RELIABILITY REPORT

EML 4551C – Senior Design– Spring 2013 Deliverable
Team 10 – CISCOR Autonomous Ground Vehicle
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A. Prototype Design and Components to be Manufactured

The goal of the CISCOR AGV project was to provide a vehicle, whose locomotion could be controlled through a computer, to serve as an off-road capable research test bed. The components designed to complete this project are not intended to be duplicated or transferred to another vehicle. The optimization of manufacturing processes for this project thus placed a higher emphasis on methods for producing high tolerance, ease of machining of parts, and cost of raw material. Because only one of each system component need ever be produced, the amount of time required for the machining of parts was given a lower, but still significant priority to allow the project to stay within the original schedule. However, the ease of machining duplicates of the system components was neglected entirely as this is never envisioned as a necessity.

A-1. Manufacturing Process Selection for Various Components of the Design

Many of the components produced for this project were manufactured using the water-jet available in the machine shop to cut outlines out of aluminum plate. This process was used to cut the plates used to mount all four systems to the vehicle. It was also used for the plates that constrained the actuators and motors to the mounting plates. The water-jet was chosen as the best process to cut these outlines due to the fact that it cut the plate faster than either milling out the pieces or cutting them with a saw. It was also more accurate than using a saw. Using a saw or a mill to cut out the pieces was initially advantageous solely due to the fact that group members were capable of operating these machines, saving time from the overall manufacturing process by eliminating the need to wait for the machine shop to run through other projects higher in the queue. This advantage was negated by the training of one group member, Cesar Mize, in the operation of the water-jet. The final advantage of the water-jet was its ability to drill clearance holes in the part outline in insignificantly more time than cutting the blank outline itself. This saved time spent at the drill press on later pieces.

The linear actuators that are used in the braking and gear shifting systems require precise axial alignment of the threaded rod to operate. Due to the short distance separating the actuator from the point of thrust application in the braking system and the already present necessity for a plastic sliding block, the simple expedient of slotting the mounting plate for the plastic slider to translate along solved the axial misalignment problem. This allowed all the braking system components to utilize lower tolerance methods of manufacture. This was not the case with the gear shifting system which featured a long range of travel and a long threaded rod extended well beyond the actuator. Because of the distances involved, and the very small amount of allowed axial deflection, the mounting plate for the actuator and the bearing block employed to ensure axial linearity required high tolerance manufacturing. So that high tolerances could be achieved, the mounting holes in this piece were manufactured by the CNC machine. Using this method, the distances and relations of the holes could be guaranteed to match the design to a very high tolerance.

The CNC machine would have been capable of milling and drilling all of the components necessary for this project to a high tolerance. This would have not have allowed the project to stay inside the original schedule however due to the long time faced by the CNC process. The CNC machine in the shop is only operated by one employee, which greatly reduces the amount of man-hours per day that go towards CNC production. Also, as none of the group members were proficient in operating a CNC machine, the manufacturing would have been further limited by waiting for other project components higher in the queue to be manufactured first. Finally, for a small number of holes per component, the amount of time actually emplacing and drilling a component is often greater for a CNC machine than a drill press. Because the remaining components of the locomotion systems did not require the high tolerances of the gear shifting system and because members of the group were familiar with the operation of the drill press, the drill press was used for the drilling, milling, and tapping required for all other parts.

Due to machine shop preferences and the desire to make all components easy to remove and reinstall, all welding was avoided during this project.

A-2 Criteria Used in the Selection Process Including Material Type

The general selection criteria for the majority of the material focused on availability and price. For these reasons, most of the material used is 6061 Aluminum ordered from McMaster Carr. Since all parts are mounted on the ATV which can handle a substantial load, individual weight of each part was not a large concern. Aluminum was chosen instead of steel particularly due to its manufacturability and corrosive resistance. Some of the other parts, not made of aluminum, were chosen for reasons other than those mentioned above. For the steering assembly, spacers were needed to lift the mount from its initial position. Black ABS plastic was used simply because of availability and the fact that a laser cutter was available to use in our lab. When installing the assembly and attaching the chain, a nominal height for the mount was unknown so shims had to be easily produced to progressively determine where the mount needed to sit. Again for the steering assembly, the sprockets and chain used needed to handle high loads and needed to be resistant to corrosion. Stainless steel was used for the reasons mentioned above accepting the slightly more difficult manufacturing process. For the gear shift assembly a block was required to be mounted to the base plate with the main shaft sliding through it. This was used to prevent deflection of the shaft while shifting gears. Nylon was used for its availability and its low coefficient of friction. The same material was used on the brake system for the slider that pressed against the grip handle of the brake system. The reasons for use were the same as those mentioned for the gear shift system.

