AC 2008-1369: TEACHING AEROSPACE ENGINEERING IN MECHANICAL ENGINEERING

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Teaching Aerospace Engineering in Mechanical Engineering

Introduction

With the limited number of undergraduate programs in aerospace engineering, it has fallen to many mechanical engineering programs to provide the engineers for the aerospace industry. This makes sense in that 80-90% of the engineering science topics are the same in both an aerospace engineering bachelor's degree program and a mechanical engineering program. Much of the difference between the two programs lies in the design/application aspects of the curriculum. With mechanical engineering programs needing to provide engineers for the aerospace industry, it seems wise to include aerospace engineering courses as technical electives. Such is the case at Michigan State University, where a course entitled Aerospace Engineering Fundamentals is available to the students. This paper deals with how one instructor developed such a course.

This paper begins with the formulation of course goals. How these course goals were addressed is then presented. This will include sample assignments and handouts. Special emphasis is placed on how students were motivated for studying aerospace engineering. The paper concludes by presenting and discussing student feedback.

Development of Course Goals

ME 440 Aerospace Engineering Fundamentals is a three credit senior level course that serves as a senior elective for the BSME requirements. It has been a popular course with over 1/3 of the annual BSME graduates (about 50) enrolling in the course. When Michigan State University was on quarters, a three course sequence in aerospace engineering existed that covered aerodynamics, propulsion, and design. The current course was established in the transition to semesters, but staffing issues led to it being rarely taught and was nearly dropped from the curriculum. At the last moment, this was avoided due to a faculty member stepping forward to claim the course and student/employer input on the need for such a course. The current course description is:

> Aerodynamics, propulsion, and flight mechanics. Vehicle and propulsion engine performance and design characteristics.

It has a corequisite of fluid mechanics and prerequisites of thermodynamics and dynamics. The primary instructor of the course has taught it primarily as an air breathing engine course. The assignment of the course to this paper's author was due to a sabbatical leave. In reviewing the above course description, the author felt that a course more consistent with the description needed to be delivered. The author has extensive alumni contacts and input was sought from those alumni in the aerospace industry (such companies as Boeing, GE Aviation, Adam Aircraft, Lockheed-Martin) as to what should be the content in a single aerospace engineering course taken by a mechanical engineer entering the aerospace industry. The primary input received was to present a course that shows mechanical engineering majors how their mechanical engineering science applies to aerospace. A secondary input was to introduce students to the history of aviation, space flight, and the aerospace industry.

With this input the following course goals from a technical perspective were set for this course:

- Apply the fundamentals of fluid mechanics, as learned in the mechanical engineering fluid mechanics course, to aerodynamic analysis, including wing design.
- Apply the fundamentals of dynamics and controls, as learned in the mechanical engineering dynamics course, to analyze the control and stability of airplanes and spacecraft.
- Apply the fundamentals of mechanics of materials, as learned in the mechanical engineering strength of materials course, to aerospace structural design.
- Apply the fundamentals of thermodynamics, as learned in the mechanical engineering thermodynamics course, in modeling aerospace propulsion systems.

Additionally, a breadth goal was set:

- Develop an appreciation for the history of aviation and space flight, and an understanding of the nature of the aerospace industry.

With the course goals set, the course itself could now be designed.

Technical Content

A first step in designing the technical content for the courses was to undertake a web based review of aerospace engineering courses at other institutions was undertaken. First, the aerospace programs at Purdue University, University of Illinois at Urbana-Champaign, and the University of Michigan were reviewed. As might be expected, there were no senior level courses that provided a broad background in the fundamentals of aerospace engineering. Either courses were focused on specific topics such as aerodynamics and propulsion or introductory courses were at the first or second year level. Next a web based review of accredited mechanical engineering programs at institutions that did not have accredited aerospace engineering was carried out. The results of this review are shown below.

Institution	Aerospace Engineering Courses
Washington State University	Applied Aerodynamics
University of Iowa	None
Kansas State University	None
Rose Holman	Intro to Aero, Propulsion, Aero Lab, Aircraft Design
Rochester Institute of Technology	Several leading to a concentration in aerospace engineering
University of Nebraska, Lincoln	Aerodynamics
Northwestern University	None
University of Wisconsin, Madison	Gas Turbines and Propulsion
Texas Tech University	None
Michigan Tech	None

Unfortunately, there are not too many examples to follow. The same difficulty was encountered in selecting. After significant review the following text book was selected for the class:

Introduction to Aeronautics: A Design Perspective by S.A Brandt, R.J. Stiles, JJ. Bertin, and R. Whitford, 2nd edition, AIAA, 2004

This book has decided design orientation to it, which actually fits nicely with the strong design component of the mechanical engineering program at Michigan State University. A topical course outline was developed and it is shown below.

