The Highlanders

Electronics Board design

Spotlight - 4499's Upside down design

These ideas are team 4499's tips and ideas...they are by no means the "best" out there!

Introductions

The Highlanders

Who are we?

- Community based team
- From 5 different schools
- Starting our 9th FRC season

Presenting today:

Cooper Ward - 4 years in FRC

Alex Torres - 2 years in FRC

Hailey Holman - 2 years in FRC

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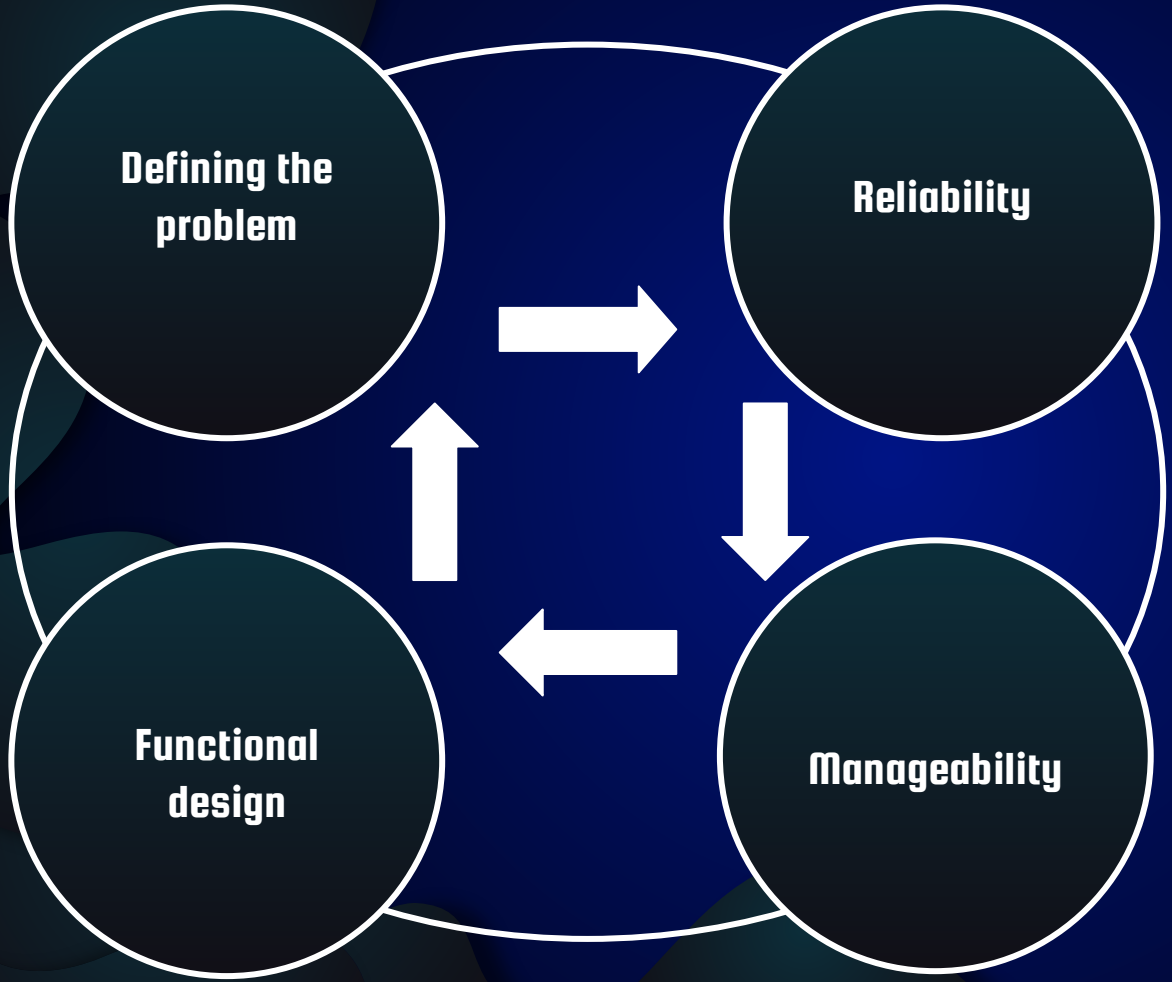
Goals

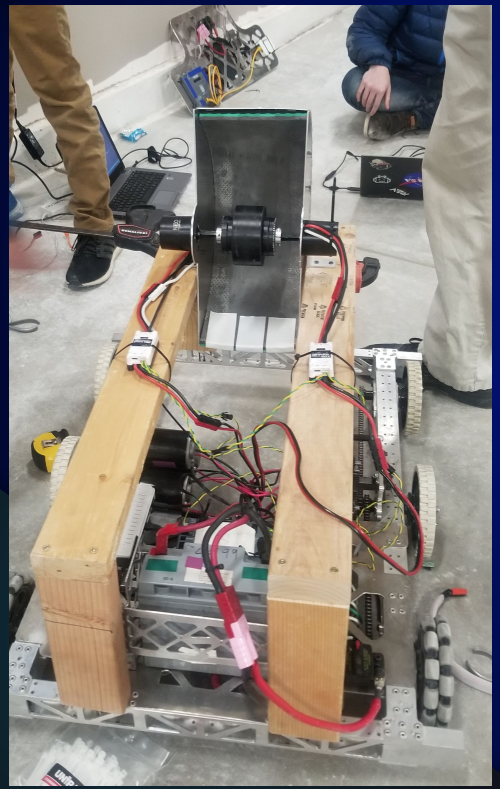
of electrical design



4499 Goals of Electrical Design

Defining the problem

How are we going to design an electronics layout without a complete robot design build?



- **General idea layouts**
  - PDP Centered
  - Battery COG
- **Chassis design**
  - Chain in tube?
  - WCD layout?
- **Location of specific things**
  - Router position
  - Cameras? Type of cameras
- **Motors**
  - Controllers? NEOS/Falcons
- **Number of motors**
  - Power Budget (next slide)
  - Motor controllers/Falcons?
- **Pneumatics?**
  - Space
  - PCM slots

Power Budget

PDP	*WITH PNEUMATICS*		VRM 1		*Note: we can get away with 1 VRM if we have a 20 amp spot somewhere else?*
SLOTS	**USED BY**		**SLOTS**	**USED BY**	*Add Pneumatics on this spread sheet*
1 (40 amp)	Falcon 500 1	Drive Train	*12v/2a*	RADIO	
2 (40 amp)	Falcon 500 2	Drive Train	*12v/2a*		
3 (40 amp)	Falcon 500 3	Drive Train	*12v/500ma*	LED LIGHT RINGS	
4 (40 amp)	Falcon 500 4	Drive Train	*12v/500ma*	Jevois PowerBuck 1	
5 (40 amp)	Falcon 500 5	Flywheel	*5v/2a*	BLINKIN LED DRIVER	
6 (40 amp)	Falcon 500 6	Flywheel	*5v/2a*	Blinkin LED DRIVER 2	
7 (40 amp)	Neo 1/Falcon 50	Arm	*5v/500ma*		
8 (40 amp)	Neo 2	Climber Winch	*5v/500ma*		
9 (30 amp)	Neo 550 1	Intake	*12Vin*	PDP	
10 (30 amp)					
11 (30 amp)	BAG 1	Magazine	**VRM 2**		
12 (30 amp)	775Pro 1	Magazine	**SLOTS**	**USED BY**	
13 (30 amp)	Neo 550 5	Indexer	*12v/2a*		
14 (30 amp)	Neo 550 6	Hood	*12v/2a*		
15 (30 amp)			*12v/500ma*	LED LIGHT RINGS	
16 (30 amp)			*12v/500ma*		
			5v/2a		
VRM PWR	VRM 1	VRM 2	*5v/2a*		
PCM PWR	PCM		*5v/500ma*		
Roborio PWR	RoboRio		*5v/500ma*		
			12Vin	PDP	

