PORTLAND STATE UNIVERSITY
DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING

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TEAM 21

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UAV Landing Aid - Design Report

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Abstract

Integration of the SightLine Landing Aid for end users is problematic. Often drone operators want to just "plug in" a component and fly their mission. Installing software components is acceptable, but any requirement for programming is a barrier to entry or a complete show stopper. Various cables, power, and other electrical connectivity issues are also difficult for vehicle integrator. Rugged or at least robust mechanical enclosures, easy mounting, and environmental reliability are equally important. Lastly, choice of optical system (camera) for the greatest range has cause adoption delays in that it has been a decision left to the integrator. Recognizing the needs from the end-users, SightLine wants to develop a plug and play precision landing aid for UAVs and expect that this new project will be highly valuable to a wide range of multi-copter integrator.

Our solution to the problem involves: I. Selecting, and building a consumer level quad-copter that will be easily customizable for testing II. Designing a camera that will connect directly to the SightLine hardware, distribute power, and facilitate communication III. Research and development of documentation and software to meet plug and play expectations.

The selection, build, and testing of a custom quad-copter is a complicated task with many variables. GPS signal degradation made indoor flight tests impossible, and safe outdoor testing locations were hard to find. We did successfully build, and autonomously fly the Pixhawk4 controlled quad-copter using QGroundControl mission planning software. In the meantime, a camera for the SightLine hardware was designed utilizing an AR0134CS optical sensor. The camera board was also designed to provide power distribution, and facilitate communication between the Pixhawk 4 flight controller and the SightLine hardware.

Based on our project, QGroundControl demonstrated a great ability to control the quad-copter autonomously. QGroundControl provides the ability to fully control all quad-copter parameters and as well as setting up a mission. We have successfully flied the drone autonomously using QGroundControl includes takeoff, land, fly the mission, and return to land. The precision landing feature on QGroundControl is not very promising. For the simple function like takeoff and landing, the position between takeoff and land was about 1 meter. For the flying to a destination and return, the difference in position was 2 meter. Additionally, before doing the flight test, we also use Mission Planner to simulate the flight and learn how to control the quad-copter's parameters.

The limitation comes from both QGroundControl and SightLine hardware. Since SightLine hardware, or 1500-SLA-kit, is unable to talk with QGroundControl and as well as, we don't know if QGroundControl is capable of talking to SightLine hardware. There will be some work that SightLine needs to do with their hardware so it will be able to talk with QGroundControl.

The project is now divided into two parts. The first part is understand the Ground Control State software (QGroundControl) and hardware such as Pixhawk 4, and SLA1500CAM. The second part will emphasize in software and communication development. SightLine and our team has determined to leave the second part of the project for the future capstone team. With our achievements on this project, we have a strong belief that the future team will be successful in this project and future function development.

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1 Project Overview

1.1 Background

SightLine Applications has developed a precision visual landing algorithm that provides an excellent set of benefits:

- Works in degraded and denied GPS environments – Safety and reliability
- Reduces operator training and landing phase complexity.
- Provides detection functions for landing zone safety - detect people, animals, or objects from entering the landing zone
- Provides a rich set of telemetry for flight controllers. 30 Hz data with range, XY offsets, relative azimuth, etc.
- Supports landing on moving platforms - ground vehicles, marine.
- Is not impacted by bright sun or low light conditions.
- Can be used with Thermal (IR) cameras as well as visible (EO) cameras
- Effective range of operation (distance to target) only limited by the size of the landing pattern used

1.2 Problem Definition

Integration of the SightLine Landing Aid for end users is problematic for two main reasons:

1. Connectivity issues with a wide range of cameras.
2. Communication issues with a wide range of flight controller hardware and software.

Currently the end user selects a camera to be used with the SightLine processing hardware. A wide range of cameras must be supported, and custom AB boards must be designed for each one to interface with the SightLine hardware. Each of these AB boards can have cable, power, and electrical connectivity issues that are problematic for the end user. There is also a wide range of flight controller hardware and software, each with a myriad of different communication protocols. Installing software components to facilitate this communication is fine for the end user, but if any programming needs to be done this is usually a complete show stopper.

1.3 Solution

The proposed solution to these problems is to develop an all in one unit (SightLine Hardware w/Camera) with plug and play capabilities that can be directly connected to a consumer level flight controller. By doing so camera connectivity and selection problems are eliminated, and communication and software deployment are made much easier for the end user. We will build an off the shelf quad-copter with autonomous flight capabilities to test communication between current SightLine hardware, and our newly designed camera interface.

1.4 Project Management

The project is divided into three sections:

1. Choosing and building an "off the shelf" quad-copter that uses a Pixhawk 4 flight controller that can be used for testing
2. Designing a camera based on the On-Semi AR0134CS optical sensor that connects directly to the SightLine hardware, distributes power, and facilitates communication between the flight controller and SightLine hardware
3. Research and development of documentation and software installers to meet plug and play expectations using QGroundControl flight control and mission planning software

