CET CPET-563: Embedded Systems Design II **Dr. Kaputa**
Spring 2019
Final Project Description **Group Name:________________________________**

1. Introduction

This is the final project for ESD II which is the culmination of the curriculum capstone experience for the Computer Engineering Technology program. This project consists of two phases which are discussed below in detail. Due to the complex nature of the challenges, groups shall be formed that consist of either three or four individuals. You are encouraged to divide up the work between team members, however you are expected to understand and be able to discuss at a detailed level each member of your team's specific design implementation.

The design sub-systems as well as management tasks are listed below although this may not be an exhaustive list. It is recommended to have at least two team members work on each section to reduce the risk of a single point failure.

○ firmware	○ systems architecture
○ software	○ requirements development
○ graphical user interface	○ system and subsystem verification
○ motor control	○ program management [cost and schedule]
○ sensor feedback	○ risk register
○ control algorithm	○ documentation
○ computer vision	○ preliminary and critical design reviews

Each topic will be covering in depth during the course however it is the student's responsibility to ask poignant questions that will help teams achieve the highest possible score for the competitions.

2. Supplied Components

Your group will be provided with the below educational drone system. Make sure to take great care of your system as it is very expensive and there are no spares units. **The drone is locked inside the gimbal for safety purposes and is not to be removed during this course.** An image of the drone as well as all of the sub-components are listed below.

Drone containing:	
☐ Snickerdoodle SOM [Zynq 7020 SoC]	
☐ LEDs [3x]	
☐ EMAX 15 AMP ESCs [4x]	
☐ EMAX 4500 KV 1106 motors [4x]	
☐ Spektrum receiver	
☐ MPU9250 IMU	
☐ ADS1015 Analog to Digital Converter	
☐ MT9V034 Camera [752,480] RGB	
☐ BMI088 IMU [2x]	
☐ Turnigy 1000 mAh 2S battery [2x]	
☐ JTAG	
Turnigy battery charger	
Drone gimbal	
Spektrum transmitter	
Orange tennis ball	
Drone case	

3. Basic Requirements

These requirements are to be verified via test and demonstration and must be signed off by Dr. Kaputa. Upon signing off these requirements, the group will be allowed to install the props onto their drone.

Drone Shall:

- ☐ control motors via PWM technique
- ☐ be able to disable all motors via the receiver
- ☐ have three modes for the motors:
  - motors off, motors spinning slowly, motors active
- ☐ have three modes for the orange LED
  - turn on the green LED solid while the bus voltage is greater than 7.4 volts
  - blink the green LED at 1 Hz when the bus voltage is between 6.8 and 7.4 volts
  - blink the green LED at 5 Hz when the bus voltage is below 6.8 volts
- ☐ interface with the receiver via the provided code

Grading: 10 points total

Task	Earned Points	Possible Points
all requirements fulfilled		10
Total		**10**

Props are not to be used until the basic requirements are signed off below by Dr. Kaputa.

Signature: ______________________________ Date: ________________

4. Manual Navigation Demo

This demo proves out the basic functionality of the UAV platform. There is no competitive part to the manual demo. All three demonstrations should be done with a single system build and a single model run.

Drone Shall:

- ☐ operate in a completely manual fashion
- ☐ hold zero pitch and yaw after calibration [demonstration 1]
- ☐ return to zero after perturbation [demonstration 2]
- ☐ be controllable with the correct polarities via the supplied receiver [demonstration 3]
- ☐ not make use of the camera
- ☐ use bus voltage compensation in the forward loop
- ☐ make use of Simulink external mode for control laws
- ☐ have a GUI displaying diagnostic information such as PWM commands, bus voltage, attitude
- ☐ log data during all three demonstrations

Grading: 15 points total

Task	Earned Points	Possible Points
demonstration 1		3
demonstration 2		3
demonstration 3		3
GUI		3
all requirements fulfilled		3
Total		**15**

5. Autonomous Navigation Demo

This demo demonstrates the autonomous capabilities of the UAV platform. There is a competitive portion of this demo where groups will battle to have the smallest yaw error after five full yaw rotations. The camera will be used for this demo as a basic sensor but not for any visual servoing. The order of the demos is meant to follow along the basic development approach of moving from simple to complex in order to vet out the basic low level subcomponents.

