S900 User Guide

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for the

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Contents

1 Theory of Operation

The DJI S900 system is a multi-roto UAS capable of short duration missions. During the course of the semester, the student in the EE656 class at UAF began work on getting it running. New integration boards were developed for future integration. Batteries have been purchased and all communication systems to control and monitor the UAS have been delivered. With the addition of the hood as well as the payload plate, the system can support a payload of about 2 kg. Payloads will be mounted on the attachment plate. The S900 system is designed to be flexible in the payloads and flight times that it can achieve.

2 Pre-Flight/Post-Flight Plan

2.1 Pre-Flight

1. Make sure you are ve miles or further from any airports.
2. Set the UAS on level ground.
3. Inspect the UAS.
   (a) Make sure props are tight.
   (b) Visually check wires and connections.
   (c) Visually check craft for damage.
   (d) Log starting battery voltages and percentage of charge.
4. Turn on camera.
5. Set camera to desired mode - check for SD card.
6. Make sure any people in the area are at least 15 feet away and aware that you are turning it on.
7. Turn on Controller.
8. Plug in Battery.
   (a) Check voltage meter.
9. Flip the onboard arming switch.
10. Setup Mission Via Mission Planner.
    (a) Upload preferred imagery into Mission Planner.
    (b) Create Waypoints for your UAS to travel.
11. Announce to everyone that you are getting ready to arm the UAS.
12. Check all equipment signals.
13. Take off and hover between 5-10 feet off of the ground and check to make sure that the UAS is reacting to your controls properly.
    (a) If using auto-flight feature via Mission Planner
        i. Put UAS in loiter mode and make sure the UAS can maintain its location.
14. Perform Mission
15. Land in open area, clear of people

2.2 Post-Flight

1. Disarm UAS with controller.
2. Disarm UAS onboard.
3. Disconnect battery.
4. Turn off controller.
5. Inspect UAS for damage or loose connections.
   (a) Feel motors and speed controllers for heat.
   (b) Inspect battery and battery connectors for signs of external wear or excessive heat.
6. Make a list of issues that need to be fixed before the next flight.
7. Log ending battery voltages and percentage of charge.

3 Assembly Instructions

3.1 Propulsion

The propulsion system of the S900 consists of the Tarot 1552 EVO Carbon foldable propellers and the S900-21 DJI motors. This section details how to attach the propellers and install the motors on the DJI S900.

3.1.1 Motor Installation

The motor numbering on the S900 is crucial for achieving stable flight. The Pixhawk autopilot needs to be able to control each of the six motors individually to safely guide the system. The numbers on each arm correspond to the matching Main Output Pin on the Pixhawk. The electronic speed controller for each motor should be connected to its corresponding output pin number. Additionally the Auxiliary output pin 1 of the pixhawk should connect to the input of the landing servos. The numbers matching the Pixhawk Main Output Pins is shown in the following figure.

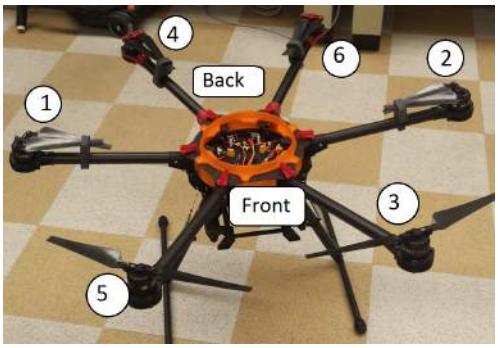

Figure 1: Motor Layout

3.1.2 Attaching Propellers

An important part of any flying machine that depends on propellers is the propeller. To make sure the propellers are properly propellent, propel yourself through this propeller guide. To attach the propellers to the motor on the S900 UAS, first make sure that the appropriate number of carbon fiber propellers and appropriate screws are present. Be sure that the clockwise and counterclockwise propellers are paired with the appropriate motors. Motors 1, 3, and 6 on the previous image are paired with clockwise propellers. Motors 2, 4, and 5 are paired with counterclockwise propellers.

