Project Deliverable F – Prototype 2

Group 8: BRAKEthrough Solutions
Submitted by Brad Cole

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November 4th, 2021
GNG2101 : Introduction to Product Development and Management for Engineers and Computer Scientists
The Centre of Entrepreneurship and Design
Faculty of Engineering
University of Ottawa

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Introduction

The purpose of this report is to document the client feedback and subsequent prototyping done for the remote braking system project. The group had several meetings with the client since the last deliverable and have undergone major prototype changes. Additionally, testing has been done for the electrical subsystems and calculations and CAD models for the brake and mounting subsystems. The group also has a prototyping plan from now until Design Day.

Problem Statement

The client needs a safe and reliable remote braking system for his son's pediatric gait trainer, the R82 Crocodile. It can be activated from a distance to let him practice walking independently—most existing brakes are manual and require the guardian to be within arms reach. This will be achieved by having a Bluetooth remote activation of a linear actuator and stopper.

Client Feedback Summary

The group had the opportunity to meet with our client a third time briefly on October 21st, and a fourth time on November 2nd. Details are the feedback for each meeting are below.

Client Meeting 3

This meeting focused on getting feedback on the group's second prototype. The group created a new prototype based on the design criteria of the second client meeting. To recap, in our second client meeting, our client had informed us that we could use a system reliant on battery power. He also emphasized that he wanted variable braking based on a force sensitive button.

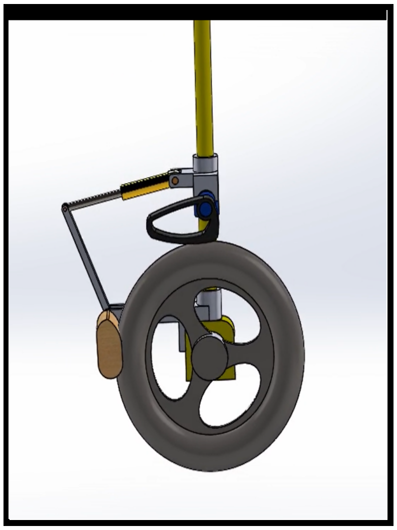


Figure 1

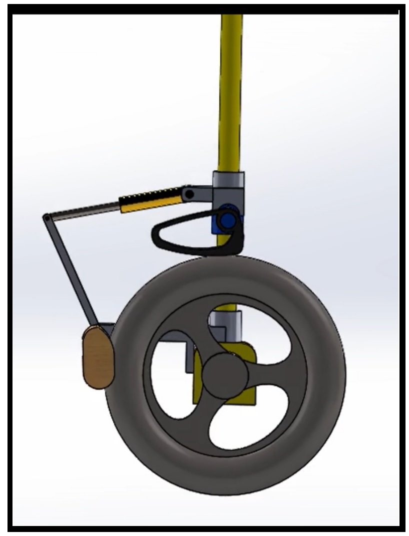


Figure 2

The group showed the client the prototype above that used a lever and linear actuator to activate the brake. This design uses mechanical advantage to stop the gait trainer. Allowing us to use a somewhat weaker and small linear actuator. In this design, the group made sure that the remote braking system did not interfere with the reverse stop that was already in place. Additionally, with the help of the linear actuator, variable braking could be done with a remote controller.

The client liked that this design did not interfere with the reverse stop that was already in place. Furthermore, he liked that the linear actuator would allow remote controlled variable braking. In contrast, the client has many problems with the lever mechanism. He was concerned about it being damaged because the gait trainer could hit various surfaces such as walls. He explained that he preferred the fact that the group's previous design was "straight down"—meaning there were no large angles in the remote braking system. He really disliked the fact that our design was angled and thought it was too complicated.

Consequently, the group knew that some major changes needed to be made to the prototype. The group decided to create an amalgamation of the first and second prototypes. The group would combine the "straight down" design of the first and the electrical components of the second design.

Client Meeting 4

In preparation for the fourth client meeting, we had come up with our third prototype. This prototype was a simplified version of the first two prototypes that used a linear actuator and stopper to break the wheel. It is “straight down” like the client requested. The group wanted to know how the client felt about this design and some dimensions of the wheel.

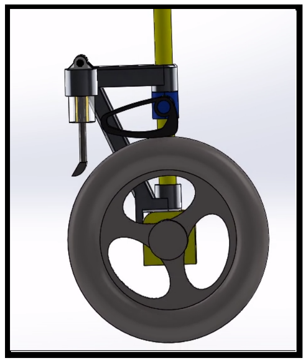


Figure 3

The figure above is the third prototype which includes a linear actuator and triangular clamp. This prototype avoids the reverse stop that is already in place on the back brake while still applying a “direct” force to the wheel.

When the group presented the client, he was pleasantly surprised. He liked the simplicity and the fact that the group adhered to all the constraints. The client did mention that he had put in place his own brakes on the same side of the wheel that our prototype is placed in this CAD model. Consequently, the group will have to flip the design to the other side of the wheel. Additionally, the client stressed that the prototype should be tested exhaustively using tests such as shear force tests and tensile tests to make sure that the product is durable.

Finally, the group will move forward with this design in the prototyping and testing phase. Note that our group could not purchase any materials during reading week because we were unsure if the client would be satisfied with the new design.

