Department of Computer Science & Engineering
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Architectural Design Specification
CSE 4316: Senior Design I
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IGVC
Autonomous Ground Vehicle

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1 INTRODUCTION

For this course, our goal is to design a Intelligent Ground Vehicle (IGVC) that will be able to autonomously navigate through a preset obstacle course by collecting and learning from data that it collects from its environment via the vehicles LiDAR, GPS and cameras. For the project we have been tasked by our sponsor to not only to build the modular body of the vehicle but also the path planning aspect using deep-learning and machine-learning algorithms.

2 System Overview

This section should describe the overall structure of your software system. Think of it as the strategy for how you will build the system. An architectural "layer" is the top-level logical view, or an abstraction, of your design. Layers should be composed of related elements of similar capabilities, and should be highly independent of other layers, but should have very clearly defined interfaces and interactions with other layers. Each layer should be identified individually and should be unique as to its function and purpose within the system. This section should also contain the high-level block diagram of the layers, as shown in the example below, as well as detailed descriptions of the functions of each layer.

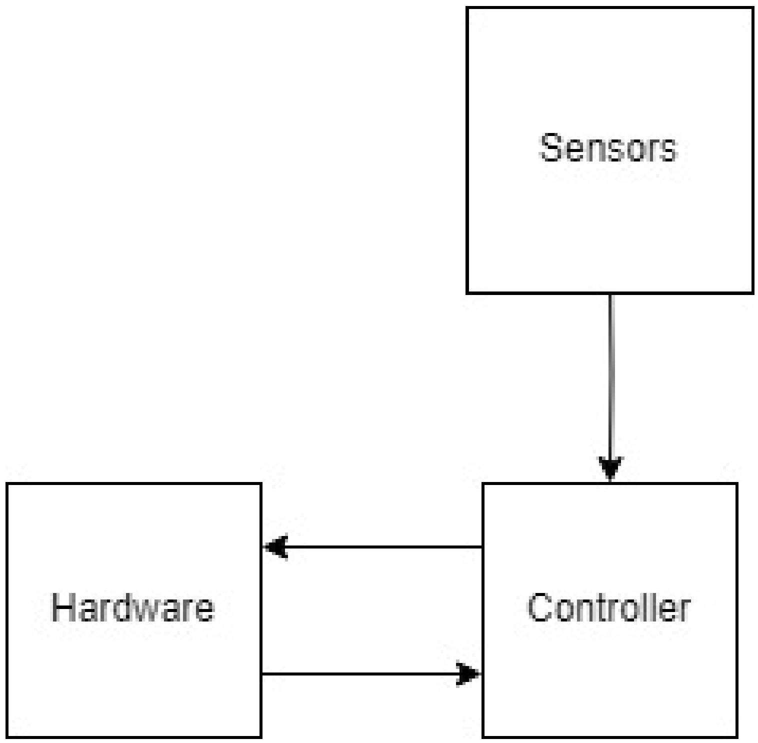

Figure 1: A simple architectural layer diagram

2.1 Sensors Layer Description

This layer holds the vehicle's sensors. These sensors gather information from the environment and then send that information to the controller layer for processing. The camera gathers images of the environment to detect obstacles via object recognition. The LiDAR creates a map of the environment that we can crosscheck with the camera's data to understand where every object is in relation to the vehicle. The GPS gives us the exact location of the vehicle and that location is sent to the controller layer for path planning.

2.2 Controller Layer Description

This layer provides the vehicle with its navigation plan for its course. To make it possible for the vehicle to navigate using deep learning and AI for a given path, a companion computer will be used. A cube orange will be used for the microcontrollers of the vehicle.

2.3 HARDWARE LAYER DESCRIPTION

This layer will be the bridge of executing the demanded control signals from the software functional on the hardware along with doing a gate-keeping job of being responsible for all low-level or close-to-abstraction level operations such as powering, circuit current regulations, motors, safety standards and allowing faster computing resources available to the primary computer for its own designated operations.

