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Title

MINI-APTERROS: A GNC demonstrator for Vertical Landing and Thrust Vector Control systems

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Abstract

The PERSEUS (Projet Étudiant de Recherche Spatiale Européen Universitaire et Scientifique) programme from the French Space Agency (CNES) offers students and future engineers the opportunity to develop their interest and vocation towards the space sector by participating in ambitious and collaborative projects aimed at developing controllable and reusable rockets through the incremental development of Guidance, Navigation and Control (GNC) demonstrators. Designing the guidance and control laws of a Vertical Landing (VL) rocket with a Thrust Vector Control (TVC) system often proves to be a challenge, as it requires complex simulation platforms to experiment and fine-tune a large number of parameters to achieve the desired performance. To overcome this issue and facilitate the process of development of such systems, PERSEUS is developing a small-scale and low-cost rocket as a test platform for implementing GNC algorithms for TVC and VL. This demonstrator, called Mini-Apterros (Mini-Advanced Propulsion Technology for Reusable Rocket and Operating System) not only allows quick testing, tuning and validation of the control laws and navigation solutions with real flights, but also to experiment with exploratory GNC technologies such as Artificial Intelligence (AI). Such technologies could drastically change the way GNC systems are developed.
Initiated as a student challenge, three versions of Mini-Apterros are being developed by distinct student teams with the same constraints. Each version has an electric propulsion system with four turbines that are controlled by the same controller, a maximum weight of 10 kg and four legs to stand on. Each version also focuses on different approaches: Mini-Apterros from University of Rennes 1 (UR1) uses a simple Proportional, Integral (PI) controller with an air deflection nozzle for TVC and cold gas thrusters for roll control, while Mini-Apterros from ENSEA Cergy has a similar GNC approach but uses smaller electric turbines for roll control and implements the TVC by orienting the propulsion system. Finally, ENSAM Bordeaux follows this mechanical approach and uses Deep Reinforcement Learning (DRL) to train a neural network to control the demonstrator. The neural network is trained by simulating flights of the vehicle in a multiphysics engine. To demonstrate the ability to effectively control Mini-Apterros, the objective mission is to lift-off and rise one meter above the ground, fly horizontally for three meters, and land safely.
At the current state of development, UR1's Mini-Apterros marked a crucial step towards achieving its mission by performing its first 10 seconds unconstrained stationary flight, which allowed to validate the mechanical system and algorithms for the TVC. The development now focuses on fully implementing the cold gas Reaction Control System (RCS) to further improve the stability of flight over longer periods of time, and on the landing phase. After achieving a constrained IA driven altitude control, ENSAM Bordeaux is improving the mechanical structure of the demonstrator and the model used to train its network in preparation for the first stationary flight.