Insert Project Roles and Responsibilities here

1.4.1 Project Timeline

Tasks

Name	Begin date	End date
Statement of Work	1/7/19	1/20/19
1st draft of SOW	1/7/19	1/13/19
Complete SOW	1/14/19	1/20/19
Qgroundcontrol learning	1/7/19	1/20/19
Pixhawk 4 learning	1/14/19	2/3/19
Pixhawk 4 Learning	1/14/19	1/27/19
Working with Pixhawk 4	1/27/19	2/3/19
Quadcopter learning	1/21/19	2/3/19
Working with Quadcopter	1/21/19	2/3/19
Code wring	1/21/19	3/10/19
Learn from sample code	1/21/19	2/3/19
Start wring a new code and debug	2/4/19	3/10/19
Create a new schematic for AB board	1/28/19	3/17/19
Start drawing a schematic for AB board	1/28/19	2/17/19
Send schematic for manufacturing	2/18/19	3/3/19
Send BOM for order	2/18/19	3/3/19
Schematic layout	3/4/19	3/10/19
Schematic test and debug	3/4/19	3/17/19
Test and simulate indoor (Pixhawk 4 + Qground Control +Quadcopter)	1/21/19	3/3/19
1500 OEM testing	1/21/19	2/3/19
Hardware + simulation model using Qgroundcontrol	2/4/19	3/3/19
3D enclosure create	3/4/19	3/17/19

Tasks

Name	Begin date	End date
First demo	3/18/19	3/24/19
Test/Debug/Code writing/Complete Enclose	3/25/19	4/7/19
Second Demo	4/8/19	4/21/19
Third Demo	4/22/19	5/5/19
Complete design and Outdoor test	5/6/19	5/19/19
Generate all required documents/ Prepare presentation	5/20/19	6/2/19
Final project presentation at PSU	6/3/19	6/7/19

Figure 1: *Project Timeline*

Above is the project timeline which was created at the beginning of the Winter term. However, things have changed a lot during our capstone, and the timeline above is just for reference.

2 Results

2.1 Quad-copter

In this project, we used a DJI Flamewheel F450 as the core for our custom quad-copter design. The parts and accessories are indicated in figure below. The total quad-copter's cost is $989.29. In the end of the project, we successfully optimized the autonomous flight using QGroundControl. Therefore, the radio transmitter and its receiver were no longer necessary which brought the cost down to $728.3 for future experiments. The entire build as well as the instructions for setup, and using the battery charger can be found in the Standard Operating Procedures Document

With the 4S battery, the quad-copter has 15 minutes flying time. A rule of thumb for optimal takeoff weight for a quadcopter is 50-70% max thrust. The tuned propulsion system with the selected motors, ESC, battery, and propellers can provide a maximum thrust of 710 g/rotor with a recommended take off weight of 350 g/rotor. This gives an optimal takeoff weight of 1.4 kg, and a maximum thrust of 2.84 kg. Our estimated takeoff weight of 1.35 kg is 54.4% maximum thrust. Based on our experiment, the custom quad-copter has demonstrated safe and stable flights, and can be fully controlled by the Ground Control Station.

Project	Capstone Quadcopter	Sightline			
Hardware Revision	V				
Date	01/31/19				
Quantity	Description	Mfg	Weight (g)	Cost Per Item	Total Cost
1	DJI FLAMEWHEEL F450 ARF KIT	DJI	604.4	$229.00	$229.00
1	DJI FLAMEWHEEL LANDING GEAR (4 pcs)	DJI	60	$17.50	$17.50
1	FrSky Taranis X9D Plus 16-Channel 2.4ghz ACCST Radio Transmitter	FrSky	N/A	$229.00	$229.00
1	FrSky X4RSB 3/16CH Telemetry Receiver Full Range	FrSky	5.8	$31.99	$31.99
2	Gens ace 14.8V 5000mAh 45C 4S LiPo Battery Pack	Gens Ace	480	$64.99	$129.98
1	PIXHAWK 4 ADVANCED DEVELOPMENT KIT	HOLYBRO	200	$210.95	$210.95
1	Discharger 1S-6S Digital Battery Pack Charger	Tenergy	N/A	$54.99	$54.99
1	PIXHAWK 4 RADIO TELEMETRY KIT	HOLYBRO	15	$39.95	$39.95
1	XT-60 CONNECTORS MALE/FEMALE	MakerDoIt	12	$11.99	$11.99
1	Prop Guards for DJI Flamewheel	Summit Link	120	$19.95	$19.95
1	RAYCorp 9450 Self-Tightening (9.4x5) Propellers. 8 Pieces(4CW,	RAYCORP	N/A	$13.99	$13.99
		ESTIMATED WEIGHT (g)	1497.2	Total Cost	$989.29

Figure 2: *Quadcopter's parts and accessories*

Figure 3: *Custom Quadcopter*

2.2 Pixhawk 4

Pixhawk 4 is a flight controller made by Holybro and PX4. Pixhawk 4 is one of the modest flight controllers and has worked stably with number of autopilot softwares such as Qgroundcontrol and Mission Planner. Pixhawk 4 is our best choice for this project because of following reasons:

- Light weight - only 15.8g
- Multi options for communication protocol such as I^2C, CAN, and several SBUS.
- Built-in GPS and provide the port for external GPS
- Easy to setup with Qgroundcontrol
- Provide plug-and-play ability

Figure 4: *Pixhawk 4*

2.3 SLA1500CAM

The 1x1.5" SLA1500CAM utilizes the On-Semi AR0134CS, a monochrome 1/3-inch 1.2 Mp CMOS digital sensor with a 74MHz output. It connects seamlessly with the SightLine SLA1500OEM image processing hardware via a 50-pin Hirose DF12 connector. With a 5V input the SLA1500CAM converts and distributes the 3.3V, 2.8V, and 1.8V required for operation.

