1. Overview
Provide a one paragraph description of the proposed program. Be specific about what degree, major, minor or option is sought.

An Aerospace Minor at MSU is being sought
The goal of this minor is to enhance Montana State University's educational mission by developing and implementing an Aerospace Minor. The objective is to make MSU graduates more attractive in the workforce marketplace.

2. Need

a. To what specific need is the institution responding in developing the proposed program?

The need for the Aerospace Minor at MSU in Bozeman is compelling, and long overdue. MSU has traditionally been the second or third supplier of engineers and engineering technologists to the Boeing Company in Seattle (Source: Boeing historical data; MSU M&IE graduate placement database. MSU has fallen a bit lower in the past several years because of Boeings emphasis to diversify its workforce and its corporate evolution for employee needs. However, MSU is still listed as a "Key University" in its College Relations Coordinating Committee.) Students work as undergraduates in MSU's Space Science and Engineering Laboratory and the Aerospace Minor will formalize the academic experience for these students. MSU has sponsored research from the US Air Force, NASA, DOE (on aerospace related topics such as Wind Energy and Fuel Cells). MSU has a very active Air Force ROTC program, which is housed in the College of Engineering. The Aerospace Minor will provide explicit support of their needs. The Mechanical Engineering program at MSU has been keeping excellent records regarding the job placement of its graduates. Approximately 1/3 of MSU Bozeman's BSME graduates over the past 10+ years find jobs in aerospace or a closely related field. In fact, recurring questions from current students, prospective students, and parents of prospective students are: WHY DON'T WE HAVE AN AEROSPACE MINOR or WHEN WILL AN AEROSPACE MINOR BE AVAILABLE?

b. How will students and any other affected constituencies be served by the proposed program?

Montana has reached critical mass with respect to aerospace being a leader for our high tech economy. Several manufacturing firms, tribal industries, and engineering firms are engaged in the field of aerospace as its primary business. In particular, CDI Aerospace has established an engineering design unit in Bozeman, with a goal to employ 100+ engineers. CDI has already participated with MSU in its offering of ME 458 Aircraft Structures to teach a module on Documentation for aerospace structural designs.

In a regional analysis, there is no counterpart for this proposed minor. The closest Aerospace Engineering programs are at the University of Washington, CU in Boulder, and the University of Minnesota. Utah State University has an aerospace emphasis (From the USU website: "USU offers BS, MS and PhD degrees in Mechanical Engineering with emphasis areas in aerospace, computational, manufacturing, and mechanical engineering."), similar to our Bio-Resources Engineering (BREN) option in Civil Engineering, but does not have a separately accredited program. The University of North Dakota offers an MS degree in Space Studies. This is aimed at different students than the proposed MSU Aerospace Minor. The proposed MSU Aerospace Minor fills both a geographical and strategic need.

c. What is the anticipated demand for the program? How was this determined?

No explicit analysis of the demand has been conducted. However, this minor is long overdue at Montana State University. MSU has a substantial number of courses, research, and presence in aerospace and closely related disciplines. Mature and new faculty have an extensive background in aerospace engineering and science, and many courses are taught with an emphasis on aerospace applications. As an interesting historical note, the current Mechanical Engineering program at Montana State University used to be named the Mechanical and Aerospace Engineering Department in the mid-1970s. A common question during advising sessions of engineering undergraduates is: When will the Aerospace Minor be available?

3. Institutional and System Fit

a. What is the connection between the proposed program and existing programs at the institution?

There is no counterpart of this Aerospace Minor at MSU.

b. Will approval of the proposed program require changes to any existing programs at the institution? If so, please describe.

A feature of the proposed Aerospace Minor is that no new courses are needed to get it going. Implementing the new Aerospace Minor will require no new course development.

c. Describe what differentiates this program from other, closely related programs at the institution (if appropriate).
There is no other or closely related program to the proposed Aerospace Minor in Montana or within a close geographical proximity (less than 250 miles) as described in item 2 b. above.

d. How does the proposed program serve to advance the strategic goals of the institution?

