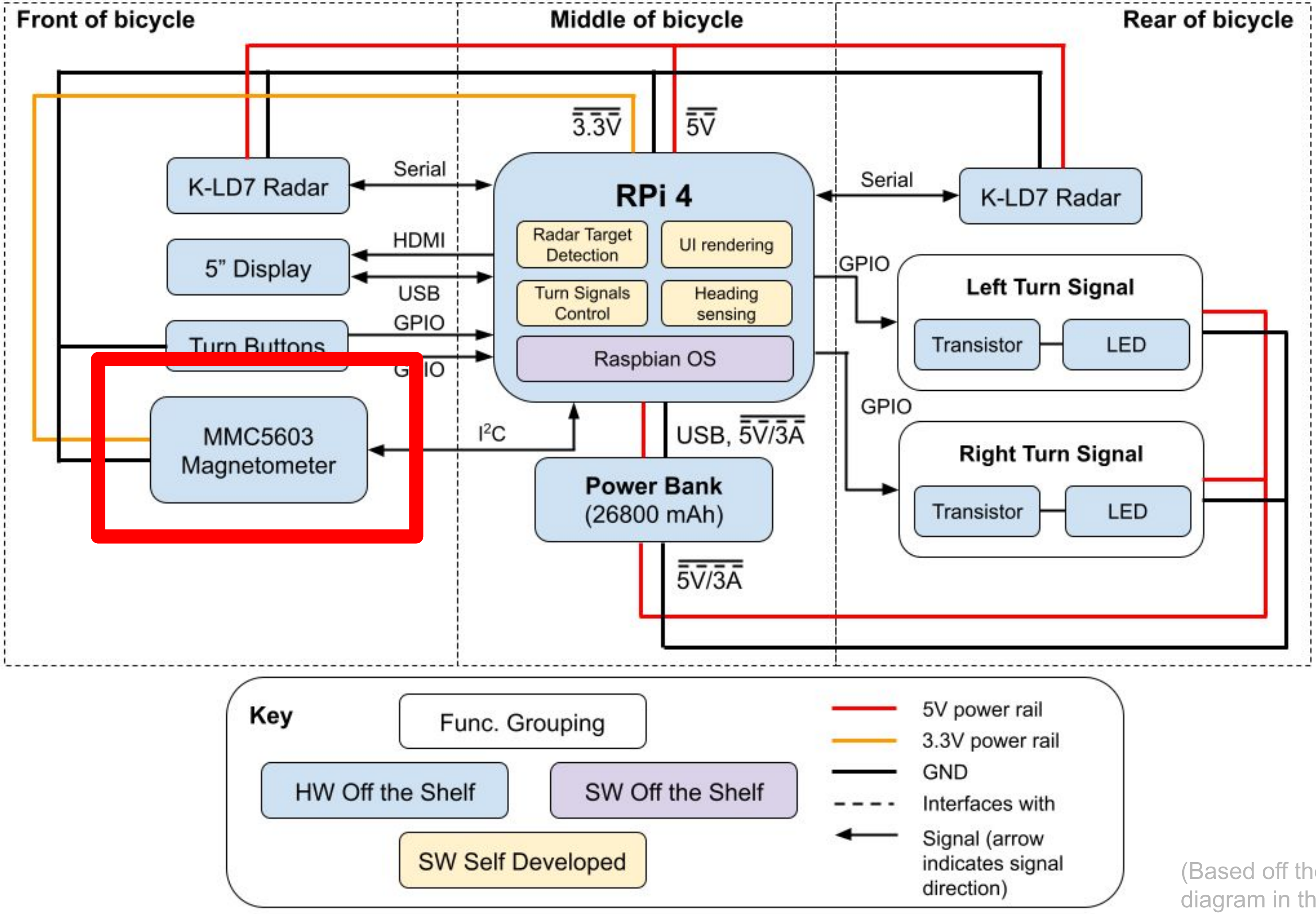
Use Case Requirements

- **Target**: Bicyclist commuters
- **Solution: Bike Safety Hub**
  - Blind Spot Detection
  - Collision Alerts
  - Turn signals

Requirement	**Metrics**
Cost	<= $200 market price
Battery Life	>= 2 hours
Detection Lead Time	>= 1.5 seconds
Uptime	>= 99.999%
Confusion Matrix	<= 40% False Negatives <= 30% False Positives
Ruggedness	IPX4
Turn Signal Visibility	>= 500 ft. (night), >= 100 ft. (day)

