Delft University of Technology
Date: **Friday July 7, 2006**

Problem 1 Requirements Analysis (30 minutes, 17 points)

Requirements are the foundations of a project, they are very important in the definition and development of a project.

a. There are two sides in the requirements analysis. What are they?
b. Because of the importance of the requirements, it is very important that each item of the requirements is set up well and truly chosen which means that requirements should satisfy some criteria. These criteria are usually called "requirements on requirements". Give 4 criteria that a requirement should fulfil.
c. How is the relation between requirement analysis, functional analysis and design synthesis? Use figures to describe the relation.
d. What are "user (customer) requirements" and "product requirements" referring to?
e. These days, one of the hot topics in aerospace is finding a replacement for fossil fuel (e.g. kerosene) for the next generation of airplanes. If a project is defined based on this need, give 4 examples of user requirements and product requirements which are relevant to the subject (4 examples for each one).
f. Give the name of two system engineering tools which can be used for analyzing the requirements. Give a very short description about how they are useful.

Problem 2 The Aerospace Market (30 minutes, 20 points)

a) Markets can be defined along many different dimensions. A useful definition in three dimensions to cover both the supply and the demand side is given by the dimensions: customer, function and technology. The dimension 'customer' can be segmented in many ways. Give 4 possible segmentations

b) Unmanned aerial vehicles can be used in many ways both for military and civil purposes. Give at least three potential markets for UAVS. Describe these markets as combinations of function and customer.

c) Explain the difference between primary demand and derived demand.

d) Give two examples of primary demand related to aircraft and two related to spacecraft

e) Explain the concept of 'supply chain' and explain why the term supply tree or supply network would be more applicable.

Problem 3 Work flow diagram, work breakdown structure and design options (30 minutes, 17 points)

Sounding rockets are sub-orbital rockets that carry a payload above the Earth's atmosphere for period of up to 15 minutes, but which do not place the payload into orbit

around the Earth. Your group is requested to design such a rocket for a payload of 1 kilogram and altitude of 70 km.

The project assignment describes three major phases: A first phase, meant to become familiar with the subject and to study typical implementations, a second phase, in which you will look into some design options and make the best choice, and a third phase, where the details of the system are designed.

a. Make a work flow diagram for each phase but limit yourself to a maximum of 8 activities in each one and clearly identify "tasks" and "products" in the diagram.
b. Describe the difference of work break down structure and work flow diagram. Make a work break down structure for one of the phases. Limit yourself with a maximum of 12 blocks.
c. Draw the design option tree for at least 2 subsystems and showing 2 options for each one. Is it an AND or an OR tree? Explain the difference.
d. Give the difference between ordinal and cardinal methods for design option selection.

Problem 4 Design Concept Selection (30 minutes, 18 points)

You want to develop an unmanned aerial vehicle (UAV), including ground station, which can be used by the fire brigade to survey areas (e.g. woods) that are prone to bush fires.

a. Give a functional flow diagram or a functional breakdown for your UAV.
b. Give a requirements discovery tree for the UAV and show/explain the relation to the functional breakdown.
c. Give design option trees for the three most important functions. Each option tree must at least have three levels.
d. Perform a trade-off for your design (use at least two criteria) and report your trade-off in a table.
e. Give the difference between ordinal and cardinal methods for design option selection.

Problem 5 Reliability and Life Cycle (30 minutes, 13 points)

a. What is the definition of "reliability of a system"?
b. Probability distributions are used in modelling the reliability of a system. Give the names of two commonly used distributions and shortly describe for which type of reliability modelling they could be used.
c. The mean time between failures (MTBF) of the control system of a LEO satellite with a constant failure rate has been determined to be θ. As a system engineer, you should set the design life so that the reliability of the system (R) is 0.9.
    1. Determine the design life in terms of θ.
    2. If two of the systems are placed in active parallel, to what value may the design life be increased without causing a decrease in the reliability?

