The Hong Kong University of Science and Technology

Course Title: Aircraft Performance and Stability

Course code: MECH3670

Number of credits: 3

Pre-/co-requisites: CENG 2220 OR CIVL 2510 OR MECH 1907 OR MECH 1910 OR MECH 2020 OR MECH 2210

Instructor: Prof. S. REDONNET (Email: redonnet@ust.hk)

Office Hours: Any time, upon email request

Course Description

The flying and handling qualities of an airborne vehicle depend on its performance and stability characteristics, which are both driven by its design orientations. This course covers the fundamentals of flight dynamics, which are approached from both a phenomenological and a methodological viewpoint. In particular, the course introduces students to the theories and mathematical frameworks that are commonly used for assessing the performance and stability of an aircraft. These aspects are then illustrated through practical examples and cases studies.

Intended Learning Outcomes (ILOs)

By the end of this course, students should be able to:

1. Master the fundamental concepts of flight dynamics
2. Use analysis tools pertaining to aircraft performance and stability
3. Solve engineering problems related to aircraft performance and stability
4. Assess the flying qualities of common aircraft

Assessments

Student performance will be evaluated according to their demonstrated achievement of the intended learning outcomes (ILOs). This course will be assessed using criterion-referencing and grades will not be assigned using a curve. Rubrics and grade descriptors are provided below to clarify the criteria used for evaluation.

Assessment Task	Contribution to Overall Course grade (%)	Due Date
Final exam	55%	Final examination period
Midterm exam	35%	Around weeks 9–11
Class attendance and attention	10%	Throughout the term

Mapping of Course ILOs to Assessment Tasks

Assessed Task	Mapped ILOs	Explanation
Examinations (Midterm and Final), Group project	ILOs 1-4	These tasks assess the students' ability to demonstrate their mastery of the theoretical knowledge (ILO1) and practical tools (ILO2, ILO3) pertaining to aircraft performance and stability, thereby proving their capacity to assess how efficient an aircraft can be (ILO4).

Grading Rubrics

Criteria	Excellent (A)	Good (B)	Satisfactory (C)	Marginal/Fail (D/F)
Flight Performance	Flawless calculation and optimization of aircraft flight envelopes, drag polars, energy-state approximations, and constraints (V-n diagrams).	Accurate performance analysis for standard flight phases. Minor numerical slips, but the physical principles are correctly applied.	Basic performance parameters are calculated but rely on oversimplified assumptions; failure to model complex flight envelope boundaries.	Inability to calculate basic performance metrics. Severe conceptual errors regarding thrust/power required vs. available.
Static & Dynamic Stability	Exact extraction of stability derivatives. Flawless interpretation of state-space matrices, eigenvalue root-locus plots, and handling qualities.	Correct estimation of major stability quantities, e.g. static margins, standard dynamic modes (phugoid, short period, dutch roll).	Can distinguish between static and dynamic stability, but struggles to calculate damping ratios, frequencies, or state-space matrices accurately.	Fails to comprehend stability criteria. Cannot identify standard dynamic flight modes from data or graphs.
Control & Handling	Insightful design recommendations for the sizing of aircraft elements, proper evaluation of control devices and laws, etc.	Sound analysis of trim requirements and control authority.	Evaluates basic trim requirements but fails to synthesize how stability can be enhanced through controls devices/laws.	Total failure to understand trim, control authority, or pilot-in-the-loop interactions.
Technical Communication & Style	Professional engineering reporting e.g. complex dynamic plots, phase portraits, and aircraft reference frames are impeccably formatted and described.	Well-structured reporting, e.g., flight data, root-locus charts, and performance curves are clear and properly labeled with minor errors.	The presentation of data is disorganized. Uses vague terminology to describe flight dynamics (e.g., "the plane wobbles" instead of "dutch roll oscillation").	Incomplete, plagiarized, or structurally deficient report that fails to meet professional engineering communication standards.

