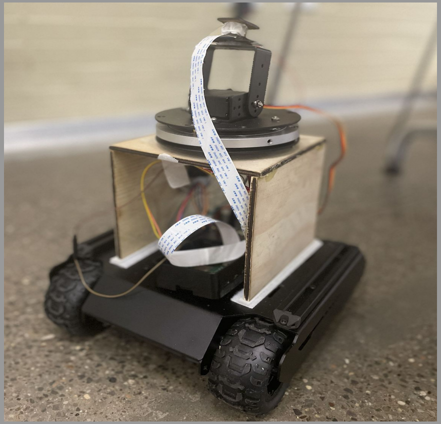
Use Case & Requirements

- A searching **rover** application that can **autonomously** locate people needing help and shine a **laser** spotlight on them
- Ideal customers are rescue agencies and humanitarian organizations
- Requirement #1: Accurate laser control and human identification
- Requirement #2: Longevity of autonomous drive of the rover
- Requirement #3: Fast response times on web application

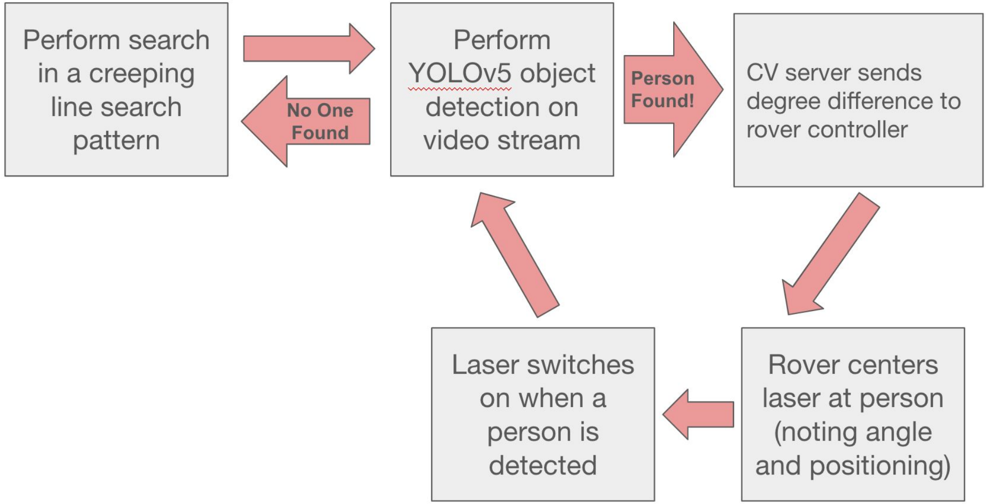


Source: https://drones.wfp.org/index.php/activities

Quantitative Design Requirements

#01 **Accurate laser control and human identification**	**#02** **Longevity of autonomous drive of the rover**	**#03** **Fast response times on the web application**
Accuracy of human identification through YOLOv5: top-1 Accuracy of **> 80%** and top-5 Accuracy of **> 90%.** False positive rate of **< 1%.**	Complete search in creeping line search pattern in **<5 minutes** at a speed of **1 m/s**	Speedup of YOLOv5 object detection through a distributed server of **5x** compared to the sequential model
Ability to turn on the laser and navigate to the laser pointing position: offset between laser and human is **± 1 feet**	Stability of rover during movement and ability to hold **0.5kg** of load like a camera, camera count, and laser circuitry	Low latency of communication between all subsystems: latency of **<50ms** between seeing a human and reporting on web app
	Cost effectiveness of the rover: **<$300**	Secure and user-friendly