Problem 6 Design for verification / design for production / design recording (30 minutes, 15 points)

a. The Space Design Process defines four methods for verification: Review of Design, Inspection, Analysis and Test. Describe all four of them in your own words.
b. Give three types of verifications tests and give an example of their application.
c. Define the difference between qualification testing and acceptance testing
d. For the cost estimate of a new product it is common use to distinguish between non-recurring cost and recurring cost. These two types of cost are related to non-recurring and recurring processes in product development. Give a definition and at least three examples of both process types.
e. Traceability and configuration control are very important aspects of quality assurance in the aerospace industry. Explain how document templates support these aspects.

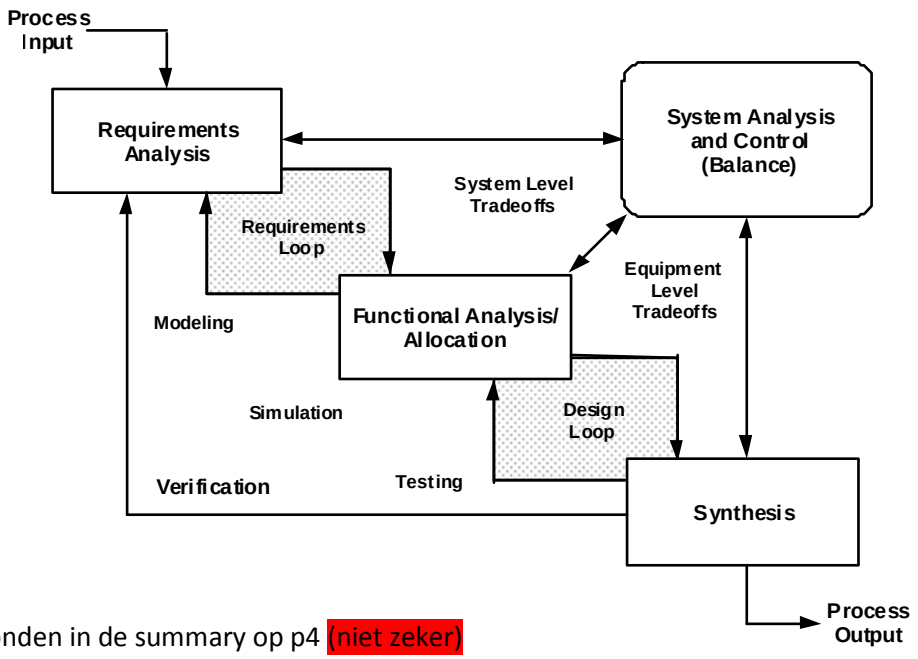
Antwoorden

Question 1

a) Gevonden in Reader Part I, blz 6-2 (goed)
1. The first one is requirements discovery, deriving system requirements from the basic mission statement, from knowledge of the environment and from everything else that matters.
2. The second one is requirement flow down, that is deriving subsystem requirements from system requirements. Essential here is to make sure that nothing is overlooked or done twice.

b) Gevonden in Lecture 3 #2, slide 28 (goed)
1. Each requirement shall have a unique identifier
2. Each sentence shall include only one requirement
3. A requirement shall be verifiable
4. The content of a requirement shall not include the reason for the requirement or a description of the design; rationales and design descriptions shall be documented separately

c) Gevonden in Lecture 3 #2, slide 16 (goed)



d) Gevonden in de summary op p4 (niet zeker)
User (customer) requirements: the product requirements (House of quality)
Product requirements: technical requirements (Parts Deployment)

e) Nergens gevonden, zelf bedacht (niet zeker)
User requirements:

- The fuel should not be too expensive compared to the kerosine
- The quality of the new fuel should be comparable or better than that of kerosene
- The new fuel should be at hand at the most airports
- The airplanes / engines of the user should be able to deal with the new fuel

Product requirements:

- The new product should have equal or better performance over kerosine
- The new product must be compatible with the engines installed
- The new product should be easy to mine/drill/gather and not be scarce
- The new product should have lesser impact on the environment

f) Gevonden in Lecture 3 #2, slide 10 en 14 (goed)

1. Requirements discovery tree: It is a structured tool in the form of an AND tree, where every element is the sum of the elements under it and nothing more, if this is true it can be verified very quickly that no requirement has been forgotten. It is also used to split requirements up in two parts, for example functional requirements versus constraints. With this tool a quick overview of the requirements is given.
2. Requirements flow down: Deriving subsystem requirements from system requirements, to make sure nothing is overlooked or done twice. This tool is based on the assumption that system requirements have been correctly and completely defined. Some system requirements usually remain to be found by subsystem designers, for example omissions or delays in discovering requirements or forces looping back (repeating steps) in the design process.

Question 2

a) Gevonden in de Reader Part I, blz 2-9 (goed)

- Demographic factors (age, sex, income)
- Brand loyalty and switching patterns
- Attitudes toward product and competing brands
- Advertising media reading/viewing patterns
- “Psychograpghics” or “life-style” characteristics of consumer

b)
c)
Primary demand: total industry demand for a given product category
Derived demand:

d) Gevonden in de Reader part I, blz 3-30 (goed)
Aircraft:

- Passenger / cargo transport
- Reconnaissance / surveillance

Spacecraft:

- Communication
- Navigation
- Earth Observation

e) Gevonden in de summary op blz 5 en in Reader Part I blz 2-15 (goed)

A supply chain is a coordinated system of organizations, people, activities, information and resources involved in moving a product or service in physical or virtual manner from supplier to customer. The entities of a supply chain typically consist of manufacturers, service providers, distributors, sales channels and consumers (end customers). Supply chain activities transform raw materials and components into a finished product that is delivered to the end customer.
A supply chain is a special instance of a supply network in which raw materials, intermediate materials and finished goods are procured exclusively as products through a chain of processes that supply one another.
Because a supply chain is so complex and not as straightforward as shown in the picture (in the summary), each part of it can also be depicted as a tree of activities or people, so in reality a supply chain is more like a supply tree or a supply network.

Question 3

c) Gevonden in de summary op blz 3 en in de Reader Part I, blz 5-4 (goed)

- An AND tree is used to indicate summing functions, where all functions are required:
    - Each element of the tree is the sum of the elements below it
    - A = B + C + D + E
    - Gives a complete picture of the system or product
- An OR tree is used to indicate alternative functions.

d) Gevonden in de summary op blz 8 (goed)
Ordinal (qualitative) : Ordinal methods: do not require from decision makers anything more than that they rank the alternatives on an ordinal scale per criterion from 'worst' to 'best'.
Cardinal (quantitative): the decision maker has to quantify the measure of satisfying a criterion on an interval scale ('rating').

Question 4

a) Gevonden in Reader Part I, blz 5-7 (voorbeeld)
In figure 5-5 a comparable functional breakdown is shown for an optical instrument, for the specific breakdown requested here this figure can be used as guideline.

b) Gevonden in Reader Part I, blz 6-8 (voorbeeld)
Figure 6-7 on this page is a general form of an RDT, so use this figure and place in each square the appropriate mission specific part requested here.

The relation between the two remains yet unknown… (niet goed)

c) Gevonden in Reader Part II, blz 8-4 (voorbeeld)
Three possible options are surveillance of the area of interest, detection of a bushfire and the report of a bushfire to the headquarters.
Figure 8-2 shows an example of a design option tree with 3 levels and some details below.
Considering this as an example, the design option tree for the three functions described above should be made up.

d) Gevonden in Reader Part II blz 8-11 (voorbeeld)
Figure 8-7 as shown here is a good example of presenting the trade-off results in a table. Some options have to be defined here for the design, for example different sensors, and the 2 criteria requested can be for example the costs and the performance. The different sensors should be to the left in the vertical column, and the criteria in the upper row. Use a clear way to show your choice.

e) Gevonden in de summary op blz 8 (goed)
Ordinal (qualitative) : Ordinal methods: do not require from decision makers anything more than that they rank the alternatives on an ordinal scale per criterion from 'worst' to 'best'.
Cardinal (quantitative): the decision maker has to quantify the measure of satisfying a criterion on an interval scale ('rating').