A-3 Decision on Where to Make Parts

All aluminum, stainless steel and nylon parts were manufactured in the machine shop located in the COE A building. These particular parts were manufactured in this machine shop due to the availability of the machines needed (CNC, Water Jet, Manual Mill, Lathe) and the training on some of these machines that Tye, Cesar, and Don already had. Many parts were manufactured by our own team with guidance from Jeremy and Dana which allowed for timely receiving of finished parts. The ABS plastic was manufactured in the STRIDe lab located in the AME building. The plastic was manufactured here due to the availability of the Universal laser cutter. Cesar had training on this machine which allowed us to produce our own parts which significantly cut down on any lead time we would have had if we had needed to send them out to another shop.

A-4. Bill of Materials and Desired System Specifications

Please refer to Appendix A for Bill of Materials and Operation Manual and Polaris 2012 Sportsman 550 manual for System Specifications.

A-5. Design Changes Needed for Manufacturability

Because this design is for a "one off" vehicle, there is no need to consider manufacturability of future parts from this design.

A-6. Assembly Drawings and Instructions

Please refer to Appendix B for Assembly Drawings and Instructions

A-7. Challenges Encountered During Manufacturing Process

During the testing of the original gear-shifting system, it was noticed that the axial alignment of the linear actuator was being deflected in part due to the misalignment of the holes drilled into the mounting plate for the bearing block. This part had originally been drilled using the drill press, which is assumed to have relatively low tolerances. The solution was to resubmit the part to the machine shop, but to this time specify the use of the CNC machine to manufacture the part, thus ensuring a higher degree of accuracy in the placement of the holes.

Due to the complex and unknown geometries encountered when working on an existing structure, many of the dimensions of the components could not initially be accurately detailed. Many components were initially prototyped in ABS using the laser cutter in the STRIDe lab, allowing for fit checks prior to manufacturing the final, aluminum part. Other parts, such as the mounting plates for the braking system were partially manufactured, with some of the holes not drilled during this manufacturing process. These parts were then mounted on the machine, and a determination of their geometrical relationship made to determine where the holes drilled during the second manufacturing process should be placed.

The unknown necessity of preventing axial deflection for the linear actuators led to the manufacture of a new mounting plate and a bearing block for the gear shifting system and the addition of a plastic slider and modification of the mounting plate of the braking system.

The original design for mounting the steering system called for using a solid 6" aluminum cube. Due to the cost and the lead time associated with obtaining this material, the design was changed to make use of .5" plates bolted together.

B. Design for Reliability

Various components of each locomotion system (steering, throttle, braking, and gear shifting) required special care to ensure reliable performance. The determination of the particular components was obvious in the initial design stages or, at worst, in the initial testing stages. The steering system components that required special care focused primarily on the sprockets and chain used. The concerns were primarily based on loading and corrosion. These concerns were addressed by material selection. Stainless steel was chosen for its high load capability and its resistance to corrosion. The throttle system component that required special care focused on deflection of the mount due to the weight of the stepper motor and the load produced when actuating the system. This concern was remedied with appropriate material selection, proper hardware, and shims to add extra support. 6061 aluminum was used due to its strength in comparison to the loading brought on by the motor weight and actuation force, 1/4-20 bolts were used to secure the mount properly to the handlebars, and rubber shims were used between the motor mount and throttle lever casing to add extra support. The braking system component that required special care involved the nylon slider block that attaches to the motor shaft and is the part of the system that pushes against the brake lever. The concern was about deflection of the motor shaft that would cause inaccurate feedback. This issue was addressed by redesigned the nylon slide and cutting a groove in the brake system mount to allow the nylon slide to move along this path without concern of deflection. The gear shifting system component that required special care involved the manufactured shaft attached between the linear actuator and the gear shift bar. The concern was also about deflection. If the shaft deflected at all, the system could potentially jam. This issue was addressed by extending the linear actuator mount and adding a slider block on the end closer to the gear shift lever. This would allow the manufactured shaft to slide through this block eliminating any possible deflection.

