

**Communications Charter**

**Engineering Committee**

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# Introduction

It is the Aim of this Engineering Committee to define the RF Communications protocol for all Wireless Communications from Air to Air and Air to Ground Stations. The goal is quite simple “Keep the Number of bytes transmitted while sending the maximum amount of data.” In addition ground to Air communications must provide a few key commands to meet Safety Requirements. The first of these commands is the Shutdown. This will have two potential outcomes from the vehicle. First if the vehicle is on the ground it will cause an instant disarming of the Motors and cause it to stop turning. The Second outcomes are that if the vehicle is airborne it will cause the vehicle to begin its landing procedures. Additionally there is another safety feature that must be implemented. That is a one that cause the vehicle to stop all forward momentum going into hover mode and ascend or descend to the specified altitude. This feature is necessary where a shutdown command would cause the vehicle to land in a position that is not safe it is primarily intended to prevent the vehicle from continuing a flight path that would potentially cause it to fly into an obstacle.

## Air to Air Communications

The Purpose of Air to Air communications is to allow the vehicles to communicate telemetry data that would indicate a potential intersection of flight paths. These flight paths need to have a method to interact and alter each crafts flight path to prevent an air to air collision. Air to Air communication will contain a public and private set of transmission Packet types. Private Packets will be encrypted.

## Air to Ground Communications

Air to Ground Communications purpose is to provide both navigational aids and Home station programming. The term navigational aid refers to the ability to put in place transponders or message repeating systems to define restricted airspace. An example of this would be the need to define a location such as an Airport or Military base that flying over would be a FAA Violation. The term Home Station communications refers to the ability to send waypoints and other miscellaneous information to the vehicle.

# Hardware Systems

The RF communications will require the use of some form of transceiver the longer the range the better however speed is more important than range. Since all communications is Line of sight the recommended distance for transmission is 2 Miles. This gives the vehicles time to nogiate paths to be altered. For the Phase Alpha of the Project the plan is to use XBee-PRO 802.15.4 Modules. The XBee Series 1 Pro Modules operate at 2.4 Ghz with a Line of Sight range of 2 Miles. They also operate over serial and offer both point-to-point (PTP), point-to-multipoint (PTM) radio running the IEEE 802.15.4 protocol. Additionally the XBee Modules are pre certified by the FCC so the headache of using other modules over our own radio system is non existent since we would not need to work with the FCC to insure Radio compliance or even the need for a HAM radio license.

## IEEE standard 802.15.4

IEEE standard 802.15.4 intends to offer the fundamental lower network layers of a type of wireless personal area network (WPAN) which focuses on low-cost, low-speed ubiquitous communication between devices (in contrast with other, more end-user oriented approaches, such as Wi-Fi). The emphasis is on very low cost communication of nearby devices with little to no underlying infrastructure, intending to exploit this to lower power consumption even more.

The basic framework conceives a 10-meter communications range with a transfer rate of 250 kbit/s. Tradeoffs are possible to favor more radically embedded devices with even lower power requirements, through the definition of not one, but several physical layers. Lower transfer rates of 20 and 40 kbit/s were initially defined, with the 100 kbit/s rate being added in the current revision.

Even lower rates can be considered with the resulting effect on power consumption. As already mentioned, the main identifying feature of IEEE 802.15.4 among WPAN's is the importance of achieving extremely low manufacturing and operation costs and technological simplicity, without sacrificing flexibility or generality.

Important features include real-time suitability by reservation of guaranteed time slots, collision avoidance through CSMA/CA and integrated support for secure communications. Devices also include power management functions such as link quality and energy detection.

# Proposed Application Layer Communications Protocol

The following Pages define the Packet structure as well as the commands and sequences. As stated in the Introduction there are technically 4 modes of communications however they really breakdown to 2 modes. Private and Public. Since Telemetry is the Primary function of Air to Air many of it’s data packets can and are likely used by Air to Ground Stations as a form of Radar or even during Phase Alpha the Tracking of the Vehicle in Flight.

## Packet Structure

A good Application layer for Serial communications requires a consistent packet format so that speed of transmission and parsing of the data is achieved in code. Let’s first discuss about the Elements of a packet.

