Aircraft Tutorial Preparation and Execution

"The history of an aircraft-*relay*"

Instructions

This document provides all necessary information you will need to prepare for and execute both the Aircraft Tutorial Preparation and the Aircraft Tutorial.
Read this entire document carefully before beginning to work on it. Before starting to read this document, you should have read the general instructions for AE3211-I tutorial preparation.

It is assumed that you have studied the lecture notes of the course with a special attention to the aircraft design specific module dedicated to **weight&balance** and **stability&control**. Some of the additional material provided on BS, related to the aforementioned topics, can be useful to perform this tutorial, hence you are advised to familiarize with it. It is assumed that you are able to use knowledge from the previous course AE2111-II (wing design modules).

Although a number of PCs is available for each table in the studioclassroom, you are strongly advised to bring your own laptop. In any case, bring a digital copy of your tutorial preparation report and all the spreadsheets you developed for that.

Project and task description

Background
In 2004 the multinational company *Bombardier* started a feasibility program for a new short–range passenger aircraft with a two podded (under the wing) jet engines.
After 5 years of preliminary analyses the Bombardier design office officially presented the new aircraft CSeries consisting of two aircraft variants: the Bombardier CS100 and the Bombardier CS300.

CS100 flight tests [credits @ Ryan Remiorz/The Canadian Press]

Even though the aircraft demonstrated superior performance with respect to most of the competitors with similar operating characteristics (E195,B737-700 etc...), financial issues of the company together with global crisis heavily affected the activity of the program, delaying the entry into service, by several years.

Mission

You and your 5 colleagues are part of the *"Preliminary Design"* office of the aircraft manufacturer company AIRBUS that decided to entry into the **CS100** program, renaming the aircraft into **"A220-100"** in partnership with Bombardier.

In particular, you have been requested to assess the Weight&Balance, Stability and Control requirements of the aircraft and its possible modification (that will be communicated during the tutorial execution session).

You are waiting also for the response from the other office departments (e.g. structure, power plant, systems etc…) to evaluate if design changes are going to affect negatively or positively the Stability and Control requirements.

Your team has been assigned a 2,5 hour group session to perform a quick design investigation and report it. The general instructions for this group assignment are provided below in this document, in the section "***Tutorial execution work***", while the specific changes of the design will be communicated to your team only at the beginning of the group session.

To make sure you can contribute to the group assignment at best, apart from reading the whole Tutorial execution work description, you will perform some individual preparation work, as specified in the section "***Tutorial preparation work***", below in this document. In this individual work you will focus on the Bombardier CS100 version, which constitutes the baseline for the redesign study. You are strongly advised to use spreadsheets or calculation software when possible (e.g. Excel or Matlab or Python scripts), so that you will be able to quickly modify and re-use most of your computations, formulas and plots, during the group session with your colleagues. If you don't find data available for the CS100, you can look for the A220-100 data set.

Tutorial preparation work (individual, at home)

In this tutorial preparation work you will focus on the current Bombardier ***CS100 (or A220-100)*** design, in particular on the **configuration with one class, 120 pax @ 31' pitch.**
The work consists of the following tasks:

1. **Familiarize** with the entire task list and **search for relevant data** and information on the CS100 aircraft (e.g., general dimensions; weights and performance data; layout of cabin, wing, tail, high lift devices, landing gear, etc.). *For the retrieval of those data, you can consult different website providing original manufacturer specifications and/or the Jane's All the World's Aircraft catalogue (available on paper at the TUD library or digitally at www.Janes.com, when accessed within the TU network). Other popular websites such as www.airliners.net and Wikipedia provide plenty of data.*
2. **Generate a table** containing the values of Maximum Takeoff Weight (MTOW), Operational Empty Weight (OEW), maximum payload weight and fuel weight@max payload, as provided by the manufacturer. The payload weight will be further split into 1) pax&cabin luggage weight, 3) frw and aft cargo hold weight. The table shall indicate the values of OEW, fuel weight and maximum payload weight also as percentage of MTOW. Make sure to indicate the assumptions, if needed, to determine some of the requested data.
3. **Generate a pie chart** that describes the weight breakdown you determined in point #2.
4. **Assume** the position of the aircraft center of gravity **c.g@OEW** (based on statistics from aircraft with similar configuration or from manufacturer data) and **generate the aircraft loading diagram**. Organize the passengers into groups, according to the seating position (window and aisle rule). Place the remaining payload weight in both the front and the aft cargo holds, according to their capacity. *Make use of drawings and payload arrangement as available on the websites of manufacturer and/or operators.*
5. **Identify the most aft and forward c.g. positions** during operation and **report** them in a **table**, indicated as percentage of the aircraft mean aerodynamic chord MAC. **Indicate** in the same table **the specific loading conditions** that are responsible for the achievement of the most aft and forward c.g. positions. In the same table, you will **report also the position of the aircraft c.g.@OEW** (indicated as percentage of MAC), **the position of the fuel c.g. and the position of the frw and aft cargo c.g. .**
6. **Provide a table** containing the following values and indicating the assumptions, if needed, to determine the values (e.g. is the MAC calculated or retrieved from manufacturer data?):
    - MAC
    - XLEMAC (position of the MAC's leading edge, measured from the aircraft nose)
    - Tail arm
    - Wing surface
    - Horizontal and Vertical Tail surface
    - Ratio tail surface/wing surface for both horizontal and vertical tails
    - Volume coefficients of both horizontal and vertical tails
    - Longitudinal position of the front gear from the aircraft nose (you can extrapolate this information from the side view of the aircraft reported in the manufacturer's manual)
    - Longitudinal position of the main landing gear: you should provide both the absolute distance from the aircraft nose and the position in percentage of the MAC (you can extrapolate this information from the side view of the aircraft reported in the manufacturer's manual).

7. **Provide a table** containing the following basic information on aircraft aerodynamics needed for the stability and control assessment:

- Cruise Mach and cruise altitude.
- Approach speed
- Assume an airfoil compatible with cruise and low speed aircraft characteristics and report lift and pitching moment characteristics (C_{l0}, C_{m0}, $C_{l\alpha}$, $C_{m\alpha}$).
- Lift rate coefficient of the horizontal tail at cruise speed
- Lift rate coefficient of the aircraft-less-tail at cruise speed considering the contribution of the wing and of the fuselage.
  Make use of data available on literature about airfoil aerodynamics or you can perform analysis using aerodynamics software described in AE211 (Xfoil, Javafoil).

8. Generate a very brief tutorial preparation report including all the items indicated above. (from task 2 to task 7!) Include your main assumptions and a proper reference list. Hint: *If you lack data or have doubts about your results, you may look at similar aircraft and statistics. If you miss information, make educated assumptions and* ***document them.***
9. Read carefully the Tutorial Execution work section of this document and start collecting some of the data required for Task 5 of the execution work (but do not report them in the preparation work deliverable)

Deliverables and requirements

- Each student must deliver her/his tutorial preparation report in pdf format. The report will be uploaded in the "*Aircraft tutorial preparation RETAKE submission"* folder that will be created on the BrightSpace page of the course.
- Full name and student ID will be clearly visible on the first page.
- The report will include all the deliverables described above for **tasks #2 up to task #7**.
- **The report should not have more than 5 pages, all included: do not include unnecessary text: be sharp in presenting the findings.**
- Plots and tables will be provided with numbered caption, axis labels, legend and units. Do not include screenshots of Excel spreadsheets.
- **The work described in the report must be your own. No group work is allowed!**

Pass criteria

The individual report is assessed on the basis of Pass/Fail criteria. You need to score Pass to access to the group tutorial.
A Pass grade is granted only when the following criteria are met:

- Report is delivered within set deadline
- Report is the result of individual work (group work is not allowed for this preparation tutorial)
- All deliverables are present and (mostly) correct.