C. Design for Economics

Because this project is only intended to produce one vehicle, the costs of manufacturing are limited to the individual component, and can ignore mass production considerations. Also, to reduce cost to the project budget, it was determined that all machining would occur in facilities at the school of Engineering so that the project would not be directly billed. To achieve this, the project was designed to be manufactured using relatively simple techniques, making the project members capable of manufacturing almost all the components, which equates to using less skilled machine shop labor.

The raw materials for this project were selected with cost and ease of machinability in mind. To this end, almost all of the components are made of either aluminum or nylon, both of which are simple to machine. Aluminum is also less expensive than other possible metals such as steel and stainless steel. Components were designed to account for standard raw material sizes to reduce purchasing costs, such as the elimination of a rare 6” solid aluminum cube, and the substitution of bolted .5” plates.

To mount the systems to the vehicle, and to assemble the systems themselves, the use of bolts and nuts were preferred over welding. Welding uses more machine shop time, and more experienced labor than the drilling and tapping required for nuts and bolts, which leads to higher costs of manufacture. The nuts and bolts were also selected from standard sizes and lengths.

Appendix A – Bill of Materials

Braking System

Label	Part	Material	Qty.
A	Modified Brake Lever	Aluminum	1
B	Mounting Plate	Aluminum	1
C	Actuator Plate	Aluminum	1
D	Handlebar Clamp	Aluminum	1
E	Plastic Slider	Nylon	1
F	Linear Actuator	N/A	1

*Nuts and bolts used to connect components not mentioned in BOM or assembly drawing.

Steering System

Label	Part	Quantity
A	Lower Mount Spacers	2
B	Mount Profile	2
C	Lower Mount Plate	1
D	Front Mount Plate	1
E	Top Mount Plate	1
F	Motor Mount Plate	1
G	Upper Mount Spacers	2
H	Upper Mount Plate	1
I	Motor/Gearbox/Encoder	1
J	Small Sprocket	1
K	#50 ANSI Roller Chain	1
L	Large Sprocket	1
M	Steering Column Coupler	2

*Top mount plate (E) not shown in assembly drawing. Currently not in use on the design.

** Lower mount spacers (A) and upper mount spacers (G) not shown in assembly drawing. Varying thicknesses for proper mounting and fitting.

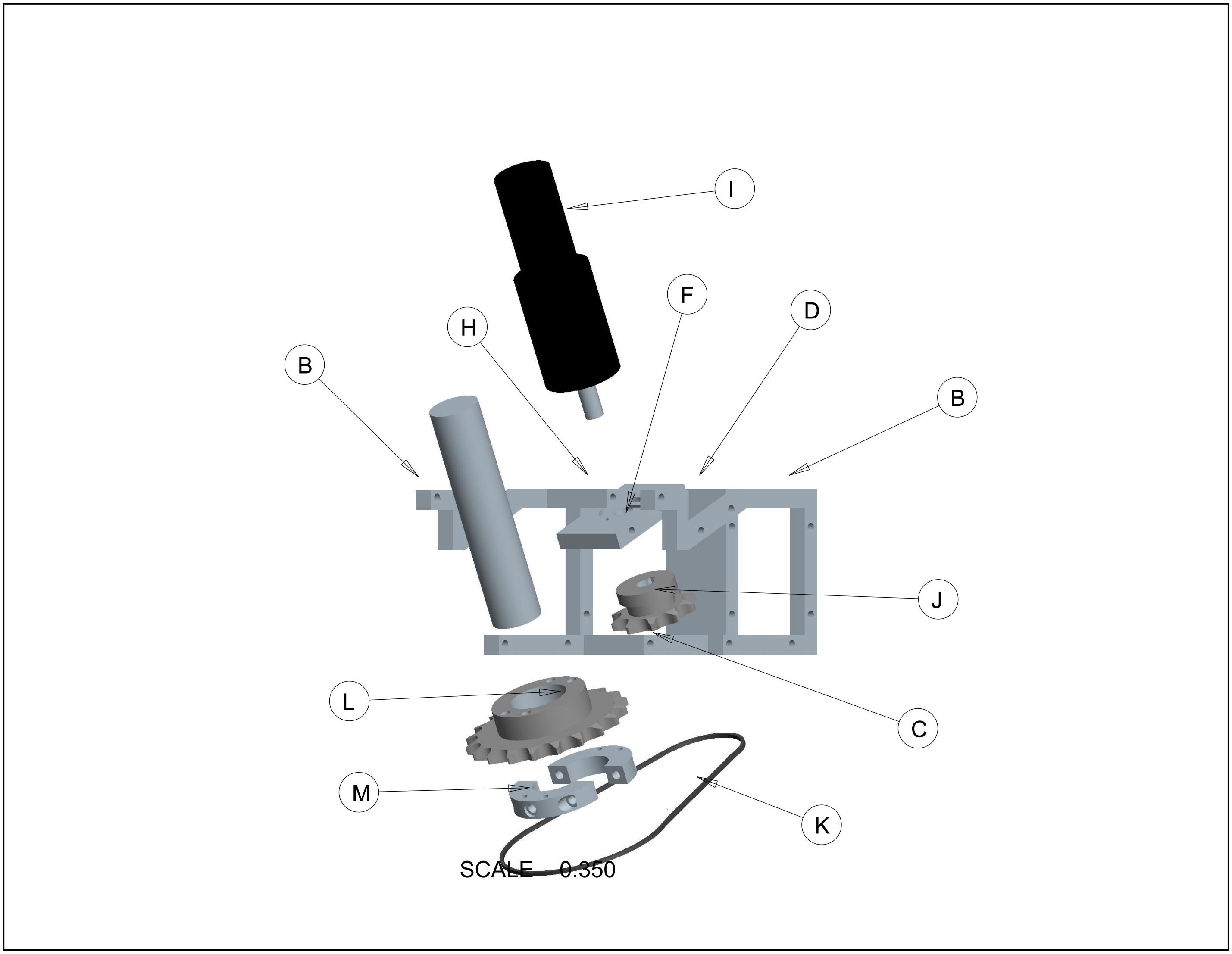
***All hardware not mentioned in BOM or assembly drawing. All hardware needed is mentioned in installation instructions.