Prototype Description

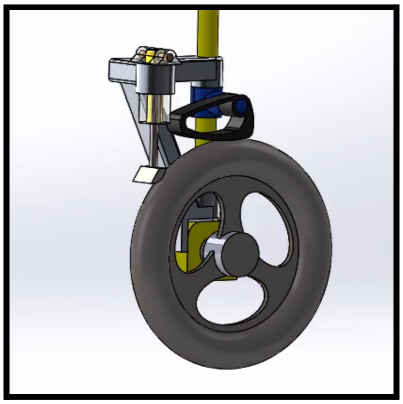


Figure 4

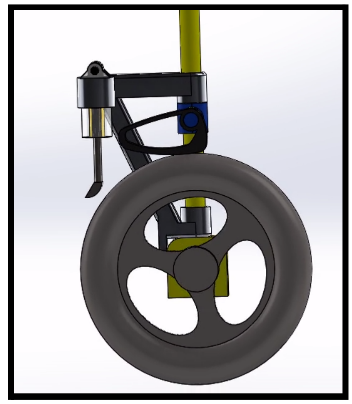


Figure 5

Third Prototype Assumptions

The images above show the remodeled third prototype. This new design recycles the in-line concept from the first prototype, which the client liked very much. The way in which this prototype works is very simple, in that its only moving part is the linear actuator, which is held in place by a fixed mount that attaches to the frame of the trainer. When the user wishes to stop the trainer, the button on the remote is pushed, activating the linear actuator. The linear actuator forces a braking surface onto the wheel, slowly and safely decelerating the trainer through direct friction.

Assumptions that had to be made with this new design were as follows. Firstly, one of the client's issues with the previous prototype was its size and shape, mainly that it extruded past the wheel of the trainer and could be damaged if struck. This new design keeps the mount and brake within the radius of the wheel, allowing the wheel to hit obstacles before it could damage the brake. Secondly, with direct application of force from the linear actuator, it had to be assumed that the linear actuator could apply a force of friction strong enough to the wheel to fully decelerate the trainer. This issue was solved in the previous prototype through the mechanical advantage applied through the lever design. Thirdly, the mounting system we designed is only a rough estimate of what we could construct. This is because we were given very few images of the actual frame of the pediatric gait trainer, and therefore had to assume that ample space above and below the standard brake mount were available. This new design will be mainly constructed of aluminum inorder to keep the weight of the brake to a minimum.