Solution Approach and Changes

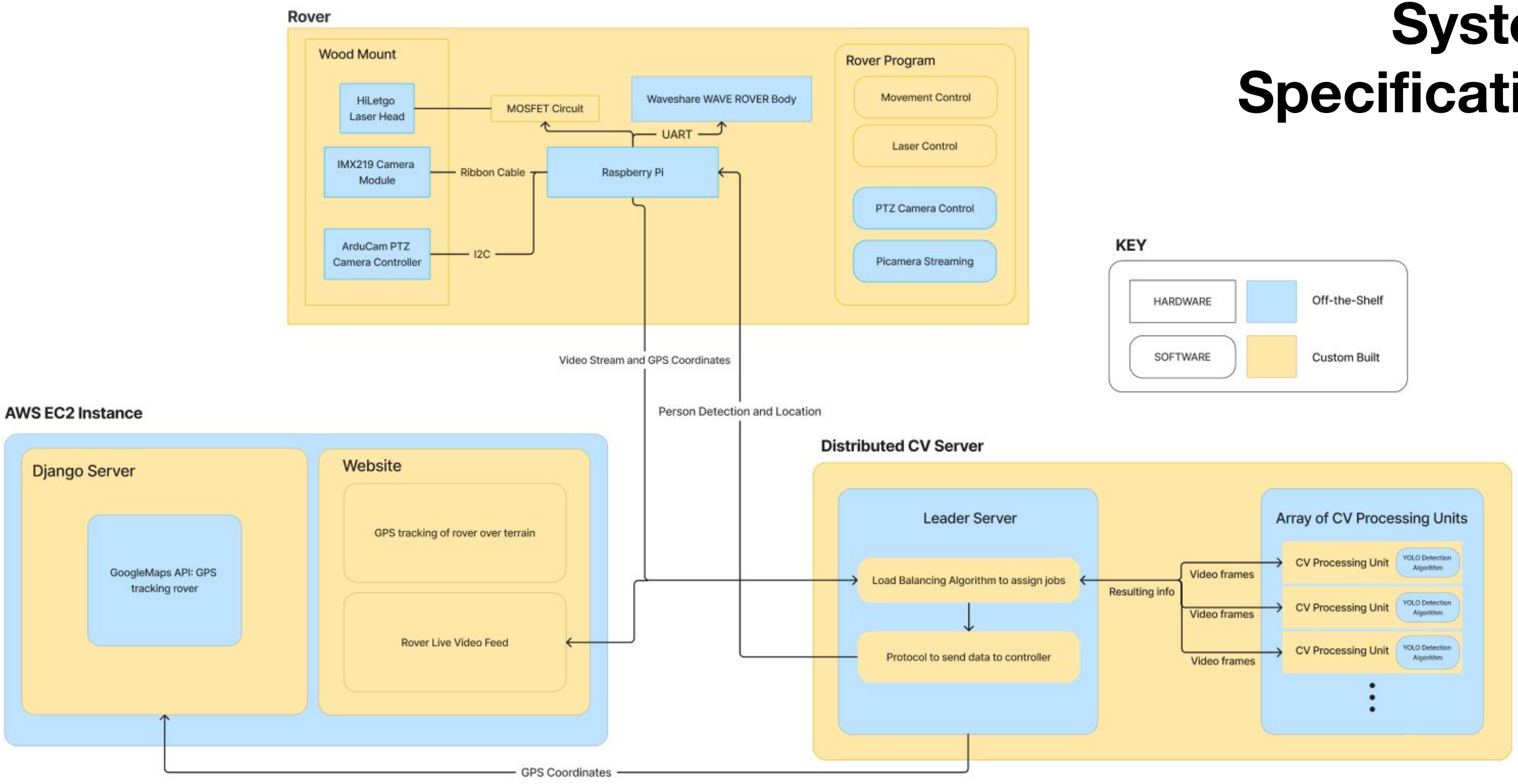


Now using a ~~drone~~ **rover**!