Throttle System

Label	Part	Quantity
A	Main Mount Plate	1
B	Shaft Extender	1
C	Lower Throttle Extend Arm	1
D	Throttle Manipulator	1

*Design uses metric screws for all mounting.

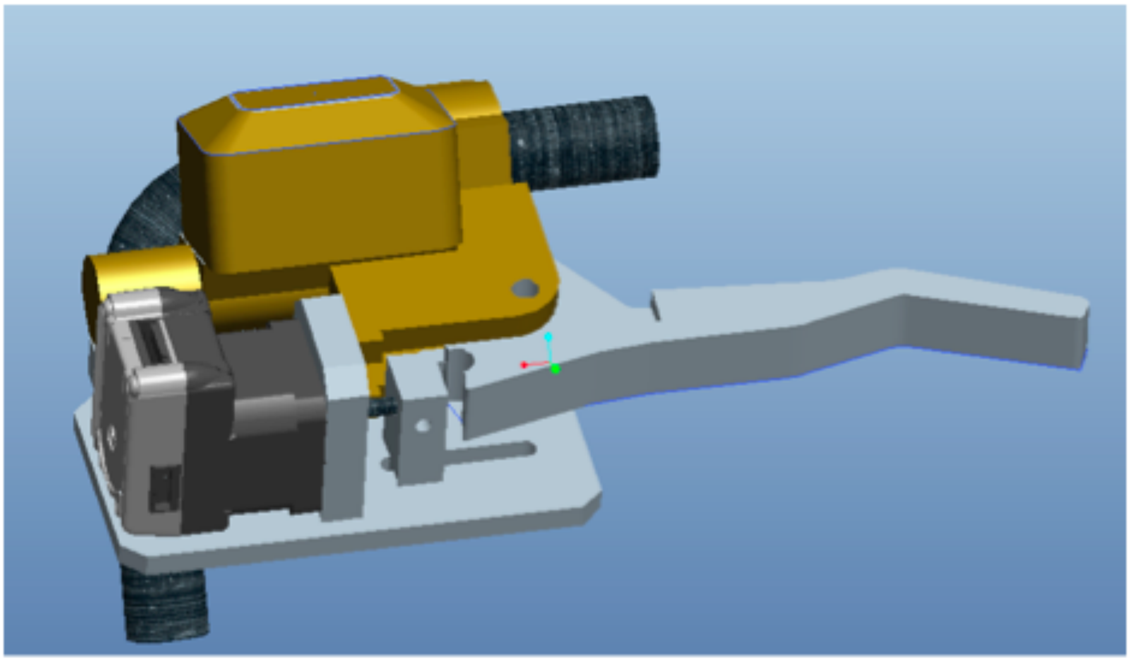
Appendix B – Assembly View and Instruction

