ADJUSTABLE HEAD TUBE ANGLE HEADSET

FINAL DESIGN REVIEW REPORT

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Abstract

This final design review report describes the design, manufacture, and test process of a bicycle headset capable of quickly and easily adjusting the effective head tube angle. The evolution of mountain bike geometry has forced bike designers to compromise between climbing and descending performance when choosing a head tube angle. A headset capable of quickly adjusting the effective head tube angle would allow riders to optimize their bike's geometry for different stages of riding. This report details the research, idea generation, concept development and selection, design, manufacturing, and testing of our adjustable head tube angle headset.

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1. Introduction

We are a team of four senior mechanical engineering students at California Polytechnic State University, San Luis Obispo. We are undertaking a project proposed by Dr. Andrew Kean, a mechanical engineering professor. Our task is to design, build, and test a headset capable of adjusting a bike's effective head tube angle quickly and without tools. As mountain bike geometry has evolved, head tube angles have become slacker to improve handling characteristics while descending. However, these slacker head tube angles compromise climbing performance. As manufacturers struggle to balance these competing effects, a need for a headset capable of adjusting the bike's effective head tube angle arises. This report describes the customer and product research, design objectives, conceptual designs and selection process, final design, manufacturing, verification, and project plan for our senior project group's development of a headset capable of adjusting a bike's effective head tube angle.

2. Background

We focused on the following categories when performing our initial research: customer research, product research, standards, and research reports.

2.1. Customer Research

We identified two main categories of mountain bikers to whom this headset will appeal. The first category contains avid mountain bikers. These riders are experienced enough to notice and appreciate the changes in effective head tube angle that the headset will offer. They ride hard and seek competitive edges wherever possible. The second category contains gear enthusiasts. These riders enjoy trying new components, are more familiar with their bike's geometry numbers, and admire their bikes both during and after a ride. Many riders fit into both categories to varying degrees.

Because each member of our senior project group fits into the categories described above, we consider ourselves customers as well. Our ability to empathize with customer needs is strengthened by being engineering students designing a product that we would like to use.

To understand other customers' wants and needs, we created an online survey. This survey asked respondents (members of Cal Poly Cycling and Cal Poly Bike Builders) about their opinions of a headset capable of adjusting the effective head tube angle and if they wanted it on their own bike. It also questioned the conditions under which a respondent would use it (results are included in Appendix A). We learned that there is high interest in a product which would allow the rider to change their effective head tube angle with not tools, in less than twenty seconds. Many riders would prefer this product to be less than 150 dollars.

Much of our understanding of why a customer would want to use this headset comes from years of riding and being interested in bikes ourselves. Talking to people during rides and at trailheads, reading bike and component reviews, and working in bike shops gave us a deep understanding of why a mountain biker would want this product on their bike. The entirety of the customer wants and needs are documented in Appendix B.

2.2. Product Research

Headsets that allow adjustment of the effective head tube angle exist. However, each one falls short of the previously listed customer requirements in different ways.

The first existing product is the VP Varial headset. This product allows the effective head tube angle to be altered ±1.5˚ from the neutral position. The Varial employs a conically shaped outer race on the ball bearing in the lower cup with a rotating, eccentric upper cup. There are no indexed positions. To adjust the headset, five bolts need to be loosened and tightened: 2 on the headset's clamping plate (shown in Figure 1a and 1b) and 3 from the stem bolts and top cap. Reviews state the adjustment time to be 2-3 minutes. This can be done trailside with one Allen wrench commonly found on cyclist multi-tools. The Varial is no longer in production but was listed online for $185 (Levy; Turnman).

Figure 1a. *Trailside picture of the VP Varial headset being adjusted (Turnman).*

Figure 1b. *VP Varial headset assembled in a shortened head tube (Turnman).*

The next relevant product is the Cane Creek AngleSet. The AngleSet uses ball-and-socket joints (shown in Figure 2a) in both the upper and lower cups paired with an eccentric top cup to achieve adjustment. This headset offers 6 fixed positions ranging from -1.5˚ to +1.5˚ in 0.5˚ increments. An assembly view is shown in Figure 2b. The AngleSet is not adjustable trailside because it requires the upper cup to be pounded out and pressed back into the head tube to change the effective head tube angle. This takes 15-20 minutes and specialized tools for an experienced mechanic to adjust. The AngleSet is in production and is currently sold for $175(Mullins; Pacocha).

Figure 2a. *Components of the Cane Creek AngleSet headset (Mullin).*

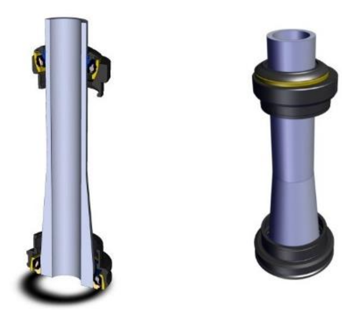


Figure 2b. *AngleSet headset supporting a tapered steer tube (Mullin).*

Other products on the market are headsets that offer a single offset effective head tube angle. These are sold by FSA, Works Components, and Superstar components, but are produced as custom parts by countless other sources. The headset cups house the bearings off-axis from the head tube. The offset cups are shown in Figure 3a and 3b. The upper and lower cups must be aligned during installation and then function identically to a traditional headset. These headsets are sold online for as little as $60 (Major).

Figure 3a. *Works Offset headset cup mounted in a frame (Major).*

Figure 3b. *Components of the Works 2˚ angle adjust headset (Major).*

Instead of adjusting the fork's steering axis relative to the head tube, some companies have decided to change other aspects of the bike's geometry to achieve similar results.
For example, Canyon employs a gas piston (shown in Figure 4a), called the ShapeShifter, acting on the linkage of their Strive Enduro race bike to change its suspension travel and geometry with the push of a handlebar-mounted lever. This raises the bottom bracket and steepens the head tube angle by 1.5˚. The contrasting static positions are shown in Figure 4b (Canyon, USA). This allows the rider to optimize their bike for climbing or descending, but it is only offered on one bike model from one manufacturer.

Figure 4a. *Canyon ShapeShifter gas piston linkage interaction (Canyon).*

Figure 4b. *Geometry alteration caused by activation of the ShapeShifter system (Canyon).*

Another product that alters the head tube angle without changing the fork's steering axis relative to the frame is Wolf Tooth's Lower Headset Cup Extender. By increasing the bottom headset cup's stack height, the fork's effective axle-to-crown measurement is increased. This slackens the head tube angle by around 1˚. The extra stack height is shown in Figure 5a and 5b (Benson).

Figure 5a. *Wolf Tooth lower headset cup extender (Benson).*

Figure 5b. *Headset extender mounted on a frame (Benson).*

2.3. Standards

The proposed headset must be compatible with existing frames, so it is crucial to understand existing standards for every component the headset interfaces with. Size standards are important because space is limited and headset tolerances are tight. Testing standards are important because a headset failure could endanger the user. We want to make sure that our headset is safe and compatible with as wide a range of bikes as possible.

2.3.1 Size Standards

As with most standards in the bike industry, many different headset standards are used in today's mountain bikes. Thankfully, there is a greater consensus in headset standards than some other areas. The most common headset in today's all-mountain bikes is a tapered steerer tube paired with ZS44 and ZS56 cups. Dimensions for these standards are provided in Appendix C (C. Jones). We will design our headset to meet these standards first with the possibility of expanding compatibility to other standards as well.

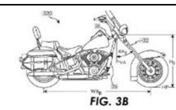
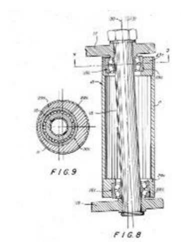
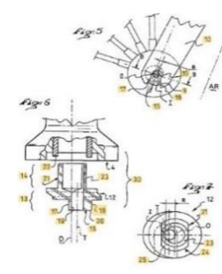
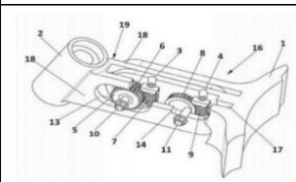
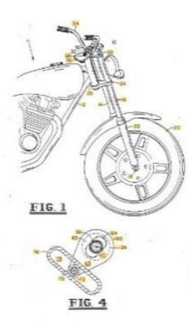
2.3.2 Testing Standards

Bicycle manufacturers primarily test their products to ASTM and ISO standards. These organizations hide their testing methods behind paywalls. We will use our Cal Poly Library resources to obtain the testing standards and subject our headset to as many tests as practical. The testing organizations mentioned above set a more rigorous standard than is required by law. To sell a bike in the United States, the Consumer Product Safety Commission (CPSC) has a lower set of standards to meet. These standards are published freely, and we will ensure that our headset exceeds these standards (CPSC, USA).

2.4 Patents

We performed a patent search to ensure that we do not reinvent someone else’s design. Many patents were intended for motorcycle use as mountain bikes did not exist at the time of filing. A summary of the 5 patents most like our design intent are shown in Table 1.

Table 1. *Summary of patents most related to our project.*

Patent Number	Patent Name	Description	Picture
US8181981B2	Variable geometry cycle frame	A linear actuator acts on a pivoting head tube assembly	
US3866946A	Motorcycle steering head angle adjustment	Eccentric bearing housings at the top and bottom of the head tube allow for a steering axis offset from the head tube angle	
US7140627B2	Front wheel suspension system	A hub-mounted eccentric axle allows the fork’s trail to be adjusted, achieving similar handling results to head tube angle adjustment	
ES2774848A1	Mechanism of vehicle geometry variation of less than two wheels	The head tube angle is adjusted by having a pivoting head tube assembly riding against a cam	
US4700963A	Variable angle steering system	The head tube angle changes with steering angle. The steer tube has a pin riding in a fixed horizontal slot that pulls the top headset cup forward and backward in its own slot	

References from top to bottom: Stenberg, Robison, Wimmer, Marin, Burns.

2.5 Research Reports

While researching the theory behind the steering axis' effects on bicycle handling, we found Cal Poly's Single-Track Vehicle Design class documentation to be invaluable. We found further information about the dynamic response and geometry influences in published research reports discussing bicycle stability dynamics.

2.5.1 Performance Influences

Out of all the bicycle geometry features, our headset will focus on the effective head tube angle, or steering axis angle. This is referenced from the vertical, shown as β in Figure 6.

