and 150 BS degrees annually – hence the 400 to 600 enrollment projection. This projected growth is also based on (i) our strong reputation for engineering, (ii) strong student interest in aerospace and space systems, and (iii) there are only four aerospace programs regionally, two in Michigan (UM, Western), none in Wisconsin, and two in Minnesota (UMN, St Cloud).

We anticipate that there will be some BSME students who will want to transfer into the BSAE program. The estimate is 50 to 60 students based on current minor and enterprise participation. For AY 24-25, the BSME enrollment is projected to increase (not counting the BSAE program) due a historically small graduating class this year.

BSME enrollment is projected to increase with the addition of the BSAE program because students will be able to double major in BSME and BSAE with only one extra semester of coursework. This also means that the BSAE-specific courses will have to be taught every semester in order to accommodate the BSME-BSAE double major.

Specialized Accreditation Requirements:

The BSAE program would be accredited through ABET. Performance indicators and assessment instruments will be developed for each of the ABET Student Outcomes (listed in section 2).

Professional Licensure Requirements:

not applicable

[4] December 12, 2023 TechTracS report from MTU Sponsored Operations Office

2. Curriculum Details

Learning Goals:

Student Outcomes associated with the program are: (ABET EAC Criterion 3)

1. an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics
2. an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors
3. an ability to communicate effectively with a range of audiences
4. an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts
5. an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives
6. an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions
7. an ability to acquire and apply new knowledge as needed, using appropriate learning strategies.

The degree program must also fulfill the ABET Program Specific Requirements, which are provided below. The program criteria will drive curriculum content and learning experiences and faculty qualifications.

Lead Society: American Institute of Aeronautics and Astronautics

These program criteria apply to engineering programs that include “aerospace,” “aeronautical,” “astronautical,” or similar modifiers in their titles.

1. Curriculum

Aeronautical engineering or similarly named engineering programs must include the following curricular topics in sufficient depth for engineering practice: aerodynamics, aerospace materials, structures, propulsion, flight mechanics, and stability and control.

Astronautical engineering or similarly named engineering programs must include the following curricular topics in sufficient depth for engineering practice: orbital mechanics, space environment, attitude determination and control, telecommunications, space structures, and rocket propulsion.

Aerospace engineering programs or similarly named engineering programs, which combine aeronautical engineering and astronautical engineering topics, must include all curricular topics in sufficient depth for engineering practice in one of the areas—aeronautical engineering or astronautical engineering as described above—and, in addition, similar depth in at least two topics from the other area.

The major design experience must include topics appropriate to the program name.

2. Faculty

The program must demonstrate that faculty members teaching upper-division courses have an understanding of current professional practice in the aerospace industry.

Assessment Plan:

The new program will follow the same assessment plan and process as the BSME program. A curriculum committee made up of elected faculty representatives review course and program changes. An assessment committee made up of interested faculty collects assessment with cooperation of the curriculum committee and course coordinators, then reviews that data and makes recommendations to the faculty as part of the continuous improvement process.

Curriculum Design:

Total Credits: 128
BSAE Curriculum Design:

Required Courses (104 cr): [AE prefix denotes a new aerospace course]

Math and Science (31 cr)
- CH1150/1151 Chemistry I + Lab
- PH2100/1100 Physics I + Lab
- PH2200/1200 Physics II + Lab
- MA1160 Calculus I w/ Technology
- MA2160 Calculus II w/ Technology
- MA3160 Calculus III + Technology
- MA2320 Linear Algebra
- MA3520 Differential Equations
- MA3710 Statistics