Students are already engaged in research internships and opportunities in aerospace or a closely related field. MSU students already do internships at NASA laboratories, especially NASA JPL, Boeing, Edwards Air Force Base, Sandia, National Wind Technology Laboratory of NREL, etc. to name a few. Also, as mentioned above, many researchers at MSU are already involved in aerospace research. The "brag value" of a formal Aerospace Minor will significantly enhance undergraduate research and internships in the field of aerospace, and will add to our credibility in graduate aerospace research. Representatives from Northop Grumman recently met with individual faculty members from the College of Engineering. They were keen to collaborate with MSU in developing business in Montana, and to participate in the Aerospace Minor (graduate needs and teaching).

As discussed above, CDI Aerospace established an aerospace design unit in Bozeman. It established its office here specifically because of its proximity to MSU, and has been hiring some of our best graduates. The Aerospace Minor could help to provide a symbiotic relationship between existing and emerging companies in Montana engaged in aerospace or a closely related industry. This will help to address the fact that most of the excellent graduates from MSU have been "export products" from Montana, helping to improve other states economies instead of ours. Several businesses in Montana can benefit from students trained in the Aerospace Minor. A brief (and by no means complete) listing of companies engaged in aerospace or related businesses is provided below:

- S&K Technologies
- CDI Aerospace
- Scientific Materials
- S2 Corporation
- Summit Design and Manufacturing in Helena
- Resodyn
- MSE in Butte
- A&S Tribal Industries
- etc.

Among the needs met (explicitly and/or implicitly) for MSU Bozeman Five Year Vision (http://www.montana.edu/upba/vision/visiondocfy06-fy11.pdf implemented 2006) by the Aerospace Minor *(impact of Aerospace Minor described in italics)*:

I. Student Body
A. MSU Bozeman will enroll approximately 13,000 headcount students. The Fall 2005 enrollment was approximately 12,250. *Aerospace Minor is a recruiting tool.*
B. Approximately 27% of these students will be nonresidents, slightly higher than the current 25% nonresident rate (counting Western Undergraduate Exchange and international students). *Aerospace Minor is a recruiting tool for undergraduate and graduate students.*

G. The Fall-to-Fall retention rate of our incoming freshmen students will increase from 70.5% to 75%, which will ultimately lead to an increase in graduation rates. *The Aerospace Minor is an explicit venue for AFROTC students.*

II. Faculty and Staff

F. A growing proportion of the faculty will have a global perspective on their disciplines and will be active participants in the international development of their fields. The University will increasingly attract a strong and diverse faculty drawn from the best educators, scholars, and researchers throughout the world*. Explicitly sanctions and enhances our ongoing and future activities in aerospace.*

III. Curriculum

A. MSU Bozeman will be nationally recognized as a leader in the integration of learning and discovery at the undergraduate level. *Aerospace Minor at MSU Bozeman fills a regional and national need.*

B. MSU Bozeman will have graduate programs that are nationally recognized for research and teaching excellence. *Already recognized, Aerospace Minor formalizes MSU Bozeman's involvement and recognition.*

D. There will be increased opportunities for interdisciplinary courses and programs and encourage team teaching across all disciplinary boundaries*. Aerospace Minor accessible for wide variety of majors at MSU Bozeman.*

IV. Research and Creativity

D. There will be a demonstrable increase in the involvement of graduate and undergraduate students in grants and contracts activity. *Opportunity to engage undergraduates and recruit graduate researchers in aerospace.*

V. Partnerships and Outreach

E. MSU Bozeman faculty and staff will directly contribute to outreach by disseminating the positive outcomes of the faculty's innovation in research and instruction. *Opportunities for faculty and staff locally, statewide, and nationally.*

H. MSU Bozeman will increase its service and development assistance to state, local, and nonprofit agencies through increased University based partnerships with these entities. *Explicit involvement with the companies listed above.*

e. Describe the relationship between the proposed program and any similar programs within the Montana University System. In cases of substantial duplication, explain the need for the proposed program at an additional institution. Describe any efforts that were made to collaborate with these similar programs; and if no efforts were made, explain why. If articulation or transfer agreements have been developed for the substantially duplicated programs, please include the agreement(s) as part of the documentation.

There is no similar program in the MUS system to the proposed MSU Aerospace Minor.

4. Program Details

a. Provide a detailed description of the proposed curriculum. Where possible, present the information in the form intended to appear in the catalog or other publications. NOTE: In the case of two-year degree programs and certificates of applied science, the curriculum should include enough detail to determine if the characteristics set out in Regents' Policy 301.12 have been met.