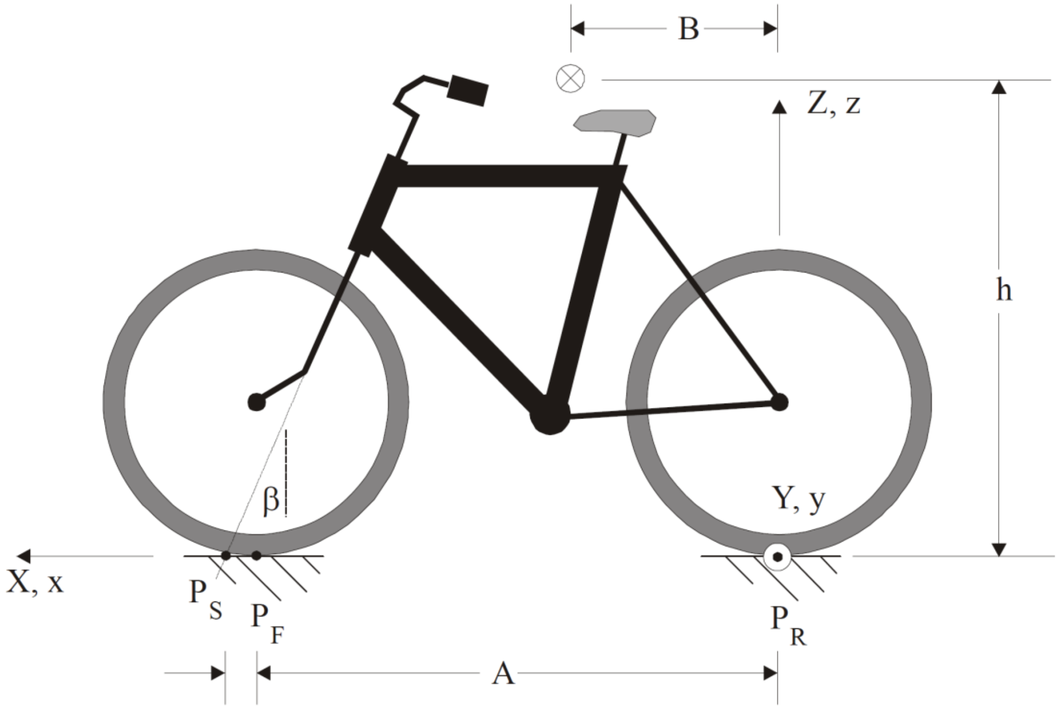


Figure 6. *Side view of a bicycle with labeled geometry variables (Patterson).*

The steering axis angle, also referenced in some documentation as caster angle, has effects on many handling characteristics: self-centering, steering acceleration as a function of input, fork flop, control sensitivity, trail, and coupling between roll and yaw. A value we can use to judge the sensitivity of the input to the bicycle is the control authority:

$$K_C = \frac{B}{A}\frac{\cos(\beta)}{R_h h} \qquad \textbf{Equation 1.}$$

A is the wheelbase, h is the height of the center of gravity from the ground, B is the distance of the center of gravity from the rear axle, R_h is the handle bar radius, and β is the inclination of the steering axis. As K_C increases, the bike's response from the same rider input becomes larger; often described as 'twitchy'. This increase in control authority can be a result of decreasing the steering axis inclination. Increasing the inclination results in more stability at higher speeds. This change in angle affects the amount of trail the front wheel has, the distance between P_S and P_F in Figure 6. As referenced by Patterson, this also increases the trail without increasing the rake; the axle offset from the center line of the steering axis. This has a negative affect with increased fork flop; the tendency for the bicycle to turn when the bicycle is rolled.

In 1970, David Jones theorized, “The contact point of the bicycle’s tire is behind the steering axis. As a result, when the bicycle leans, a torque is developed that turns the front wheel.” Continuing this theory, as the steering axis is brought further from vertical and the inclination of the steering axis, angle β, is increased, the point of contact will move further behind the steering axis and the torque about the steering axis will increase; increased fork flop. A slacker head angle leads to increased torque transmitted from the ground, making it more difficult for the rider to counteract ground forces. A steeper head angle has the opposite effect. While climbing, quick steering changes are needed to keep balance at very low speeds which is achieved by a steeper steering axis (Canyon, USA). Downhill, a slacker angle aligns the suspension more with the force vector of bumps and obstacles in the path where effortless steering changes are less important (D. Jones; Santa Cruz, USA).

2.5.2 Dynamic Model of Stable Speed Range

Better stability increases a rider’s comfort and confidence. Jason Moore and Mont Hubbard investigated how optimizing geometry features could increase stability across a range of speeds. Wheelbase, front wheel size, trail, and head tube angle were all variables modified to show their effects on a bicycle’s stable speed range. Moore and Hubbard developed a dynamic model to determine which parameters could demonstrate self-stabilizing characteristics.

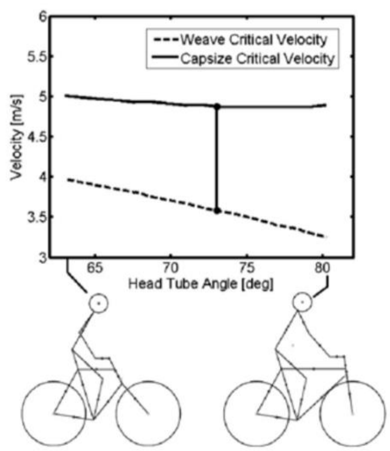


Figure 7. *Critical Speed Range vs Head Tube Angle, from Parametric Study of Bicycle Stability (Jones).*

The stable speed range is bound by two critical velocities; capsize and weave. Capsize and weave critical velocities corresponded to their high and low speed stability limits, respectively. Figure 7 shows how a slacker head tube angle increases the weave critical speed, raising the lower bound of the stable speed range. Additionally, head tube angle showed little effect on the capsize critical velocity. Moore found that slack head tube angles are suited to higher speeds for adequate responsiveness while steeper angles have a much broader stability range which extends into lower speeds.

2.6 Forces and Loading

The headset is a highly loaded component. It encounters large forces relative to the amount of material used due to size constraints. Understanding loading cases and how forces are transmitted will be important during our detailed design.

Maury Hull, a UC Davis mechanical engineering professor, performed off-road testing on mountain bikes to quantify loading cases. Using load cells, accelerometers, and data acquisition equipment, loading percentages of rider weight at various points on the bike were determined. We will be interested in the front wheel's loading because it applies forces to the fork and then the headset. The test was performed using a full-suspension mountain bike on an 8% decline off-road surface.

The test results showed that the front wheel's vertical loading increased by 31% from static loading when riding, while the horizontal loading increased by 4% from static loading (Hull). Considering these numbers include impact forces, they show a surprisingly low loading increase. However, mountain bike suspension is typically run soft relative to other suspension applications. Additionally, the riders were not stated to be riding aggressively. Running stiffer suspension and riding more aggressively would increase the front wheel loading, and we will account for these factors in our calculations. This study gives us a helpful baseline loading increase to begin designing around.

3. Objectives

After evaluating our customer observations and background research, we developed the following problem definition:

Avid mountain bikers who want to adjust their bikes' geometry for climbing and descending need a device, compatible with existing frames, which allows easy and quick adjustment of the steering axis. This will improve the rider's confidence and comfort by matching the bicycle's handling characteristics to the trail conditions. This adjustability will reduce instability while climbing and descending.

Summarizing our customers' observations, mountain bikers want the ability to steepen their effective head tube angle for climbing and slacken it for descending. Achieving this adjustment with a headset is desirable because it is a non-proprietary component that can be installed on existing bikes. Mountain bikers want this adjustment to be quick and tool-free. They will accept some extra bulk and weight, but within reason. Mountain bikers want a range of adjustability that will provide appreciable differences in ride quality. They want a neutral adjustment setting and are willing to pay a premium for the adjustment this headset will offer. The headset should not sacrifice safety or reliability. A list of customer wants and needs is included in Appendix B.

3.1 Boundary Diagram

To visualize how the headset will interact with riders and their bikes, we drew a boundary diagram. The red rectangle denotes where our headset will interface with the larger system, shown in Figure 8.

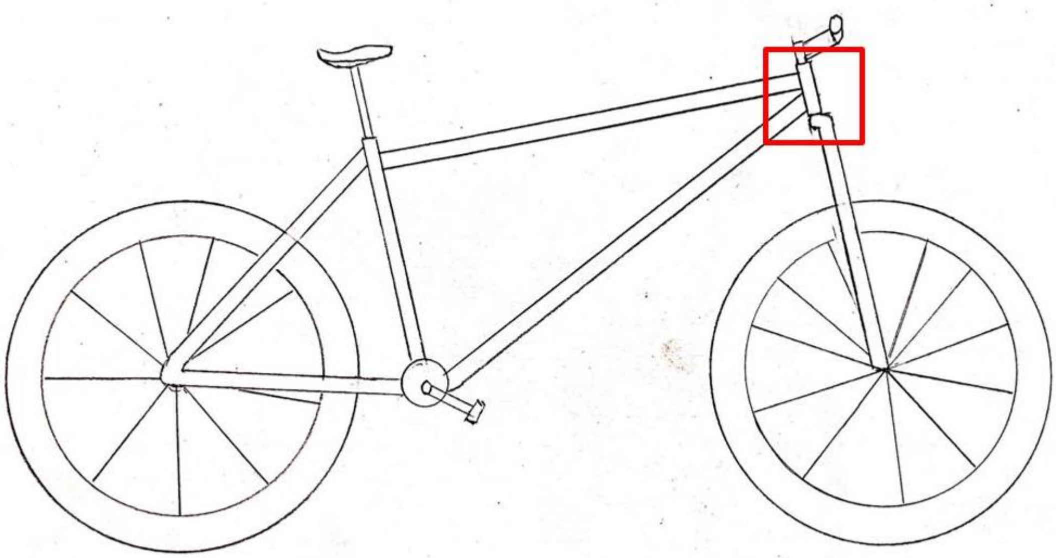


Figure 8. *Boundary diagram for the headset*

3.2 Summary of Customer Wants and Needs

Through conversations with Dr. Kean, surveys of the Cal Poly Cycling team and Cal Poly Bike Builders, and our own extensive experience, we summarized the following list of customer needs and wants (full list in Appendix B):

- The ability to steepen the effective head tube angle for climbing and slacken it for descending by 2 degrees each way from neutral.
- A non-proprietary component that can be installed on existing bikes.
- Quick and tool-free adjustment.
- A range of adjustability that will provide appreciable differences in ride quality.
- Neutral adjustment setting.
- A product that does not sacrifice safety.
- Relatively low-profile, but small addition of bulk or weight is acceptable.

3.3 QFD House of Quality

We created a House of Quality, included in Appendix D, to develop effective engineering specifications that we will use to test our project against customer needs. This method takes the customer needs, possible customers, and pre-existing products and ranks and compares them against each other. We created effective tests and specifications that relate to each customer need. The results rank the importance of the engineering specifications, telling us which is most important to focus on in the design stage.

From our house of quality, we learned that repeated, relatively long-term test riding will be our most effective method of testing our headset. We also learned that our customer base places more value on factors such as safety, adjustability, silence, and appearance than on weight, maintenance, or durability. We gained a better understanding of where competing products excel which will help us decide which design features to avoid or incorporate.

3.4 Engineering Specifications

To evaluate how well our headset meets our design criteria, we developed the engineering specifications outlined in Table 2, on the next page. The target values set goals for us to reach throughout the design process. The tolerances provide flexibility if we cannot reach a goal. The risk factors (H for high, M for medium, L for low) describe how risky we predict meeting the design specification will be. The compliance (T for test, I for inspection, S for survey) describes how we will verify that our design meets the specifications.

Table 2. *Engineering specifications and associated factors.*

Spec #	Specification Parameter	Target Value	Tolerance	Risk	Compliance
1	Adjustment Time	20 sec	Minimum	M	T
2	Tools Needed to Adjust	Tool-less	Minimum	M	I
3	Weight	250 grams	Maximum	M	T
4	Resemblance to Normal Headset (Survey)	Results confirm low profile, or is not larger than VP Varial	Maximum	H	S
5	Real-World Test Rides	Acceptable review from rider	Maximum of 20% non-acceptable responses	L	T, I
6	Range of Adjustability Test	Must change angle ±2° and have at least 3 positions	Minimum	L	T
7	Production Planning Meeting with Manufacturer	Easily/cheaply manufacturable. $100 in materials, 2 hours of shop time.	Maximum	L	I
8	Test Rotation of Handlebars	Rotates freely at least 90˚ from center position in either direction (180° total)	Minimum	L	T
9	Maintenance Test	Must take 5 rides before necessary maintenance	±1 Ride	M	I

Next, we will describe how each of these specifications will be tested.