Engineering (73 cr)
- ENG 1101 Engineering Analysis and Problem Solving
- ENG1102 Engineering Modeling and Design
- MEEM2110 Statics
- MEEM2150 Mechanics of Materials
- MEEM2201 Introductory Thermodynamics
- MEEM2700 Dynamics
- AE2500 Principles of Aerospace Engineering
- AE2580 Space Environment & Operations
- MEEM2901 ME Practice 1
- MEEM2911 ME Practice 2
- MEEM3750 Dynamic Systems
- AE3501 Aerospace Systems Engineering Practice
- AE3511 Spacecraft Engineering Practice
- AE3520 Aerodynamics
- AE3521 Aerodynamics Lab
- MEEM4230 Compressible Flow
- MEEM4720 Space Mechanics
- AE4520 Aerospace Propulsion (currently MEEM4820)
- AE4510 Aerospace Materials & Structures
- AE4521 Aerospace Propulsion Lab
- AE4550 Spacecraft Thermal Control
- AE4570 Spacecraft Dynamics and Control
- MEEM4901 Senior Capstone Design I
- MEEM4911 Senior Capstone Design II
- 6 credits of Technical Electives

Essential Education (24 cr not included above):
- Seminar: met by ENG1101
- Math: met by degree requirements
- Natural & Physical Science: met by degree requirements
- STEM: met by degree requirements
- Composition
- Foundations of the Human World
- Distribution Pathway:
  - Communications Intensive
  - Arts and Culture
  - Intercultural Competency
  - STEM: met by degree requirements
  - SHAPE elective
  - Essential Education Experience
- Activities for Well-Being and Success

BSAE Model Schedule showing semester-by-semester plan and demonstrating completion time:

Semester	Course	Credits	Pre-reqs	Concurrent Pre-reqs	Co-reqs
1-Fall	CH1150/1151 University Chemistry I + Lab	4			
	PH1100 Physics I Lab	1		MA1160	
	MA1160 Calculus I w/ Technology	4			
	ENG1101 Engineering I	3		MA1160	
	Composition	3			
	Total Credits	15			
2-Spring	PH2100 Physics I	3	MA1160	PH1100	
	MA2160 Calculus II w/ Technology	4	MA1160		
	MA2320 Linear Algebra	2	MA1160		
	ENG1102 Engineering II	3	ENG1101	MA1160	
	Foundations of the Human World	3			
	Total Credits	15			

Highlighted courses are new.

Semester	Course	Credits	Pre-reqs	Concurrent Pre-reqs	Co-reqs
3- Fall	AE2500 Principles of Aerospace Engineering	3	ENG1102		
	PH2200/1200 Physics II + Lab	4	PH1100 PH2100 MA2160	PH1200	
	MA3160 Calculus III + Technology	4	MA2160		
	MEEM2110 Statics	3	MA2160		
	MEEM2901 Mech. Engineering Practice 1	2	ENG1102 UN1015	MEEM2110	
	Activities for Well-being and Success	1			
	Total Credits	17			
4-Spring	MEEM2150 Mechanics of Materials	3	MEEM2110		
	MEEM2201 Introductory Thermodynamics	3	CH1150 CH1151 MA2160		
	MEEM2911 Mech. Engineering Practice 2	3	MEEM2110 MEEM2901	MEEM2201	
	MEEM2700 Dynamics	3	PH2100 MEEM2110		
	AE2580 Space Environment & Operations	3	ENG1102 PH 2200		
	Communications Intensive	3			
	Total Credits	18			

Semester	Course	Credits	Pre-reqs	Concurrent Pre-reqs	Co-reqs
5-Fall	MA3710 Statistics	3	MA2160		
	MA3520 Differential Equations	2	MA2320 MA2160		
	AE3501 Aerospace Systems Engineering Practice	4	MEEM2150 MEEM2700 AE2500 AE2580	MEEM2911	
	AE3520/3521 Aerodynamics + Lab	4	MA3160 MEEM2201 MEEM2911 AE2500		
	Intercultural Competency	3			
	Total Credits	16			
6-Spring	MEEM3750 Dynamic Systems	4	MA3520 MEEM2700		
	AE3511 Spacecraft Engineering Practice	3	AE3501		
	MEEM4230 Compressible Flow	3	AE3520/3521		
	MEEM4720 Space Mechanics	3	MEEM2700	MEEM4230	
	Essential Education Experience	3			
	Total Credits	16			