### Elements of a packet

1. **Vehicle Identification Number/Ground Station Number(GSN)(16 Bytes)** – the VIN number for a vehicle is hard coded into the communications stream this serves several purposes. The first purpose is the ability to identify a vehicle by it’s radio communications. Think of it as a computers IP address without it Point to Point communications required for Flight path nogiations would not be possible. While there are some that would be concerned with a Big brother scenario of being able to track an individual a Vehicle must be identified. We do not see it any different than a License plate. And that tracking has some security positives as well. Stealing a Quad Car would not be possible through other means but it would provide a way to track a stolen vehicle while it is in use.
2. **Command(2Bytes)**- the command identifies the type of Data being sent or the action to be performed by the Vehicle.
3. **Command Data Length(2Bytes)** – the Command Data Length tells the receiving system the length of the data in bytes to follow.
4. **Command Data(xBytes)**-The command data is specific to the Command specified.
5. **Checksum(4Bytes)-** The Checksum provides an easy way to validate that the proper receipt of the data sent in the packet was received. The Checksum is calculated by adding up each byte starting at the Command.

## Commands

|  |  |  |  |
| --- | --- | --- | --- |
| Command | Description | Origin | Command Data Length |
| 0x0001 | Heart Beat Telemetry | Vehicle | 20 |
| 0x0002 | Shutdown | Ground Station | 16 |
| 0x0003 | Hover | Ground Station | 20 |
| 0x0004 | Add Waypoint | Ground Station | 28 |
| 0x0005 | Take Off | Ground Station | 20 |
| 0x0006 | Travel to Waypoint | Ground Station | 25 |
| 0x0007 | Travel to Waypoint and Land | Ground Station | 25 |
| 0x0008 | Yaw to Heading | Ground Station | 22 |
| 0x0009 | Ascend to Altitude | Ground Station | 24 |
| 0x000A | Descend to Altitude | Ground Station | 24 |
| 0x000B | Land | Ground Station | 20 |
| 0x0064 | Collision Imminent | Vehicle | 32 |
| 0x0065 | Collision Imminent Response | Vehicle | 24 |
| 0x00C8 | Restricted Airspace | Ground Station Beacon | 36 |

## Telemetry Packets

Telemetry Packets transmit telemetry data.

### Heart Beat Telemetry – Once Every Second

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| VIN | Command | Data Length | Command Data | Checksum |
| 16 Bytes | 0x0001 | 0x0014 | Altitude (4Bytes)  Latitude(4Bytes)  Longitude(4Bytes)  Heading(4Bytes)  Speed Mph(4Bytes) | 4Bytes |

*Sample Packet (HEX)*

000000000000000000000000000000000001001400007A780000012A000021A2000000250000004A00000000

## Safety Packets

Safety Packets are commands sent to a Vehicle to From the Ground to the Vehicle to either force a shutdown of the Motors or to force Navigation for Safety Reasons.

### Shutdown

Forces a Motor shutdown or Instant Landing Sequence

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| GSN | Command | Data Length | Command Data | Checksum |
| 16 Bytes | 0x0002 | 0x0016 | VIN(16Bytes) | 4Bytes |

*Sample Packet (HEX)*

000000000000000000000000000000000002000000000002

### Hover

This command forces to vehicle to perform a full stop to forward momentum and hover at the specified Altitude.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| GSN | Command | Data Length | Command Data | Checksum |
| 16 Bytes | 0x0003 | 0x0020 | VIN(16Bytes)  Altitude(4Bytes) | 4Bytes |

*Sample Packet (HEX)*

00000000000000000000000000000000000300200000000000000000000000000000000120A4741600000000

## Navigation Packets

Navigation Packets are commands sent to a Vehicle to From the Ground. They are used for everything from setting Waypoints to Navigation Operation.

### Add Waypoint

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| GSN | Command | Data Length | Command Data | Checksum |
| 16 Bytes | 0x0004 | 0x0000 | VIN(16Bytes)  WayPointId(1Byte)\*  Altitude (4Bytes)  Latitude(4Bytes)  Longitude(4Bytes) | 4Bytes |

*\*Identifies a location saved in the EEProm of the Navigation System. Prototype systems can only store 255 Waypoints. However future vehicle should be able to handle a much greater number of Waypoints.*

*Sample Packet (HEX)*

000000000000000000000000000000000002000000000002

### Take Off

Tells the Vehicle to take off and ascend to the altitude specified.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| GSN | Command | Data Length | Command Data | Checksum |
| 16 Bytes | 0x0005 | 0x0000 | VIN(16Bytes)  Altitude (4Bytes) | 4Bytes |