Design Requirements

Requirement	**Metrics**
Radar Detection Distance	>= 14 m
Radar Measurement Accuracy	<= ±10 % deviation
Radar Update Frequency	>= 10 Hz
Trackable Simultaneous Targets	>= 3 targets
Total System Power Consumption	<= 13.4 A



Front of bicycle

Middle of bicycle

Rear of bicycle

3.3V

5V

K-LD7 Radar

Serial

5” Display

HDMI

USB

Turn Buttons

GPIO

GPIO

MMC5603 Magnetometer

I²C

RPi 4

Radar Target Detection

UI rendering

Turn Signals Control

Heading sensing

Raspbian OS

USB, 5V/3A

Power Bank (26800 mAh)

5V/3A

Serial

K-LD7 Radar

GPIO

Left Turn Signal

Transistor

LED

GPIO

Right Turn Signal

Transistor

LED

Key

Func. Grouping

HW Off the Shelf

SW Off the Shelf

SW Self Developed

5V power rail

3.3V power rail

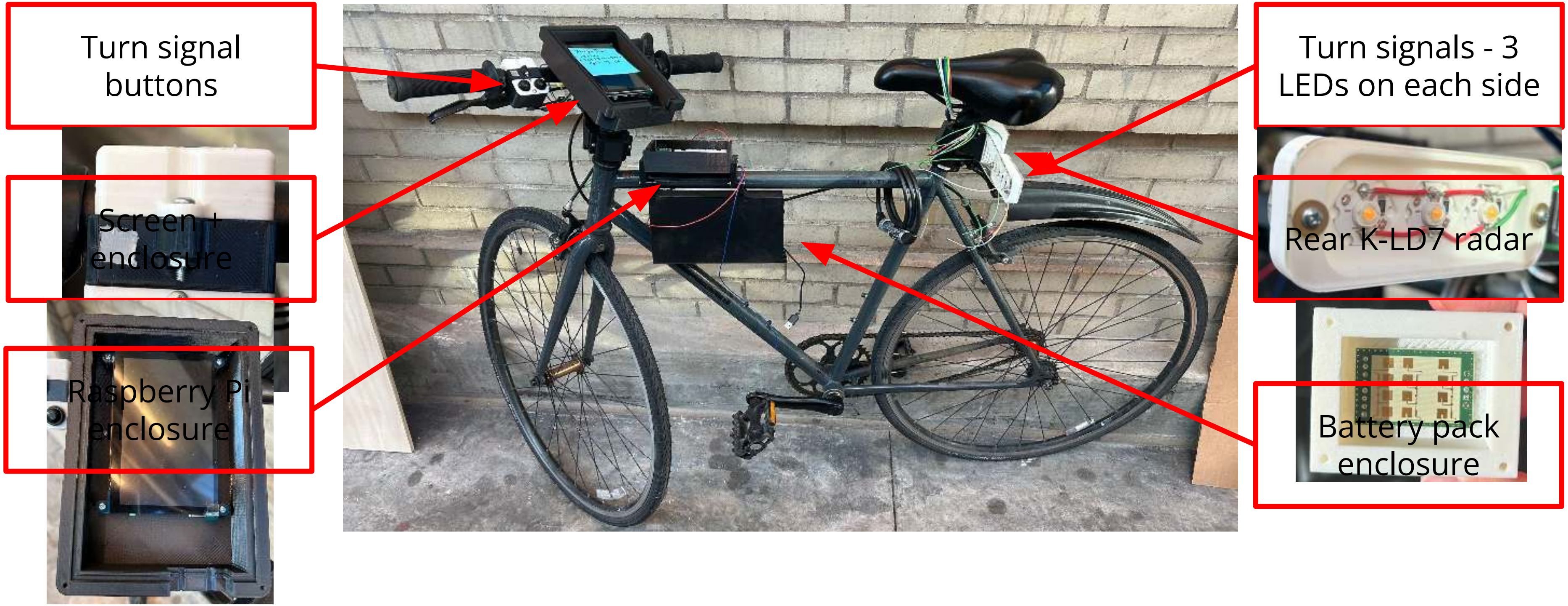
GND

Interfaces with

Signal (arrow indicates signal direction)