1. A range of mountain bikers will be tasked with adjusting the headset installed on a mountain bike. They will be explained how to adjust the headset and asked to perform the adjustment process three times in a row. The final time will be recorded to simulate familiarity with the system.
2. The number of tools needed to adjust the headset will be recorded.
3. All parts of the product assembly will be weighed on a scale.
4. Mountain bikers will be asked to rate how closely our designed headset resembles a normal headset.
5. Five mountain bikers will be selected to ride a bike with our headset installed. 10 miles of riding on technical trails will be requested. Their experiences encompassing all aspects of our product will be recorded.
6. An inclinometer will measure the maximum and minimum angle of the steering axis.
7. A manufacturing engineer will be presented with the detailed plans and their statement on manufacturability will be recorded. Material costs and predicted shop time will be recorded.
8. The possible fork/handlebar rotation angles will be measured, and free rotation will be checked for.
9. After the first five rides, the headset assembly will be disassembled to check for wear. This will also be performed following long-term testing.

We assigned a high-risk assessment to resemblance to normal headsets because we anticipate needing to use a bulkier design than normal headsets use. We want to keep this challenging specification because it sets a high standard for us to work towards.

4. Concept Design

The concept design process began with a functional decomposition of our headset assembly. We generated ideas for each of these functions and prototyped the best concepts. We used Pugh matrices to compare ideas for each function and a morphological matrix to combine these function-level ideas into system-level ideas. We compared these system level ideas using a weighted decision matrix, which pulled weights from our house of quality (Appendix D) and determined our design direction. The design direction determined by this process will be a headset using a toothed top cup and headset spacer to locate the steerer tube. An over-center lock provides slack for adjustment and then preloads the headset, while the steerer tube pivots using a spherical bearing in the bottom cup.

4.1 Ideation and Function Concept Prototypes

We performed a functional decomposition to identify our headset's main functions. The functional decomposition breaks the headset's use into its general, sub, and basic functions. Our functional decomposition is shown on the next page in Figure 9. Our headset's general function is to adjust the effective head tube angle. We divided the headset's sub functions into three groups: its ability to preload the headset assembly, adjusting the head tube angle by pivoting, and holding different head tube angles using a locating mechanism. Below each sub function are its basic functions. These are the smallest and most detailed functions that will be performed by the headset.

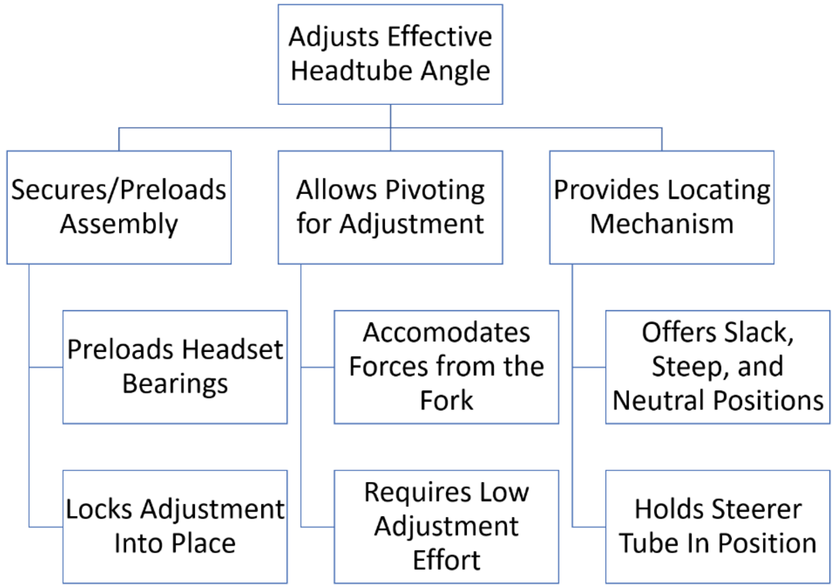


Figure 9. *Functional decomposition tree.*

Next, we generated ideas for each sub function shown above without concern for feasibility, cost, or practicality. This helped us maximize the number and diversity of our ideas. A brain-dump took place where each member tried to sketch and describe as many ideas as possible in twenty minutes. We shared our ideas with the team so that other members could create new ideas from the ideas of others. These ideas are compiled in Appendix E.

Another process we used was brainwriting where each member creates one sketch for five minutes before passing it to the next member who builds upon the idea. This cycle happened until each member saw each sketch once. Afterwards, each person described their own sketch and their edits to the other sketches. We found that each person understood the sketches differently which led to some confusion but also new ideas. The sketches from the brainwriting exercise are included in Appendix F.

As we moved onto the next steps, we filtered out ideas that were easily identifiable as impractical. The remaining ideas were compared and further filtered using a series of decision matrices.

4.2 Pugh, Morphological, and Weighted Decision Matrices

To begin moving from subjective to objective design, we created different types of decision matrices. These matrices helped us narrow down our design alternatives, ultimately arriving at our final concept design. The Pugh Matrices compared each idea for a specific function against one another which led to the most promising solutions for each function. A Morphological matrix took the most promising function solutions and helped us to create numerous combinations. The Decision matrix used the weighting assigned by the house of quality exercise to compare the top system-level designs based on our customer needs and wants.

4.2.1 Pugh Matrices

Pugh matrices compare each function design alternative to a baseline. Elements of the VP Varial headset served as our datum because it is the most competitive alternative to our intended design. We assigned values to each function idea based on how well it met the relevant customer need criteria compared to the datum. Here (+), (-), and (S) are used to denote if an idea is better (+), worse (-), or similar (S) compared to the datum. The totaling each score where a positive total indicates an idea more effective than the datum and a negative is less effective.

For each of our headset's three sub functions, we created a Pugh matrix. These are included in Appendix G. We selected the highest scoring ideas from our Pugh matrices to be included in our morphological matrix, shown in Table 3.

4.2.2 Morphological Matrix and Concept Sketches

Most of our ideas for each function are independent of other functions. This allowed us to create a morphological matrix to combine different function-level ideas into system-level ideas. By choosing a single idea from each row, different methods of achieving each function were put together to form various complete assembly ideas. Our morphological matrix is shown below in Table 3.

Table 3. *Morphological Matrix.*

Function	Idea 1	Idea 2	Idea 3	Idea 4	Idea 5
Freely Adjusting	Rotating Eccentric Cups	Convex Cups	Pinned Pivoting Bearing Housing	Spherical Bearing (Top or Bottom Cup)	Inner Headtube Assembly
Preloads Assembly	Screws	Eccentric Notch/Slot Lock	Threaded Spacer	Over-Center Lock	External Threading on Cup
Locating Mechanism	Inner Assembly	Rotating Eccentric Cups	Notches and Pins (Single Point)	Teeth (Multi-Point)	

Each member created four system-level ideas, some of which were very similar. The team analyzed each idea and chose the six ideas that seemed most feasible and effective. These top ideas are arranged and analyzed in the weighted decision matrix. The first idea is shown below in Figure 10.

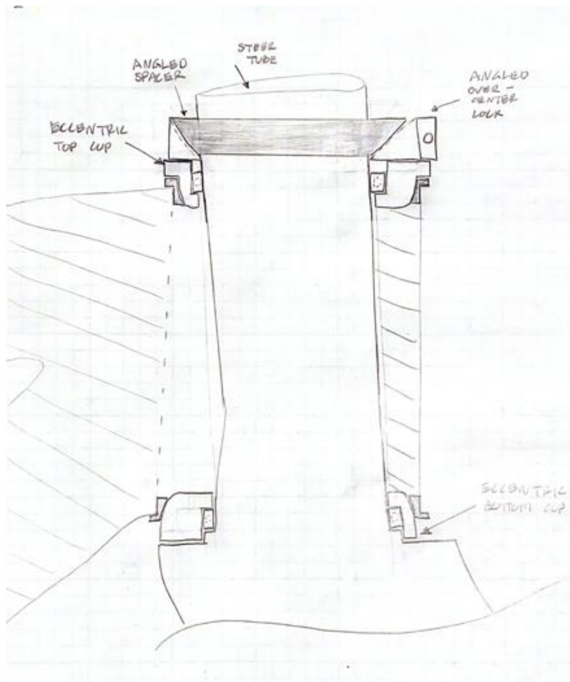


Figure 10. *Idea 1, Rotating eccentric cups with axial expanding quick release.*

This headset uses two rotating, eccentric cups to locate the steerer tube. By rotating the offset bearing housings opposite each other, the effective head tube angle is adjusted. Rotating the offset bearing housings the same way allows a neutral position, albeit with a lengthened or shortened reach. Combining this concept with either a threaded headset spacer or expanding axial quick release created two of the ideas in our weighted decision matrix.

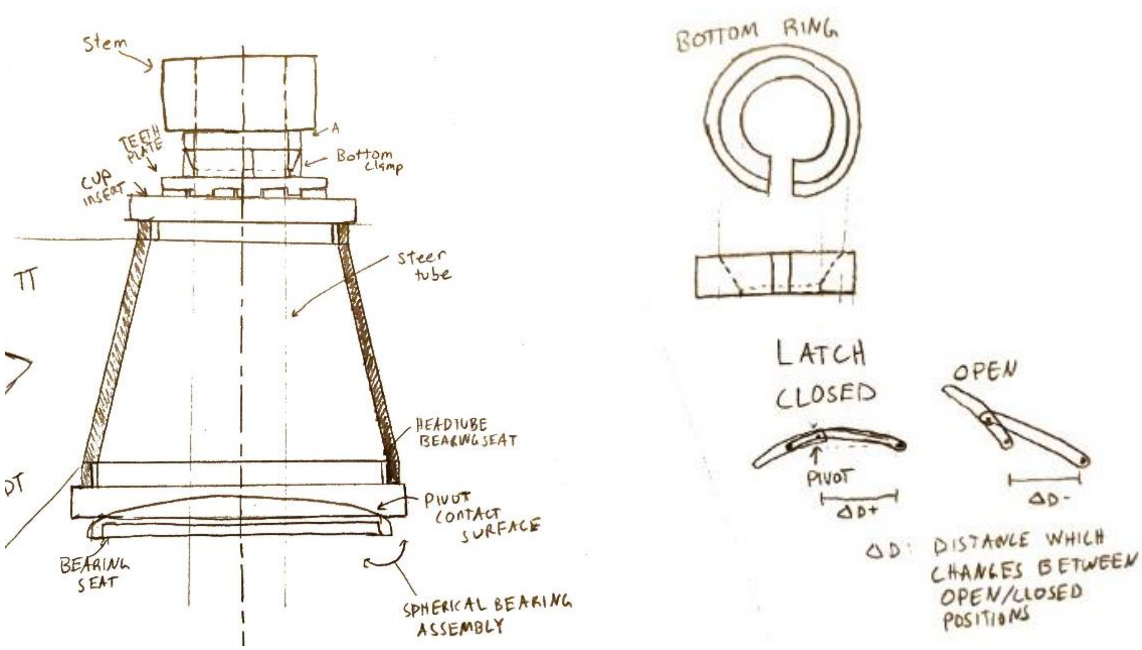


Figure 11. *Idea 2, Spherical bottom bearing with axial expanding quick release and locating teeth.*

Idea 2 utilizes an axial expanding compression ring mated to a conical spacer, shown in Figure 11. When the lever is tightened, the spacer assembly height increases, preloading the bearing and steerer/head tube assembly. The height difference the conical spacer provides is directly related to the height of the teeth. The axial expanding quick release's functional mechanism is the pivot point location referenced to the line of action between clamping surfaces. This is a potential way to apply an over-center latch design as a locking mechanism.

