Delft University of Technology
Course: Systems Engineering & Technical Management Techniques (AE3-S01)
Date: **March 31, 2004**

Problem 1 Technical Risk Assessment (30 minutes, 16 points)

You have to assess the technical risk in an UAV development using variable airfoil geometry by means of smart materials. A technique often used in technical risk assessment is the so-called Risk Map, which is basically a two-dimensional matrix or table.

a. Which two "factors" determine the risk in a Risk Map?

b. How can you "mathematically" express risk?

c. Which technical aspect is often taken to estimate the frequency with which a risk may occur? Can you give at least four typical entries on the ordinal scale determining this frequency?

d. Which kind of events may be considered by the other factor determining the risk? Can you give at least three typical entries in the ordinal scale used for that axis of the Risk Map?

e. Draw a typical Risk Map. Where are the items with the highest risk located?

f. Indicate how you are going to mitigate the risks. Which two typical risk mitigation approaches may be taken? What is the result of each of these approaches?

g. In case of the UAV: Which risk items or elements would you put as high risks where in the Risk Map and why?

Answer (16 points)

1a 2 points

Probability of occurrence; Severity of impact or consequence

1b 2 points

Risk = probability x impact

1c 2 points

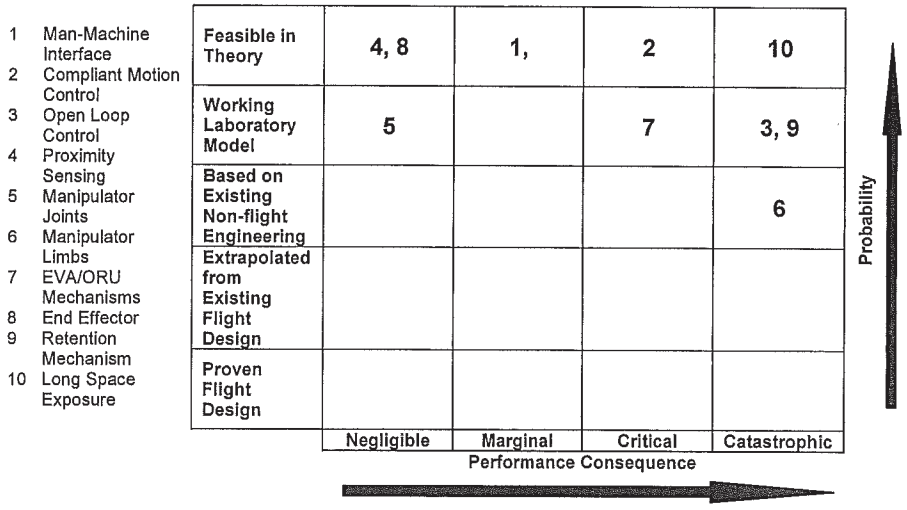
State of Technology (generally taken, not project or company specific)

Any four of: Feasible in Theory, Working laboratory model, Based on existing non-flight engineering, Extrapolated from existing flight design, Proven flight design

1d 2 points

Severity of impact is expressed in terms of mission, cost or schedule. *Any three of:* Catastrophic, Critical, Marginal, Negligible

1e 2 points



Note: Functions (1-10) at left hand side do not need to be included and do not need to be placed in the Risk Map to obtain full score.

Highest risks are in the top right hand corner.

1f 3 points

There are two ways to mitigate the risk:

- Do (pre-)development. This results in increasing technology maturity.
- Redesign, such that the risk item or element becomes less critical for system, mission or project.

The result is that the risk items or elements move to the bottom and/or to the left of the Risk Map.

1g 3 points

High risk items for the UAV are the variable air foil and the smart materials. Probability of both items to be estimated somewhere between "feasible in theory" and "working laboratory model", severity of impact or performance consequence between "critical" and catastrophic.