Course Outline

Week of	Topics
8/28	Principles of Powered Flight
9/4	***Labor Day (9/4)***, **Video: History of Flight**
	Principles of Powered Flight
9/11	Aerodynamics: Drag on Surfaces
9/18	Aerodynamics: Lift on Surfaces, **Video: Military Aircraft**
9/25	Aerodynamics: Wing Design
10/2	Aircraft Stability and Control
10/9	Spacecraft Stability and Control, **Exam #1**
10/16	Aerospace Structures, **Video: Aerospace Industry**
10/23	Aerospace Structures
10/30	Propulsion: Air Breathing Engines
11/6	Propulsion: Air Breathing Engines, **Video: History of Space Flight**
11/13	Propulsion: Rocket Engines
11/20	Propulsion: Rocket Engines, ***Thanksgiving (11/23, 11/24)***
11/27	Compressible Flow, **Exam #2**
12/4	Vertical Take-off Aircraft, ***Design Day (12/8)***

Final Exam: Tuesday, December 12, 3:00-5:00 p.m.

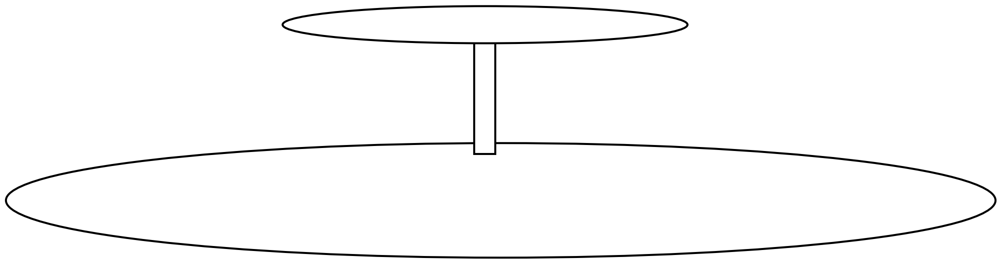
The next step was to develop lecture notes for the topics. Since the lectures did not come exclusively from the text book, several handouts (lecture summaries) were developed to distribute to the students. These may be found at the course web site:

http://www.egr.msu.edu/classes/me440/somerton/

This site also provides the homework assignments and exams for the course. To provide a sense of the technical detail the course went into, the five problems of the final exam are presented below.

Problem 1

A novel aircraft has its main wing mounted on a pylon above the fuselage as shown below.



Determine the maximum height of the pylon for this aircraft to support the drag force acting on the wing.

Aircraft speed: 50 m/s
Aircraft altitude: 2 km
Wingspan: 16 m
Wing chord length: 2 m
Airfoil: 1408
Angle of attack: 4º
Pylon cross-section: 0.05 m x 0.05 m
Pylon material: balsa wood

Problem 2

Determine the wingspan required for the following aircraft:

Aircraft speed: 90 m/s
Aircraft altitude: 4 km
Wing chord length: 0.7 m
Airfoil: NACA 2418
Angle of attack: 8º
Fuselage mass: 1000 kg
Wing geometry: rectangle
Wing material: Solid aircraft spruce
Average wing thickness: 0.10 m

Problem 3

Determine the percent theoretical air required for a ram jet engine burning octane with an inlet temperature of 280 K to produce an exit velocity of 1300 m/s?

Aircraft altitude: 12 km
Burner air inlet temperature: 320 K
Burner pressure: 8 times the ambient pressure

Problem 4
Consider an aircraft flying at 120 m/s at 5 km with the following characteristics:

Aircraft mass: 7,000 kg
Wing pitching moment: 800 Nt·m
Wing lift: 50,000 Nt
Wing aerodynamic center: 2.5 m ahead of the center of gravity
Tail wing pitching moment: 0 Nt·m

Determine the tail wing lift and position required for pitch trim condition.

Problem 5
Determine the combustion chamber temperature required for the turbojet engine described below.

