Professional Issues for Engineers 4

Systems Engineering Assignment 1: Functional Breakdown and System Interfaces

Quadcopter Drone

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(a) Make a list of the functional blocks of a quadcopter drone.

The functional blocks of a quadcopter drone, broken down into subdivisions are as follows:

- **Central Flight Controller (Microcontroller)**, example: the ATMel ATMega2560 @16MHz [1].
- **Hardware Abstraction Layer (HAL) Sensors:**
  - Inertial Measurement Unit (IMU) with Accelerometer and Gyroscope.
  - Ultrasound Altitude Sensor.
  - Temperature Sensor.
  - Pressure Sensor (Barometer).
  - Compass/ Magnetometer.
  - Distance Sensors - to be used for anti-collision systems.
    - LIDAR (Light Detection and Ranging).
    - Ultrasonic (Sonar).
    - Infrared.
  - GPS (Global Positioning System) - allows for location of the drone at any time, assists with navigation.
- **Onboard Communication Protocols:**
  - Bluetooth - send commands/ data.
  - Radio Control (RC) Transceiver - Two way transmitter/receiver allows manual control of drone.
  - WiFi - send commands and delivery instructions, upload firmware.
  - Radio Frequency (RF) Transceiver - allows sending of data to the drone from a computer or microcontroller using a two way transmitter/ receiver.
  - Video Transmitter - used to send live feed of camera data.
- **Drone Propulsion System:**
  - 4x Electronic Speed Controllers (ESCs) - allows control of speed and direction of the motors from the flight controller.
  - 4x Brushless DC Motors.
  - 4x Motor Mounts.
  - 4x Propellers.
    - 2x Standard Propellers.
    - 2x Pusher Propellers - placed on back of drone to push drone forward [2].
  - 4x Propeller Savers - prevents propeller from rotating in the event of a crash reducing damage to the propeller.
  - 4x Propeller Guards - provide a fixed ring or cushion around the propeller, if the drone collides with an object the guards are contacted first preventing damage to the propeller.
- Drone Status LEDs - can be used to indicate battery life, power status, charging state, whether data is being transferred, etc.
- 4K Camera (60FPS) - allows for real time visual data from the drone, assists with navigation.
- SD Card - visual data from the camera can be stored onto the SD card.
- Landing Gear.
- Payload Mechanism (Grabber/ Claw) - will be used to pick up and release packages.

- **Power Supply:**
  - Voltmeter - allows measuring of battery status.
  - Power Switch - turns drone on and off.
  - Battery.
  - Access Port (USB-C) - can be used for charging and also to connect to computers (PC, Laptop, Tablet) in order to upload new firmware to the drone.
- Software - this includes the drone's firmware but also the delivery instructions and routes that will be uploaded to the drone.

(b) Draw a Block Diagram Showing the Inter-connection of These Blocks.

The functional block diagram showing the inter-connection of blocks making up the Quadcopter Drone can be seen in Figure 1.

(c) List the External Interfaces for the Drone and its Environment.

The Quadcopter Drone is required to interface with many external objects and devices in the outside world. These include:

- Exterior Obstacles (Buildings, Trees, Birds, Cars, People) - Since the drone's main use case is as a delivery vehicle, it will be operating in urban areas to deliver payloads to customers. Onboard distance sensors such as LIDAR and ultrasonic sensors can be used to avoid these objects.
- Weather Conditions (Temperature, Wind) - Onboard sensors will allow the drone to assess external temperature, pressure and wind conditions. This will allow the drone to assess when it is safe to fly and potentially gather data for meteorologists [3].
- Satellites (GPS) - Communicating with satellites allows the use of GPS to locate the drone at any time.
- Charging Cable - The drone interfaces with this to allow charging. It will be connected to a power socket and then plugged into the USB-C charging port.
- Air Traffic Control Towers - Locational and altitude data of the drone will be sent over RF communication protocols to nearby air traffic control towers to allow them to monitor drones in the airspace and prevent collisions with aeroplanes and helicopters.
- Other Unmanned Aerial Vehicles (UAVs) - The drone will have systems on board to monitor the position and altitude of other nearby delivery drones in order to prevent collisions autonomously.
- Packages/ Payload - The drone will interface with the packages using the payload mechanism (grabber), locating their exact position with distance sensors (LIDAR), picking them up, and dropping them off at the correct location to the customer.
- The Internet - The drone will need to interface with the internet using wireless communication protocols so it can receive live, up to date delivery routes as the company processes orders.
- Computers (PC, Smartphone, Tablet) - The drone will interface with these devices through the charging access port and over the wireless communication protocols. This will allow new firmware for the drone to be uploaded to the flight controller from the computer by developers at the company. The live camera feed can be viewed. Saved footage from the camera can be uploaded to computers by removing the SD card.