PCM	Mechanism/Conne
Port 0	Ratchet/Brake
Port 1	Ratchet/Brake
Port 2	Climber Deploy
Port 3	Climber Deploy
Port 4	
Port 5	
Port 6	
Port 7	
Pressure Sw.	Pressure Switch
Compressor out	Compressor
CAN	To motor controllers
Vin	PDP

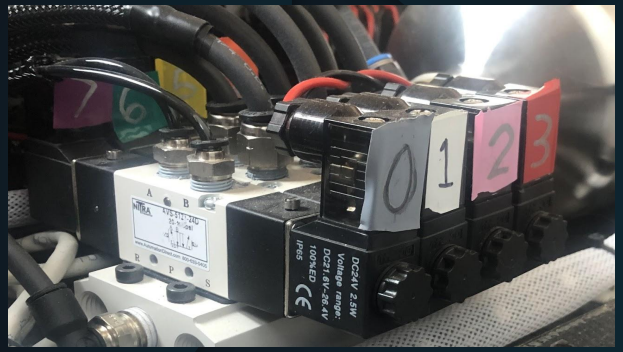
PDP	*NO PNEUMATICS*		VRM 1		
SLOTS	**USED BY**		**SLOTS**	**USED BY**	
1 (40 amp)	Falcon 500 1	Drive Train	*12v/2a*		
2 (40 amp)	Falcon 500 2	Drive Train	*12v/2a*	RADIO	
3 (40 amp)	Falcon 500 3	Drive Train	*12v/500ma*	LED LIGHT RINGS	
4 (40 amp)	Falcon 500 4	Drive Train	*12v/500ma*	PowerBuck 1	
5 (40 amp)	Falcon 500 5	Flywheel	*5v/2a*	BLINKIN LED DRIVER	
6 (40 amp)	Falcon 500 6	Flywheel	*5v/2a*	Blinkin LED DRIVER 2	
7 (40 amp)	Neo 1	Climber arm	*5v/500ma*		
8 (40 amp)	Neo 2	Climber Winch	*5v/500ma*		
9 (30 amp)	Neo 550 1	Intake	*12Vin*	PDP	
10 (30 amp)	Neo 550 2	Intake			
11 (30 amp)	Neo 550 3	Magazine	**VRM 2**		
12 (30 amp)	Neo 550 4	Magazine	**SLOTS**	**USED BY**	
13 (30 amp)	Neo 550 5	Indexer	*12v/2a*	Jetson Nano	Realsense
14 (30 amp)	Neo 550 6	Hood	*12v/2a*		
15 (30 amp)	Neo 550 7	Spinner	*12v/500ma*	Powerbuck 2	2nd Je Vois Vision Camera
16 (30 amp)	Neo 550 8	Spinner	*12v/500ma*		
NO SLOT	Neo 550 9	Leveler	*5v/2a*		
			5v/2a		
VRM PWR	VRM 1	VRM 2	*5v/500ma*		
PCM PWR	PCM		*5v/500ma*		
Roborio PWR	RoboRio		*12Vin*	PDP	
RELAY					
SLOTS	**USED BY**				
1	Jetson Nano				
2					
3					

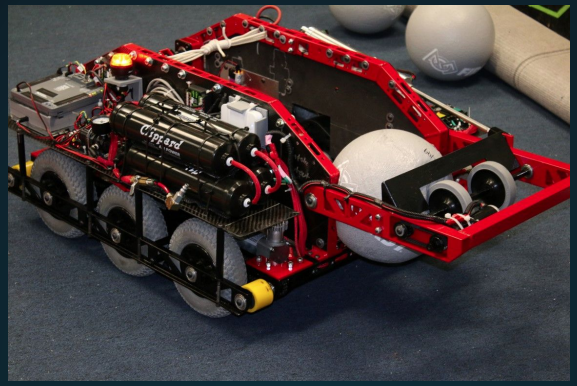
Reliability

- Secured
  - Sheathing
  - Cable Chain
- Easy to maintain
  - Quick replacement
- Test wires/connection
  - Pull/tug

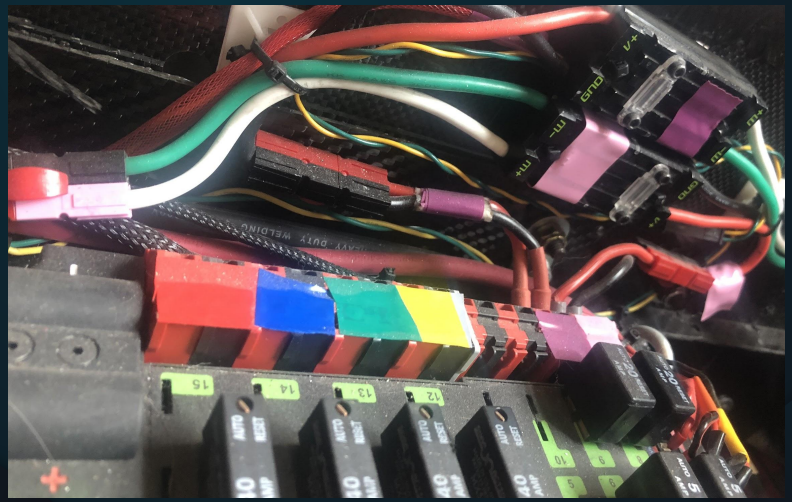
2018 - Lesson Learned:
"Dont underestimate a simple design that never breaks down"....
As a team we all learned this and made this a requirement for future robot designs.

Manageability



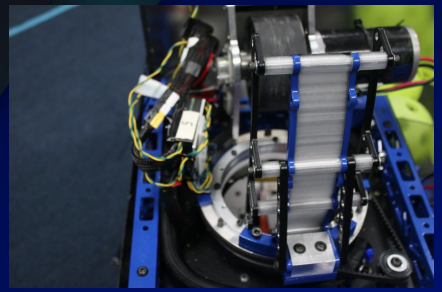


- How to find problems
- Label wires
- Color code the motors
  - PDP to motor
  - Solenoid to piston
- Route wires
- Do not make large bundles of wires



Functional Design

- Shooter with flywheel
  - Vibrations
  - Wires not near wheel/chain



- Multidirectional arm
  - Wire movement
  - Cable chain
    - Works well when repetitive motion are in place, and a single direction

- Climber
  - Movement up and down
  - Sensor placement

- Storage (of game elements)
  - Space for storage of those pieces.
  - Sensor placement
    - Analog sensor wires near motors can cause interference
    - NavX near motors can also cause interference

- Elevator
  - Movement up and down
  - Sensors placement

“I swear, if I see another one of you grabbing a battery by its cables I will smite you.”

— Cooper Ward

Constraints

Rules, Design, Team imposed

CONSTRAINTS: TYPES

Rules – Game Manual

Rule imposed restrictions are the easiest to find (because they are written down for you)

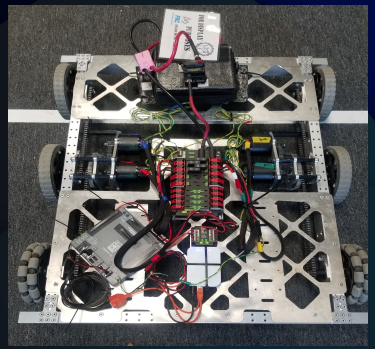
Design

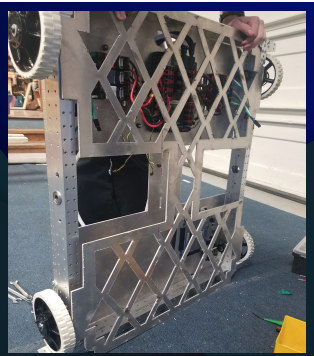
Just because you are allowed to do it within the rules, is there a reason to do it?