Aircraft speed: 120 m/s
Aircraft altitude: 7 km
Engine thrust: 10,000 Nt
Engine intake area: 0.2 m^2
Compressor pressure ratio: 5
Nozzle Exit Temperature: 770 K

Though these are clearly simpler than corresponding exam problems from the topic specific aerospace engineering course, they still have a rigor that would demonstrate the mechanical engineers ability to apply basic principles to aerospace applications.

The course results for this exam were very satisfactory with a high of 100%, a low of 68%, and an average of 90%. The distribution is shown in Figure 1

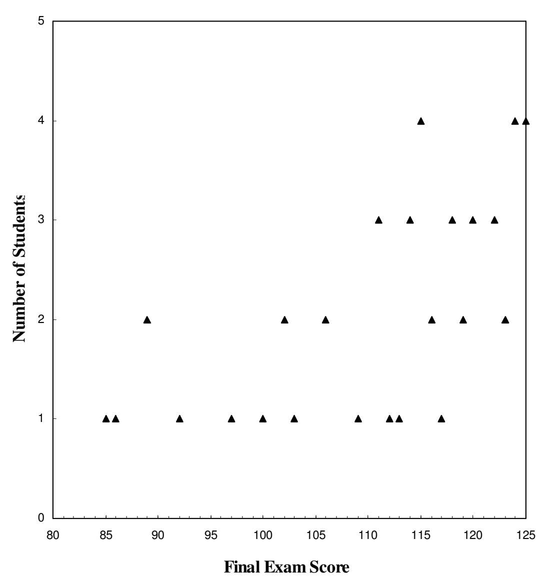


Figure 1 Final Exam Distribution

This graph show that many students did very well on the final exam.

Breadth Content

This is a popular course, but some of the students are not aviation or space crazy (and knowledgeable) as most aerospace engineering students. To maintain student interest and keep them enthused about aerospace engineering several non-traditional teaching approaches were employed. An approach called the Hot Topic of the Week was used in which an aerospace topic of interest to the students was presented once a week in a 15 minute presentation. These topics were solicited from the students on the second day of class. Index cards were distributed to the class and they were instructed to write a question concerning aerospace that might not be covered in the technical material of the class. Then each Friday a card was randomly selected, and the question would form the basis of a 15 minute lecture by the course instructor the next Friday. Table 1 shows the questions of these lectures

Table 1 Hot Topics of the Week

1. Being a race car driver, can you talk about the relations among the aerodynamics of the wing/body of the car and the down force?
2. How much does cargo weight change the flight mechanics of a plane?
3. Are commercial airliners really equipped with a turbine that drops out of the fuselage as a triple redundant way to control the air foils?
4. What about the Blue Angels?
5. How do you become part of the Blue Angels?
6. What is the secret to the perfect paper airplane, if it exists?
7. What part do composites play in things like thrust reversers and nozzle equipment?
8. How do hang gliders fly?
9. Who was the first country to take flight and when?
10. Could Maverick have done an inverted roll with the MIG?
11. Where are we with respect to commercial space flight?

Some of these questions fit very nicely with the technical topics of the course, while others are just of general interest. Question #1 came at an ideal time in the class, as the topic of lift had just been introduced, so that the 15 minute lecture on down force was quite technical. For the perfect paper airplane question (#6), the directions for the world record holder was distributed, the class made the airplane and tested their plane within a competition down the hallway of the engineering building. Web research was used for nearly all of the lectures. A power point presentation was composed for the lecture and it was as graphically appealing as possible. An example may be found in Appendix A.

To instill in the students a sense of the history of aviation and space flight a series of videos were used. As seen in the course outline provided above, four videos were shown doing class time. The videos worked well in broadening the students' education. The History of Flight and the History of Space Flight videos came from the Century of Flight series. The Discovery Wings collection provided the Military Aircraft video. It was a real challenge to find a video on the history of the aerospace industry. To give the students at least a sense concerning the industry, the Learning Channel's production on the Airbus A380 was used. All of these are available at

DiscoveryStore.com. As instructor, the author had considerable concern that the video sessions might become nap time for the students. To counter this, a quiz was prepared for each video that was taken while watching the video. An example is shown in Figure 2. The quiz is quite simple and the questions are in the order that the topic appears in the video, but the quizzes did serve their purpose of keeping the students engaged. An extension of the video classes was the movie night. Co-sponsored with the ASME and Pi Tau Sigma groups, an auditorium was reserved and Apollo 8 was shown with popcorn and soda. Finally, a more conventional approach was taken by bringing in a guest lecturer from GE Aviation to discuss working in the aerospace industry and the use of computational modeling to solve aerospace engineering problems.