The Course of Study is uncomplicated, and all of the courses, facilities, and expertise are in place for the framework of an Aerospace Minor. In fact, the implementation of this minor is overdue. The Course of Study for the Aerospace Minor is as follows:

i) **28 course credits for the Aerospace Minor**; In some cases, this may be accomplished within the maximum 128 credits for certain B.S. degrees at MSU (with the Aerospace Minor inclusive).

ii) <u>Required Courses</u>

Table 1 Required Core Courses for the Aerospace Minor

Course	Credits	Rationale
Math 181	4	Basic Differential Calculus class, necessary for quantitative aerospace courses
Math 182	4	Basic Integral Calculus class, necessary for quantitative aerospace courses
Physics 211	4	Basic science central to aerospace
Physics 212	4	Basic science central to aerospace

Total Required Course Credits 16

These courses are central to all engineering, physical sciences, and chemistry at MSU. This core group makes the aerospace minor applicable to Mechanical Engineering, Electrical Engineering, Physics, Civil Engineering, Chemical Engineering, Chemistry, and Industrial Engineering.

iii) Aerospace Electives

To establish a cogent, meaningful Aerospace Minor, three categories of elective courses have been established. These categories and applicability to aerospace are shown in Table 2 below.

Table 2 Aerospace Elective Course Categories

Category	Impetus
Materials and Structures	needed for development of aerospace systems; structures, hardware, sensors, system packages, etc.
Thermo/Fluids	needed for an understanding of aeronautical systems, momentum equations relevant to propulsion systems, environmental needs, etc.
Focused Topics	This is a series of focused and advanced topics applicable to aerospace. These courses include design, dynamics and control, Computer Aided Design (CAD), space science, etc.

These categories have been carefully selected by MSU faculty with expertise in aerospace (academic and industrial) to form the backbone of the aerospace minor.

iv) Specific Aerospace Elective Courses

Students will take one course out of each of the following categories. These advanced topic courses have been selected to satisfy the requirements of the minor established in Table 2 above and are listed in Table 3 below.

Table 3 Aerospace Elective Courses

Materials and Structures *(Students take at least one of the following)*

Course	Rationale
ME 464 Mechanical Behavior of Materials	advanced structural materials class
ME 463 Composite Materials	advanced materials, very important to aerospace structures
ME 458 Aircraft Structures	unique MSU course developed in conjunction with Boeing and CDI Aerospace engineers
ME 465 Finite Elements	basic analysis technique for

	aerospace systems
Phys 442 Novel Materials	specialty materials course
ME 480 Engineering Materials	specialty materials engineering course

Thermo/Fluids *(Students take at least one of the following)*

Course	**Rationale**
EM 335 Fluid Dynamics	fluid mechanics, applicable to aerospace and momentum equations related to aerospace systems
EM 435	Steady and unsteady flow; computer applications
ME 324	Engineering Thermodynamics
ME 326	Heat Transfer
ME 426	fluid mechanics with topics applicable to aerospace
ME 454 HVAC	applicable to aerospace systems environmental control
MET 430 Fluid Power Technology	applicable to aerospace control Systems

Focused Topics *(Students take at least one of the following)*

Course	**Rationale**
ME 448 Tooling	Tooling for aerospace structures
ME 411 Computer Aided Design	Advanced CAD principles
I&ME 422 Introduction to Simulation	modeling methodologies, data sampling and analysis
EE 308 Signal Analysis	Analysis of System Data
EE 321 Controls	Aerospace control systems
EE 422 Modern Control	Additional controls course
EE 465 Microcontroller Hardware	Control of aerospace systems with Microcomputers
EE 482 Electro-Optics	Advanced aerospace sensor system
ENGR 310	Introduction to Engineering Design
ME 422 MEMS	Micro-Electro-Mechanical Systems
Phys 426	Modern Optics
Phys 427	Laser Applications
Phys 435	Astro-Physics

Aerospace Elective Course Credits	**9 minimum**

Notes: The additional constraint will be imposed on Aerospace Specific Electives. **IF A COURSE IS A REQUIRED COURSE FOR THE STUDENT'S MAJOR DEGREE PROGAM, IT WILL NOT BE ACCEPTED AS AN AEROSPACE MINOR ELECTIVE.** Additional Clarification: Elective courses in a student's major degree program are not considered as required courses, and can be used as Aerospace Minor electives. This forces students to take his/her elective courses in areas to emphasize the breadth applicable to aerospace. Pre-requisites for courses will need enforcement.