Team Imposed

You have found a solution that satisfies the rules, and the design of the robot. But, are there any team imposed restrictions that nullify that solution?

CONSTRAINTS: RULES





Rule constraints are easy to identify, here are some examples:

- R64 *The Wireless Bridge must be mounted on the ROBOT such that the diagnostic lights are visible to ARENA personnel.*
- R65A RSL . *mounted on the ROBOT such that it is easily visible while standing 3 ft. (~ 100 cm) in front of the ROBOT,*
- R43 *The 120A circuit breaker must be quickly and safely accessible from the exterior of the ROBOT. This is the only 120A circuit breaker allowed on the ROBOT.*

Rules change from year to year, even in electronics! What once had to be restrictive, might now be more forgiving with its placement.

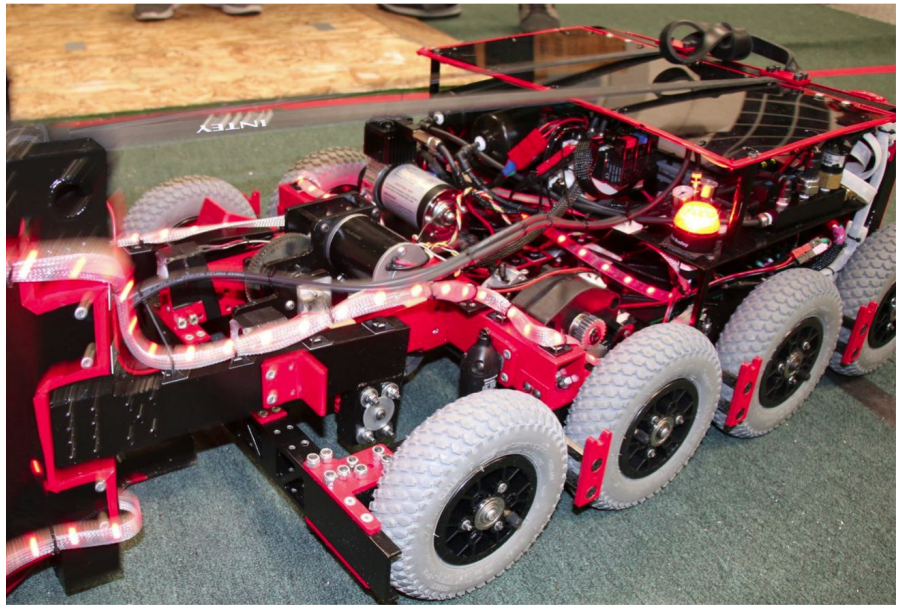
How you work within these constraints is up to you, they are non-negotiable requirements for certain components.

CONSTRAINTS: Design

- Wireless radio
  - Highest place on robot
- Battery cables
  - Smallest run of cables
- Roborio
  - Accessible location
- How to protect components
  - Router/RoboRio/Camera
  - Bottom of robot
  - Secure battery
  - Avoid having other wires near your battery, as it can crush other cables.

CONSTRAINTS: Team Design/Robot Design

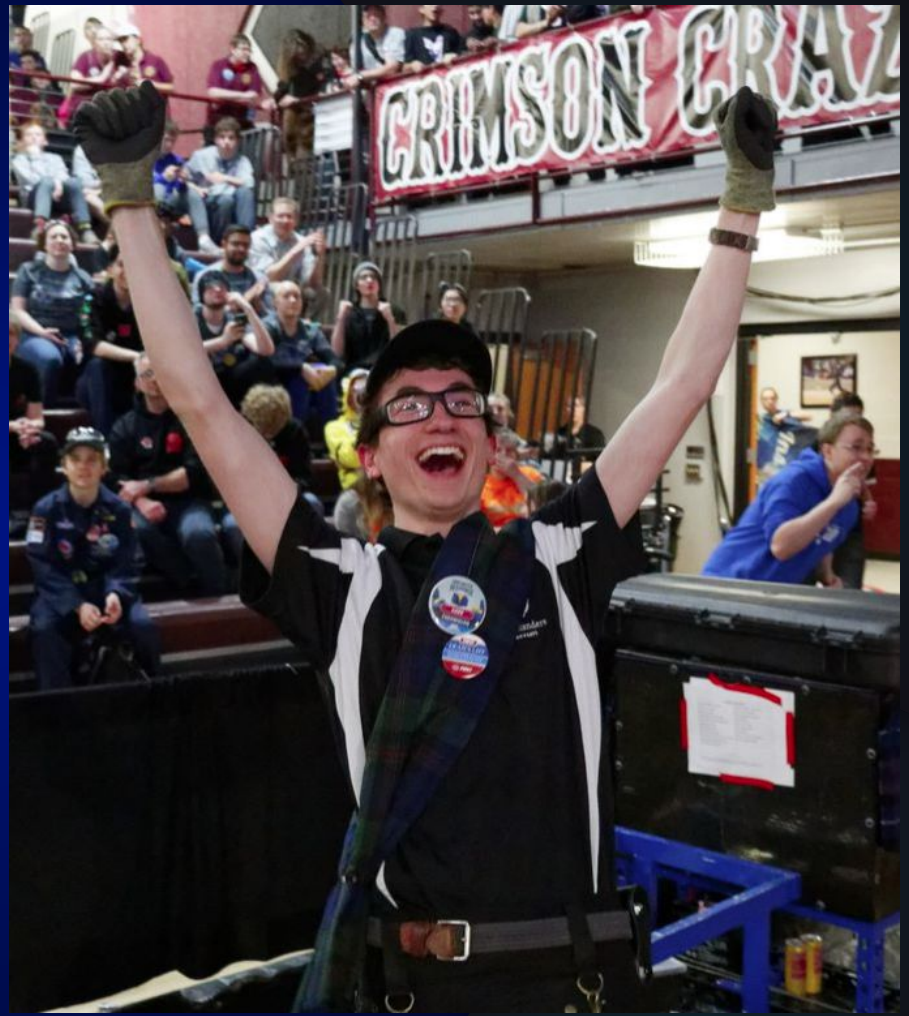
So...you just designed where all components are placed and .... the mechanical team decides to place the shooter right in the middle of your layout...and they see no problem with that...



- Be flexible :)
- Be willing to move everything around if needed
- Communicate
- Defend your space!
- CAD your layout and integrate within subteams
    - Main components
    - Wires not necessary
- Leverage changes positively

“AHHHHHHHHHHHHHHHHHHHHHHHHHHHHHH!!!!!!!!!”