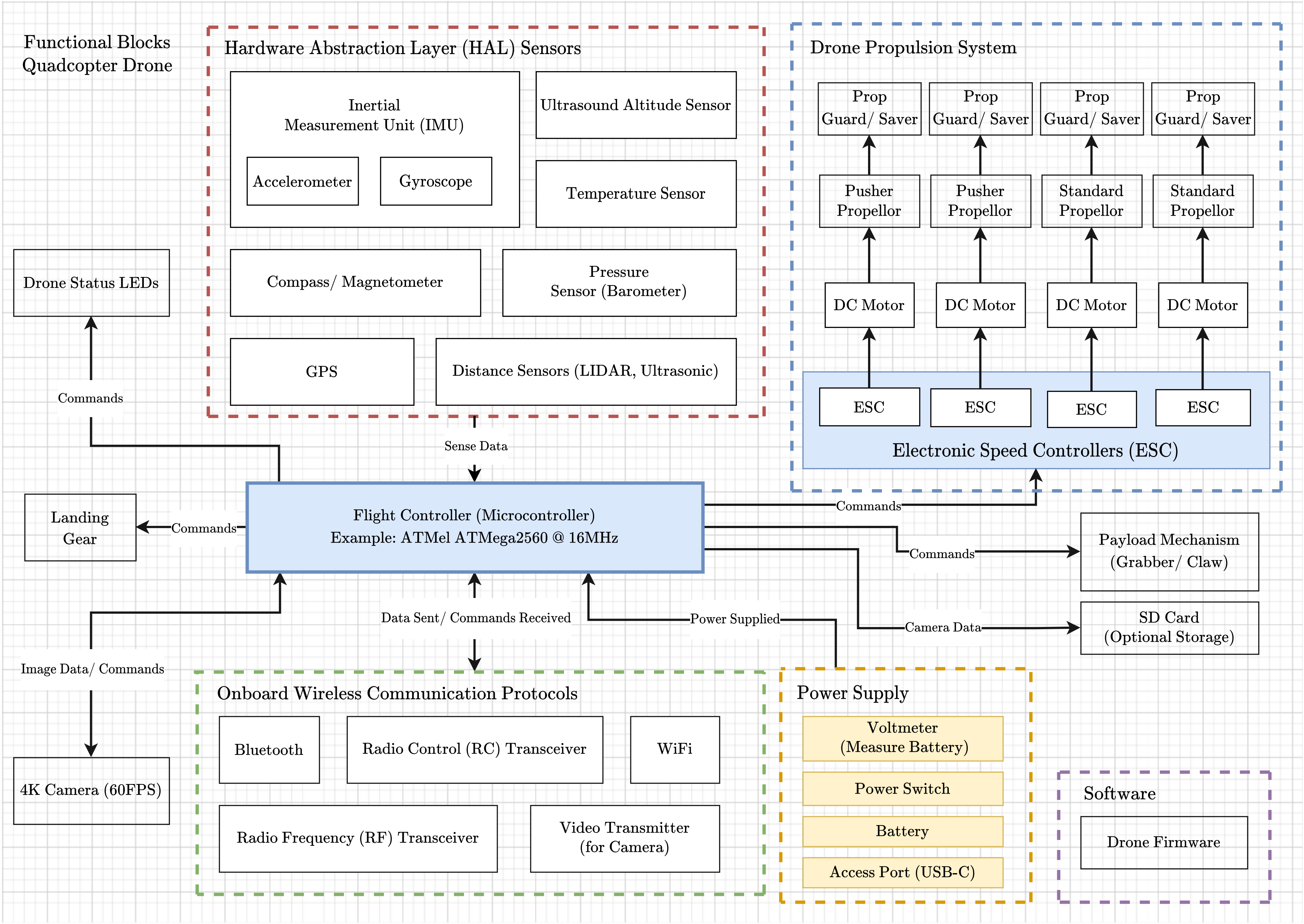

Figure 1: Functional Block Diagram showing inter-connections of blocks on Quadcopter Drone

(d) List the stakeholders (people or groups of people who have an interest or may be affected) in operation of a drone-based delivery system.

