

Waterloo Formula Electric 2022/2023 Year in Review

UNIVERSITY OF
Waterloo



Department of Mechanical and Mechatronics Engineering

A Report Prepared for:

The University of Waterloo

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Part I

Preamble

1 Background

In the competition year of 2022/2023 (which I shall refer to as the 2023 season) the team decided to bring a very similar vehicle to competition as in previous years. The current iteration of the vehicle has stemmed from design decisions made in 2017/2018. Design has been very iterative and continuous, the accumulator has been a WIP throughout 2019-2021 with the accumulator being in a “ready-to-use state” by summer of 2021, even then without waterproofing, proper insulation/isolation and it’s fair share of issues.

The team structure had myself (Owen Brake) as the technical lead and Will Bellotto as the team lead. I handled most of the electrical/firmware/tractive work while Will handled most of the operations and mechanical work.

At Formula Hybrid 2023 the team performed generally successfully. The team blew through electrical inspection on the first try due to the extensive preparation and documentation performed. The mechanical inspection went fairly well, there were some minor request made which did moderately impede team progress but the team was fully inspected well ahead of schedule. The team won the Scrutineers, and the Project Management awards. The team struggled on the leaderboard due to certain engineering failures that occurred. causing complete failure of the vehicle.

2 Responsibility

As the technical lead I take the sole responsibility for the failures as laid out in the next section.

Part II

Failures and Lessons Learned

3 Organization

3.1 Leads

One failure point of the Waterloo Formula Electric team in the 2022/2023 season was the team lost a significant number of lead members. Depending on how you count it 4 members of the leads team were either removed or resigned. This poses a significant burden on the team as now a leadership role has a vacuum and that role has to be picked up by another person.

The cause of this is multi-factorial. The team still suffers from California brain drain. As a team we propel members and build them up to have the skills to work at major California tech companies like Tesla or Apple. Those members get those co-op jobs then quit the team because in their mind “they’ve made it”, the team is just a distraction. Some would argue this is quite logical but it is irresponsible to the youth who now have lost another potential mentor. It is also untrue unless someone wishes to remain at the skill level of a junior intern for the rest of their life.

Another notable issue was the idea of a “lead” was very blurred this term. A lead and a non-lead was a very pointless term, some leads demonstrated leadership while others did not. It seemed those in the leads were simply “senior” engineers.

3.2 Team Engagement and Communication

3.2.1 Communication Amongst Members

In an effort to promote friendship and a sense of enjoyment among members in Fall 2022 an effort was made to produce more social events and improve the social standing of the team. Efforts were made to add levity and humor to the team. To an extent this was successful for a portion of the team it appears enjoyment increased and participation rose somewhat.

However, a non-trivial amount of members appear to have felt alienated. Notably the women would be very uncomfortable in these very inappropriate moments. The levity rose to highly inappropriate jokes being made in very public, full team settings.

Respect will be dealt with in a little bit, but communication also degraded completely to blame and every person for themselves. Members were publicly shamed and humiliated. Often members would publicly shame others to make up for their own insecurities.

3.2.2 Professionalism

The team's professionalism dropped significantly. While I was on term the professionalism was fairly well maintained, in the SDC (Student Design Centre) we would have fun while still remaining professional: putting up Christmas Tree + Decorations and playing music at a reasonable volume.

But, noticeably when I left the team took a huge dip in professionalism to the point of reaching a toxic frat house atmosphere. When I returned to Waterloo various disrespectful jokes were painted across this walls of the bay. The entire front of the bay door was covered in Red Bull box covers. The day I returned there were 5-7 members just drinking Red Bulls, chatting and watching 1 person screwing in a bolt on the car. 0 productivity and an active repellent to new members and work.

3.2.3 Respect

A big issue on the team has been a lack of respect towards members, I will try to break down each paragraph into the types of disrespect displayed towards members.

