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HAP-ALPHA: MODEL UPDATING BASED ON GROUND VIBRATION TEST AND THE INFLUENCE ON LOADS AND AEROELASTICITY

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ABSTRACT

This paper presents the results of the ground vibration test (GVT) of the HAP-alpha and a comparison with the structural modeling using finite elements (FE). A 3D rendering image of the HAP-alpha configuration, currently under development at the DLR [1], is shown in Figure 1. The idea is to create an extremely light weight aircraft ($m_{design} = 136$ kg) that flies very slowly ($V_{EAS} = 9.0$ to 11.0 m/s) but is highly efficient in terms of propulsion and aerodynamic performance (AR = 20) and is powered by solar electric energy. Because many design aspects are driven by aeroelasticity [2–4], the validation of the aeroelastic modeling is essential.

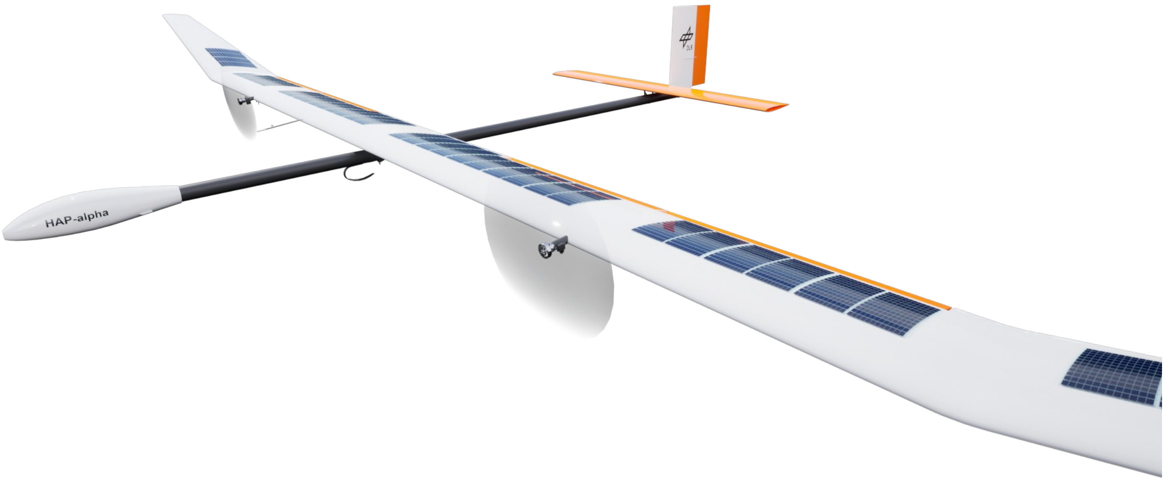

Figure 1: 3D rendering of the High Altitude Platform (HAP-alpha).

This paper addresses the following research questions:

- How good/reliable was the FE model?
- What is the influence of the GVT on loads?
- Does the updated model lead to any restrictions w.r.t. the initial design? Can we still fly the whole flight envelope?

The successful Ground Vibration Test (GVT), performed efficiently by specialists of the DLR Institute of Aeroelasticity, marks a significant milestone on the path towards flight testing. Figure 2 shows the aircraft in a hangar at DLR's National Experimental Test Center for Unmanned Aircraft Systems located in Cochstedt, Germany.

As can be seen in Figure 2, the aircraft was tested without the upper and lower foil-type skin and for the boundary condition, a three-point bungee suspension was selected. The bungee locations (left / right engine pylon and tail, indicated by white arrows) were chosen in such a way that the elastic deformations of the aircraft remain small and to avoid excessive roll or yawing motion of the aircraft during the test and to ensure a sufficiently low-frequency rigid body motion. The background of these decisions as well as more details will be discussed.

Generally speaking, the agreement between EMA and FE modes is very good and all relevant modes are included. Also, the frequency of up to 15.0 Hz is more than sufficient for the intended aeroelastic applications. Figure 3 shows the MAC matrix between EMA and FE modes, before and after model updating. A mixed agreement can be seen for the initial FE model, however, fundamental characteristics such as the 2n wing bending (before 0.95 Hz, updated 0.99 Hz) or the symmetrical wing torsion (before 6.96 Hz, updated 8.46 Hz) showed

