1. ABSTRACT

Zeppelin FC 26, a team formed in 2014, has undergone exponential growth. We have delved into diverse and challenging endeavors, ranging from systems integration to design and development of airframes using advanced composite technology. Last year, our venture into AUVSI SUAS 2015 yielded a valuable experience in understanding the demands and resource limitations of developing a fully functional Unmanned Aerial System. For SUAS 2016, Zeppelin FC 26 believes in the vision of delivering a high performance UAS and strives to meet the ever increasing demand for pioneering research in the field of Unmanned Aviation. Not just the competitions ahead, but we believe in introducing this technology in India at a larger scale, making people familiar with its pros and cons, and in accordance to the recent security threats, enhancing the technology such that it serves as an asset to the nation by intelligently protecting itself from being misused.

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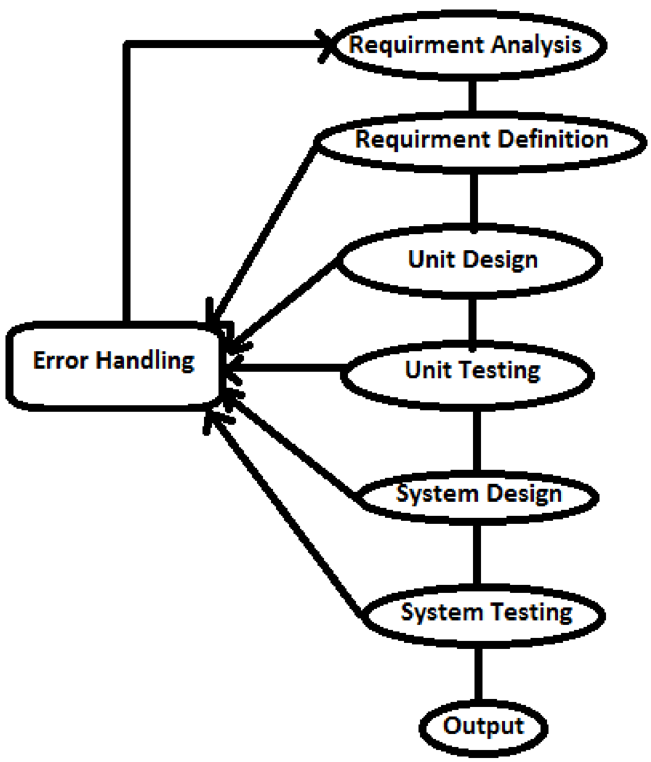
2. PROPOSED TECHNICAL APPROACH

The work throughout this project sequentially followed the given activity flow: Zeppelin's approach for the development of the UAS was precision based. The idea was to trade off performance and accuracy against the number of tasks attempted, and extract maximum output with minimum input. For this perfect combination of SUAS standard, we have taken into consideration numerous test flight results, and optimized the UAS accordingly. Safety, combined with cost effectiveness and reliability, was the main aim of Zeppelin and was achieved by a thorough analysis of each and every component used. We kept constant focus to ensure modularity throughout the design of the UAV. This enabled us to obtain the best combination for a UAV of SUAS standard.



3. PLANNED TASKS

After thoroughly going through the rule book, analyzing the tasks, and keeping in mind the technology available in our budget, we decided to go for the following tasks

- Primary Tasks
    - Autonomous Flight Task
    - Search Area Task
- Secondary Tasks
    - Off-axis target
    - Emergent target
    - SRIC (Simulated remote information center)
    - Interoperability

Primary tasks were assigned a higher priority than the secondary ones. Instead of quantitative, our approach was qualitative. The primary focus was on completing tasks with precision and accuracy, even if it meant accomplishing lesser number of tasks.

4. REQUIREMENTS ANALYSIS

Keeping in mind our requirements and the availability of materials, we had to follow a strict selection procedure to obtain the best fit. A modular approach was implemented to test the various components.