There has been a very noticeable disrespect towards members by singling out and roasting members. This is a very serious issue that must be addressed as the team has a very toxic atmosphere right now. Certain members seem to think it is acceptable to roast or ridicule other members on their work, this is completely unacceptable and in the future severe consequences will be meted out. This comes from: 1. an insecurity in the roasting member, 2. a desire to appear superior, 3. an understanding that members enjoy critiquing and ridiculing people behind their back, in fact some people have been praised for doing this.

There has been a very noticeable disrespect towards certain members by abdication of work. Most members view it acceptable to completely slip deadlines, abandon projects or submit completely incomplete or unacceptable work. This is not okay, it puts an incredible burden on other members as that work has to be picked up. As an example there were multiple times before testing events or before a competition inspection that members were explicitly told "this needs to get done", failure would result in a missed testing event or failed inspection. Most of the time these tasks would not get done as members understand

that someone else will carry the slack for them. This puts an incredible burden on these “carrying” members and adds a tremendous amount of risk to the project.

3.2.4 Communication to Members

Communication to members has been quite poor. Vehicle and team goals have not been adequately and frequently described to general members. Progress at competition and decisions made have not been effectively communicated as it is no one person’s explicit role to do this.

3.3 Participation

Participation in Waterloo Formula Electric is extremely poor. Dedication is effectively 0. Most people showed up to the Formula Electric bay to contribute to the competition effort the day before we leave. A small minority showed up with 2/3 days of work before competition (an already too late date to be an effective contributor). I would put the hard working contributors at maybe 3-5. Casual members would extend to about 8/9. Effectively non-existent contributors or extremely new members would be the rest, a truly shocking distribution considering 26 people came to competition.

People use this team as a platform to jump to high paying US co-ops and don’t care to contribute any time or effort. The vast majority of members won’t even contribute 25 minutes to the team a week, many are at 0 hours.

3.4 Operations

The operations team has been effectively absent for this past year (despite 1 or 2 members putting in some effort to hit deliverables). This strongly affects vehicle progress as work that should be done by the operations team is beared by the vehicle team.

Some examples:

- I had to book the competition house, I had to search for a suitable venue and front the money
- I or another vehicle team member have been collecting truck/trailer keys and booking them
- I or another vehicle team member have been booking the testing spaces.
 - I’ve had to stop vehicle work to drive to a track to make sure it’s open

- No operation member printed any posters for recruitment despite my constant pestering, Will had to make one at the last minute before a student fair
- We missed competition pre-registration and lost a small amount of points
- I had to delegate members to handle operations roles at competition like food, social events and transportation
- Finance is absent
- 0 recruitment work done
- Hazardous waste disposal arrangement and various Faculty<-->Student communication has been handled by myself.
- Social events are arranged by myself
- Project Management has been done by me and the subteams, 0 overlooking from the operations team
- Significant pestering was required to get merchandise and livery rolling
- Social media has been 0 besides a few posts by vehicle members

4 Competition Preparation

4.1 Documentation

The documentation we prepared for competition was extensive and appropriate. The judges were clearly impressed. An extensive amount of work was performed to correct the atrociously wrong ESF-2 submitted in the 2021/2022 season and it clearly paid off.

In the future the documentation should be up to this standard, the team should be documentation things throughout design, assembly and validation. Every rule should be checked and validated for rules compliance.

4.2 Vehicle Readiness

As in previous years the vehicle was not ready on time. I ended my internship a month early to come back to the team and get the vehicle in a ready state. Unfortunately when I returned the mech team wasn't close to finishing up the vehicle. A half-working vehicle

was placed on the track in early April. Composites were not placed on the vehicle until 1 day before departure to competition. The vehicle should really be on the track, being tested in February through to mid April.

In April there were numerous pieces missing from the vehicle: loose bolts, constant pedal box work, etc.

4.3 Quality Control and Validation

A really big issue was quality control and validation.