3 Subsystem Definitions & Data Flow

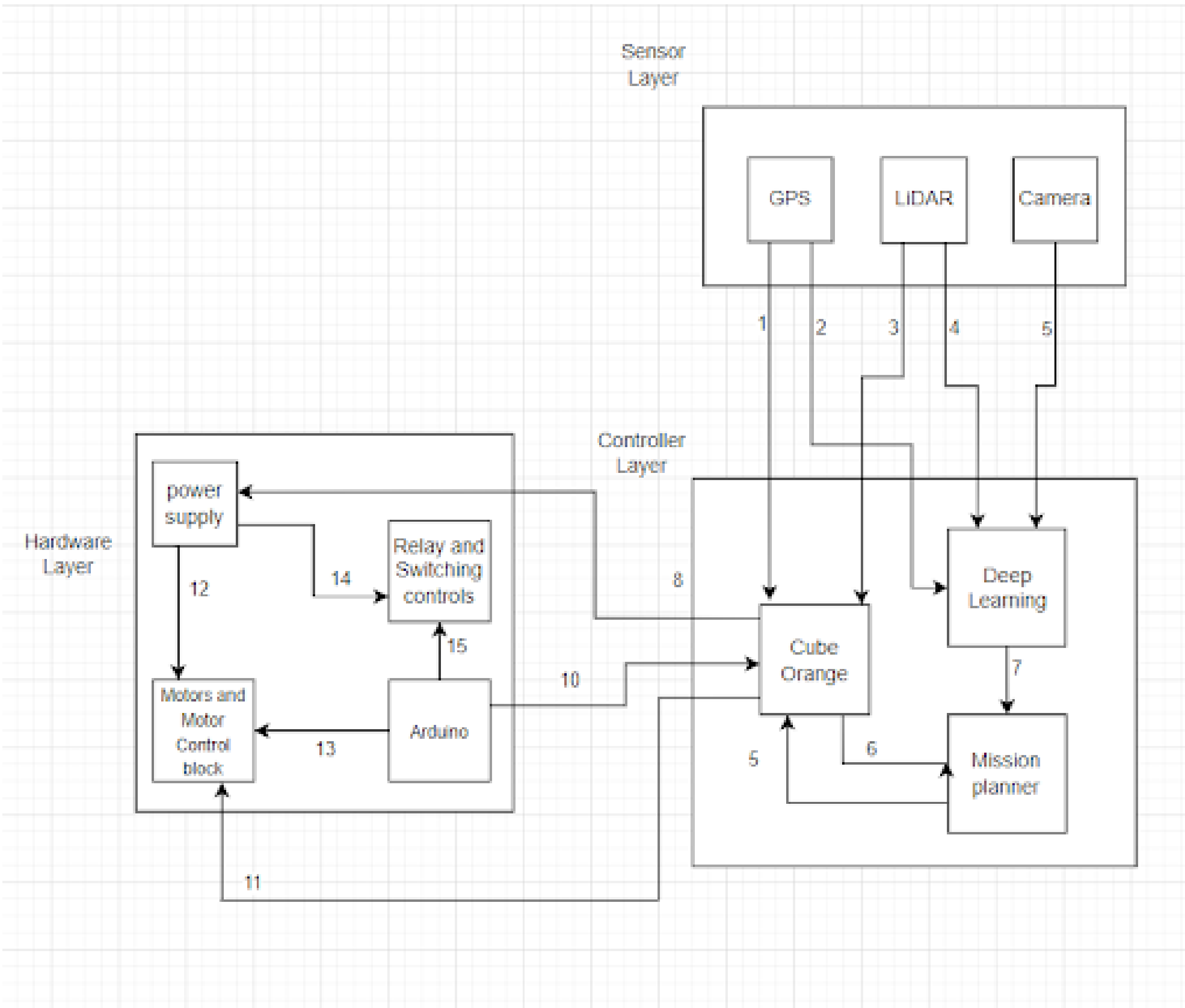

Figure 2: A simple data flow diagram

4 Sensor Layer Subsystems

In the sensor layer we have the systems that will gather information from the environment. This information will be passed to the vehicles controllers as they perform the AI and deep learning computations.

