# Syllabus

12:00 pm - 1:15 pm Tuesdays, Thursdays or asynchronous
Seng Liang Wang Hall 2555 / online

## Contact information

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Office hours: Thursdays 1:15 to 2:00 in person,
2:00 - 2:30 online purdue-edu.zoom.us/j/4517193939

TA Jeffrey Pekosh jpekosh@purdue.edu
Office hours: In person: Mondays 3:00-5:00pm ARMS 3119, Fridays 1:00-3:00pm 3119
Online, Tuesdays 5:00-6:00pm, Thursday 4:00-5:00pm purdue-edu.zoom.us/j/97786731681

## Learning Outcomes

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 about measurement geometries, 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.

Upon completion of the class, the students are equipped with a fundamental Matlab toolset to investigate their own STM or SSA problems. Specific learning outcomes are: Signals: Measurement simulation and processing. Dynamics: orbit determination, propagation in the presence of uncertainty in the non-linear regime. Presentation and communication skills: Presentation of formulation of technical content, critical evaluation of published technical content.

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 Matlab 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. Coordinate systems space fixed: right ascension, declination, geocentrioc, topocentric
2. Coordinate systems Earth fixed: elevation, azimuth, aberration
3. Coordinate systems: time systems, hour angle computation
4. Coordinate systems: J2000, nutation and precession models simple and complex
5. Orbit propagation: spherical expansion of the gravity field and pines implementation
6. Orbit propagation: third body effects
7. Orbit propagation: SRP and drag
8. Uncertainty Propagation
9. Probability of collision between two space objects and time of closes approach.
10. Initial orbit determination: admissible regions
11. IOD: Admissible regions: connection of two regions
12. First orbit improvement: least squares, introduction linear least squares
13. First orbit improvement: least squares, non-linear least squares
14. First orbit improvement: covariance discussion
15. 2nd orbit improvement: Kalman filter as a test case
16. 2nd orbit improvement: Extended Kalman filter in the orbit problem
17. Orbit improvement and orbit propagation
18. Two line elements and SGP4
19. Sensors, CCD response in astrometric observations
20. Influence of the optics in astrometric measurements
21. Space object characterization using optical measurements

## Grading

2% Brightspace quizzes
58% homework
40% final project (presentation, report, interaction)
No final exam.

Letter grades are assigned at the end of the semester ranging from A+ to F.

## Copyright, Sources, AI, and Large Language Models

All course materials are copyright protected. Students are free to use them as part of the class. Distribution is only permitted with instructor approval. Uploading materials on webshare sites (e.g., CourseHero) is explicitly prohibited.

The use of all sources used in homework, and project have to be explicitly declared.

AI and Large Language Models (e.g., ChatGPT, BERT, PaLM, Gemini, T5, Turing NLG....)

is not permitted unless explicitly stated. All parts of LLMs need to be explicitly declared as sources and all parts have to be explicitly marked as direct quotations.

## Brightspace Quizzes

Weekly a small quiz is posted on Brightspace. Completion of the quiz releases the course materials of the upcoming week.

## Homework

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

Where it applies, the code is to be embedded in the pdf in the relevant parts and handed in a runable form via a zip file (relevant instructions are provided on the homework problem sheets).

### Homework due dates

Homework is expected to be submitted by the time indicated on the homework sheet. When submitted within 2h of the indicated due date, no points are deducted. When submitting 24h or more after the due date, your homework is still graded, but zero points are awarded. In the time window between 2 and 24h after the due date the maximum obtainable points are gradually reduced commensurate to the time passed since the due date.

## Code guidelines: Homework and Code Example

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.

## Final Project

The final project consists of the parts of making a presentation video, and a final report. In the video you have to be visible at at least one instance.

The final project consists of the following elements: The selection of a relevant publication with respect to the topics of the class. The publication has to be shown to Prof. Frueh for approval prior to start working on the project. You cannot be an author or be mentioned in the acknowledgments of the selected paper. Results of the chosen publication are to be reproduced. A presentation and report has to consist *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 time for each person is limited to no more than 12 minutes (anyone is allowed to stop watching after 12 min are passed). Videos have to be submitted via Kaltura by:
**Dec 2, 11:00pm**.

In addition, a final project report between 10 and 30 pages long, and (as additional file(s), not counting towards the page limit) the code used to generate your results, is to be handed in by:
**Dec 6, 11:00pm**

## Final Project Interaction

Each student watches at least 12 other online presentations and posts the following what they liked about the presentation, an element of improvement and one general question and one technical question to the for the presenter. Besides posting your comments and questions, you also hand in one document listing what videos you watched, your questions and comments in one file on gradescope.

The presenter has to answer all questions that have been posed.
Post questions by: **Dec 5, 11:00pm**
Answer all questions by: **Dec 6, 11:00pm**

To compensate for the time to attend presentations and engage in Q&A, or watch the videos and the postings, class is canceled at the following times:
no class on Dec 3 and Dec. 5.

## 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.

**Nondiscrimination Statement and Reporting**
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. More details are available on our course Brightspace table of contents, under University Policies.

The School of Aeronautics and Astronautics is also committed to a climate of inclusion; if you need to report an issue of hate or bias, you may use the link at the top right of our page here: `https://engineering.purdue.edu/AAE/aboutus/Diversity/index_html`

**Mental Health**
If you find yourself beginning to feel some stress, anxiety and/or feeling slightly overwhelmed, try Therapy Assistance Online (TAO), a web and app-based mental health resource available courtesy of Purdue Counseling and Psychological Services (CAPS). TAO is available to all students at any time by creating an account on the TAO Connect website, or downloading the app from the App Store or Google Play. It offers free, confidential well-being resources through a self-guided program informed by psychotherapy research and strategies that may aid in overcoming anxiety, depression and other concerns. It provides accessible and effective resources including short videos, brief exercises, and self-reflection tools.

If you need support and information about options and resources, please contact or see the Office of the Dean of Students. Call 765-494-1747. Hours of operation are M-F, 8 a.m.- 5 p.m.

If you find yourself struggling to find a healthy balance between academics, social life, stress, etc., sign up for free one-on-one virtual or in-person sessions in West Lafayette with a Purdue Wellness Coach at RecWell. Student coaches can help you navigate through barriers and challenges toward your goals throughout the semester. Sign up is free and can be done on BoilerConnect. Students in Indianapolis will find support services curated on the Vice Provost for Student Life website. If you're struggling and need mental health services: 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 mental health support, services are available. For help, such individuals should contact Counseling and Psychological Services (CAPS) at 765-494-6995 during and after hours, on weekends and holidays, or by going to the CAPS offices in West Lafayette or Indianapolis.

**Academic Integrity**
Academic integrity is one of the highest values that Purdue University holds. Individuals are encouraged to alert university officials to potential breeches of this value by either emailing `integrity@purdue.edu` or by calling 765-494-8778. While information may be submitted anonymously, the more information that is submitted provides the greatest opportunity for the university to investigate the concern.

**Emergency Preparedness and Readiness**
See the separate document posted on Brightspace in the Emergency Preparedness and Readiness folder.