To: Dr. David Willy and Sean Veden

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Subject: Implementation Memo

The HPVCP project is a design project which specifically requests an improved version of a human powered vehicle propulsion system. The goal of this is to adequately use the power provided by a human operator and generate a maximum amount of energy from human power through use of leg muscles. The objective, developed later on, for this project is to design a vehicle capable of storing extra energy that can be utilized whenever extra power is required. Thus far we have redesigned our system, created a prototype of our electrical system and components, and have refined our customer and engineering requirements.

At the beginning of the semester, we were still in the process of designing the propulsion system. In the conversation with Dr. Perry, we found a new goal. Redesign an obsolete vehicle and make it a new usable vehicle. The team believes that this is also an important part of the engineering design. Let the lost items become more efficient and practical by adding new accessories and systems.

In the original design, human power was input through petals and transmitted to the wheels. In the summer vacation, the team designed to input power through cycling and rowing, and then use a flywheel to store a large amount of lost energy, so as to achieve the purpose of reducing energy consumption. In the subsequent design, we added this energy transmission propulsion system to the old vehicle. We redesigned the propulsion system and decided to repair the previous damage.

IIn the new design, we added several brackets and shafts to support our clutch and flywheel. We carefully designed the specific dimensions and related data of the clutch and flywheel to ensure that they can be installed on the vehicle without engineering problems and engineering damage. The team specifically measured the data of the original vehicle and redrawn the CAD. The team also used solidworks to draw CAD of flywheel and clutch. This helps us provide assistance in actual assembly and testing.

1 Customer Requirements (CRs)

Our customer requirements were originally created with Dr. Trevas however, has since left NAU. Changes between the customer requirements from Summer 2021 to this semester are primarily due to the change of our customer. The most significant requirement change is for maximum and efficient use of multiple muscle groups. Originally this entailed the creation of a row bar along with pedaling to increase energy created from the body. We have also refined our requirements with the help of our current clients. Our customer requirements are as follows:

1. Store Energy to be Used Later ------------------------------------ **High**
2. Achieve Max Usable Energy Storage ----------------------------- **High**
3. Display Bike Speed -- **High**

4. Display Flywheel Speed/Energy Stored in Flywheel ----------- **High**
5. Display Efficiency -- **Mid**
6. Low Budget -- **Mid**
7. Safe to Operate --- **Low**

Our main objectives are to use and store human powered energy safely and efficiently while also displaying informative metrics to the user. The purpose of storing energy is to set this HPV apart from all the others in the past. That was one of the goals given by our original client. Our new client, Perry Wood, liked the idea of an energy storage/recovery system on an HPV. For this purpose, Energy storage is our main focus now moving forward. Achieving max energy storage and displaying flywheel energy storage and speed go hand in hand as the display metrics will allow us to test our energy storage efficiency. Energy storage capabilities was an original client requirement, but since our client has changed, our priority for attaining max energy storage has increased. As such we plan to spend much effort on testing, calculating, and refining our energy storage capabilities.

Most HPVs do not have a displayed speed, since it is not a very important part of the design. For our design however, this is very important. Displaying speed, energy, and efficiency metrics are a high priority due to it's multipurpose use. Calculating and displaying these metrics will not only allow us to test our requirements in an efficient manner but will also allow the user to most efficiently use our HPV. This is an important part of setting our HPV apart from all the others.

Lastly, safety and budget have the lowest priorities. The budget priority is low as we have already calculated our planned purchases and do not foresee any budget increases. Safety is also a low priority as the HPV will not be in use for a long period of time, as well as the fact that the frame has already been built by a previous HPV team, who we can assume took high measures of safety into account in their design. So far the team has not come across any safety concerns with the existing vehicle, except for a broken steering, which we plan to fix. The greatest addition to safety measures for our vehicle is the planned addition of a flywheel cover, and possibly a roll cage if the client requests one

2 Engineering Requirements (ERs)

An important part of any engineering project is the Engineering Requirements. Without these, there is no goal to design to. Our project started with a very unclear set of requirements, since the scope and final product were a little unclear as well. With the start of the new semester, and the change in client, our scope and requirements became much more clear. Almost all of the following ERs have been updated or added since last semester.

