Delft University of Technology

Faculty of Aerospace Engineering

Resit Exam AE3211-I: Systems Engineering and Aerospace Design

August 16th, 2017, 13:30 pm

General Rules and Instructions

- ✓ This is a "closed book" exam. You are not allowed to use any books, lecture notes or other study materials. Use of graphical calculators is not allowed.
- ✓ 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 10 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.

Read the entire space part including all questions, before starting to answer them.

Juno Mission to Jupiter

Juno is a NASA space probe orbiting the planet Jupiter. It was built by Lockheed Martin and is operated by the Jet Propulsion Laboratory (JPL). The spacecraft was launched from Cape Canaveral Air Force Station on August 5, 2011 (UTC), as part of the New Frontiers program, and entered a polar orbit of Jupiter on July 5, 2016 (UTC) to begin a scientific investigation of the planet. After completing its mission, Juno will be intentionally deorbited into Jupiter's atmosphere.

Juno will measure Jupiter's composition, gravity field, magnetic field, and polar magnetosphere. It will also search for clues about how the planet formed, including whether it has a rocky core, the amount of water present within the deep atmosphere, mass distribution, and its deep winds, which can reach speeds of 618 km/h. Jupiter has a maximum and a minimum distance from the Sun of 4.95 and 5.46 AU, respectively.

Juno is powered only by solar arrays, commonly used by satellites orbiting Earth and working in the inner Solar System, whereas radioisotope thermoelectric generators are commonly used for missions to the outer Solar System and beyond. For Juno, however, the three largest solar array wings ever deployed on a planetary probe play an integral role in stabilizing the spacecraft as well as generating power.

The spacecraft hosts 9 instruments, among others a microwave radiometer which comprises six antennas mounted on two of the sides of the body of the probe. They will perform measurements of electromagnetic waves on frequencies in the microwave range: 600 MHz, 1.2, 2.4, 4.8, 9.6 and 22 GHz, the only microwave frequencies which are able to pass through the thick Jovian atmosphere. The radiometer will measure the abundance of water and ammonia in the deep layers of the atmosphere up to 200-bar pressure or 500–600 km deep. The combination of different wavelengths and the emission angle should make it possible to obtain a temperature profile at various levels of the atmosphere.

The spacecraft has a Launch mass of 3,625 kg, a Dry mass of 1,593 kg and mass after orbit insertion at Jupiter of 2378 kg. Its dimensions are 20.1 × 4.6 m, providing a Power of 14 kW at Earth and 435 W at Jupiter. Juno uses a bipropellant LEROS 1b main engine. It uses hydrazine and nitrogen tetroxide for propulsion and provides a thrust of 645 N. For attitude control and to perform trajectory correction manoeuvres, Juno utilizes a monopropellant reaction control system (RCS) consisting of twelve small thrusters that are mounted on four engine modules.

Questions : Total of 35 points

(a) Provide a Mission Statement for Juno. ***(4 points)***

(b) Draw a high-level System Description diagram of such mission (=system) including all relevant mission architecture elements and communications and label them. ***(4 points)***

(c) Identify a key stakeholder and write down a proper stakeholder requirement for that stakeholder. Also, write down a brief motivation for it. If needed, document an associated assumption you made. ***(4 points)***

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

(e) Which verification method do you chose to verify the child requirement you provided in your answer to question (d)? ***(2 points)***

(f) Draw a subset of the N2-chart related to the following subsystems:

- Attitude
- Communications
- Power
- as well as scientific payload.

and add the relevant interfaces. The Attitude subsystem has to serve at least 3 possibly conflicting requirements. Which are these and what are at least 2 options to solve those conflicts? ***(5 points)***

(g) Check the expected spacecraft power value at Jupiter, given in the text above, by computing it from the power value at Earth. What is difference of your computed and the above value in the text (answer required in %)? How comes? ***(4 points)***

(h) What makes a Jupiter mission different and more difficult compared to an Earth satellite mission, when it comes to verification of its subsystems? Give 3 reasons and motivate! ***(4 points)***

(i) Which subsystems, related to h, do you think are mostly affected and why? What should engineers do to secure the proper function of the spacecraft at Jupiter a. in the design phase, b. in the V&V phase? ***(4 points)***

Part 2 - Aircraft Questions

1 Consider the V-n diagram provided in **figure 1** (**6 points in total**):

a. Provide a definition of load factor (n), both in your own words and using a formula **(1 point)**
b. Using the plot in figure, provide the value of the aircraft stall speed **(1 point)**
c. Using the plot in figure, provide the value of the ultimate load factor to be used for estimating the weight of a wing by means of a class II weight estimation method **(1 point)**.
d. Based on the plot in figure, explain whether the most critical load case for the given aircraft is due to gust or maneuver **(1 point)**.
e. According to the CS25, what is the main aircraft parameter necessary to establish the highest load factor in the maneuver diagram? **(1 point)**
f. Explain why it is (or it is not) allowed to design an aircraft using a higher load factor than the maximum obtained by plotting the V-n diagram? **(1 point)**

Figure 1

2 Explain why the following statements are correct or wrong. Please note that by only stating true/false no points are scored **(6 points):**

a. In order to use a class II weight estimation method, it is necessary to have a preliminary definition of the aircraft geometry
b. The fuel weight estimated using a class II weight estimation method might differ from the one obtained using a class I weight estimation method, thus iterations are necessary to converge to a consistent value
c. In order to use a class I weight estimation it is necessary, among other data, to know the typical flight mission of the aircraft (e.g. cruise range and speed, loitering time and diversion range to reach alternative airport, etc..)
d. The aircraft OEW is one of the necessary input to use a Class I weight estimation method
e. Typical class II wing weight estimation formulas include all parameters necessary to account for the spanwise lift distribution on the wing

f. Different class II weight estimation methods are available in literature (Torenbeek, Raymer, etc.). In order to produce the most reliable weight prediction for a given aircraft it is convenient to select and combine the most accurate weight estimation formulas from the various Class II methods.