Problem 2 The Aerospace Market (30 minutes, 17 points)

a. Describe the different functions of the Marketing Department in the Systems Engineering Process (hint: look at the different phases in the System Life Cycle).

b. Give the three major elements (dimensions) of a market definition.

c. Analyse the Boeing 7E7 product description given below and give a definition of the market for this product based on the three major elements of a market definition.

d. Give a SWOT analysis of the product-market combination as found in c.

e. Give an aircraft market segmentation based on customers

f. Give an aircraft market segmentation based on products

g. Give a Space Market segmentation based on users (customers)

New Boeing 7E7 to Be Made Largely of Composites

The key factor is that Boeing's new jet has to help airlines make money in a world where passengers demand coast-to-coast round trips for $198, an industry where the jetset image has given way to something else. "This has become a commodity market, people are going to wind up in the airborne equivalent of a Greyhound bus. One of the things we are trying to get back with this airplane is the similarly sort of excitement when the airplane flies over. When it taxis up, when you get on it, people will instantly recognize the 7E7."

This month, Boeing Senior Vice President of 7E7 Development Mike Bair walked local civic leaders through the 7E7, a plane designed to make the airlines money in the gritty world of modern airline travel and bring back some of what's been lost.

Not only would the 7E7 have a swoopy exterior, but a sexy interior that passengers would ask for.

A plane would fly long routes, up to 8,000 nautical miles at high speed, bypassing many of the hub airports passengers now cram through.

The plane would also be wired for the Internet where so called "e-enabled" passengers would have more entertainment choices in the air. The plane could also self-diagnose problems and call ahead for parts at the next airport.

"But this is a multi-billion dollar investment that we do once every 10 years on average," said Bair. "It is absolutely critical that we do it right. That's what is driving everything in this program is to make sure we get it right."

Boeing's new 7E7 will become the first commercial jet to be made with most of its primary structure consisting of composite materials.

Some of the composite materials that will be used include graphite and toughened epoxy resin, and TiGr, a titanium/graphite composite. The graphite/epoxy material will make up the bilk of the composite materials used in the 7E7, while the titanium/graphite composite will be used for the wings.

Composite materials got the nod over rival aluminium alloys as they provided greater durability, reduced maintenance, and increased potential for future development. Interestingly, there was little weight difference between the two materials and the cost of the fabricating composite components has become more competitive.

It is also possible that sensors will be embedded into the composite structures to monitor the health and help schedule maintenance.

Answer (17 points)

2a 1 points

Functions: mission need statement definition, requirements definition, trade-off criteria, sales, after sales

2b 2 points

Customer, functions, technology

2c 4 points

Customer: airlines, airforce (tanker)
Functions: passenger transport in the medium and long range, fuel transport and refuelling system
Technology: composite airframe, low fuel consumption engines

2d 4 points

SWOT Analysis subject	
S(trengths)	W(eaknesses)
Potentially low maintenance airframe (no corrosion, no fatigue): Potentially low weight airframe (composite) therefore low SFC Potentially low fuel consumption: low SFC engines Attractive appearance, new interior look	Technology unfamiliar to most airlines Not part of a Boeing family of aircraft Expensive technology
O(pportunities)	T(hreats)
Start of new family that will substitute metal aircraft. Technology can be translated to other fields of business	Scepsis within industry Unexpected problems in technology

2e 2 points

Leisure, business, training, utility, corporate, regional airlines, major airlines

2f 2 points

Piston, turboprop, jets, regional ac, large transport aircraft

2g 2 points

Primary demand behind the space market is the demand for communication, navigation and earth observation services and for scientific research
- Infrastructure including the manufacture, test, delivery and launch of satellites, other spacecraft, and related hardware;
- Telecommunications including transmission of international telephony services, interconnection with national telephone networks, and distribution of video signals for cable and television programmers;
- Emerging Applications like remote sensing, geographical information systems (GIS) or global positioning services (GPS);
- Support Services like publishing, business consulting, financial, legal and space insurance

Problem 3 Interface Analysis (30 minutes, 16 points)

Analyze the interfaces of an ironing system with at least the following elements

- Steam iron
- Ironing board
- Electrical network
- User

a. What is the Mission Need Statement for this system?

b. Is this system complete? Give a rationale for your answer.

c. Name the primary functions of each of these elements, also for additional elements you may need to complete your system.