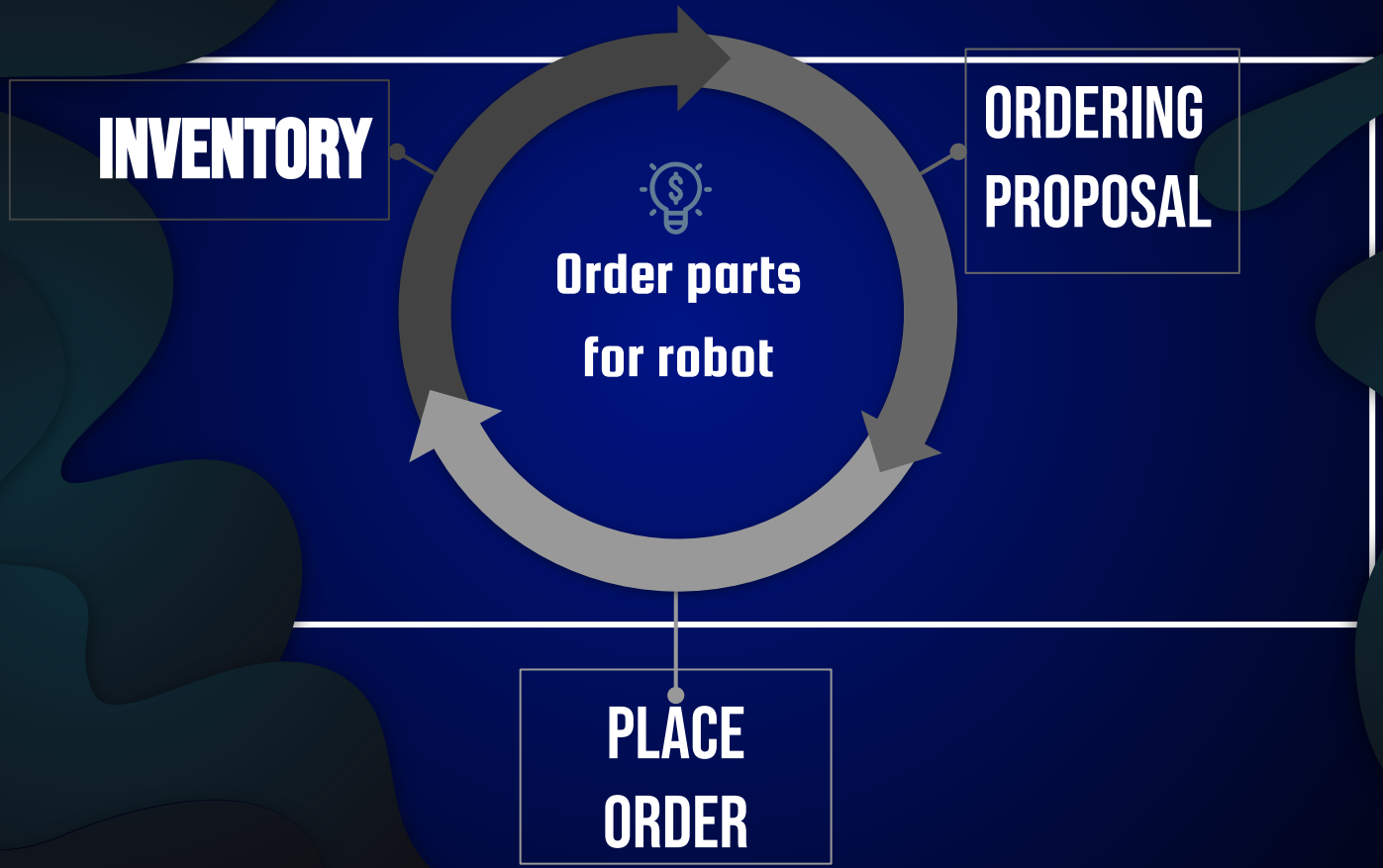
— Everyone



Our Ordering Process

Why do we do this?

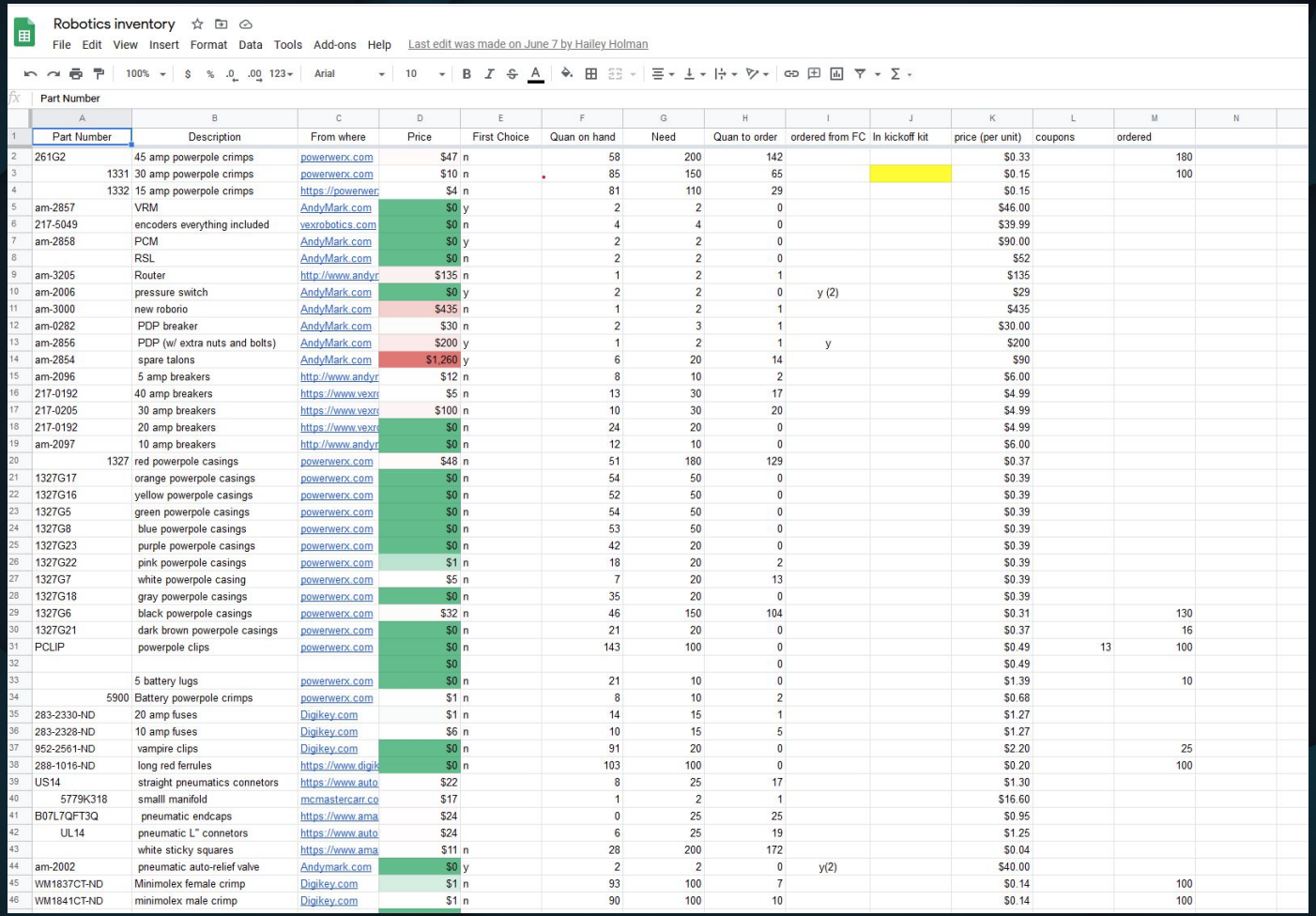
Answer? Mentors make us



Inventory

- **Count how many of each component you have (yes this will take a while!)**
  - COUNT CRIMPS
  - WIRE LENGTHS
  - SHIELDING
  - ELECTRONIC COMPONENTS (PDP, PCM, VRM, ETC.)
    - This is usually done after round 1 of FIRST Choice (to see if we can get extra electronics)
- **First Choice**
  - TRY TO GET AS MUCH ON FIRST CHOICE AS POSSIBLE
  - USE THE VENDOR VOUCHERS!
- **Find new Components that are effective for your team**
  - CHECK VENDORS FOR NEW PRODUCTS
    - If you have the opportunity to go to world championships, talk with vendors in person to see if they have anything new for the FRC field.
    - Be sure to check in with teams who have had this opportunity, they may have found some new components.
  - LOOK FOR ALTERNATIVE COMPONENTS

Inventory Spreadsheet



Robotics inventory

File Edit View Insert Format Data Tools Add-ons Help Last edit was made on June 7 by Hailey Holman

