Engineering Tripos Part IIB, 4A4 Aircraft Stability and Control, 2023-24

Module Leader

Dr W Graham [1]

Lecturer

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Lecturer

Dr M Vera-Morales [2]

Lab Leader

Dr W Graham

Timing and Structure

Michaelmas (8 lectures) and Lent (6 Lectures) + 2 tutorial/examples classes + coursework. Assessment: coursework 100%

Prerequisites

A working knowledge of Part IA and IB fluid mechanics and control theory will be assumed.

Aims

The aims of the course are to:

- Develop an understanding of the dynamics of an aircraft in flight, and an appreciation of how their characteristics may be improved using automatic control systems.

Objectives

As specific objectives, by the end of the course students should be able to:

- Appreciate how the equations of motion for an aircraft follow from Newton's second law, and how they may be simplified to the small-disturbance form;
- Understand how the free modes of motion follow from the equations of motion, and be aware of the approximate derivations of the modes;
- Know the factors determining the static stability of an aircraft, and understand the significance of the position of the centre of gravity;
- Have a knowledge of basic control strategies for autopilots, and their effects on aircraft stability;
- Appreciate that the dynamic characteristics of the aircraft may be improved by feedback control, and understand how this concept applies to stability augmentation systems, and command augmentation systems.

Content

The flight test part of this module has a number limit. If it is oversubscribed, selection will be made on a competitive basis, subject to priority being given to students in Engineering Areas 3 (Aerospace and Aerothermal Engineering) and 8 (Instrumentation and Control). The module can be taken without participating in the flight tests.

Please also note that the first 4A4 lecture will be a briefing session only (lectures start in week 5). Attendance at the briefing session is essential; if you are forced to miss it, contact the course leader by the end of week 1 at the latest.

Aircraft Stability (8L, Michaelmas term, Dr W.R. Graham)

- Aircraft equations of motion, small disturbance form, stability derivatives.
- Longitudinal motion: phugoid mode, short period oscillation and approximate forms.
- Lateral motion: roll subsidence, dutch roll, spiral mode and approximate forms.
- Static stability of aircraft: longitudinal stability, directional stability, lateral stability.

Automatic Control Systems (6L, Lent term, Dr M. Vera Morales)

- Root locus plots and their use in designing feedback control systems.
- Response to control inputs.
- Autopilots: pitch and roll angle control, effect on aircraft dynamic response and stability.
- Stability augmentation systems: pitch rate SAS & yaw damper as means of improving dynamic stability characteristics, relaxed static stability.
- Command augmentation systems: C-star criterion as basis for longitudinal CAS in fly-by-wire aircraft.

Coursework

Flight tests on Cranfield flying laboratory at the end of the Michaelmas term. Assessment of static and dynamic stability based on flight test data. Design study for an automatic control system for the aircraft.

Coursework	Format	Due date & marks
Static stability Learning objective: • understand how flight-test assessment of static stability is conducted in practice	Individual report Anonymously marked	Lent term Weds week 0 [10/60]
Modes of motion Learning objective: • appreciate requirements and difficulties in estimating dynamic stability properties	Individual report Anonymously marked	Lent term Weds week 3 [10/60]
Transfer functions Learning objective: • appreciate requirements and difficulties in estimating dynamic stability properties	Individual report Anonymously marked	Lent term Weds week 6 [10/60]

Coursework	Format	Due date & marks
Control systems design and final report Learning objective: • use Matlab tools to generate and analyse conceptual control-system designs	Individual report Anonymously marked	Lent term Fri week 10 [30/60]

Booklists

Please refer to the Booklist for Part IIB Courses for references to this module, this can be found on the associated Moodle course.

Examination Guidelines

Please refer to Form & conduct of the examinations [3].

UK-SPEC

This syllabus contributes to the following areas of the UK-SPEC [4] standard:

Toggle display of UK-SPEC areas.

GT1

Develop transferable skills that will be of value in a wide range of situations. These are exemplified by the Qualifications and Curriculum Authority Higher Level Key Skills and include problem solving, communication, and working with others, as well as the effective use of general IT facilities and information retrieval skills. They also include planning self-learning and improving performance, as the foundation for lifelong learning/CPD.

IA1

Apply appropriate quantitative science and engineering tools to the analysis of problems.

IA2

Demonstrate creative and innovative ability in the synthesis of solutions and in formulating designs.

KU1

Demonstrate knowledge and understanding of essential facts, concepts, theories and principles of their engineering discipline, and its underpinning science and mathematics.

KU2

Have an appreciation of the wider multidisciplinary engineering context and its underlying principles.

E1

Ability to use fundamental knowledge to investigate new and emerging technologies.

E2

Ability to extract data pertinent to an unfamiliar problem, and apply its solution using computer based engineering tools when appropriate.

E3

Ability to apply mathematical and computer based models for solving problems in engineering, and the ability to assess the limitations of particular cases.

E4

Understanding of and ability to apply a systems approach to engineering problems.

P1

A thorough understanding of current practice and its limitations and some appreciation of likely new developments.

P3

Understanding of contexts in which engineering knowledge can be applied (e.g. operations and management, technology, development, etc).

US1

A comprehensive understanding of the scientific principles of own specialisation and related disciplines.

US3

An understanding of concepts from a range of areas including some outside engineering, and the ability to apply them effectively in engineering projects.

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