ME 440

Aerospace Engineering Fundamentals

Video Quiz #3

Student Name

1. How many passengers will the A380 hold?

a. 400
b. 1000
c. 600
d. 300

2. What is the development cost for the A380?

a. $265 million
b. $7.10 billion
c. $265 billion
d. Way too much

2. What materials go into the construction of the wing? Circle all that apply.

a. Titanium
b. Aluminum
c. Stainless Steel
d. Carbon Fiber

3. Where are the fuselage assemblies manufactured?

a. Japan
b. Great Britain
c. France
d. Germany

5. What will be the production rate of the A380?

a. 1 plane per week
b. 1 plane per day
c. 1 plane per month
d. 6 planes a year

6. What are the transport methods for the parts of the A380? Circle all that apply.

a. River Barge
b. Ocean Vessel
c. Cargo Plane
d. Trucks

7. What do you see as the biggest problem with the A380 manufacturing process?

Figure 2 Example Video Quiz

Student Feedback

Student feedback was collected with the survey shown in Fig. 3.

ME 440
Aerospace Engineering Fundamentals

Course Survey

Please respond to the following questions.

1. The videos watched in class enhanced my learning of aerospace engineering.

Strongly Agree   Agree   Neutral   Disagree   Strongly Disagree

2. The video quizzes were good to keep me focused on the videos.

Strongly Agree   Agree   Neutral   Disagree   Strongly Disagree

3. The weekly Hot Topics enhanced my learning of aerospace engineering.

Strongly Agree   Agree   Neutral   Disagree   Strongly Disagree

4. I am confident that I can apply the principles of solid mechanics to aerospace engineering.

Strongly Agree   Agree   Neutral   Disagree   Strongly Disagree

5. I am confident that I can apply the principles of fluid mechanics to aerospace engineering.

Strongly Agree   Agree   Neutral   Disagree   Strongly Disagree

6. I am confident that I can apply the principles of thermodynamics to aerospace engineering.

Strongly Agree   Agree   Neutral   Disagree   Strongly Disagree

7. I am confident that I can apply the principles of controls to aerospace engineering.

Strongly Agree   Agree   Neutral   Disagree   Strongly Disagree

Please share any other comments concerning the course on the other side of this paper.

Figure 3 Student Survey

Table 3 shows the numerical results.

Table 3 Numerical Averages of Student Survey

Question	Average
1	4.28
2	4.36
3	4.14
4	4.38
5	4.32
6	4.14
7	4.10

Strongly Agree: 5, Agree: 5, Neutral: 3, Disagree: 2, Strongly Disagree: 1

In Fig. 4 the results for the non-traditional approaches are shown and a similar graph is shown for the technical concepts in Figure 5.

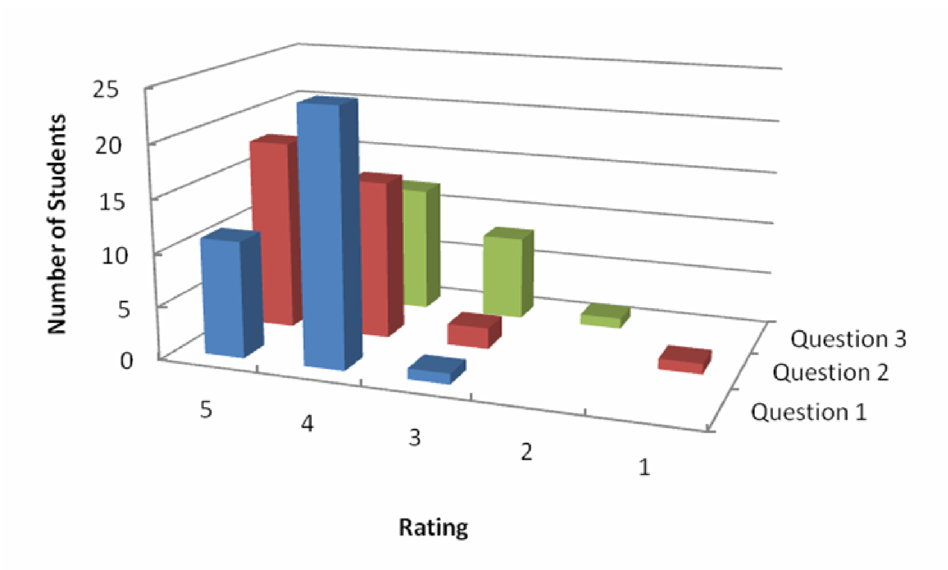


Figure 4 Student Responses for Non-traditional Approaches

These results would indicate that the non-traditional teaching approaches were quite effective. As for applying the techncial areas to aerospace engineeirng, the student ratings are consistent with the order that the topics were covered in the class. It may have seemed to the students that the the aerospace topics associated with themrodynamics and controls were rushed, coming at the end of the class.