v) An additional three (3) or more credit course from Table 3 will complete the 12 elective courses for the Aerospace Minor. An appeal to include additional classes for the Aerospace Minor can be made if the student/instructor can make a cogent argument as to how the course is relevant to aerospace ala Table 2.

vi) In summary, the MSU Aerospace Minor consists of 16 required course credits plus 12 elective course credits as outlined above for a total of 28 course credits. In its initial offering, the Aerospace Minor course electives are strongest in the fields of materials and structures, but the architecture of Tables 2 and 3 is open to accommodate the breadth of aerospace engineering and science for the minor, and provides a framework for evolution and improvement.

b. Describe the planned implementation of the proposed program, including estimates of numbers of students at each stage.

Implementation of the program will require little more than including the Aerospace Minor in the MSU COURSE BULLETIN and will not require a phasing-in. It can be available immediately.

A conservative estimate of students involved in the Aerospace Minor would be over thirty (30) students. This was estimated from the fact that 30% of Mechanical Engineering students go into aerospace careers (ME has approximately 60 graduates/year), the MSU AFROTC has 22+ cadets in Aerospace Studies (It is anticipated that most of them would focus their elective courses on the Aerospace Minor).

Given that the Aerospace Minor is applicable to Mechanical Engineering, Electrical Engineering, Physics, Civil Engineering, Chemical Engineering, Chemistry, and Industrial Engineering, it is difficult to estimate the total number of students participating in the minor. However, since the Aerospace Minor is working within the existing infrastructure, some metrics for its impact are provided in Table 4 below.

Table 4. Impact of Implementing the MSU Aerospace Minor

• Break-even point?	0* FTE students
• Enrollments / year?	Nearly unlimited
• Graduates / year?	Nearly unlimited
• MT jobs / year?	10-15**

*There is no start-up investment required, so the “break even point” for number of students is irrelevant.
**Based on estimates from job placements in Montana Companies engaged in Aerospace (e.g. Resodyn, MSE, CDI, Scientific Materials, etc.); actual numbers could be much higher.

5. Resources

a. Will additional faculty resources be required to implement this program? If yes, please describe the need and indicate the plan for meeting this need.

No additional faculty resources are needed at this time to implement the Aerospace Minor program. As-needed resources to conduct the program are listed in Table 5 below.

Since 1996, MSU has had the Space Science and Engineering Laboratory. It is housed in Physics and has a substantial track record in aerospace related curricula and research. Also, there are other Physics faculty at MSU whose prime area of focus is aerospace hardware development. Three recent additions in the M&IE Faculty make the Aerospace Minor important at this time. The new M&IE Department Head, Chris Jenkins, has a long track record of research in lightweight materials and structures with applications to space structures, and is a consultant to NASA and the Air Force. Another faculty hired in 2006 worked at NASA before joining MSU with expertise in Materials Science. The M&IE also recently hired another tenure track faculty with a Ph.D. in Aeronautics and Astronautics. In addition, there is expertise in aerospace research in each of the three areas outlined in Table 2 within the College of Engineering, Chemistry, and Physics. Furthermore, many of the Faculty at MSU have worked for aerospace or closely related industries before coming to MSU. The expertise and credentials for Faculty to support the Aerospace Minor is without question. The Aerospace Minor will serve to bring these factions together, and to formalize collaborations.

b. Are other, additional resources required to ensure the success of the proposed program? If yes, please describe the need and indicate the plan for meeting this need.