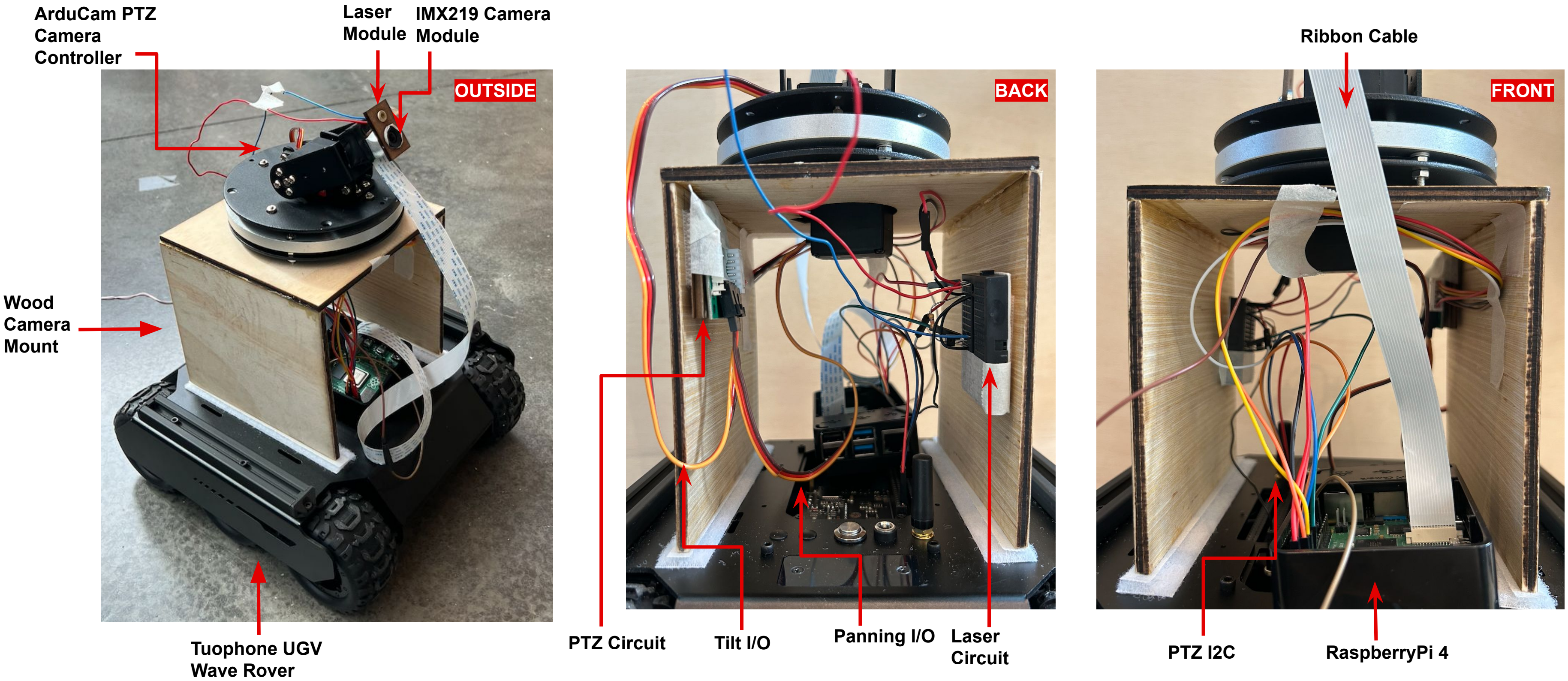
Impact

- **Social:** Providing aid remotely in dangerous scenarios
- **Cultural:** Offer aid to people without discrimination of human bias while searching
- **Global:** Less need for direct intervention in SAR operations worldwide, more human lives kept safe