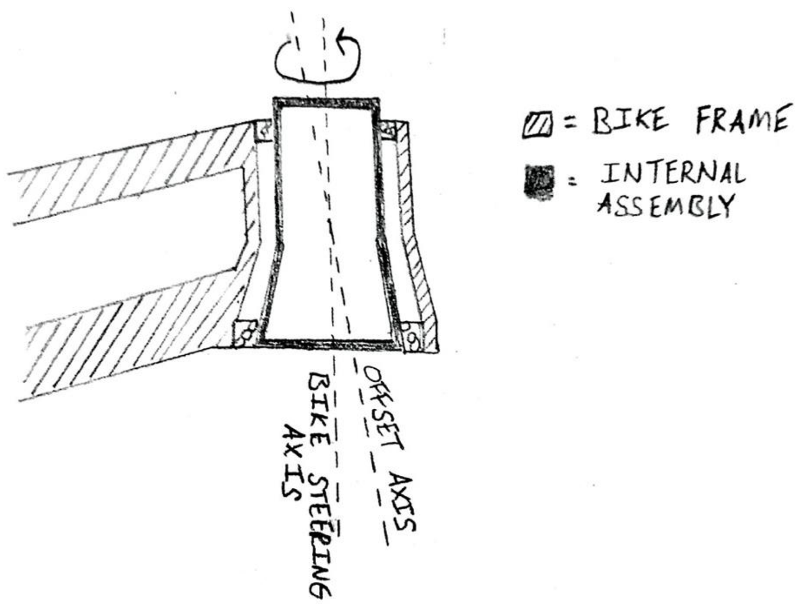


Figure 12. *Idea 3, Inner head tube assembly with locating notch/slot.*

Idea 3, shown in Figure 12, is a head tube assembly internal to the bike's head tube uses a standard headset mounted off-axis. By rotating the inner head tube assembly relative to the bike frame, the steering axis offset can be changed. This allows for slackening and steepening of the effective steering angle but does not allow for a neutral position. Locating notches and latches would secure the assembly in place. This idea could use a standard star-nut and top cap for bearing preload, never requiring adjustment.

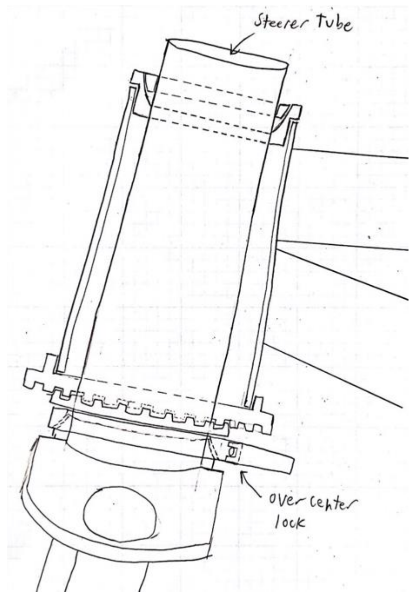


Figure 13. *Idea 4, Spherical top bearing with over-center lock and bottom locating teeth.*

Idea 4 flips the locating teeth and spherical bearing locations from Idea 2. As shown in Figure 13, the top spherical bearing acts as a pivot which allows the steerer tube axis to change angle. The locating teeth are now on the bottom headset cup. Riding forces and impacts would increase the teeth's clamping pressure, securing the assembly. An axial expanding quick release would also be used in this idea.

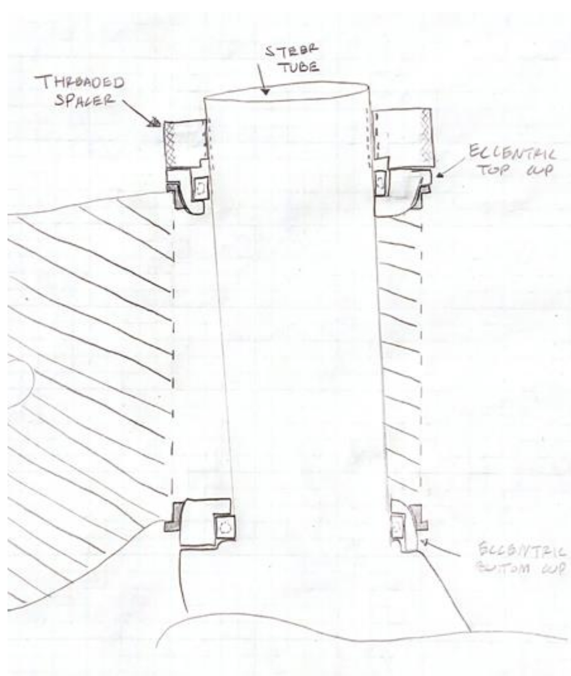


Figure 14. *Idea 5, Rotating eccentric cups with threaded headset spacer.*

Idea 5 resembles Idea 1 in Figure 11, although it uses a threaded spacer to preload the assembly as opposed to an axially expanding locking mechanism, shown in Figure 14. Eccentric top and bottom cups allow the steering axis to differ from the manufacturers desired head tube angle. The rider would loosen the threaded spacer first, then adjust the eccentric cup orientations. Tightening the spacer would make up for the difference in effective head tube length created by changing the steering axis.

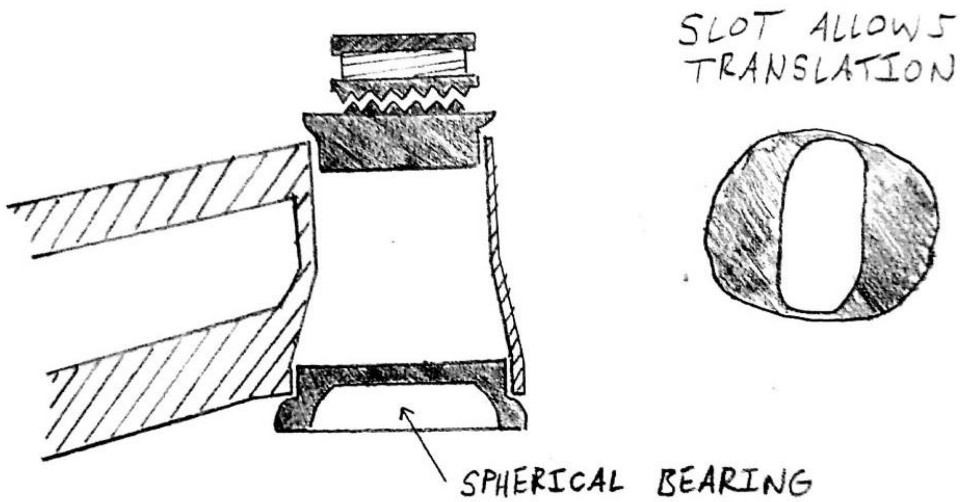


Figure 15. *Idea 6, Spherical bottom bearing with threaded spacer and locating teeth.*

Idea 6 in essence is identical to Idea 2 but uses the threaded headset spacer described in Idea 5. Shown in Figure 15, the top headset cup is slotted to allow the steerer tube to translate fore and aft relative to the top cup. The cup press fit with the frame would keep the slot oriented correctly.

4.2.3 Weighted Decision Matrix

The weighted decision matrix, located in Appendix H, served as our final tool in the controlled convergence process. We put each of the top system-level ideas into the decision matrix with all the customer needs and wants and their respective weights. We scored each idea for how well it fit each need or want, and we multiplied that score by the respective weight. The highest scoring idea in the weighted decision matrix should theoretically be the most suited to satisfy our requirements.

Idea 2 accumulated the highest total score in this matrix, and we agreed that this should become our design direction. It has the least moving parts and may have the fewest elements to fail. We thought the tooth locating system would have more holding power than the friction of the rotating eccentric cups.

Idea 6 scored the second highest in this matrix, and it will be employed as an alternative because it uses a different preload mechanism that we believe still has promise. If the axial expanding quick release does not provide enough clamping pressure on the locating teeth, we may switch to the threaded headset spacer.

The third highest score was received by Idea 3, but this design must be ignored because it does not include a neutral angle position. As we move on with our design direction, we will perform preliminary analyses to show that our chosen design will satisfy our specifications. If our chosen design direction proves to be unreliable or impractical, we may sacrifice the neutral position and choose idea 3.

4.3 Final Concept Design for PDR

Our controlled convergence process helped us choose Idea 2 from our weighted decision matrix as our final design concept. This design features a spherical bearing seated in the bottom cup, shown in Figure 16c, to allow the steerer tube to pivot. This element satisfies our function of needing to provide the steer tube with a means of adjusting the effective head tube angle. The locking mechanism of our final design is an over-center lock with an angled inner surface to provide the system with preload, shown in Figure 16b, to secure the assembly in place. The design will use locating teeth on the top headset cup and a matching headset spacer, shown in Figure 16a, to lock the adjustment in place. Figure 16d shows a cross section of the headset assembly to help visualize how the components interface with each other.

We used materials that were easily sourced and easy to work with to create concept prototypes. These physical models of our chosen design direction helped us verify that each component would satisfy the function it was designed to fulfill. We each created a subsystem of our larger assembly to divide the workload in a socially distant manner. The concept prototypes are shown below in figures stated in the previous paragraph.

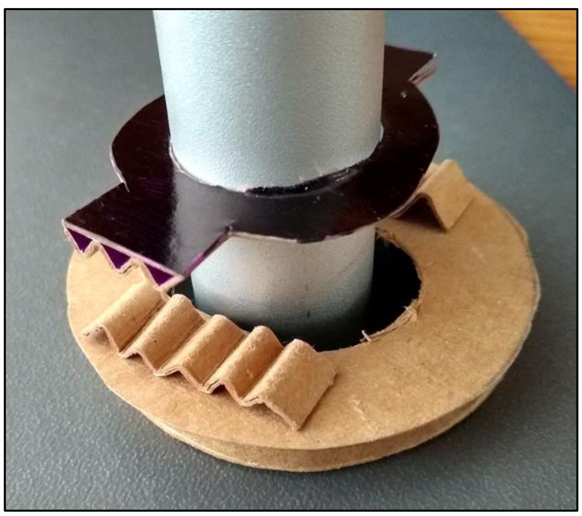


Figure 16a. *Top headset cup concept prototype.*

Figure 16b. *Top headset cup concept prototype.*

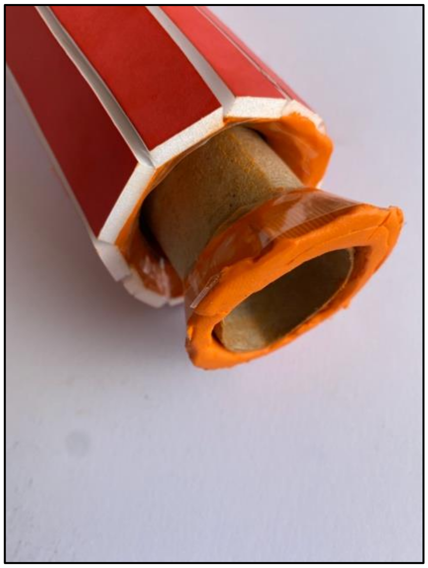


Figure 16c. *Bottom headset cup concept prototype.*

Figure 16d. *Cross section of headset assembly installed in a tapered head tube.*

By building our concept prototypes roughly to scale, we verified that our ideas are possible to fit into the size constraints set by head tube sizes. The concept prototypes also helped us learn how components would fit together and where clearance issues might arise. Most importantly, building the concept prototypes helped us better visualize our components within the assembly. Better spatial understanding of our system let us add more detail to our design.