Figures 6 and 7 shows a comparison from the University's Students' Opinion of Courses and Teaching System between two different offerings of the course. These results would seem to indicate that the course refvision was a signifant improvement over its previous form.

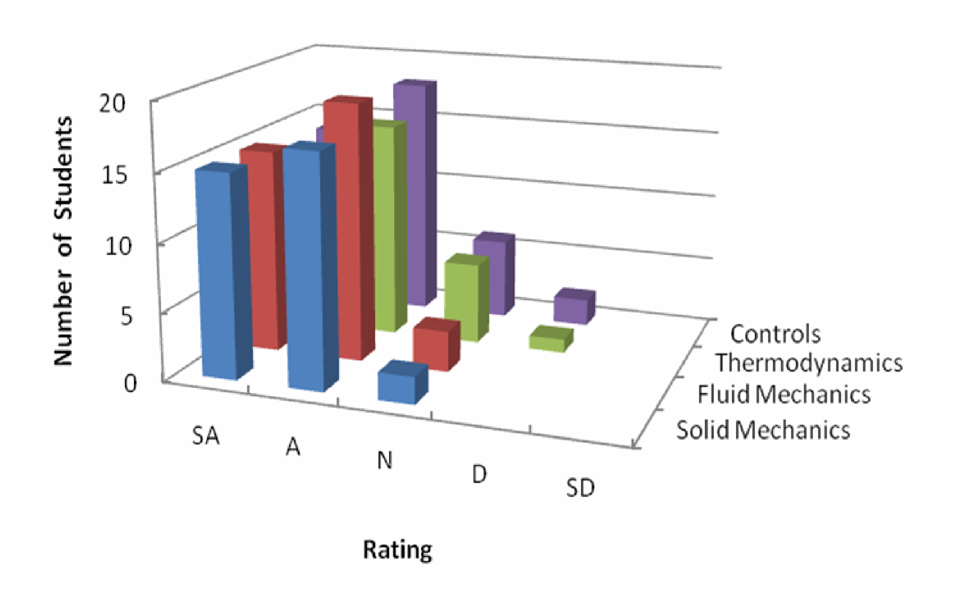


Figure 5 Student Responses for Technical Areas

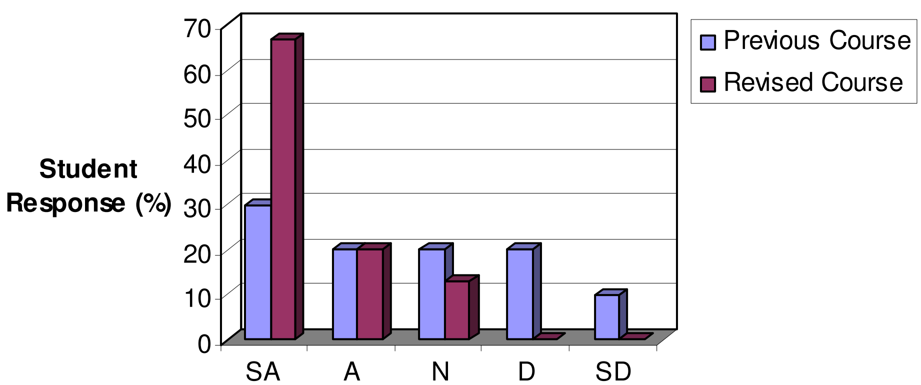


Figure 6 Student Response to: Overall was the instructor effective?
SA: Strongly Agree A: Agree N: Neutral D: Disagree SD: Strongly Disagree