2.1 ER #1 (changed from summer): Optimal Energy Storage

2.1.1 ER #1: Optimal Energy Storage - Target = 600 J

The most important requirement for this propulsion system as it now stands is energy storage. Originally it was planned to have two forms of propulsion on the vehicle, as well as an energy storage system. When the scope changed to retrofitting the design to an existing HPV, this was no longer feasible. In order to keep most of the original design, the team and client decided that a purely energy storage based HPV would be the best choice. The target that was set was based on a rough estimate of the maximum kinetic energy that can be stored in the movement of the HPV. The weight of the HPV is still unknown, but was estimated to be roughly 25 kg, with a max speed as designated in ER #3. The total kinetic energy of the vehicle is roughly 2 kJ. If a flywheel can store roughly half of that energy, it can return a similar amount of energy to the vehicle when needed.

2.1.2 ER #1: Optimal Energy Storage - Tolerance = ± 100 J

The tolerance for this engineering requirement is approximately 10% of the total system kinetic energy. Since the difference in weight between the flywheel and the vehicle are vastly different, there is not much room for error in the energy storage system if it is to be effective.Thus the tolerance is a maximum of 10% of the total system energy. This was a metric decided on by the team, and their vision of how this vehicle is to function.

2.2 ER #2 (changed from summer): Regenerative Braking Efficiency

2.2.1 ER #2: Regenerative Braking Efficiency - Target = 15% Efficient

Efficiency has always been an important metric to this project. Since last semester however it has been brought to the attention of the team that the original efficiency of 10% was not reasonable if the energy storage system was going to be worth the investment of time put into it. Thus the goal now is to have the efficiency at 50%. This means that the energy taken out of the flywheel is roughly 50% of the energy that was put into the flywheel. This can also be considered from a velocity standpoint. If the storage system brings the vehicle to a stop, it should be able to start the vehicle giving it roughly half of its original velocity. This requirement has to do with not only the flywheel, but also the quality of the friction plate and the amount of pressure applied to it. The team will need to run many tests in order to achieve this target efficiency.

2.2.2 ER #2: Regenerative Braking Efficiency - Tolerance = ± 2.5%

This tolerance is very high, allowing the team to work with many different layouts. Ideally the system efficiency would land within 5% of the target, and that is what we will aim for. In order to do this we plan to try out multiple gear ratios with sprockets in order to reach the maximum storage and efficiency.

2.3 ER #3 (changed from summer): Max Speed

2.3.1 ER #3: Max Speed - Target = 20 mph

The max speed of the vehicle is an important factor in calculating the total energy consumption and storage. This ER goes along with the CR of displaying the speed, as well as keeping the rider safe. The speed of the HPV determines the total system kinetic energy, which directly translates to the total energy that can be stored. In order to ensure that the energy storage can be efficient, but that the rider is safe while operating the vehicle, the max speed has been set to 20 mph. Note that this is not the top speed of the vehicle, but rather the speed at which the display will issue a warning to slow down. Anything past this speed is a good opportunity to engage the clutch, adding more energy into the flywheel.

2.3.2 ER #3: Max Speed - Tolerance = ± 5 mph

This tolerance was not a specific calculated one, but more of a safety measure taken to ensure that the rider can keep control of the vehicle. This tolerance, as well as the target speed, are merely rough guesses based on typical bicycle speeds since the current HPV being retrofitted is not yet operational. The ± 5 mph tolerance allows the rider to operate at a slightly faster speed if needed. The max speed should not fall below 15 mph however, or the regenerative braking system will not be as efficient as planned.

