Delft University of Technology

Faculty of Aerospace Engineering

Exam AE3211-I: Systems Engineering and Aerospace Design

April 7th, 2016, 9:00am

General Rules and Instructions

- ✓ This is a "closed book" exam. You are not allowed to use any books, lecture notes or other study materials.
- ✓ Exam duration is 3 hours.
- ✓ This exam consists of three parts:

  Part 1) A sample case of SE space problem with open questions **(35 points)**;

  Part 2) A set of aircraft questions **(35 points)**;

  Part 3) A set of multiple choice questions **(30 points)**.

- ✓ Please give your answers to the three parts of the exam on different sheets. For the multiple-choice questions, use the answer sheet provided to you.
- ✓ Don't forget to put your name and student number on each page!!
- ✓ Answers shall be given in English only.

Part 1 – Space Sample Case

Carefully read the case description below and use the provided information to answer the final questions (a), (b), (c), (d), (e), (f), (g), (h), (i), (j). Give a concise but complete answer to each one of the questions.

The Delfi-PQ Mission

Given the success of CubeSats, a satellite standard based on a unit 10x10x10 form factor (typically around 1 kg of mass), which uses Commercial-Off-The-Shelf technology and piggy-back launches using so-called payload orbital deployers (POD), the next challenge for making benefit from the miniaturization, is the so-called PocketQube which is based on a 5x5x5 cm standard form factor. Up to now, no successful PocketQube mission has been operated in space. The Faculty of Aerospace Engineering is embarking on this challenge which will not only demonstrate new technology, but also motivate students in their studies. In addition, if starting from a simple baseline approach, and developing this baseline further, it is expected that the frequency of launches can be increased to about 1 per year, as opposed to 1 per four years, the first one to be launched in 2017. Finally, increased visibility is expected and innovation is triggered, another key task universities have.

You are project leader for the first triple-unit PocketCube, called Delfi-PQ, at Space Systems Engineering (SSE) of the Faculty of Aerospace Engineering of TU Delft. The project is at a very early stage.

Questions

(a) Provide a Mission Statement for the Delfi-PQ mission. ***(4 points)***

(b) What is the expected mass of the Delfi-PQ satellite? Motivate your answer in 1 sentence. ***(2 points)***

(c) Draw a System Description diagram of the mission (=system) and label the elements. ***(4 points)***

(d) Draw and explain briefly the Spiral Model of Systems Engineering. What would be a reason to prefer the V-model over the Spiral model for Delfi-PQ? ***(3 points)***

(e) Identify a key stakeholder (outside of TU Delft) and write down a proper stakeholder requirement for that stakeholder. If needed, document an associated assumption you made. ***(3 points)***

(f) Write down a system requirement and a subsystem requirement, which is a child of the system requirement. ***(4 points)***

(g) Which are the methods you chose to verify the two requirements written for question (f) above? ***(2 points)***

(h) Suppose the PocketQube would be released from the International Space Station (ISS). Which velocity increment would be needed to separate the satellite from the ISS by 1 km within 5 minutes? Write down the equation and provide the answer in units of m/s. Could the relative dynamics be described by linear relations for

- long times
- large separations?

Motivate your answers! ***(4 points)***

(i) Make a Design Option Tree for a navigation systems at least on 2 levels, not counting the level on the top of the tree. Mark the non-feasible ones and motivate your reasons. ***(5 points)***

(j) Which criteria would you propose for a graphical trade-off of navigation system concepts and their associated weights? Motivate your criteria and weights! ***(4 points)***

Part 2 - Aircraft Questions

1. Although the plot shown in Figure 1 is specific for the Boeing 747, it actually represents the typical behaviour of any subsonic aircraft. ***(4 points)***
   a. Explain the plot briefly. ***(2 out of 4 points)***
   b. Why is this plot relevant for the generation of the aircraft scissor plot? ***(2 out of 4 points)***