Semester	Course	Credits	Pre-reqs	Concurrent Pre-reqs	Co-reqs
7- Fall	MEEM4901 Senior Capstone Design I	2	MEEM3750 AE3511	MA3710 AE4550 AE4510	
	AE4550 Spacecraft Thermal Control	3	AE3511 AE3520/3521		
	AE4510 Aerospace Materials & Structures	3	MEEM 2150 AE2580		
	Technical Elective	3			
	SHAPE elective	3			
	Activities for Well-being and Success	1			
	Total Credits	15			
8-Spring	MEEM4911 Senior Capstone Design II	2	MEEM4901 MA3710		
	AE4520 Aerospace Propulsion (currently MEEM4820)	3	AE3520/3521	MEEM4230	AE4521
	AE4521 Aerospace Propulsion Lab	1			AE4520
	AE4570 Spacecraft Dynamics and Controls	3	MEEM3750	MEEM4720	
	Technical Elective	3			
	Arts and Culture	3			
	Total Credits	16			

New Course Descriptions:

Course Title	Cr	Description
AE2500 Principles of Aerospace Engineering *This course is an adaptation of the current MEEM4810 Introduction to Aerospace Engineering. MEEM4810 will be discontinued.*	3	Introductory course covering the principals of aerospace engineering. Topics include principles of flight, rocketry and propulsion, space mechanics, aerospace materials, introduction to jet engines, basics of space environment and thermal management in space. Prerequisites: ENG1102
AE2580 Space Environment and Operation	3	Introductory course on space environment and operations. Topics include, planetary and space environments, space mission operational aspects and consideration of space and planetary environment. Basics of spacecraft functionality and design considerations will be discussed in the various operational environments from launch, to cruise, to arrival, to operation and end of life. Prerequisites: ENG1102, PH2200
AE3501 Aerospace Systems Engineering Practice	4	This course will introduce Aerospace System Engineering. A project will guide students through the practice of applied system engineering. Topics covered include definition of scope, requirements, requirement flow-down, validation and verification methods, concept of operations, failure mode and effects analysis, risk mapping, interface control definitions, design reviews, project phases and life cycle, documentation, traceability and application of standards. Students create simulations and validation procedures to verify that components and assembled system meet desired requirements. Experimental methods, simulation, data processing, comparing experimental and analytical results, and engineering communication methods are emphasized. Prerequisites: MEEM2150, AE2500, AE2580, MEEM2700 Concurrent Prerequisite: MEEM2911
AE3511 Spacecraft Engineering Practice	3	This course will teach students the processes and concepts necessary to design, build, and integrate spacecraft components into a vehicle. As the overarching theme, the course will use an Interface Control Specification to highlight and isolate mechanical, thermal, and electrical requirements that are necessary to integrate components into a functioning spacecraft in the space environment. Fundamental concepts of structural mechanics and heat transfer will be reinforced through experiments designed to quantify component interfaces to determine compatibility. Simulation techniques will support and extend experiments to verify component performance. Space industry standard testing processes, such as Test Like You Fly philosophy and NASA General Environmental Verification Standard, addressing vibration loads, mechanical shock, and thermal balance will be introduced and referenced throughout the course. Prerequisites: AE3501
AE3520 Aerodynamics	3	This course addresses the fluid dynamics of gases and convection heat transfer around the aircraft and through propulsion systems. Potential flow, boundary layer, characteristics of laminar and turbulent flows, wall friction, Reynolds analogy, and convection heat transfer correlations are discussed. The course covers the introductory discussion of aircraft dynamics, stability, and control. Prerequisites:MA3160, AE2500, MEEM2911 Required Co-Requisite: AE3521
AE3521 Aerodynamics Lab	1	Students develop testing and simulation skills as they validate the airfoils, wings, and model aircraft. The goal of this course is to characterize the model airplane designed and fabricated by students against simulations. To reach the goal, students learn the fundamentals of aerodynamic measurement methods. Required Co-Requisite: AE3520