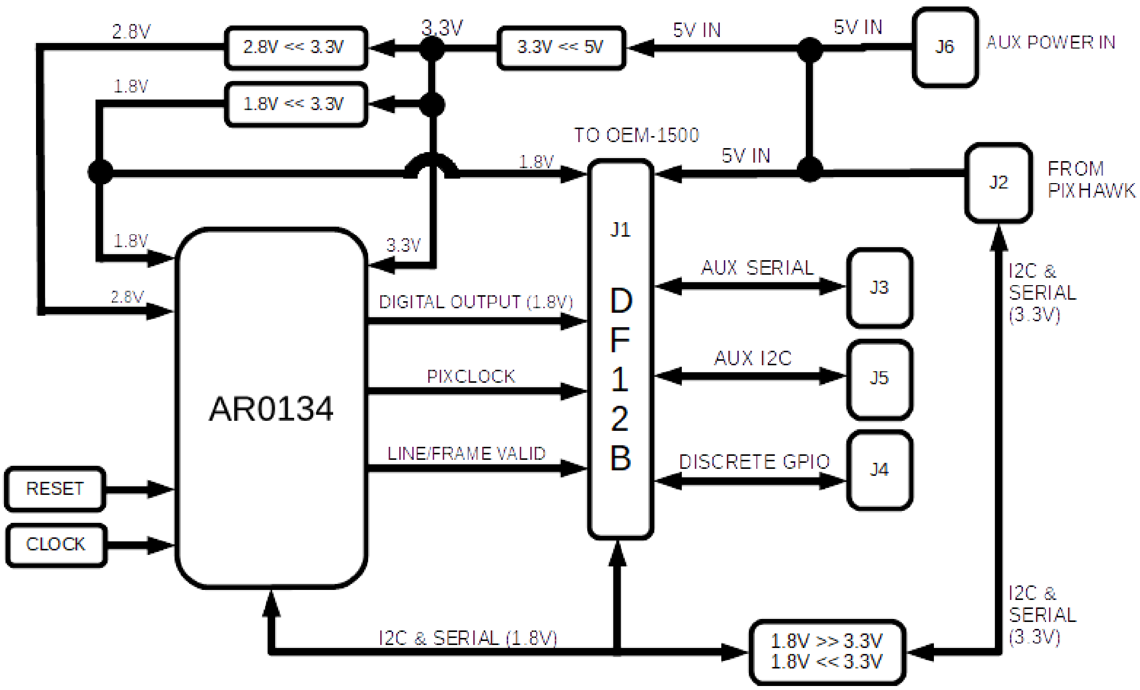

Figure 5: *Level 1 block diagram of SLA1500CAM REV 8.0*

The SLA1500CAM also provides bi-directional level translation for serial and I2C communication between the SightLine hardware, the flight controller, and the optical sensor. There are an additional four I/O ports using standard Molex and JST connectors:

- Power and serial communication for the flight controller
- Auxiliary I2C bus
- Auxiliary serial communication
- Auxiliary power in

The schematic and PCB were designed using EAGLE CAD 9.2.1. Many of the component footprints and devices were unavailable and were designed specifically for the project. This involved designing the device, footprint, schematic symbol, and linking material data to each device. The entire EAGLE library for the SLA1500CAM can be found in the GitHub repository.