The Stakeholders who may be affected by the operation of a drone-based delivery system are:

- Investors in the private company developing the drones - will be concerned with profits of the company as well as avoiding controversy.
- Customers of the new drone-based delivery system - will want fast, cheap service.
- Companies that utilise the delivery drones to distribute their products to customers - will want to pay a low cost to deliver their products and reach as many customers as possible.
- Electronic and Software Engineers working at the company developing the drone - will be concerned with the complexity of the design of the drone and "specification creep".
- Government Aviation Authorities - will want to minimise collisions of UAVs with other aerial objects and ensure the drones abide by aviation standards and regulations.
- Delivery drivers currently working where the drones would be operational - will be concerned about losing their jobs.
- Health and safety departments - will want to minimise any danger of injury to the general public.
- Legal teams within the company - will be concerned with minimising risk of litigation arising from privacy breaches or health and safety issues.
- Other Government Bodies - will want to regulate how the delivery drones operate [4].
- Environmental advocacy groups - drones may use low amounts of power and may be a more environmentally friendly option than current delivery vehicles.
- Personal Privacy advocacy groups - will want to preserve personal privacy rights, prevent surveillance of customers and sale of data to third parties.
- Military/ National Security Organisations - will want to ensure drones do not pose a cybersecurity threat. They will require the drones have secure encryption of communications and data in order to prevent bad actors or criminal organisations from gaining access to the drones systems/ data.
- Non-customer members of the General Public (under the flight path of the drone).

(e) Take one example stakeholder and explain how their interests may affect the design of the system.

A key stakeholder whose interests may affect the design of the system is "customers of the drone-based delivery system". Firstly, customers will want the delivery to be fast and convenient. Typically drones can reach speeds of $15 - 65km/h$ [5]. The choice of motor and propellers for the design will be affected as they will be selected based on their maximum possible velocity. The body of the drone will be designed to minimise weight and the shape will be optimised for speed when flying. The desire for speed may also limit the maximum weight of the objects the drone can deliver. Drones can typically carry payloads of up to $5kg$ [5], but if we want to achieve maximum speed this may not be possible. A counterpoint to this is that for convenience purposes customers may want to have heavy goods delivered via drone. There will have to be a trade off in the design process between speed and maximum weight of the payload.

Secondly, drone-based delivery has the potential to reduce costs for the customer since almost half of current logistical costs are in the final mile of delivery [6]. Keeping costs low for consumers may incentivise using cheaper materials during the design process such as plastic and aluminium as opposed to carbon fibre or $G10$ (variation of fibreglass) [1]. This may negatively impact longevity as a side effect. Finally, some customers may also be concerned about the environment and so will want the drone to be designed with this in mind [5]. This may incentivise the company to try and reduce power consumption of the device during the design process to make the battery last longer.

A large percentage of potential customers also have concerns about drone-based technology. In one survey it was found that 44% of US based customers liked the concept of a drone-based delivery system, while 34% disliked it [5]. Therefore, the design of any drone-based delivery system will have to work to mitigate these concerns and improve public confidence.

One such concern is privacy. Customers do not want to lose control of their personal information to third parties. Delivery drones equipped with cameras pose a risk to privacy as they will be flying over private homes. This will influence the design of the drone in two ways. Firstly, from a technical/ design standpoint it will encourage higher levels of encryption and security built into the flight controller's communication protocols. This will prevent the interception of data by bad actors such as hacking groups or criminal organisations. Privacy concerns may also encourage restrictions on how the live camera feed can be accessed by developers at the company.

Secondly, it will encourage the company to put in place a robust and clear document outlining how it will manage personal data and will incentivise them not to sell data to third parties. It will also encourage companies to work with government data regulators to build public trust.

Another concern is public safety. Customers are aware of possible malfunctions that can occur and may be worried about their safety in the event of a drone crashing [5]. The company may want to hire a number of health and safety experts to review and approve the drone design. In terms of the technical design, it will incentivise development of robust anti-collision detection systems such as those on board DJI drones [7]. These use a combination of LIDAR, infrared and ultrasonic sensors. In the event of collision an emergency stop procedure may be developed to immediately stop the rotors from spinning and therefore prevent damage to cars, planes or other infrastructure and prevent injury to people. All these technical measures will improve public confidence.

