

TU DELFT

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Aerospace Engineering

## DESIGN SYNTHESIS EXERCISE

# ATLAS

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### AIRSHIP FOR TRANSPORTING LARGE AEROSPACE STRUCTURES FINAL REPORT

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## Changelog

- v1.0:**
- First Version
- v1.1:**
- Change in conclusions with respect comparison between ATLAS and current system (numerical value), also the relevant sentences in Compliance matrix.
  - Equation 10.15:  $\sigma_f$  is changed into  $\sigma_c$ .

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## Preface

This is the final report of the Design Synthesis Exercise (DSE) Group 7 which contains the design of a High Capacity Transport platform. As a group of ten aerospace engineering students from Delft University of Technology we have the chance to apply the knowledge gathered over the last years to a practical end in this Bachelor project.

The report describes the design process starting from a winning concept that came out of the conceptual trade-off described in the midterm report. The winning concept is a hybrid airship and is worked out during this detailed design phase. The configuration and the main performance characteristics of the airship are determined.

As a group we would like to thank our tutors Rene Alderliesten, Tobie van den Berg and Xiaomin Wu for always giving us great advice. The critical view on our work as well as the support helped us during the whole project and especially in the detailed design phase.

We want to acknowledge Justin Koning for his helpful CFD calculations on the fuselage of the airship. Further we want to thank Leo Veldhuis for giving us advice on aerodynamics. We are very grateful to Wim Verhagen for his support on the systems engineering tools and we want to thank Kim van der Linden for assisting us with oral presentation techniques during the whole DSE. As a Zeppelin expert we want to thank Erwin Krijger for his presentation at the faculty. Furthermore, we want to acknowledge Prof.dr.ir. E. Torenbeek for his advice in the final stage of the design.

Delft, 11th June 2010

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## Summary

The hybrid airship concept came out as the winning concept in the trade-off. This concept was worked out into detail regarding sizing, weight, structures, materials, control, stability, performance, propulsion, lift, drag, manufacturing, operations, costs, RAMS, risks and sustainability.

The first step was to make a preliminary estimation on weight, sizing and configuration. At this stage the maximum take-off weight had already grown from  $230 \cdot 10^3$  [kg] to  $340 \cdot 10^3$  [kg]. This resulted in an increase of dimensions of the airship to eventually 174 [m] in length by 99 [m] in width by 43 [m] in height in order to house the additional gas.

During the aerodynamic design it was determined that the most efficient system could be obtained by having 70% of the maximum take-off weight lifted by the helium and 30% by either vertical thrust vectoring or dynamic lift of the airfoil shaped body, which was adapted from the NACA 38025 airfoil. The drag coefficient was estimated by dividing the airship as a wing section with straight sharp edges and a conventional airship shape for the round edges. Subsequently a CFD computation was performed, which allowed to give a more accurate value for the drag coefficient.

As far as the propulsion was considered it was chosen for a six tilt rotor engine configuration. The power required was calculated by looking at the hover power, cruise power, and power needed for the transition phase from vertical take-off to horizontal cruise flight. Each engine had to deliver a maximum power of roughly 5000 [hp]. This power was realized by a two-bladed rotor with a radius of 11.8 [m]. At this stage the engines could be selected, which led to an estimation of the amount of fuel required. The airship consumed 22.5% less fuel than the Airbus Beluga.

Regarding stability, the position of the payload bay and the engines had to be adjusted to bring the center of gravity to the front of the airship, resulting in an increase in stability properties of the airship. To make it stable and to have sufficient control, a horizontal control surface had to be implemented. The airship was, such as most aircraft, laterally unstable, hence a vertical tail plane must be added. Horizontal and vertical tail planes were combined into a V-tail to reduce the profile drag of control surfaces. The area of the movable part of the tail was also calculated.

Regarding structures, it appeared that a non-rigid airship was not feasible because of the shape of airship. The solution was to add a skeleton of aluminum I-beams. The engine and control surface supports were designed with the acting loads in mind. Finally the landing gear configuration and position was determined. The materials were chosen in compliance with the structural design. The load carrying structure was made out of aluminum 7075, the envelope was a three layer polymer. The subsystems, such as fuel systems, environmental control and flight instruments, were added and incorporated in the design.