4.1 GPS

The GPS subsystem will be responsible of obtain real-time coordinates of our vehicle. It will communicate with the cube orange and the companion computer for position control and AI calculations respectively.

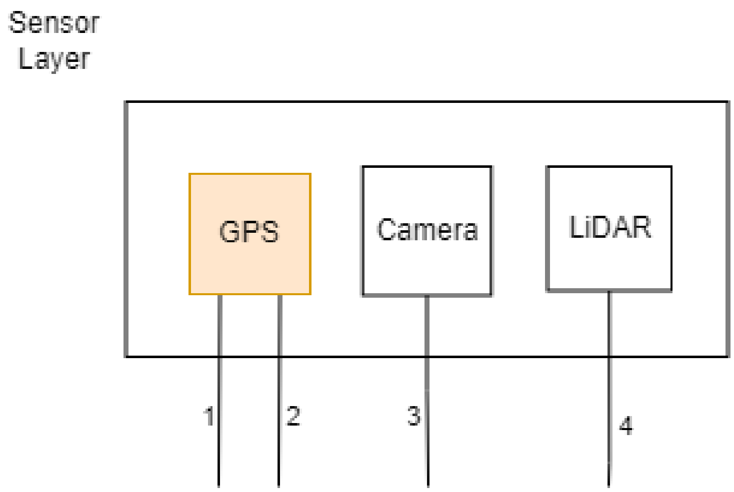

Figure 3: Example subsystem description diagram

4.1.1 Assumptions

We assume that the GPS will be precisely calibrated so that the current coordinates stay within reasonable expectations.

4.1.2 Responsibilities

The GPS is responsible of obtaining the vehicle's precise location and sending that location to the cube orange. The cube orange will then send this coordinators to the mission planner so that it can update the vehicles current position in relation to the mission's way-points. It will also send the coordinates to the companion computer for storage. This is for the purpose of testing and evaluation after different trials.

4.1.3 Subsystem Interfaces

Table 1: Subsystem interfaces for the GPS

ID	Description	Inputs	Outputs
#1	Connection to the Cube Orange	N/A	GPS Coordinates
#2	Connection to the companion computer	N/A	GPS Coordinates

4.2 Camera

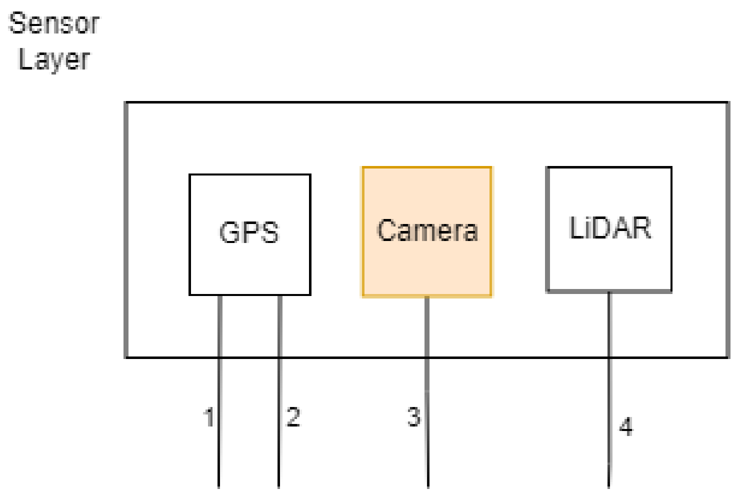

Figure 4: Camera diagram

4.2.1 Assumptions

We assume that the Camera will be calibrated to the center of the vehicle. We also assume that the camera will be able to perform it's task outdoors.

4.2.2 Responsibilities

This system is responsible of taking images of the environment in front of our vehicles path and then sending this image to the companion computer as an input for object recognition system.