Third Prototype Electrical System

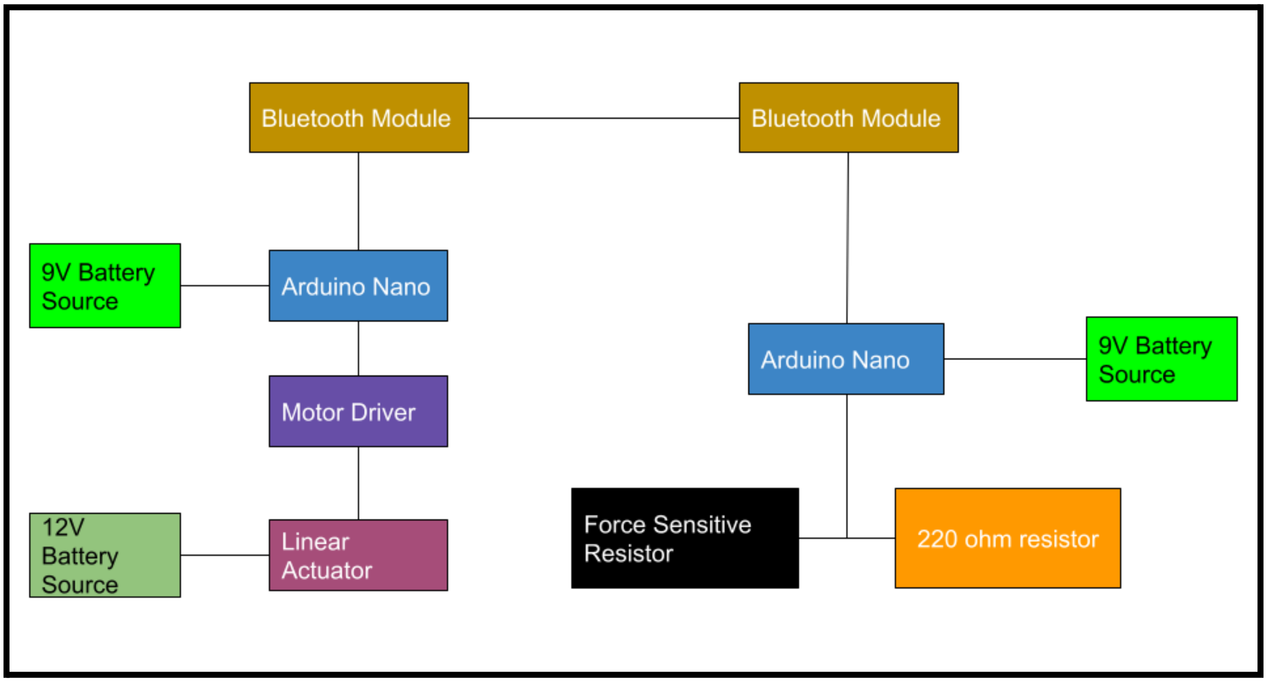


Figure 6: Block Diagram of the Electrical System

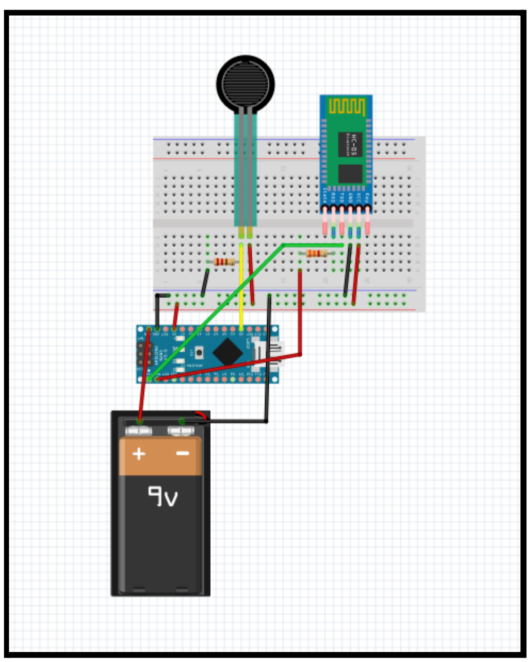


Figure 7: Fritzing Diagram of the Force-Sensitive Resistor (FSR) Circuit

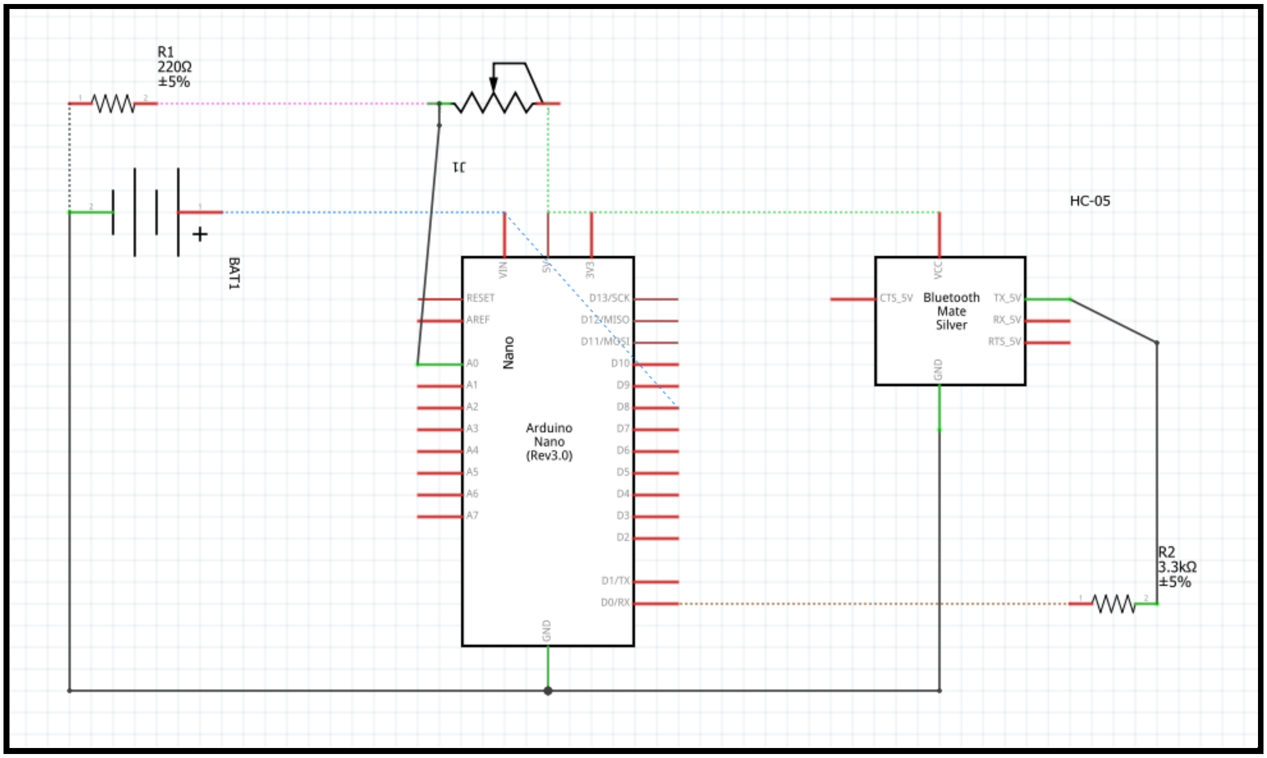


Figure 8: Schematic of the FSR Circuit

The above figures show the prototype of the electrical system. It involves hooking up an arduino nano to a 9V battery and a voltage divider between an FSR and a 2 kOhm resistor. The voltage between these two is picked up by A0 to measure the voltage drop across the FSR, which can be used to determine the force used on the resistor. The reading on pin A0 can be transmitted over the bluetooth module to another Arduino Nano, which controls the linear actuator through a motor driver. A PWM pin will be used to send a PWM signal to the motor driver which controls the speed of the actuator. The motor driver depends heavily on the amperage the linear actuator draws from the Nano.