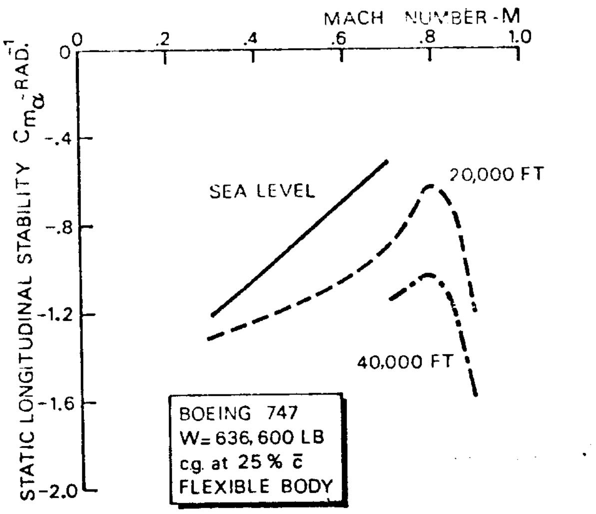

Figure 1

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2. In order to design a conventional transport aircraft that is longitudinally stable and controllable at all operational conditions, the designer typically looks for the most convenient combination of wing longitudinal position w.r.t. the fuselage and horizontal tail size (and position). ***(10 points)***
   a. Why adjusting the longitudinal position of the wing is so convenient? ***(4 out of 10 points)*** Discuss the pro & cons of two (2) alternative solutions to the wing positioning, which can be used to fulfill the stability and controllability constraints at all operational conditions. ***(3 out of 10 points)***
   b. List, in execution order, the main steps of the process performed by designers to investigate the effect of the longitudinal wing position on the operational center of gravity range of an aircraft. As starting point of the process, you can assume the availability of an initial estimation of the weight and center of gravity of all the main aircraft components. You can make use of a flow block diagram instead of a list. ***(3 out of 10 points)***

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3. Let's consider a canard aircraft configuration. ***(6 points)***
   a. Sketch its typical scissor plot. Indicate the stability, neutral stability and controllability curves (indicate on the plot which curve is what, and provide the axis labels). ***(2 out of 6 points)***
   b. Does it differ from the scissor plot of a conventional aircraft? If yes explain how and why? ***(2 out of 6 points)***
   c. Can you explain why the use of very highly effective high lift devices is not recommended (or even possible) for a canard configuration? ***(2 out of 6 points)***

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4. Making use of the reference system and simplified representation of the forces (no drag, no thrust) acting on an aircraft provided in Figure 2, derive the equation $x_{c.g.}=f$(Horiz tail volume coefficient, …) that defines the allowed most aft position of the center of gravity, such that static longitudinal stability is guaranteed. Assume a positive static stability margin equal to 10% of the mean aerodynamic chord length. Show the main steps of your derivation and briefly state your assumptions. ***(4 points)***

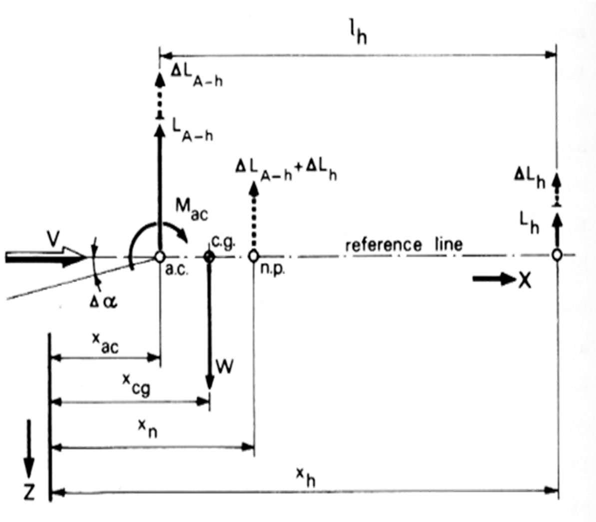

Figure 2

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5. Explain why the following statements are correct or wrong ***(5 points)***:
   a) As it can be clearly observed on an aircraft scissor plot, by lowering the wing downwash gradient, the aircraft becomes more controllable. ***(1 point)***
   b) In order to lower the structural weight of a wing, it is convenient to use airfoils with lower thickness ratio and avoid the wing podded engine configuration. ***(1 point)***
   c) A tailless aircraft (ignore the effect of the propulsion system) can be longitudinally statically stable only when its neutral point is located sufficiently after its aerodynamic center. ***(1 point)***
   d) The vertical tail volume coefficient of an aircraft with two wing podded engines is generally larger than for an aircraft with two fuselage podded engines. ***(1 point)***
   e) A small decrease in the static stability margin can lead to a lighter horizontal tail. ***(1 point)***

