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Development of a Zero-Field/Hanle Vector Magnetometer for Exploring Magnetic Fields in Space

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Optically pumped magnetometers have been integral to scientific space applications since the 1960s [1]. They not only explore the Earth's magnetic field aboard missions such as Swarm (since 2013) [2] and CSES-1 (since 2018) [3], but also the magnetic fields of other planets and their moons. Notable missions include Pioneer 11 (Jupiter flyby in 1974), Mariner 10 (Mercury flyby in 1974) and Cassini (orbiting Saturn from 2004 to 2017) [1]. Currently, an optically pumped scalar magnetometer is on its way to Jupiter aboard the JUICE mission expected to arrive in 2031 [4]. Additionally, several instruments will be launched into Earth orbits soon, such as on CSES-2 (scheduled for 2025) and on NanoMagSat (scheduled for 2027) [5]. Despite all these achievements, the fluxgate magnetometer remains the most widely used magnetometer in space [6]. This type of instrument employs a feedback coil system with a ferromagnetic core for vector measurements [7].
The presentation will provide an overview of the requirements for magnetic field measurements in various mission scenarios, as well as the challenging environmental conditions during launch and the subsequent year-long operation in space. It will consider the advantages of fluxgate magnetometers and optically pumped scalar magnetometers to determine the performance characteristics required for a potential replacement by a single optical vector magnetometer.
Building on the technologies and experience developed for the Coupled Dark State Magnetometer [3,4], the presentation will show the progress of a zero-field/Hanle vector magnetometer prototype, currently being developed with the space application requirements in mind.

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