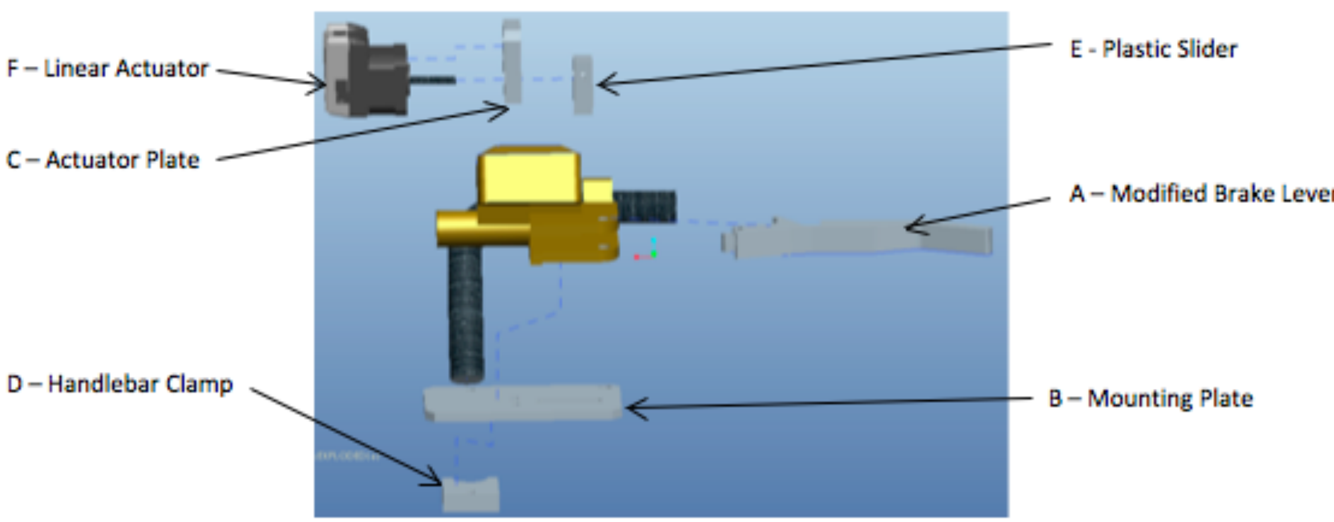


Steering System Assembly Diagram

Steering System Assembly Instructions

1. Remove steering column from ATV by removing both pinch bolts from the bottom of the column near the PSU and the bearing block approximately half way up the column. Pull straight up.
2. Hold large sprocket slightly above PSU and slide steering column down through the large sprocket back onto the PSU input. Reattach bolts mentions in step 1.
3. Take both halves of steering column coupler and attach them on either side of the steering column below the large sprocket. Fasten with 1” M6 bolts.
4. Take a 3” 1/4-20 bolt and slide through first half of coupler, through drilled hole on the steering column, and through other side of coupler. Fasten with nylon insert 1/4-20 nut.
5. Use four 1.5” 1/4-20 bolts and nylon insert 1/4-20 nuts to attach large sprocket to steering column coupler.
6. Away from the ATV, construct the motor mount using the mount profile, lower mount plate, front mount plate, motor mount plate and upper mount plate as seen in the assembly using 0.75” 1/4-20 bolts.
7. Attach motor to motor mount plate as seen in the assembly using M4 screws.
8. Slide small sprocket onto motor shaft below the motor plate and tighten attached set screw.
9. Using the necessary amount of spacers below the lower mount plate and upper mount plate, place mount onto battery tray and upper support bar. Attach the lower mount plate to the battery tray using two 1.5” 1/4-20 bolts with corresponding nylon insert 1/4-20 nuts. Attach upper mount plate to upper support bar using a 1/4-20 nylon insert nut.
10. Wrap #50 ANSI roller chain around both sprockets and link using provided #50 chain connector links.

