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# INCREMENTAL NON-LINEAR DYNAMIC INVERSION CONTROL OF A SOUNDING ROCKET

**Abstract**

This paper investigates the applicability of Incremental Non-linear Dynamic Inversion (INDI) in flight control of a sounding rocket.

In March 2009 the student society Delft Aerospace Rocket Engineering (DARE) launched the amateur rocket Stratos carrying one student experiment. The members designed and build the rocket engines, vehicle and electronics them selfs. By reaching 12.5 km they set the European record for amateur rockets. As expected the passively stabilized rocket, weathercocked into the wind, decreasing the apogee altitude. By stabilizing future rockets, greater altitudes can be reached. This allows a longer flight time above minimum experiment altitude and thus increasing payload possibilities.

The proposed vehicle is a sounding rocket actuated with active canards. The control forces and moments generated by these canards are heavily dependent on airspeed and air density. Due to the large flight envelop, a conventional flight control system requires gain scheduling. When attempting to reduce the complex design load for determining those gains and enhancing the closed-loop control performance, advanced non-linear control systems should be considered. By applying the Non-linear Dynamic Inversion (NDI) technique, the original non-linear system is feedback-linearized. A single linear outer-loop controller is used to complete the closed-loop system. However uncertainties in the rocket model and environmental conditions cause imperfections in the linearization. This could degrade the performance of the closed-loop system.

NDI has been shown to be effective in controlling a missile performing skid-to-turn maneuver by Devaud. This control design was performed under the assumption of constant mass. Sieberling has demonstrated the resilience of an INDI control system towards cg location and model uncertainties when applied to an UAV.

In this paper it is investigated to which extent the INDI controller can be based on the assumption of constant mass for a variable mass system. The large mass flow out of the solid rocket engine varies the cg location and influences the inertia tensor which forms an important part in the solution of the INDI.

To evaluate the performance of the INDI compared to conventional NDI, simulations are performed. These include: full non-linear equations of motion, the canard effectiveness under environmental conditions and the variations in cg locations and the mass/inertia properties. It shows the INDI setup is robust against all stated variations over the conventional NDI design.