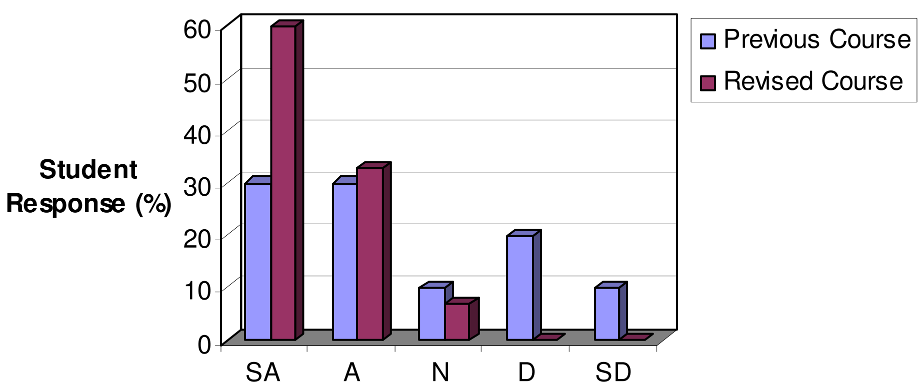
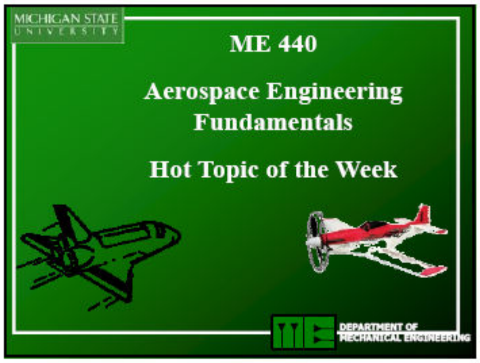


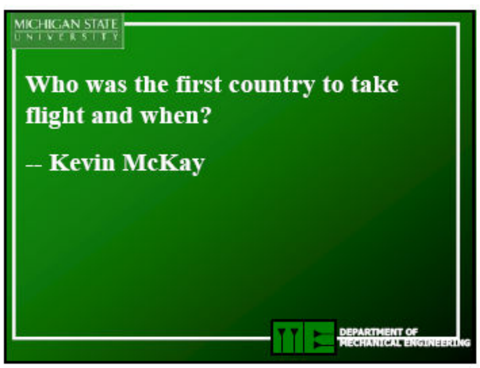
Figure 7 Student Response to: Overall was the course wothwhile?
SA: Strongly Agree A: Agree N: Neutral D: Disagree SD: Strongly Disagree

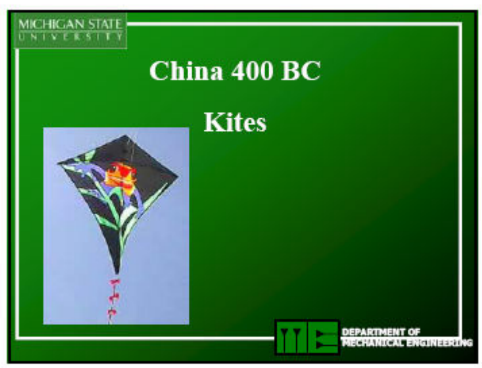
Lessons Learned

1. Very few other mechanical engineering programs teach an aerospace fundamentals course.
2. There are very few textbooks suited to such a course.
3. The course is meaningful to the students with simple, real world examples.
4. Students' appreciation for the history of aerospace engineering can be achieved through video classes and the hot Topic of the Week lecture.
5. Revamping courses takes a considerable amount of time and resources and are probably not rewardable at most universities.

Appendix A Hot Topic Presentation







Flying like a Bird

Human arms are not like a bird's wings and can not move with the strength of a bird's wing.

Aeolipile

Ancient Greek engineer, Hero of Alexandria, mounted a sphere on top of a water kettle. A fire below the kettle turned the water into steam, and the gas traveled through pipes to the sphere. Two L-shaped tubes on opposite sides of the sphere allowed the gas to escape, which gave a thrust to the sphere that caused it to rotate.

1485 Leonardo da Vinci
The Ornithopter

Concept of the modern helicopter!

1783 - Montgolfiers
First Hot Air Balloon

6,000 feet in height and 1 mile distance

1799 - 1850's - George Cayley
The Glider


MICHIGAN STATE UNIVERSITY
1891 Otto Lilienthal
DEPARTMENT OF MECHANICAL ENGINEERING


MICHIGAN STATE UNIVERSITY
1891 Samuel P. Langley
Aerodrome
DEPARTMENT OF MECHANICAL ENGINEERING


MICHIGAN STATE UNIVERSITY
1903 Wright Brothers
Wright Flyer
DEPARTMENT OF MECHANICAL ENGINEERING