To further verify our selected concept, we created a CAD model built around exact dimensions we are constrained by. An isometric view of the CAD model is shown below in Figure 17. Components are color-coded and labeled by subsystem. The grey components are non-modifiable: the head tube will be part of an existing bike and the bearings will be sourced.

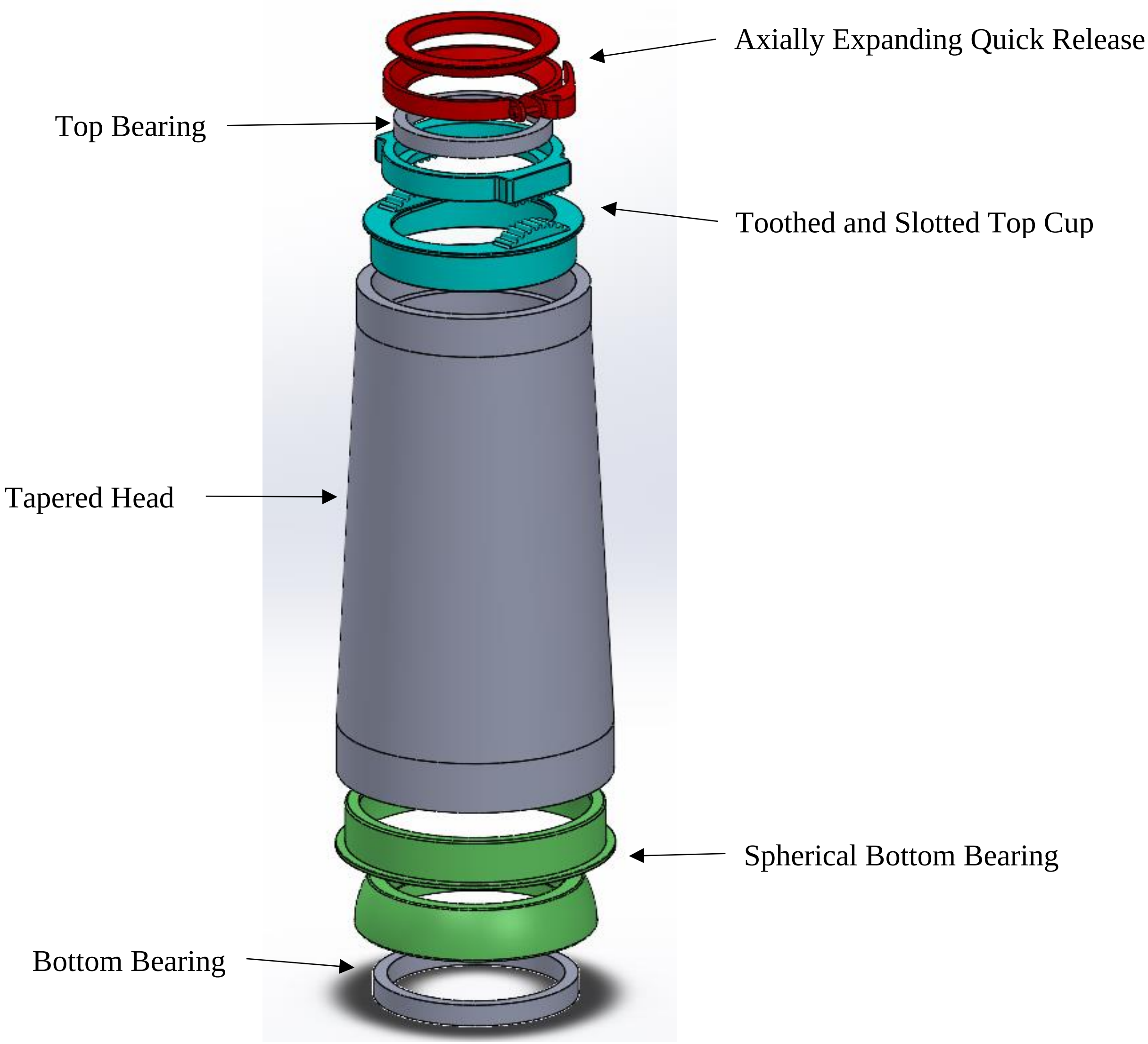


Figure 17. *Isometric view of CAD model.*

We created the CAD model with manufacturability in mind. Most components will be machined on a CNC lathe with extra milling operations required for the top headset cup, over-center lock, and toothed spacer. We will consider purchasing an existing quick release system to serve as our over-center lock. We will source bearings after sizing calculations. We will machine other components from an aluminum alloy. If the teeth on the top headset cup deform when testing, we will switch to a steel alloy for that component. We are considering adding a bolt-on toothing feature to the top headset cup for testing. This would allow different tooth geometry to be quickly tested without unnecessarily machining a new top cup each time. Our CAD model is designed around a head tube that accepts ZS44/56 headsets (dimensions in Appendix C).

The amount of slacker and steeper head tube angle positions is yet to be decided, but our design will offer a minimum of three positions: one slacker, one steeper, and neutral. Due to the limited space at the top of the head tube, we do not foresee there being enough distance to allow multiple slack and steep positions, but this is a detail we will confirm as we perform further analysis.

For the rider to make an adjustment of the head tube angle they will first loosen the over-center lock by opening its latch, therefore releasing the preload from the assembly, allowing the steer tube to move freely within the head tube. From there, the rider may adjust the position of the steer tube by pushing the teeth forward or pulling them rearward, steepening or slackening the effective head tube angle, respectively.

4.4 Final Concept Design for CDR

Following PDR, we received important feedback questioning the stress concentrations related to the locating teeth on both the top cup and top bearing holder, as well as the overall strength of these teeth depending on their size and shape. In addition to this, it is unclear whether the strength needed to preload the assembly and the force needed to hold the teeth together effectively is within the same range of magnitude. Coupling these concerns with the knowledge that the manufacturability of the teeth would be difficult, the need for axial displacement of the bearing holder to clear the teeth, the difficulty of meshing more than one tooth correctly on the curved arc of the steerer tube, and a limitation of space to make enough teeth to allow for at least three positions and big enough to withstand the forces, we held several team meetings to explore other ideas for the locating system.

The proposed solution eliminates the need for axial displacement of the top bearing holder, allows for three positions (steep, neutral, slack), and is promising in supporting the forces present at the top cup. This proposal is a pin connection between the top bearing holder and the top headset cup shown in Figure 18. The grey bearing holder slides along a curved surface whose radius matches the distance to the pivot of the headtube. A new hole for each position on both parts is necessary because the arc length imposed by the rotating headtube two degrees forward and backward displaces 5 mm either direction. This distance does not allow one hole to reach three holes on the other part due to the diameter of the holes together being longer than 5mm. By adding three holes on each part, we can space the holes out and design for sufficient material between each hole to create adequate strength. The steep and slack positions are reached by removing the preload by opening the axial over center lock and aligning the front or rear holes on both parts, respectively.

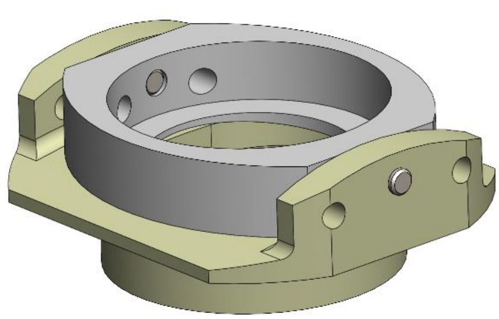


Figure 18. *Isometric view of top cup final design.*

The most effective method of preload was also discussed after insight that considerable axial displacement along the steerer tube was not needed at the top cup. This is because the bearing holder can slide laterally along the top cup mating surface when the pins and preload are removed. With this limitation removed, several ideas in Figure 19 were presented among the team. The bottom right is a camlock which resembles how many such camlock hoses join. Rounded cams align a groove by rotating the cam into the groove with force. The bottom left is a conical spacer manufactured by OneUp components which effectively is our conical spacer idea without the toolless over center lock. In the top frame, there is a shim spacer idea by simply forcing the fork between the two spacers which creates a slight vertical displacement, possibly enough to create a preload.

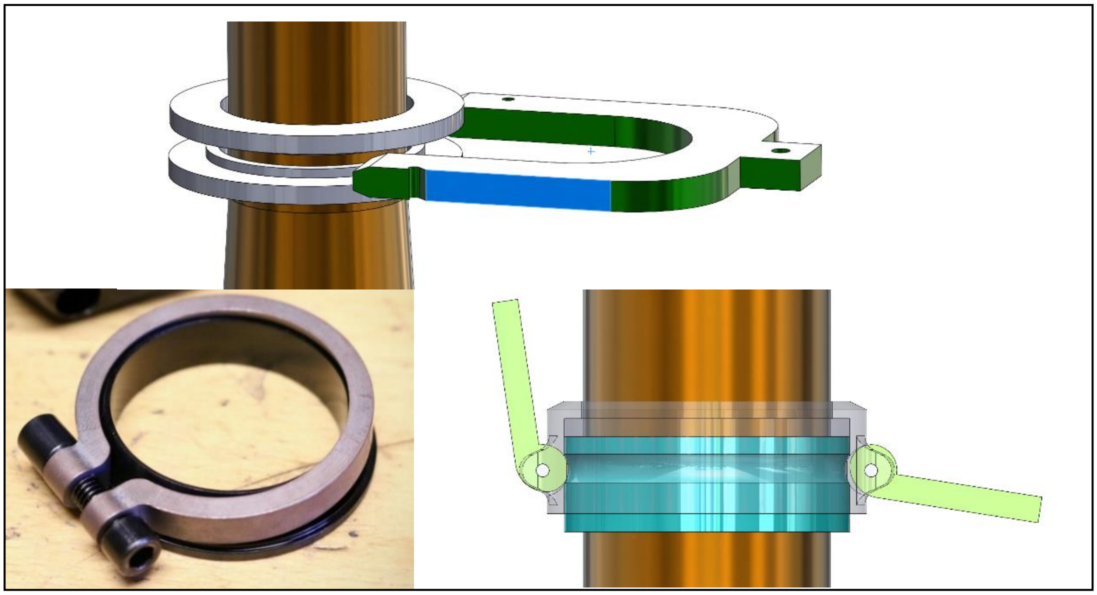


Figure 19. *Possible preload methods.*

After analyzing each idea, the OneUp component was selected as the most promising considering our limited access to the machine shops and the possibility of purchasing the component and modifying it to accept an over center lock instead of the included bolt. The proposed design is shown in Figure 20.

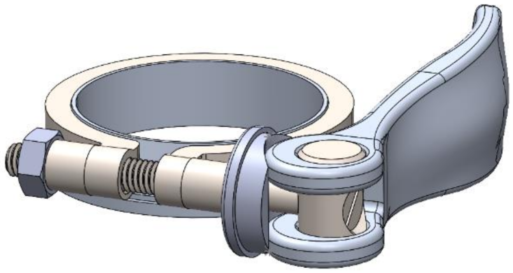


Figure 20. *Possible preload assembly.*

To secure the pins in the top cup and bearing housing, a locating pin clip has been designed. A thin strip of stainless steel will perform as a spring and hold the pins. It will be shaped in such a way that it is a loop and cannot come off the frame during riding. The springiness of the band will hold the pins in the holes and allow the user to compress the band in the perpendicular direction to the springs to pop them out of the top cup holes to change positions.