On the mechanical aspect multiple very poorly designed components were placed on the vehicle. Many red flags were raised and few warnings were heeded and at competition the judges identified issues on our vehicle in relation to quality control and poor build practices. It is also the case that proper mechanical validation has not been performed, often parts would be machined then left for assembly at a later time, the day before testing assembly would be attempted but would fail as the part was not properly machined/design and 0 validation was performed.

On the firmware side of things there was significant impediments to work on the vehicle. Throughout the Fall 2022 and early Winter 2023 term a very large number of commits were published adding very minor functionality and almost every single commit had serious bugs which caused the vehicle to fault or have degraded performance. Upon a post-mortem analysis it was clear that people would just edit the firmware, not even flash the firmware to a board and call it a day. Multiple commits had 0 line coverage in their validation, if the developer had even tried to enter that piece of code they wrote it would have been clear that they had made mistakes. Also, little to no code review was performed, there were multiple cases of logical flaws and mistypes that should have been so easily caught in code review if even 5 minutes of code review was performed. I spent the entire month of August 2022 testing and ironing out all the historical firmware bugs to get a reliable vehicle, almost all of that progress was eradicated by the time I returned in April 2023.

5 Testing

5.1 Testing Sites

We had serious issues with acquiring testing sites. The only 2 realistic options are: FRC (Fire Research Center) and Lot C. Lot C is only available during the weekends. FRC has

marginal access, we never had any issues getting in and testing but we never quite “had it booked”, so it was a little bit of a bizarre experience.

The more serious issue with testing was weather. Most days where testing was going to be attempted had terrible weather it be: terribly cold temperatures, precipitation or storms.

5.2 Organization

Testing organization was fairly horrendous. Testing days were decided the day before. This was because while working on the vehicle to get access to the track I would have to: book vehicles, check out the track, get the keys and vehicles from the lots, organize packing, etc. There should be a testing RE (Responsible Engineer), this role was not adequately filled in this last term and needs to be taken by a dedicated member who will not be pressed with technical work during testing season. This person needs to be completely resilient, able to organize testing logistics throughout any period including the exam period (they don't have to be there but they have to coordinate key handover, track booking, etc.).

5.3 Single Point of Failure

A significant issue with testing was the fact that it all depended on one person. If I was not there for testing, testing would not occur. This puts an incredibly burden on one person as I would be getting maybe 2/3 hours of sleep every day for many days in a row. I would have to be debugging and testing on minimal sleep and also working on the vehicle after testing. This is not how it should be, there should be shift days for vehicle testing. This is somewhat infeasible though as the following criteria must be met for a testing event:

- If something goes wrong in the firmware/electrical there must be someone who can fix the issue
- There must be someone there with an understanding of the vehicle's systems and someone who is responsible such that any firmware/electrical changes will not pose a safety issue to the driver or potentially damage the vehicle
 - (There are multiple incidents of permanent damage to the vehicle due to unsupervised work on the car)

- There must be someone there such that in the event of an electrical fault (IMD or AMS) they can provide guidance on how to act safely when interacting with it

Another factor is that often the testing goals are set and require me, e.g: tuning Traction Control, tuning Torque Vectoring, getting endurance data, etc.

6 Formula Hybrid 2023

6.1 Observations from other Teams

6.1.1 Professionalism

Other (good) teams are highly professional. They appear like a team, they are coordinated in terms of merchandise. They aren't making fools of themselves. When you approach their bays the members appear knowledgeable and professional.

6.1.2 Design Event

For the design event other (good) teams were highly prepared. Our team was very minimally prepared. It was clear their work was coherently layed out and significant effort was made to appear professional. Due to technical bandwidth issues the design event for our team was not started until the day before we left for competition. This is unacceptable, we should be ready before we even leave for competition.

6.1.3 Vehicle Completion

The best teams had a vehicle that was very complete. It was still quite noticeable that the best teams had work to be done at competition when things broke down. But this work was minimal, there was no zip tying on the way to inspection, their vehicles appeared clean and ready to compete.