The whole project was divided into the following modules

- **Airframe**
- **Electronics**
- **Flight Control Board**
- **On Board Computer**
- **Networking**

Airframe

Although the airframe was readily available, it had its own limitations. Balsa wood frames and foam based aircrafts were available online but needed to be shipped in, leading to a high cost and time factor. Buying the raw material and fabricating our own frame helped us in understanding the aerodynamics and other mechanical aspects of the frame while simultaneously reducing the cost factor. The raw materials available included Coroplast sheets, High Density Polyethylene foam, and Balsa wood. Wood frame would increase the total weight, involved a difficult fabrication procedure and needed to be extremely precise. The material cost was relatively high and future maintenance was expensive too. Thus we chose Coroplast sheets and HDPE foam to initiate the process.

Electronics

Electronics mainly consisted of Electronic Speed Control, Brushless DC Motors, and Lithium Polymer Batteries. This module required a lot of theoretical calculations to find the optimal configurations as all these needed to be collaborated and synchronized. Due to the presence of an upper limit on weight and power supply, and poor availability of resources, we limited ourselves to a narrow range of configurations.

Flight Control Board

Being the brain of the aircraft, the Flight Control Board needs to perform a wide range of tasks. Starting with manual controlling, we went through various options like KK board, Naza, HKPilot32, and Pixhawk. KK board and Naza turned out to be unreliable while Pixhawk seemed to be out of budget. After working with HKPilot32 for a year we realized it provided us freedom with a lot of features including autonomous flight along with an affordable price. However, it was not very reliable and didn't provide stability to the aircraft. After a lot of efforts and an increase in our budget, we were able to finalize Pixhawk, which turned out to be the ideal solution.

On Board Computer

An OBC helps in performing additional tasks like providing the system extensions for communication, visualization etc. Raspberry Pi, along with a Linux Operating System provided an edge from programming point of view and helped us accomplish various obstacles at affordable costs. We chose Raspberry Pi 2 B+ for our systems.

Networking

To transmit data between the Ground Station and the UAV various networking components were needed. To meet the bandwidth requirement, power and range of transmission, cost, and availability we chose Aomway transmitters and receivers for Imagery, Edimax Wi-Fi module for Wi-Fi connections (for SRIC), 3dr telemetry with Pixhawk for TM data, and RCB 6i Tx/Rx for manual controls.

5. ARCHITECTURAL DESIGN

The architectural design of the system can be divided into two main sub architectures viz aircraft architecture and ground control station architecture.

Aircraft

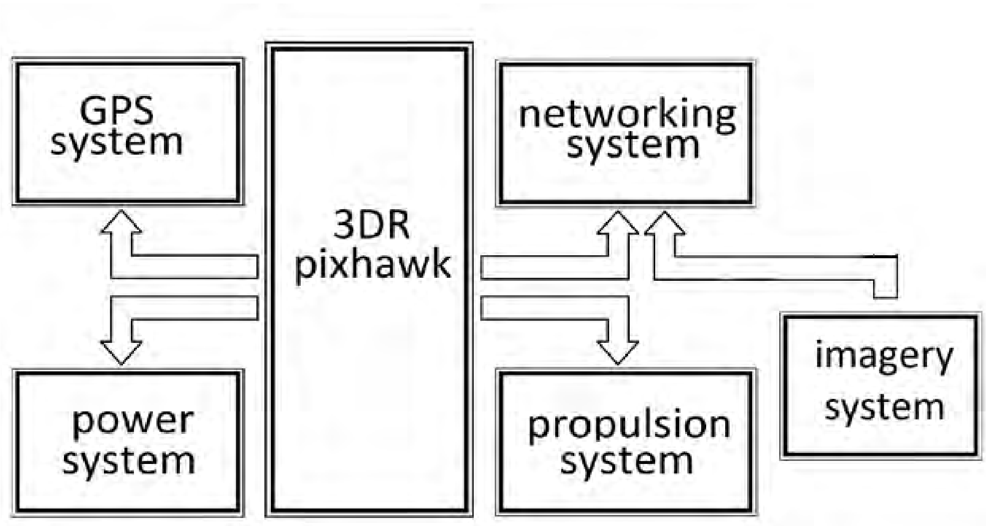


Fig. Aircraft Architecture

The basic architecture of the plane is defined in figure above. It is the level 1 diagram of the aircraft electronics systems. Each module can be further specified into detailed architecture as follows:-

