AEROSPACE ENGINEERING

Preparatory studies for the NASA INCUS mission

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Context of the research activity	The research of this PhD aims at contributing to the development of the AOCS for the NASA INCUS mission in collaboration with NASA-JPL and Blue Canyon Technologies and to assess the impact of the attitude control onto the mission requirements. The control of the pointing of the three Ka-band radars on board the constellation train is crucial for the success of the mission that is focused at the study of the evolution of convective clouds and the determination of convective mass fluxes, a key observable to validate numerical weather prediction models.
Objectives	Deep convection has a profound influence on Earth's climate system. Updraft plumes in deep convective clouds are in the tropics the principal pathway by which heat, moisture, mass and trace gases are transported into the upper atmosphere. Observations of the occurrence and magnitude of vertical transport in deep convection are simply not available over the tropical oceans and sparsely available over land. Ground-breaking novel observations of convective clouds are expected from the NASA's Earth Venture Program Investigation of Convective Updrafts (INCUS) mission (https://www.Nasa.Gov/press-release/nasa-selects-new-mission-to-study-storms-impacts-on-climate-models) with the launch in 2026 in low Earth orbit of a constellation of satellites equipped with Ka-band (35 GHz) radars and microwave radiometers in close formation (with separation of the order of few minutes). This observing system will allow to globally observe the explosive evolution of storms as never done before and should therefore provide new observables to test the realism of convection-permitting cloud resolving models. These models will represent the backbone of future operational weather forecast models, which are currently run at or near 5 km but will soon move to finer resolution capable of resolving convection. The success of the mission critically relies on controlling the three mission spacecrafts in formation with separations of the order of 30 and 90 secs and on being able of pointing the push-broom Ka-band antennas at the same convective cells within 1/5 of the radar footprints (of the order of 8 km). Scope of the PhD is to perform ancillary studies in preparation of the mission with two main goals: a) To identify and assess solutions for the attitude determination and control for highly-accurate pointing, and for station-keeping and constellation

	maintenance. This work will be done in strict collaboration with the group at JPL led by S. Tanelli (Instrument PI of the INCUS mission). b) To introduce the pointing uncertainties in a simulator of the radar and radiometer measurements applied to a fine temporal (sub-minute) and spatial (sub-km) resolution outputs from the WRF model. This will allow to assess the impact of the pointing uncertainties in the mass flux estimations. The study will capitalize on advanced radar and radiometer simulators (accounting for the viewing geometry, the radar sensitivity, the antenna pattern, the pulse compression schemes, etc) developed in the past ten years within the research team. The project will contribute to improve the convection forecasting capability considering various temporal and spatial scales and promoting the seamless prediction concept, from Nowcasting to Numerical Weather Prediction (NWP), Global Circulation Models (GCM), and Convection-Permitting Models (CPM), with the aim to advance from the early warning up to the future projections in climate change scenarios. These objectives are also included in the National Recovery Plan of Italy (PNRR), Mission 2 – Component 4 aimed at the safeguard of the national territory and water resources. In this frame there is an explicit call for actions intended to strengthening predictive capacity of climate change effects through advanced and integrated monitoring and analysis systems and prevention and contrast of the consequences of climate change on hydrogeological instability phenomena and the vulnerability of the territory.

Skills and competencies for the development of the activity	This project offers an excellent opportunity to develop and apply innovative and robust AOCS for satellite that maintain a formation and satisfy stringent pointing requirements and novel radar techniques to remote sensing of clouds and precipitation. The student will be trained in a wide range of topics including radar meteorology and remote sensing. Applicants should have a science or engineering degree. Knowledge of the modern control system for space applications, small satellites missions and systems and Guidance, Navigation and Control strategies would be beneficial. Programming skills in matlab (Simulink)/Python/C/Java/C++ and knowledge of signal propagation and numerical modelling could also be advantageous.