Delft University of Technology

Faculty of Aerospace Engineering

Exam AE3211-I: Systems Engineering and Aerospace Design

September 30th, 2014, 18:30

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). Give a concise but complete answer to each one of the questions.

Active removal of space debris

Space debris (i.e. artificial objects in space which are of no more use, such as defunct satellites, upper stages and smaller pieces), is more and more causing a threat for operational space missions and the capabilities and services they provide. The Kessler syndrome predicts an avalanche of debris objects in the future in Low Earth Orbit (LEO), because new debris will generate more new debris, even if all launchers would be stalled. International regulations dictate that the presence of artificial objects in LEO is only allowed for a maximum of 25 years.

Active debris removal (ADR) is a technology which uses a space-based system, e.g. a satellite, to help removing space debris from their potentially hazardous orbits. You are designing an ADR system to demonstrate removal technology for a micro-satellite. For your mission to be a success, you must demonstrate that your technology is able to cope with a non-cooperative target (i.e. potentially rotating), with only rough orbit information available, using no specific docking mechanisms and no tracking sensors. The surface, dynamic properties and exact satellite shape are assumed to be more or less unknown. As a constraint, you are required that your ADR technology MUST NOT generate more debris!

Questions

(a) Provide a Need Statement and a Mission Statement for the ADR demonstration mission. ***(6 points)***

(b) Suppose you want to inspect the defunct satellite using a dedicated ADR satellite. Name 1 bus subsystem and 1 payload which is most critical to achieve your mission. Motivate why these are most critical. ***(4 points)***

(c) Suppose you want to image the debris object with an optical camera and be able to identify details of 10 cm while imaging from a distance of 50 m. Write down the equation to compute your attitude control accuracy as an angle $\delta\alpha$ and compute its value in arc-minutes. Which system aspects have to be taken into account to be able to do a successful imaging? (List 4 different aspects from different areas of your system). ***(6 points)***

(d) Draw a Functional Flow Block Diagram (FFBD) for the proximity operations of the ADR mission, i.e. before the removal starts. The diagram should comprise about 4-7 functions. Pick one of those functions, and break the FFBD down into a lower level. ***(4 points)***

(e) Assume you have been given the task to design the ADR demonstration. To do that, you develop a design option tree (DOT) to systematically identify the options. Draw a DOT showing all options on at least 2 levels (not counting the single box on the highest level). Make sure that you end at a level where a "net capturing device" (i.e., a device that uses a net to capture the debris) appears as one of the options. Note: Make sure you capture **ALL** the options. ***(6 points)***

(f) Assume now that the net capturing device has been selected as the most promising option. Specify the needs from this net capturing device on ALL other sub-systems of the ADR satellite. Identify the 2 most important ones and specify why they are most important? ***(3 points)***

(g) How do you verify the net capturing device performance without being in space? ***(3 points)***

(h) Which types of test do you have to perform for a net capturing device and why? Make a list and argue! ***(3 points)***

Part 2 - Aircraft Questions

1. A given process (P1) consists of 3 main tasks (T1, T2 and T3). T1 requires D as input and produces A and B as output. A is input for T2 and B is input for T3. T3 needs also the input C, which is an output of T2. T3 produces the output E, which is an input for T2, and the output D, which is input for T1. For the given process you will provide the following diagrams: ***(5 points)***
   a) A Work Breakdown diagram. ***(1 out of 5 points)***
   b) A Work Flow diagram. ***(2 out of 5 points)***
   c) An N2 chart. ***(2 out of 5 points)***

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2. Consider the two overlapped loading diagrams in the following figure. They belong to two mid-range jetliners of similar payload and mission. One has a wing podded engines configuration; the other a fuselage podded engines configuration. ***(6 points)***
   a) Indicate which diagram belong to the aircraft with fuselage podded engines and briefly justify your answer. ***(2 out of 6 points)***
   b) Give a definition of trim drag in your own words (no formula required). ***(2 out of 6 points)***
   c) Indicate which of the two aircraft is likely to experience more trim drag during operation and briefly justify your answer. ***(2 out of 6 points)***

