ECE 416: Senior Design Project II
Comprehensive Design Review

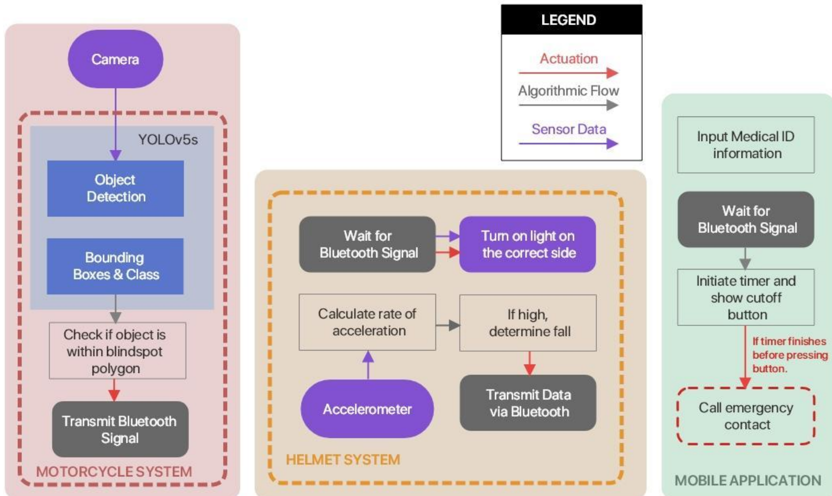
Handout

Team 21
Siddhanta Shreshtha, Dhruv Vikram Krishna, Paige Wadas, Jeff Wang

Table of Contents

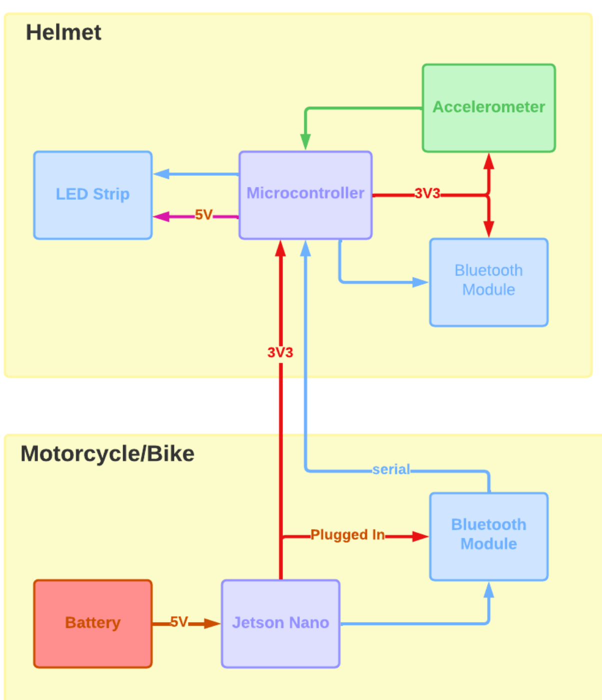
System Design

Software



Hardware

For CDR:



Power Considerations

Helmet

- PCB power consumption, calculator from component specifications
  - Absolute maximum: 1.85A – 7.73W
    - 3.3V: 1.13A – 3.73W
    - 5V: 800mA – 4W
  - Typical: 218.38mA – 1.07W
    - 3.3V: 18.38mA – 60.65mW
    - 5V: 200mA – 1W
  - Power conversion from 5V to 3.3V
    - DC/DC converter that provides 91-93% efficiency
      - Maximum output is 15W, for 3Vcc components to consume
- Battery
  - Rechargeable LiPo 5V 2A, 5Ah
  - Life calculated from component specifications:
    - Minimum: 4hr 25min
    - Typical: 22hr 53min

Motorcycle

- Jeston power consumption, calculated from testing
  - Maximum: 4A – 20W

Specifications

Bluetooth

- **If a vehicle is detected in the blind spot of the motorcycle, LEDs will be used to notify the rider on the correct side of the object detected – left or right or both.**
    - *Verification*: Demonstration
- **If a vehicle is detected in the blind spot of the motorcycle, color LEDs will change to indicate how close the vehicle/object is to the motorcycle.**
    - *Verification*: Demonstration
- **The blind spot detection algorithm will process at least 10 frames per second.**
    - ***<u>Justification</u>***: The system will be sufficient to detect vehicles moving upto 200 mph. To travel 31.5 ft (length of car + blindspot area) at 200 mph, it takes 0.108 seconds.
        - This means that the FPS > 1/0.108