AE4521 Aerospace Propulsion Lab	1	Students will obtain hands-on experience of the operation and performance characterization of aerospace propulsion systems in three modules that are jet propulsion, electric aircraft propulsion, and rocket propulsion. In the jet propulsion module, students test compressors, exhaust nozzles, and an entire jet engine. The electric aircraft propulsion module covers the characterization of propellers, electric motors, and electric aircraft. The rocket propulsion module includes the testing and analysis of small-size solid rocket motor. Prerequisites: AE3520/3521 Required Co-Requisite: AE4520 (currently MEEM4820)
AE4550 Spacecraft Thermal Control	3	This course covers fundamentals of heat transfer with applications to spacecraft thermal control. Heat transfer topics focus on steady and transient heat conduction (1D and 2D) as well as single and multiple surface radiation. Passive thermal control topics include thermal straps, coatings and tapes, MLI, thermal interface materials and gaskets, thermal switches, phase change materials, heat pipes, and radiators. Active thermal control topics include heaters, thermoelectrics, louvers, fluid loops, and flexible/morphing radiators. Computational engineering tools (Thermal Desktop, FEA) is used to demonstrate thermal control strategies that meet spacecraft temperature, temperature stability, temperature gradient, and heat flux requirements for structures, instruments, and telecommunications. Prerequisites: AE3520/3521, AE3511
AE4570 Spacecraft Dynamics and Control	3	This course covers spacecraft kinematics, dynamics, stability and control including actuation and sensing techniques. Simulation-based analysis is introduced to illustrate concepts and connect theory to practice. Prerequisites: MEEM3750 Concurrent Prerequisite: MEEM4720
AE4510 Aerospace Materials & Structures *This course is an adaptation of the current MEEM4150 Intermediate Mechanics of Materials. MEEM4150 will be discontinued.*	3	This course will address the most relevant aspects of the materials and structures used in aeronautical and space vehicles. The fundamentals of lightweight alloys, high-performance super alloys, ablative materials, and fiber-reinforced composite materials will be covered, including structure-property relationships. The fundamentals associated with structural behavior of thin-walled aerospace structures will be covered, including torsion, warping, bending, and buckling. Basic concepts of adaptive structures will be introduced. Prerequisites: AE2580, MEEM2150, MA3520

Program-specific policies, regulations, and rules:

The BSAE program will utilize the existing BSME polices; notably, a “C” or better in MA2160 Calculus II in order to enroll in MEEM2110 Statics and MEEM2201 Thermodynamics.

Double Major: BSME & BSAE:

The BSAE degree program has been designed to be state-of-the art with a primary focus on astronautics. The program leverages MEEM courses and MEEM faculty (faculty will teach both MEEM and AE courses). The program has also been designed to facilitate students earning a double major with one extra semester of coursework. The two routes to a double major are laid out here; the first with BSAE as primary and the second with BSME as the primary.

BSAE as Primary: Additional courses to earn BSME (24 credits):

- MSE2100 Material Science
- EC3400 Economic Decision Analysis
- EE3010 Circuits & Instrumentation w/ Lab
- MEEM3201 Fluid Mechanics & Heat Transfer
- MEEM3400 Mechanical Systems Design & Analysis
- MEEM3600 Introduction to Manufacturing
- MEEM3901 ME Practice 3
- MEEM3911 ME Practice 4

6 credits of BSAE technical electives can be satisfied by MEEM3400 and MEEM3600. The result is that the double major can be earned with **18 additional credits of BSME courses.**

BSME as Primary: Additional courses to earn BSAE (36 credits):

- AE2500 Principles of Aerospace Engineering
- AE2580 Space Environment & Operations
- AE3501 Aerospace Systems Engineering Practice
- AE3520 Aerodynamics + AE3521 Lab
- AE3511 Space Engineering Practice
- AE4550 Spacecraft Thermal Control
- AE4570 Spacecraft Dynamics and Control
- MEEM4230 Compressible Flow /Gas Dynamics
- MEEM4720 Space Mechanics
- MEEM4820 Aerospace Propulsion + AE4521 Lab
- AE4510 Aerospace Materials and Structures

15 credits of BSME electives can be satisfied by the 4000-level BSAE courses and 3 credits of free elective can be satisfied by any BSAE course in this list. The result is that the double major can be earned with **18 additional credits required for the BSAE**

Faculty Qualifications:

Current MEEM faculty bios can be found at: https://www.mtu.edu/mechanical/people/faculty/

3. Resources needed to support new program

Library and other learning resources needed:

The current library subscriptions in engineering include support for aerospace engineering. No additional library resources are anticipated to support the BSAE program.