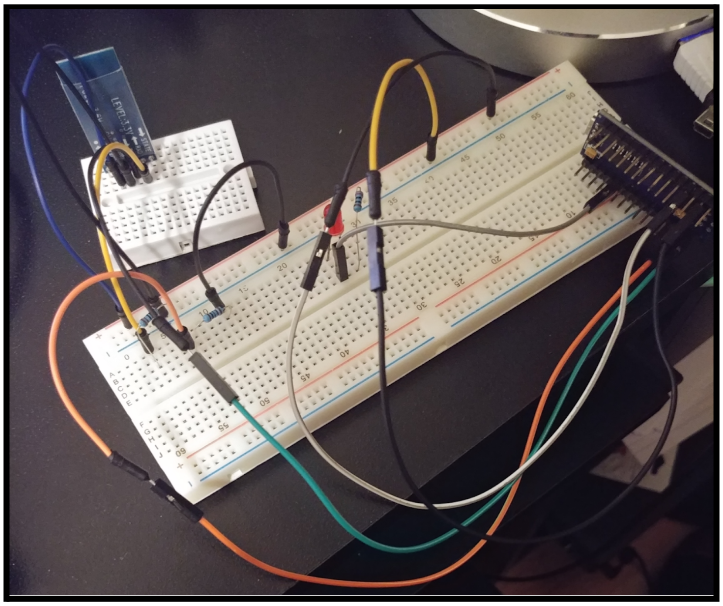


Figure 9: Circuit Prototype of Arduino and Bluetooth HC-05 Module

Figure 9 shows our first prototype of the Bluetooth module, wiring it to our arduino nano to test its function. Unfortunately despite the correct connections, the bluetooth module would not run indicating further testing.

Calculations and Target Specifications and Testing

Seeing that our group was not able to do much testing, we aimed to set target specifications and do some calculations to help ascertain the part specifications required to meet target specifications. We determined via internet research that the average mass of a child is about 25.8 kilograms. The average stopping distance we wanted was around 1 meter, and given that the average walking speed is 2 meters per second (which is a generous value), to brake would require the wheel to apply a decelerating force of about $(25.8\ kg)(2\ m/s^2) = 51.6\ N$ with the ground. This however is only for flat surfaces, and further testing would have to occur for sloped surfaces. More details could be given if we knew the kinetic coefficient of friction for the material the tire is made of, and the surface area the brake pad covers on the wheel. In terms of rigorous testing of our prototype, we could not do very much. Below we have tried to compensate for this with a specification and metrics list for our third prototype.

Table 1: Target Specification Comparison

Design Specifications	Relation (=, < or >)	Value	Units	Verification Method	Third Prototype	Comments
Functional Requirements						
Braking Distance	<	Ideal: 1 Acceptable: 2	m	Testing	N/A	Non-functional prototype
Range of Transmission	<=	Ideal: 10 Acceptable: 8	m	Testing	N/A	Non-functional prototype
Speed of Transmission	<=	Ideal: 0 Acceptable: 500	ms	Testing	N/A	Non-functional prototype
Constraints						
Cost	≤	Ideal: 100 Functional: 150 (with permission)	CAD	BOM Estimation	$0	Free from the MakerLab and MakerStore (about $21)
Battery/power life	>	Ideal: 12 Acceptable: 8	hours	N/A	N/A	Non-functional prototype
Non-functional Requirements						
Mass	<	Ideal: 5 Functional: 5	lbs	Measuring	5-6 (Just One Brake)	Made of Aluminium

Many of our target specifications are still valid. The primary change that was made is regarding the mass of the brake, as we now know we are using aluminum and are only considering one brake. The cost of the third prototype only included the bluetooth module and Arduino Nano from the MakerStore and MakerLab.

Table 2: Bill of Materials

Item	Description	Quantity (Approx.)	Price	Source
Aluminium Flat Bar	Used to make a mounting system for the brake. We got this for free at the Manufacturing Training Centre.	3' ($0.11/ft)	Free ($3.96)	Makerstore
Micro Linear Actuator/Push Pull Solenoid	Used to engage and disengage brakes.	1	$25-$30	Makerstore
5A Motor Driver	Used to interface with the linear actuator and control its speed.	1	$20.99	Amazon
9V Battery	It's a battery for the Arduino Nanos. We will not be purchasing as multiple team members own one.	2	Free ($1-$4)	Owned by team members. Makerstore https://makerstore.ca/shop
Bluetooth HC-05	Allows for bluetooth communication using Arduino. (There was only one left at the MakerLab).	1	$12.99	MakerLab
Bluetooth HC-05	Allows for bluetooth communication using Arduino. We got it for free because someone gave it to us.	1	Free. ($12.99)	Owned by team members.
12V Battery	Used to power the linear actuator.	1	$8.95	Amazon https://www.amazon.ca/Energizer-A23-GP23AE-Alkaline-Batteries

Arduino Nano	Used for logic and communication.	2	$8.00	MakerLab
Pushbutton	Digital Button	2 – 3	Free	Owned by multiple Team Members
Pressure Sensitive Button	Analog push button dial for braking force control.	1	$6.95	SparkFun
RGB LED	LED with ability to change colors for battery indication.	2	Free	Owned by multiple Team Members
Arduino Casing	Protects arduino	1	Free	3D Printed in L'Abbe
Controller Casing	Protects arduino in controller	1	Free	3D Printed in L'Abbe
Total			$89.84 (Approx.)	

