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Towards Controls Noise Co-Design for the ET-LF, Test Mass Seismic Attenuation and Suspensions

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The Einstein Telescope, low-frequency interferometers (ET-LF) will extend the detection band for gravitational-waves down to 3Hz [1]. Reaching these low-frequency sensitivities requires orders-of-magnitude improvements beyond the designs of second generation observatories, advanced LIGO [2] and Advanced Virgo [3]. Experience with these existing detectors has shown that they have been limited by technical and other noise sources below tens of Hertz [4, 5], upon reaching astrophysically significant sensitivities. Consequentially technical noises must be considered, as a matter of design, to ensure that the ET-LF observatory meets its sensitivity requirement.

One core subsystem of the ET-LF design is the test mass seismic isolation and suspension system. This has the primary goals of ensuring the core optics operate as free masses in the gravitational-wave detection band, isolating these mirrors from ground displacements, and providing a controls interface to ensure that the interferometer remains at its operating point. These goals are constrained by the requirements to not spoil the observatory's sensitivity with suspension thermal noise or technical noise injection. Previous system level studies [6] of the baseline test mass seismic isolation and suspension system showed that the inclusion of just the simplest technical noise exceeds the sensitivity requirement for ET-LF.

We present a test mass seismic isolation and suspension concept which satisfies the ET-LF sensitivity for this simplest technical noise requirement. To meet this constraint the conceptual design includes key aspects of controls co-design for the test mass seismic isolation and suspension. As a first step the baseline design is extended with an active inertial isolation platform. Secondly the warm and cryogenic suspension stages must include key controls co-design principles which are most simply achieved with adjustments to their mechanical design. Care is taken to ensure the cryogenic suspension is adjusted in ways consistent with detailed thermal noise and cooling studies [7]. With these alterations optimal controls techniques are used to distribute longitudinal interferometric actuation over the suspension's three penultimate stages, thus satisfying ET-LF's sensitivity requirement.

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