(Based off the example block diagram in the handout)

(Almost) Complete Solution - Hardware



Turn signal buttons

Screen + enclosure

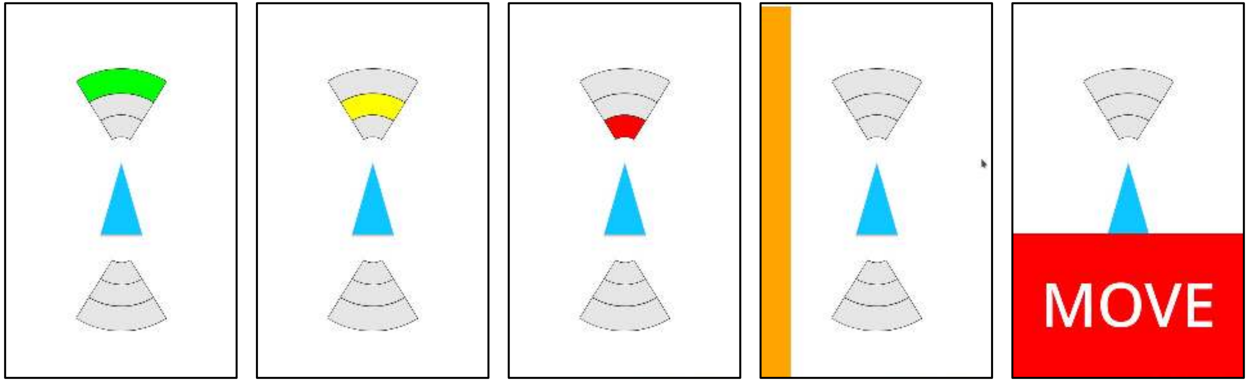
Raspberry Pi enclosure

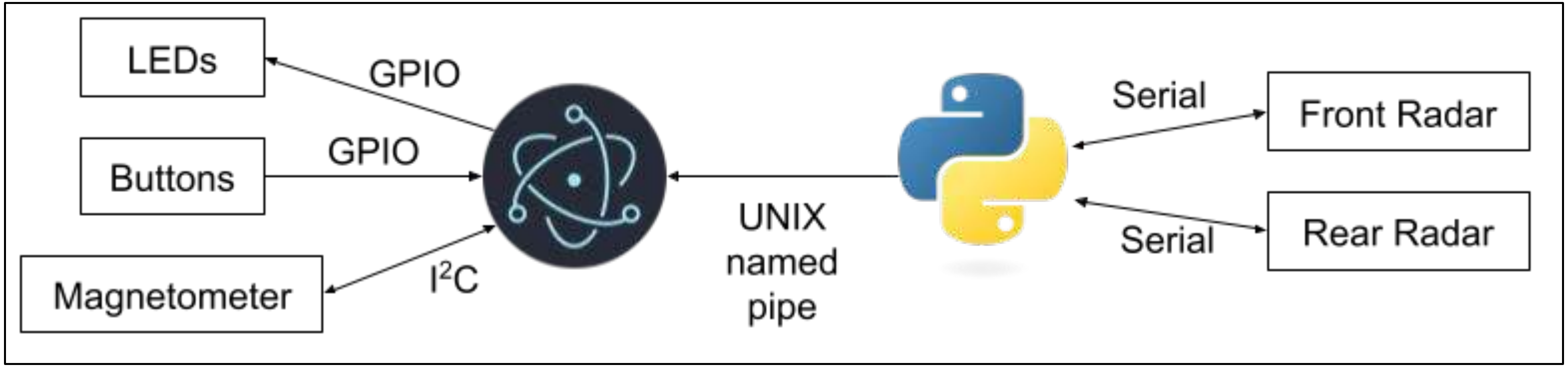
Turn signals - 3 LEDs on each side

Rear K-LD7 radar

Battery pack enclosure

Complete Solution - Software





Use Case Test Plans

Metric	Method	Pass Metric
Battery Life	● Record the running time of the system under normal use	>= 2 hrs
Detection Lead Time	● Record time from when an indicator appears on a screen until the vehicle passes by	>= 1.5 seconds
Uptime	● Record time that radars respond to data queries on RPi, divide by total application runtime	>= 99.999% uptime

