Engineering Faculty Document No. 47-23

November 7, 2022

Memorandum

To: The Faculty of the College of Engineering

From: The School of Aeronautics and Astronautics

Date: November 7, 2022

Re: New Graduate Course, **AAE 53300 Space Traffic Engineering Management**

The faculty of the School of Aeronautics and Astronautics have approved the following new course. This action is now submitted to the Engineering Faculty with a recommendation for approval.

Course no. **AAE 53300 Space Traffic Management**
Fall, Lecture, Cr. 3
Pre-req – AAE 340 or equivalent, or permission of instructor

Description: The course teaches the basic techniques and concepts relevant to Space Traffic Management (STM) and Space Situational Awareness (SSA) from a rigorous engineering perspective. The class starts with learning how measurements are collected and processed and then moves on to the non-linear orbital motion and astrodynamics in the near-Earth realm. The focus is on orbit determination and orbit improvement of satellites and space debris to detect new objects and maintain custody of them. Lastly, the class focuses on determining the probability of collision of two resident space objects. At the end of the course, the students are equipped with a fundamental Matlab toolset to investigate STM or SSA problems on their own.

Reason: Currently, no other class exists that focuses on the problem of space domain awareness. Furthermore, passive measurements to space objects using optics or radars, probability of collision, and initial orbit determination without a priori information are not covered in other courses.

William A. Crossley

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J. William Uhrig and Anastasia Vournas Head of Aeronautics and Astronautics, and Professor of Aeronautics and Astronautics

Learning Outcomes:

At the end of the course, the students are equipped with a fundamental understanding and an implementation of a Matlab toolset to investigate their own STM or SSA problems. They have completed the recreation of an active research topic as published in recent literature.

1. Demonstrate fundamental understanding of sustainable use of space.

2. Determine engineering and simulation of information collection for STM.

3. Demonstrate Initial Orbit Determination and Orbit Improvement using passive measurements.

4. Determine Orbital perturbations in the near-Earth and cislunar region.

5. Determine Computation Probability of Collision.

Course Demand:

Graduate – 20 Undergraduate – 10

Course Enrollment History

AAE59000 - Space Traffic Management		**201810**	**201910**	**202010**	**202210**	**202310**	**Total**
GR - Graduate School	IDE - Interdisciplinary Engineering		1			1	**2**
Continuing Education	AAEN - Aeronautics & Astronautics		7			14	**21**
GR - Graduate School	AAEN - Aeronautics & Astronautics	7	11	9	13	13	**53**
PWL	IESE - Int Ecog Sci & Eng				1		**1**
AE - School of Aero and Astro Engr	AAE - Aero & Astro Engineering	1	14	9	4	14	**42**
Totals		**8**	**33**	**18**	**18**	**42**	**119**

Syllabus

Contact information

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Course Content

The course teaches the basic techniques and concepts relevant to Space Traffic Management (STM) and Space Situational Awareness (SSA) in the near-Earth realm from a rigorous engineering perspective.

The class starts with learning how measurements are collected and processed and then moves on to the non-linear orbital motion and astrodynamics in the near-Earth realm. The focus is on orbit determination and orbit improvement to detect new objects and maintain custody of them. Lastly, the class focuses on determining the probability of collision of two resident space objects.

At the end of the course, the students are equipped with a fundamental Matlab toolset to investigate their own STM or SSA problems.

The class is open to undergraduate students and counts as Dynamics and Controls area for them.

Required Course Materials

No book is required; the course script will be made available on Brightspace. Optional books for reference that cover parts of the course materials are:
David Vallado, Fundamentals of Astrodynamics and Applications, Microcosm Press, 2013
Oliver Montenbruck, Satellite Orbits - Models, Methods and Applications, Springer, 2000
Bob Schutz, George Born, Byron Tapley, Statistical Orbit Determination, Academic Press, 2004

The use of and coding in Matlab is required for this course; a student edition is sufficient; helpful packages are the statistics and image processing package.

A LaTeX compiler (e.g., MiKTex (windows), TeXstudio (mac), overleaf (online)) is required to complete the homework assignments.