Draw two N^2 charts with the elements on the diagonal.

d. Identify in the first N^2 chart, using the N^2 chart conventions, the interfaces between the elements by putting a cross in the squares where an interface is present.

e. Identify in the second N^2 chart the interfaces by indicating each individual interface by one or more words.**Answer (16 points)**

3a 2 points

To enable a human operator to put clothing of several materials in the desired shape.

3b 2 points

The system is not complete. Missing elements are: the **item to be put in shape** and **water supply.**

3c 4 points

Functions of elements:

Steam iron	Exert pressure on clothes Provide heat to clothes Humidify clothes Provide interface to user
Ironing board	Support clothes Support iron
Electrical network	Provide energy to steam iron
User	Control iron Control item to be ironed Set up ironing system Provide water to iron
Item to be put in shape	Provide clothing to users Allow to be put in desired shape
Water supply	Provide water to steam iron

Reduce proportionally, when functions are missing.

3d 3 points

steam iron			X	X	
X	**ironing board**			X	
X		**electrical network**			
X	X	X	**user**	X	X
			X	**item to be ironed**	
X					**water supply**

Note: Crosses may be mirrored relative to the diagonal. If interfaces are missing: reduce points proportional.

3e 5 points

steam iron			report status	provide pressure, heat, humidity	
support	**ironing board**			support	
provide energy		**electrical network**			
control iron	set up	activate/ deactivate	**user**	position	control
			shelter from heat/cold	**item to be ironed**	
provide water					**water supply**

Note: If the number of interfaces in 3e is less than those identified in 3d: reduce points proportional.

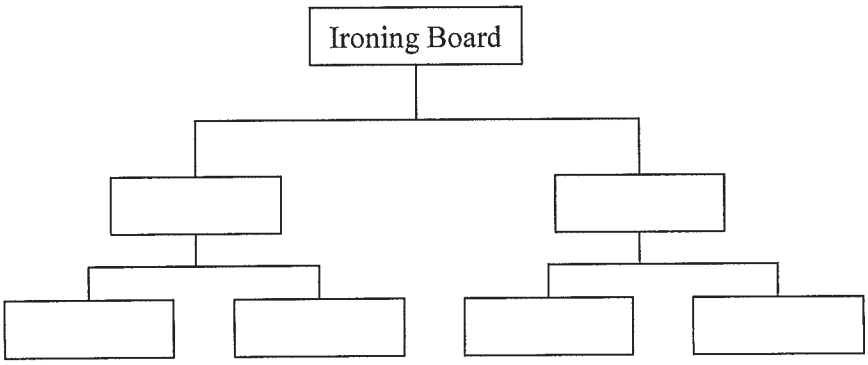
Problem 4 Design Concept Selection (30 minutes, 17 points)

Consider again the ironing system of problem 3. You are in control of the design of the ironing board.

a. What is a design option tree ?

b. Is the tree an AND or an OR tree? Explain the difference

c. Give a design option tree with at least three levels and two options per branch:



d. What is a trade-off process?

e. Give three trade-off drivers for your ironing board design process.

f. Give the difference between ordinal and cardinal methods for design option selection.

Answer (17 points)

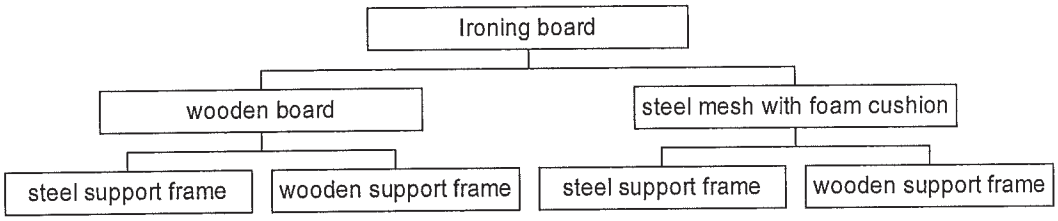
4a 3 points

A design tree shows potential solutions for the design problem on different aggregation levels. Each branch shows an option that can have different lower level options.

4b 2 points

In an AND tree all entries in the tree together form the total answer to the underlying problem
In an OR tree each branch below a tree entry forms an alternative solution.

