**3. APPROACH**

UAS Alert helps a UAS operator be more aware of what’s in the airspace around them. Alerts are displayed on the ground station display when any ADS-B OUT signal is received by the on-board module. Giving the UAS pilot a better view of the airspace around them will mitigate any UAS from infringing on the paths of other aircraft potentially causing a mid-air collision.

**3.1. System Overview**

UAS Alert consists of multiple subsystems in order to collect information received on the on-board module and aggregate it with information imported from an online source. This will provide a more complete mapping of surrounding aircraft in order to provide alerts to the user. Below, Figure 3.1 shows a high-level overview of UAS Alert and external subsystems that interact with it.

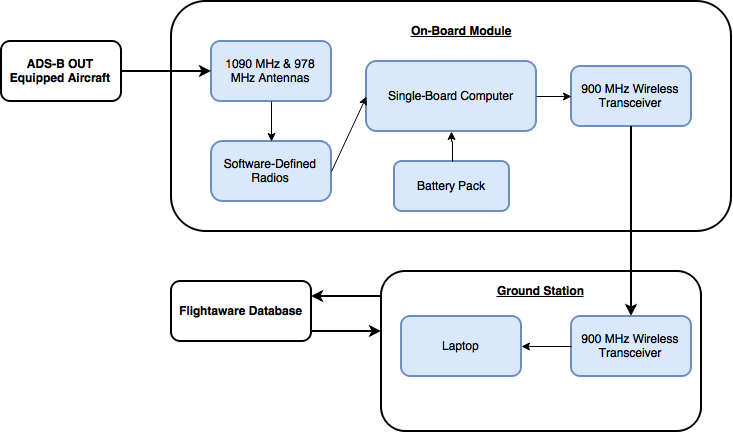


Figure 3.1 UAS Alert overview.

**3.2. Hardware**

UAS Alert will incorporate a reasonable amount of hardware components to make a sufficient and user-friendly system. This section will discuss the main hardware components. Each component with alternative options will have a discussion on the pros and cons for each option along with reasons for final decisions.

**3.2.1. Power Source and Requirements**

The power source for UAS Alert will give an operational time that can last the full duration of flight time capable of the UAV it will be attached to. Taking a summation of the current drawn from the Raspberry Pi, the two SDRs, and the RF module, a good estimation can be made on what the power source capacity should be. The Raspberry Pi 3 Model B requires a 5 V input and draws around 400 mA with nothing attached to it. The XBee 900 draws a max current of 215 mA when it is transmitting. The product of the total current being drawn and the amount of time in hours will give the ampere-hour rating. Below is formulated description of the power source capacity needed for UAS Alert.

The operation time will be in a maximum range to give a safe estimate. Rechargeable Lithium-Ion batteries are being considered for the power source. The power source will be rechargeable through a USB connection.

**3.2.2. Software-Defined Radio**

The on-board module attached to the drone will use two software-defined radios (SDRs) in order to receive information from aircraft broadcasting on 978 MHz and 1090 MHz. High-gain 978 MHz and 1090 MHz antennas will attach to the SDRs. SDRs were a clear choice for this design due to the lower price, smaller size, and more simplicity compared to conventional hardware radio systems. These radios perform signal processing and modulation/demodulation with the CPU of a computer instead of hardware.

**Table 3.2.2. Software-Defined Radios**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **SDR** | **Frequency Range** | **Frequency Stability** | **Price** | **Choice** |
| NooElec NESDR SMArt | 25MHz-1700MHz | 0.5PPM | $21.95 (per SDR) | ✓ |
| NooElec NESDR Nano 2+ | 25MHz-1750MHz | 0.5PPM | $22.95 (per SDR) |  |
| RTL-SDR.com | 500kHz-1.7GHz | 1PPM | $24.95 (per SDR) |  |
| Stratux 1090ES & UAT Radio | 1090MHz & 978MHz | Unknown | $34.99 (both) |  |

All of the SDRs in this table use the R820T2 tuner IC and the RTL2832 USB interface IC. With all of the prices being somewhat similar, thorough documentation and specifications was a big factor in choosing an SDR. The NooElec NESDR SMArt was chosen for this design for two main reasons, it has technical specifications and has an integrated heatsink for cooling the SDR. The Stratux SDRs were originally used and tested. While these SDRs were extremely compact, they also got extremely hot after extended use. Both the NooElec Nano and the Stratux SDRs had the exact same design and dimensions so it is reasonable to assume that the NooElec would have the same cooling issues. The RTL-SDR.com SDR had a lower frequency stability and was too large to have two running side-by-side on our Raspberry Pi. This leaves us with the NooElec NESDR SMArt SDR. This SDR is well documented and performs extremely well when compared to other SDRs such as the Stratux SDRs.

**3.2.3. Development Boards**

A single-board computer will be used for the on-board module. The purpose of the single-board computer is to interpret the information being received from the two SDRs and send it to the ground-station via the transceiver.

Qualities that are needed are multiple USB inputs, Linux based software, and the ability to support 1.2 amps. USB inputs are important because of the amount of power each port can provide in comparison to the GPIO pins which can only provide small amounts of power. Linux software must also be required because dump1090 only runs on Linux capable devices. Also, 1.2 amps is the estimated current draw from the devices needed to run every device simultaneously.

The following table lists the features of the boards that were considered.