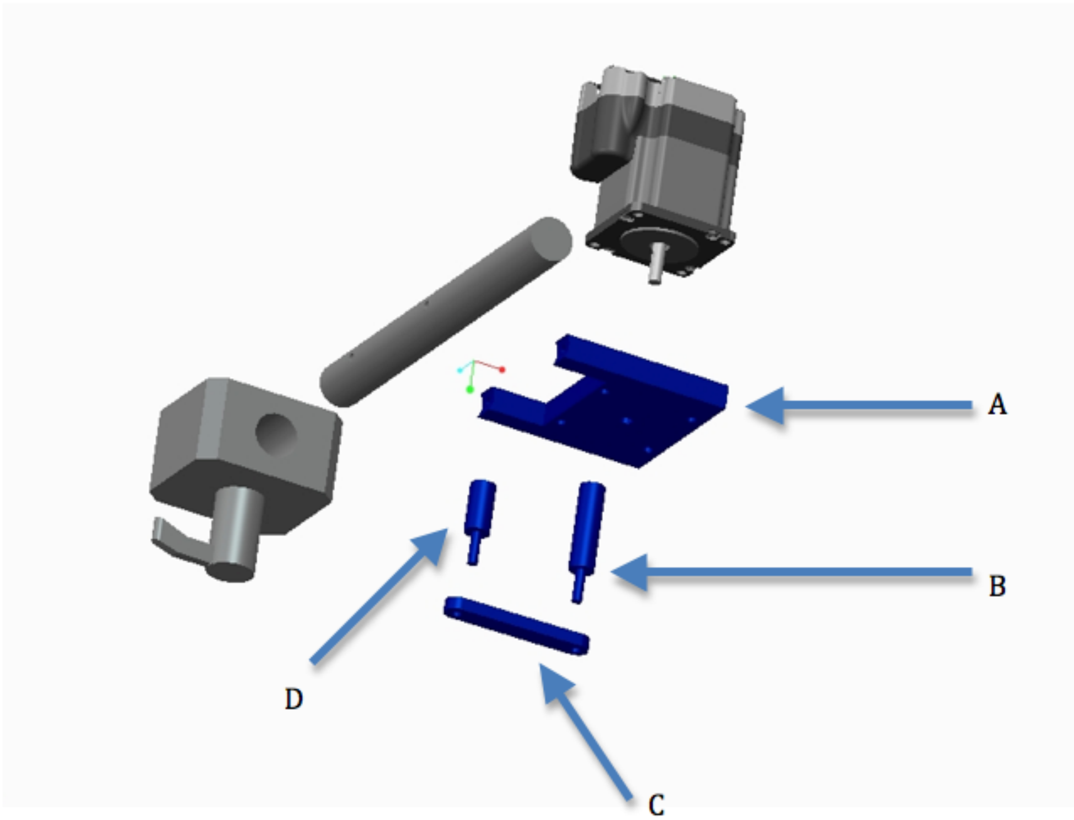




Brake System Assembly Diagram

Braking System Assembly Instructions

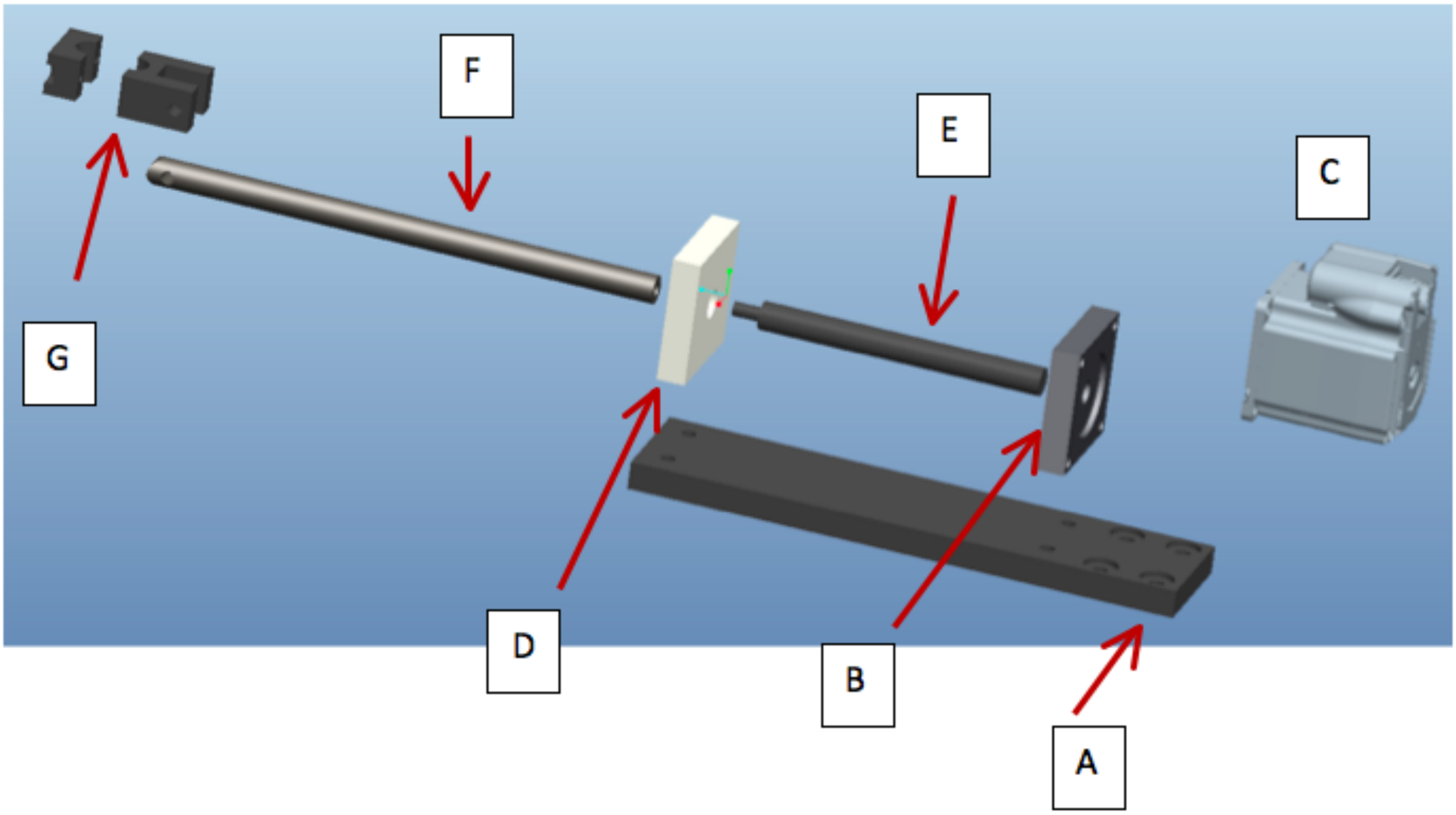
1. Mount the Modified Brake Lever to the existing Brake Master Cylinder.
2. Mount the Handlebar Clamp to the handlebar below the Brake Master Cylinder.
3. Install the Mounting Plate by placing it below the Brake Master Cylinder, and connecting to the Handlebar Clamp which it will rest upon.
4. Mount the Linear Actuator to the Actuator Plate.
5. Mount the Actuator Plate upon the Mounting Plate.
6. Emplace the Plastic Slider in the slot in the Mounting Plate.
7. Thread the threaded rod from the Linear Actuator into the Plastic Slider.
8. Adjust setscrew in Plastic Slider to mate to Actuator threaded rod.



Throttle System Assembly Diagram

Throttle System Assembly Instructions

1. Mount Main Base Plate (A) onto handle with 2x 2'' M5 screws
2. Mount Schneider M-Drive 23 Actuator to main base plate
3. Attach Shaft Extender (B) to output motor shaft with 2x M1 set screws
4. Attach Lower Mount Plate (C) to Shaft Extender (B)
5. Attach Throttle Contact (D) to Mount Plate (C)



Gear Select System Assembly Diagram

Gear Select System Assembly Instructions

1. Assemble Mount
    - Aluminum Base Plate
    - Plastic Support: ¼-20 with Friction Lock Head Screw (2)
    - Actuator Mount: ¼-20 Pan Head Screw (2)

2. Attach Mount to Goliath
    - Place mount on top on Goliath arm and plastic on bottom
        - ¼-20 Button Head Screws (4)
        - ¼-20 Friction Lock Nut (4)
    - Make sure that mount is aligned with shift arm

3. Attach Actuator to Mount
    - M-5 Thread Screws (4)
    - M-5 Nut (4)

4. Install Connector Link
    - Thread M-Drive Screw into M-Drive Actuator
    - Thread ¼-20 nut onto end of thread
    - Screw Black connector link onto end of actuator screw and tighten with nut

5. Install Connector Joint
    - ¼-20 Black Hex Head Screw

6. Connect connector pin to connector link
    - ¼ in pin/screw

7. Connect Actuator to system
    - Connect parallel communication system
    - Connect to power