Eagle Library for SLA1500CAM

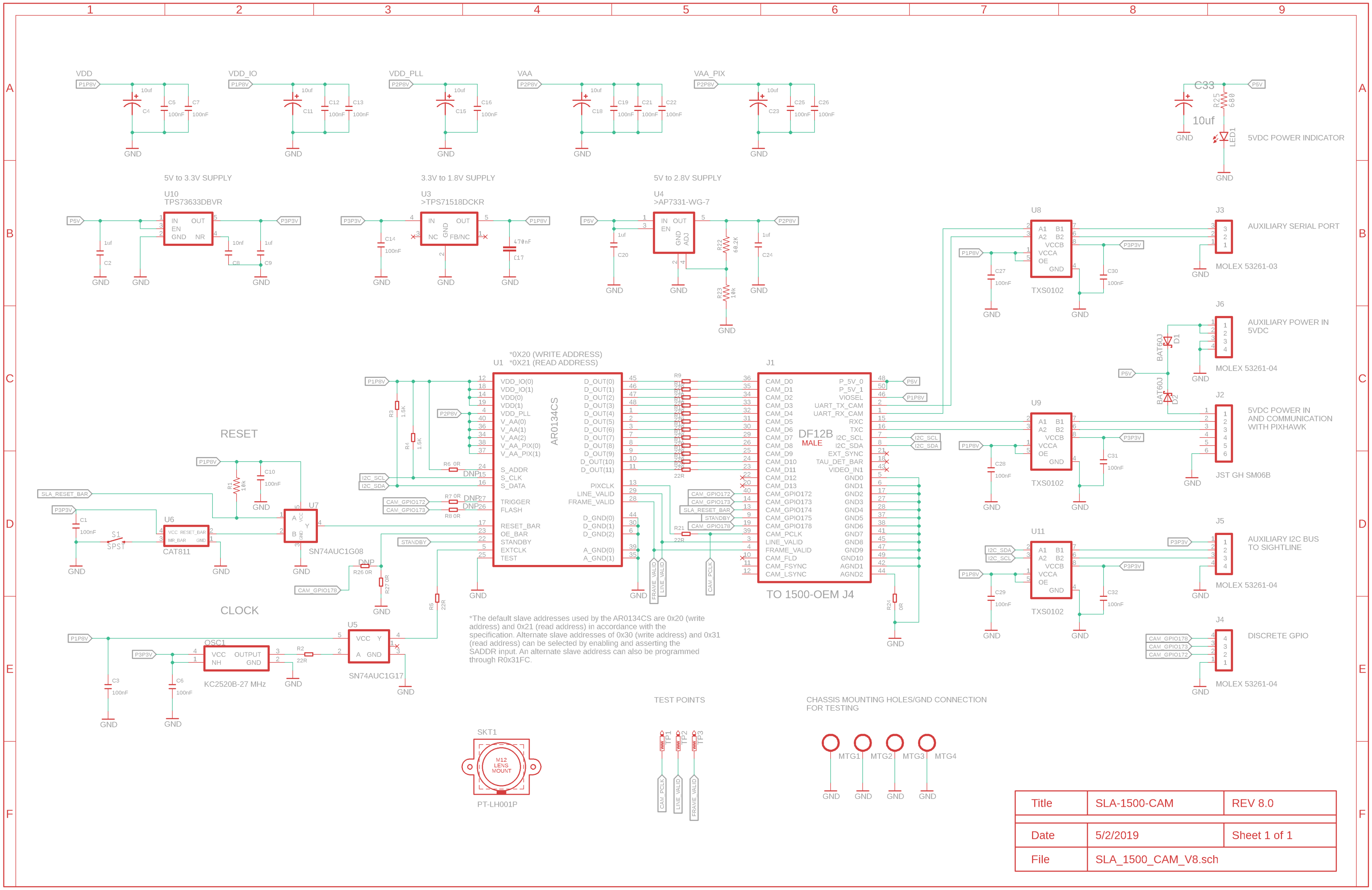

Figure 6: *SLA 1500 CAM REV 8.0 Schematic*

2.3.1 Connector Summary

LABEL	MFG PART NUMBER	FUNCTION	MATES WITH
J1	HIROSE DF12B-50DS-0.5V(86)	50-Pin Digital Connector, Connects Directly to OEM-1500 J4	HIROSE 1500-OEM J4 [DF12B(5.0)-50DP-0.5V(86)]
J2	JST SM06B-GH	5VDC Power, Serial and *I2C Communication With Pixhawk	JST GHR-06V-S
J3	MOLEX 53261-0371	Auxiliary Serial Communications for Sightline Debugging	MOLEX 51021-0300 / CAB-0302
J4	MOLEX 53261-0471	Discrete GPIO Lines from 1500-OEM	MOLEX 51021-0400 / CAB-0401
J5	MOLEX 53261-0471	Auxiliary I2C Bus to Sightline	MOLEX 51021-0400 / CAB-0401
J6	MOLEX 53261-0471	Auxiliary 5VDC Power In	MOLEX 51021-0400 / CAB-0401

Figure 7: *Connector summary for SLA1500CAM REV 8.0*

2.3.2 Connector J1

Digital camera, serial, power for SLA1500OEM
This connector is designed to mate with the SLA1500OEM J4 connector.

PIN	DESCRIPTION	SINGAL LEVEL	PIN	DESCRIPTION	SIGNAL LEVEL
1	UART RX CAM	VIOSEL	2	UART TX CAM	VIOSEL
3	LINE VALID	VIOSEL	4	FRAME VALID	VIOSEL
5	DGND		6	DGND	
7	12C SDA	VIOSEL	8	I2C SCL	VIOSEL
9	CAMGPIO 175	VIOSEL	10	NO CONNECT	
11	NO CONNECT		12	NO CONNECT	
13	CAMGPIO 174	VIOSEL	14	CAMGPIO 173	VIOSEL
15	RXC	VIOSEL	16	TXC	VIOSEL
17	DGND		18	NO CONNECT	
19	CAMGPIO 178	VIOSEL	20	NO CONNECT	
21	NO CONNECT		22	NO CONNECT	
23	CAM D11	VIOSEL	24	CAM D10	VIOSEL
25	CAM D9	VIOSEL	26	CAM D8	VIOSEL
27	DGND		28	DGND	
29	CAM D7	VIOSEL	30	CAM D6	VIOSEL
31	CAM D5	VIOSEL	32	CAM D4	VIOSEL
33	CAM D3	VIOSEL	34	CAM D2	VIOSEL
35	CAM D1	VIOSEL	36	CAM D0	VIOSEL
37	DGND		38	DGND	
39	CAM PCLK	VIOSEL	40	CAMGPIO 172	VIOSEL
41	DGND		42	AGND	
43	NO CONNECT		44	AGND	
45	DGND		46	VIOSEL	1.8V
47	DGND		48	POWER IN	5V
49	DGND		50	POWER IN	5V

Figure 8: *Connector summary for J1*

The GPIO connections for J1 are as follows:

- CAMGPIO 172 is connected to DNP Resistor R7 to AR0134 TRIGGER
- CAMGPIO 173 is connected to DNP Resistor R8 to AR0134 FLASH
- CAMGPIO 174 is connected to AR0134 RESET
- CAMGPIO 175 is connected to AR0134 STANDBY
- CAMGPIO 178 is connected to DNP resistor R26 to AR0134 OEBAR

AR0134 OEBAR is tied to ground with 0 OHM resistor R27.
***R27 MUST BE REMOVED BEFORE R26 IS INSTALLED AND CAMGPIO 178 CAN BE USED.**

