University of Colorado **Boulder**

Computer Science Senior Design
Project Description Template 2021-22

The goal of a Senior Design project is to challenge undergraduate students as they transition to industry and advance development within your organization. The project description should be written in language appropriate to undergraduate students with limited experience in your field of specialization.

Please indicate therein if your project requires US citizens only or has other restrictions.

The project description should:

- Include design, test, and build phases
- Require a maximum of 15 hours per student per week, 6 students per team
- Be approximately equivalent to a 9-month project for an entry-level engineer

You may request your project be multidisciplinary. Given enough notice, we will collaborate with students across the College of Engineering and Applied Science, Computer Science and possibly the Leeds School of Business.

Please return this form package to Amy.L.Richards@colorado.edu with a cc to nicholas.vita@colorado.edu

Project Description Template

Northrop Grumman
Falls Church, VA
https://www.northropgrumman.com/

Project Title: Your suggested title for the project (make it as short as possible)

Quantum AI at the Edge

Industry Description and Company Products: Provide students with some information on your industry and products.

Northrop Grumman solves the toughest problems in space, aeronautics, defense and cyberspace to meet the ever evolving needs of our customers worldwide. Our 90,000 employees are Defining Possible every day using science, technology and engineering to create and deliver advanced systems, products and services.

We build some of the world's most advanced aircraft. From the innovative B-2 Spirit stealth bomber to the groundbreaking X-47B, in addition to powerful airborne sensors and systems.

We are a leading provider of full-spectrum cyber across land, air, sea and space. From preventing cyber attacks to securing military communications and giving our customers a decisive advantage, our capabilities are second to none.

We provide critical logistics, sustainment and modernization services for everything from America's emergency services infrastructure to combat vehicles on the battlefield.

We are a world leader in the design, development and production of naval systems. From sonar that can map the deepest depths of the ocean to anti-submarine systems and advanced electronic warfare, we're constantly evolving to counter increasingly sophisticated threats at sea.

We've been pioneering in space for over 60 years and we continue to push the boundaries of what's possible. From the Lunar Module to the latest space telescopes (e.g. James Webb Space Telescope), from national security launch systems and payloads to advanced communications satellites, our space capabilities are unrivaled.

Contact Information: Designated technical contact (mentor) for the student team
Name, Title: Alec Carlisle, Cyber Systems Engineer
Email: Alec.Carlisle@ngc.com
Phone: (303)581-4967

Why students should choose this project: Students are presented with a selection of projects from our industry partners so they can select the one that best matches their interests and skill set. Consider adding information in this section as to why you feel your project would be an appealing senior design experience.

This project will give students an opportunity to familiarize themselves with new technology, as well as what's involved to take an idea from research and development to deployment.

Project Background and Objective: Brief explanation of the company, project, and desired objective(s).

The idea is to apply quantum AI to train a simple classifier network and then use that network for inference on an emulated embedded platform. Current AI solutions require performance improvements in training, and these solutions are being deployed to new domains. Simple classifiers are starting to show promise on quantum processors, and these classifiers are deployable on edge processors for inference. U.S. Citizens only please.

Project Requirements: The project requirements and constraints should be stated in broad and simple terms. The specific details will be established between the client and the team.

1. SVM and MLP classifiers will be trained using OpenCV and/or TensorFlow to establish baselines.
2. IBM Qiskit and Google Cirq will be used to implement SVM and MLP and compared with the baselines in terms of accuracy. These models should be run first in simulation and then on IBM and Google quantum processors. A variety of feature counts should be explored to find the point at which convergence on conventional hardware takes longer than a quantum processor. See https://www.nature.com/articles/s41586-019-0980-2 for further background.
3. The classifiers should then be used for inference on a XILINX Vitis emulator to demonstrate similar performance to what was seen in training.

Deliverables: The client is asked to indicate the desired deliverables in the project. The final deliverables will be established through negotiation between the team and the client as a stage of the project.

1. Analysis comparing baseline classifiers with quantum versions and libraries
2. Datasets used for analysis
3. Training code
4. Analysis of inference on emulated platform and code

Skill Requirements: The client is asked to suggest the skill areas the students may need in order to complete the project.

I'm not expecting students to necessarily have these skills, but it would be good for the team to at least be interested in one or more of the following.

1. AI
2. Quantum Computing
3. Embedded Programming

Images: Please include relevant images for this project. For example, these can be existing designs on which you would like the students to improve or photos of an existing apparatus with which they may work.