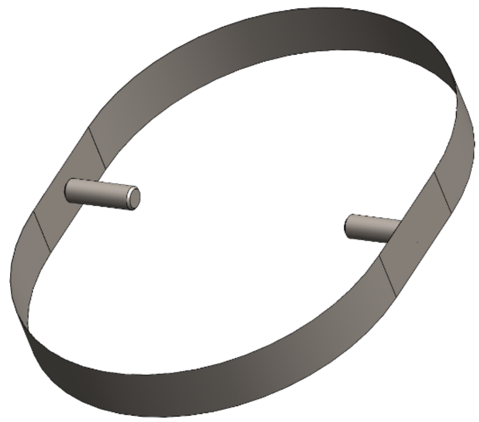


Figure 21: *View of locating pin clip.*

4.5 Preliminary Design Risks

Large forces carried by the steerer tube, possible unsafe use of the device, and unfavorable environmental conditions are all hazards that we will have to design for (full Risk Hazard Checklist in Appendix M).

The length of the fork on a bicycle creates a large moment arm for any forces at the front wheel to create large forces at the head tube. Due to the constraints of size and material thickness by the size of the head tube and the interface between it and the steerer tube, careful design will need to be done to accommodate these large forces. Possible mitigations of this risk will be the use of high strength materials and added material. We are particularly concerned about the locating pin holes' strength. We will ensure that this locating method is thoroughly tested.

The device will require correct adjustment by the user to result in safe use. We will design the adjustment method to be as easy as possible. We will also provide documentation to the user to help them understand the adjustment process.

The device will see environments ranging from hot and dusty to cold and wet. We plan to develop a product that is sealed off from harsh environmental conditions. We do not want concern for our product's reliability to impact a rider's decision to go riding in bad weather.

5. Final Design

The final design of the adjustable headtube angle headset will allow the user to select three different usable headtube angles trailside.

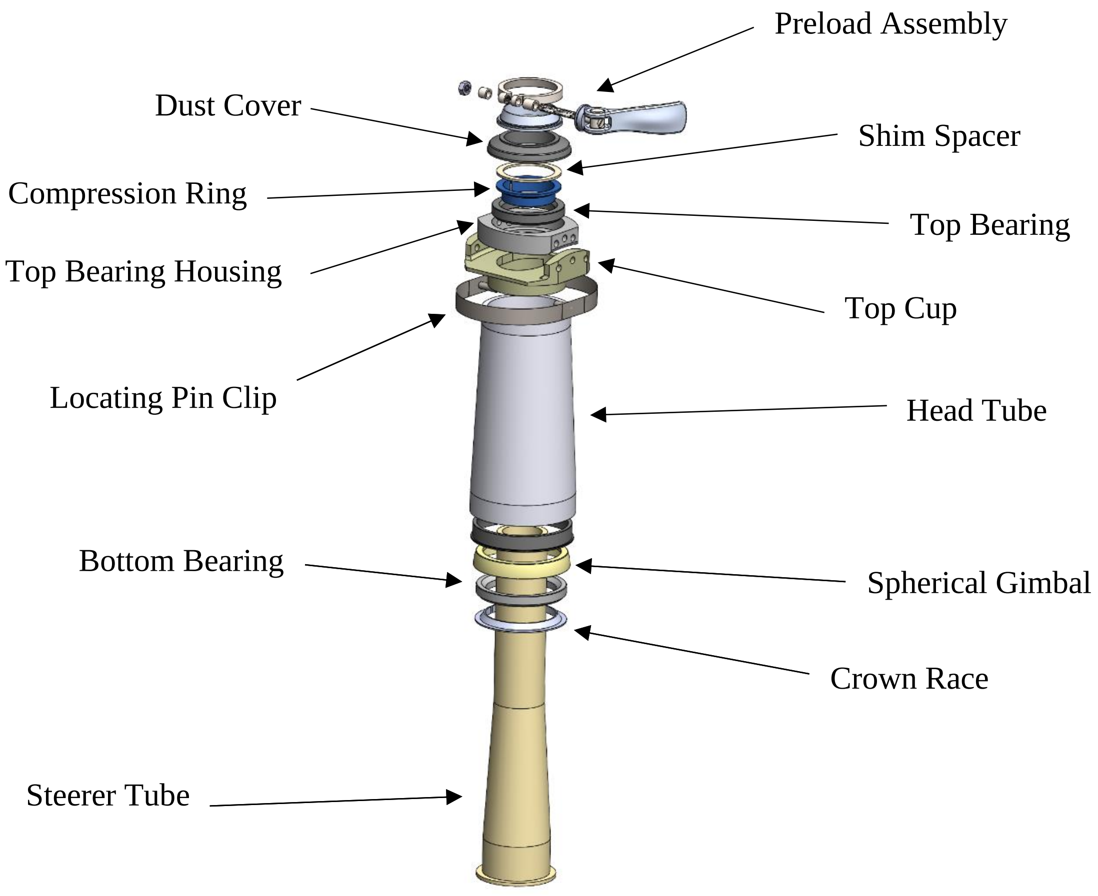


Figure 22: *Exploded view of full assembly*

Referencing Figure 22, beginning at the top of the headset assembly, the bottom of the stem and any headset spacers will contact the top surface of the One-Up EDC Preload component (top component in Figure 22). The bottom surface of the over expanding conical spacer contacts the top surface of the dust cover, which transfers it to the compression ring and shim spacers, pressing down upon the top bearing's inner race. The bottom and outer radial surface of the top bearing's outer race mates with the bore on the top bearing housing so that all loads from the steerer tube are transferred to the housing. The top bearing housing slides along the top curved surface of the top headset cup with the flat pin hole surfaces of each component sliding against each other as well. The top cup fits concentrically in the top of the headtube.

The bottom headset cup fits within the bottom of the headtube and the spherical bottom bearing housing fits within the cup. The bottom bearing's outer race fits into the bore in the spherical bottom bearing housing. The bottom bearing's inner race contacts the crown race on the fork.

5.1 Preload Assembly Design and Analysis

The preload assembly consists of a One-Up EDC Preload Kit component, which will be altered to use a toolless cam handle to initiate compression instead of the included bolt and nut. The ring provides axial compression by reducing the diameter of a stainless-steel outer ring sitting on an inner, conically tapered steel ring, as shown below in Figure 23.

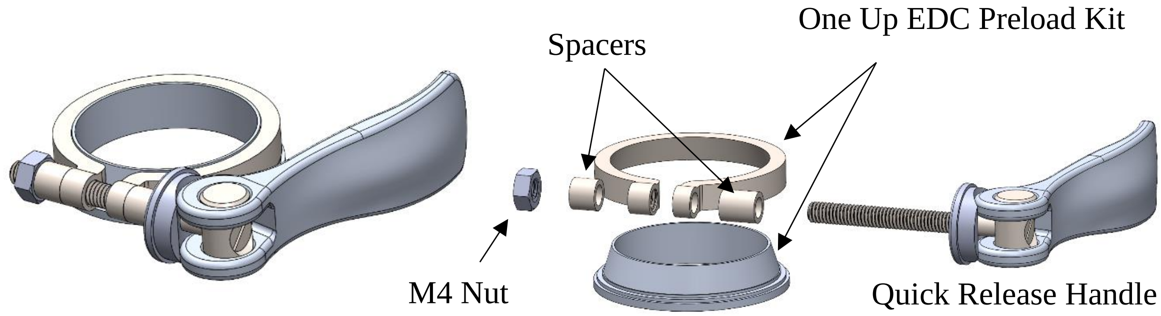


Figure 23: *Compressed and exploded views of preload assembly.*

Reducing the diameter of the outer ring pushes the inner ring axially in one direction and the outer ring in the opposite direction by moving the contact between the rings to a smaller diameter on the inner ring. This creates axial displacement and applies axial force to the top of the top bearing and the bottom of the stem, preloading the headset assembly. The M4 stud cam handle will be purchased from McMaster Carr. It will slide through the holes in the compressing ring and be retained by a nut. The cam profile creates a compression distance of 1.2 mm from the cam being fully open to fully closed. A handle angular displacement of 90˚ accomplishes this compression. The stud is made of steel. The handle is made of black, powder coated aluminum. A spacer is added between the compression ring holes and the washer on the cam handle so the cam handle can close properly and not contact the ring. The stack height of the compression ring and tapered ring is 8mm when not expanded and 10mm when expanded. Appendix I contains detailed drawings for the preload compression lock assembly and components in drawing numbers 1200 to 1260.

The OneUp expanding conical spacer has been proven in the market as able to provide headset preload and withstand the associated forces. It also has been tested on one of our group member's bikes without issue. The cam handle is rated for a clamping force of 550 pounds. This is far higher than the clamping force needed to compress the rings, calculated by relating the bolt's torque specification to the clamping force on the standard assembly. We do not have concerns for this assembly's functionality or load carrying capacity.

5.2 Top Cup Assembly Design and Analysis

The top headset cup assembly supports and allows angular adjustment to the steerer tube. The assembly allows the effective headtube angle to be changed by providing translational motion of the top bearing housing. Please refer to Appendix I for detail drawings of the top cup assembly and relevant parts drawing numbers 1100 to 1170.