Drone Shall:

- ☐ perform calibration in manual mode
- ☐ be able to toggle between manual and autonomous **modes** via receiver rate switch
  - HI => manual, LO => autonomous
- ☐ enter **autonomous navigation** mode via a "0" on the flight mode switch
- ☐ abort any autonomous routines upon flipping back to manual mode
- ☐ perform trajectory 1 immediately after entering autonomous mode [demonstration 1]

Pitch [deg]	Yaw [deg]	Relative Time [sec]
0	0	0
30	0	3
0	0	9
-30	0	12
0	0	15
0	90	18
0	0	21
0	-90	24
0	0	27

- ☐ immediately start trajectory 1 upon re-entering **autonomous navigation** mode
- ☐ perform trajectory 2, exactly 15 seconds after finishing trajectory 1 [demonstration 2]. During the 15 second interval the drone shall be manually zeroed in yaw based upon feedback from the camera relative to a green tennis ball. [manually move drone in yaw until camera reads 0 in yaw]

Pitch [deg]	Yaw [deg]	Relative Time [sec]
0	0	0
0	360 * 5	30

- ☐ not make use of the camera for rotation
- ☐ make use of camera for trajectory 2 calibration and final yaw location
- ☐ not make use of the magnetometer
- ☐ make use of Simulink external mode for control laws
- ☐ have a GUI displaying diagnostic information such as PWM commands, bus voltage, attitude
- ☐ log data during both demonstrations

Grading: 20 points total

Task	**Earned Points**	**Possible Points**
demonstration 1		5
demonstration 2 [solo]		5
demonstration 2 [competitive]		4
GUI		3
all requirements fulfilled		3
Total		**20**

6. Basic Tracking Demo

This demo puts together all components of the system to enable fully autonomous visual servoing.

Drone Shall:

- ☐ be able to toggle between manual and autonomous **modes** via receiver rate switch
  - HI => manual, LO => autonomous
- ☐ enter **basic tracking** mode via a "1" on the flight mode switch
- ☐ track an orange tennis ball via visual servoing
- ☐ blink the orange led when entering **basic tracking** mode
- ☐ turn the orange led solid when the ball has been detected
- ☐ make use of Simulink external mode for control laws
- ☐ have a GUI displaying diagnostic information as well as the real time video feed
- ☐ ball shall be held a distance between 1 and 4 meters away
- ☐ log data during both demonstrations

Grading: 25 points total

Task	**Earned Points**	**Possible Points**
ball detection [user demo]		5
visual servoing [user demo]		5
ball detection [watching TBD video]		3
visual servoing [watching TBD video]		3
GUI		6
all requirements fulfilled		3
Total		**25**

7. Advanced Tracking Demo

This demo is extra credit and adds a wow factor by enabling face tracking or pose estimation via April tags.

Drone Shall:

- ☐ be able to toggle between manual and autonomous **modes** via receiver rate switch
  - HI => manual, LO => autonomous
- ☐ enter **advanced tracking** mode via a "2" on the flight mode switch
- ☐ track a **face** or an **april tag**
- ☐ blink the blue led when entering **advanced tracking** mode
- ☐ turn the blue led solid when the face or april tag has been detected
- ☐ make use of Simulink external mode for control laws
- ☐ have a GUI displaying diagnostic information as well as the real time video feed
- ☐ face or april tag shall be held a distance between 1 and 4 meters away
- ☐ log data during both demonstrations

Grading: 10 bonus points total

Task	**Earned Points**	**Possible Points**
detection [user demo]		2
visual servoing [user demo]		2
detection [watching TBD video]		1
servoing [watching TBD video]		1
GUI		2
all requirements fulfilled		2
Total		**10**

8. Grading

The final project grade will be determined based upon the below chart

	Points
Manual Navigation Demo	15
Autonomous Navigation Demo	20
Basic Tracking Demo	25
Advanced Tracking Demo [bonus]	10
System Requirements Document + VCRM	10
Qualification Procedure and Report	10
Focus Area Tech Memo [individual grade]	15
Weekly financials [.5 pts per week]	5
Videos	Not required but highly recommended
Total	110

9. Deliverables

1	System requirements document + VCRM
2	Qualification procedure and report
3	focus area tech memo [state high level significance, block diagrams] [bring this to job interview]
4	formal presentation slides [PDR]
5	formal presentation slides [CDR]
6	Demonstration data packet containing plots of key parameters and signals during all demo runs
7	videos take during demonstrations

10. Tips

- Frontload your work on this project. Plan to finish at least 1 week ahead of time.