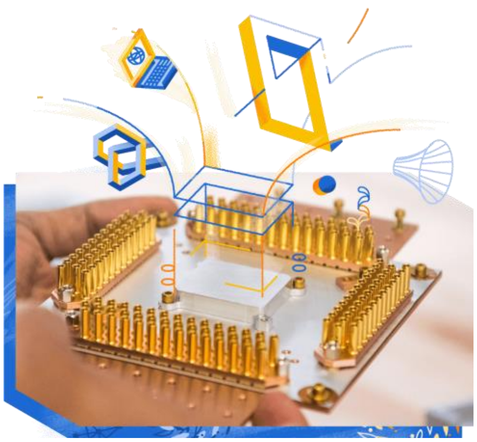

Figure 1: https://quantumai.google/quantum-computing-service

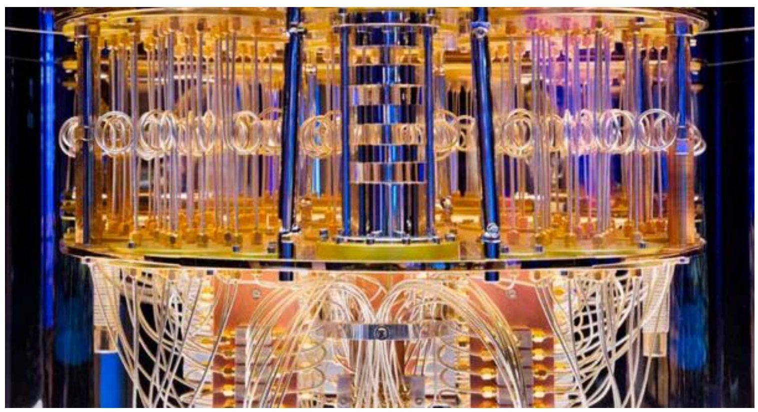

Figure 2: https://qiskit.org/

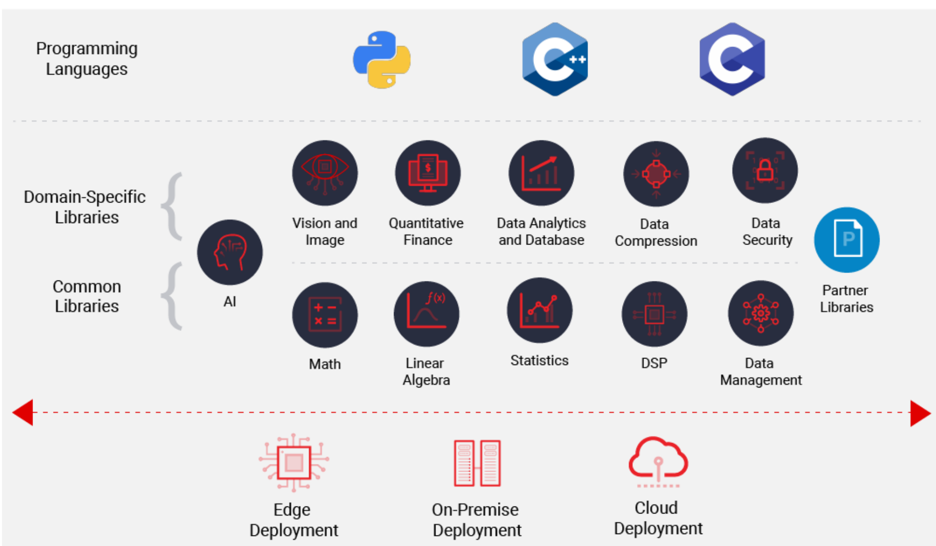

Figure 3: https://www.xilinx.com/products/design-tools/vitis/vitis-platform.html

Sample Project Description:
Compact Magnetic Sensor (CMS) Project

1. Project Title: Low-cost Compact Magnetic Sensor System for Detecting Space Weather Magnetic Signals

2. Contact Info: Email@company.com Phone: (XXX.XXX.XXXX)

3. Introduction to Space Weather magnetic effects

The Earth's magnetic field is generated by a geodynamo in the Earth's core. The magnetic field surrounds the planet and its effects stretch far into space forming the magnetosphere. Luckily for us (and all other life on Earth) this magnetic field serves as a buffer against solar wind particles that would otherwise strip away the atmosphere. The interaction between the magnetic field and the time varying solar wind cause complex time variations in the Earth's magnetic field. These time variations (e.g., Fig 1.) have amplitudes from 1's to 100's of nanotesla (nT) when measured at the Earth's surface (out of a nominal baseline value of 20,000 to 60,000 nT depending on location). The goal of this project is to create a very low-cost sensor capable of recording this magnetic variation.