6.1.4 Coherent Vehicle Story

A big thing we need to improve is having a coherent vehicle story and design. Our vehicle has been Hodge-podged together for the last 4/5 years, there are multiple random design elements stuck together which don't make for a cohesive design. Other teams have exact purposes and explanations for each component on their vehicles, this is something we must implement at the next design iteration.

6.2 Observations on our Team

6.2.1 Why'd they come?

We brought 26 people to competition. We failed to learn our lesson from last year when we brought 30 members. There were way too many people brought, the sheer volume is not the issue but the proportion of members who enjoy the experience and the proportion of members who care or have something to do.

At least 50% of the team was sitting in lawn chairs in the paddock around heaters chatting while the major workers were grinding. They would only pop out to say “why'd the car fault” or some vain comment about themselves. It was shameful, embarrassing and unprofessional. To me it is very unclear why these people even came to competition. I had the philosophy that we should invite many people to give them the opportunity but it's clear we need to say no to more people, I myself have a ban list for next year.

Well over half of the people at competition I would consider severe under performers, people who haven't contributed in >6 months to the team and have done basically 0 work. In one instance someone came to competition when their last contribution was over a year prior. It's unacceptable, no one should get special privileges, no one should be at competition if they're not passionate and/or useful.

Not only this, but members would actively impede work. Constantly complaining about trivial matters, requiring hand holding to do everything, taking up precious work space in the paddock.

6.2.2 Talking Bullshit to the Judges

A big failure of mine was not pushing more the topic of “SHUT THE FUCK UP” when judges are around. We lost respect and points because:

1. People who weren't supposed to be at the design event, just showed up uninvited
2. In the paddock, people would spout nonsense to judges, clearly incorrect information.

Members who either respond to judges questions with “I don't know” which makes the team look like fools. But even worse members would talk to judges and say lies like “we didn't do this” or “we did do this”. Afterwards I talked to a lot of the judges 1 on 1 and they told me instances where members told them things in the final design presentation and I told these judges that the facts they were given were completely false. If you don't know something why would you lie, it so actively cripples the team?

6.3 Failures at Competition

6.3.1 Firmware Regressions

A significant issue I struggled with both before competition and at competition was firmware regressions. We achieved 3rd place in the acceleration event at Formula Hybrid. The reason we were 3rd is because a firmware regression resulted in the car faulting at the very end of the acceleration event. Completely unacceptable.

6.3.2 Encoders

A big issue we had was in regards to the encoders. We use front encoders for our Traction Control Algorithm. Our traction control algorithm significantly improves vehicle handling and acceleration event times and autocross speeds. Without the encoders the vehicle is so crippled it's not even funny. Unfortunately due to a circus of errors the encoders did not end up being truly functional and it strongly affected our scores. I will quickly breeze over the issues we had:

1. Parts were not properly packed which meant we had to late 1 day delivery for a high price-tag these tiny mounting components from Waterloo to New Hampshire
2. Extra components were not purchased (despite insistence) so when the encoders actually fully broke there was no chance of replacement
3. Parts for the encoders were straight-up lost (connects to point 2)

6.3.3 Emrax Motors

For the past few years the right side of the powertrain has been noticeably stiff. It has always been assumed it's because of friction on the right side of the powertrain. At competition that hypothesis has appeared to have been completely rejected. At competition during an autocross run the vehicle faulted. Upon rolling the vehicle off the track it became clear that the triggered fault was an IMD fault. This indicates a low resistance from the tractive system path to the low voltage ground. This is one of, if not the most dangerous fault that can occur, because of this I quickly pulled out the high voltage equipment, suited up and performed the necessary insulation checks. It became clear that the low voltage system was not high voltage energized at the current time, thus I assisted the driver in exiting the vehicle safely.

The demons then began. It was pretty clear the insulation would only degrade when the vehicle was precharged. After extensive testing it also became clear the insulation would only degrade when connected to the motor controllers. After extensive testing after that it became clear it was the right motor with the insulation fault, a pretty severe one.