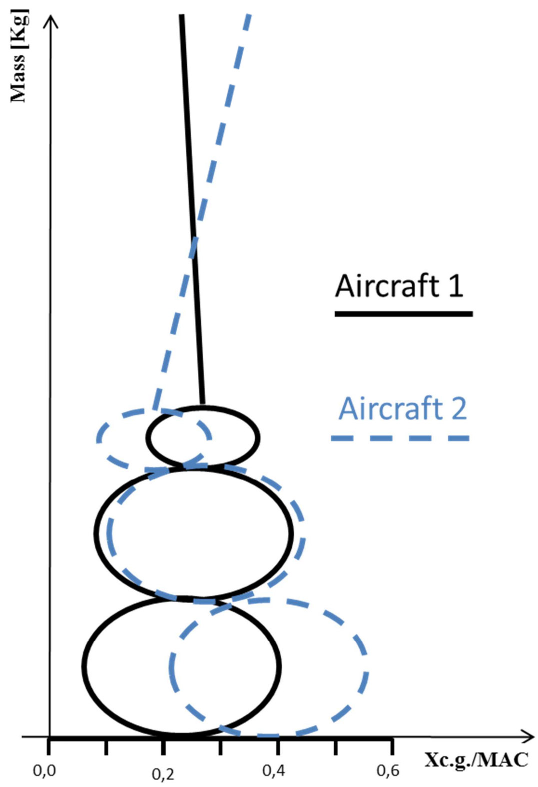

Figure 1: question 2

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3. In order to perform a proper wing weight prediction it is necessary to know the weight of the wing first. This is just one of the many “chicken-and egg” problems that can be found in aircraft design. ***(4 points)***
   a. Plot the forces applied to a generic wing. ***(1 out of 4 points)***
   b. Explain how the abovementioned wing weight estimation problem is generally tackled. ***(2 out of 4 points)***
   c. Explain the consequences of ignoring the weight of the wing itself during the sizing process of the wing structure. ***(1 out of 4 points)***

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4. Provide a qualitative scissor plot for a CANARD aircraft (include also the neutral stability curve). ***(9 points)***
   a. Indicate which curve is what, and provide labels and units on the plot axes. ***(2 out of 9 points)***
   b. On the same plot, show the effect of implementing a more effective high lift device system (e.g. a double slot flap instead of a single slot flap) and justify the eventual modification to the plot. ***(1+2 out of 9 points)***
   c. Explain what are the consequence of this flaps change in terms of allowed c.g. range (keeping the same canard size). ***(2 out of 9 points)***
   d. Explain why a reduction of the static stability margin can have a positive/negative effect on the allowed c.g. range (for a given canard size). ***(2 out of 9 points)***

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5. The plot on next page illustrates the Cm-alpha curve of a general aviation aircraft featuring a conventional tail configuration. ***(11 points)***
   a) Give a definition of trim point, BOTH in your own words AND using a formula. ***(2+1 out of 11 points)***
   b) If possible, indicate the trim point on the plot. ***(1 out of 11 points)***
   c) Give a definition of longitudinal static stability, BOTH in your own words AND using a formula. ***(2+1 out of 11 points)***
   d) State whether the given aircraft is stable, neutrally stable or unstable. ***(1 out of 11 points)***
   e) Add on the plot (use the grid for accuracy) one possible combination of curves (one representing the tail contribution and the other representing the tailless aircraft) leading to the given Cm-alpha curve, where the tail generates negative lift at the trim point. Briefly justify your plot. ***(2+1 out of 11 points)***