Part Number

	Part Number	Description	From where	Price	First Choice	Quan on hand	Need	Quan to order	ordered from FC	In kickoff kit	price (per unit)	coupons	ordered
2	261G2	45 amp powerpole crimps	powerwerx.com	$47	n	58	200	142			$0.33		180
3	1331	30 amp powerpole crimps	powerwerx.com	$10	n	85	150	65			$0.15		100
4	1332	15 amp powerpole crimps	https://powerwer	$4	n	81	110	29			$0.15		
5	am-2857	VRM	AndyMark.com	$0	y	2	2	0			$46.00		
6	217-5049	encoders everything included	vexrobotics.com	$0	n	4	4	0			$39.99		
7	am-2858	PCM	AndyMark.com	$0	y	2	2	0			$90.00		
8		RSL	AndyMark.com	$0	n	2	2	0			$52		
9	am-3205	Router	http://www.andyr	$135	n	1	2	1			$135		
10	am-2006	pressure switch	AndyMark.com	$0	y	2	2	0	y (2)		$29		
11	am-3000	new roborio	AndyMark.com	$435	n	1	2	1			$435		
12	am-0282	PDP breaker	AndyMark.com	$30	n	2	3	1			$30.00		
13	am-2856	PDP (w/ extra nuts and bolts)	AndyMark.com	$200	y	1	2	1	y		$200		
14	am-2854	spare talons	AndyMark.com	$1,260	y	6	20	14			$90		
15	am-2096	5 amp breakers	http://www.andyr	$12	n	8	10	2			$6.00		
16	217-0192	40 amp breakers	https://www.vexr	$5	n	13	30	17			$4.99		
17	217-0205	30 amp breakers	https://www.vexr	$100	n	10	30	20			$4.99		
18	217-0192	20 amp breakers	https://www.vexr	$0	n	24	20	0			$4.99		
19	am-2097	10 amp breakers	http://www.andyr	$0	n	12	10	0			$6.00		
20	1327	red powerpole casings	powerwerx.com	$48	n	51	180	129			$0.37		
21	1327G17	orange powerpole casings	powerwerx.com	$0	n	54	50	0			$0.39		
22	1327G16	yellow powerpole casings	powerwerx.com	$0	n	52	50	0			$0.39		
23	1327G5	green powerpole casings	powerwerx.com	$0	n	54	50	0			$0.39		
24	1327G8	blue powerpole casings	powerwerx.com	$0	n	53	50	0			$0.39		
25	1327G23	purple powerpole casings	powerwerx.com	$0	n	42	20	0			$0.39		
26	1327G22	pink powerpole casings	powerwerx.com	$1	n	18	20	2			$0.39		
27	1327G7	white powerpole casing	powerwerx.com	$5	n	7	20	13			$0.39		
28	1327G18	gray powerpole casings	powerwerx.com	$0	n	35	20	0			$0.39		
29	1327G6	black powerpole casings	powerwerx.com	$32	n	46	150	104			$0.31		130
30	1327G21	dark brown powerpole casings	powerwerx.com	$0	n	21	20	0			$0.37		16
31	PCLIP	powerpole clips	powerwerx.com	$0	n	143	100	0			$0.49	13	100
32				$0				0			$0.49		
33		5 battery lugs	powerwerx.com	$0	n	21	10	0			$1.39		10
34	5900	Battery powerpole crimps	powerwerx.com	$1	n	8	10	2			$0.68		
35	283-2330-ND	20 amp fuses	Digikey.com	$1	n	14	15	1			$1.27		
36	283-2328-ND	10 amp fuses	Digikey.com	$6	n	10	15	5			$1.27		
37	952-2561-ND	vampire clips	Digikey.com	$0	n	91	20	0			$2.20		25
38	288-1016-ND	long red ferrules	https://www.digik	$0	n	103	100	0			$0.20		100
39	US14	straight pneumatics connetors	https://www.auto	$22		8	25	17			$1.30		
40	5779K318	smalll manifold	mcmastercarr.co	$17		1	2	1			$16.60		
41	B07L7QFT3Q	pneumatic endcaps	https://www.ama	$24		0	25	25			$0.95		
42	UL14	pneumatic L" connetors	https://www.auto	$24		6	25	19			$1.25		
43		white sticky squares	https://www.ama	$11	n	28	200	172			$0.04		
44	am-2002	pneumatic auto-relief valve	Andymark.com	$0	y	2	2	0	y(2)		$40.00		
45	WM1837CT-ND	Minimolex female crimp	Digikey.com	$1	n	93	100	7			$0.14		100
46	WM1841CT-ND	minimolex male crimp	Digikey.com	$1	n	90	100	10			$0.14		100

Order proposal to mentors

- **Spreadsheets!**
  - Easily accessible for all mentors
- **Explain reasoning for your order and why**
  - Are there any better deals from different vendors?
  - Shipping cost comparison?
  - Why are they necessary?
    - Everything on your order should have a justification as to why you're ordering it.
- **Consolidate vendors (to reduce shipping cost)**
  - After comparing shipping prices
  - After comparing the price of the component on different websites
  - Quantity discounts (don't order 40 when box of 50 is cheaper)

Ordering Spreadsheet

,	Description	Link	price (per unit)	Quan on hanc	Need	Quan to Order	Price	Amount getting	Cancel?	Pack of #?	rdered from F	In kickoff kit	coupons
Amazon													
	zipties	https://www.ama	$13	1	1	0	$0	0		500			
	15mmX30mm cable chain	https://www.ama	$21	0	3	3	$63	3		1.00m			
	white sticky squares	https://www.ama	$6.02	1	2	1	$6	100		100			
	1" heat shrink for batteries	https://www.ama	$38.99	1	1	0	$0	0		100.00ft			
	5V Individually addressable LED lights	https://www.ama	$32.88	0	2	2	$66	32.8		16.40ft			
	On / off Switch	https://www.ama	$31.78	2	3	1	$32	1		1			
	clear nylon sheathing	https://www.elec	$0.55	0	25	14.75	$0	14.75	y	1.00ft			
SHIPPING							$0						
POST SHIPPING TOTAL							$0						
CLIPPARD													
11130-Q	1/4in NPT muffler	https://www.clipp	$3	0	4	4	$0	4	Y	1			
AVT-12-1	TINY AIR TANK (250psi) 1in cubic volume	https://www.clipp	$11	0	0	0	$0	0	Y	1			
VYH1-0804-CI	1/4in Vinyl Tubing	https://www.clipp	$11	2	2	0	$0	0.00ft		50.00ft			
PRE-TOTAL							$0						
SHIPPING							$15						
VOUCHER							-$20						
POST SHIPPING TOTAL							-$5						
CFORCE													
CF011X	Portable monitor	https://cforcedes	$119	0	0	0	$0	0	y	1			
CABLE TIES & MORE													
BSSCE1.00-25	nylon openable sleeve	https://www.cabl	1.32	25.00ft	25.00ft	0.00ft	$0	0		1			
SUPER BRIGHT LEDs													
AE70-GCOB	70mm light ring green	https://www.supe	$2.88	1	2	1	$0	1	y	1			

“So the [roborio] has to move… again…”

— 4499’s Electrical Team

“So the [compressor] has to move… again…”

— 4499’s Electrical Team

“So the [router] has to move… again…”

— 4499’s Electrical Team

“So the [air tank] has to move… again…”

— 4499’s Electrical Team

“So the [camera] has to move… again…”

— 4499’s Electrical Team

Team Practices

Electronic

Crimping	Board Design/Fabrication	Mounting/securing components/Assembly
Sensors	CAD/ Design	Pneumatics

Crimping

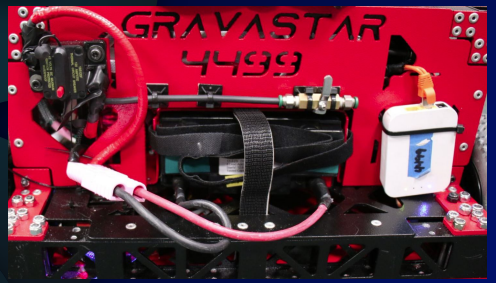
- **Standardized instructions for crimping**
  - OUR TEAM USES A “FORMULA” WHEN USING OUR CRIMPS.
    - This means a type of connector should be crimped the same way every time so they can be interchangeable with other cables.
- **Use the proper crimps for the connector you’re using**
  - Pliers, vices, and hammers will never give you the quality connection given when you use the proper crimper.