System Specification

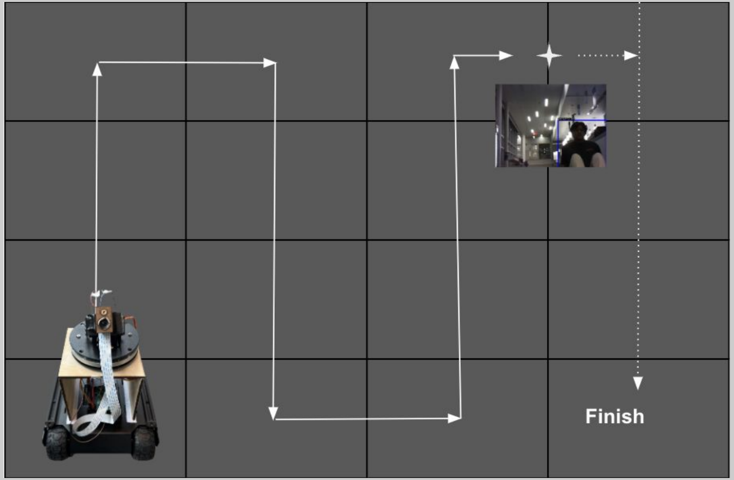


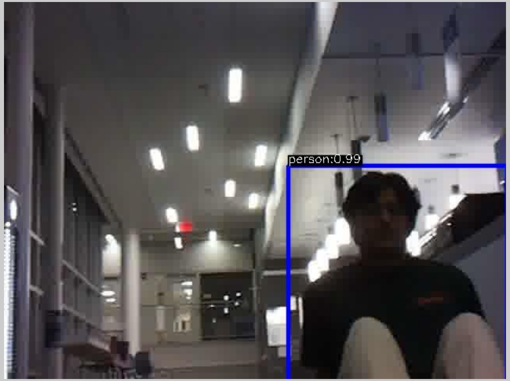
Rover Hardware



Final Demo Plans

- **Test arena:** 16’ by 16’ flat concrete flooring surrounded by tall cardboard panels
- **Test setup:** Rover placed at edge of arena; 1 human randomly placed
- Rover follows creeping line search pattern and points the laser at the person once detected
- We ensured the human was detected in different positions (sitting, standing, face covered) considering all of our design requirements





Testing, Verification, and Metrics

Requirements	Testing	Metrics
Accurately identify humans in a flat landscape	Unit test images of people in different flat environments, body parts hidden, multiple people	Top-1 Accuracy: > 80% Top-5 Accuracy: > 90%
Autonomous rover control	Checkpoint tests of creeping search and targeted rotation	Can move in pre-specified pattern, and correctly rotate to laser-pointing position if person found (± 1 feet of staying on course)
Low latency	Time taken to send, process, and return information based on video data	Latency of detection, data routing, and result processing: < 5s
Point light to person's location	Comparison tests between person's actual coords vs laser-pointed coords vs calculated coords video frame data	Offset in person location and calculated location: ± 0.5 feet Offset in person location and laser-pointed location: ± 1 feet
Power consumption	Drive time of rover with and without laser + actuator attachment	Maintain <5 minute loss of drive time when searching

Testing

- **UNIT TESTING** with multiple (x) repeated trials
- **CV**: Ensure the human is detected in the image (20)
- **Moving control**: Run creeping line search, and see if it stays on track (20)
- **Latency**: Clock the time between video being sent, human being detected, and rover being notified (20)
- **Laser accuracy**: Measure distance between laser pointed location and “center of human” when the rover settles on target (20)
- **Power consumption**: Run rover with/without paraphernalia until dead (2)

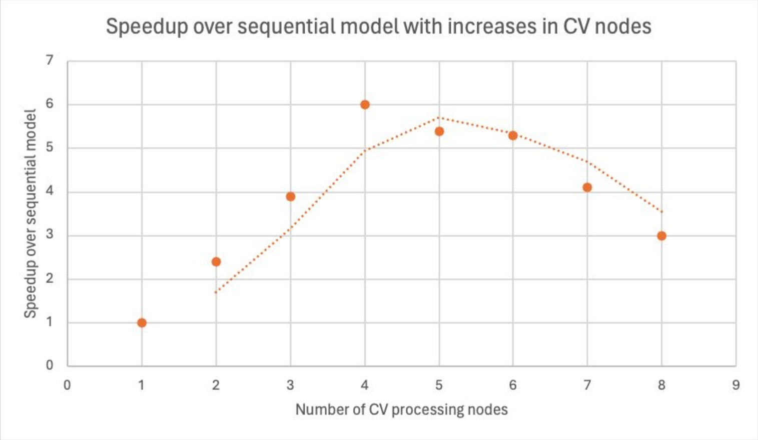
- **Overall Testing**: Find human during the search, and adjust laser to point
    - See video here!