The night before the endurance event we had to completely rip open the powertrain, extract this motor and perform some insulation band-aid solutions. By cleaning it up we found the insulation perhaps marginally improved. There's not much one can do, opening and **resealing** the Emrax motors is practically impossible, especially in a residential house in New Hampshire.

At the endurance event we managed to get it to do 2 laps but it faulted coming around the bend due to the same IMD fault.

After the event after discussing with judges and inspectors the hypothesis we developed was that one of the windings in the motor has either had the enamel corroded off or a winding has broken and it's close enough to the stator such that it will arc at our Tractive System Voltage. The autocross run just so happened to have bumped the wire closer so it would cause a real issue. This also explains why the right motor has always been more stiff.

6.3.4 Mechanical Issues

There were numerous mechanical issues experienced at competition of which I don't want to get extensive detail into. I will quickly list out some points of improvement:

1. Rules compliance has improved significantly but some more work is needed
 - (a) (Rules Compliance should not be done at competition)
2. Extras, extras, extras, we almost didn't show up to competition because we broke a hub. Money is not an issue
3. Quality Control as stated above

6.3.5 Buzzer

Why is our buzzer not sufficiently specced? We measured at like 78dBa when the rules says minimum 80dBa. We should just purchase an insanely loud buzzer for EM. Also someone decided to tape up the buzzer :|.

Part III

Next Steps

7 Project Management

There was inadequate project management performed throughout the last year. This was in part due to the school killing our JIRA access 1/3 of the way through our term. Even the mechanical team though that used JIRA, deadlines slipped constantly.

There needs to be strict project management, strict deadlines and a clear understanding of how the vehicle is coming together and what needs to be done. For next year a proper project management system is required.

In my opinion it's time to sunset JIRA, it's awful, it's slow, requires you to constantly login, it's a mess. I will look and test out some open-source and/or self-hosted solutions. OpenProject and Kanboard seem like sensible options.

Each task needs to be properly made and planned out with deadlines.

8 Organization

A significant reorganization of the team is required for this upcoming year. A lot of lessons have been learned and it's become quite clear the principle of having an "electrical lead", a "tractive lead" and a "mechanical lead" are not efficient or sustainable. What should be done is things should be broken up into REs (Responsible Engineers), that is the entire project will be broken down into tiny subsystems.

My recommendation for the breakdown I shall display here, those names in "(brackets)" are not actual REs that's just categorization:

- Technical Lead
 - (Electrical)
 - * Wire Harness
 - * Accumulator Lid
 - * Accumulator Segments
 - * (Each new board being produced, below are hypotheticals)
 - WiCAN 2.0

- Inverter
- BMU/AMS respins
- WSBs
- TSAL
- * Motors and Inverters
- * Charging
- * Firmware Validation (HITL and Unit Tests)
- * Beaglebone Software
- * Board Firmware Support
- * Electrical Validation (HITL and Unit Tests)
- * Grounding
- * ESF Lead
- * Electrical Rules Compliance
- (Mechanical)
 - * Suspension
 - * Frame
 - * Mechanical Powertrain Design
 - * Composites
 - * Livery
 - * Pedal Box
 - * Brakes
 - * Steering
 - * Impact Attenuator
 - * Cooling Loop
 - * Firewall
 - * Dashboard
 - * Uprights/Hubs/Wheels
 - * Board Enclosures
 - * TSMP Enclosure
 - * Accumulator Box
 - * Belts, Restraints, Driver Equipment
 - * SES Lead

- * Mechanical Rules Compliance
 - Data and Telemetry (We should have someone determine all the various things we should be telemetering: strain gauges, wheel speeds, temperatures, etc.).
 - Waterproofing
- Team Lead (Operations)
 - Finance Manager
 - * Sponsorships
 - * Budgeting/Purchasing
 - Project Management and Deliverables
 - Merchandise and Social Media
 - Testing Organization
 - Workspace Manager (Inspections, Cleanliness, Inventory, Procurement of Tools)
 - Recruiting and Outreach

People should have highly specific responsibilities that they focus on to develop mature understanding of their systems. People can have multiple roles in this but each person should be the most experienced/understanding on the roles they control. Each of the roles suggested above have varying technical difficulty and work burden.