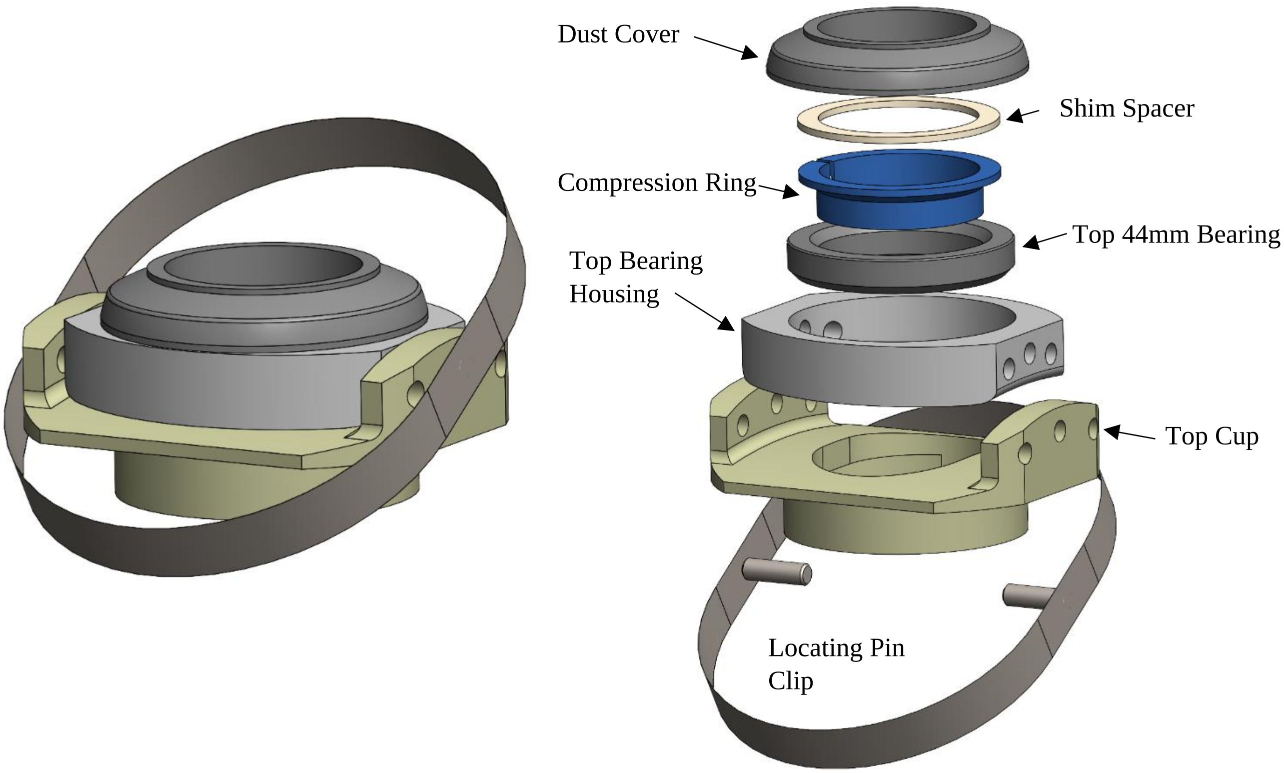


Figure 24: *Compressed and exploded views of top cup assembly.*

The bottom cylindrical portion of the top cup is press fit into the top of the headtube. The friction created by the interference fit will not allow the top cup to rotate within the headtube. The bearing housing slides on the curved top surface of the top headset cup which accounts for the radius of curvature as the steerer tube pivots. Different steerer tube angles are selected by aligning the holes on the top cup and bearing housing and putting pins through the holes on both sides. The pins are connected by a 3D printed component to a Velcro strap which is used to provide tension around the top cup and hold the pins in position during riding. The pins lock the top bearing housing in place. There are three adjustment settings. For steep, align the frontmost holes on the bearing housing with the frontmost holes on the top cup. For neutral, align the middle holes on the bearing housing with the middle holes on the top cup. For slack, align the rearmost holes on the bearing housing with the rearmost holes on the top cup. Three holes in each component are needed because the arc length the steerer tube makes at the top of the head length is about the same as the diameter of a hole. That would not allow for any material between the holes.

Both the top cup and bearing housing are made from 7075 aluminum alloy, the pins are 316 stainless-steel, and the band is a plastic Velcro (hook and loop) system. The bearing is purchased preassembled and sealed, being made from steel components. A dust cover, shim spacers, and compression ring sit atop the bearing. These components are standard parts for every headset. The dust cover keeps foreign objects from reaching the top bearing and raises the preload assembly enough to clear the top cup when the steerer tube is rotated within the headtube to steer. The compression ring fits in between the top bearing and the steerer tube and transfers loads from one to another. It holds the steerer tube tightly within the top bearing, keeping them concentric due to the conical shape. The shim spacer allows the dust cover's rubber gasket to be properly preloaded. All parts are purchased from Cane Creek and McMaster Carr except for the top cup, bearing holder and 3D printed components which are manufactured by the team.

Our analysis conducted includes testing for yielding in the material surrounding the pin holes, pin shear failure, and overall FEA for load carrying capacity. Our maximum loading case was defined as 6010 N of force at the top cup. Using a yield strength of 530 MPa for 7075 aluminum, and a hole diameter of 4 mm, our current design yielded a minimum cross-sectional area through the holes of 36.83 mm^2. This design yielded a factor of safety of 6.16. Using shear for a circular pin, yield strength of 669 MPa, a factor of safety of 2 was found for each pin at our maximum loading case for a total factor of safety of 4 for the pins shearing. The torque on the top cup pin hole uprights was modeled by calculating the moment created by the max load case at the pin hole transferred along the moment arm to the centerline of the cross-section. The maximum torque was 58Nm. Using a correlation torque on rectangular cross-section beams the maximum stress seen by one side is 100 MPa which corresponds to a factor of safety of 3. Overall FEA confirmed our design's load carrying capacity. Proposed testing during the testing stage in May will consist of testing the top bearing housing on an Instron tensile test machine to determine the maximum force the top bearing housing can withstand. Yielding at the pin holes is our largest safety concern, so we think it is important to test it most thoroughly.

5.3 Bottom Cup Assembly Design and Analysis

Figure 25: *Views of AngleSet bottom cup (left) and spherical gimbal (right).*

The bottom cup assembly is the steerer tube's pivot point. This pivoting is achieved by creating a spherical mating surface between the bottom headset cup and the bottom bearing housing. We purchased the spherical contact bottom cup from Cane Creek's AngleSet. The only difference between the custom assembly we would machine and this commercial assembly is the AngleSet's pivot point is non-concentric with the headtube. Its pivot center is 1mm offset from concentric. If used in the final design without modification to the top assembly, this cup would cause the range of adjustability to be from +2.5° to -1.5° or +1.5° to -2.5°. However, we could modify our top assembly design to accommodate the AngleSet.

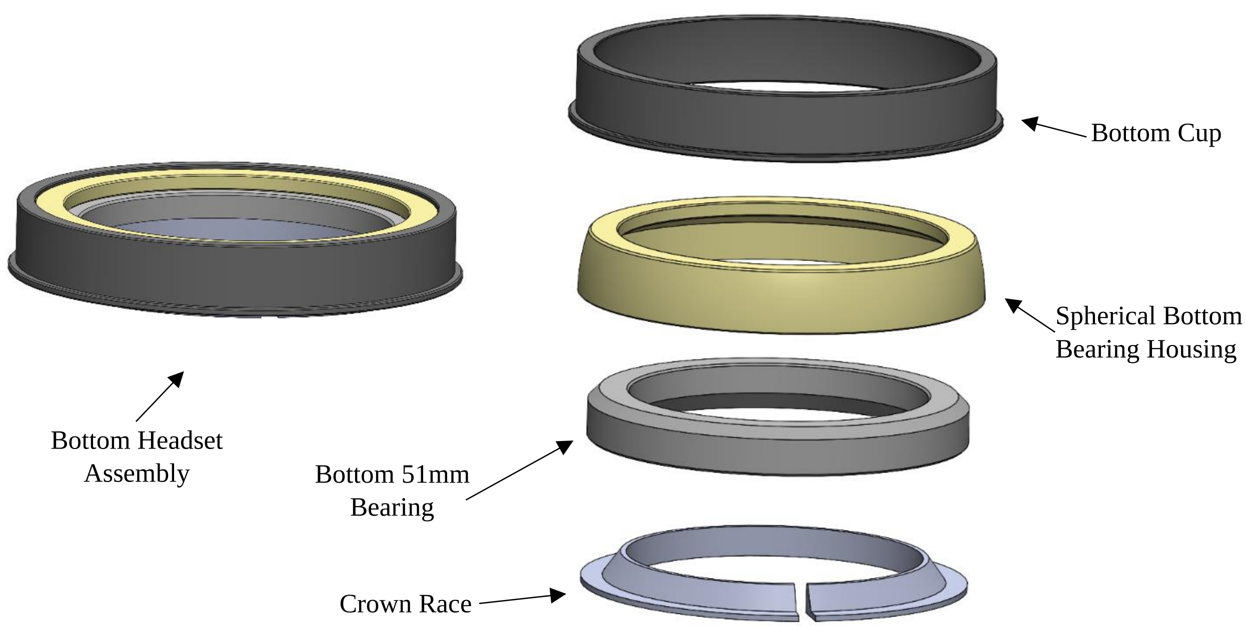


Figure 26: *Compressed and exploded views of the bottom headset cup assembly.*

If the AngleSet does not work for our design, we will manufacture the bottom cup from stock material and still use the spherical bearing housing purchased from Cane Creek. The custom-made bottom cup will hold the pivot concentrically and would provide an adjustability of 2 degrees each way from neutral. The upper cylindrical portion of the bottom cup fits into the bottom of the headtube with a slight interference press fit which keeps it from rotating within the headtube. The spherical mating surface is modeled with a radius of 27.2 mm. Detailed drawings can be found in Appendix I. Drawing numbers from 1300 to 1340 correspond to the bottom cup assembly.

Before we planned to purchase the AngleSet, we created FEA models to investigate how different bottom cup designs would handle our maximum loading case. Standard bottom headset bearings have an outside diameter of 52mm. The internal diameter of a tapered headtube is 56mm. Housing the spherical bottom bearing housing within the headtube necessitates thin walls for both the cup and housing. Dropping the spherical contact surfaces below the headtube to provide room for thicker walls removes the lateral support provided by the headtube. These designs are shown below in Figure 27.

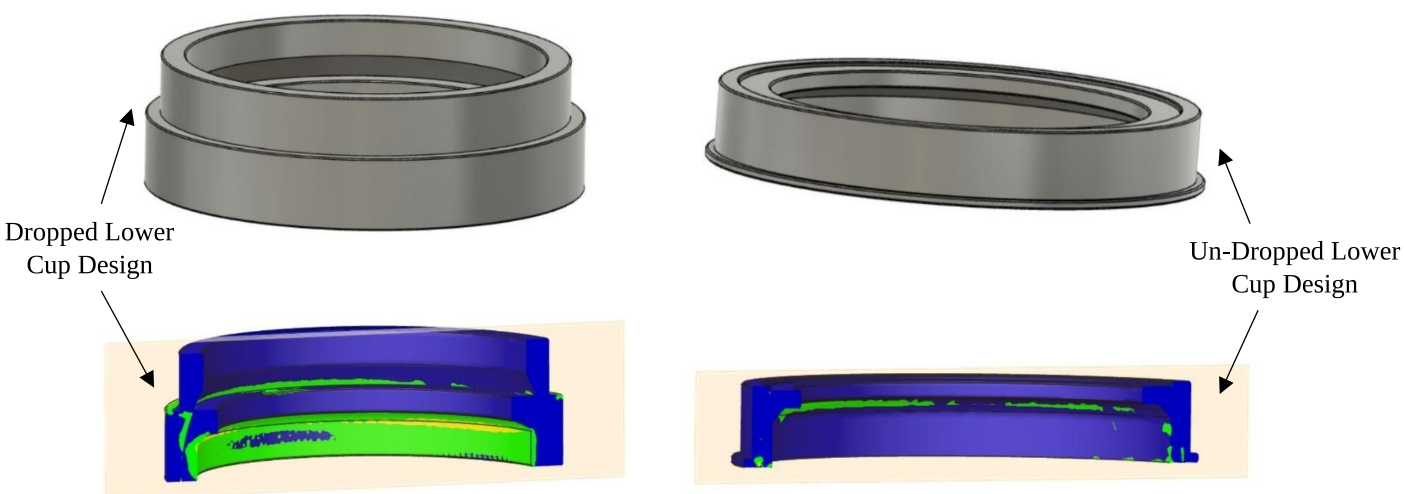


Figure 27: *FEA comparison of bottom headset assembly designs.*

The headset cup that held the bearing within the headtube, show on the right, had higher factors of safety than the design that dropped the bearing housing. The dropped bearing housing could not withstand the lateral loads as well without the headtube's support. If we machine our own bottom headset cup and bearing housing, we will house the bearing housing within the headtube. To improve this design further, we sourced a bottom headset bearing with a 51mm outer diameter. This allows for an extra millimeter of material to be used, strengthening the design. We designed our lower headset assembly to a factor of safety of 2 per industry standards. This factor of safety assumes our loading case described in Section 5.5.

5.4 Full Assembly and Functionality

Our final design allows the steerer tube angle to be adjusted relative to the frame quickly and without tools. Refer to drawing E1000 of Appendix I for a complete labeled exploded full assembly drawing.