          FPS > 9.25
        - Therefore, the minimum FPS to cover the top speeds of some of the fastest consumer vehicles is 10.
        - Note: this is assuming that at the end of the previous frame, the vehicle is at the edge of the blindspot, therefore this calculates the minimum FPS required for the <u>worst</u> case scenario.
    - *Verification*: This was verified by measuring the total time taken to process 25 minutes of video and dividing by the number of frames processed. The algorithm achieved 10.56 FPS.
- **The blind spot detection system must detect all vehicles within the blind spot region with a detection accuracy of at least 91%.**
    - ***<u>Justification</u>:*** The balancing of object-detection accuracy vs processing speed is what we took into consideration, while adjusting our system to meet these specs.
        - We can pick a Yolo model with more layers to increase the accuracy, but the processing speed will not give the required FPS.
    - A popular car blind spot detection system (BLIS) has detection accuracy of 91%. We used this to base our specification.
        - Source: C. T. Chen and Y. S. Chen, "Real-time approaching vehicle detection in blind-spot area," 2009 12th International IEEE Conference on Intelligent Transportation Systems, 2009, pp. 1-6, doi: 10.1109/ITSC.2009.5309876.

- *Verification:* We conducted a drive test and recorded the detection outputs and video inputs of the system. Selected 100 frames and compared detections of algorithm versus actual presence of vehicle in blindspot (manually). Results are as follows:
True Positives	True Negatives	False Positives	False Negatives
112	76	9	3
    - Accuracy = (TP+TN)/(TP+TN+FP+FN)
      = (112+76)/(112+76+9+3)
      = 94%
    - Note: Since 2 detections are possible per frame (left and right), there are more detections than number of frames.

- **The blind spot detection system must identify the user of dangerous vehicles in the blindspot in highway scenarios, adjacent lanes and behind.**
    - *Justification*: During urban driving, motorcycles weave in between vehicles and parked cars - which would lead to a lot of false positives.
        - As a result, we assume a highway driving scenario.
        - Highway motorcycle accidents account for 91% of fatal motorcycle accidents.
            - Source: *2019 data: Passenger vehicles - crashstats.nhtsa.dot.gov*. (n.d.). Retrieved March 9, 2022, from https://crashstats.nhtsa.dot.gov/Api/Public/Publication/813152
    - *Verification*: Demonstration during demo and demo test video
        - Source of Blindspot Location: M S M Hashim et al 2019 IOP Conf. Ser.: Mater. Sci. Eng. 670 012075 doi:10.1088/1757-899X/670/1/012075

Blindspot Detection

- **If a vehicle is detected in the blind spot of the motorcycle, LEDs will be used to notify the rider on the correct side of the object detected – left or right or both.**
    - *Verification*: Demonstration
- **If a vehicle is detected in the blind spot of the motorcycle, color LEDs will change to indicate how close the vehicle/object is to the motorcycle.**
    - *Verification*: Demonstration
- **The blind spot detection algorithm will process at least 10 frames per second.**

- *Justification*: The system will be sufficient to detect vehicles moving upto 200 mph. To travel 31.5 ft (length of car + blindspot area) at 200 mph, it takes 0.108 seconds.
  - This means that the FPS > 1/0.108

    FPS > 9.25
  - Therefore, the minimum FPS to cover the top speeds of some of the fastest consumer vehicles is 10.
  - Note: this is assuming that at the end of the previous frame, the vehicle is at the edge of the blindspot, therefore this calculates the minimum FPS required for the worst case scenario.
- *Verification*: This was verified by measuring the total time taken to process 25 minutes of video and dividing by the number of frames processed. The algorithm achieved 10.56 FPS.

