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Corresponding author: RIBOLDI Carlo Emanuele Dionigi
e-mail of corresponding author: carlo.riboldi@polimi.it
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Title

On the Optimal Preliminary Design of High-Altitude Airships: Automated Procedure and the Effect of Constraints

Authors

Carlo E.D. RIBOLDI [1], Alberto ROLANDO [2], Stefano CACCIOLA [3], Gregory REGAZZONI [4], Ilaria SPADAFORA [5]*

** Corresponding author*
[1] *Department of Aerospace Science and Technology, Politecnico di Milano, 20156 MILANO, Italy, carlo.riboldi@polimi.it*
[2] *PACE Aerospace & IT GmbH, 14059 BERLIN, Germany*
[3] *Department of Aerospace Science and Technology, Politecnico di Milano, 20156 MILANO, Italy, stefano.cacciola@polimi.it*
[4] *Department of Aerospace Science and Technology, Politecnico di Milano, 20156 MILANO, Italy, gregory.regazzoni@mail.polimi.it*
[5] *Department of Aerospace Science and Technology, Politecnico di Milano, 20156 MILANO, Italy, ilaria.spadafora@mail.polimi.it*

Abstract

When ground observation or signal relaying in the vicinity of an unfriendly operative scenario are of interest, such as for military actions or disaster relief, high-altitude airships (HAA) offer some technical benefits. Featuring a milder cost and higher deployment flexibility with respect to lower-Earth orbit satellites, these platforms, often baptized as high-altitude pseudo-satellites (HAPS), operate sufficiently far from the ground to provide better imaging coverage and farther-reaching signal relaying than standard low-flying systems, such as aircraft or helicopters. Furthermore, flight in the higher atmosphere offers stable airstreams and highly-predictable solar energy density, thus ideally giving the chance of smooth operation for a prolonged period of time [1].

However, the design of airships for the task is often conditioned by the need to go through the lower layers of the atmosphere, featuring less predictable and often unstable aerodynamics, during the climb to the target altitude [2].

A first way of effectively tackling the issue of reaching the higher layers of the atmosphere, and thus allowing for the design of a machine best suited to matching optimal performance at altitude, is represented by the deployment of the HAA by means of a missile. However, since the HAA platform shall take the role of a launcher payload, the feasibility of the mission is subject to a careful negotiation of specifications, such that the ensuing overall weight of the airship is as low as possible.

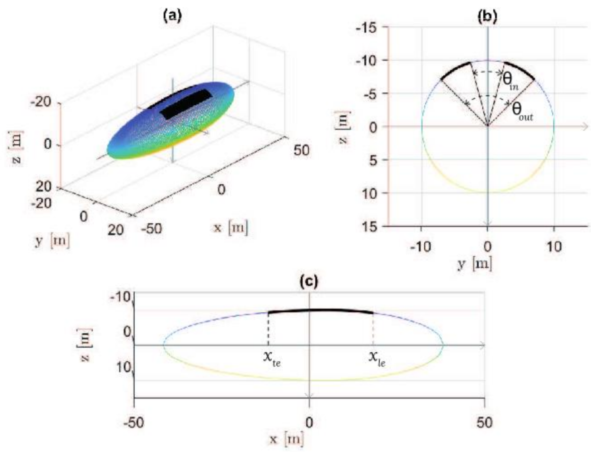

Figure 1. Example preliminary sizing of the HAA hull and solar arrays arrangement

In a second scenario, the airship is optimized to carry out also the climb from ground level to the target altitude. In this case, the resulting design would be suboptimal in terms of performance during the cruise phase, but the ability to autonomously execute the entire mission profile (i.e. without employing a rocket-powered carrier) would represent a useful asset [3][4].

For analyzing both scenarios and produce a preliminary sizing of a high-altitude airship, a design loop is therefore introduced, taking into due consideration all constraints bound to weight (clearly including payload) lifting ability, energy self-sustainability of the airship platform, flight performance and structural integrity. The proposed procedure bends itself to the inclusion in an optimal framework, with the aim of seeking a design solution automatically. Among the features of the design point are the weight breakdown (including structure and batteries), the shape of the hull, the sizing of solar arrays, etc.

Figure 2. Investigating the adaptability of an airship designed as an HAA for a HAPS mission over L'Aquila, considering flights above locations all over the world.

A validation of the adopted models and assumptions on existing HAPS has been performed first. Parameterized studies on the airship optimal shape are presented, highlighting the impact of operative and technological constraints on the resulting sizing solutions. This allows understanding the effect of exogenous variables, like environment settings or the geographical flight position, strongly impacting solar power harvesting effectiveness as well as stratospheric wind intensity [5][6], in steering the design of an HAA.

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