2.4 ER #4 (changed from summer): Display Flywheel Metrics and Speed

2.4.1 ER #4: Display Metrics - Target = Correctly Displayed

One of the customer requirements is that the rider be able to see the speed, energy and efficiency metrics. This leads to a very simple engineering requirement with a yes/no or on/off metric. If the flywheel energy, total kinetic energy, HPV speed, and regenerative braking efficiency are all displayed correctly then this requirement has been met. If not, more testing is required to ensure that it is met. Though the ER is simple, this is an important step for ensuring that the vehicle can be operated at maximum efficiency. Without the screen displaying these metrics, and notifying the rider when their speed is too fast, or the difference in energy is sufficient to engage the clutch, there is no way of knowing the speed of the vehicle or optimizing the energy storage feature.

2.4.2 ER #4: Display Metrics - Tolerance = None

Since this ER has a very simple on/off target, there is no tolerance required. As stated before, if the screen displays all the metrics correctly the ER has been met. There will be a significant amount of tests run to ensure that all sensors are reading correctly, and that they are transferring data correctly to the LCD screen.

2.5 ER #5 (changed from summer): Develop Threshold of Usable Energy

2.5.1 ER #5: Usable Energy Threshold - Target = 300 J

As part of the displayed metrics, the team would like to show the vehicle operator when it would be beneficial to engage the clutch, changing it from stored to kinetic energy. The value of 500 J is meant to be the difference between the stored energy and the total kinetic energy. If the difference is 500 J or more, it will be useful to use it to add energy to the vehicle. The 500 J value was chosen specifically because it is half of the desired target energy storage, and a quarter of the total possible system kinetic energy. Keep in mind that any amount of energy added to the system is helpful, but if it is to make any difference to the speed of the heavy system it needs to be near this value.

2.5.2 ER #5: Usable Energy Threshold - Tolerance = 50 J

This tolerance is again only 10% of the target value for the ER. That is because energy, and tracking energy and differences in energy is so important to this project. If the difference in energy is more than 10% off of what is being displayed, then the driver will not be able to get a useful amount of energy out of the system.

2.6 ER #6: Budget Limit

2.6.1 ER #3: Cost under $1,500 - Target = $1,250

This engineering requirement is very self explanatory. The maximum we are able to spend is $1500, so we have set ourselves a target of $1,250. Though this number may seem high for a project strictly focused on propulsion, it allows for a lot of “wiggle room” to choose the best parts for our system. The team’s plan is to spend less than this.

2.6.2 ER #3: Cost under $1,500 - Tolerance = ± $250

By setting a $250 tolerance, the team had to lower their maximum target value to be $1,250 since the goal is to not go over $1500. A tolerance of $250 also allows for any parts that break in the assembly and testing phases of this project.

3 Design Changes

Since the beginning of this semester, the team has had to adapt a design to an existing vehicle, and almost entirely restart the project from the ground up. When adapting the system to the existing HPV, the biggest issue was integrating the dual input power system, and this has since been changed. Past that major change, the accompanying subsystems, such as the clutch, also had to be changed but only slightly.

3.1 Design Iteration 1: Change of Frame Choice

While the original design scope did not expand past propulsion, the team assumed the system to sit on a basic rail chassis. The current design has been adapted to an existing HPV, which required a complete rearranging of the layout, in order to accommodate a user functioning past just being a motor. The current system has bypassed the second input of the hand-crank, in order to allow the user to steer. This also meant that the team had to move the components of the system to now accommodate being a pedal driven cycle only. The new pedal only vehicle will be primarily driven by a standard bicycle drive. To achieve this, the team decided to do away with the original design, where the pedals were on a common shaft. The main change when moving the drive to be pedal only, was relocating the flywheel and clutch assembly, as well as the transfer axle.