Topics to be covered:

1. Two line elements and SGP4
2. Sensors, CCD response in astrometric observations
3. Influence of the optics in astrometric measurements
4. Coordinate systems space fixed: right ascension, declination, geocentrioc, topocentric
5. Coordinate systems Earth fixed: elevation, azimuth, aberration
6. Coordinate systems: time systems, hour angle computation

7. Coordinate systems: J2000, nutation and precession models simple and complex
8. Initial orbit determination classical methods, Gauss, Herrick Gibbs etc
9. Initial orbit determination modern methods: admissible regions
10. IOD: Admissible regions: connection of two regions
11. First orbit improvement: least squares, introduction linear least squares
12. First orbit improvement: least squares, non-linear least squares
13. First orbit improvement: covariance discussion
14. Orbit propagation: spherical expansion of the gravity field and pines implementation
15. Orbit propagation: third body effects
16. Orbit propagation: SRP and drag
17. 2nd orbit improvement: Kalman filter as a test case
18. 2nd orbit improvement: Extended Kalman filter in the orbit problem
19. Probability of collision between two space objects and time of closes approach.
20. Covariance representations in non-linear dynamics, orbit improvement and orbit propagation

Grading

10% coding example
45% homework
45% final project
No final exam.

Letter grades are assigned at the end of the semester according to the following grade range: A+ 97–100%, A 93-96%, A- 90-92%, B+ 87–89%, B 83–86%, B- 80-82%, C+ 77–79%, C 73-76%, C- 70-72%, D+ 67–69%, D 63–66%, D- 60–62%, F 0–59%.

Coding Example

In the coding example, the student presents a new piece of Matlab code with explanations and justifications to the class. The code is an implementation of the content of the previous lecture. A use case of the code example is to be mentioned. A list associating each student to a presentation date for the coding example with respect to the content of the preceding class is published on Brightspace during the first week of class. Please note the coding guidelines that apply to both: The coding example and homework. Coding example should be between **8 - 15** minutes long. You can bring your own laptop (hdmi connection available, if you need adaptors, let me know I can bring some), or login to your computer account on the classroom computer.

Code guidelines

The code has to follow a pep8 coding style. Pep8 is a format originally designed for Python. The external document published on Brightspace outlines the formatting requirements and best practices and how they are adapted to the Matlab environment. Every third line has to be a comment.

Homework Guidelines

Homework is to be handed in as a pdf file, generated using LaTeX.

The homework document is to be handed in via Gradescope. When it applies, the code is to be embedded in the pdf in full (relevant instructions are provided on the homework problem sheets).

Final Project

The final project consists of the selection of a relevant publication of the topic. The publication has to be discussed before starting to work on the final project with Prof. Frueh for approval. You cannot be an author or be mentioned in the acknowledgments of the selected paper. Results of that publication are to be reproduced. A presentation has to be given consisting *at minimum* of the following parts:

1. Introduction to the topic
2. Justification of the research
3. Context of the publication and research content (other publications)
4. Explanation of the methodology and results of the paper
5. Comparison of your reproduced results with the results stated in the paper
6. Your comments and observations on the research and the comparison
7. Conclusions.

Presentations are 10 minutes long plus 5 minutes for Q&A (15 min per presentation in total).

Presentations are given in the week after the thanksgiving break:

In addition, a final project report between 10 and 20 pages long, and the code that was used to generate your results, is to be handed in by the end of finals week by the end of the day (midnight):

Friday Dec. 16, 11:59pm

Boilermaker Pledge, Diversity and University Resources

As a boilermaker pursuing academic excellence, I pledge to be honest and true in all that I do. Accountable together - we are Purdue.

Purdue University is committed to maintaining a community which recognizes and values the inherent worth and dignity of every person; fosters tolerance, sensitivity, understanding, and mutual respect among its members; and encourages each individual to strive to reach his or her own potential. In pursuit of its goal of academic excellence, the University seeks to develop and nurture diversity. The University believes that diversity among its many members strengthens the institution, stimulates creativity, promotes the exchange of ideas, and enriches campus life. Purdue's nondiscrimination policy can be found at: `http://www.purdue.edu/purdue/ea_eou_statement.html`.

CAPS Information: Purdue University is committed to advancing the mental health and well-being of its students. If you or someone you know is feeling overwhelmed, depressed, and/or in need of support, services are available. For help, such individuals should contact Counseling and Psychological Services (CAPS) at (765)494-6995 and `http://www.purdue.edu/caps/` during and after hours, on weekends and holidays, or through its counselors physically located in the Purdue University Student Health Center (PUSH) during business hours.

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