- **The blind spot detection system must detect all vehicles within the blind spot region with a detection accuracy of at least 91%.**
  - *Justification:* The balancing of object-detection accuracy vs processing speed is what we took into consideration, while adjusting our system to meet these specs.
    - We can pick a Yolo model with more layers to increase the accuracy, but the processing speed will not give the required FPS.
  - A popular car blind spot detection system (BLIS) has detection accuracy of 91%. We used this to base our specification.
    - Source: C. T. Chen and Y. S. Chen, "Real-time approaching vehicle detection in blind-spot area," 2009 12th International IEEE Conference on Intelligent Transportation Systems, 2009, pp. 1-6, doi: 10.1109/ITSC.2009.5309876.
  - *Verification:* We conducted a drive test and recorded the detection outputs and video inputs of the system. Selected 100 frames and compared detections of algorithm versus actual presence of vehicle in blindspot (manually). Results are as follows:
    -

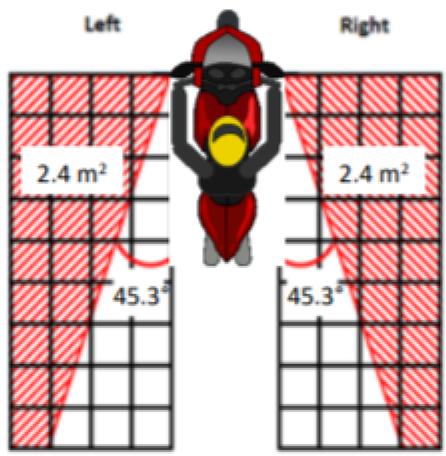
True Positives	True Negatives	False Positives	False Negatives
112	76	9	3

    - Accuracy = (TP+TN)/(TP+TN+FP+FN)

      = (112+76)/(112+76+9+3)

      = 94%
    - Note: Since 2 detections are possible per frame (left and right), there are more detections than number of frames.

- **The blind spot detection system must identify the user of dangerous vehicles in the blindspot in highway scenarios, adjacent lanes and behind.**
    - *Justification*: During urban driving, motorcycles weave in between vehicles and parked cars - which would lead to a lot of false positives.
        - As a result, we assume a highway driving scenario.
        - Highway motorcycle accidents account for 91% of fatal motorcycle accidents.
            - Source: *2019 data: Passenger vehicles - crashstats.nhtsa.dot.gov*. (n.d.). Retrieved March 9, 2022, from https://crashstats.nhtsa.dot.gov/Api/Public/Publication/813152
    - *Verification*: Demonstration during demo and demo test video



- Source of Blindspot Location: M S M Hashim et al 2019 IOP Conf. Ser.: Mater. Sci. Eng. 670 012075 doi:10.1088/1757-899X/670/1/012075

Fall Detection

- **The true fall detection rate for all 4 types [link] of falls should be no less than 93% [link] with no more than 10% error margin false fall detection for each type of fall.**
    - *Justification:* There are 4 types of common falls relating to motorcyclists in the professional setting that are outlined in papers that look for the correlation between the type of fall and injury location/severity link. It is important for the system to accurately detect falls in order to ensure the safety of the rider.

- o Observational Study Vital and Clinical Signs Motorcycle Accident on a Racetrack: Data from 104 motorcycle crashes were analyzed. Lowsider crashes represented 67 (68%) accidents, highsider crashes accounted for 20 (20%)
- o Observational Study Vital and Clinical Signs Motorcycle Accident on a Racetrack: There were 78 crashes: 58 lowsides, 13 highsides
- o Automatic Fall Detection using Smartphone: Low detection threshold 8.0 High 17.3. 93% true detection rate
  - *Test Verification:* We tested 120 total fall scenarios with 30 falls for left and right lowside and highside crashes. Lowside falls (68% link) were tested at ~20° (average lean angle link) with highside falls (20% link)at 90°. The four types of falls, we found that the total percentage of false detection (fall occurred, system did not recognize) to be 6.67% with left high and low side falls having the most percentage of false positives with 9% and 13% respectively (right high with 3.33% and right low with 0%). 112 crashes detected, mean -16.30; minimum -26.82 and maximum -6.02.
  - -16.304375 (95% CI -17.2 to -15.4). Margin of Error: 0.925 "With 95% confidence the population mean is between -17.2 and -15.4, based on 112 samples."

- **If a fall is detected, LEDs and phone app will be used to notify the rider.**
  - The system must be quick and robust when detecting falls to ensure the rider's safety. The system must be quick to detect falls so that it can contact emergency services as soon as it recognizes the rider requires medical attention. Apple's implementation for fall detection for their apple watches detects fall when the user is imobile for one minute and then begins a 30 second countdown [Link]. In our case the accelerometer on the helmet is able to recognize instantaneous acceleration thus the time required must be lower.
    - *Verification:* Demonstration

Hardware

Helmet

- **PCB size does not exceed 3.5"x3.5"**
  - *Justification*: Model needs to be compact and light to fit compactly on the helmet
  - *Verification*: Inspection
    - Actual is 2.66" x 3.12"
- **System does not consume more over 2A**
  - *Justification*: To function best for longevity and to make it easier for the user to recharge the device less often.