Use Case Test Plans

Metric	**Method**	**Pass Metric**
Confusion Matrix	● Compare system against real traffic and see the detection results	<= 40% false negatives, 30% false positives
Ruggedness	● Test with IPX4 test protocol ● Ride around in poor conditions and verify functionality still works	Passes IPX4 test + works in adverse conditions
Turn Signal Brightness	● Engage turn signal, walk backwards until no longer visible - calculate distance using Google Maps	>= 500 ft. (night), >= 100 ft. (day)

Design Requirement Test Plans

Metric	Method	Pass	Actual
Max detection range (rear)	● Align vehicle with rear of bicycle, drive forward until radar return is detected - record reported radar distance	>= 14 m	24.82 m
Max detection range (side)	● Same as above, except align to right of bicycle	>= 14 m	14.08 m
Distance Accuracy	● Randomly stop at a certain distance from the rear of the bicycle, measure distance from radar to front of vehicle	<= ±10 % deviation	3.07%
Velocity Accuracy	● Drive at 5 mph* towards bicycle and record reported velocity	<= ±10 % deviation	7.00%*

Design Requirement Test Plans

Metric	Method	Pass Metric
Power Consumption	● Place ammeters between outputs of battery pack and RPi 4 + LEDs, sum current draw	<= 13.4 A
Radar Update Frequency	● In the UI, start a 1 second timer and count the number of data updates while an object is moving towards the bicycle	>= 10 updates in that period
Simultaneous Target Tracking Ability	● Have three people spaced apart, walking towards radar	All three targets reported accurately

Design Trade-offs

Embedded System Factors:

- Performance
- Power draw
- Heat
- USB max current

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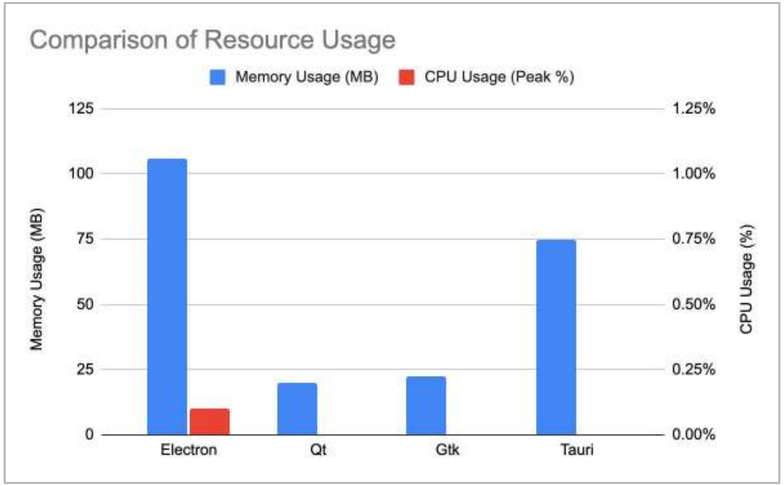
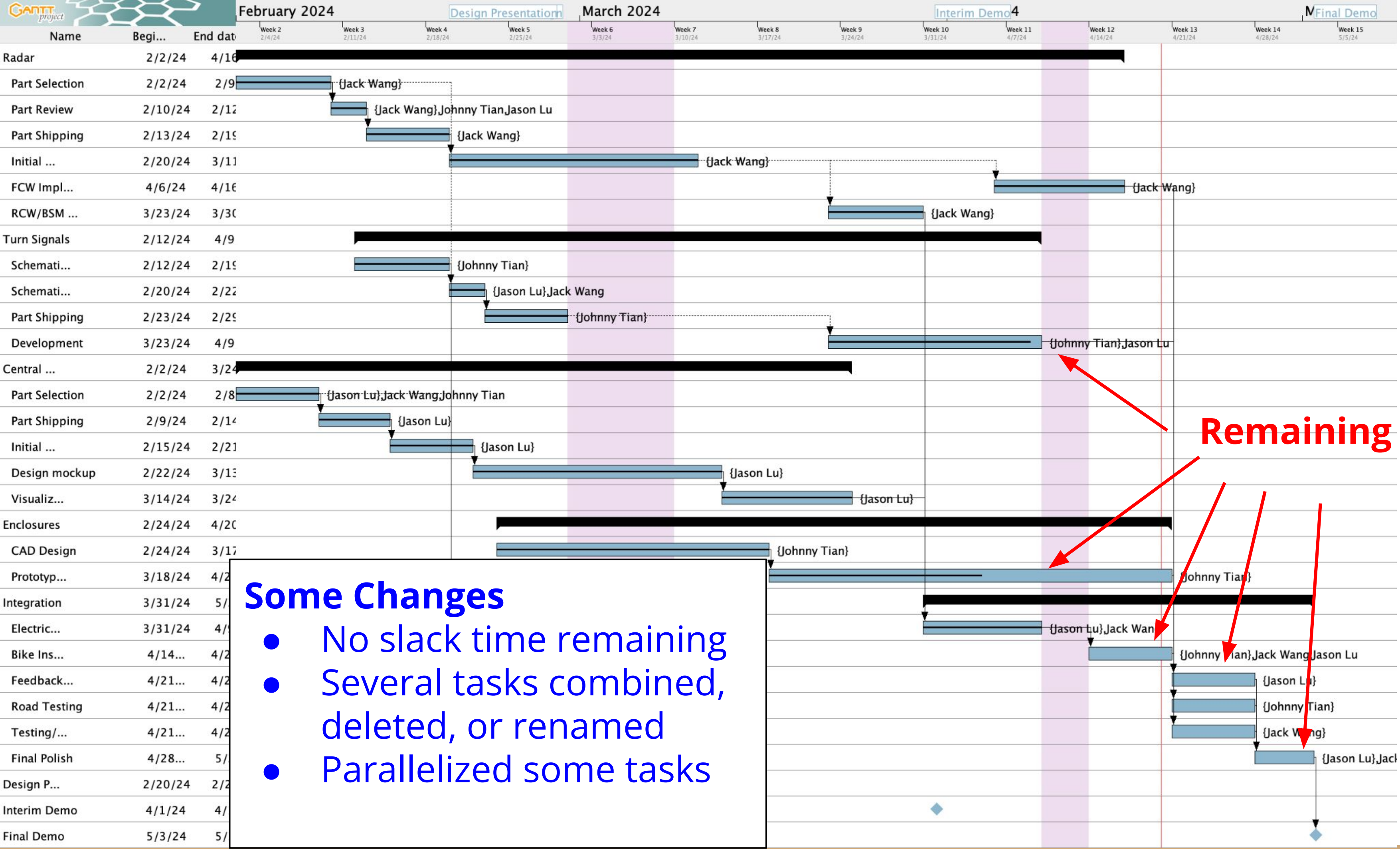
UI Factors:

- Cross-platform support
- Language/Framework/Tooling familiarity
- Adoption
- Baseline resource usage
- Cross-compilable





Name	Begi...	End dat
Radar	2/2/24	4/16
Part Selection	2/2/24	2/9
Part Review	2/10/24	2/12
Part Shipping	2/13/24	2/19
Initial ...	2/20/24	3/11
FCW Impl...	4/6/24	4/16
RCW/BSM ...	3/23/24	3/30
Turn Signals	2/12/24	4/9
Schemati...	2/12/24	2/19
Schemati...	2/20/24	2/22
Part Shipping	2/23/24	2/29
Development	3/23/24	4/9
Central ...	2/2/24	3/24
Part Selection	2/2/24	2/8
Part Shipping	2/9/24	2/14
Initial ...	2/15/24	2/21
Design mockup	2/22/24	3/13
Visualiz...	3/14/24	3/24
Enclosures	2/24/24	4/20
CAD Design	2/24/24	3/17
Prototyp...	3/18/24	4/2
Integration	3/31/24	5/
Electric...	3/31/24	4/
Bike Ins...	4/14...	4/2
Feedback...	4/21...	4/2
Road Testing	4/21...	4/2
Testing/...	4/21...	4/2
Final Polish	4/28...	5/
Design P...	2/20/24	2/2
Interim Demo	4/1/24	4/
Final Demo	5/3/24	5/

Remaining work

Some Changes

- No slack time remaining
- Several tasks combined, deleted, or renamed
- Parallelized some tasks

Lessons Learned

Logistical

- Build in as much slack time as you can
- Parallelize tasks as much as possible

Technical

- JavaScript is pretty powerful
- Using a magnetometer as a compass is not trivial
- Data communication through named pipes
- Radar usage