Figure 2: Propeller Parts

Once all of the parts are present, stack the parts onto the screws. First slide on the spacing bar, then a washer, the propeller, and lastly the second washer.

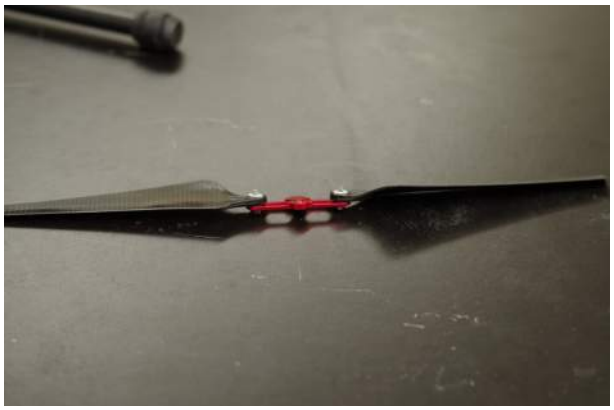

Figure 3: Propeller Parts

Being careful not to lose any components, flip the stacks into the top of the motor. Tighten the screws until hand tight.

Figure 4: Propeller Attachment

3.2 Payload

The payload system of the S900 consists of a payload bay with rails to support a wide array of payloads. In addition to this, some payloads will be supported directly that are anticipated to be commonly used, such as the Lightbridge video system. This section outlines how to install payloads into the standard payload bay as well as providing the locations for any specifically supported payloads.

3.2.1 Hood Attachment

The dome for the S900 protects the electrical components in addition to providing attachment points for the GPS and compass.

To secure the dome to the S900s frame, screw it to the top. The domes fin indicates which direction the UAS faces.

Figure 5: Payload Hood

3.2.2 Payload Bay

The S900 has a rail system for mechanical integration of the payload and battery. There is a set of adjustable mounting brackets provided to which payloads may be attached, although some payloads may need their own mounts depending on their dimensions. The payload and battery must go through a weight balance test to ensure the center of gravity is approximately in the center of the UAS. This can be accomplished by adjusting the location of the battery and payload by sliding them along the rails until the appropriate center of gravity is achieved. Tighten screws and check that the battery and payload are secure.

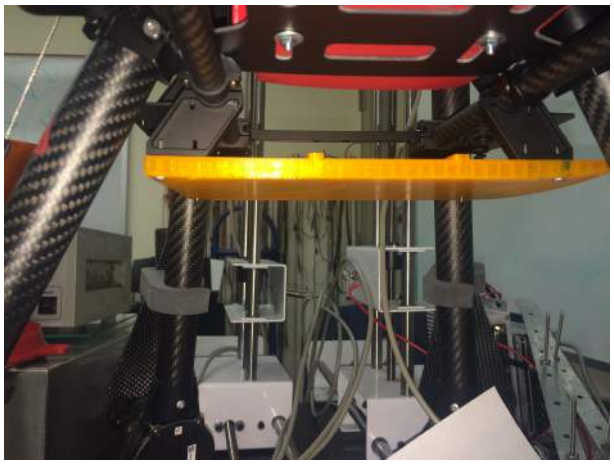

Figure 6: Payload Plate

3.3 Power

The power system consists of high capacity Lithium-Polymer batteries. This section outlines how to install these batteries into the S900 and where they will be placed.

3.3.1 Battery Connection

Attach Turnigy Multistar High Capacity 6S 20Ah Lipo battery pack to battery tray. Make sure to use insulated container and attach temperature and charge sensors.

Figure 7: Battery Attachment

Connect the black connector and then the red connector to power on.