2.3.3 Connector J2

5VDC Power in and serial communication with Pixhawk 4

PIN	DESCRIPTION	SIGNAL LEVEL
1	POWER IN	5V
2	TXC	3.3V
3	RXC	3.3V
4	NO CONNECT	
5	NO CONNECT	
6	GND	

Figure 9: *Connector summary for J2*

2.3.4 Connector J3

Auxiliary serial port

PIN	DESCRIPTION	SIGNAL LEVEL
1	GND	
2	RXC	3.3V
3	TXC	3.3V

Figure 10: *Connector summary for J3*

2.3.5 Connector J4

Discrete GPIO

PIN	DESCRIPTION	SIGNAL LEVEL
1	GND	
2	CAMGPIO 172	1.8V
3	CAMGPIO 173	1.8V
4	CAMGPIO 178	1.8V

Figure 11: *Connector summary for J4*

2.3.6 Connector J5

Auxiliary I2C bus to SightLine

PIN	DESCRIPTION	SIGNAL LEVEL
1	VSENSE	3.3V
2	I2C SDA	1.8V
3	I2C SCL	1.8V
4	GND	

Figure 12: *Connector summary for J5*

2.3.7 Optical Centering of AR0134

The optical center of the AR0134 in the ILCC48 package is at (-0.96mm,-2.0um) relative to the packages physical center as shown in the figure below from the AR0134 data sheet.

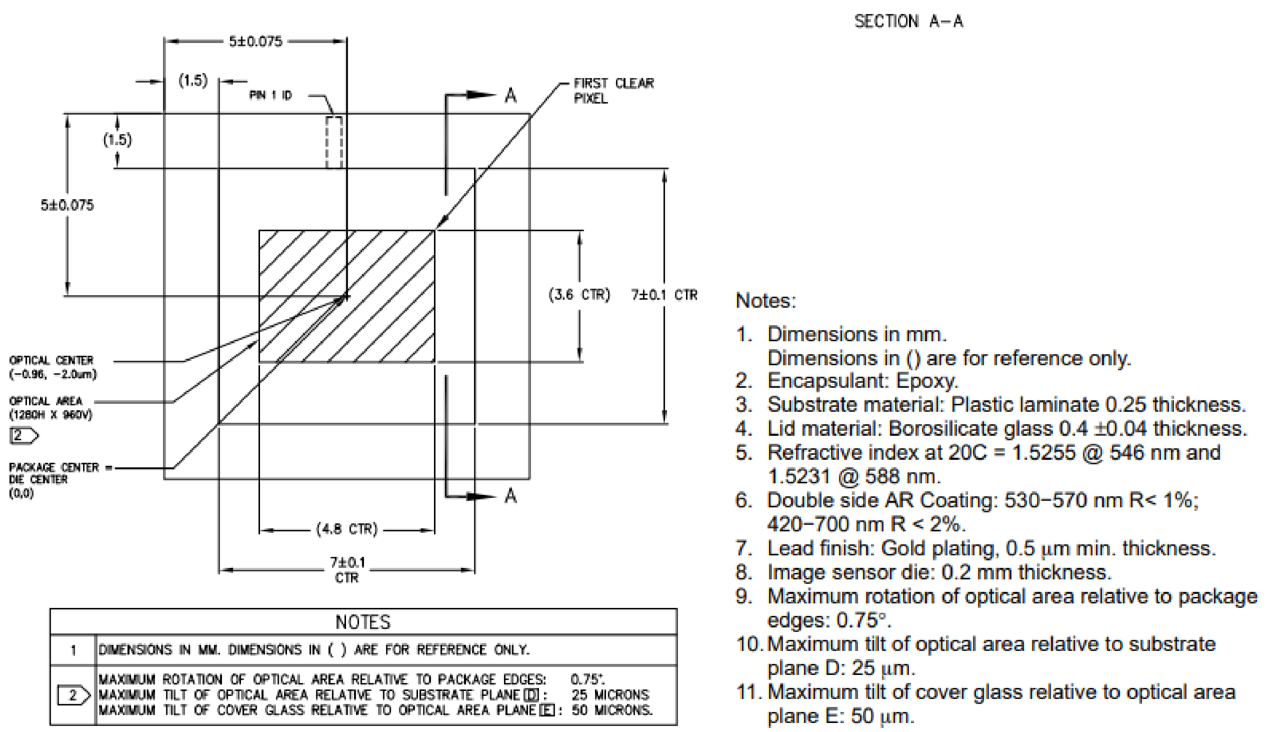

Figure 13: *Optical center for AR0134*

The AR0134 had to be offset (0.96mm, 2.0um) relative to the lens center on the layout as shown below.

