An accurate, long-term stable, and truly global terrestrial reference frame is critically important to addressing scientific challenges connected to the monitoring of changes affecting the Earth system, e.g. plate tectonics, earthquakes monitoring, ice melting and sea level changes monitoring, and others. Consequently, the terrestrial reference frame realizations need to be characterized by accuracy, stability, continuous availability and updates. The recent worldwide used realizations of the International Terrestrial Reference Frame (ITRF) are ITRF2014 and the newest ITRF2020. The space geodetic techniques that contribute to the ITRF realizations are Global Navigation Satellite Systems (GNSS), Satellite Laser Ranging (SLR), Doppler Orbitography and Radiopositioning Integrated by Satellite (DORIS), and Very Long Baseline Interferometry (VLBI). Current ITRF realizations still did not meet the 1-mm or better quality requirements of International Association of Geodesy. The SLR technique contributes for the realization of ITRF by defining the origin and scale of the frame, provide precise information about coordinates of globally distributed network of stations, and others. SLR contribution to ITRF is based only on laser measurements to dedicated spherical geodetic satellites, i.e., LAGEOS-1/2 and Etalon-1/2.

The active low Earth orbiters (LEOs) are Earth observing missions orbiting with an altitude below 2000 km. These type of satellites are characterized by particular mission objectives, such as sea-level change and sea-surface temperature mapping for Sentinel-3A/B, gravity field determination for GRACE and GRACE-FO, geomagnetic measurements for SWARM-A/B/C missions, generation of a global and high-precision Digital Elevation Models for TanDEM-X and TerraSAR-X. Many of these LEOs are equipped with space geodesy instruments contributing to the ITRF, i.e., GNSS receivers, SLR laser retroreflectors, and DORIS receivers. Currently, the contribution of LEOs for the realization of the ITRF is rather minor and considers only the DORIS technique. However, the SLR measurements to LEOs constitute 81% of all SLR observations, whereas 9% and 10% consider spherical geodetic and GNSS, respectively. Also, SLR to LEOs are not considered in the SLR contribution to ITRF.

In this project for the first time we provide long-term realization of terrestrial reference frame based on integrated SLR measurements to microwave based orbits of LEO satellites. We will focus on data from three space geodesy techniques and 14 LEO satellites collected from over ten years to perform the multi-LEO combination for high-quality estimates of SLR station coordinates and geocenter. Over the recent decade, we observe an increasing emergence of LEO satellites with space geodesy instruments onboard, which provide high-quality data for global geodesy and are characterized by very precise orbit determination products at the level of 1-cm or better. It creates considerable potential for investigations of LEO-based reference frame realization as a contribution to the ITRFs.

The multi-LEO combination will be performed for satellites which are tracked by laser stations and are characterized by microwave-based precise orbit determination products provided by GNSS and DORIS. We will investigate the quality of orbital products by performing independent SLR validation procedure. Next, we identify and reduce systematic effects affecting SLR, by modeling range biases, tropospheric biases for long-time period. Multi-LEO satellite combinations for determination of SLR station coordinates will be preceded by testing of different processing scenarios, e.g., single-satellite solutions, observation weighting strategies, and evaluating trends and seasonal signals in derived parameters. We derive a SLR-based terrestrial reference frame, whose quality will be verified by comparisons with external reference frame realizations.

Expected results will contribute to the development of satellite geodesy techniques, the realization of ITRF, and the determination of global geodetic parameters. The SLR observations to LEOs will be used for new applications through precise determination of SLR station coordinates and will possibly expand the contribution of SLR to the future realizations of ITRFs. LEO satellites and their mission operators will gain another, new, practical applications in monitoring, and understanding processes taking place in the constantly changing dynamic Earth system. All of these will contribute to a better understanding of geodynamic processes and phenomena that occur in the system Earth and which are monitored by global geodetic parameters and precise terrestrial reference frames. Enhanced terrestrial reference frames and global geodetic parameters improve space geodesy data delivered to scientific institutions, companies, societies, and other institutions. Thus, they contribute to many areas of life, such as monitoring of natural and anthropogenic induced phenomena and hazards, e.g., earthquakes, tsunami, ice melting, and sea level, civil engineering and mining, e.g., reference systems for surveying, agriculture, e.g., monitoring of vegetation quality, erosion, and soil hydrology, or transport, e.g., vehicle navigation.