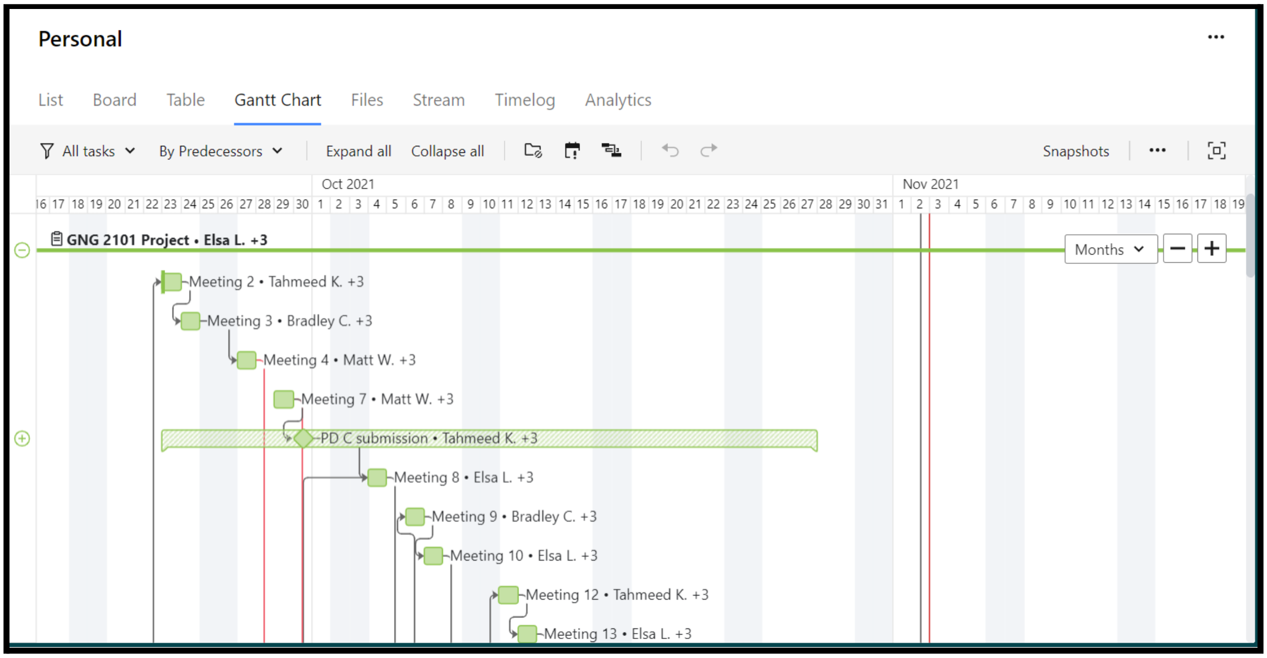
The Bill Of Materials above was updated since our last deliverable. We intend to update it more before we ask our project manager and teaching assistant before we submit.

Conclusion

In conclusion, the group has a clear prototyping plan from now until Design Day. While we have planned for tests without it, we plan to meet at least twice before Design Day with the client's gait trainer to accurately test the prototype. The group will have a prototype of each subsystem by the end of the week of November 7 and a comprehensive one for the week of November 14. That week, we will test our comprehensive prototype on the gait trainer. The week of November 21, we will have an adjusted prototype to test on the gait trainer one final time.

Our group has done multiple iterations of our prototype, thus far. We have learned what it truly means to receive client feedback and apply it to our design. We now have a satisfactory prototype that we may proceed with. We will be ordering all of our items as soon as possible.