- Autopilot System (3DR Pixhawk)
- GPS System
- Power System
- Networking System
- Imagery System
- Propulsion System

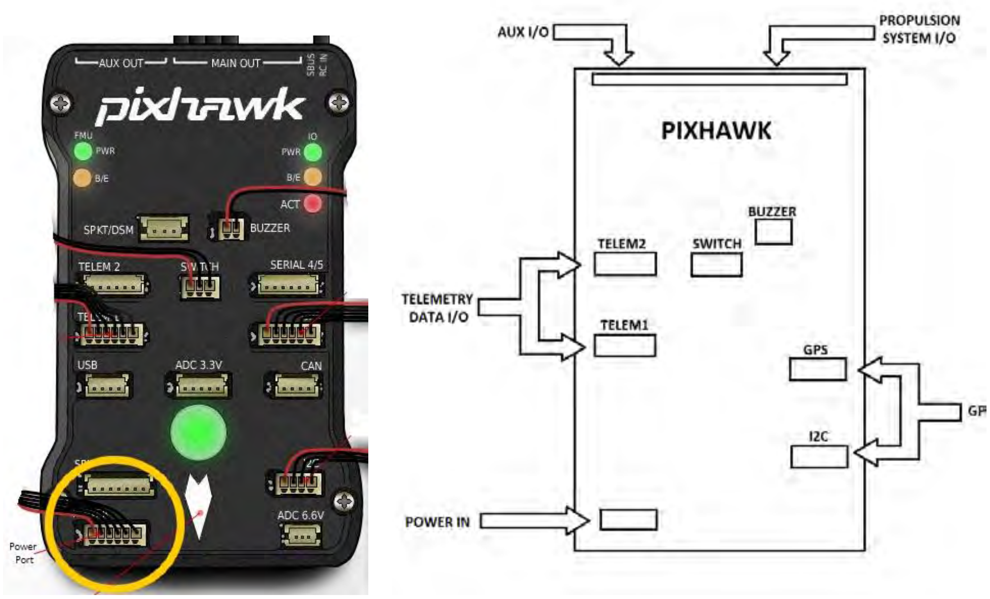


Fig. Autopilot System (3DR Pixhawk)