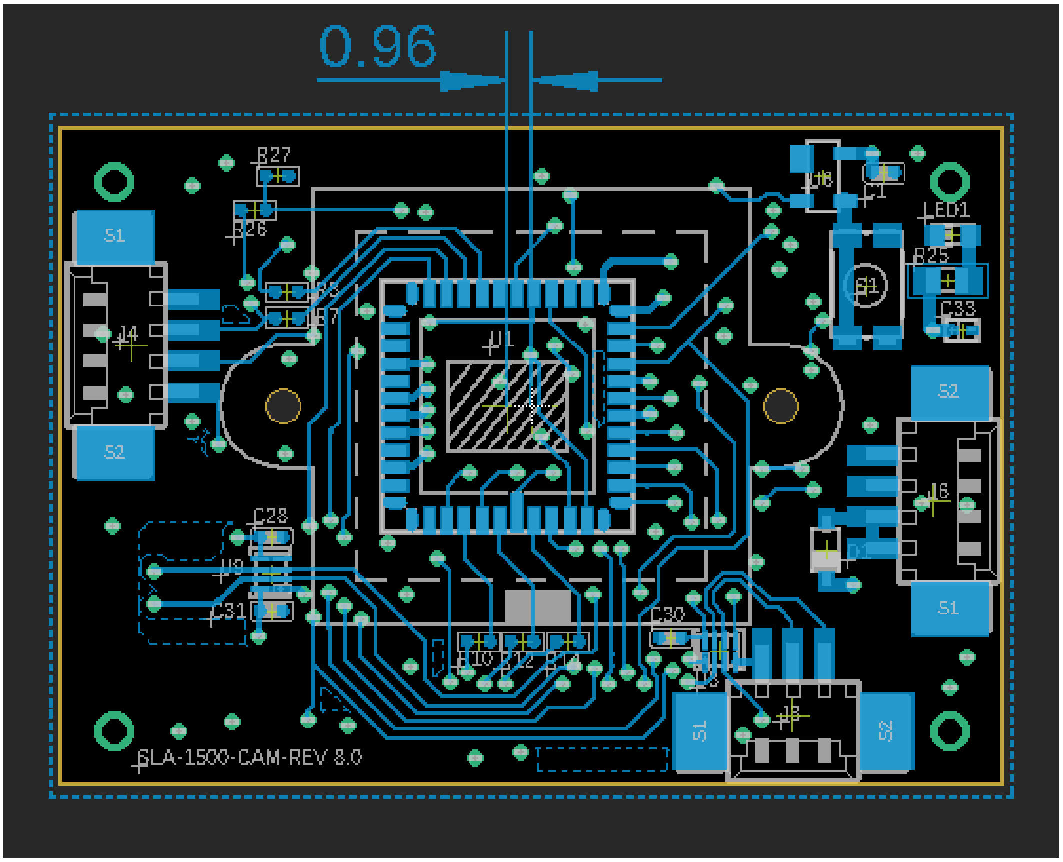

Figure 14: *Layout for SLA1500CAM showing optical center offset of AR0134*

2.3.8 Power Grid

Besides component placement and signal routing, the power grid for the SLA1500CAM was an integral and complex part of the design. Three voltage regulators were used to translate the 5V input to 3.3V, 2.8V, and 1.8V. There were also four TXS0102 bidirectional open gate level translators that had to be positioned next to 3.3V and 1.8V rails. The power grid is shown below.

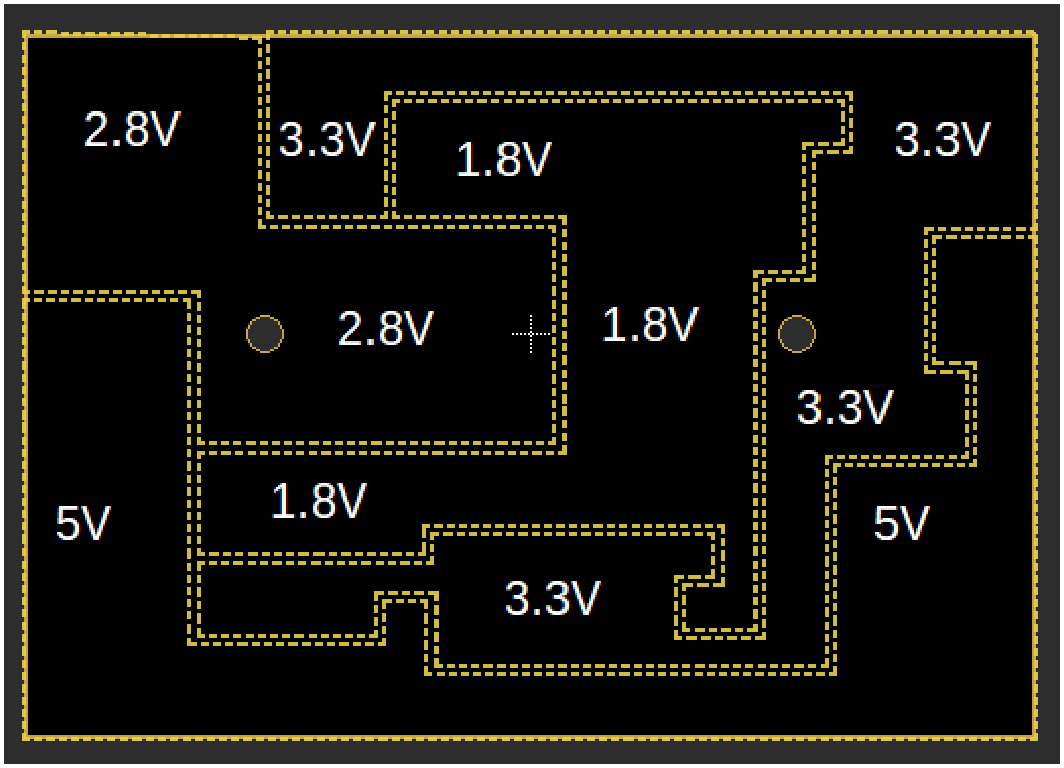

Figure 15: *SLA1500CAM power grid*

2.3.9 Test Points

In addition to the test points referenced in the SLA1500CAM Test Plan, there are three test points as listed below