- See me to bless off your design before you go too far down the wrong path.

- Use version control.

- Meet at least weekly to keep all group members honest.

- follow Kaputa's rules to design by. **[Make it work, make it right, make it fast]**

11. Key Dates

PDR	10 am – 11:50 am in the ESD Lab on April 1st and April 3rd
Game Day	All day on April 27th [Imagine RIT]
CDR	8 am - 10:30 am in GOL 2690 on May 1st

12. WARNING

- **LiPo batteries can be very dangerous. Always store the battery in the fire proof bag and use with extreme caution. Never let a battery charge unattended.**

- **Drones can be very dangerous. Verify that the props are snugly attached to the drone and that the drone is snugly attached to the gimbal before each test flight. Never stick your fingers into the props even when the drone is powered off. Never remove the drone from the provided gimbal.**

13. Euler Angles

Yaw – [z axis]   [+ psi is compass heading]

Pitch – [y axis]   [+ theta is pitch nose up]

Roll – [x axis]   [+ phi is roll right wing down]

Accelerometer is opposite of direction traveled [- G when sitting]

x and y are position

u and v are velocities

Force [newtons] = mass [kg] * 9.8066 m/s^2

right wing down [+ wx]

nose up [+wy]

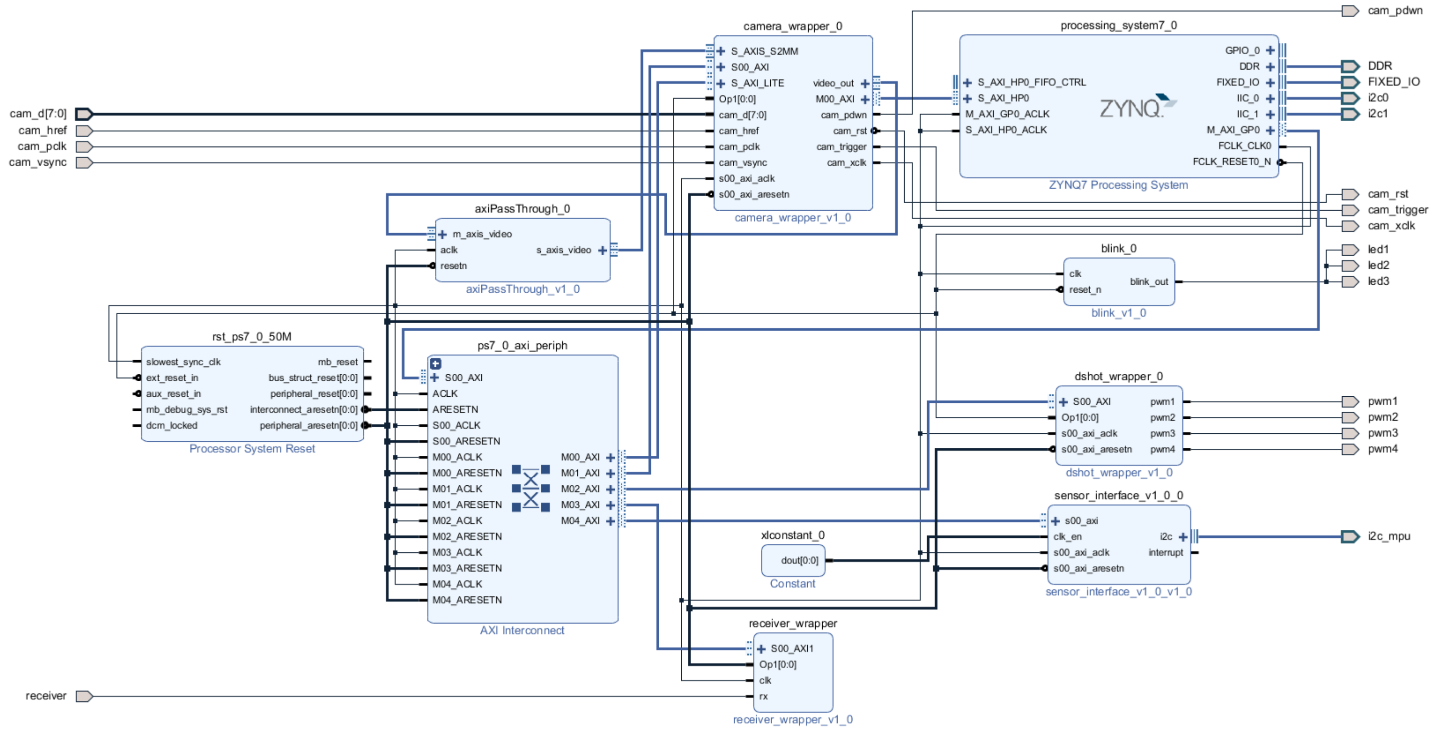
nose right [+wz]

