Since late 2022, the surge in language models using neural network architectures has driven a significant increase in computational power and energy demands. For example, each query to models such as GPT-3 consumes approximately 4 watt-hours, with such models handling millions of queries daily. To address the need for more efficient computing with less energy, this project explores the integration of **magnonics** and **spintronics**, with particular focus on **in-memory computing**. This approach combines data storage and processing in the same physical location, thereby reducing data transfer times and energy consumption, and enabling faster and more energy efficient computation.

Magnonics, a field within nanomagnetism and nanoscience, utilizes spin waves to transmit, store, and process information without the need for electric charges. A spin wave is a collective oscillation of the spins (magnetic moments) in a material, which looks like ripples running through water. The material supporting the propagation of spin waves is termed a magnonic medium, through which these waves can travel, enabling the transmission and manipulation of information. Typically, ferromagnetic materials are employed for this purpose, as they can sustain long-range magnetic order, meaning their magnetic moments align in the same direction. **Magnetic racetracks** are spintronic devices, that store data in the form of magnetic domains along a ferromagnetic nanowire. A magnetic domain is a region within a magnetic material where the magnetic moments (spins) are aligned in the same direction, and these domains can vary in size and shape. The boundary between two magnetic domains with different magnetization directions is known as the domain wall, where the magnetic moments change orientation from one domain to the other. Each domain acts as a cell of memory. These domains can be shifted using current or magnetic field pulses, allowing data access. Thus, magnonics and spintronics are very well suited to design devices for in-memory computation, due to possible use of the same media for data storing and information processing. In-memory computing can greatly benefit the development of **artificial neural networks**, which mimic the way the human brain processes information. Unlike traditional neural networks, artificial neural networks offer the potential for large-scale models to be trained and deployed more effectively, with lower operational costs and improved performance.

This project proposes to use the motion of magnetic domain walls to store information and process data codded in propagating spin waves. Our target device, features a two-layer design: a magnonic medium and racetrack memory. The magnonic medium, a thin magnetic film, hosts spin waves that perform computations. Above it, the racetrack memory contains reprogrammable magnetic domains that store information. The movement of these domains alters the magnetic properties of the magnonic medium, allowing spin waves to read and process data directly from the racetrack. This interaction facilitates in-memory computing, enabling complex and efficient data processing, particularly useful for artificial neural networks. Therefore, ***our goal is to utilize reprogrammable arrays of magnetic racetracks to control spin wave propagation in underlying thin films, where spin waves act as information carriers. We aim to develop an elemental scalable unit based on the above concept to introduce the compute-in-memory paradigm using a magnonic-spintronic device for neuromorphic calculations***. This elemental unit can serve as a fundamental building block for creating advanced computing architectures that mimic the human brain, achieving high efficiency and performance in neural network computations.