3.2 Design Iteration 2: Relocation of the Flywheel Assembly

The original system design was to have the flywheel on common shafts shared by other components of the dual input system. This was then changed to having two shafts, to carry the flywheel and clutch, and to carry the intermediary gears. this would no longer work, as the transfer gears would no longer be going from one side of the vehicle to the other, and no longer would they fit next to the user, or underneath.

Because the flywheel and clutch assembly was moved, the method of using it was also changed. while originally the drive system would all go to the same side of the rear wheel, the team decided to split the drive methods. By redesigning the clutch system, the drive to the clutch would come off of the left side of the bike (the brake side), and the pedals would be rerouted and operated traditionally, with no interference from the additional drive elements. This design allows the clutch to constantly be spinning with the rear wheel, and disengaged as its neutral position. This was achieved by designing the clutch as an inner, and outer shaft, that mate and spin as one when engaged. This design will also save space, and be more compact than the original design, which is important because the whole system sits right behind the drivers head in its' new location.

One other effect of relocating the clutch system is that it now needs to be routed through the frame to get to the rear sprocket. In order to reroute the chains, the transfer axle was moved to be behind the driver, rather than underneath, which allows for a short and direct path for the chain to go from the wheel, to the intermediary gears, and finally to the clutch. Being that the chain no longer has to switch sides, since the sprocket will connect directly to the brake mounts, the chain is now much shorter than originally intended, meaning less loss in the stem due to less components needing to be moved.

4 Future Work

At this point in the project, the team has finalized almost all of the design aspects. With the exception of the transfer shaft housing, which will just be a tube on a stand-off to house two bearings, all components have been designed. The main portion of the design was considering what components the team would be able to use to carry the clutch components, however with those selected, the team was able to finalize all design aspects of the propulsion since the last presentation.

The work that now needs to be accomplished is fabrication and systems integration. With the parts ordered, the team now has to submit work orders, based on the final designs and completed CAD. Once the work orders are completed, the team can begin assembling the propulsion system in its permanent housings. The team's goal is to have the system functional by the time of the second hardware review, however the entire vehicle may not yet be operable. The reason that the vehicle as a whole may not be operable is due to the fact that the vehicle chosen to be retrofitted with the new propulsion system is not itself functional at the moment.

With the propulsion system assembled, the next step for the team is to get the measurement apparatuses in place. These will be the systems that provide data directly to the user, on a display that is easily visible. The needed metrics are speed, flywheel energy (calculated off of angular velocity), and threshold of which the energy is usable.

4.1 Further Design

The only current plans for further design for the team, are if alterations will be made to improve the design further. The current goal is to get the existing design working, and tested, and then consider redesign. The only components still needing a final design are the housing or the standoffs for the transfer axle housing and for the LCD display. Both of the standoffs are designed, but require a final placement on the vehicle, which has not been included in the existing designs.

In the subsequent design, we will mainly focus on the design of the shaft, the bearing and the connecting part of each part. The most important thing in our design should be the clutch and flywheel design. But in the process of further improving the design, the design of the shaft is also a key element that supports whether we can use the clutch and flywheel. We will use the knowledge in mechanical design I and II to define the relevant requirements of the shaft. Finally, calculate the safety of the shaft and use Solidworks finite element analysis to detect it.

4.2 Schedule Breakdown

Here is our schedule, a link to a more detailed schedule is here.

Assignment	Start	End
System Redesign	23 August	20 October
Midpoint Presentation	09 October	15 October
Build Design	13 October	5 November
Individual Analysis	17 October	27 October
Hardware Review 2	27 October	5 November
Software Polishing	27 October	3 November
Testing	6 November	13 November
Polish Build	14 November	24 November
Website Check 2	14 November	24 November
Final CAD	6 November	12 November
UGRADS Poster	6 November	8 December
Final Presentation	7 November	18 November
Assembly Manual	7 November	18 November
Final Report	14 November	8 December
Final Website Check	30 November	7 December
Deliver Final Product	1 December	8 December