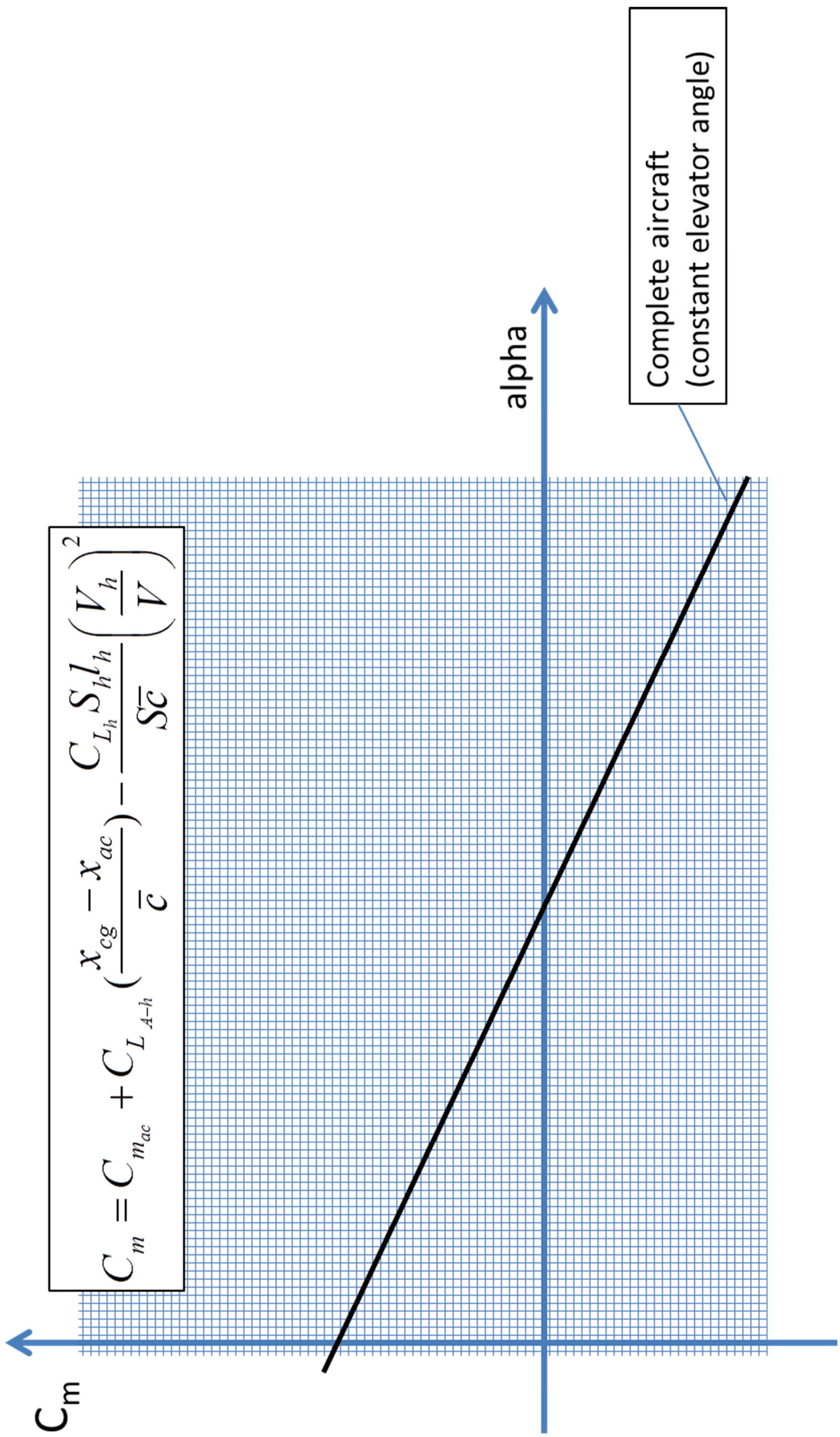

Figure 2: question 5

Part 3 - Multiple-Choice Questions

(1) Which one of the following is a correct definition of "system"? ***(3 points)***

(A) An interdisciplinary approach that enables the design of successful components.

(B) An operational environment, the boundaries of which are not clearly defined.

(C) A set of components, without a description of the specific relationships between them.

(D) A set of interrelated components working together to accomplish a common purpose.

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

(A) REQ-A: An appropriate contact time with the ground station shall be ensured.

(B) REQ-B: The transmission frequency shall be in the X-Band and the satellite antenna diameter shall be less than 2 m.

(C) REQ-C: Global Earth coverage shall be obtained by using horn antennas.

(D) REQ-D: The 8FSK modulation method shall be used.

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(3) Only one of the following sentences related to test and analysis is not correct. Which one is the only incorrect sentence? ***(3 points)***

(A) Analysis is always preferred to test when it is practical, cost effective and safe.

(B) Test is always preferred to analysis when it is practical, cost effective and safe.

(C) Analysis shall be used when flight conditions cannot be accurately simulated.

(D) Analysis shall be used when it is not economically feasible to test the entire spectrum of flight conditions.

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(4) Only one of the following propulsion system requirements can in any case be verified by test, whatever the available resources are. Which is the requirement to be (always) verified by test? ***(3 points)***

(A) REQ-A: Propulsion system mass shall be lower than 10±0.1 kg.

(B) REQ-B: Propulsion system total impulse shall be higher than 10 Ns.

(C) REQ-C: Propulsion system vacuum specific impulse shall be higher than 10 s.

(D) REQ-D: Propulsion system minimum impulse bit duration shall be lower than 10 ms.

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(5) An Earned Value Management analysis typically includes three curves. What do these three curves represent? ***(3 points)***

(A) Actual Cost Work Performed(ACWP), Actual Cost Work Scheduled (ACWS), Budgeted Cost Work Scheduled (BCWS)

(B) Actual Cost Work Scheduled (ACWS), Budgeted Cost Work Scheduled (BCWS), Budgeted Cost Work Performed (BCWP)

(C) Actual Cost Work Performed(ACWP), Actual Cost Work Scheduled (ACWS), Budgeted Cost Work Performed (BCWP)

(D) Actual Cost Work Performed(ACWP), Budgeted Cost Work Scheduled (BCWS), Budgeted Cost Work Performed (BCWP)

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(6) What is the correct order for the risk management process? ***(3 points)***

(A) Identification, Planning, Assessment, Handling, Analysis
(B) Planning, Identification, Assessment, Analysis, Handling
(C) Identification, Assessment, Planning, Handling, Analysis
(D) Planning, Identification, Handling, Analysis, Assessment

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(7) In many development programs, resource contingencies are assigned to incorporate the effect of uncertainty into the design. Contingency allowances are a function of: ***(3 points)***

(A) Design disciplines and project length
(B) Project objectives and design disciplines
(C) Design maturity and type of hardware/software
(D) Number of design concepts and project length

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(8) The 'Design for X' approach (e.g. Design for Manufacturing, Design for Assembly) is applicable only when there are explicit: ***(3 points)***

(A) Design options for X
(B) Requirements for X
(C) Verification methods for X
(D) All of the above

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(9) 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) Research, Development, Test and Evaluation
(C) Disposal
(D) Operations & Support

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(10) Which of the following cost estimation techniques is most suitable for use in estimating the cost of a detailed aircraft design for a new variant in an aircraft family? ***(3 points)***

(A) Deterministic, analytical model-based cost estimation
(B) Parametric cost estimation
(C) Analogous cost estimation
(D) Simulation-based cost estimation