14. Mechanical Conventions

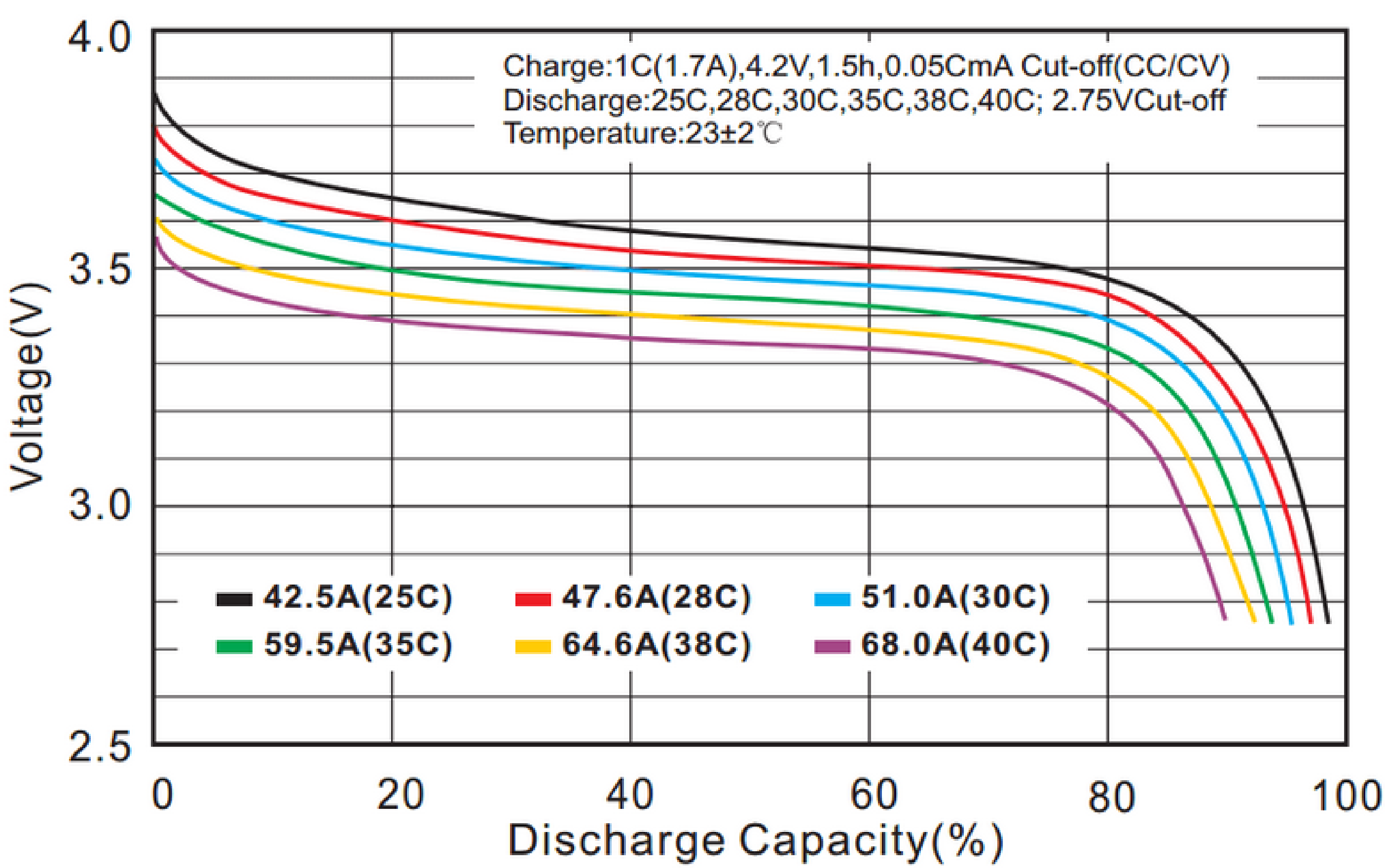
```
      +x fwd

1(cw)    2(ccw)
                   +y right
4(ccw)   3(cw)


     +z down
```