Board Design/Fabrication

Material
- Aluminum Sheets
- Carbon Fiber (careful it conducts electricity)
- Corkboard

Covers
- Lexan
- Aluminum

Mounting/ Securing Components

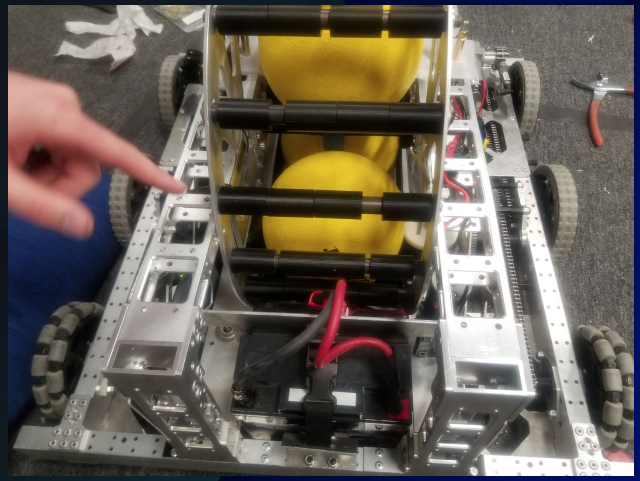


- When zip-tying cables down, do not put too much strain on them. Over time this can cause shearing and disconnection issues.
- Cable tie mounts are used when there is no other mounting solution
- Double sided sticky tape is used for vibration dampening and extra security on components

Mounting batteries:

- Vertical mounts result in less dropped batteries on the field (from our experience)
- Use either an elastic band or buckle to secure the battery in place.
- *We have learned this the hard way a few too many times.*

Sensors



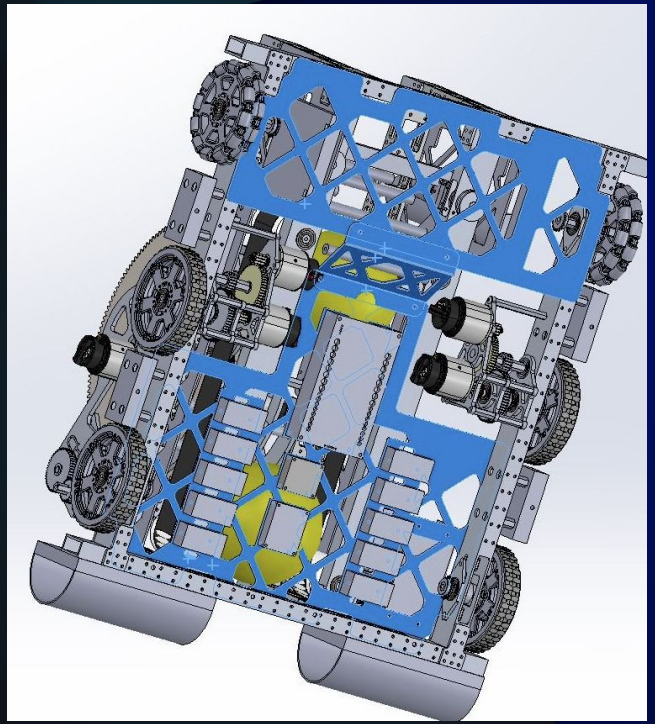
Plan

- **Make a plan on location**
  - WHERE DO THE SENSORS NEED TO COMMUNICATE INFORMATION FROM?
    - e.g. Telling how many game elements you're currently holding and where they are.
- **How are wires run to the sensor**
  - HOW MANY WIRES DOES IT NEED?
    - Is it like a beam break, where it's like two sensors?
  - WHAT SIGNAL TYPE IS THE SENSOR?
    - PWM, DIO, Analog, Relay?
- **How long will the wires need to be?**
  - IF THE SENSOR IS ON A MOVING COMPONENT, BE SURE TO GIVE SOME SLACK TO THE WIRE (SO IT CAN ACTUALLY MOVE)
- **Label your sensor cables**
  - USUALLY WITH COLORED ELECTRICAL TAPE.

Rigid mounting solutions

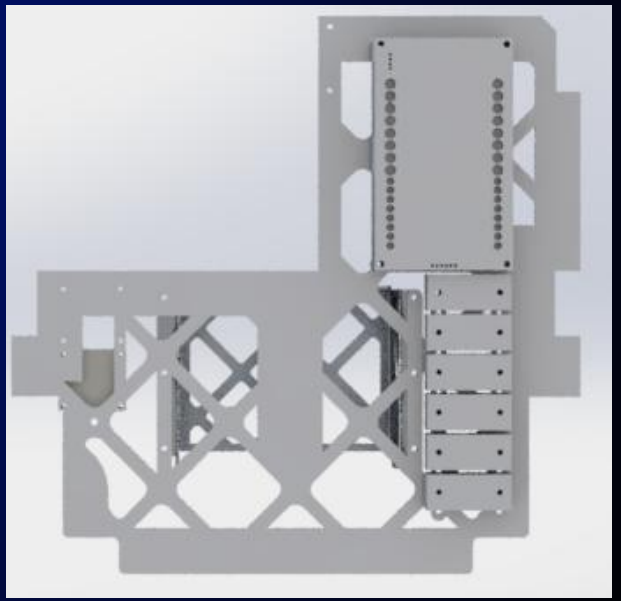
- Limit switches - add hardstops
- Camera mounts
- Light ring

CAD/Design

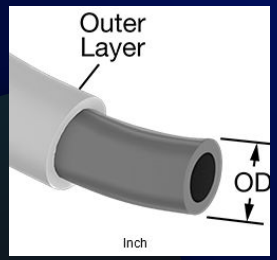


Solidworks

- We don't design wires since it is tricky and time consuming
- Linear/Circular sketch pattern to create lattice
- Very simple boxes that represent components, allow for less rendering, and easier CAD instead of using complicated 3D models.



Pneumatics



How we mount pneumatics

- **Avoid sharp turns**
  - PNEUMATIC TUBING TENDS TO NOT PERFORM TOO WELL WHEN BENT TOO MUCH.
    - Ask yourself, where are the tightest corners of my tubing (those are likely to be failure points)

What do we use?

- NOT JUST 1/4IN TUBING
  - For components such as a pancake piston with not much stroke, we use 1/8in tubing.
- QUALITY FITTINGS
  - McMaster and Automation direct have some very high quality fittings that we use.
- QUALITY TUBING
  - The tubing we use from Mcmaster is abrasion resistant, and allows a much tighter grip when put into PTC fittings.

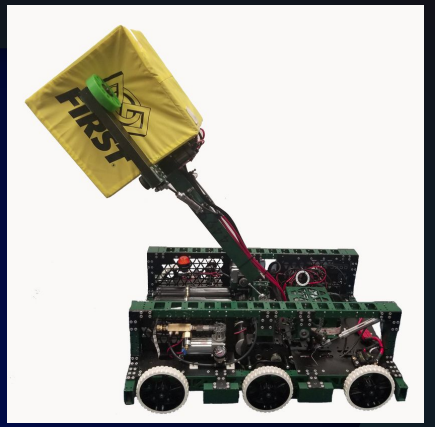
“Howdy!”

