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Title

Total Energy Control for the Automatic Landing of UAS with Large Aspect Ratio and Low Wing Loading

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Abstract

Unmanned aerial systems (UAS) are a rapidly growing market for numerous and diverse civil and military applications. As an alternative for the increasing number of satellites in orbit, high-altitude platform stations (HAPS) are under development for aerial surveillance or as telecommunication hubs. To achieve long endurance for the intended missions, HAPS are typically designed as fixed-wing aircraft with a large aspect ratio and low wing loading. They are operated in the lower stratosphere, where environmental conditions allow for geostationary operations. Even though the landing is a short phase of the intended mission, here the aircraft can be exposed to severe turbulence and it is operated in dense airspace, where it has to arrange with applicable approach procedures and with surrounding traffic and terrain.

In the projects FCL-HALE and IBAS-TUB, TU Berlin developed the flight control functions (FCF) that enable the fully automatic operation of a HAPS aircraft from automatic take-off to landing. For FCF development, a high-fidelity non-linear flight mechanical model of a representative aircraft that is developed by Leichtwerk AG (see Fig. 1) is available. For preliminary FCF design, linear methods in MATLAB are used. Implementing the FCF as flight control laws (FCL) in Simulink/Stateflow yields a so-called *Prototype Model* that is integrated into the non-linear simulation. The preliminary design is optimized by using both linear and non-linear simulation results.

To control the longitudinal aircraft motion, a cascaded controller structure is selected. The inner control loop provides pitch control. It is optimized to normalize the pitch motion response inside the flight envelope. Based on the adapted pitch dynamics, Lambregts' concept of the Total Energy Control System (TECS) is used to decouple altitude and airspeed dynamics and thereby, to unify the aircraft specific dynamics and the energy exchange dynamics [2].

This article summarizes the FCF design for automatic landing of the HAPS aircraft based on total energy control. As no certification requirements for the Autoland function of unmanned HAPS aircraft exist, the requirements are derived from comparable requirements for commercial air transport [3] and applicable standards for fixed-wing UAS [4]. The landing procedure (see Fig. 2) is developed to suit the applicable ICAO standards and recommended practices [5].

The Autoland function has to ensure that airspeed, vertical speed and pitch attitude are within the specified tolerances during approach and at touchdown. For this control task, the control allocation is modified over the runway and the flaps are continuously used to directly control the vertical speed. This article describes deviations from classical TECS and outlines the integration of the Autoland function into the TECS-based cascaded controller structure.

Certification of transport aircraft requires reliability and robustness of the design. The CS-AWO requirements [3] were adapted and compliance was demonstrated by Monte-Carlo-Analyses. Near the ground, compensation of the vertical turbulence was difficult due to the aircraft's low wing loading and very low approach speed. It should be validated that the relatively large upwind turbulence that the model generates is realistic. To account for unexpected environmental conditions, this article additionally proposes monitor functions that command a go-around, if one of the monitored criteria is violated, as this indicates that a continuation of the landing may result in an accident.

Figure 1: Project "StratoStreamer" HAPS aircraft by Leichtwerk AG [1]

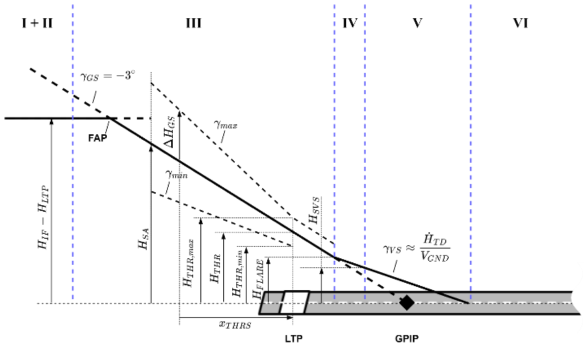

Figure 2: Vertical profile of the landing procedure

References

[1] Kickert, R.: *High Altitude Platform Stations (HAPS)*. In: Magazin Luft- und Raumfahrt, Heft 2/2021, S.17-19. Bonn, 2021.

[2] Lambregts, A. A.: *Vertical flight path and speed control autopilot design using total energy principles*. In: Proceedings of the AIAA Guidance and Control Conference 1983, No. AIAA 83-2239, Gatlinburg,TN: 1983.

[3] EASA: *Certification Specifications and Acceptable Means of Compliance for All-weather Operations* (CS-AWO). Issue 2, Cologne: January 2022.

[4] EUROCAE: *MASPS for RPAS Automatic Take-off and Landing (ATOL)*. ED-283, Issue 1, Saint-Denis, France: February 2021

[5] ICAO: *Procedures for Air Navigation Services - Aircraft Operations* (PANS-OPS). ICAO DOC 8168, Sixth Edition. Montreal, Canada: 2018