Suitability of existing space, facilities, and equipment:

There are four new laboratory-style courses that will require space and equipment; Aerodynamics Lab, Aeropropulsion Lab, Space Engineering Practice, and Spacecraft Thermal Control. These courses are essential to fulfilling the ABET Program Criteria curriculum requirements.

Next semester, the Mechanical Engineering Department will begin expansion into the 11th floor of the R. L. Smith Building. A final decision has not yet been made as to space allocation of the 11th floor and the subsequent movement of equipment, facilities, and laboratories elsewhere in the building. That said, the consensus is that ***the addition of the 11th floor provides sufficient space for the BSAE undergraduate labs***. The current plan is to utilize a portion of the 11th floor for the portions of the new BSAE labs (AE3511, AE3521, AE4521) to accommodate a steady BSAE enrollment of 400 students (100 students/year). Other space in the R. L. Smith Building will be used for the jet engine test cells.

The department will *need* to begin the demolition and refurbishment of the 11th floor space no later than summer 2024 in order to have the new BSAE labs developed in time for students who transfer into the BSAE program beginning in Fall 2025.

Program Costs:

This program cannot be implemented without additional faculty and staff to support these new students so that the department's student-to-faculty ratio does not increase. The BSAE program will also need equipment, software, and building/facility upgrades to support the unique hands-on curriculum. Some equipment will be large purchases while others will require in-house design and fabrication. Multiple identical test stands will be needed to accommodate the anticipated number of students in the BSAE courses. The following equipment and software needs are anticipated:

- Industry-standard aerospace simulation software – STK, Thermal Desktop, XFOIL
  - collaborative instructional space (similar to MEEM 120) that can accommodate 50 to 60 students in multiple two-hour instructional sections per week
- (2) 12" x 12" closed-circuit wind tunnels
- 6 DOF load balances
  - test models including adjustable CG for stability studies
  - convective heat transfer modules
  - instrumentation and DAQ; including field measurements using LDV
  - building upgrades to manage thermal control of wind tunnels
- Custom test stands for design, build, and integration of spacecraft components
  - mechanical shock and vibration load testing
  - thermal testing with vacuum chambers
  - electrical isolation and EMI susceptibility testing
  - residual line-of-sight jigger test bed for directed telecommunications
  - reaction wheel testing
  - instrumentation and DAQ for these setups
- (2) jet engine test cells
  - also requires building updates to accommodate fuel storage
  - electric propulsion test stands
  - rocket engine test cells that can accommodate hybrid rockets
  - instrumentation and DAQ for these setups

Additional program costs include marketing of the program.

Three enrollment models are presented. The first model (Table 1) caps enrollment at 50 new students per year with a steady-state enrollment of 200+ students and an annual tuition revenue of $2 million per year based on $10,000 net per student per year. This enrollment and tuition revenue model is the minimum, and unrealistic based on current student interest, lack of regional programs, and industry demand. Two additional models are presented that have scaled enrollment growth.

Table 1. Enrollment and Revenue Model with restriction of 50 students per year.

	1st year enrollment	cumulative students (4 yr)	annual tuition revenue	cumulative tuition revenue
AY 25-26	50	50	$500k	$500k
AY 26-27	50	100	$1,000k	$1,500k
AY 27-28	50	150	$1,500k	$3,000k
AY 28-29	50	200	$2,000k	$5,000k
AY 29-30	50	200	$2,000k	$7,000k
AY 30-31	50	200	$2,000k	$9,000k
AY 31-32	50	200	$2,000k	$11,000k

Table 2 shows the enrollment and tuition revenue model for a 100 student annual enrollment cap year with a cap of 50 students for the first two years. This is the mid-size model that has a steady-state enrollment of 400+ students and $4 million in annual tuition revenue.

Table 2. Enrollment and tuition revenue model with restriction of 100 students per year.