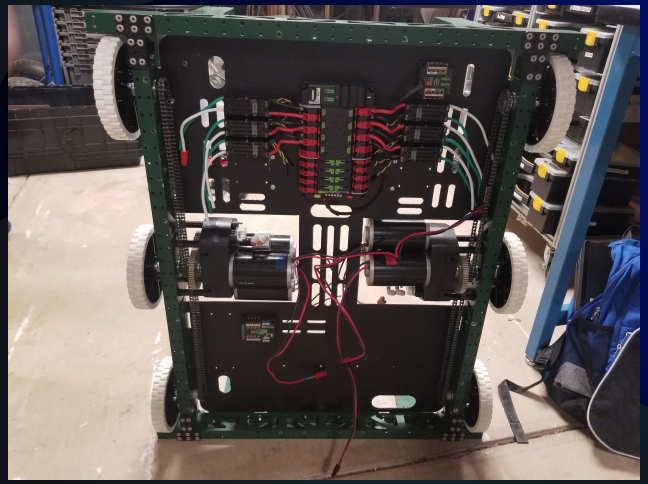
— **Jack Herlihy**

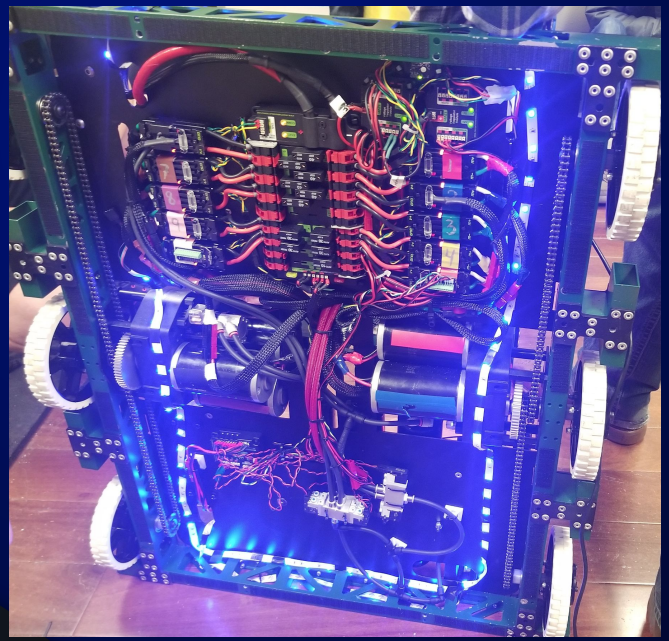
Upside down design

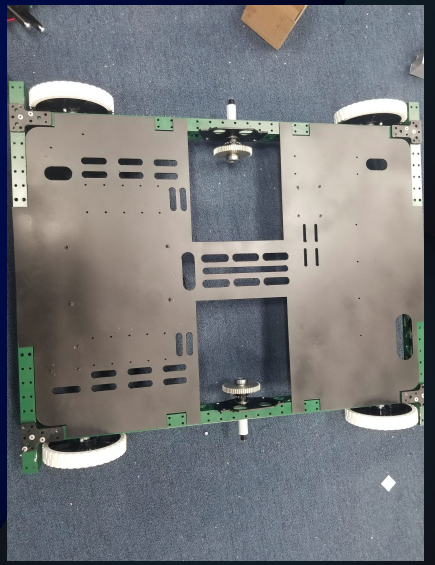
2018 robot

- Simplistic Design lended to more space to be utilized
- First year of upside down electronics
- Easy communication between Mechanical and Electrical
- Quick Maintenance
- Components and wires safely secured







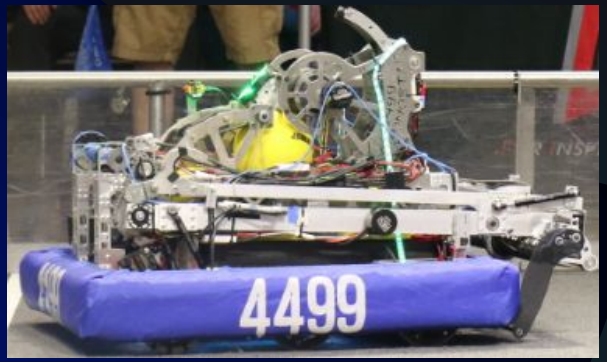


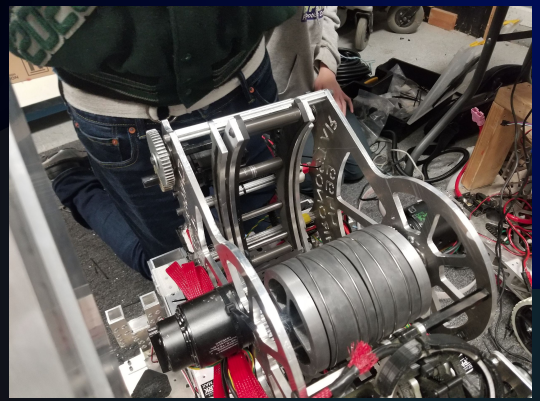
2020 robot

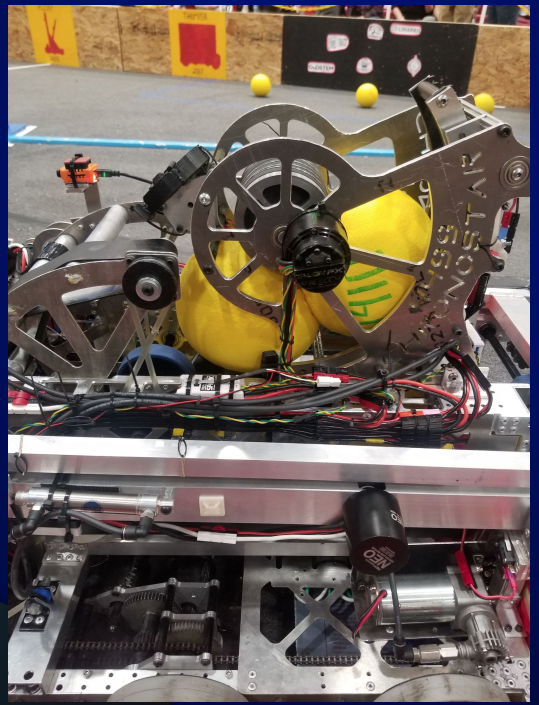
- Rapid Changes lead to redesign
- Limited space due to complexity of robot
  - Manageability issues
  - Robot design constraints

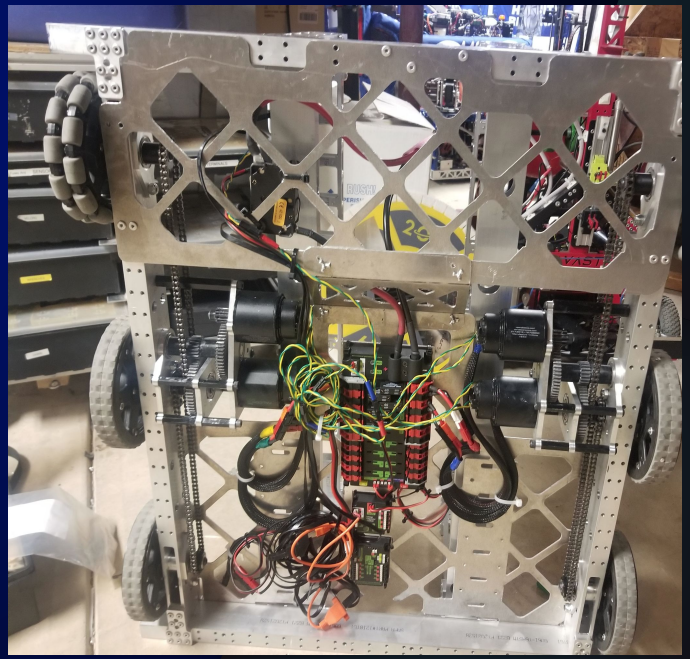
Improvements?