Noise pollution caused by a large number of drones may also be of concern to some customers. This will affect the design. By increasing the diameter of the propellers and decreasing the rotational speed the noise of the drone can be reduced. This has already been tested on ATLAS-T stealth drones and resulted in significant noise level reductions of $10dBA$ [8].

(f) Draw a 'System of Systems' block diagram of a drone-based delivery system.

The 'System of Systems' block diagram of a drone-based delivery system is shown in Figure 2 below.

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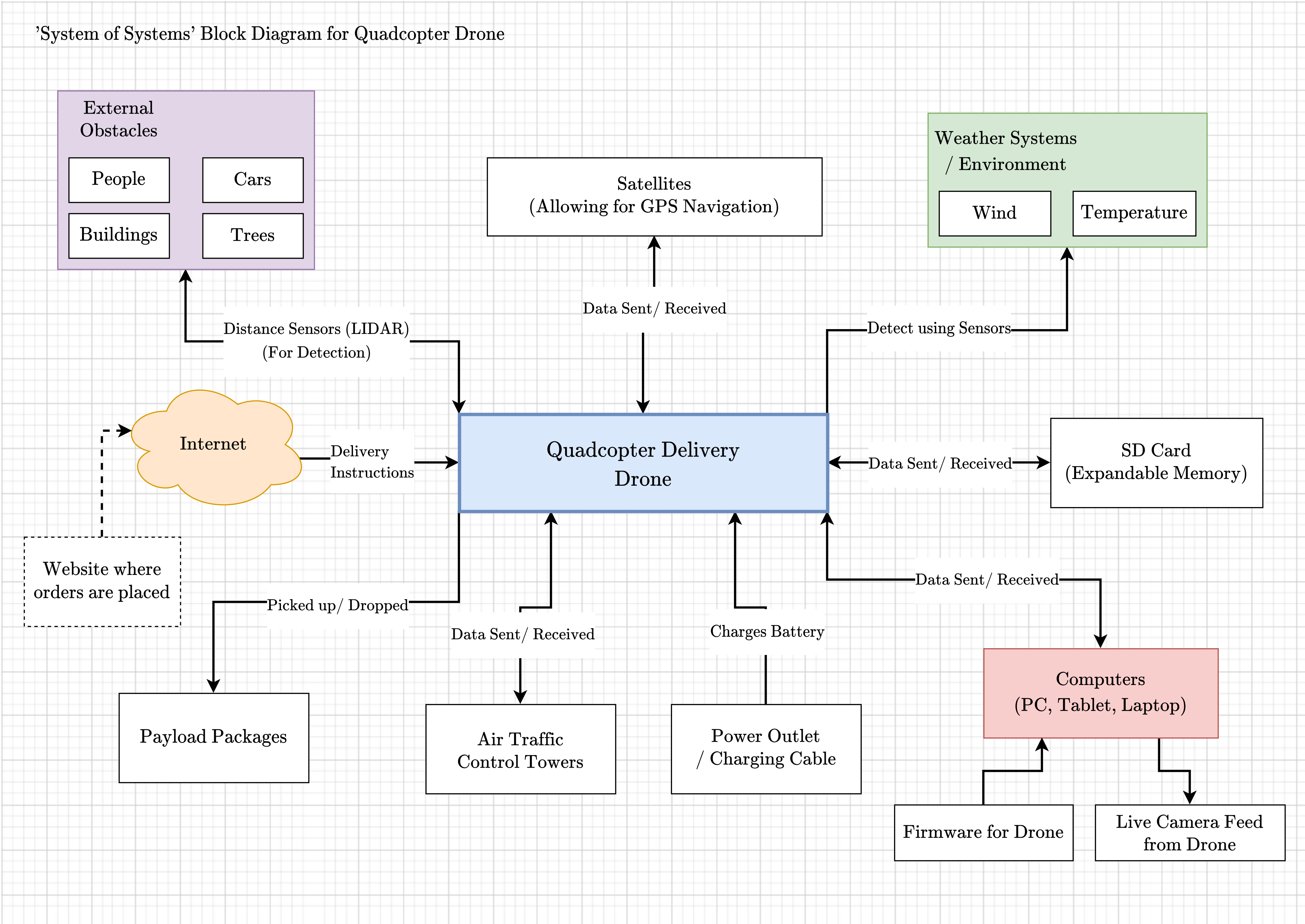

Figure 2: 'System of Systems' Block Diagram of a Drone-Based Delivery System