4c 3 points



4d 3 points

The process in which values are allocated to design properties and choices are made based on a comparison between dissimilar properties.

4e 3 points

Cost, durability, weight

4f 3 points

In ordinal methods the decision maker ranks the alternatives per criterion on an ordinal scale to the measure in which the criterion is satisfied, and the criteria in the order of their importance.
In cardinal decision methods the decision maker must quantify his judgements on the effectiveness of the alternatives and the importance of the criteria on an interval scale.

Problem 5 Technical Performance Measurement for an aircraft with electrical propulsion. (30 minutes, 17 points)

You are developing a manned aircraft intended to fly around the world without landing (range > 40000 km). The aircraft uses durable energy for its electrical engines.

a. Give a breakdown of the aircraft in subsystems. Can you name a standard often used for an aircraft breakdown? In which way is your breakdown different from that standard?

b. Which conventional technical resource budgets are of most importance for your aircraft? Give a rationale, why you select them. Are they the same as those used for a conventional airliner?

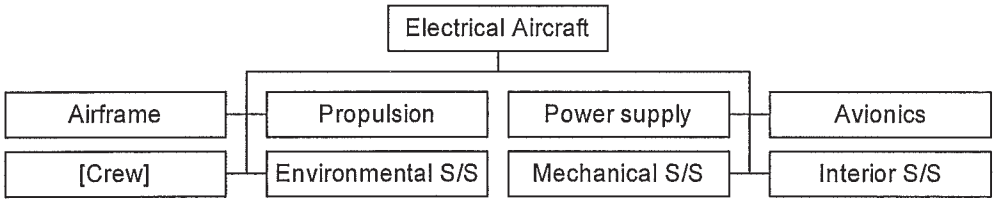
c. Which unconventional Technical Performance Management parameters would you select for your aircraft? Give a rationale for your selection.

d.

Answer (17 points)

5a 9 points

Functional breakdown (**6 points**):



ATA Specification 100 breakdown (**1 point**)

Propulsion does not include fuel; Power supply includes power provision to propulsion (**2 points**)

5b 4 points

Mass (always important).

Power, as well generated power as stored power, is in this case a second, as it is essential for propulsion and hence for primary performance and safety. This is not the case for conventional airliners.

(Production) cost is very important for airliners, but probably less for this aircraft, as it is probably some "world record" machine.

5c 4 points

Range will be a prime TPM parameter, as it is the essence of the mission. In this case it will be a complex one, as it is the sum of daylight and night performance, which will probably be very different.

A good second one probably will have to do with safety or emergency operations if e.g. the propulsion system fails (partly) in the middle of the Pacific Ocean (gliding range).

Problem 6 Design for verification (30 minutes, 17 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. Consider a liquid fuel tank. Give for each of the four verification methods given in (a) a requirement that you would verify with that respective method.

c. Give the role of verification in the aircraft certification process.

d. Define the difference between qualification testing and acceptance testing

e. What will be the main difference in structural test programs used for qualification and acceptance testing respectively?

f. When can you use a finite element calculation as verification for the strength of an aircraft structural part?

Answer (17 points)

6a 2 points

Review of Design: a verification based on an inspection by experts of design documentation (drawings, reports, test data etc)
Inspection: a verification based on an inspection by experts of a product
Analysis: verification of a design by calculations of its properties by accepted means and comparison with the required property values
Test: verification by subjecting a product or a model of a product to a test in which the relevant operational conditions are simulated.

6b 4 points

Review: Corrosion protection
Inspection: Electric bonding
Analysis: Static strength
Test: Fatigue behaviour

6c 4 points

Verification is done to have objective evidence from a reliable source that compliance material presented to the authority is adequately prepared and checked.

6d 2 points

Qualification testing: testing done to show that a design type fulfils the applicable requirements
Acceptance testing: testing done to show that a specific product is likely to fulfil the design requirements

6e 2 points

The load levels: will be at ultimate for qualification testing and at a lower level for acceptance testing

6f 3 points

When the design principles are well known and material properties are available.