University of Michigan

AEROSP568 – Computational Methods for Engineered Systems Design
Winter 2026 Syllabus

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Instructor: Gökçin Çınar

1 Catalog Description

Examines computational and statistical methods for the design of complex engineered systems. Topics include design of experiments, surrogate modeling and surrogate-based optimization, sensitivity analysis, and mixed-variable design space exploration. Aerospace examples highlight advanced aircraft and propulsion system concepts, including methods for co-optimization of aircraft, propulsion, and energy/power management.

2 About the Instructor

My name is Gökçin Çınar (pronounced *goeck-chin chin-r*; she/her/hers; cinar@umich.edu). I am an Assistant Professor in the Department of Aerospace Engineering, and the Director of the **I**ntegrated **D**esign of **E**fficient **A**erospace **S**ystems (IDEAS) Lab. My research interests include computational methods for aerospace systems design, integration, and optimization with a special focus on future aircraft concepts and propulsion architectures. I've been a part of the University of Michigan family since January 2022. Prior to that, I earned my Master's and PhD degrees in aerospace engineering from Georgia Tech and then worked there as a Research Engineer for three years.

3 Schedule and Delivery Method

Lectures: Tuesdays and Thursdays from 1:30 pm to 3:00 pm, in 1008 FXB.

Office Hours: TBD

Calendar: Refer to the Canvas course calendar for important dates.

Delivery and Attendance: Lectures are primarily in-person and attendance is expected, unless noted otherwise.

4 Course Topics

Topics covered include:

- **Foundations of Complex Systems**
  - Introduction to complex systems and systems thinking
  - Nonlinearity and emergent behaviors

  - Systems design processes, the "digital Vee" framework
  - Validation and verification
  - Introduction to quality engineering; Taguchi method
  - Computational design methods

- **Future Flight Concepts (a brief overview)**
  - Current challenges and opportunities in aviation
  - Novel propulsion technologies (electrification, batteries, hydrogen, etc.)
  - Economic and life-cycle considerations

- **Physics-based Modeling for Hybrid-Electric Systems**
  - Electrified propulsion system architecture and component modeling
  - Graph-based architecture representation and generation
  - Energy-based flight mission performance analysis
  - Operational considerations: energy and power management strategies
  - Aircraft and propulsion system sizing and synthesis
  - Co-design of system, subsystems, and hybrid operations

- **Statistical and Data-driven Methods:**
  - Introduction to probability and statistics for engineering design
  - Analysis of main and interaction effects (Screening, Morris method, Pareto charts)
  - Sampling strategies strategies Design of Experiments (factorials, space-filling designs, Monte Carlo)
  - Linear and non-linear regression and surrogate modeling (Response Surface Methodology, Radial Basis Functions, Kriging, Artificial Neural Networks)
  - Model adequacy checks, residual analysis, validation, and testing
  - Global and local sensitivity analysis (variance-based and moment-independent methods)
  - Multi-dimensional trade studies and prediction profilers
  - Mixed-variable design space exploration and surrogate-based optimization

While the physics-based modeling topics covered in this course mainly run through hybrid aircraft propulsion system examples, **the methods we cover are broadly applicable to any engineered systems design problem** where computational models are required.

5 Pre-requisites

Basic programming proficiency is assumed for all students. Students are free to choose their preferred programming languages or software tools for their assignments. A background in statistics, aircraft or propulsion system design is advantageous but not required. The course is accessible to engineering students from various backgrounds.

6 Online Tools and Communication

Canvas will be used to distribute the lecture notes and other supplementary materials. Announcements will be posted on Canvas. If you have any questions about the course content, assignments, and logistics outside the office hours, please use Piazza. If your question is in general nature, please post them on Piazza publicly so that everyone can benefit. You can email me at cinar@umich.edu about any personal matters or private concerns that may arise during the semester.

7 Course Project

Students will define their own problem (subject to instructor approval) to develop and apply the methods learned throughout the semester. The project includes relevant assignments, a final presentation, and a final report.

Success in these projects typically entails mastering applicable techniques and methods, determining necessary data and modeling scope, developing models and simulations, performing comprehensive data analysis, and creating dynamic visualizations (such as for design space exploration, trade studies, sensitivity analysis, i.e., tools taught in this course) to present results.

Each student is required to submit a final project paper in the format of an AIAA conference paper. The final paper submissions should be in PDF format at the semester's end. Although publishing a paper is not required and not part of the course evaluation criteria, students should aim for publication-quality in their research papers.

More information about the projects, including the assignments and guidelines, will be provided during the semester.

8 Grading Structure

Student performance in this course will be evaluated based on the following components:

- Assignments (40%)
- Final project presentation (25%)
- Final project report (25%)
- Project code submission along with a complete and clear readme file and inputs and instructions to reproduce your work (5%)
- Participation (5%)

Important Rules

- All assignments must be submitted by 11:59 pm on the due date. The late policy is a 10% penalty per day. If you think you cannot submit on time due to exceptional circumstances, please let me know in *well in advance*.
- Assignment submissions must be made through Canvas by uploading a PDF file (with the exception of source codes).
- Do not use email to ask course-related questions, unless it does not make sense to ask them on Piazza.