In this past year we had 3 mechanical leads and 3 electrical leads this lead to an obfuscation of responsibility. Each person is stepping over the other, one person will take a large burden of the work, others will feel no sense of responsibility towards their work.

If an RE abandons their post they will lose their post.

9 Design

I will not perform a complete vehicle analysis in this document. This will be a limited plan, indepth analysis running simulations and actual numerical analyses is required.

9.1 Vehicle Analysis/Design

Per the advice of multiple judges at competition we should consider that in our redesign that we should assembly a minimum viable vehicle, each component on the vehicle should have a strong justification in terms of points in competitions.

As an old racecar driver at competition said “a race car is not flexible, it’s not an all-rounder, it must be designed to fit it’s very specific niche [events]”. We should be removing extraneous functionality that has no justification.

9.1.1 Extraneous Complexity on the Vehicle

I shall list some extraneous and complex parts of our vehicle, they may have a justification but we need to create a stronger justification case for them.

- Rear Wheel Sensor Boards
 - Literally just an extra failure surface, should be removed unless rear encoders or rear strain gauges are deemed necessary
- DCU
 - The DCU is so shit, it’s a CAN node which just forwards button presses
 - The code for it is so awful it’s not even funny
 - This could be fixed with a proper rewrite of the firmware or you merge it with the VCU (strongly simplifies wire harness)
- 2 Inverters + 2 Motors
 - We don’t have a strong justification for having them besides torque vectoring
 - They add substantial mass, failure surface area, packaging issues and installation pains
- Adjustable pedal box
 - Literally pointless, it’s never been moved

9.2 Accumulator

A new accumulator for 2023/2024 is required to compete in FSAE michigan. It’s quite clear that we are energy limited, especially due to certain events which dropped our pack capacity by probably around 20-30%.

The current plan is the 70s12p pack. This is heavy, it’s large, but hopefully it will mean the vehicle is never energy limited and we’ll have a lot more leeway with endurance and autocross events. We’re also nearly cutting our internal resistances in half compared to the 70s7p pack, which could mean forced air convection cooling is not even necessary.

The main point for the accumulator is let's make it simple. A big pain point is this awful lid with wires criss crossing. We should take the time, respin the BMU if necessary but make a sensible lid outline and ensure proper GLV/TS spacings.

The segments should not be press-fit in as they were previously, it means taking apart the accumulator is physically and mentally painful.

The removal and access of the lid should be trivial, disconnect it from your segments.

Start with waterproofing as a design point not an afterthought. We should not ever be afraid of water ingress as we should know we're waterproof.

Alot of this writing is nonsense, the accumulator analysis is "complete". The important thing is we need significant mechanical support on the box design, part of the PM process will be outlining specific tasks to be completed. We need to ensure the accumulator components are procured and assembled quickly and expeditiously.

9.3 Powertrain

Now that we're down a motor it's clear we need to perform a powertrain redesign.

9.3.1 Motors

2 Emrax 208s is quite stupid, they are 86kW of peak power each and 56kW continuous power. At most FSAE competitions (except Hybrid) you are limited to ever getting over 80kW, if you surpass that you are DQed. We are also primarily traction limited, the only time we're hitting peak powers is when our wheels are spinning freely which should not be happening.

We could run the analysis and determine if a single Emrax 208 would work, it probably would be pretty good. However, Emrax motors are extremely power dense so stepping it up to a single Emrax 228 might be the best solution, in fact it's the typical FSAE thing to do. We should run the detailed analysis though using a model of our vehicle to see the effects on our acceleration and autocross scores.

9.3.2 Single Motor Discussion

Single motor drive is probably the correct solution. Single 228 with a differential.

We should redesign the power transmission (gear/sprocket) system to be properly efficient we don't currently run in the most efficient Emrax power region. We should ensure our ratios have us in the most efficient region for endurance.