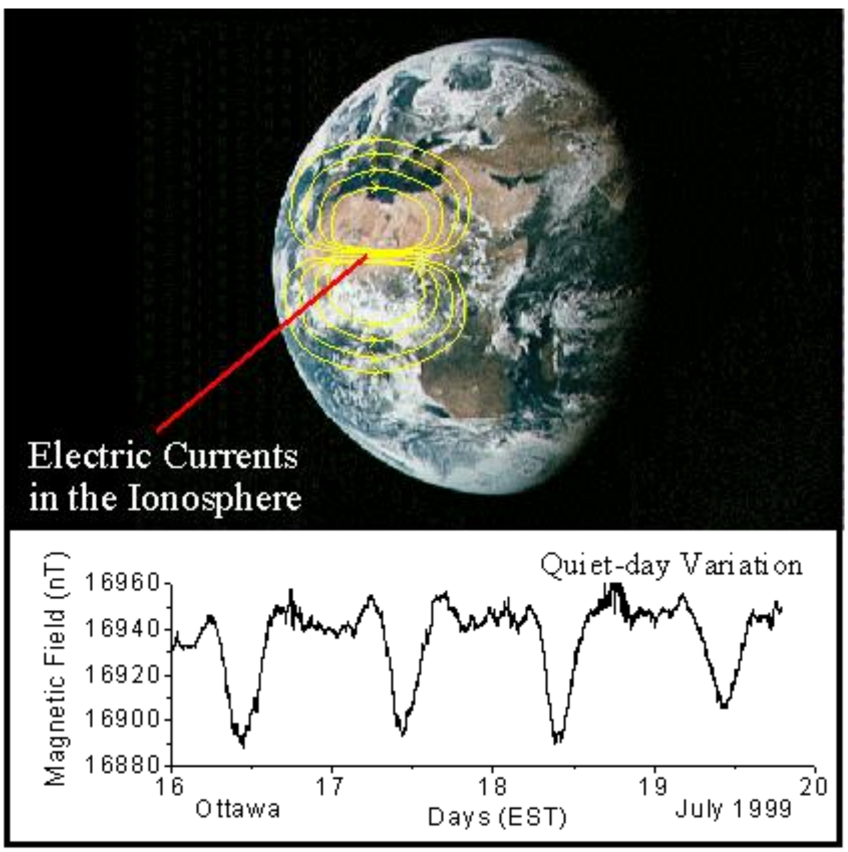

Fig. 1 - Example of magnetic variations due to space weather effects (http://www.spaceweather.gc.ca/svr-en.php) .

Global models of the Earth's magnetic field are critical to digital navigation. Advanced navigation requires models of the time variations caused by the solar wind. Construction of these models requires measurements of these effects at the Earth's surface. Science quality data are only available from a widely spaced network of formal observatories. These formal observatories are extremely expensive to build, maintain, and operate. The ability to collect useful space weather magnetic variations on a much wider spatial scale will be a real game-changer in the understanding and ability to predict magnetic variation.

4. Project Background and Objective:

Science quality magnetic data are collected with low-noise sensors in relatively noise free environments. Following this protocol, an accuracy of about 1 nT is routinely achieved. The purpose of this project is to explore the possibility of creating a low cost (under $300) magnetic sensor system that is compact in form and can measure space weather magnetic signals with amplitudes of 10 nT or better. The system is intended to occupy a fixed location and monitor the time variation (on a minute by minute frequency) of the vector magnetic field at that location. The fixed location will typically be in a magnetically quiet environment that may not include access to power. Thus, the system must have the capability of running in battery mode for a minimum of a week.

A previous capstone project (Crowdmag External Sensor - CES) explored the use of Fluxgate sensor technology for an inexpensive sensor system. The CES project was successful and can serve as an excellent reference for the current project. Several of the CES project members will be available as consultants for the current project. The use of Fluxgate sensor technology assures excellent accuracy, but unfortunately limits the ability to achieve the low-cost goal (i.e., the sensor alone costs over $600). The current project will focus on building a solution using multiple, lower cost sensors. For example, the MEMS technology[1]used in cell phones should be considered. However, other low-cost sensors should be considered as well.

Item	Stationary mode
System resolution	1 nT
Accuracy	10 nT (vector)
Sampling	1 minute
Timing accuracy	5 sec/mo

Table 1. Specifications for the sensor system.

[1] "MEMS magnetic field sensor - Wikipedia." https://en.wikipedia.org/wiki/MEMS_magnetic_field_sensor. Accessed 11 Apr. 2017.

An example of a possible low-cost space weather sensor system would involve three 3-component MEMS magnetic field sensors which could be interrogated and then processed to produce 3 component magnetic field values. For example, a DA14580 microprocessor (or other similar microprocessor) with Bluetooth could process the sensor inputs and send the data periodically via Bluetooth to a phone while consuming power as little as 11mW (e.g. Philips, 2014). The MEMS magnetic sensor should be kept in a "magnetically clean" location in the PCB board. A non-volatile memory chip could be used to store the data locally. The whole system could be powered by rechargeable battery or alternately by a mini USB connection (5 V). A simple LED interface should indicate the main functions of the CMS such as recording, charging, low-battery and data-transfer. The magnetic sensors and the electronics board could be mounted on a 3D printed platform and case with a weatherproof seal. The sensor system could be buried in the ground (for thermal stability), and the phone could either be kept always near the sensor (for real-time data) or be connected periodically. A smartphone app would need to be created to interface with the compact magnetic sensor (via Bluetooth), and to download and display the sensor data.