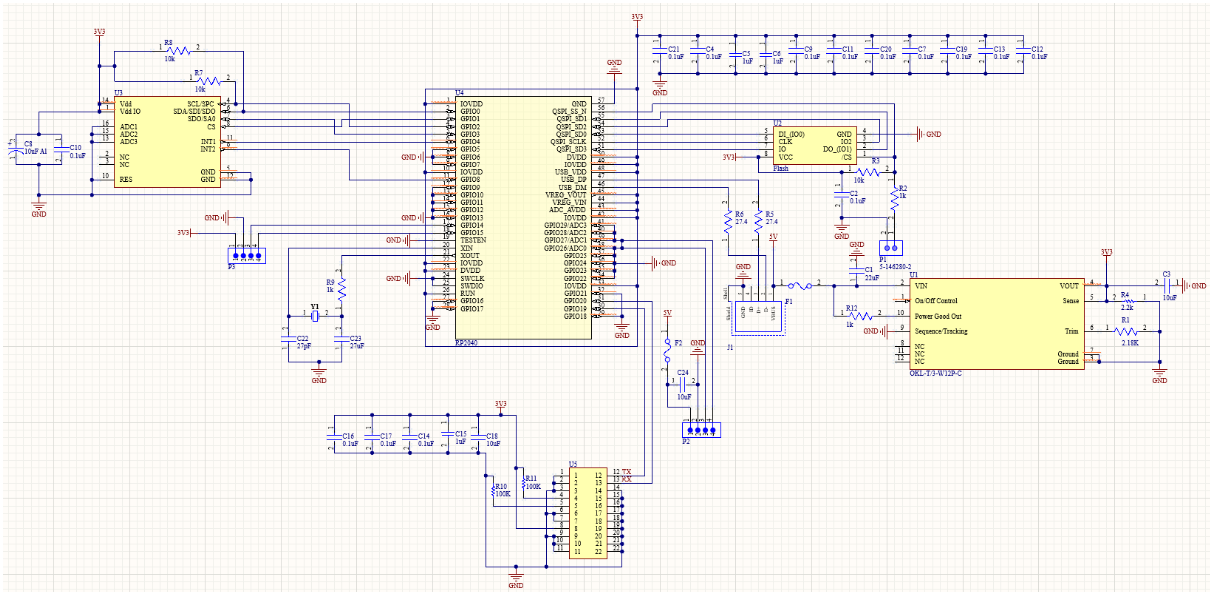
    - *Verification*: Test and Analysis
        - Calculated from the datasheets with the various voltages used, the system's absolute max should test to be 1.85A
- **System will last for at least 2hrs**
    - *Justification*: The system needs to have longevity as a mobile device so the user does not need to constantly recharge the helmet
    - *Verification*: Test and Analysis
        - Calculated from the datasheets and battery(LiPo 5V 2A, 5Ah) the minimum is 4 hr 25 min

Motorcycle

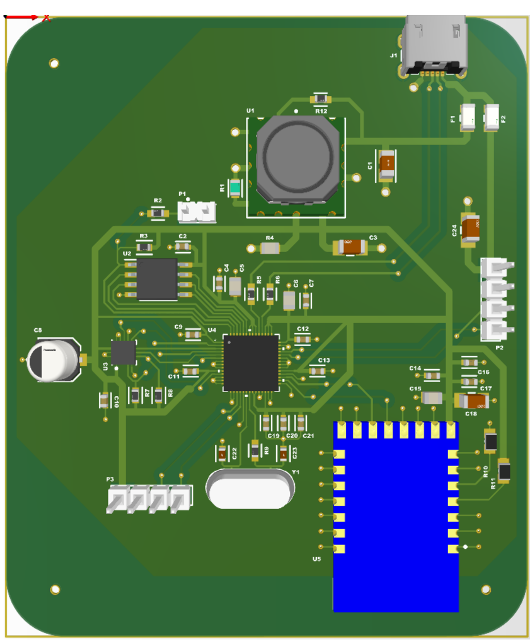
- Power consumption is within range for a motorcycle port to use as the external 5V power source
    - *Justification*: Needs to be able to work with most motorcycles so that the user can effectively use the device without needing to get an additional power source
    - *Verification*: Inspection