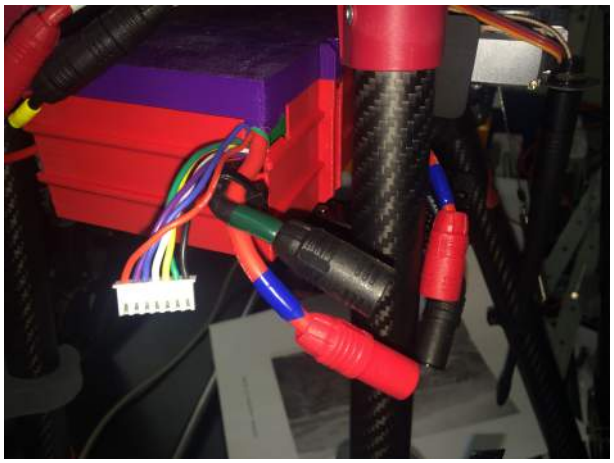

Figure 8: Battery Connection

The battery connections have reverse voltage protection to protect systems from damage due to improper battery connection. The batteries are also equipped with keyed connectors to ensure proper battery connections.

3.4 Communication

The communications subsystem consists of the Lightbridge, PixHawk and DX8 Manual Controller. This section outlines how to install each subsystem and what each system is connected to as well as what kind of connection is used.

The air system is installed with the rest of the optional payloads. There are many gimbals that support the mounting of the Lightbridge directly to the gimbal. This particular section will be updated when the final location on the S900 is decided upon.

The antennas will be mounted using the antenna mounts placed on the landing gear of the S900. If antenna cable extensions are required, they will be run along the legs of the landing gear to connect

the antennas to the Lightbridge transceiver.

The HDMI or the AV connection on the Lightbridge will be connected to the camera. Only one of these connections may be connected.

Air system power is provided to the Lightbridge via the provided power cable.

The DBUS cable is the connection between the flight controller and the Lightbridge.

3.4.1 Pixhawk Installation

Pixhawk will be mounted to the custom PCB that provides the voltage regulation to the other payload on the S900. The controller will be connected to the pixhawk. The GPS module will be connected to this device to enable autonomous flight.

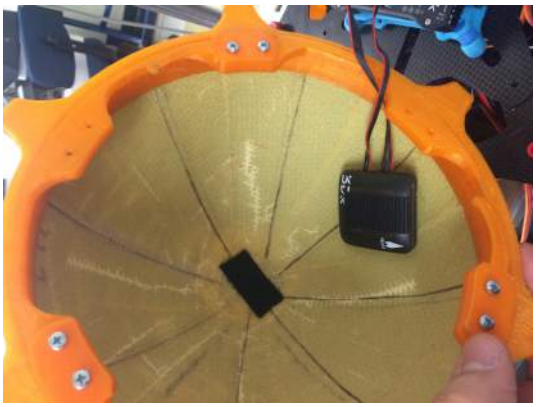

Figure 9: GPS Attachment

The mounting foam included with the pack will be placed between the pixhawk and the mounting point if required. Most other systems will be controlled by this system, specifically the motors. Power will always be the last thing connected after all other connections have been verified to be correct. Ensure the arrow on the pixhawk is pointing towards the front of the S900.

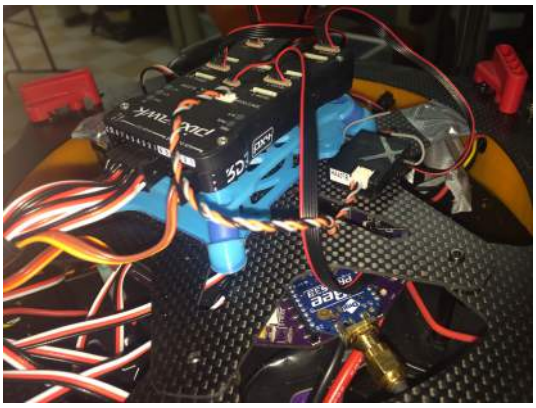

Figure 10: Pixhawk Connection to Integration Board

3.4.2 Manual Controller (DX8)

The manual controller will not need any assembly as it is a package that is self-contained. It should be turned on and connected after initial setup and synchronization.

3.5 Ground Station/Auto Pilot

The ground station will obviously not be aboard the S900, but the system still needs to be set up when out on a mission. This section consists of how to set up the ground station and prepare the laptop for communication with the S900.