Wrike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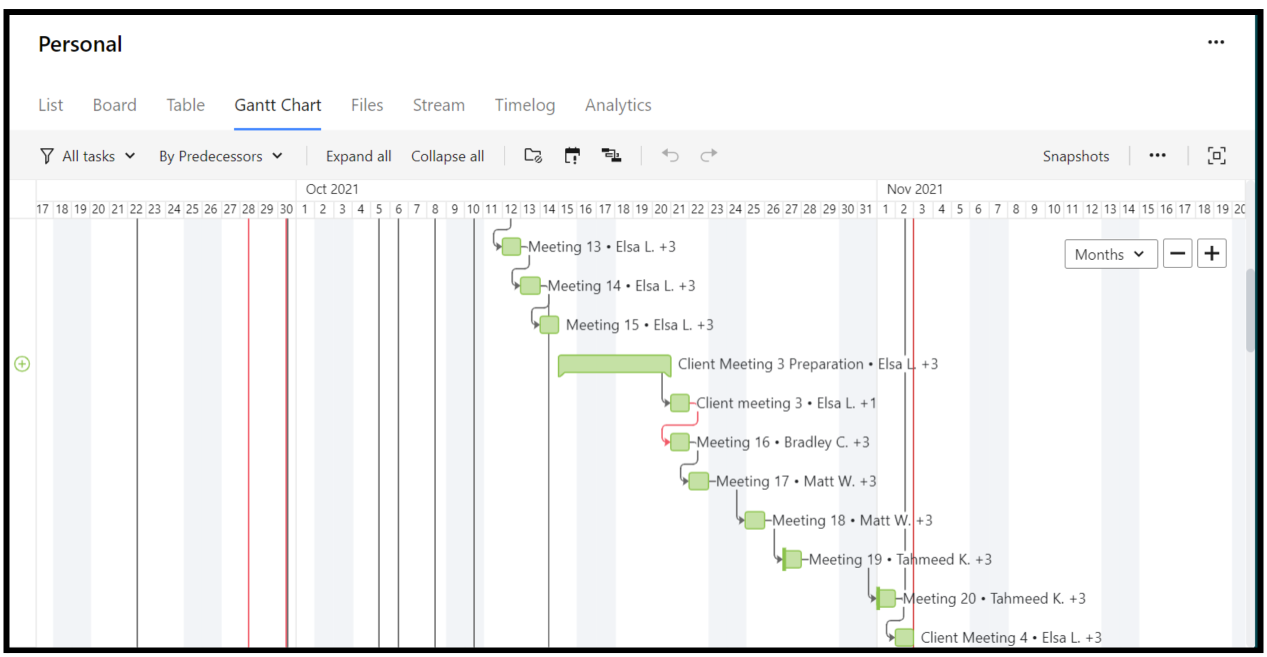
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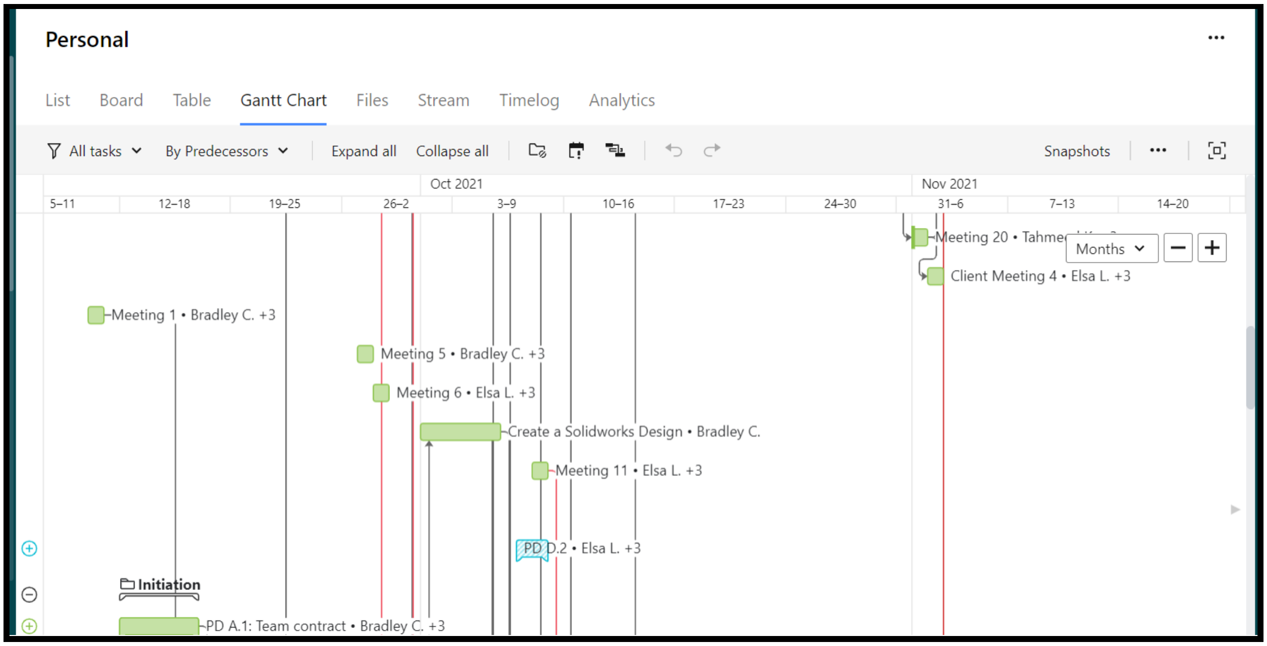
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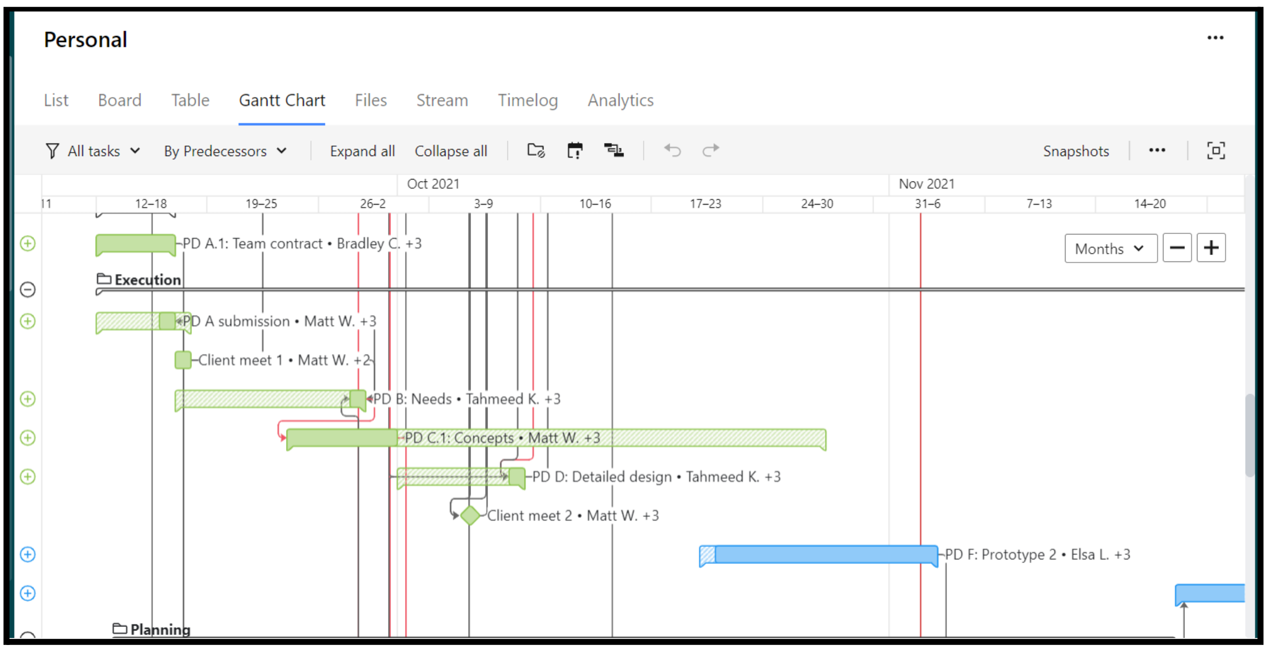