Results

Requirements	Goal Metrics	Results
Accurately identify humans in a flat landscape	Top-1 Accuracy: > 80% Top-5 Accuracy: > 90%	Top-1 Accuracy: **95%** Top-5 Accuracy: **100%**
Autonomous rover control	Can move in pre-specified pattern, and correctly rotate to laser-pointing position if person found (± 1 feet of staying on course)	Average Distance Off-Course: **8.2 feet**
Low latency	Latency of detection, data routing, and result processing: < 5s	Average Time: **1.44s-1.64s**
Point light to person's GPS location	Offset in person location and calculated location: ± 0.5 feet Offset in person location and laser-pointed location: ± 1 feet	Avg Offset in person location and calculated location: **± 0.3 feet** Avg Offset in person location and laser-pointed location: **± 0.38 feet**
Power consumption	Maintain <5 minute loss of flight time when searching	Average Loss: **8 minutes**

Design Tradeoffs

- Rover vs. drone (10x cheaper)
- Preset search pattern vs. random exploration
- Panning camera vs. fixed camera
- Manual camera control vs. autonomous camera control
- Accuracy of laser vs. speed (2x slower)
- Number of worker nodes vs. speedup (4)



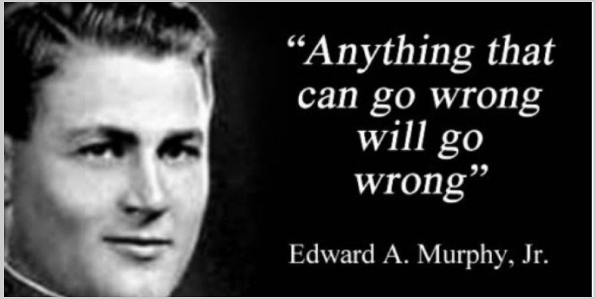
Source: https://drones.wfp.org/index.php/activities

