ELECTRICAL, ELECTRONICS AND COMMUNICATIONS ENGINEERING

DET - Study of Advanced Solutions for GNSS-based Orbit Determination and Time Synchronization

Funded By	Dipartimento DET
Supervisor	DOVIS FABIO - fabio.dovis@polito.it
Contact	DOVIS FABIO - fabio.dovis@polito.it MINETTO ALEX - alex.minetto@polito.it
Context of the research activity	Telecommunications, Radio Navigation.
Objectives	Global Navigation Satellite Systems (GNSS) are increasingly recognized as a key enabler for autonomous Positioning, Navigation, and Timing (PNT) beyond the operational limits of the Space Service Volume (SSV), addressing the growing demand for onboard navigation capabilities in lunar and cislunar exploration missions. As deep-space operations continue to rely predominantly on ground-based tracking infrastructures, the development of reliable onboard Orbit Determination and Time Synchronization (ODTS) techniques has become essential to enhance mission autonomy and resilience. In this context, reduced-dynamic filtering approaches represent a promising solution, as they offer improved solution continuity under conditions of sparse GNSS visibility compared to purely kinematic methods, while maintaining robustness against dynamic mismodeling. The extension of GNSS-based navigation into the Earth–Moon system has therefore emerged as a strategic frontier for satellite-based PNT, supporting an expanding portfolio of scientific and exploration missions in cislunar space. Despite this potential, the Earth–Moon environment—particularly at lunar distances—constitutes an extreme operational regime for GNSS payloads. GNSS visibility is severely constrained, as only satellites located on the Earth's far side are observable by nadir-pointing antennas, with frequent line-of-sight obstructions caused by Earth occultation. These geometric limitations result in prolonged intervals of reduced satellite availability. In addition, severe free-space path losses significantly attenuate the received signals. Although individual measurement quality remains comparable to terrestrial performance, overall navigation accuracy is substantially degraded due to unfavorable satellite geometry and limited observability. The objective of this PhD research is to study, design, and validate navigation

	filter architectures capable of delivering ODTS solutions with performance levels suitable for space mission requirements. To this end, sequential Bayesian estimation techniques incorporating an orbital propagator —commonly referred to as orbital or reduced-dynamic filters—are investigated as a core methodological framework. By numerically integrating the spacecraft equations of motion under modeled perturbations, these filters enforce physical consistency of the estimated trajectory between successive GNSS measurements. Two key characteristics make orbital filters particularly well suited for high-altitude GNSS applications: their ability to preserve solution continuity during GNSS outages or periods of sparse visibility, and their reduced dependence on instantaneous measurement observability, which mitigates the adverse effects of poor satellite geometry. Building upon earlier studies that demonstrated Extended Kalman Filter (EKF)-based orbital navigation for lunar transfer orbits and compared EKF and sigma-point filtering techniques for low lunar orbit navigation, this PhD activity will extend and systematically assess these approaches. Furthermore, alternative filtering strategies capable of providing robust ODTS solutions will be explored. The research will be conducted addressing the proper signal processing algorithms for the navigation unit, leveraging on both high-fidelity simulated datasets and experimental measurements collected during the Lunar GNSS Receiver Experiment (LuGRE), which are publicly available. This combined simulation-and-flight-data approach will enable a comprehensive evaluation of navigation filter performance under realistic in-space and cislunar operational conditions.

Skills and competencies for the development of the activity	The candidate should have a background in communciation systems, radio navigation and positioning or related fields, with good knowledge estimation theory, and GNSS-based navigation. Experience with Bayesian filtering techniques, numerical simulation, and scientific programming is required. Familiarity with space mission of orbital mechanics, and experimental data analysis is highly desirable.