	1st year enrollment	cumulative students (4 yr)	annual tuition revenue	cumulative tuition revenue
AY 25-26	50	50	$500k	$500k
AY 26-27	50	100	$1,000k	$1,500k
AY 27-28	100	200	$2,000k	$3,500k
AY 28-29	100	300	$3,000k	$6,500k
AY 29-30	100	350	$3,500k	$10,000k
AY 30-31	100	400	$4,000k	$14,000k
AY 31-32	100	400	$4,000k	$18,000k

Table 3 shows enrollment and tuition revenue model for a steady enrollment of 600 BSAE students, which is a reasonable projection based on student demand, lack of regional programs, and state and national industry needs. The enrollment growth is scaled from 50 students to 150 students per year over the first 4 years

Table 3. Enrollment and tuition revenue model at a steady enrollment of 600 BSAE students.

	1st year enrollment	cumulative students (4 yr)	annual tuition revenue	cumulative tuition revenue
AY 25-26	50	50	$500k	$500k
AY 26-27	75	125	$1,250k	$1,750k
AY 27-28	100	225	$2,250k	$4,000k
AY 28-29	150	375	$3,750k	$7,750k
AY 29-30	150	475	$4,750k	$12,500k
AY 30-31	150	550	$5,500k	$18,000k
AY 31-32	150	600	$6,000k	$24,000k

1. 108.1.2: Criteria for Financial Evaluation of Proposed Academic Programs

1. Relation to University Strategic Plan

Michigan Technological University's stated vision and mission are as follows:

> **Vision**
> Michigan Tech is a globally recognized technological university that educates students, advances knowledge, and innovates to improve the quality of life and to promote mutual respect and equity for all people within the state, the nation, and the global community.
>
> **Mission**
> Create solutions for society's challenges by delivering action-based undergraduate and graduate education, discovering new knowledge through research, and launching new technologies through innovation.

Aerospace engineering advances knowledge and improves quality of life across the nation. Across the state and locally there are numerous companies and industries engaged in aerospace-related work. A key component of the aerospace industry is the discovery of new knowledge and launching new, innovative technologies. Aerospace science and engineering are priorities of the nation as well as globally. The inherent global interaction across the aerospace community fosters cultural awareness and mutual respect.

Michigan Tech already provides specialized curriculum that is focused on aerospace engineering. There is a minor in aerospace engineering and two Enterprises that have an aerospace focus. These two Enterprises currently have more than 150 students participating. A third aerospace related Enterprise is in the process of starting.

2. Impact on University Enrollment

a. Projected number of students in the program: The long-term projected enrollment is anticipated to be between 400 and 600 students with 100 to 150 students starting each year. We anticipate that the student demand will be too high to accommodate this enrollment at the start of the program, and that an enrollment cap will be needed until additional faculty and facilities are in place.

This enrollment projection is based on the number of current students actively engaged in aerospace studies and national enrollment in BSAE programs as compared to mechanical engineering. From the 2020 ASEE report (the latest available) the ratio of mechanical engineering students to aerospace engineering students is a factor of 7.6 for BS degrees awarded and 5.4 for enrollment. If we are on the national average with a projected enrollment next year of 1250 BSME students (based on current graduating seniors and a similar first-year enrollment next year) we could expect a steady-state enrollment between 160 and 240 aerospace students based solely on national averages. That said, enrollment in aerospace programs nationally is skewed with a few large programs. The top 20 programs graduate more than 100 students per year. We anticipate moving quickly into the top 20 in BSAE degrees awarded annually (as we have been historically in BSME) , which based on the 2020 ASEE report would be between 100 and 150 BS degrees annually – hence the 400 to 600 enrollment projection. This projected growth is also based on (i) our strong reputation for engineering, (ii) strong student interest in aerospace and space systems, and (iii) there are only four aerospace programs regionally, two in Michigan (UM, Western), none in Wisconsin, and two in Minnesota (UMN, St Cloud).