3 Answer the following questions related to trim drag **(4 points in total):**

a. Write the mathematical formula to express trim drag and specify the meaning of each coefficient in the formula **(2 points)**
b. Why (or why not) an aircraft with large center of gravity range is generally subjected to larger trim drag than an aircraft with small c.g. range? **(1 point)**
c. Why (or why not) reducing the surface of the horizontal tail would be beneficial to reduce trim drag? **(1 point)**

4 Aircraft horizontal tails can be categorized in three groups according to the way they can move with respect to the airframe, i.e. fixed, adjustable and full moving tails. Generate a qualitative scissor plot (include axis labels, draw the stability, neutral stability and control curve, and add a legend for clarity) to illustrate the effect(s) of the abovementioned three types of tails. What is a typical maximum lift coefficient for a full moving tail: -0.1, -1 or -10? (**4 points**)

5 In order to support the horizontal tail sizing process, it is convenient, during the balancing of the aircraft, to organize the operative empty weight contributions of the main aircraft components in two groups: fuselage group and wing group. Answer the following questions. Note that points are earnt only when correct justifications are provided. **7 points in total.**

a. In which of the two groups should you include the weight of passenger and freight? **(1 point)**
b. In which of the two groups should you include the weight of the fuel? **(1 point)**
c. Consider the two aircraft in figure 2. In which of the two groups should you include the weight of the main landing gear **(2 points)**
d. Consider the Piaggio Avanti P180 business jet (figure 2 left): in which group should you include the weight contribution of aft tail, wing and forward tail? **(2 points)**
e. Consider the F18 fighter plane (figure 2 right): in which group should you include the weight contributions of the missiles? **(1 point)**

Figure 2

6 Answer the following questions related to the concept of longitudinal stability (**8 points in total**):

a. Give a definition of neutral point (**2 points**).
b. Write the relevant aerodynamic derivative whose value (larger, smaller or equal to zero) is indicating whether the aircraft is longitudinally stable/unstable/neutrally stable (**1 point**).
c. Explain the relation between the value of such derivative and the position of the neutral point w.r.t. the center of gravity (**1 point**).
d. Consider the case of a tailless aircraft and explain how its aerodynamic center and neutral point are located with respect to each other **(1 point).**
e. Does the position of the neutral point change with the aircraft speed? in case, how does it change? Either it changes or not, explain why? **(2 points)**
f. Explain why an aircraft with wing podded engines is more (or less) longitudinally stable than one with fuselage podded engines? **(1 point)**

Part 3 - Multiple-Choice Questions

(1) There are "requirements on requirements", in order to ensure the effective use of requirement in the design process. Among the following sentences, only one is NOT a correctly formulated requirement on requirements: indicate it.? ***(3 points)***

(A) The content of the requirement shall include the reason for a description of the design.
(B) The inclusion of essential, design-to, requirements shall be complete.
(C) Each requirement's unique identifier shall not be re-used in the event the requirement is deleted.
(D) A requirement sentence shall not include a summary of the design aspects covered by the requirement.

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(2) Only one of the following hypothetic requirements for the AOCS subsystem of the DelFFi satellites developed by TU Delft cannot be considered acceptable with respect to the VALID criteria: indicate it. ***(3 points)***

(A) The AOCS subsystem shall provide and receive all data in the 64-bits floating point format.
(B) The AOCS subsystem shall provide the attitude angles of the satellite every 0.5 seconds.
(C) The AOCS subsystem shall have a reasonably low mass.
(D) The AOCS subsystem shall withstand a maximum acceleration of 6g without any mechanical damage to its components.

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(3) In the Design Option Tree for the electrical power subsystem of a new TU Delft nano-satellite with an extended lifetime of at least 5 years, only one of the following options will NOT be discarded during the first "eliminating concepts" phase and will advance to the final selection process: indicate it. ***(3 points)***

(A) Use of a very long cable connecting the satellite to the power station on ground.
(B) Use of a new type of rollable solar panels that can be unrolled once the satellite is in orbit.
(C) Use of a wireless system for transferring the necessary power from the International Space Station to the satellite. Rumours say that NASA is developing such a system and it will be qualified for flight within the next 5 years.
(D) No use of any power generation systems (all the required power for the entire lifetime is stored in batteries that are charged before launch).

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(4) Only one of the following sentences is incorrect about verification: indicate it.? ***(3 points)***

(A) Verification methods for a product consists of inspection, analysis, demonstration and test.
(B) Verification = Proof of compliance with design solution specifications and descriptive documents.
(C) Verification = Confirmation by examination and provision of objective evidence that the specified requirements have been fulfilled.
(D) Verification = Proof that the product accomplishes the intended purpose based on stakeholder expectations.

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(5) 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: The propulsion sub-system shall provide a vacuum specific impulse higher than 300 s.
(B) REQ-B: The peak power consumption of the propulsion system during ignition or heating shall lower than 15 W.
(C) REQ-C: The propulsion sub-system must provide a vacuum thrust higher than 10 N.
(D) REQ-D: The propulsion sub-system mass shall be lower than 20 kg.

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(6) Which one of the following propulsion system test phases is always performed on the actual Flight Model (FM)? ***(3 points)***

(A) Development Tests
(B) Qualification Test
(C) Acceptance Test
(D) None of the above

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(7) In Technical Performance Measurement (TPM), which of the following values take into account contingencies?

(A) Specification value and actual value
(B) Target value and specification value
(C) Current value and target value
(D) Specification value and current value

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

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

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

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

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(10) What is the correct order for the risk management process?

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