4.2.3 Subsystem Interfaces

Each of the inputs and outputs for the subsystem are defined here. Create a table with an entry for each labelled interface that connects to this subsystem. For each entry, describe any incoming and outgoing data elements will pass through this interface.

Table 2: Subsystem interfaces for Camera

ID	Description	Inputs	Outputs
#3	Connection to the companion computer	N/A	Data(Image)

4.3 LiDAR

4.3.1 Assumptions

We assume that the day of the competition the weather will be clear. The rain's water drops can absorb, scatter, or reflect the light from the LiDAR, giving false readings.

4.3.2 Responsibilities

The LiDAR is responsible for creating a map of the vehicle's surrounding so that the vehicle can can detect where a possible obstacle is in relation to the vehicle itself.

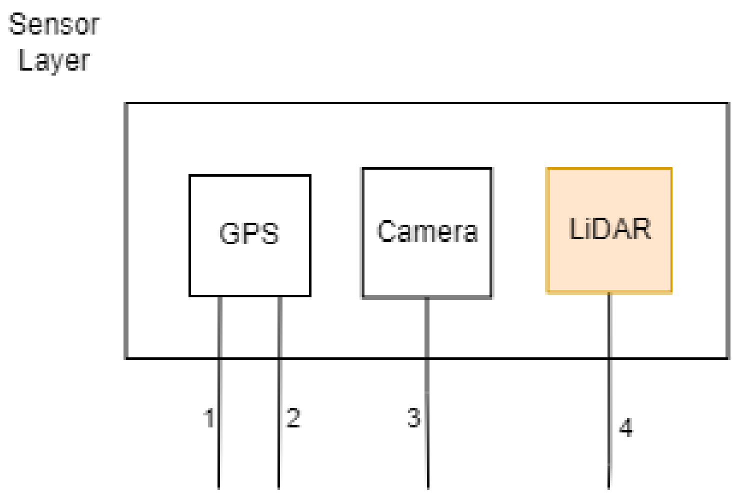

Figure 5: Example subsystem description diagram

4.3.3 SUBSYSTEM INTERFACES

Table 3: Subsystem interfaces for LiDAR

ID	Description	Inputs	Outputs
#4	Connection to the companion computer	N/A	Data(Point Cloud)

5 Controller Layer Subsystems

The control layer will be responsible for the movement of the vehicle. For this vehicle, the controls will come from the deep-learning and AI aspects that will be implemented in the software in order to train the vehicle. Three of the components connected to the companion computer (The camera, LiDAR and GPS) can all be found in the sensor layer which will help with the autonomous navigation of the vehicle.

5.1 Companion Computer

This computer will be used for the computation of the vehicle needs to navigate through the obstacle course (deep-learning and AI components) with the help of the Cube orange.

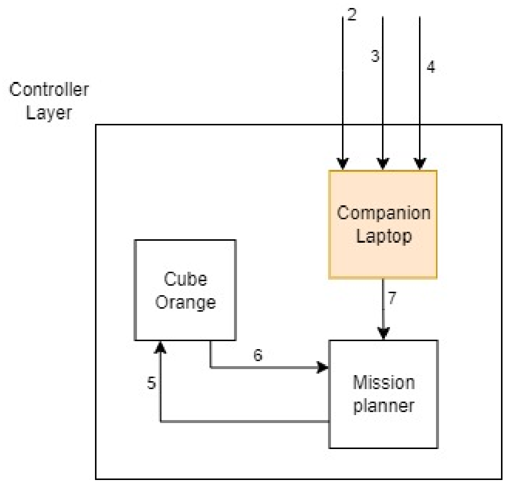

Figure 6: Companion Computer Diagram

5.1.1 Assumptions

The computation computer will be able to collect the data that is needed for learning from the cameras and the lidar and produce proper outcomes.

5.1.2 Responsibilities

This computer will be used for on-site path planning for the vehicle as it navigates a course.