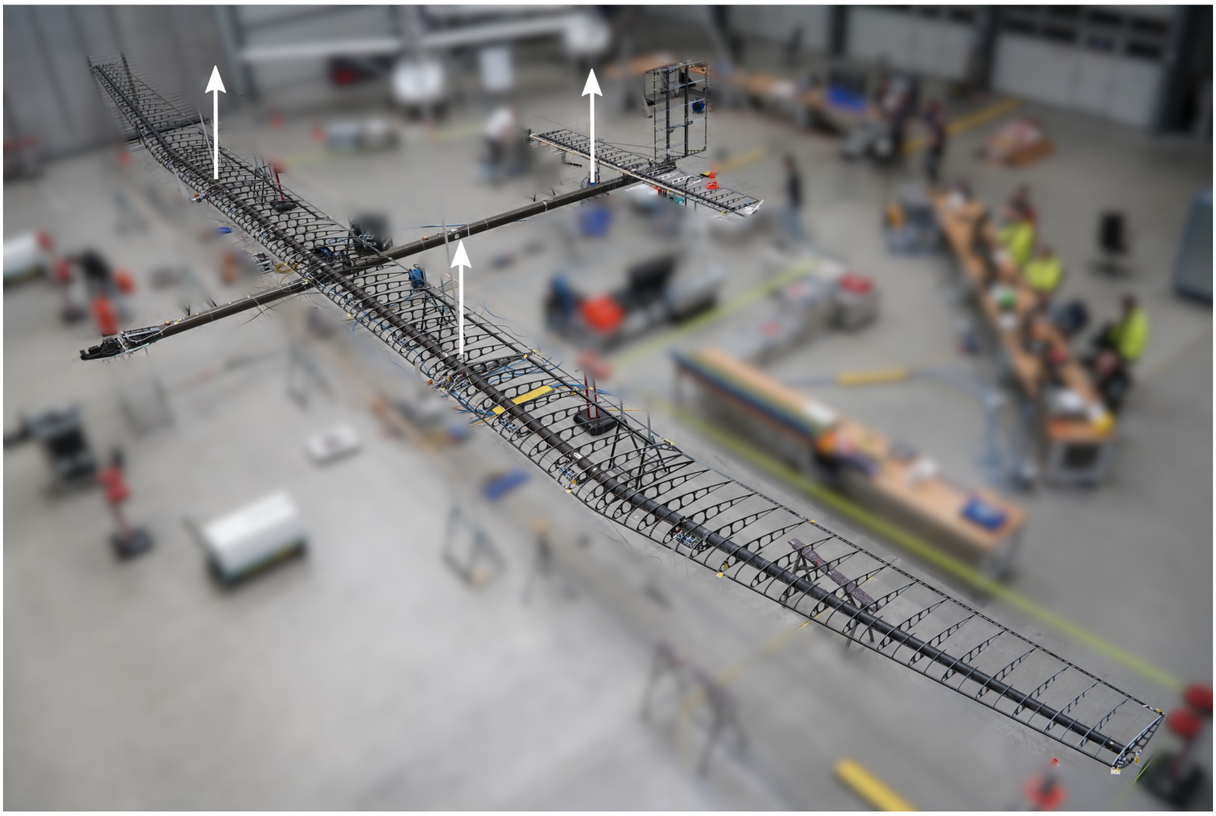

Figure 2: The High Altitude Platform (HAP-alpha) during the ground vibration test, bungee suspension indicated in white

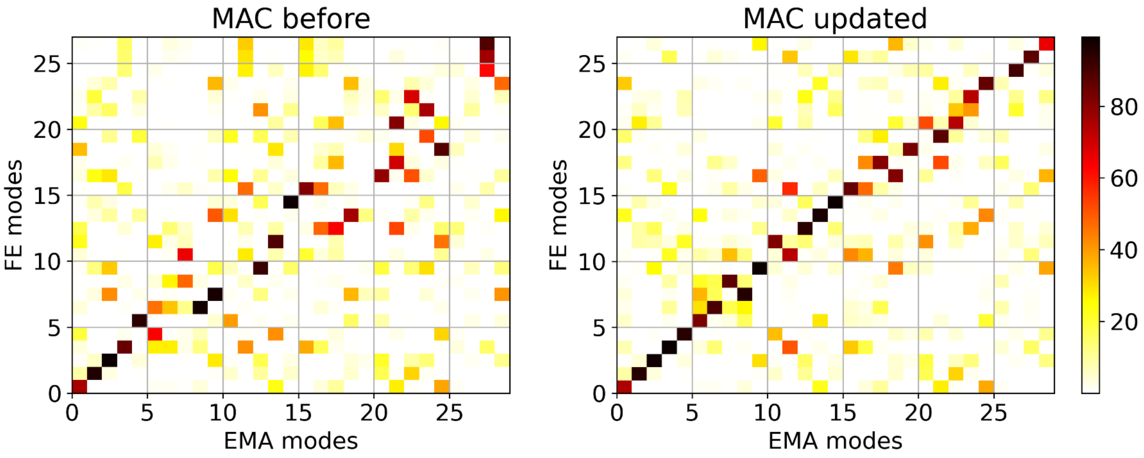

Figure 3: MAC matrix between EMA and FE modes, before and after model updating

a good agreement. After the model updating, the MAC matrix shows a much clearer correlation along the diagonal.

The influence of the updated model on loads and the structural sizing will be discussed in detail in the final version of this manuscript. In addition, all aeroelastic analyses, including flutter, the flight shape, control surface effectiveness, etc., are investigated and included in the manuscript.

To the authors' best knowledge, there are no publications with respect to model updating and ground vibration testing of a similar vehicle. In addition, there is no publication that can show/evaluate the influence of the GVT on other aeroelastic disciplines and/or the aircraft design.

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