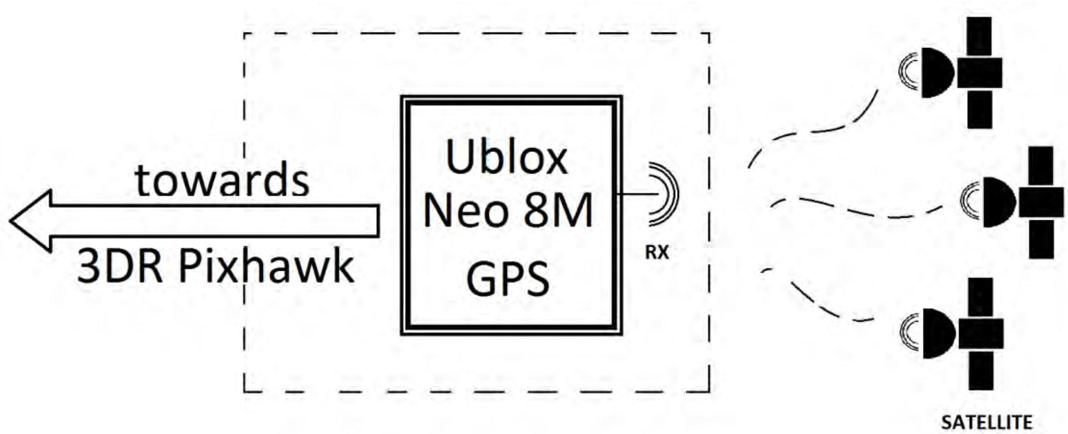


Fig. GPS Architecture

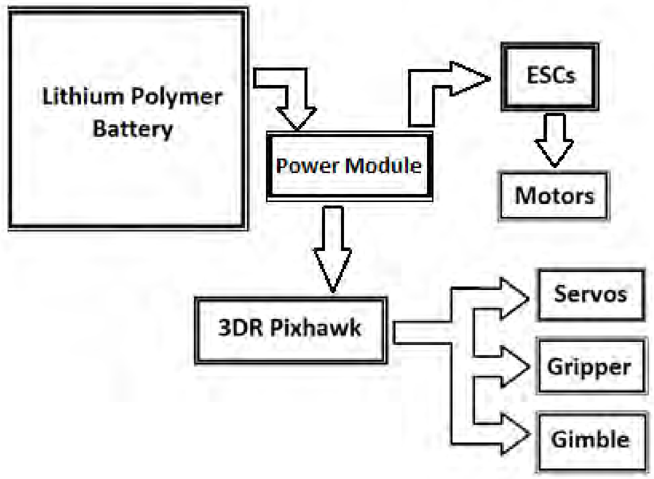


Fig. Power System Architecture

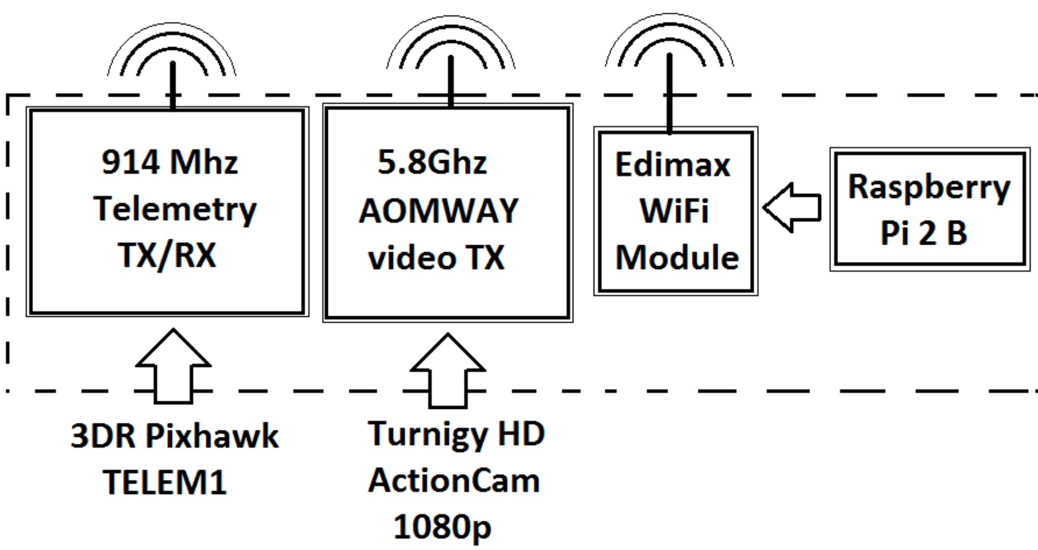


Fig. Networking System Architecture

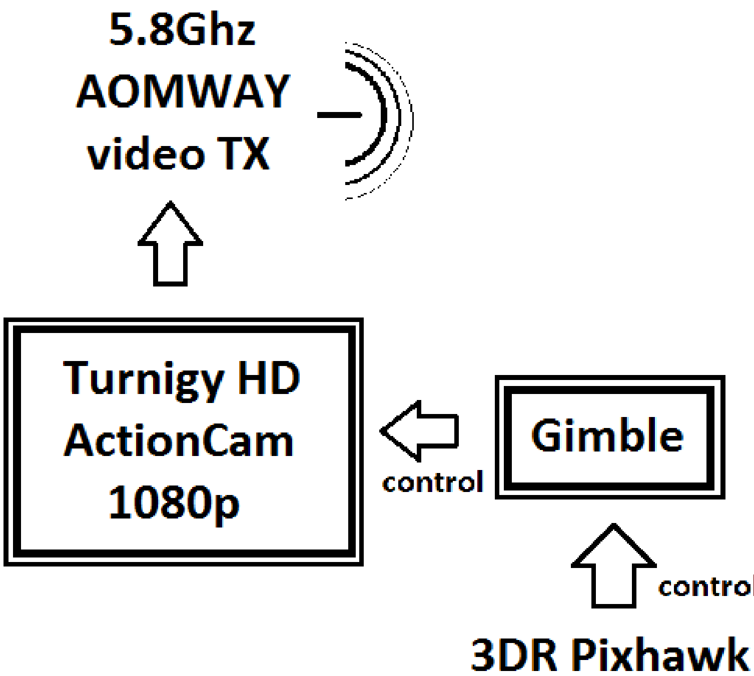


Fig. Imagery System Architecture

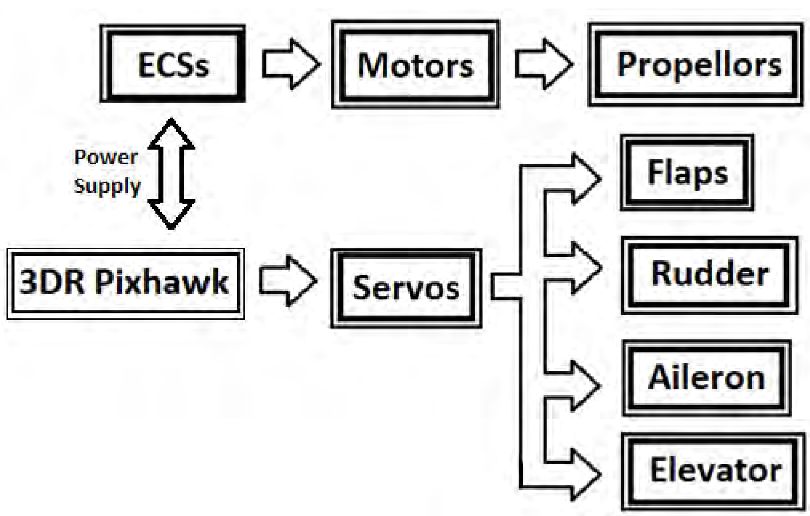


Fig. Propulsion System Architecture

Ground Control Station

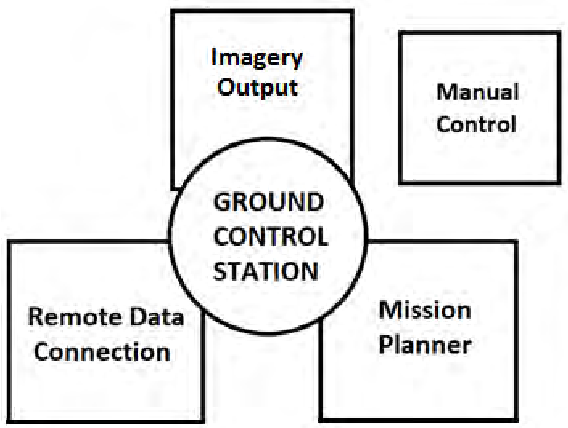


Fig. Ground Control Station Architecture

The basic architecture of the ground control station is defined in figure above. It is the level 1 diagram of GCS. Each module can be further specified into detailed architecture as follows:-