**Table 3.2 Development Boards**

|  |  |
| --- | --- |
| **Raspberry Pi** | **Arduino** |
| Raspberry_Pi_3_1_of_4_711f1ffe-af5e-4923-aa7f-d80651396258_1024x1024.jpg | Arduino-uno-perspective-transparent.png |
| Open Source  Multiple USB 2.0 Inputs  45 grams  2.5 Amps  Linux based | Open Source  6 Digital & 6 Analog Inputs  25 grams  0.7 Amps  Java/Linux based |
| ✓ |  |

From the above table the Raspberry Pi 3 is the ideal candidate for the intended purposes. The Raspberry Pi features multiple USB inputs, Linux software, and can supply 2.5 amps.

**3.2.4. 1090 MHz and 978 MHz Antennas**

ADS-B data is received on both 1090 MHz and 978 MHz frequencies. This design will need two separate antennas to receive the all of the necessary data from approaching planes and ADS-B ground stations. The antennas used need to be able to operate without a grounding plane. ADS-B signals are vertically polarized requiring a horizontal grounding plane if a monopole antenna was used. A horizontally oriented grounding plane could interfere with the control or video signals of the drone to the operator and would also increase the size of the on-board system. Because of this, dipole ADS-B antennas were chosen to avoid these issues. Figure 3.2.4. demonstrates the differences in monopole and dipole antennas [1].

|  |  |
| --- | --- |
| Monopole antenna.gif | Dipole antenna.gif |
| Example of simple monopole antennas with a grounding plane | Example of simple dipole antenna that doesn’t require grounding plane |

**Figure 3.2.4. Monopole and Dipole Antennas**

**Table 3.2.4. Antennas**

|  |  |  |  |
| --- | --- | --- | --- |
| **Antennas** | **Description** | **Price** | **Choice** |
| HUACAM HCM98 Antenna Kit | No Specifications | $16.99 |  |
| NooElec ADS-B Discovery 5dBi Antenna Bundle | High Gain, Documentation, Affordable | $16.95 | ✓ |
| NooElec ADS-B Discovery 3dBi Antenna Bundle | Documentation and Specs, Affordable | $12.95 |  |
| ADS-B High Gain Antenna DMURRAY14 Kit | Large Community use with Stratux Kits | $19.99 |  |

The NooElec ADS-B Discovery 5dBi Antenna Bundle was chosen for this design. Other antennas for ADS-B use had much less documentation. These antennas use are sleeve dipole antennas and do not require grounding planes for good signal reception.

**3.2.5. RF Modules**

This table compares the two RF Modules that were considered.

**Table 3.2.1 RF Modules**

|  |  |
| --- | --- |
| Xbee 900hp | Synapse RF 266PC1 |
| Xbee.PNG | Synapse.PNG |
| 128-bit AES Encryption  LOS Range: | 128-bit AES Encryption  LOS Range: |
| ✓ |  |

**3.3. Software**

The software used for this project will be based upon elements of Dump1090, Dump978, and PiAware. This software is used to demodulate and decode 1090 Mode S messages and 978 UAT messages, respectively.

**3.3.1 Ground Station**

The UAS Alert ground station will be based on PiAware. PiAware offers services that allow the user to receive synthetically derived ADS-B positions of aircraft that are not ADS-B equipped. This is achievable through multilateration (MLAT) when the aircraft is detected by three or more FlightAware receivers. This will increase the accuracy of the data that UAS Alert provides the user.

The alternative to FlightAware’s multilateration service would be FlightRadar24. However, PiAware is more accessible and well documented.

**3.3.2 Demodulation Software**

As mentioned above, dump1090 and dump978 are commonly used demodulator and decoder software for Mode S and UAT messages. They are open source and feature single-bit error correction using 24-bit cyclic redundancy check (CRC). For the project’s purpose, only portions of dump1090 and dump978 will be used. Although dump1090 also decodes the message into a human-readable display of the data field (velocity, position, identification, among other things), the software for the device attached to the UAV will only need to send raw data to the ground station where it will be interpreted. Additionally, not all of the data fields are relevant to the purpose of the design, and may be omitted before sending. This will reduce the data payload per message being sent to the ground station via the transceivers. No alternative software was found for SDR demodulators that dealt with ADS-B. In order to focus more on implementations, the team chose to use this open-source software instead of trying to fully design it on our own.

**3.3.3 Operating System**

In order to support our software choices, the operating system must be a linux-based. Dump1090, dump978, and PiAware are all built to run on a linux-based machine. There is a version of dump1090 that is compatible with windows. However, no such version exists for dump978. Raspian is a linux based operating system for the Raspberry Pi and will be what is used for this design due to the team’s previous experience with Raspbian and for compatibility purposes for all software involved.

**3.3.4 Device Drivers**

The device on the flight-frame will incorporate software that will drive the transceivers and remove unnecessary portions of the demodulated dump1090 data before transmission as mentioned above. This code will be written in C++ and Python 3.

**3.3.5 Display and Alerts**

UAS Alert will feature a map overlay of all detected aircraft. This feature will be written in Python 3 and will use Google Maps to display the coordinates of the surrounding aircraft. Alerts and simple advisories will be given to the user when the UAV is in danger of colliding with an approaching aircraft. These simple advisories will include directions to make maneuvers such as ascend or descend as needed.

**References**

[1]L. Frenzel, "What’s The Difference Between A Dipole And A Ground Plane Antenna?", *Electronicdesign.com*, 2013. [Online]. Available: http://electronicdesign.com/wireless/what-s-difference-between-dipole-and-ground-plane-antenna. [Accessed: 26- Sep- 2016].