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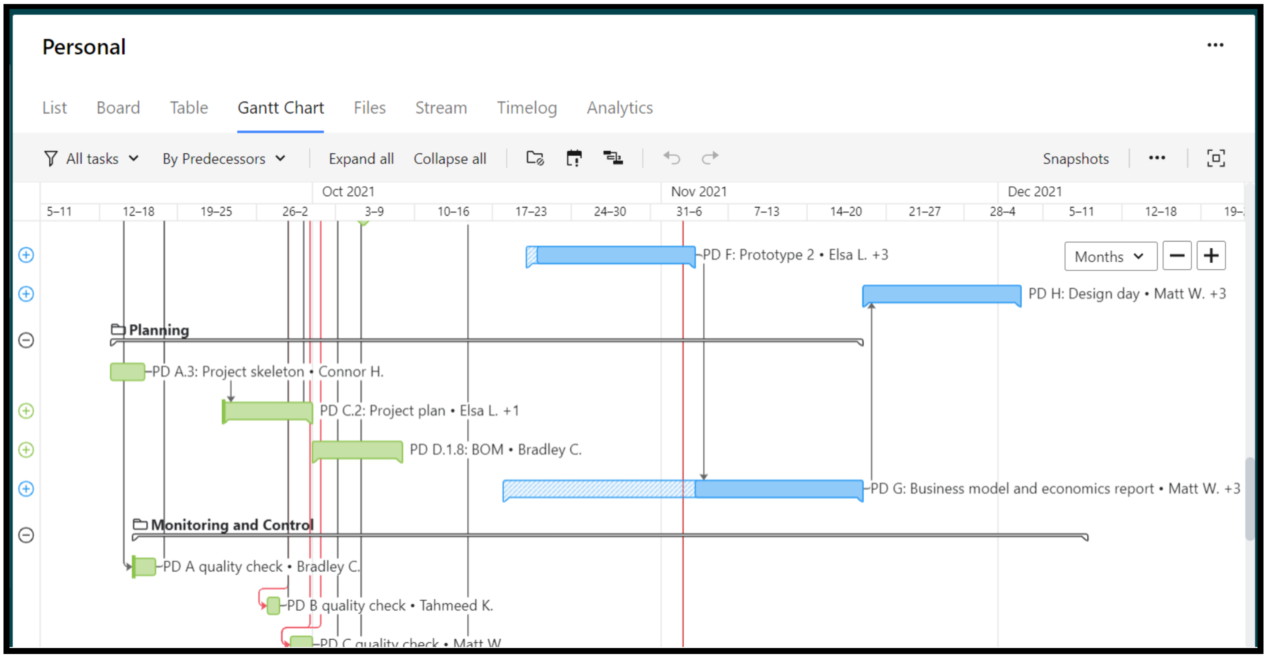
Planning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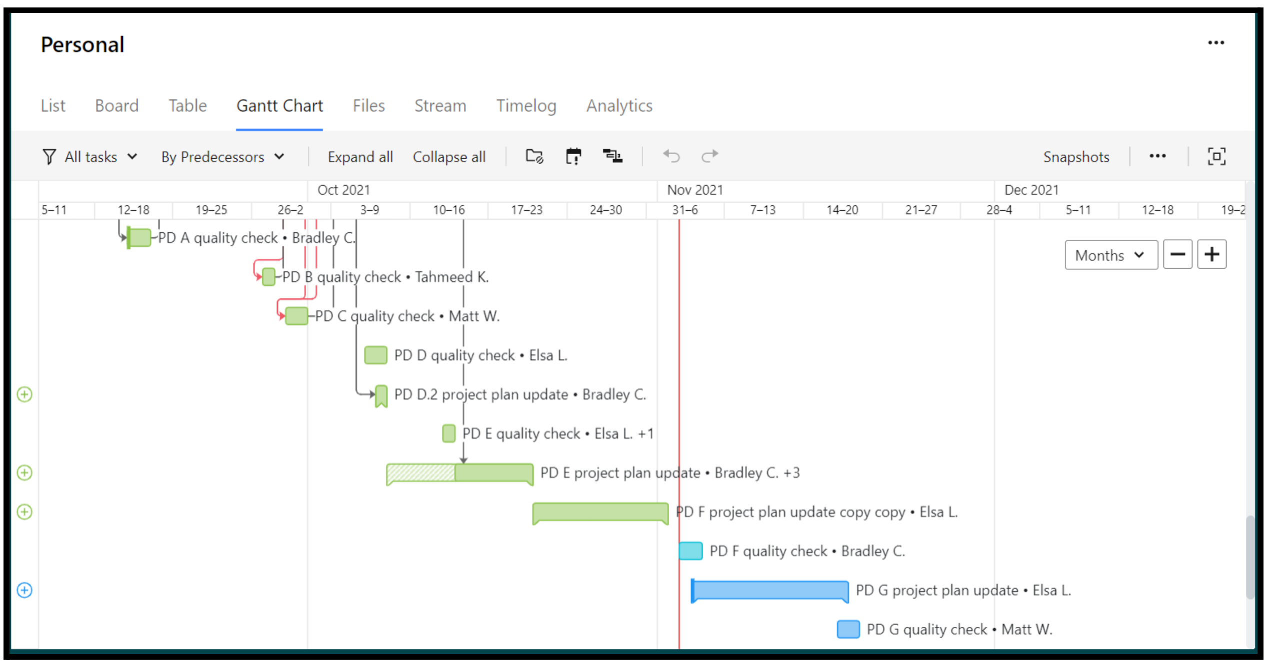
