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Hybridization of atomic and electrostatic accelerometers for satellite control and gravity field recovery

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Satellite gravimetry missions like GRACE and now GRACE-FO measure the global gravity field and its variations in time. Gravity field solutions are typically estimated monthly, but a higher accuracy and a better temporal resolution is required for various applications in the geosciences. With the addition of the laser ranging interferometer (LRI) to GRACE-FO, a significant improvement over GRACE concerning inter-satellite ranging was achieved. The determination of the non-gravitational forces acting on the satellites, however, remained conceptually unchanged. In ground-based applications, e. g., gravimetry and inertial navigation, the progress in the development of cold atom interferometry (CAI) leads to drift-free, accurate, smaller, more robust and reliable quantum sensors. Experiments on sounding rockets and aeroplanes demonstrate the potential of this technique and open up possibilities for applications on satellite missions.

We investigate potential next-generation gravity missions (NGGM) following the GRACE design, employing an LRI with GRACE-FO characteristics and the utilisation of CAI in combination with classical accelerometers. A CAI accelerometer also offers the possibility to better determine degree 2 gravity field coefficients, due to its long-term stability. A closed-loop simulator has been developed to test different scenarios of orbit configurations and system/instrument parameters. Regarding the orbit configurations, parameters like inter-satellite distance, orbit altitude and repeat cycle are varied. The results will be evaluated based on recovered gravity fields.

As further benefit, the concept of a CAI based drag-free control system is investigated and its impact on possible satellite orbits for NGGMs and the resulting gravity fields is discussed. As the control system is of critical importance for the success of the mission, key parameters are analysed. Furthermore, the requirement for the drag compensation depends on the knowledge of the accelerometer's scale factor. Related to this aspect, requirements on the drag compensation are derived for different scenarios. We will present first results of the simulation studies.

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