

HAP ALPHA: GROUND VIBRATION TEST OF THE ULTRA-LIGHTWEIGHT HIGH-ALTITUDE PLATFORM STRUCTURE

Carsten Thiem, Ralf Buchbach, Julian Sinske, Keith Soal, Martin Tang, Robin Volkmar, Tobias Meier and Arne Voß*

**German Aerospace Center (DLR), Institute of Aeroelasticity
Bunsenstr. 10, 37073 Göttingen
Germany*

ABSTRACT

INTRODUCTION

The paper presents the ground vibration test (GVT) of the High-Altitude Platform (HAP) alpha structure. The test was performed by the Institute of Aeroelasticity of the German Aerospace Center (DLR) at the DLR facility in Cochstedt, Germany in April 2025. The HAP alpha is a very light and unmanned fixed-wing aircraft structure which should fly for very long duration in stratospheric heights driven by solar power. In these altitudes and with the possibility to carry up to 5 kg of payload it can be a cost-efficient alternative to satellites in certain fields of application like earth observation or for communication networks. With a wingspan of approx. 27 m and a total weight of around 136 kg, including the weight of the batteries, the first elastic modes are expected at very low frequencies. [1] Therefore, a significant challenge for the GVT is the elastic suspension of the structure.



Figure 1: Artist impression of the High-Altitude Platform

GROUND VIBRATION TEST

Ground Vibration Tests are performed in the last steps of prototype ground testing, usually some weeks before the first flight is planned. The purpose of the test is to create an equivalent modal model of the structure containing eigenfrequencies, mode shapes, generalized masses and damping ratios. These parameters from the real prototype structure are then used to update the Finite Element Model (FEM) which is used later on e.g. for flutter analysis. Regarding the ultra-lightweight structure of HAP alpha, special focus was on the equipment used for this test. The added masses from sensors, cables, etc. should be as small as possible resulting in an optimized sensor grid for the structure and a mechanism to route the cables apart from the structure. Measuring the low frequencies predicted for the elastic modes of the

structure using piezoelectric acceleration sensors also had its challenges. The sensors have a hardware-related high-pass behaviour. The low acceleration amplitudes at low frequencies further reduce the signal-to-noise ratio.

A total of 111 acceleration sensors were used in the GVT to ensure a comprehensive experimental modal analysis of the structure in frequency range of interest up to 30 Hz.

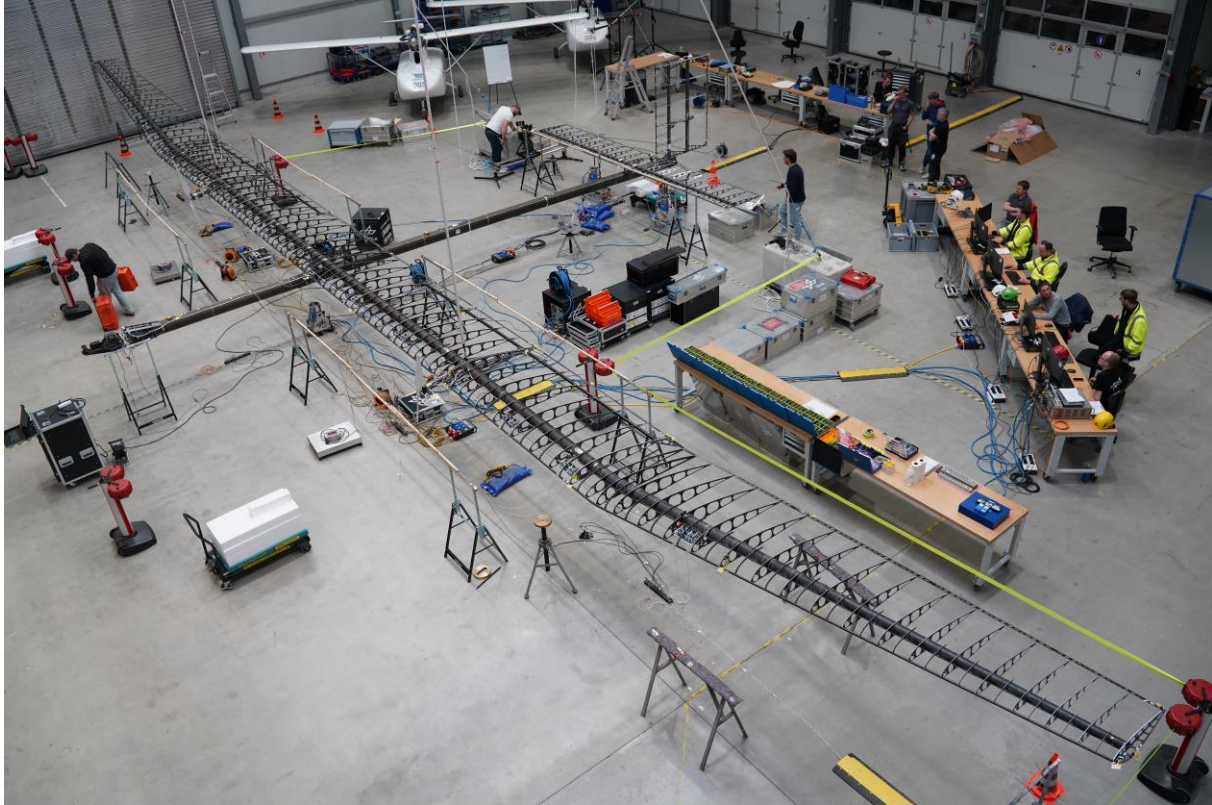


Figure 2: GVT setup of the High-Altitude Platform

SUSPENSION

Another big challenge for the ground vibration test was the realisation of a suitable suspension for the HAP alpha structure. The predictions from the FE-Model assumed the first elastic modes to appear at around 1 Hz. In order to approximate free-free boundary conditions, the highest rigid body frequency should be significantly lower than the lowest elastic frequency. As a rule of thumb, the distance between them should be a factor of 3, which means the rigid body modes should be lower than 0.33 Hz.

From past tests profound experiences were available using elastic ropes to ensure a very soft suspension for different structures ranging from glider prototypes to wind turbine blades. Therefore, this suspension should also be used in this test. Since the stiffness depends on the length of the elastic ropes and the hangar was only 10 metres high, a deflection mechanism with pulleys was mounted close to the ceiling. By deflecting the ropes and attaching them close to the ground, the effective length could be almost doubled. [2]

The pulleys were built out of high-quality bicycle components to ensure cost-effective parts having negligible friction loss when the structure oscillates in heave-motion.

SUMMARY

The test was successfully performed within five working days executing 46 measurement runs at seven different exciter locations. During the test 49 different modes were identified in the frequency range up to 30 Hz excluding the rigid body modes. The highest rigid body mode (Heave) was identified at 0.246 Hz while the lowest elastic mode was identified at 0.994 Hz showing that the free-free suspension worked as expected.

REFERENCES

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