- Mission Planner
- Remote Data Connection

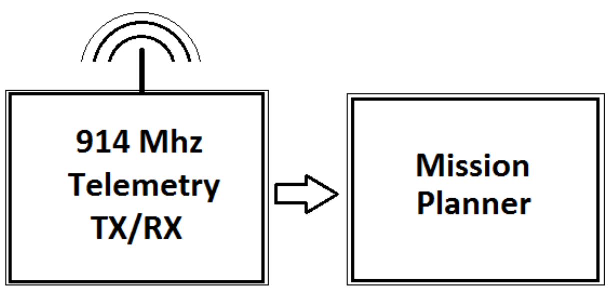


Fig. Mission Planner Architecture

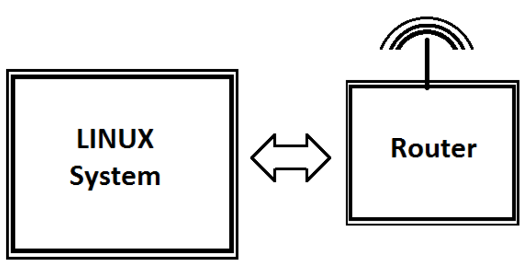


Fig. Remote Data Connection Architecture

6. TECHNICAL SPECIFICATIONS

The final description and technical specifications of the drone are as follows

Fixed Wing Glider

Due to numerous crashes the image of the refurbished plane is provided. We tend to provide the finishing touches in the looks at the end, before leaving for USA

Properties

- Longer flight time
- Can reach remote areas and travel longer distances
- Fast maneuvering
- Suitable for higher altitude flights
- Aerial mapping can be achieved at higher rates
- Good payload capacity
- Long Battery life

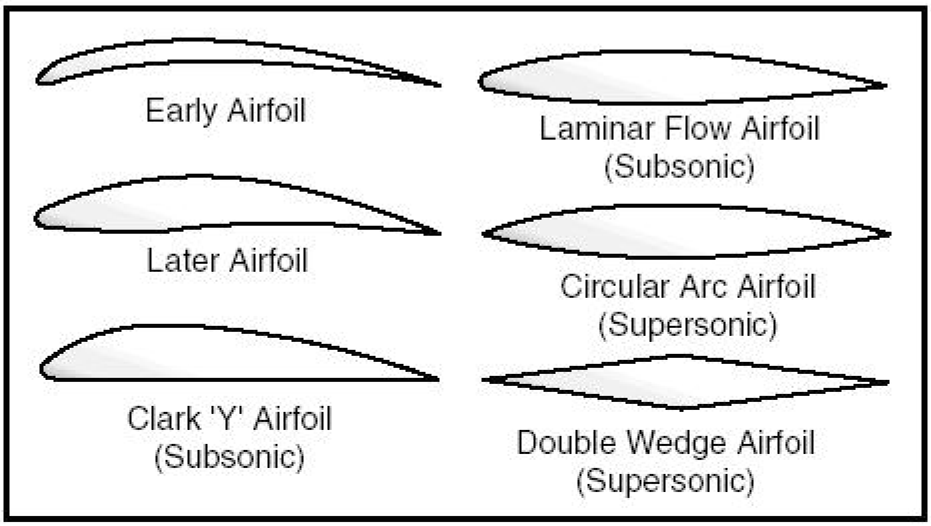
Airframe		HDPE Foam / Coroplast
Electronics	**BLDC Motors**	1000kv (X 2)
	ESCs	30 amps (X 2)
	LiPo Batteries	4000mah 4 cell 30C
	Propellers	10X4.5E (X 2)

7. TESTING AND EVALUATION

In order to evaluate the reliability of the various units and the system as a whole, field tests were organized on regular basis. Modularity of the system was maintained during the whole process, where the various units were examined separately and brought together to calibrate the system. This was done as follows

- **Airframe testing**

The aerodynamics and stability test of the airframes was done initially by subjecting the designs to hand launches, followed by motor propelled flights. A simple hand launch was enough to determine whether the airfoil design and the span of the wing were strong enough to support the total weight, and glide longer distances while reducing the battery consumption of the motor.