A production and assembly plan was proposed. The airship frame would be assembled from 13.7 [m] long beam sections. At this stage a better weight estimation was made, it grew to  $389 \cdot 10^3$  [kg].

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This allowed to iterate the entire process starting with this new maximum take-off weight.

The last phase was to plan the operations, the risks, RAMS and improve the initial cost estimation. The highest risk was delayed due to unfavorable weather, since the airship was by regulation not allowed to take off at a wind force stronger than 4 [Bft]. The risk of overrunning the budget, which was identified in the midterm report appeared to be realistic. The total life cycle cost more than doubled and were estimated to be four billion dollars. The profitability and other markets were analyzed, which could be fulfilled if a second airship had been built.

The outcome of this design process was a transportation platform that fulfills the initial requirements. The cheapest concept was chosen during the trade-off and the improvement in fuel consumption with respect to the Airbus Beluga was almost met (22.5% improvement instead of the 25% required). The operational cost of the Atlas platform was 13.8% more expensive than the current A380 parts transportation system but has the advantage of being point to point, faster, and more fuel efficient. It is up to the customer to decide whether or not the investment cost justifies the improvement in operations.

Contents

1	Introduction	1
	Bibliography	2

**LIST OF SYMBOLS**

## Nomenclature

A/C .....	Aircraft
ATLAS .....	Airship for transporting large aerospace structures
CAD .....	Computer aided drawing
CAE .....	Computer-Aided Engineering
DSE .....	Design Synthesis Exercise
FBS .....	Functional breakdown structure
FFD .....	Functional flow diagram
HiCaT .....	High Capacity Air Transport
ISA .....	International standard atmosphere
MTOW .....	Maximum take-off weight
NACA .....	National Advisory Committee for Aeronautics
PW .....	Pratt & Whitney
RAMS .....	Reliability, Availability, Maintainability, Safety
US .....	United States
USD .....	United States Dollar
UV .....	Ultra violet
WBS .....	Work Breakdown Structure
WFD .....	Work Flow Diagram



# Chapter 1

## Introduction

During the last few decades the aircraft industry has grown exponentially in size and has become expensive in terms of financial and intellectual resources. In order to share these costs and the risk of huge investments the industry has evolved into an international partnership. However, this risk sharing comes at the cost of logistical challenges of transporting large sections and components. Nowadays, these challenges have been met by using huge aircraft, usually adapted from existing versions, or the challenges were met by naval or land based systems or by a combination of these.

The Airbus A380 is a similar project with multi-national involvement and due to its size, an even bigger logistical challenge. A specifically modified transport aircraft – the Airbus Beluga – can transport aircraft sections of other aircraft, but it does not have the capability to transport the much larger sections of the A380 aircraft. Therefore a combination of naval, land and airborne transportation methods are being used to transport A380 sections across locations all over Europe. The project's objective is to design a platform that fulfills this task more efficiently.

This report highlights the detailed design of a hybrid airship that came out as a winning concept in the conceptual design phase. The design of the Airship for *Transporting Large Aerospace Structures* – ATLAS – is worked out in different phases. In the first phase the configuration and rough weight estimation of the airship is determined. In the second phase the main performance characteristics of the design are determined. In this phase the technical aspects such as lift, drag and propulsion are calculated and the final configuration is known. In the third phase the structure as well as the stability characteristics are determined and a more accurate weight estimation is achieved. In the fourth phase management aspects such as cost, markets and risks are worked out.

The project approach of the design exercise is described in chapter ?? while the problem is then analyzed in chapter ?. Reflection on the manner how the final concept was generated is given in chapter ?. The detailed design starts with an preliminary configuration in chapter ?. In chapter ? and ? specific design considerations on aerodynamic design and propulsion is presented. Stability and control are assessed in chapter ?. Later, an intermediate design is discussed in ?. Structural design and material selection is discussed in chapter ?, while airship systems are treated in chapter ?. Assembly considerations and production is explored in chapter ?. Next an intermediate weight estimation is given in chapter ?. A further iteration with additional CFD data is presented in chapter ? before entering the operations part in chapter ?. Some final concept specifications are given in chapter ?. The last part of the report consists of the design evaluation in chapter ?, a follow up project description in chapter ? and the conclusions and recommendations in chapters ? and ?.

## **Bibliography**