5.1.3 Subsystem Interfaces

Receives data from the GPS,cameras and lidar and send the data to the mission planner

Table 4: Subsystem interfaces for companion laptop

ID	Description	Inputs	Outputs
#2	Connection from the GPS to the companion computer	Data	N/A
#3	Connection from the camera to the companion computer	Data	N/A
#4	Connection from the LiDAR to the companion computer	Data	N/A
#7	Connection from the companion computer to the mission planner	N/A	Controls

5.2 Mission Planner

This will be the raspberry pi which will handle ROS. Allowing the companion laptop to send commands to the robot to perform.

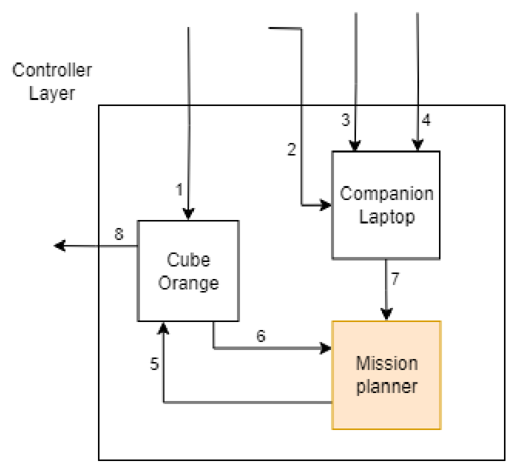

Figure 7: Mission Planner Diagram

5.2.1 Assumptions

This computer will abstract robot controls making it easier for the companion laptop to interface with.

5.2.2 Responsibilities

This computer will be used for translating and executing commands sent out by the companion laptop.

5.2.3 Subsystem Interfaces

Receives instructions from the companion robot and converts them for use by the cube orange.

Table 5: Subsystem interfaces for mission planner

ID	Description	Inputs	Outputs
#5	Connection from the Mission Planner to the Cube Orange	N/A	Data
#6	Connection from the Cube Orange to the Mission Planner	Data	N/A
#7	Connection from the Companion Computer to the Mission Planner	Data	N/A

5.3 Cube Orange

This will give us information on motors, battery, gps, and other parts of the robot.

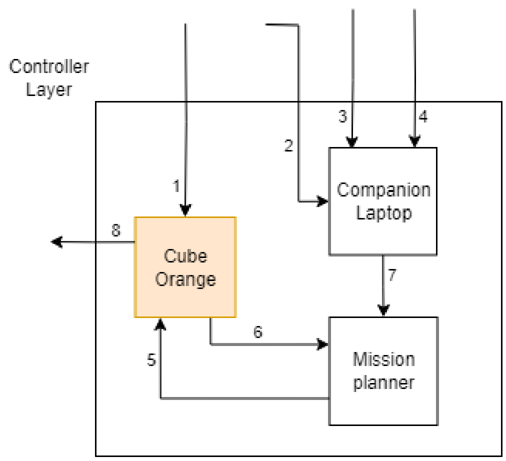

Figure 8: Cube Orange Diagram

5.3.1 Assumptions

The cube orange will give us information such as motor position and speed, the gps location of the robot, and the battery capacity that it has.

5.3.2 Responsibilities

It will be responsible for sending information to and executing commands sent by the mission planner.

5.3.3 Subsystem Interfaces for Cube Orange

Receives instructions from the mission planner and converts them to actionable results.

Table 6: Subsystem interfaces for Cube Orange

ID	Description	Inputs	Outputs
#5	Connection from the Mission Planner to the Cube Orange	Data	N/A
#6	Connection from the Cube Orange to the Mission Planner	N/A	Data

6 Hardware Layer Subsystems

In this section, the hardware layer is described with its division in the architecture as shown in Figure 9 where a general outline is presented of all the functioning layers in the vehicle starting from how the software issues commands to how they are directed to the specific hardware components Table 7 below expands more detail about the connections numbered in figure 9. The highlighted components will be elaborated further in this section.