3.5.1 Initializing Mission Planner

1. Open Mission Planner
2. Select Flight Plan
3. Right click on the map, click map → tool → prefetch. This will download a map of the selected location

3.5.2 Initial Setup of PixHawk with Mission Planner

1. Install mission planner software onto laptop if it is not already installed.
2. Connect the PixHawk to the computer via a micro USB connection.
   (a) The computer will now install any necessary drivers for the PixHawk.
   (b) Do not load any firmware yet, cannot install firmware while connected to the Mavlink.
3. Select Initial Setup and install the necessary firmware.
4. While the PixHawk is connected to the computer select communication option → Communication: PX4 FMU and Rate: 115,200.
5. Select Connect → Initial Setup → Mandatory Hardware.
6. Select the frame type/orientation.
7. Select the option to enable the compass, allow auto deceleration and specify the PixHawk.
   (a) Alternatively you can select Live Calibration adn walk through the wizard.
8. Select the option to enable the Accelerometer, select calibrate and walk through the wizard to calibrate the PixHawk.
9. Select RC calibration to teach the pixhawk to work with the RC transmitter, turn on transmitter, and calibrate.

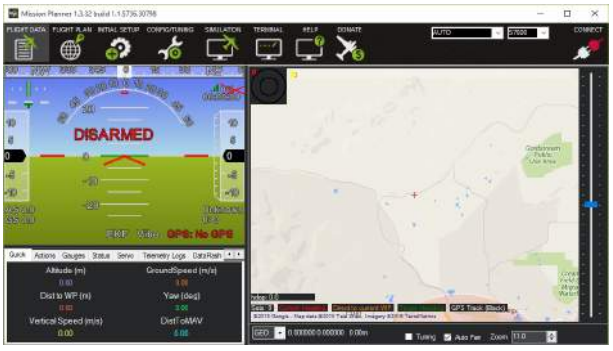

Figure 11: Sample Mission Planner Screen

4 Disassembly Instructions

4.1 Propulsion

The propulsion system should not be removed under normal circumstances, but in the event that it malfunctions and needs to be replaced, instructions are provided in this section on how to remove.

4.1.1 Removing Propellers

To remove the propellers from the UAS, begin by unscrewing the two screws that are holding them in place on the top of each motor. Once the screws have been removed, be sure not to lose either screw, the top plate, or the four washers.

4.1.2 Removing Motor

To remove the motors and dampeners from the UAS, start by removing the screws from the screws holding the motor and vibration dampeners to the arm of the UAS. Once the screws are removed, carefully store the 8 washers, 4 dampeners, mounting plate, and motor in a safe place.

4.2 Payload

The disassembly of the payload is simply the reverse of the assembly. This section will cover how to specifically remove any payloads from the rails of the payload bay and what needs to be done to ensure no harm comes to the payloads or the rails.

4.2.1 Payload Removal Procedure

Unscrew the payload from the mounting mechanism attached to the rails.

4.3 Power

Proper removal of the battery system of the S900 is important to prevent any damage to wires or connectors. This section outlines the necessary procedure to remove the batteries without causing harm to the rest of the system.

4.3.1 Battery Removal

Disconnect the red connector then black connector to power off.

Remove battery pack from battery tray.

4.4 Communication

4.4.1 Lightbridge Removal

The first step in removing the light bridge will be to remove the power source, then remove all other connections into the Lightbridge.

Antennas can be removed from the landing gear and the Lightbridge removed from its resting place on the S900.

4.4.2 Pixhawk Removal

Disassembly will not be necessary under ordinary circumstances. In case it must be removed, first remove power cables. Proceed to unplug the rest of the connections carefully without damaging them. If the foam is used to attach the PixHawk to the board, lightly pull upwards with increasing force until it comes off.

4.4.3 Manual Controller (DX8) Removal

The DX8 does not have any disassembly.

4.5 Ground Station/Auto Pilot

The ground station must be put away after the mission. This section describes the proper method of disassembling the ground station and putting it back into the case.

4.5.1 Ground Station Disassembly

Properly close all applications that are open on the laptop. Shut down the computer and disconnect all peripherals. Lightbridge and accompanying monitors should be powered down as well, since they will work in conjunction with the laptop to provide maximum connectivity. Once everything is powered down it should be placed back into the storage containers. A sample storage container is given in the following figure.