9.3.3 Hub Motor Discussion

The possibility for hub motors is extremely appealing. It significantly improves our traction which will improve our acceleration times. The analysis should be done urgently to determine the effect hub motors would have on our vehicle compared to a single Emrax 228.

It's an extremely appealing project to me but I see some very obvious downsides:

- Extremely increased failure surface
- HV cabling running near the driver
- Have to spec and find in-hub motors
 - They're expensive and niche
- Maybe have to design gearbox, high risk task
- Higher mechanical design complexity for uprights and hubs

I would love to do the task, I could design a highly power dense inverter for said hub motors as well as source hub motors. But the value has to be proven numerically so we should run these simulations perform these analyses and determine how many more points would we actually gain and what is the risk tradeoff.

9.3.4 Inverters

These Sevcon inverters need to die, one way or another. Further analysis is required on budgetary matters and risk-benefit tradeoff. The analysis is being cooked up.

9.4 Chassis

Our vehicle weighed in at 580lbs at competition. Significantly, significantly heavier than the rest of the competition. The mechanical team should be spending significant time to find the heavy points of the vehicle and shrink them down. With this in mind we should ensure we maintain healthy safety factors, we've seen components fail on the vehicle, especially with an electric vehicle we must be very careful.

10 Manufacturing, Assembly, Installation

The team needs to be significantly better at manufacturing and assembly. There has been severe quality control and timeline issues.

One method to improve will be having a complete project breakdown into tasks. That way the exact progress can be clearly tracked. Members will have clear, exact understanding of what to do. After manufacturing and assembly, members must upload validation evidence to their task for documentation.

I've left the manufacturing section fairly empty, I'd like some more feedback from other members on how we can develop these processes to fix our efficiency, we are a very inefficient team when it comes to this process. The chassis of the vehicle should not be complete in March.

10.1 Extras

Every point in which we can feasibly acquire extras we will. In the past there has been concern about funding, that issue will be dealt with in a later section. The primary point is that every time we do not have extra components we are gambling the entire vehicle's success on one piece, it's significantly more cost-effective when risk is considered to produce extras.

We should have younger members grinding out manufacturing constantly, it helps build experience. We will have strict quality control checks to ensure they don't mess it up, but this is how the younger members learn, by trying and failing, stock is very cheap in the grand scheme of the vehicle.

10.2 Quality Control

Quality Control is a serious issue and one that has to improve dramatically. As stated having validation evidence in PM tasks will hopefully be a critical piece. Whenever something is installed on the car or is prepared for assembly there should be a second set of eyes, if it involves an RE's subsystem then they should be at the final design review and review post-installation.

We must develop a culture where installing a sub-par component is significantly worse than not installing that component because it is not ready.

11 Operations

11.1 Funding

Funding is a critical issue going into the 2023/2024 season. I strongly believe the funding we require we shall acquire. It will require a concerted effort. We should attempt to budget out what we expect to need for this upcoming year and properly spec out WEEF and Sponsorships.

The Accumulator will be very expensive, a new motor will be highly expensive, whatever we intend to do with the inverters will be quite expensive.

Various board respins add up.

We should prepare a full year budget and determine if we require assistance with funding. Should this be necessary I shall arrange a meeting with Professor Teertstra and explain how the importance of acquiring extra funding.

11.2 Recruiting

The team needs to be better at recruiting. For the past 5 years we have been awful at it. Throughout September we should be going to every 1A-3B main engineering program class (e.g MTE100, ME100, etc) and pitching Waterloo Formula Electric. We should have signs up around E5/E7 and around campus like RCH, DP, etc.

We should actively be recruiting people on social media and assisting people as they join the team.

11.3 Competitions

The competition season has not fully completed thus the full roster of competition is not released as of yet. Going into the 2023-2024 season we should be attending more than 1 competition a year.

Certainly FSAE Michigan EV, perhaps Formula Hybrid, perhaps FSAE West if they decide to bring that back, perhaps FSG.