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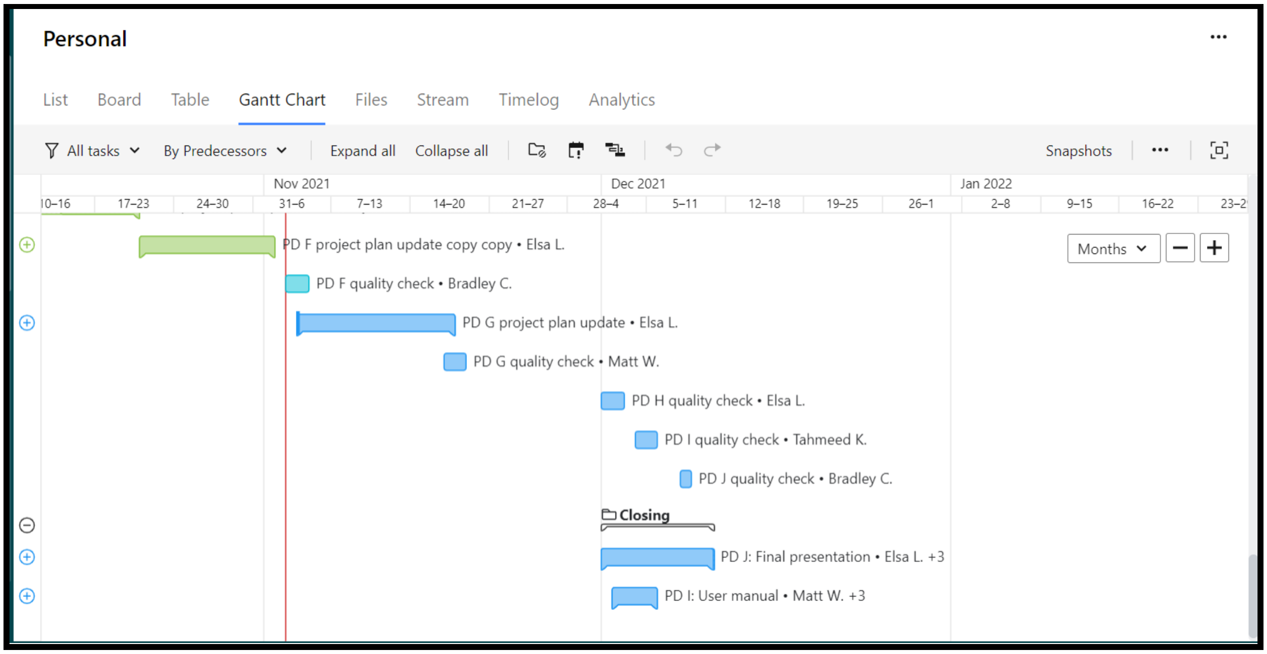

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PD J quality check • Bradley C.
Closing
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PD I: User manual • Matt W. +3