Figure 12: A Sample Container

5 Use Instructions

5.1 Propulsion

Use of the propulsion system will be through monitoring the motor usage characteristics at the ground station. This section will also cover the expected operation characteristics of the propulsion system.

5.1.1 Monitoring the Motor

Monitor motor speeds and ensure motors are operating within expected range.

5.2 Payload

Payload is not a system that is used. For instructions on how to attach payloads to the payload rails, see the assembly section.

5.2.1 Payload Bay

How to use the payload will vary from payload to payload. Check the payload's user manual for instructions on use.

5.3 Power

The power system is not specifically used. This section will be a discussion of what to expect from the batteries as well as how to inspect the connections and wires.

5.3.1 Battery Use

Proper use of the battery is integral to keeping a battery for as long as possible. The information on how to maintain the battery is present in the Maintenance section. Given below is an example of typical battery characteristics of a Lithium Polymer battery.

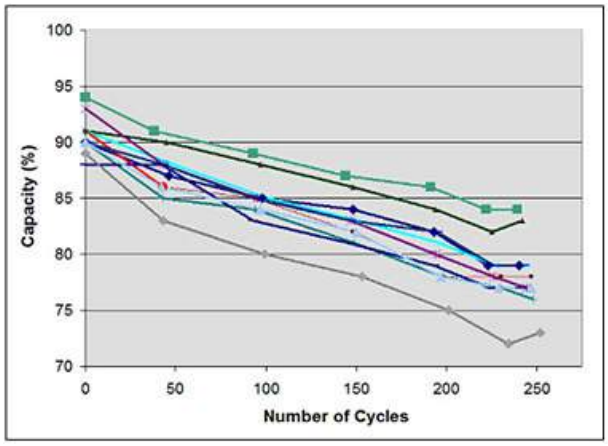

Figure 13: Sample Battery Characteristics

5.3.2 Ensure Good Connections

As outlined in the assembly instructions, it is important to ensure that the battery is fully connected to the rest of the system.

5.4 Communication

The communications systems have a large amount of usage information specific to each system. As such, it is recommended to read the data sheets for each system in addition to the summaries present in this document. Data sheets can be found in the digital archive.

5.4.1 Using Lightbridge

Power on the air system first, then the ground system. The video link indicator will turn solid green then change to flashing green when the ground and air systems are communicating normally.

Connect the ground system to an HDMI monitor to display the image, alternatively, the Lightbridge app can be used to display the image.

Lightbridge also has the ability to control the S900 if that feature is used.

Occasionally the firmware of the Lightbridge should be updated. This is done by connecting a PC to the ground system using a Micro-USB cable. Click on the upgrade icon to check for upgrades and install them if the system requires it.

Operating the Lightbridge is essentially keeping radio contact with the S900. In this section, the maximum distance of the S900 system is outlined. The limitation of the system will be presented to ensure that the user knows what to expect from the system when in flight.

5.4.2 Using Pixhawk (Mission Planner)

The PixHawk is another system that is not used in the typical sense of operating it. In this section a description of the data that is transmitted will be presented along with how to read the data that is transmitted by the system.

Make sure that the correct style of aircraft is chosen in mission planner, it will affect how the system issues controls.

5.4.3 DX8 Controller Use

Using the DX8 to control the S900 is described here. All the controls available will be listed with a pointer to the actual controller to show where the control is. Sensitivity of controls should be outlined in this section as well, as well as an outline of how to control the S900.

Figure 14: DX8 Controller Layout

5.5 Ground Station

The ground station use is primarily on how to use mission planner. This section will specify how to use this program and any other tools that will fall to ground station that is not already covered in another system. For example, Lightbridge will be covered in the communication section.

5.5.1 Laptop Use

Mission planner is the software that is used for getting back telemetry data from the S900 as well as program the autopilot with the waypoints that will be traveled on the mission. Instead of filling this document with how to use mission planner, a link to the mission planner website is provided. From there, links to the other settings and features can be found and used for learning purposes.