Tutorial execution work (in group, in class)

During the tutorial execution session, your team will have 2,5 hours-time to perform a quick re-design study. The goal is to assess and/or deal with the impact of *some requirements or design configuration changes* requested by the customer (from here on addressed as *customer input*) on a baseline aircraft design. In this case:

- the baseline aircraft design is the CS100
- the customer input is specific to the design of the new version of the CS100

The specific customer input, together with the specific design questions to be addressed, will be communicated to the group only after the beginning of the tutorial execution session.
Typical matters to be handled during the group tutorial are (some of) the following:

a. Assess and/or deal with the effect of the customer input on the aircraft weight&balance.
b. Check whether re-design actions are required to make sure the customer input is not preventing the aircraft to fulfill the stability and control (S&C) requirements
c. Propose and/or implement necessary re-design/modifications
d. Verify that the redesigned/modified version of the aircraft fulfills S&C requirements

Tasks for the Tutorial Execution

1. Briefly analyze the outcomes of the tutorial preparation work from all team members. Identify the common points and the eventual conflicts between the applied methods and outcomes.
2. Harmonize the outcomes of the preparation work performed by all the team members and define **one consolidated data set** and **one analysis spreadsheet** to produce all the deliverables requested in the tutorial preparation work.
3. Read carefully the received customer input
4. Set up the team and organize the group work in order 1) to assess the impact of the customer input and 2) address all the specific (re)design questions.
5. Document your group work in a tutorial report providing evidence that all the (re)design questions contained in the customer input have been answered. Explain the logical flow of your work activities, report the **main** calculation steps, **all** your assumptions, the **relevant** used/computed input and output data and **all** sources of used information. In particular:
    a. Generate two (2) **weight tables** as indicated in **Task 2** of the preparation tutorial. One table for the CS100, one for the new aircraft version (include only the changed values w.r.t. the baseline design). Preferably you will combine the two tables in one.
    b. Generate two (2) **loading diagrams** as indicated in **Task 3** of the preparation tutorial. One diagram for the CS100, one for the new aircraft version (only if changed w.r.t. to the baseline design). Preferably you will display the two loading diagrams together on the same plot.
    c. Provide two (2) **c.g. data tables** as indicated in **Task 4** of the preparation tutorial. One table for the CS100, one for the new aircraft version (include only the changed values w.r.t. the baseline design). Preferably you will combine the two tables in one.
    d. Generate **the complete scissor plot** (stability + neutral stability + controllability curves) for the new aircraft version.
    e. **Provide a table** displaying the data necessary to build the scissor plot(s). You shall indicate at least the following data:
        - Cruise speed
        - Approach speed
        - Tail-wing speed ratio (Vh/V)
        - Lift rate coefficient of the tail at cruise speed

- Lift rate coefficient of the aircraft-less-tail at cruise speed, including the separate contributions of:
  - Wing
  - Fuselage
- Wing downwash gradient
- Position of the aerodynamic center of the aircraft-less-tail, evaluated both at cruise and approach speed, and including the following separate contributions:
  - Wing
  - Fuselage
  - Nacelles
- Maximum horizontal tail lift coefficient (indicate also the type of tail, e.g. full moving, fixed, etc.)
- Zero Lift pitching moment coefficient of the aircraft-less-tail, including the separate contributions of:
  - Wing (indicate the assumed 2D wing profile)
  - Flaps (indicate the type of high lift devices)
  - Fuselage
  - Nacelles

Hints: *since this part of the assignment was not included in your preparation work, it will require more time than the preceding tasks. Hence,* ***start working on the scissor plot as soon as possible and be prepared with the main assumption (e.g. you could have already an idea about the airfoil and the HLDs before to start the tutorial)!***
Show only the main calculation steps and do not waste time editing equations in your report; when needed, just copy them from the lecture notes.

f. Provide the table indicated in **Task 5** of the preparation tutorial, for both the CS100 and the aircraft new version.
g. Address the specific (re)design questions provided by the customer during the tutorial session (the customer input will be made available via BB at the beginning of the tutorial session)

Hint: *If you lack data or have doubts about your results, you may look at similar aircraft and statistics. If you miss information, make educated assumptions and document them. When required, make use of what you learnt in AE2111 to compute lift coefficients, etc.*

Deliverables and pass requirements

Each group must deliver an electronic version of the report (in PDF format) not later than the end of the tutorial session. Instructions about the uploading process will be given during the tutorial. The general requirements for the report are the followings:

- The report must provide clear evidence that you have dealt with all the required tasks.
- The report must include the deliverables indicated above for **task #5**.
- The report should not have more than 10 pages, all included.
- The report shall clearly indicate on the front page the name and the student numbers of all the team members, as well as the group name assigned during the tutorial session.
- The report must represent a group work. It is expected that all group members contribute equally to the work. It is assumed that all members of the group have agreed and taken responsibility for all parts of the reported work.