Engineering Tripos Part IIB, 4A4 Aircraft Stability and Control, 2021-22

Module Leader
Dr W R Graham

Lecturer
Dr W R Graham

Lab Leader
Dr W R Graham

Timing and Structure
Michaelmas and Lent Terms. 14 lectures + 2 examples classes + coursework. Assessment:
Coursework/Report/end Lent Term/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 of 30. 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
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Engineering) and 8 (Instrumentation and Control). The module can also 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 W.R. Graham)

- 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 Jetstream 31 flying laboratory. Assessment of static and dynamic stability based on flight test data. Design study for an automatic control system for the aircraft. A report on the stability assessment and design study forms the basis for module assessment. If the COVID-19 situation permits, the flight tests will take place at the end of the Michaelmas term. Otherwise a representative data set will be made available.

<table>
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<tr>
<th>Coursework</th>
<th>Format</th>
<th>Due date &amp; marks</th>
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<tbody>
<tr>
<td>Module report</td>
<td>Individual Report</td>
<td>Lent term Mon week 10</td>
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<tr>
<td>Stability assessment and design study</td>
<td>anonymously marked</td>
<td>[60/60]</td>
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</tbody>
</table>

Learning objective:

- understand how flight-test assessment of static stability is conducted in practice;
- appreciate requirements and difficulties in estimating dynamic stability properties;
- use Matlab tools to generate and analyse conceptual control-system designs.

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 [2].

UK-SPEC

The UK Standard for Professional Engineering Competence (UK-SPEC) [3] describes the requirements that have to be met in order to become a Chartered Engineer, and gives examples of ways of doing this.

UK-SPEC is published by the Engineering Council on behalf of the UK engineering profession. The standard has been developed, and is regularly updated, by panels representing professional engineering institutions, employers and engineering educators. Of particular relevance here is the 'Accreditation of Higher Education Programmes' (AHEP) document [4] which sets out the standard for degree accreditation.

The Output Standards Matrices [5] indicate where each of the Output Criteria as specified in the AHEP 3rd edition document is addressed within the Engineering and Manufacturing Engineering Triposes.

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Links
[1] mailto:wrg11@cam.ac.uk