`http://planner.ardupilot.com/wiki/mission-planner-overview/`

6 Maintenance Instructions

6.1 Propulsion

The propulsion system will need to be maintained. To this end, it will consist of inspection procedures and what should be done if certain symptoms are discovered. The motor and propeller will each have a maintenance procedure list here.

6.1.1 Propeller Inspection

Check propeller leading edge(s) for damage; run a fingertip over each leading edge to feel for chips, bends and cracks. Check each propeller mount for 2 screws in mounting bracket. Additionally, check if the manufacturer torque markers on screws and propeller covers are still present and undamaged.

Pictures of how to replace the propeller should be included here in the case of damage

6.1.2 Motor Check

Check ESC and power connectors at the base of each frame arm that connect to the center frame. Check exposed ESC/power wires at the end of each frame arm, for damage/wear. Check each frame arm for CW or CCW marking and matching propeller type.

Examploe picture of motor wear possible?

6.2 Payload

The payload system must be maintained like every other system. In this section, methods of checking the payload bay for damage will be covered. It will outline what to look for to determine whether the mounting plates or rails are damaged and the way/s to fix or replace them.

6.2.1 Payload Hood Maintenance

Check the dome for cracks or damage.

6.3 Power

This section outlines how to deal with the batteries on the S900. It covers battery logs, how they function and how to visually inspect them, how to dispose of them and how to properly charge them.

6.3.1 Battery Functionality

Lithium-ion batteries require routine maintenance in order to maximize lifespan. Note that the typical lifespan of a battery is around 300 to 500 charge cycles if the battery is fully discharged during use. The lifespan of the battery is dependent on the depth of discharge experienced during routine use [1].

In an effort to extend battery life, the following measures can be taken to extend battery life. Note that the following are not always ideal for the missions required by the system. First, the number of

cycles of a batterys life increases if the battery is not fully discharged during use. A battery is also stressed when held at a higher temperature and a high cell voltage during storage. If the charge of the battery is lowered from 4.2 Volts per cell, then the number of cycles will also increase. For each 0.1 Volt per cell lower, the number of cycles approximately doubles. It is clear from this that the lowering of the peak charge voltage will ultimately limit the capacity. However, by bringing the cell voltage again to 4.2 Volts per cell, the battery will resume its normal capacity.

6.3.2 Battery Storage and Disposal

When placing batteries into storage for long periods of time the battery should be at 30-50% capacity. The battery should be kept at the charge and be checked on at least every 6 months. The battery ideally should be stored separately from the rest of the components and at temperatures 5-20 °C [2].

The battery should be carefully handled. Follow proper battery disposal methods that can be found for your region. A battery that is damaged or punctured should not be used and any fluid released should be carefully handled. Do not allow the battery to reach temperatures above 60 °C.

6.3.3 Battery Logs

After charging a new battery, it is important to note the run time of the system to develop a basis to compare with future runs. If the battery appears to be running for a shorter period of time (on the order of 80% of the original flight time) or the battery requires a much longer period of time to charge, then a replacement battery should be considered. As with all batteries, it is important to follow the charging procedures given by the battery for optimal battery life.

6.4 Communication

Much of the maintenance in communications is preventative and ensuring that everything looks operable. This section lists what to look for before flight to give the greatest chance of success.

6.4.1 Lightbridge Maintenance

Connections must be checked before takeoff to ensure nothing will come loose. This includes the video, power and antenna connections. This is done to prevent any loss of signal or components from hitting anything and causing damage to the S900 or the environment. Cables must also be examined to ensure they do not fail midflight.

The Lightbridge can be tested by placing one meter from the ground station and verifying there is a solid connection.

Antennas should be checked for stable attachment to the S900 frame so they do not fall off. Specific instructions for this entire section will be given once integration has be completed.

In addition to verifying that all physical connections are stable, the software of the Lightbridge should be updated regularly to provide optimal performance. This is covered in the user manual for Lightbridge and should be referred to if more detail is desired.

6.4.2 Pixhawk Maintenance

The PixHawk Maintenance is similar to the Lightbridge. All connections should be verified as secure.