TEST POINT	DESCRIPTION
1	CAM PCLK
2	LINE VALID
3	FRAME VALID

Figure 16: *SLA1500CAM test points*

2.3.10 Bill of Materials

PROJECT		SLA1500CAM			SIGHTLINE APPLICATIONS	
HARDWARE REVISION		REV 8.0				
DATE		5/2/2019				
Qty	**Reference**	**DNP**	**DESCRIPTION**	**MANF**	**MPN**	**SLPN**
1	U4		300mA, LOW QUIESCENT CURRENT, FAST TRANSIENT LOW DROPOUT LINEAR REGULATOR, ADJUSTABLE OUTPUT, 5V to 2.8V, 3.1 x 1.7mm	Diodes Incorporated	AP7331-WG-7	SL00740
1	U1		1/3-inch 1.2 Mp CMOS digital image sensor with an active-pixel array of 1280 (H) — 960 (V) ILCC48 package	On Semiconductor	AR0134CSSM00SPCA0-DPBR	
1	U6		IC, SUPERVISOR, MICROPROCESSOR POWER SUPPLY, 2.93V, ACTIVE LOW RESET, SOT143-4	On Semiconductor	CAT811STBI-GT3	
1	J1		DF12B-50DS-0.5V(86)SMT Hirose Male 50-pin connector	Hirose	537-0309-6 86	SL00297
1	OSC1		KC2520B-27MHZ OSC, CRYSTAL CLOCK, SMD, CMOS, 2.25V TO 3.63V, 4mA, 27.0000MHz, 2.5MM x 2.0MM	Kyocera	KC2520B27.0000C2GE00	
1	LED1		LED BLUE DIFFUSED 0603 SMD	OSRAM Opto Semiconductors Inc.	LB Q39E-N1OO-35-1	
1	U7		IC, AND GATE, SINGLE, 2 INPUT POSITIVE, SGL, SOT23-5	Texas Instruments	SN74AUC1G08DBVR	
1	U5		IC, BUFFER, SINGLE SCHMITT-TRIGGER, 9mA, 0.8V TO 2.7V, SOT23-5	Texas Instruments	SN74AUC1G17DBV	
1	U3		50-mA, 24-V, 3.2-Î¼A Supply Current Low-Dropout Linear Regulator in SC70 5-Pin Package, 3.3 to 1.8V, 2.15 x 1.4mm	Texas Instruments	TPS71518DCKR	SL00260
6	R6, R7, R8, R24, R26, R27	R6,R7,R8,R26	SMD-RES-0R-5%-1/16W(0402)	Yageo	RC0402JR-070RL	
2	R3, R4		SMD-RES-1.5K-5%-1/16W(0402)	Yageo	RC0402JR-071K5L	
21	C1, C3, C5, C6, C7, C10, C12, C13, C14, C16, C19, C21, C22, C25, C26, C27, C28, C29, C30, C31, C32		CERAMIC 100NF-10V-10%-X5R(0402)	Yageo	CC0402KRX5R6BB104	
2	R1, R23		SMD-RES-10KOHM-1%-1/10W(0603)	Yageo	RC0603FR-0710KL	
1	C8		CERAMIC-10NF-50V-10%-X7R(0402)	Yageo	CC0402KRX7R9BB103	
6	C4, C11, C15, C18, C23, C33		Tantalum Capacitors - Solid SMD 10uF 6.3V 20% 0402, 1.1x0.6x0.35mm	AVX	F980J106MUALZT	
4	C2, C9, C20, C24		CERAMIC-1UF-10V-10%-X5R(0402)	Yageo	CC0402KRX5R6BB105	
15	R2, R5, R9, R10, R11, R12, R13, R14, R15, R16, R17, R18, R19, R20, R21		SMD-RES-22R-1%-1/16W(0402)	Yageo	RC0402FR-0722RL	
1	C17		CERAMIC 470NF-6.3V-10%-X5R(0402)	Yageo	CC0402KRX5R5BB474	
1	R22		SMD-RES-62K-1%-1/10W(0603)	Yageo	RC0603FR-0762KL	
1	R25		SMD-RES-680R-1%-1/10W(0603)	Yageo	RC0603FR-07680RL	
2	D1, D2		DIODE SCHOTTKY 10V 3A SOD323	STMicroelectronics	BAT60JFILM	
1	J2		1.25 MM SIDE-ENTRY 6-PIN SMT CONNECTOR	JST	SM06B-GHS-TB	
1	J3		1.25mm Pitch PicoBlade Header, Surface Mount, Right-Angle, 3 Circuits, Tin (Sn) Plating	MOLEX	532610371	
3	J4, J5, J6		1.25mm Pitch PicoBlade Header, Surface Mount, Right-Angle, 4 Circuits, Tin (Sn) Plating	MOLEX	532610471	
1	SKT1		PT-LH001P Plastic M12 Lens Holder, 20mm Hole Spacing	M12 LENSES	PT-LH001P	
1	S1		Momentary Switch (Pushbutton) - SPST - SMD - 4.6X2.8MM	C&K	KMR221GLFS	
1	U10		Cap-Free, NMOS, 400-mA Low-Dropout Regulator with Reverse Current Protection 5.5 to 3.3V, SOT-23 5-pin, 2.9 x 1.6 mm	Texas Instruments	TPS73633DBVR	
3	U8, U9, U11		TXS0102 2-Bit Bidirectional Voltage-Level Translator for Open-Drain and Push-Pull Applications	Texas Instruments	TXS0102DQM	

Figure 17: *SLA1500CAM BOM REV 8.0*

2.4 Software

2.4.1 Qgroundcontrol

Qgroundcontrol is an open-source software which allows users/developers design and optimize their own unmanned aerial vehicle. The laptop that installs the Qgroundcontrol is called Ground Control Station (GCS). Qgroundcontrol allows users/ developers adjust and control every single parameter of the drone as well as set up a mission for the drone flying autonomously including take-off and precision landing. Qgroundcontrol is developed by PX4, and it's optimized to work best with Pixhawk family especially Pixhawk 4. By using a transmitter telemetry and a receiver telemetry, Qgroundcontrol can send the command to the Pixhawk 4 and then control the quadcopter wirelessly which provides a great opportunity to develop plug-and-play ability for quadcopter and Sightline SLA-1500-CAM.
Our project has proved that Qgroundcontrol can fully control and communicate with the quadcopter even when the quadcopter is up in the air.