There are no additional resources needed to implement the program. With the significant need for the Aerospace Minor, a concern might be that it could actually overtax the existing resources. However, the Course of Study has been carefully planned to minimize the impact on the participating academic units. The impact on additional resources at MSU is described below.

i). Library – the library has sufficient holdings for the courses offered for the Aerospace Minor courses; the courses in Table 3 have been taught in the past with these resources. In special instances, books have been purchased and put on reserve for students enrolled in classes.

ii). Computer services – all of the computer services and needs are in place to adequately offer the courses. However, companies such as Sikorsky Aircraft, Boeing, and CDI Aerospace in Bozeman have asked why we do not use CATIA for our Computer Aided Design Classes. This minor will be used as justification for us to ask these companies to purchase MSU site licenses for computer programs of specific interest to aerospace

iii). Telecommunications – none will be specifically needed, but we may engage aerospace companies in teleconferences to help guide our course offerings. If there is substantial interest from other MUS institutions in participating in the MSU Aerospace Minor, telecommunications may be an effective way to engage them.

iv). Equipment – no new equipment is needed at this time. However, as we continue to use the EFAC process to enhance our teaching laboratories, we will ensure that the hardware and software is germane to the Aerospace Minor course offerings.

v). Space/Capital Requirements – None are requested to implement the Aerospace Minor

vi). Support Services – No support services are needed to implement the Aerospace Minor

A summary of the impact is provided in Table 5. No additional resources are needed to coalesce our existing activities in aerospace for the Aerospace Minor.

Table 5. Resource Allocation needed for the MSU Aerospace Minor

• Total program budget?	$ 5,000*
• Faculty FTE?	1/3*
• Staff FTE?	0

*If Adjunct Faculty are needed to enable any of the courses in Table 3, the approximate cost to cover a three credit course is $5,000. This will be done on an “as needed” basis. Costs will be covered under the current MSU funding model.

A feature of the proposed Aerospace Minor is that no new courses are needed to get it going. Implementing the new Aerospace Minor will require minimal course development. However, the Elective Course Categories of Table 2 have a very open architecture. These categories have specifically been developed by Faculty at MSU with degrees in aerospace, or others who have had substantial careers in aerospace. Virtually every course topic germane to aerospace can be captured by these categories. There are already discussions underway to develop courses such as Aerospace Science and Engineering (which could be captured in the Advanced Topics category), a new fluids course with an emphasis on aerodynamics and gas dynamics relevant to aerospace, a new graduate course in fluids specific to aerospace, etc. The Montana Space Grant Consortium, under the direction of Dr. Bill Hiscock has expressed keen interest in developing and explicitly supporting the MSU Aerospace Minor through its activities and funding.

6. Assessment.

How will the success of the program be measured?

M&IE has had in place for a number of years a comprehensive and successful assessment plan for all of its programs.
(see http://www.montana.edu/wwwprov/assessment/assessmentplans.htm).
We continually assess objectives and outcomes at the program and course levels. These assessments are mandatory for our national accreditation (ABET), an accreditation we have held for many years. Our current assessment plan and assessment methods will be consistently applied to the Aerospace Minor.

However, we will provide specialized assessment that focuses on such issues as student, employer, and alumni satisfaction aimed specifically at the minor. Aerospace Minor gradation rates and student placement will be monitored. In particular, a concern is that not all courses in Table 3 are of the same rigor. We will need to closely monitor and ensure that students do not take the "path of least resistance" when selecting their elective courses, and take corrective action as necessary. We will continue to monitor the progress of our graduates, with the specific emphasis on aerospace related activities. Since our students are already substantially engaged in aerospace related activities, and have a long track record of successful careers in aerospace, the Aerospace Minor has been needed for a long time to serve our students. This is a case where MSU has the responsibility to provide academic support for well-established demand.

7. Process Leading to Submission

Describe the process of developing and approving the proposed program. Indicate, where appropriate, involvement by faculty, students, community members, potential employers, accrediting agencies, etc.

The proposed curriculum was first presented to the ME Curriculum Committee and faculty for approval. Then the proposed curriculum was presented to the Lysle Wood Professorship Review Committee for review and feedback. The Review Committee membership consists of the three M&IE Program Coordinators, the MSU Space Science and Engineering Laboratory, and the Boeing Company. (The Lysle Wood Professorship was established to provide aerospace development opportunities for faculty and students.) The proposed Aerospace Minor has been reviewed by the MSU College of Engineering Curriculum Committee, the MSU Undergraduate Studies Committee, and the Academic Affairs sub-committee of Faculty Senate. These committees all gave their approval.

Mechanical Engineering and the College of Engineering at MSU each have Industrial Advisory Boards with members from aerospace companies, such as Boeing, CDI Aerospace, and Spirit Aviation. The implementation and progress of the program will be periodical reviewed by these boards. We will engage these members for specific guidance and support for the Aerospace Minor.