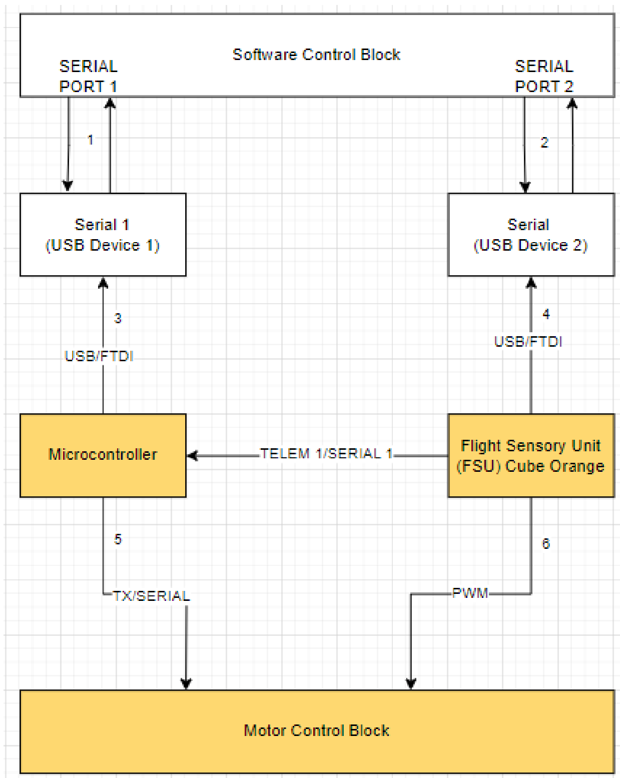

Figure 9: A simple architectural layer diagram of the hardware controls of the Vehicle

Table 7: Subsystem interfaces of Hardware Abstraction

ID	Description	Inputs	Outputs
#1	Serial Connection (Primary computer to Micro-controller)	Data	Data
#2	Serial Connection (Primary Computer to FSU (Flight Sensory Unit))	Data	Data
#3	Serial Interface of Micro-Controller	Controls	Data
#4	Serial Interface of FSU (Cube Orange)	Controls	Data
#5	Uni-Directional Serial interface to Motor Control Unit	Controls	N/A
#6	PWM Controls from FSU to Motor Control Unit	Controls	N/A

6.1 Motor Control Block

This section details the motor control block which is the front line of execution of any control commands issued by the system. There are priorities of commands sent to the MCB (Motor Control Block) since one command may be more urgent than the other. The priorities of the two commands sent to the MCB are FSU Control (Low Priority) and Micro-Controller Commands (High Priority). This is shown in Figure 10 and elaborated in Table 8 about the signals it comprises of. It is to note that the priority signals as shown in the figure are mixed between Hardware and software layers and have been established for coherence

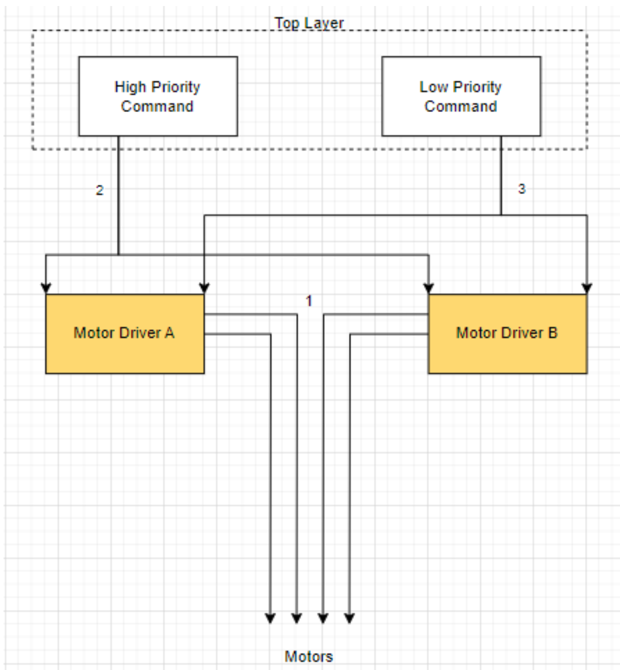

Figure 10: Motor Control Block of the Vehicle

6.1.1 Assumptions

It is assumed that there is synchronous and uninterrupted communication between the Microcontroller and the Flight Sensory Unit to determine what priority of command needs to be executed.