Here is a link to a similar product that we know about:

http://www.twinleaf.com/vector/VMR/index.html

5. Project Requirements:

A. Output: time-stamped, three component (x, y, z) magnetic field values
B. Onboard storage: ability to store values for later download
C. Onboard control: ability to access and modify onboard device control
D. Thermal sensor/stability: ability to maintain operating temperature and/or to track and report operating temperature
E. Communication: ability to communicate with a Bluetooth device (such as a phone) for data download and device control
F. Cost: low cost for parts and assembly (<$300)
G. Size: compact (water bottle size or smaller)
H. Rugged: reasonable water/weather resistance

6. Deliverables:

A. Working device
B. Documentation of device components and assembly procedure
C. Instruction manual for device
D. Report on known shortcomings with the device and suggestions for future improvements

7. Skill Requirements:

A. Need to design overall device (electronics and control)
B. Ability to evaluate component specifications (especially magnetic sensors)
C. Manage analog to digital conversion of sensor signal
D. Design and create Interface with smartphone
E. Onboard data storage and control
F. Temperature sensitivity strategy and calibration plan

8. Why you should choose this project:

To quote (approximately) from Obi-Wan Kenobi: “there is an unseen force that surrounds us, can guide us, and protect us” - this can be said of the magnetic field of the Earth (MFE). It surrounds us - the MFE is present everywhere within the Earth, on the surface, and above the Earth to the outer edge of the magnetosphere (see figure). It can guide us - we can map the MFE and then use a compass to orient ourselves relative to the local field direction. It protects us - the MFE deflects harmful radiation from the solar wind and prevents our atmosphere from destruction (just look what happened to Mars…).

By accepting the challenge of this project, you will directly contribute to better mapping and understanding of this fundamental component of the Earth environment. In detail the MFE is very complex (both due to natural and man-made magnetic objects and disturbances). Also, the MFE is dynamic as it reacts daily to complex currents operating within the magnetosphere. A new, low-cost external magnetic sensor will expand the ability of citizen scientists to investigate the MFE both to satisfy their own curiosity but also to assist sponsor scientists with global modeling and understanding.

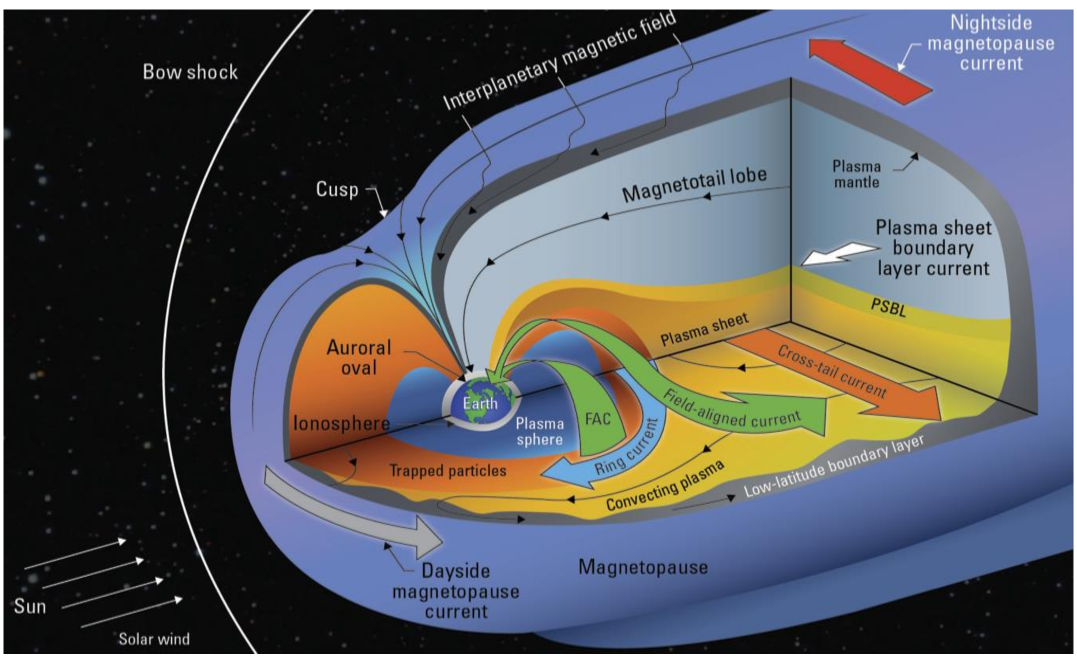

Figure 2. Illustration (sketch) of the Magnetosphere - the portion of space affected by interaction with the Earth’s internally generated magnetic field.