Final Grade Descriptors:

Grades	Short Description	Elaboration on subject grading description
A	**Excellent Performance**	The student demonstrates an exceptional, intuitive grasp of flight mechanics: • **Problem Solving**: Masterfully derives and solves the aircraft equations of motion for both steady (performance) and perturbed (stability) flight states. Correctly evaluates complex multi-variable trade-offs, such as the effect of center of gravity migration on static margin and dynamic stability modes. • **Data Analysis**: Reveals a high autonomy in utilizing flight simulation or test data to extract stability derivatives. Identifies and quantifies higher-order dynamic couplings (like cross-coupling between roll and yaw) flawlessly. • **Engineering Judgment:** Proposes sophisticated design fixes (e.g., sizing a vertical tail for lateral stability) backed by theory.
B	**Good Performance**	The student demonstrates a solid, reliable understanding of flight mechanics: • **Problem Solving**: Properly derives and solves the aircraft equations of motion for both steady (performance) and perturbed (stability) flight states. Correctly calculates standard performance metrics (e.g., range, endurance, rate of climb, V-n diagrams) and assesses static longitudinal/directional stability without major conceptual errors. • **Data Analysis**: Effectively processes flight data to identify primary dynamic modes (phugoid, short-period, dutch roll, spiral) and extracts relevant damping ratios and natural frequencies. • **Engineering Judgment**: Offers logical engineering solutions to stability deficiencies, and relates mathematical criteria (e.g., stability roots) to real-world aircraft handling qualities.
C	**Satisfactory Performance**	The student demonstrates a basic understanding of flight mechanics, which however lacks depth: • **Problem Solving**: Solves performance and stability problems using standard textbook formulas, but struggles when conditions deviate from ideal assumptions. • **Data Analysis**: Can identify standard stability modes from clear plots but struggles to elaborate on their specificities (e.g. to calculate damping ratios or explain the physical mechanism behind the aircraft's motion). • **Engineering Judgment**: Can explain aircraft behavior but relies too heavily on qualitative descriptions, showing a weak link between the mathematical models and the physical flight characteristics.
D	**Marginal Pass**	The student grasps the fundamentals of flight mechanics, but does not understand most of the intricacies: • **Problem Solving:** Can solve performance problems using standard textbook formulas, but struggles in handling stability problems (e.g. cannot use a state-space model for aircraft dynamics, or determine whether an aircraft is statically stable, etc). Confuses critical performance parameters (e.g., maximum range vs. maximum endurance conditions).

		• **Data Analysis:** Can barely identify standard stability modes from plots. • **Engineering Judgment**: Struggles in explaining aircraft behaviors, solely relying on qualitative descriptions, with no capacity to link the mathematical models and the physical flight characteristics.
F	**Fail**	The student fails to grasp the fundamental mechanics of atmospheric flight: • **Problem Solving:** Cannot solve performance and stability problems, even using standard textbook formulas. • **Data Analysis**: Misinterprets basic flight telemetry, cannot differentiate standard stability modes (e.g. short-period vs. phugoid modes). • **Engineering Judgment**: Engineering conclusions are absent or fundamentally flawed, showing a lack of understanding regarding how pilot inputs or atmospheric conditions affect aircraft safety and control.

Course AI Policy

The use of AI tools is not needed nor permitted in this course.

Communication and Feedback

Assessment marks for individual assessed tasks will be communicated via Canvas within two weeks of submission. Students who needs clarification about the assessment of their performance should consult the instructor and/or teaching assistants within five working days after the marks are posted.

Required Texts and Materials

1. Lectures material

2. Textbook: Yechout et al., « Introduction to aircraft flight mechanics », AIAA Education Series, 2003

Other recommended references

- Cook, M. V. « Flight Dynamics Principles », 2nd ed. Elsevier, 2007

- Stengel, R. F., « Flight Dynamics », Princeton University Press, 2004

Academic Integrity

Students are expected to adhere to the university's academic integrity policy. Students are expected to uphold HKUST's Academic Honor Code and to maintain the highest standards of academic integrity. The University has zero tolerance of academic misconduct. Please refer to Academic Integrity | HKUST – Academic Registry for the University's definition of plagiarism and ways to avoid cheating and plagiarism.