Company Information

Company Name	*Caterpillar Corporation*	Date Submitted	*10/13/23*
Project Title	*Design and Build of an IMU Test Apparatus (CAT_IMU)*	Planned Starting Semester	*Spring 2024*

Senior Design Project Description

Personnel

Typical teams will have 4-6 students, with engineering disciplines assigned based on the anticipated Scope of the Project.

Please provide your estimate of staffing in the below table. The Senior Design Committee will adjust as appropriate based on scope and discipline skills.

Discipline	Number	Discipline	Number
Mechanical	2	Electrical	2
Computer	2	Systems	

Company and Project Overview:

Caterpillar is the world's leading manufacturer of construction and mining equipment, diesel and natural gas engines, industrial gas turbines and diesel-electric locomotives. We are a leader and proudly have the largest global presence in the industries we serve. For more than 90 years, Caterpillar Inc. has been making sustainable progress possible and driving positive change on every continent. Customers turn to Caterpillar to help them develop infrastructure, energy and natural resource assets.

This project will be with the Clayton (NC) Machine Development Center (CMDC), where more than 200 engineers, prototype technicians and expert operators work to design, build and test machines in one location. The CMDC has dedicated 150 acres for machine development and features a half-mile, high-speed machine track, 10 test and demonstration areas and seven machine operation areas to prove machine reliability and durability. The Clayton facility manufactures small wheel loaders and serves as a product distribution center for backhoe loaders. This project will be associated with inertial measurement units that are used on Caterpillar products.

Project Requirements:

Caterpillar Inertial Measurement Sensors (IMUs) are used to measure and provide information about an object's orientation, acceleration, and angular velocity. By integrating data from accelerometers, gyroscopes, and sometimes magnetometers, IMUs enable the precise tracking of an object's movement and position in three-dimensional space. This information is for applications that require accurate motion sensing, such as navigation systems and virtual reality. IMUs are used to provide real-time feedback and control, allowing for dynamic and responsive operation in various fields.

The IMU is measuring 6 degrees of freedom. They measure accelerations and velocities on 3 axes and then calculate angles from those measurements. The IMU's output is distributed using an SAE J1939 Controller Area Network (CAN) serial data communications protocol in three specific messages (angles, accelerations, and velocities). These messages are communicated across the CAN bus at 100 Hz (or one message every 10ms).
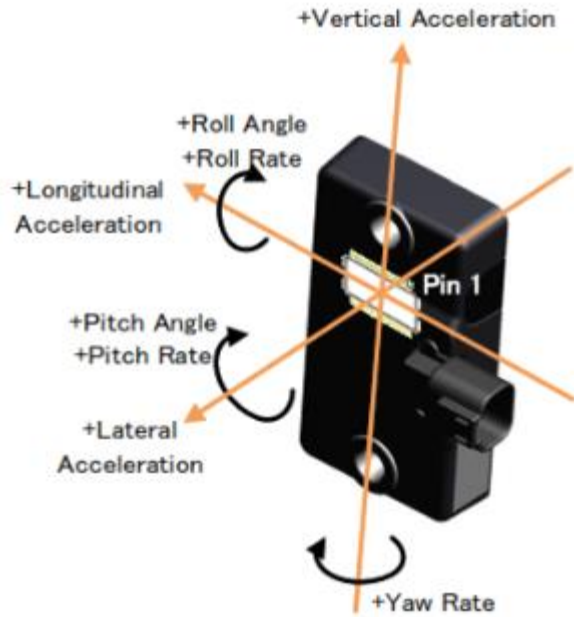
The objective of this project is to design and build a test fixture to measure the performance of IMU's. The test fixture will be required to accommodate the following 3 IMU's:

The test fixture will need to compare IMU sensor outputs to known angles, velocities and accelerations that must be measured by the test apparatus in comparable timeframes. The student team will create a mechanism to mount, power, orient, and collect the sensor and truth (the actual known values) data. The apparatus must be capable of accurately orienting in three dimensions (roll, pitch and yaw) and translating in one axis. The roll and pitch axes must be able to rotate +/- 180deg and the yaw axis must be capable of continuous 360deg rotations. The yaw, pitch and roll functions should be able to operate up to 10rpm. The translation of the test apparatus must be at least 1 meter and be able to reach a max-speed of 1m/s. The yaw axis should be mounted to the ground and the yaw mechanism needs to be mounted to the translation function; the roll and pitch should be mounted in any order onto the translation function. To say this another way, the mechanism should be constructed from ground to yaw to translation to pitch/roll. The mechanism needs to be sturdy and have smooth motion. We can discuss this in more engineering terms (defining smooth motion) during the project, but the IMU sensors cannot measure anything above 6 G's. If any of these requirements drive the system to be too costly or difficult, we can compromise during the project on either cost or specifications. Ultimately the data from the apparatus (the truth data) must then be overplotted with the IMU sensor data for various motions to then compare the results from all the sensors.

Expected Deliverables/Results:

- Test apparatus that performs the above functions.
- User interface that allows entry of the sensor being tested information and test conditions.
  - For example, define the angles or velocities for each axis to move and in what order and then being able to name the test file.
- Apparatus to provide accurate data measurements for acceleration, velocity, and angles (ranges agreed with Caterpillar).
- System to output a data file that can be easily plotted to compare an accurate/repeatable measurement of the sensor motion and compare that to the sensor's output.
  - Data cannot be ported out to any external (or internet sites) locations. It must remain local to the computer that interfaces with the test apparatus.

Disposition of Deliverables at the End of the Project:

Students are graded based on their display and presentation of their team's work product. It is mandatory that they exhibit at the Expo, so if the work product was tested at the supporter's location, it must be returned to campus for the Expo. After the expo, the team and supporter should arrange the handover of the work product to the industry supporter. This handover must be concluded within 7 days of the Expo.

List here any specific skills, requirements, specific courses, knowledge needed or suggested (If

none please state none):

- Cad modeling and mechanism design
- Precision metrology
- Computer programming and serial communication
- CAN networking
- Data acquisition systems
- Data management
- Graphical User Interface
- Control system development to command and deliver the desired motions.
- May need to travel to Clayton, NC site.