15. Joystick Conventions

16. Vivado Block Diagram



17. LiPo Discharge Curve



Memory Map [FPGA AXI]

ESC

Memory Address	Contents	Bits	Full Scale
0x43C00000	enable	1	0: off, 1: on
0x43C00004	CH1 Cmd	11	40,000 RPM
0x43C00008	CH2 Cmd	11	40,000 RPM
0x43C0000C	CH3 Cmd	11	40,000 RPM
0x43C00010	CH4 Cmd	11	40,000 RPM

Receiver

Memory Address	Contents	Bits	Full Scale
0x43C10000	CH1 Cmd	11	2048 counts
0x43C10004	CH2 Cmd	11	2048 counts
0x43C10008	CH3 Cmd	11	2048 counts
0x43C1000C	CH4 Cmd	11	2048 counts
0x43C10010	CH5 Cmd	11	2048 counts
0x43C10014	CH6 Cmd	11	2048 counts
0x43C10018	CH7 Cmd	11	2048 counts
0x43C1001C	CH8 Cmd	11	2048 counts
0x43C10020	CH9 Cmd	11	2048 counts

IMU 1 [MPU9250]

Memory Address	Contents	Bits	Full Scale
0x43C20000	X Acceleration [ax]	16	
0x43C20004	Y Acceleration [ay]	16	
0x43C20008	Z Acceleration [az]	16	
0x43C2000C	Roll Rotational Velocity [wx]	16	
0x43C20010	Pitch Rotational Velocity [wy]	16	
0x43C20014	Yaw Rotational Velocity [wz]	16	

LEDs

Memory Address	Contents	Bits	Full Scale
0x43C30000	LED 1 Enable	1	
0x43C30004	LED 1 Enable	1	
0x43C30008	LED 3 Enable	1	
0x43C3000C	LED 1 Period	32	
0x43C30010	LED 2 Period	32	
0x43C30014	LED 3 Period	32	
0x43C30018	LED 1 Duty	32	
0x43C3001C	LED 2 Duty	32	
0x43C30020	LED 3 Duty	32	

Memory Map [OCM AXI]

Optitrack

Memory Address	Contents	Bits	Full Scale
0xFFFC0000	x	32	float
0xFFFC0004	y	32	float
0xFFFC0008	z	32	float
0xFFFC000c	ui	32	float
0xFFFC0010	vi	32	float
0xFFFC0014	wi	32	float
0xFFFC0018	qx	32	float
0xFFFC001c	qy	32	float
0xFFFC0020	qz	32	float
0xFFFC0024	qw	32	float
0xFFFC0028	time	32	float

Camera

Memory Address	Contents	Bits	Full Scale
0xFFFC1000	X		
0xFFFC1004	Y		
0xFFFC1008	Z		
0xFFFC100C	pitch		
0xFFFC1010	roll		
0xFFFC1014	yaw		

ADC

Memory Address	Contents	Bits	Full Scale
0xFFFC2000	Bus Voltage		