Frame	Properties	Problems
Fixed Wing	Normal structure	Low payload capacity
Flying Wing	Combined elevator and ailerons	Low payload capacity
Fixed Wing Glider	Larger wing span High payload capacity	Difficult to handle due to large wing span

- **Electronics and propulsion Testing**

With a tradeoff between high torque and power, and cost and weight, creating the ideal power supply and propulsion system turned out to be a major dilemma.

Electronics Combinations	Properties	Problems
Motor: 1000kv Propelor: 10X4.5 ESC: 30 amps LiPo: 12.6V 2.2A 3S	Low Cost High Availability	Lower payload capability Low Torque
Motor: 750kv Propelor: 12X10 ESC: 30 amps LiPo: 16.8V 4A 4S	High Payload capability High Torque	High Cost Low Availability

- **Manual Flight and range testing**

For the manual control of the aircraft we got our hands on two Tx/Rx combos viz Turnigy 9x and Avionics RCB 6i. While Turnigy 9x had 9 channel control as compared to 6 channels in RCB 6i, the receiver needed a ppm encoder to translate before communicating to the Pixhawk and had a very short range. RCB 6i on the other hand worked exceptionally well.

Fig Turnigy 9X and Avionics RCB 6i

- **Autopilot Testing**

After working for a year with HKPilot32, which turned out to be disastrous by proving unreliability midair, Pixhawk saved us a great deal. For about a year it has been extremely reliable and has piloted aircrafts that were impossible to fly manually.

Fig Pixhawk and HKPilot32

- **Payload Testing**

Payload consisted mainly of the Camera, Gimbal and the OBC Raspberry Pi. All of them were tested off the plane and on the plane midflight.

Fig GoPro Hero 3 and Turnigy ActionCam 1080p

The camera chosen by ZeppelinFC-26 is a **Turnigy HD Wi-Fi Action Cam** full HD video camera. The camera has a 170° wide-angle lens and has an image sensor of 12 mega pixels CMOS. This choice was based on the ability to control the camera and for its picture quality and high frame rate for a point and shoot camera. The significant features of our camera are:

• Popular form factor allowing it fit most GP3 camera gimbals

• Full 1080P HD video recording

• Wi-Fi connectivity allowing streaming of live video and wireless menu function access

• Integrated 1.5" LCD screen

• 170° wide-angle lens

• 12 mega pixels CMOS sensor

• Lightweight at only 58g with battery installed

• HDMI output for playback on other devices

• 4X digital zoom

• Removable 900mAh lithium battery (rechargeable)

• Up to 70 minutes battery life when recording in full 1080P HD

Fig Banana Pi and Raspberry Pi

Raspberry Pi B2+ was selected as it was easily available and cheap. Its features are as follows:

- A 900MHz quad-core ARM Cortex-A7 CPU
- 1GB RAM
- 4 USB ports
- 40 GPIO pins
- Full HDMI port
- Ethernet port
- Combined 3.5mm audio jack and composite video
- Camera interface (CSI)
- Display interface (DSI)
- Micro SD card slot
- VideoCore IV 3D graphics core

9. Conclusion

Zeppelin worked throughout the year to prepare a stable UAV that could meet the SUAS standards and provide highly precise payload support and maneuvering capabilities. Zeppelin will continue to test the systems up until the competition, responding to the lessons learned through the test flights. Zeppelin has designed, fabricated and tested an unmanned air system, using a systems engineering approach that is capable of successfully completing the 2016 competition mission objectives set forth by AUVSI. Based on that approach and numerous system tests, we feel confident that autonomous waypoint navigation, area search, manual target recognition and air drop task can be accomplished at the 2016 competition.