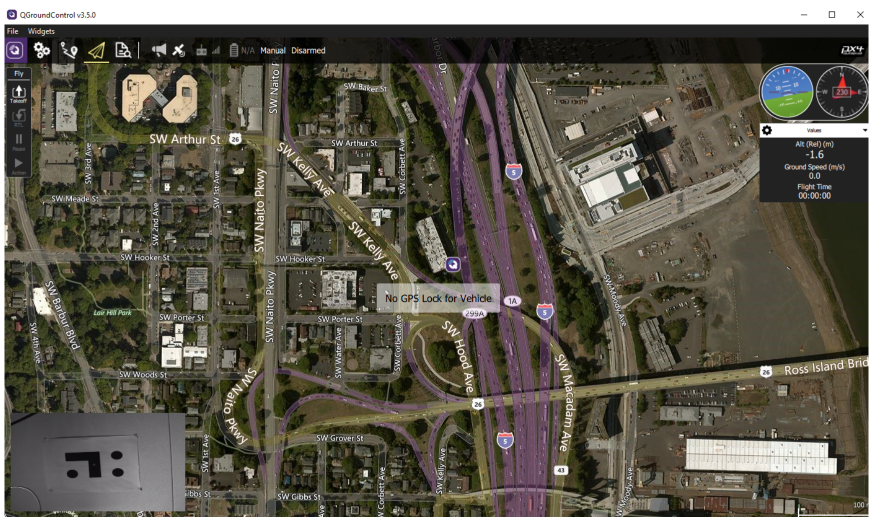

Figure 18: *Qgroundcontrol*

2.4.2 Mission Planner

Alternatively, Mission Planner is a autopilot software which is developed by Ardupilot team. Similar to Qgroundcontrol, Mission Planner provides a good way to control the drone autonomously as well as adjust the drone's parameters. In this project, the Mission Planner is used to simulate the drone's behavior virtually by using Software In The Loop (SITL) technique. The SITL technique is extremely helpful in understanding the drone's behaviors and how to control the drone wirelessly without crashing an actual drone. The simulation provides varieties of tools and command that can change the speed of drone, speed and direction of wind, precision landing, and flight mode.

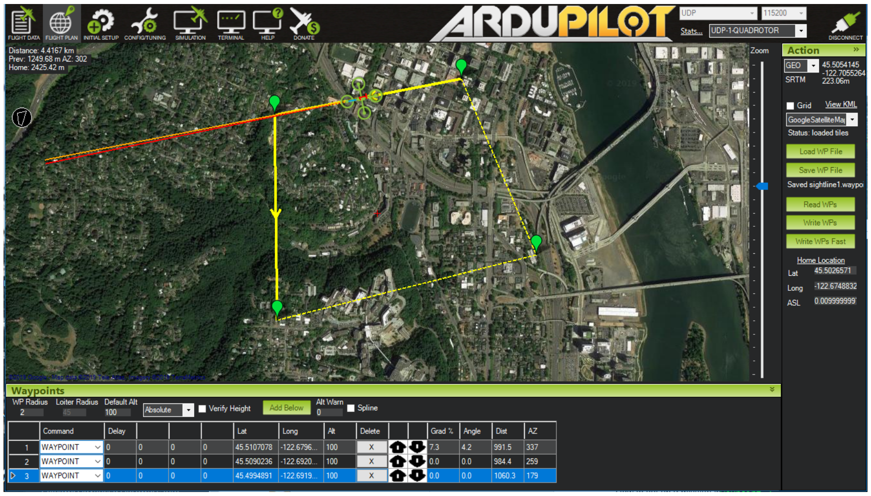

Figure 19: *Setup a mission in Mission Planner*

3 Conclusion/What's Left to do

Throughout the capstone project, we have gained a lot of experience which is not only academic experience but only real world experience, and how to deal with some problems in a team. On the project side, we have successfully developed the SLA-1500-CAM. However, due to manufacturing delay, we haven't had a chance to test the board yet. We have also gain insight into communication between Qgroundcontrol, Pixhawk4, and Sightline SLA-1500 kits.

We have successfully completed autonomous flight and landing with custom quadcopter with flight controller, Pixhawk4, and Qgroundcontrol. Importantly, we were able to record the video when the vehicle was up in the air by using SLA-1500 kits which promissingly provides the ability to develop plug-and-play feature in the future with SLA-1500-CAM, Qgroundcontrol and Pixhakw4.

However, The compability issues remain with Qgroundcontrol and Sightline hardware because Sightline SLA-1500 kits wasn't able to send the signal to Qgroundcontrol. Potentially, a new project will focus on software and communication between SLA-1500-CAM and Qgroundcontrol for a future team that is interested in drone communication protocols. With our achievements on this project, we believe that full integration of the SLA-1500-CAM with plug and play capabilities can be achieved.

4 References

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