Question 5

a) Gevonden in de summary op blz 15 (goed)
The reliability of a system is the probability that a system will perform in a satisfactory manner for a given period of time when used under specified operating conditions.

b) Gevonden in de summary op blz 16 en in Reader Part II, blz 11-6/7 en 11-10 (goed)
The negative exponential distribution: This distribution has a constant failure rate and is therefore representative for random failures, for example, for systems with a large number of components. For a negative exponential distribution the failure rate can be determined from the number of failures and the operating time. Failure rate = number of failures / total operating time. Used in a model for useful life period, at the end of the infant mortality period.
Poisson distribution: Can be used to model parallel networks, which are passive redundant systems. The Poisson distribution is valid here under the assumption that passive systems do not fail (which is not absolutely true) and the switch is perfect (Rswitch = 1)

c) Gevonden in summary op blz 16 en in Reader Part II blz 11-9 (goed)
1. Use the reliability function to find that R = 0.9 = e^(-t/theta), so we find that -0.10536 = -t/theta and so t = 0.10536theta, with t the design life.
2. With an active parallel the reliability becomes R = Ra + Rb – Ra * Rb = 1 – (1-Ra) * (1-Rb). So we know R = 0.9 and Ra = Rb, substituting this we get 0.9 = 2Ra – Ra^2. So with abc-formula we can show that Ra^2 – 2Ra + 0.9 has solutions Ra = 1.31623 and 0.683772234. Reliability can not be higher than 1, so choose Ra = Rb = 0.683772234 = e^(-t/theta). So we find that t = 0.38013theta. Which is an increase with almost factor 4.

Question 6

a) Gevonden in Reader Part II, blz 9-2 (goed)
Review of design: Establish by inspection of design documentation that the product answers the requirement.
Inspection: Establish by inspection of the product itself that it answers the requirement.
Analysis: Establish by mathematical or other analysis techniques that the product answers the requirement often in combination with tests to validate the mathematical model describing the product.
Test: Establish a test on (a representative model of) the product that it answers the requirement.

b) Gevonden in Reader Part II, blz 9-3 t/m 9-6 (goed)
Structural testing: Simulate the mechanical loads during handling, launch and in orbit operation. An example of application is acoustic load testing of rockets and rocket mounted items.
Thermal testing: Simulate the system under operational thermal conditions. An example of application is the thermal vacuum test to verify workmanship, using high temperatures some bad soldering joints in a structure can be exposed.
Integration testing: Done to find out if all system elements fit and work together. An example is the software test performed to check the correct functioning of software onboard the A380 on simulated hardware in a simulated environment.

c) Gevonden in Reader Part II, blz 9-5/6 (goed)
Acceptance testing: The flight model of each space vehicle or component of a space vehicle is subjected to an acceptance test. This test is a subset of all tests carried out on the product during its development. The conditions used are, however, more benign. The purpose is to establish correct workmanship and to show that the flight model performs equally well as the previous models tested.
Qualification testing: This can be of any type like structural, thermal or integration testing. Models are tested with a margin on top of the expected nominal conditions. It can be done on separate models using an either structural, thermal, electrical or engineering model, or it can be done on one model only.

d) Gevonden in summary blz 18 en Reader Part II blz 10-2 en 10-3 (goed)
Non-recurring processes: processes executed once for every product type. Examples are:
1. Multiple production concept generation (in production design process)
2. Design selection (in production design process)
3. Programming of machines (in technical part of the production process planning and preparation)

Recurring processes: processes repeated for every product of a specific type
1. Manufacturing of parts
2. Final assembly
3. Delivery to customer