b. Source of new students: This program will be primarily new students. Some current BSME students will want to transfer into the BSAE program; estimated to be 50 to 60 students based on current minor and enterprise participation. That said, the BSME enrollment is projected to increase as a result of the BSAE program because students will be able to double major in BSME and BSAE with only one extra semester of coursework. This also means that the BSAE-specific courses will have to be taught every semester in order to accommodate the BSME-BSAE double major.

c. Correlation between BSAE demand and existing enrollment patterns: Michigan Tech is planning for long term enrollment growth. Aerospace engineering is projected to have a 6% growth in employment nationally through 2032. There is a critical shortage of engineers, technicians, and scientists in aerospace industries and national labs. Student demand is such that some Aerospace Engineering degree programs are having to turn away qualified students because they have exceeded program capacities.

d. Current enrollment in the unit: The Mechanical Engineering – Engineering Mechanics department has an undergraduate enrollment of 1100 that is projected to be 1250 next year due a historically small graduating class and high 1st year enrollments over the last three years. The graduate enrollment is 335.

3. Impact on Resources in the Home Department

a. Faculty lines: Additional faculty and staff will be required to support this program.

b. Faculty and student labs: Three new courses that include laboratory-type content are required. Most of these new facilities AE3511, AE3521, AE5421) can be accommodated using a portion of the 11th floor of the R. L. Smith Building. For safety reasons, there will need to be room refurbishment in a subbasement lab to accommodate the jet engine lab. The department will need to begin the demolition and refurbishment of the 11th floor space no later than summer 2024 in order to have the new BSAE labs developed in time for students who transfer into the BSAE program.

The additional faculty will need offices and lab space, which will be assigned and/or requested at the time of hiring.

c. Advising: BSAE students will be advised in the current Mechanical Engineering Advising Center. As the program grows and matures, an additional Academic Advisor will be needed by the start of AY 27-28.

d. Assessment: Aerospace Engineering is accredited by ABET and will be assessed using established processes in the department and the College of Engineering.

4. Impact on Resources Required by Other Units within the University

a. Other academic units: This BSAE program will help propel the university towards the enrollment goal of 10000 students. As a result, over a period of 4 years, there would be an increase of 50 to 150 students in CH1150/1151, PH1100/2100/1200/2200, and MA1160/2160/2320/3160/3520/3710 as well as ENG 1101/1102. Additional instructional support will likely be needed in these units.

b. Information Technology and Library: All students will be required to have a laptop that meets the minimum requirements for the software used for the course. Two software packages will be needed on university systems and student laptops, STK and Thermal Desktop (both are part of ANSYS). There is no identified need for additional resources needed by the library to support this program.

5. Assessment of the ability to obtain the necessary resources assuming requested funds are obtained

With the department expansion into the 11th floor of the R. L. Smith Building, there is sufficient space for the educational part of the BSAE program and major lab equipment is available through multiple vendors.

a. Faculty lines: There is high demand for aerospace engineers in industry. Marketing and position announcements will be critical to effective faculty recruitment. ITF hires may include persons who are interested in a second career as a Professor of Practice.

6. Past Proposals

The department has not initiated any other new degree programs in the last 5 years.

7. Department Budget Contribution

a. Department's total general fund budget: $8.55M
Department's general fund base budget for AY 2022-23 per the Compendium.

b. Tuition revenue generated by BSME/MSME students: $30.08M
Data from the Compendium for AY 2022-23.
BSME Tuition: 1,125 x 30 credits (15 per semester) x $653 per credit (in-state tuition) = $22.04M
MSME Tuition: 320 x 18 credits (9 per semester) x $1,395 per credit (in-state tuition) = $8.04M

c. Tuition revenue generated by the department: $13.20M
BSME Tuition Revenue: 13,752 SCH x $653 = $8.90M
MSME Tuition Revenue: 3,083 SCH x $1,395 = $4.30M

8. How do the benefits from this program compare to other alternatives that are currently under consideration or development?

This program will attract students who would not otherwise attend Michigan Technological University and serves an important role in the state and national interest in aerospace. Adding this program within mechanical engineering will leverage Michigan Tech's existing aerospace expertise and courses. As a result, the resources required are modest for establishment of a large, hands-on engineering degree program and the program can be initiated quickly.