Project Management

task/milestone	description	person/people with primary responsibility	start date	finish date	Wed 2/7	Wed 2/14	Sun 2/18	Wed 2/21	Wed 2/28	Fri 3/1	Wed 3/6	Wed 3/13	Wed 3/20	Wed 3/27	Wed 4/3	Wed 4/10	Wed 4/17	Sun 4/21	Wed 4/24	Wed 5/1
Perform material research	Perform research on correct materials to buy (motors, Arduino components, etc.), especially finding the right drone	David	2/7	2/14	x	x														
Load Balancing Algorithm (1/2)	Perform research on optimal load balancing algorithms and implement in Go	Ronit	2/7	2/14	x	x														
General Website Setup	Create base template for Django website, do front/backend setup of site, and research hosting live video streaming	Nina	2/7	2/14	x	x														
Design Presentation Slides	Design Presentation Slides	All	2/14	2/18		x	x													
Find methods for obtaining drones	Find where and how to purchase/obtain drones to use that are suitable for our needs - talk with robotics professors (like Basti)	David	2/14	2/21		x	x	x												
Load Balancing Algorithm (2/2)	Implement the load balancing algorithm in Go, and finish unit testing. Research fetching the video stream from the DCC	Ronit	2/14	2/21		x	x	x												
Implement GPS Tracking	Research and implement GPS tracking of drone using GoogleMaps API on top of Django website	Nina	2/14	2/21		x	x	x												
Talk with Basti, Work on rover pivot by re-examing parts and redesign project	Talk with Prof. Basti about drones, Talk with Tamal and Kim about failure, redesign project to be accomadating for rover over drone usage	David	2/21	2/28				x	x											
Rover Camera & Communication Research	Research camera modules with moving feature that can be attached to rover, order, research new communication methods of camera data to Ronit and monitoring site since drone fly app is removed	Nina	2/21	2/28				x	x											
Computer Vision Algorithm on the Distributed Server	Implement the Computer Vision Algorithm on the CV processing units. Integrate with video frames and unit tests	Ronit	2/21	2/28				x	x											
Obtain rover project materials, initial work, spring break	Order rover and PTZ camera, examine rover code	David	2/28	3/13					x	x	x	x								
Implement communication from Raspberry Pi to the Distributed CV server	Use FFMPEG to receive a uploaded video stream and break it into several frames for batch processing in Go	Ronit	2/28	3/13					x	x	x	x								
Implement working PTZ camera on RPi desktop	OS conversion from Buster to Bullseye, Firmware updates and changes to fix stale external trigger issue with camera, order new ribbon cables in order to fix no camera display issue, implement PTZ on RPi with nondeprecated libraries that OpenCV can support	Nina	2/28	3/13					x	x	x	x								
Obtain more mats, switch from rover wifi to UART comms	Purchase smaller batteries and laser heads, test with rover web app, work out the correct JSON commands to send over UART	David	3/13	3/20								x	x							
PTZ refinement and camera debugging	Implement keyboard press control of PTZ gimbal using Arducam libraries and continue debugging camera firmware/potentially hardware issue of stream going stale and no camera display showing	Nina	3/13	3/20								x	x							
Integrate frame breakdown with CV server code/ build laser pointing circuit	Build a laser pointing circuit using the Raspberry Pi pins and GPIO. Integrate frame breakdown with the Distributed CV server and write unit tests	Ronit	3/13	3/20								x	x							
Rover movement with UART comms	Work out the correct JSON commands to send over UART and/or debugging rover movement, set up new RPi for concurrent work (VNC, ssh, Bullseye)	David	3/20	3/27									x	x						
Camera Frankenstein	Order new imx219 camera and attach to camera serial data of RPi along with PTZ portion of broken camera and disable communication between the components to allow for separate movement and live stream, research live streaming from RPi to personal computer	Nina	3/20	3/27									x	x						
Communication from CV server to rover	Write scripts to use TCP to communicate from the CV server to the rover to turn on the laser pointer	Ronit	3/20	3/27									x	x						
Finalize rover movement and tuning	Get controlled movement for rover through extensive debugging, and tune it to do exact turns and movement	David	3/27	4/3										x	x					
Real time communication of video data	Implement RPi streaming communication through use of OpenCV and picamera2 libraries to send video data to Ronit and monitoring site and embed stream into site through iframe	Nina	3/27	4/3										x	x					
Monitoring Site Refinement & Scripting	Create script that will have preset camera movement pattern to look around and also further flesh out web application with manual movement controls of camera	Ronit	3/27	4/3										x	x					
Threading	Have the code running on one RPi with threading between video streaming and code logic, or by using two RPis	All	4/3	4/10											x	x				
Laser pointer accuracy	Coordinate math to be able to point laser correctly, accounting for angle and positioning; Work with CV server to handle location and pointing logic	Ronit & David	4/3	4/10											x	x				
Integrate physically together	Integrate everything, make mount	All	4/10	4/17												x	x			
Final Presentation Slides	Final Presentation Slides	All	4/17	4/21													x	x		
Test entirety of setup	Make sure everything is integrated and working with server and website	All	4/17	4/24													x	x	x	
Prepare for final demo	Fine-tune anything that is needed	All	4/24	5/1															x	x

Lessons Learned

- **START EARLY!**
- Thorough research of OS compatibility and deprecated libraries is required with each component
- Integration and communication of components is tricky, and latency considerations are important
- **Murphy is always watching**
  - Always assume something will break and prepare ahead for it
  - Always push any changes to GitHub in case of hardware failures
  - If it's not a software or firmware issue, it could potentially be a hardware issue



Source: https://www.freightnews.co.za/article/tariff-classifications-how-avoid-murphys-law