- For all assignments, coding, presentations, and reports, you are permitted to use AI tools as long as you adhere to the following guidelines:
  - You are fully responsible for all work you submit, regardless of how it was generated. This means you must carefully review, verify, and understand any content produced with AI. Any errors in the final work are your responsibility.
  - You must clearly and accurately disclose any use of AI in your work. This disclosure should be made within the body of your submission, such as in a footnote or a dedicated section of your report and assignments.
- All students are expected to abide by the University of Michigan College of Engineering Honor Code.

9 Other Suggestions (optional but beneficial)

Some personal tips that can greatly facilitate your project report and the quality of your work:

- In research groups, LaTeX is commonly used for preparing scholarly articles, and I highly recommend that you adopt the same practice. You can use LaTeX through platforms like Overleaf, git, or a shared folder system. LaTeX streamlines formatting, taking care of references, figures, table placement, in-text hyperlinks, enumerations, and lists efficiently.
- I suggest using a reference manager like Zotero or Mendeley. These tools help organize references, annotate them with comments, and seamlessly integrate with LaTeX.
- The course project will require you to develop your own code. In such cases, consider using a version control tool such as git or GitHub. They allow you to track changes in your code, collaborate with others, and manage various versions of your project efficiently. There are many free online tutorials you can refer to.

10 Course Culture

The engineering field does not operate separately from our identities, and we must work together to create an inclusive climate in our classroom. All of you are part of this class and belong here, and I will do everything in my power to ensure that all students in this course are supported and have an equitable learning opportunity. I am committed to a class culture that welcomes and serves students of all ages, ethnicities, genders and expressions, national origins, religious affiliations, sexual orientation, disabilities, socioeconomic backgrounds, and other visible and non-visible differences.

I will foster a respectful, welcoming, and inclusive environment and expect each student to contribute. If at any time the words or actions of myself or your classmates make you feel uncomfortable, please let me know so that I can take appropriate and timely action if necessary. Your suggestions are encouraged and appreciated at any time. Please let me know by email if your pronouns or name differ from those on record with the university.

11 Religious/Cultural Observance

Students who have religious or cultural observances that coincide with this class should let the Instructor know via email within the 3 weeks from the start of the course. Students who expect

to miss classes or other assignments as a consequence of their religious observance will be provided with an alternative opportunity to complete their academic responsibilities.

12 Course References

There is no single textbook for this subject, but useful material can be found in numerous books and other references cited in the lecture notes. Lectures will draw from a variety of sources, including scholarly articles; specific references will be provided with the notes for each lecture. These materials provide a broad foundation for the topics discussed in the course and are accessible online through the University of Michigan library.

- A. Forrester, A. Sobester, and A. Keane, *Engineering Design via Surrogate Modelling: A Practical Guide*, John Wiley & Sons, 2008.
- R. H. Myers, D. C. Montgomery, and C. M. Anderson-Cook, *Response Surface Methodology: Process and Product Optimization Using Designed Experiments*, John Wiley & Sons, 2016.
- M. H. Kutner, C. J. Nachtsheim, J. Neter, and W. Li, *Applied linear statistical models*. McGraw-hill, 2005. *(Also a useful resource to refresh your knowledge of linear regression.)*
- D. C. Montgomery, *Design and Analysis of Experiments*, John Wiley & Sons, 2017. *You can also use the 2013 edition, which is available online at U-M Library.*
- A. Dean, D. Voss, D. Draguljic, *Design and Analysis of Experiments*. Springer Texts in Statistics. Springer, Cham, 2017. *Chapter 20 - Computer Experiments.*
- C. E. Rasmussen and C. K. I. Williams, *Gaussian Processes for Machine Learning*, Volume 1, MIT Press, 2006. Available online for free at: `https://gaussianprocess.org/gpml/`
- D. C. Montgomery and G. C. Runger.*Applied statistics and probability for engineers*. John wiley & sons, 2010. *(useful if you wish to refresh your knowledge of probability and statistics.)*
- S. Flumerfelt, K. G. Schwartz, D. Mavris, and S. Briceno, *Complex Systems Engineering: Theory and Practice*, Volume 256, American Institute of Aeronautics and Astronautics, Inc., 2019.
- J. Morio and M. Balesdent, *Estimation of Rare Event Probabilities in Complex Aerospace and Other Systems: A Practical Approach*, Woodhead Publishing, 2015.
- C.-T. Su, *Quality Engineering: Off-Line Methods and Applications*, CRC Press, 2013.
- I. Moir and A. Seabridge, *Aircraft Systems: Mechanical, Electrical, and Avionics Subsystems Integration*, Volume 52, John Wiley & Sons, 2011.

The University of Michigan library has several additional books (in both physical and digital forms) relevant to the topics covered in this course. For additional assistance, your may contact Paul Grochowski (`grocho@umich.edu`), the Aerospace Engineering Subject Librarian.

Other References and Resources

- NASA Technical reports server: `http://ntrs.nasa.gov/search.jsp`
- AIAA Electronic Library: `https://aiaa.org/IframeTwoColumn.aspx?id=4745`
- Google Scholar: `http://scholar.google.com`