- Group of wires
- stand-offs
- adjustable camera mount

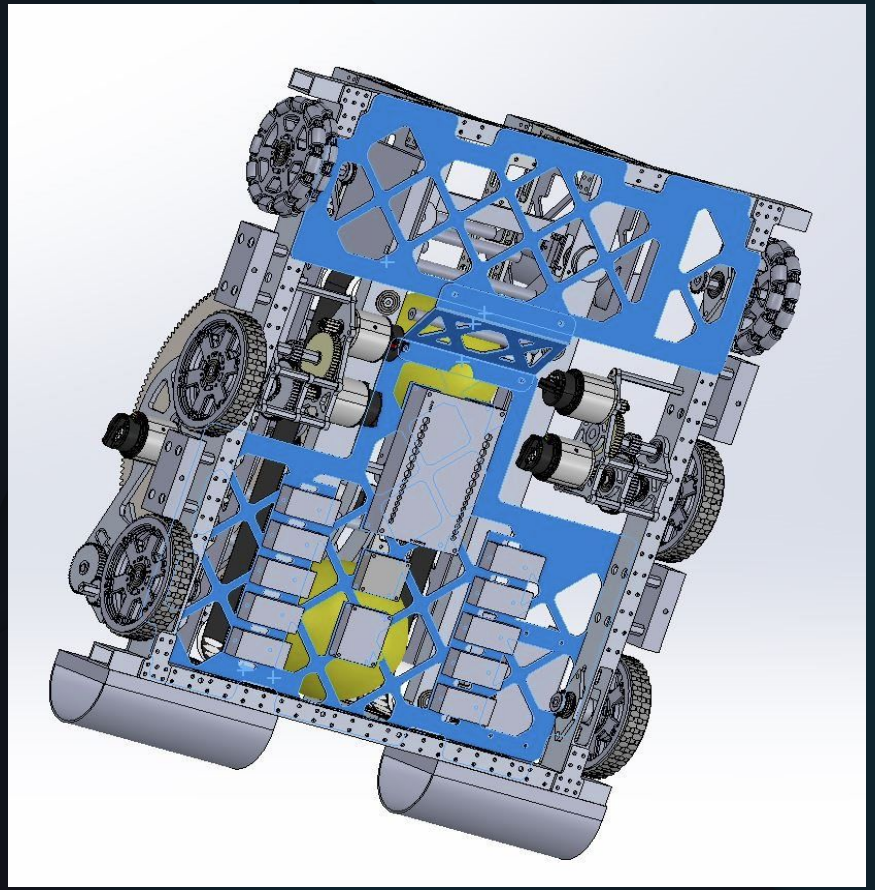


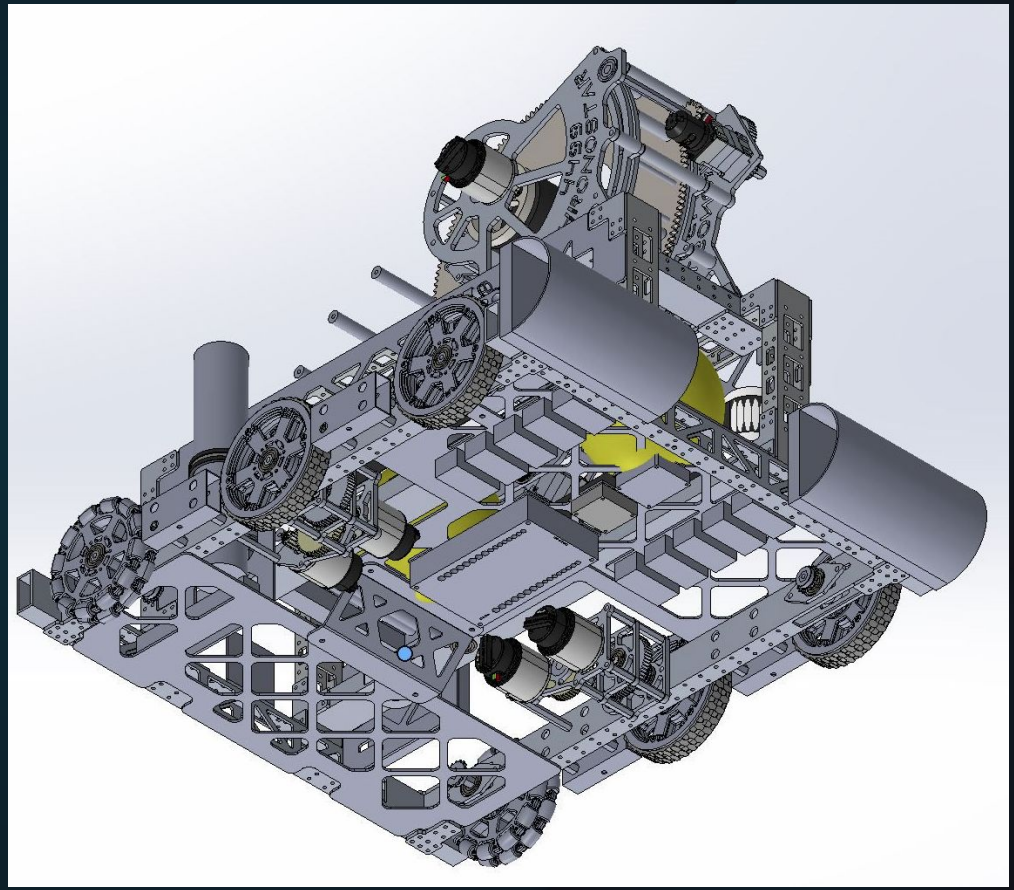






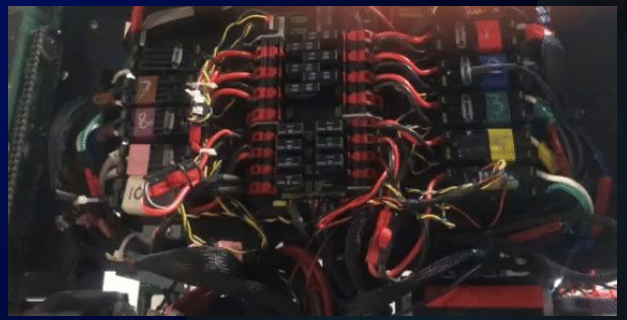
2020 Robot CAD Design





Generic Upside down Design Tips

- **Use a <u>removable</u> cover on the bottom of your robot to protect vital components**
  - This cover should also preferably be clear, so you can see signal lights to troubleshoot issues without taking the cover off.
- **Assemble components before mounting board to robot**
- **Certain components need to be visible (RoboRIO, RSL, etc.)**
- **Certain components may be too big to fit underneath**
- **Add access points for wires to reach to mechanisms**



“Are you freaking kidding me right now Cooper?”

— Alex Torres

Troubleshooting

How to troubleshoot quickly?

- **Identify what specifically is “broken”**
  - What components could be the issue?
  - Is it actually an electrical problem?
- **Voltmeter**
  - Check if grounded to frame
  - Continuity between wires
  - Check if voltage is passing through wires
- **Process of Elimination**
  - Individually verify each component is working correctly in a chain of relying components

“HEY! Safety glasses!”

— **Hailey Holman**

Lessons learned

Communication is KEY

Test every connection after a match

Never assume a wire/crimp will last forever

Expect a lot of unplugging and replugging from the RoboRIO (use ethernet and USB extenders for more accessibility, and so the ports don't break)

Make spare cables, especially the ones that are hard to make.

References

Tool/Item	Website	Picture
Powerpole Crimper	Amazon	
Battery Crimper	Amazon	
Crimper for ferrules	Amazon	
Precision Microfit Crimper	Amazon	
Pneumatic tubing cutters	Automation Direct	

Supplies and Components

Our commonly used electrical supply list

Questions