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6. Consider the plot and the equation given in Figure 3. The given curves are those of a given general aviation aircraft featuring a conventional tail configuration. ***(6 points)***:
   a. Draw on the same plot (use the grid for accuracy) the curve representing the aircraft-less-tail contribution AND justify your drawing. ***(1 out of 6 points)***
   b. Explain whether the aircraft-less-tail is stable/unstable or neutrally stable. ***(1 out of 6 points)***
   c. Explain whether, at the given trim point, the tail is generating zero, positive or negative lift. ***(2 out of 6 points)***
   d. Assuming a negative value of the aircraft pitching moment Cm_{ac}, explain whether the center of gravity is located in front, behind or on top of the aerodynamic center of the aircraft less tailplane. ***(2 out of 6 points)***

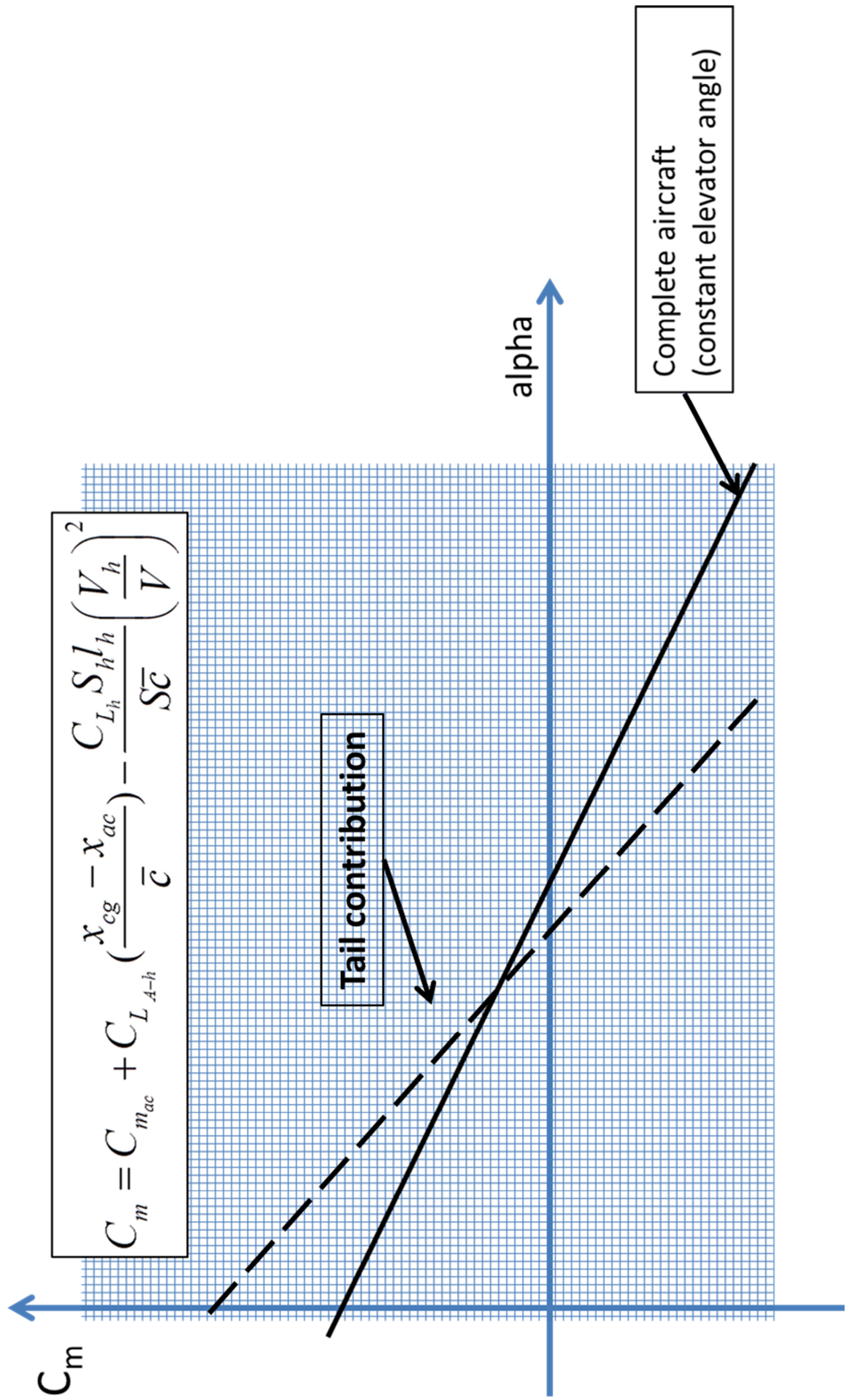

Figure 3 (Question 6)

Part 3 - Multiple-Choice Questions

(1) Only one of the following sentences related to stakeholders is not correct. Which one is the only wrong sentence? ***(3 points)***

(A) A stakeholder is a party who affects or can be affected by a system
(B) Stakeholder needs are normally translated into stakeholder requirements
(C) The users of a system are stakeholders
(D) All stakeholders are customers

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(2) Only one of the following hypothetic requirements for the tele-communications sub-system of a satellite can be considered as correctly formulated. Which one is the only correct requirement? ***(3 points)***

(A) REQ-A: The antenna must work in the S-band frequency.
(B) REQ-B: The transmission power shall be lower than 5 W and the antenna diameter shall be less than 1 m.
(C) REQ-C: The electronic components shall be chosen among high-efficiency ones.
(D) REQ-D: The downlink budget shall close with a margin of at least 3 dB.

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(3) Which one of the following sentences correctly indicates the way how stakeholder needs must be formulated? ***(3 points)***

(A) Stakeholder needs must include the “what” and “how” and be formulated in technical language
(B) Stakeholder needs must include the “what” and “how” and be formulated in the stakeholder’s language