Proper connectivity should be possible at a close range and tested before every use.

Software updates should be run regularly through mission planner.

6.4.3 Manual Controller (DX8) Maintenance

The controller needs minimal maintenance and will require changing the batteries/ charging the batteries before use. Do not soak in water due to it being bad for electronics.

6.5 Ground Station/Auto Pilot

The ground station must be maintained just like every other system. This section will describe how to keep the ground station running quickly and smoothly and maintain any hardware associated with it.

6.5.1 Laptop Maintenance

Ensure that all updates are installed on the laptop before running a mission. It is possible that it auto-updates while on the mission otherwise.

6.5.2 Hardware Maintenance

Ensure that all connections are tight. Make sure hardware shows no signs of damage.

7 Parts List

7.1 Propulsion

Item: 15 x 5.2 inch, 13 gram, 1552/1552R foldable propellers

Description: The propellers used with the system are carbon fiber for increased durability.

Price: $17.90 each

Item 41 x 14 mm stator, 400 rpm/V, 500 W, 158 gram electric motor.

Description: The standard motor that comes with the DJI S900 system.

Price: $36.40 each

7.2 Payload

Item: Payload Hood

Description: The payload hood will be designed by UAF students and allow for covering on the S900 when it is necessary.

Price: Based on the printing or manufacturing requirements.

Item: Payload Bay

Description: The Payload bay will be designed by UAF students. It will allow a plethora of payloads to be attached and held securely to the S900. The idea is to have a standardized attachment for maximum flexibility when choosing different payloads for missions.

Price: Based on the printing or manufacturing requirements.

7.3 Power

Item: Turnigy Multistar 1600mAh 6S 10 C High Capacity LiPo Battery.

Price: $178.90 each

Item: Power Connectors

Description: Wire connections will be required for every subsystem that uses power, these will generally come with each subsystem that is purchased.

Price: Included in cost of other subsystems

7.4 Communication

Item: Lightbridge

Description: Lightbridge is a high definition video system that connects to the camera and transmits it to the ground station. It also has the ability to act as the remote control system if that option is taken advantage of in this system.

Price: $999.

Item: PixHawk Kit

Description: The PixHawk is an Autopilot system for Autonomous Vehicles. It is a PPM-input autopilot that is usable with many different receivers. It is capable of controlling various aspect of flight including motor control and programmable waypoints. It will serve as the main brains of the S900 and will be connected to GPS so its location is always known. The kit comes with GPS module, PPM encoder, airspeed sensor and various other attachments that would prove useful in different circumstances.

Price: $539.00.

Item: XBee XTEND

Description: The XBee-XTEND is a 900 MHz radio frequency module used to transmit the data from the S900 to the ground station to enable the monitoring of telemetry.

Price: $179.00

Item: XBee Dipole Antennas

Description: These antennas are used to convert the electrical signal and propagate it through free space. This will transmit the telemetry data to the receiver at the ground station to be monitered.

Price: $9.00

Item: XBee USB Adapters

Description: The USB adapters are used to connect the XBee at the ground station to the computer. This will allow mission planner to interpret and display the data for human reading.

Price: $24.00

Item: Manual Controller (DX8)

7.5 Ground Station/Auto Pilot

Item: Panasonic Toughbook 54

Description: The toughbook is used for increased resistance to the elements. It runs Mission Planner and other programs to run the mission and communicate with each of the subsystems. It is also used to set up the communication units on board the Stalker.

Price: $1300-2000

Item: Pelican Case

Description: This item is used to store the Stalker and ground station while it is in transit. During operations it will also house the laptop, displays, and receiver/transmitters for the mission.

Price: $1000+

References

[1] Battery University (*BU-808: How to Prolong Lithium-based Batteries) 2015* *http://batteryuniversity.com/learn/article/how_to_prolong_lithium_based_batteries 2015.*

*[2] Tektronix (*Lithium-Ion Battery Maintenance Guidelines 2015 `http://www.newark.com/pdfs/techarticles/tektronix/LIBMG.pdf`