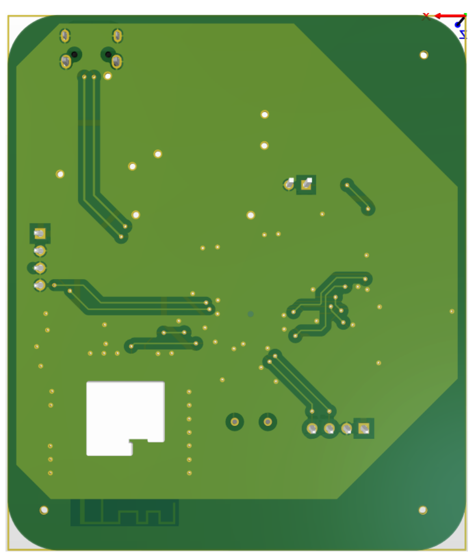
PCB

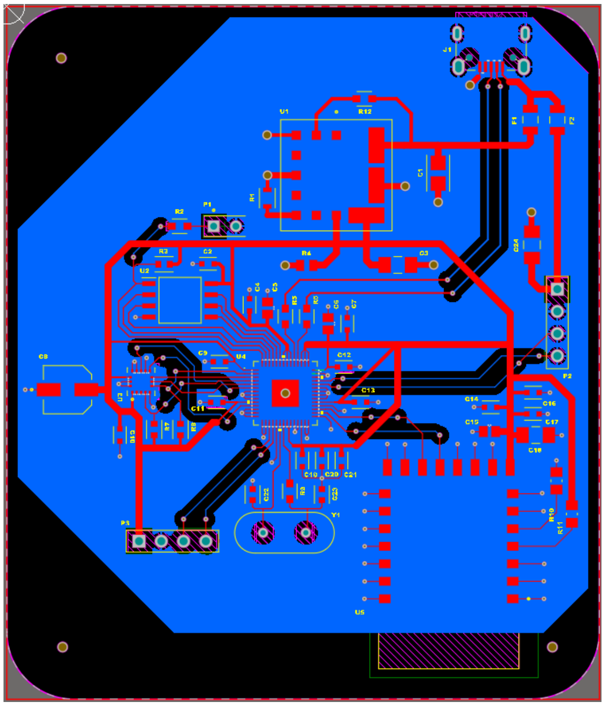
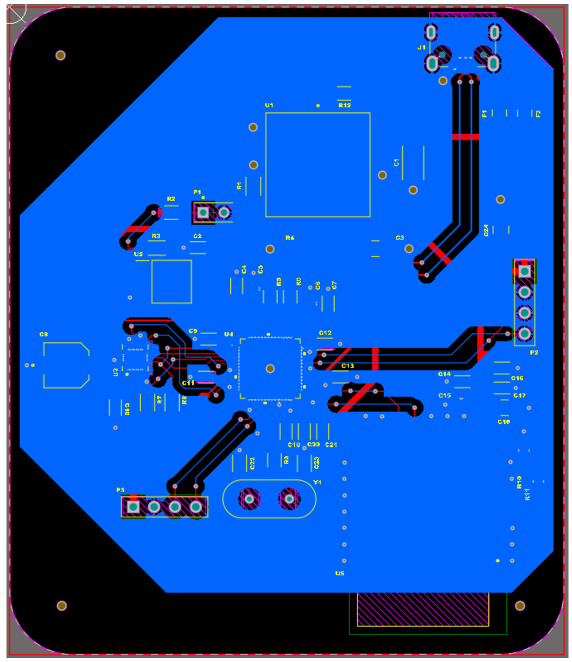
Schematic