(C) Stakeholder needs must be solution-free and formulated in technical language
(D) Stakeholder needs must be solution-free and formulated in the stakeholder’s language

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(4) Which one of the following is the correct definition of “killer” requirement? ***(3 points)***

(A) A requirement which drives the design to an unacceptable extent
(B) A requirement which drives the design more than average
(C) A requirement which is of primary importance for the customer
(D) A requirement which cannot be formulated without knowing the stakeholder needs

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(5) Which one of the following is not a fundamental criterion to select the verification method (test or analysis) of a requirement? ***(3 points)***

(A) Available facilities
(B) Schedule constraints
(C) Risks
(D) Stakeholder needs

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(6) According to ESA ECSS standards, in which phase of a project does the system end of life normally occur? ***(3 points)***

(A) At the beginning of phase E
(B) It can occur at any moment during phases C, D or E
(C) During phase F
(D) At the end of phase E

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(7) In terms of *risk mitigation*, which measure can be taken to reduce risk? ***(3 points)***

(A) Choose a different technology
(B) Decrease allowable design margins
(C) Increase set of design parameters
(D) Reduce number of redundant systems

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(8) Which Technical Performance Management (TPM) parameter is typically important for aircraft? ***(3 points)***

(A) Delta-V budget
(B) Pointing accuracy
(C) Thrust
(D) Launcher envelope

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(9) Which probability distribution is typically used to model *wear-out* of technical components? ***(3 points)***

(A) Negative exponential distribution
(B) Normal distribution
(C) Poisson distribution
(D) Binomial distribution

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(10) For multi-copy, long-term deployment products such as aircraft, which phase of the product life cycle is associated with the highest cumulative costs? ***(3 points)***

(A) Production
(B) Operations & Support
(C) Research, Development, Test and Evaluation
(D) Disposal