6.1.2 Responsibilities

The responsibility of this block is to ensure that upon later implementation there will be coherence for manned (manual) and unmanned (autonomous) missions and the same motor logic will be used without making any changes to the hardware

6.1.3 Subsystem Interfaces

The motor driver receives both types of commands and executes them concerning their priority. Within the system, the subsystem interfaces play a crucial role as they receive precise PWM signals, enabling effective control over various components. To ensure smooth functionality, the subsystem draws power from the batteries, providing the necessary energy for operation. Once powered, it efficiently delivers the required DC voltage to activate and regulate the motors' performance, contributing to the overall system's seamless operation

Table 8: Subsystem interfaces of Motor Control block

ID	Description	Inputs	Outputs
#1	Electrical Connections to Motors of the Vehicle	N/A	Current
#2	SPI/Serial Bus protocol for Motor control on High-priority	N/A	Controls
#3	PWM Signals from the FSU (Cube Orange) on Low-priority	N/A	Controls

6.2 Flight Sensory Unit

This section details the Flight Sensory unit which though has been called Cube Orange in many parts of this document, comprises a wide range of sensors and connections to execute manned operations and or guided modes. Figure 11 shows a block diagram of the logical units inside the FSU.

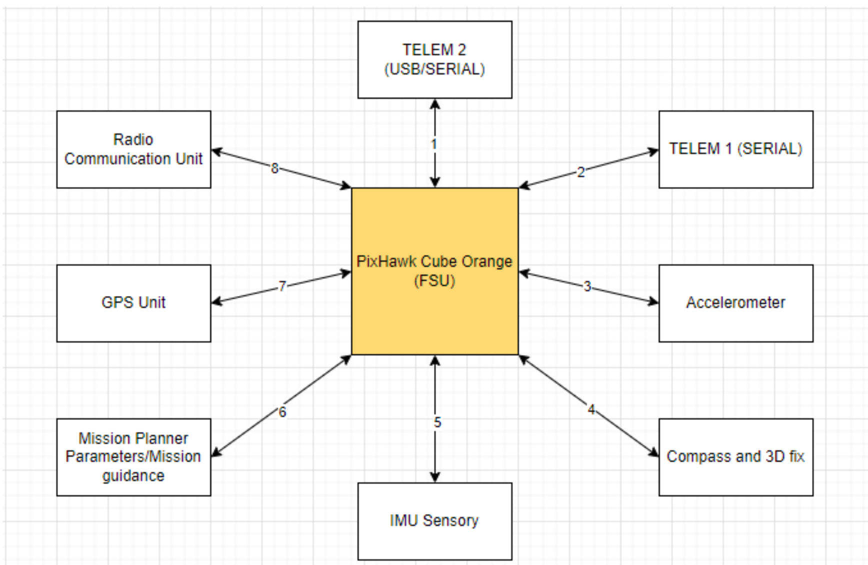

Figure 11: Flight Control Unit (FSU) Sensory

6.2.1 Assumptions

It is assumed that there is synchronous and uninterrupted communication between the components and sensors to and from the FSU (Cube Orange)

6.2.2 Responsibilities

The responsibility of this block is to regulate that there is adequate information for guided or unguided missions and help autonomous controls.

6.2.3 Subsystem Interfaces

The following are the system interfaces in the FSU unit.

Table 9: Subsystem interfaces of Motor Control block

ID	Description	Inputs	Outputs
#1	Serial Communication to Microprocessor	data	Controls
#2	Serial Communication to Primary Computer	data	Controls
#3	Data from Sensor	feedback	data
#4	Data from Sensor	feedback	data
#5	Data from Sensor	feedback	data
#6	Data from Sensor	feedback	data
#7	Data from Sensor	feedback	data
#8	Data from Sensor	feedback	data

References