Board Layout





BOM

Item	Part Number			Cost	Quantity Needed	Quantity Ordered
External						
Ambient Light Sensor	BH1750FVI-TR			$4.50	1	1
Light System		DotStar LED Strip		$19.95	1	1
Helmet				$60.00	1	1
Battery		LiPo 5V 2A 5000mAh		$0.00	1	1
				$84.45		
PCB						
U1	OKL-T/3-W12N-C	DC/DC Converter		$6.20	1	3
U2	W25Q128JVSIQ	Flash Memory		$1.88	1	2
U3	LIS3DHTR	Accelerometer		$4.95	1	2
U4	RP2040	Microcontroller		$1.00	1	3
U5	EMB1061 (113990637)	Bluetooth		$4.00	1	3
Y1	FOXSLF/120-20	Crystal		$0.35	1	5
F1,F2	SF-1206HV10M-2	Fuses		$0.93	2	5
C1	1206YD226MAT2A	22uF 1206		$0.46	1	10
C2, C4, C7, C9, C10, C11, C12, C13, C14, C16, C17, C19, C20, C21	C0603C104K5RAC3121	0.1uF 0603		$0.09	14	20
C3, C18, C24	C1206C106K4RACTU	10uF 1206		$0.25	3	10
C5, C6, C15	C0805X105K8RAC7210	1uF 0805		$0.75	3	10
C8	EDK106M035A9DAA	10uF Aluminum Electrolytic Cap		$0.34	1	5
C22, C23	C0603C270J3HACTU	27pF 0603		$0.04	2	10
R1	RT0805BRD072K18L	2.18K Ohm 0805		$0.43	1	5
R2, R9, R12	CHP0603AFX-1001ELF	1K Ohm 0603		$0.54	3	5
R3, R7, R8	RCA060310K0FKEAHP	10K Ohm 0603		$0.30	3	6
R4	WCR0805-2K2FI	2.2K Ohm 0805		$0.10	1	5
R5, R6	PCF0603R-27K4BT1	27.4K 0603		$0.53	2	5
R10, R11	CPF0805B100KE	100K Ohm 0805		$0.51	2	5
P1, P2, P3		Thu-hole male pin headers		$0.00	3	--
J1		USB Type-B female header		$0.00	1	--

FPR

Deliverables

- Refurbished website
- Built and functioning custom PCB
- Helmet and Motorcycle components mounted in compact custom enclosures
- Proximity detection implemented for at least 2 ranges
- Luminosity of LEDs determined by light sensor
- Wireless bluetooth connection from motorcycle to helmet
- Refurbished app
- GPS tracking for emergency services alert on app
- Implementation of API for calling emergency services

Budget

Item	Cost	Quantity	Total
Motorcycle:			
HQ Camera	$50.00	1	$50.00
Wide Angle Lens	$25.00	1	$25.00
Accelerometer & Gyroscope (MEMS)	$6.95	1	$6.95
Raspberry Pi 3 A+	$25.00	1	$25.00
USB V4.0 Bluetooth Adapter	$13.95	1	$13.95
		M Subtotal	$120.90
Item	Cost	Quantity	Total
Helmet			
Light Sensor	$4.50	1	$4.50
Accelerometer	$4.95	1	$4.95
Raspberry Pi Zero W	$14.00	1	$14.00
SD Card	$9.99	1	$9.99
LED RGB Strip NeoPixel	$17.95	1	$17.95
Level Shifter	$3.95	3	$11.85
Helmet	$69.99	1	$69.99
Dot Star LED	$24.95	1	$24.95
113990637 Bluetooth Module	$4.00	1	$4.00
Raspberry Pi RP2040 Microcontroller	$1.00	1	$1.00
Adafruit LIS3DH Triple-Axis Accelerometer	$4.95	1	$4.95
PCB Parts	$67.66	Various	$67.66
		H Subtotal	$235.79
H & M Subtotal	$356.69		
Total Shipping Costs:	$93.39		
Total	$450.08		

Timeline

Legends
Dhruv = DVK
Jeff = JW
Paige = PW
Sidd = SS

Task	Team Member(s)	Start — End Dates	Spring Break 3/14 — 3/19	Week 1 3/21 — 3/25	Week 2 3/28 — 4/1	Week 3 4/4 — 4/8	Week 4 4/11 — 4/15	FPR 4/19 — 2/22
			M T W TH F	1 2 3 4 5	M T W TH F	M T W TH F	M T W TH F	M T W TH F
Overall System								
Website Design refined	SS	Spring Break						
PCB Building and Testing	PW	12/20 — 2/1						
Enclosures for motorcycle and helmet	PW, DVK	2/2 — 2/11						
Phone app refined	JW	Winter Break						
Blindspot Detection								
Proximity Detection	DVK	12/20 — 1/28						
Implimention for light sensor to determine intesity of the lights	DVK	1/31 — 2/11						
Bluetooth transmission for motorcycle to helmet	JW	2/8 — 2/23						
Fall/Crash Detection								
GPS tracking for ES alert on app	JW, SS	2/2 — 2/22						
Fall detection functioning on PCB microcontroller	SS	2/10 — 2/22						
Implimentation of Noonlight API for calling ES	JW	2/22 — 2/4						