*Sample Packet (HEX)*

000000000000000000000000000000000002000000000002

### Travel to Waypoint

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| GSN | Command | Data Length | Command Data | Checksum |
| 16 Bytes | 0x0006 | 0x0000 | VIN(16Bytes)  WayPointId(1Byte)\*  CruiseAltitude (4Bytes)  Speed(4Bytes) | 4Bytes |

*\*Identifies a location saved in the EEProm of the Navigation System. Prototype systems can only store 255 Waypoints. However future vehicle should be able to handle a much greater number of Waypoints.*

*Sample Packet (HEX)*

000000000000000000000000000000000002000000000002

### Travel to Waypoint and Land

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| GSN | Command | Data Length | Command Data | Checksum |
| 16 Bytes | 0x0007 | 0x0000 | VIN(16Bytes)  WayPointId(1Byte)\*  CruiseAltitude (4Bytes)  Speed(4Bytes) | 4Bytes |

*\*Identifies a location saved in the EEProm of the Navigation System. Prototype systems can only store 255 Waypoints. However future vehicle should be able to handle a much greater number of Waypoints.*

*Sample Packet (HEX)*

000000000000000000000000000000000002000000000002

### Yaw to Heading

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| GSN | Command | Data Length | Command Data | Checksum |
| 16 Bytes | 0x0008 | 0x0000 | VIN(16Bytes)  Heading(2Bytes)  DegreesPerSecond(4Bytes) | 4Bytes |

*Sample Packet (HEX)*

000000000000000000000000000000000002000000000002

### Ascend to Altitude

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| GSN | Command | Data Length | Command Data | Checksum |
| 16 Bytes | 0x0009 | 0x0000 | VIN(16Bytes)  Altitude (4Bytes)  ClimbRate(4Bytes) | 4Bytes |

*Sample Packet (HEX)*

000000000000000000000000000000000002000000000002

### Descend to Altitude

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| GSN | Command | Data Length | Command Data | Checksum |
| 16 Bytes | 0x000A | 0x0000 | VIN(16Bytes)  Altitude (4Bytes)  DescentRate(4Bytes) | 4Bytes |

*Sample Packet (HEX)*

000000000000000000000000000000000002000000000002

### Land

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| GSN | Command | Data Length | Command Data | Checksum |
| 16 Bytes | 0x000B | 0x0000 | VIN(16Bytes)  Descent Rate(4Bytes) | 4Bytes |

*Sample Packet (HEX)*

000000000000000000000000000000000002000000000002

## Air to Air Collision Avoidance Packets

The Air to Air Collision Protocol is quite simple the first vehicle to calculate that it will intersect with another vehicle will send an Imminent Packet pointing out the Intersection location. A response from the Intersecting Vehicle will acknowledge that it heard the warning with an altitude change that it will perform to remove the risk.

### Collision Imminent

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| VIN | Command | Data Length | Command Data | Checksum |
| 16 Bytes | 0x0064 | 0x0000 | VIN(16Bytes)  Milliseconds To Collision(4Byte)  Intersection Altitude (4Bytes)  Intersection Latitude(4Bytes)  Intersection Longitude(4Bytes) | 4Bytes |

*Sample Packet (HEX)*

000000000000000000000000000000000002000000000002

### Collision Imminent Response

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| VIN | Command | Data Length | Command Data | Checksum |
| 16 Bytes | 0x0065 | 0x0000 | VIN(16Bytes)  New Altitude (4Bytes) \* | 4Bytes |

\*Responding Vehicle alters it’s Altitude to Avoid Collision and notifies Sending Vehicle it’s expected Altitude at point of Intersection as an acknowledgement.

*Sample Packet (HEX)*

000000000000000000000000000000000002000000000002

## Beacon Packets

### Restricted Airspace

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| GSN | Command | Data Length | Command Data | Checksum |
| 16 Bytes | 0x00C8 | 0x0000 | Number of Polygon Points(4Bytes)  Points[]\*  Polygon Latitude(4Bytes)  Polygon Longitude(4Bytes) | 4Bytes |

\*The Array is sequential Latitude ,Longitude, Latitude ,Longitude Etc.. All Points will build a Polygon of restricted Airspace.

*Sample Packet (HEX)*

000000000000000000000000000000000002000000000002