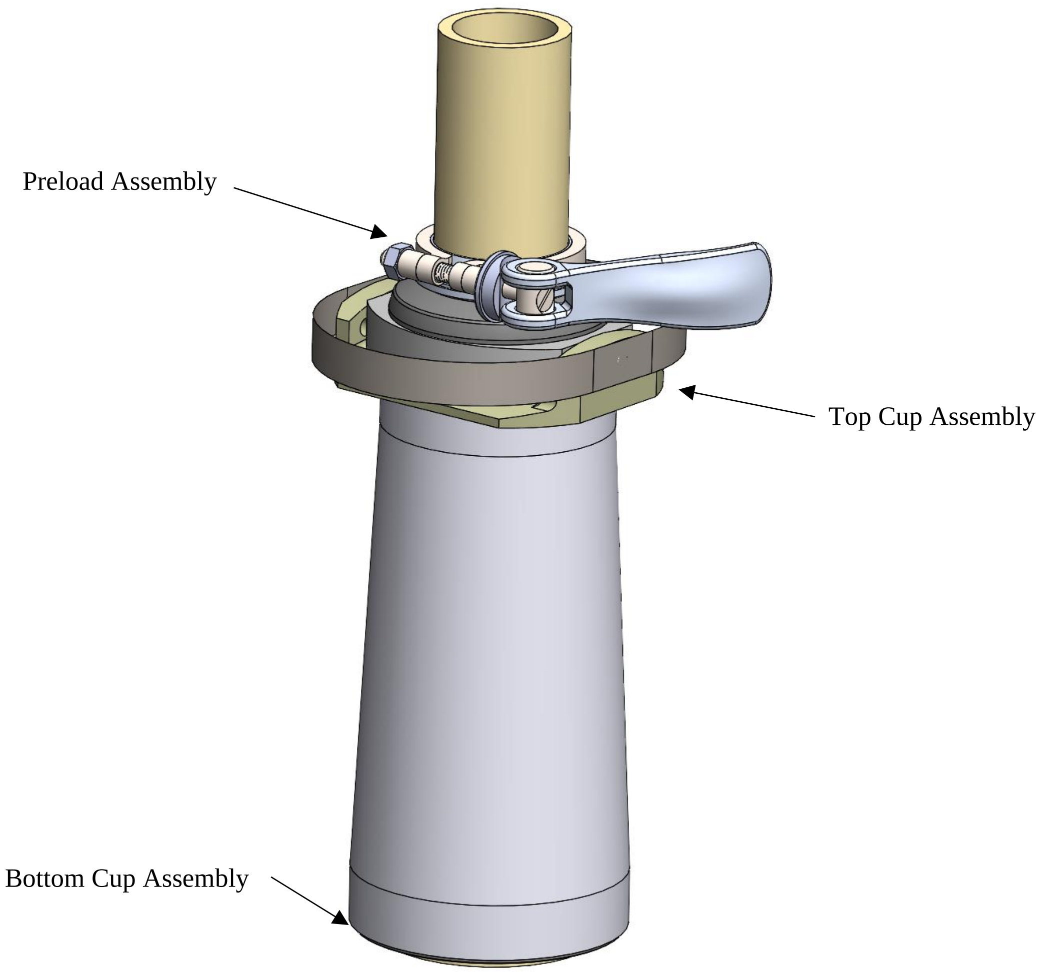


Figure 28: *Complete headset installed in a headtube.*

Beginning from a setup where all components are locked down and no adjustment is possible, the user removes the preload by opening the quick release handle on the preload assembly. This relieves the pressure on the top bearing housing, allowing it to be adjusted. Removing the pins fully from their holes allows the top bearing housing to slide forwards or backwards on top of the top cup. This movement is constrained to one plane by the upright features on either side of the top cup that the pin holes pass through. A position is selected by aligning the desired holes as defined in Section 5.2. The pins are inserted in the holes that align and the quick release cam handle is closed. This preloads the assembly and makes it ready to ride. Some adjustment of the quick release nut may be necessary to fine-tune the preload.

Our headset is designed to provide ±2˚ of adjustment from the stock headtube angle. A SolidWorks simulation for our adjustment angle is shown below in Figure 29.

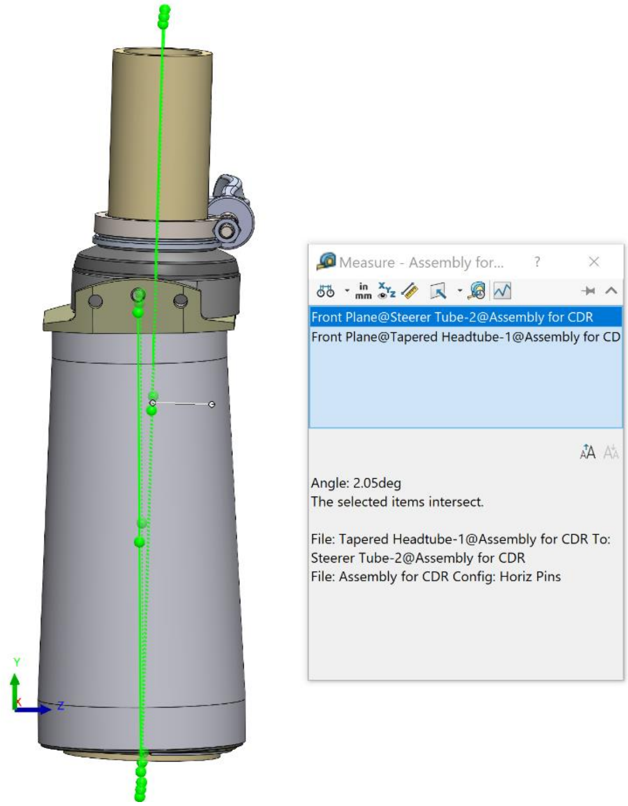
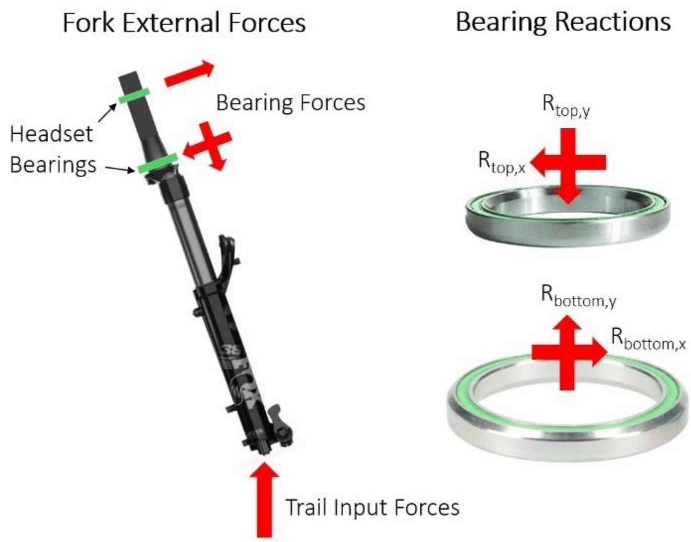


Figure 29: *View of measured angle offset.*

As shown by the measurement box in Figure 29, an angle of 2.05 degrees is reached when the slack position is aligned. The same angle is reached in the steep position. Following this measurement, components were hidden to be sure the steer tube did not contact the top cup or any other component that could possibly hinder its rotation to 2.05 degrees. No contact was made, and our design was verified.

5.5 Loading Case

To define our loading case, we needed to find a value for the forces experienced by the fork's axle. A Stanford study performed by Hull found a maximum load of 1900N normal to the ground when riding aggressively on a mountain bike with a suspension fork. We applied this value to a free body diagram of the most aggressive bike geometry we anticipate the headset being used for. Geometry examples include the longest axle-to-crown measurement of any modern single-crown fork, the slackest headtube angle, and shortest headtube. We also incorporated a maximum braking case into our analysis. These hand calculations can be found in Appendix K. A summary loading diagram is shown below in Figure 30.



Results

Reaction Force	Magnitude (N)
$R_{top,x}$	3771
$R_{top,y}$	1556
$R_{bottom,x}$	4663
$R_{bottom,y}$	1812

Figure 30: *Loading case summary diagram.*

Because the headset geometry allows the angular contact bearings to carry axial load in one direction, all the trail input forces' axial components are carried by the bottom bearing. Similarly, all the rider input forces' axial components from the handlebars are carried by the top bearing. The bearing reaction forces are crucial in our design because all of the forces from the fork are translated to the frame through the bearings.

We found that braking reduced the radial bearing loads but increased the axial bearing loads. We took the maximum axial and radial loads from each to define our loading case. We recognize that actual loading may be higher than we calculated, but we are confident that we have a safe starting point. As riding is such a variable that cannot be controlled in a broad user context, we controlled our testing to gradually increase aggressivity. We also used a top bearing loading test to analyze the effect of high loading on the top bearing housing, discussed in our Testing Section.

5.6 Structural Prototype

For our structural prototype, we 3D printed several of our design's main components out of ABS so that we could mock-up the assembly to check for fitment. We would also gain insight into components we might need to resize to fit within a reasonable stack height or human factors related issues.

Figure 31. *Assorted 3D printed parts as the structural prototype.*

Parts 3D printed include the bottom cup, spherical bearing housing, top cup, top bearing housing, and locating pin clip (Figure 31). These parts paired with existing parts within a stock headset assembly, such as top and bottom bearings, shims, and a purchased One-Up expanding conical spacer complete the required parts to model most of our design's functionality.

Figure 32: *Structural prototype installed on bike.*

From our structural prototype, we learned our designed parts integrated well with the existing headtube and steerer tube (Figure 32). The components successfully allowed the effective headtube angle to be adjusted. Without the purchased spherical bottom cup assembly, we are not yet able to report if the steerer tube reaches two degrees of angular rotation in each direction. However, we are confident that we will reach our design target of ±2˚.

5.7 Final Design Updates

Following prototyping and testing, the team decided to move away from the metal retention band for the pins. Prototypes turned out to not allow for enough springiness and making the band large enough to not permanently deform in use made the band very large and intruding on the rider’s space as well as an eyesore. Through efficient ideation, we came up with a design to implement a Velcro system where the pins are connected to a Velcro strap by a 3D printed plastic connector. The pins are inserted into the top cup and then the Velcro strap tightened and overlapped to provide a tension and hold the pins in the top cup during riding. We are confident in this design as Velcro is already used greatly in the mountain biking industry as an attachment method from saddle bags to shoes. The 3D printed attachment design is pictured in Figure 33. See drawing number 1141 in Appendix I for the detailed drawing of this component.

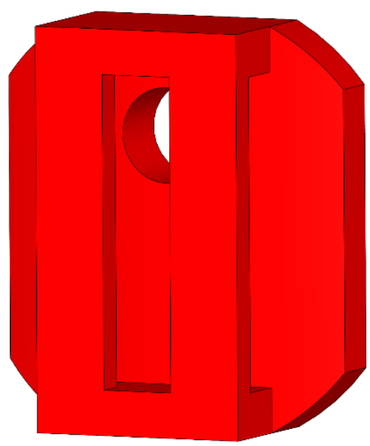


Figure 33: *3D Printed Pin Attachment Component.*

The pin will be fixed into the hole of the 3D printed component by a bonding element or by heating the pin and inserting to melt the plastic to it and hold the pin. The Velcro will be guided under the bridges seen in the front of the component and Velcro will loop one bridge to hold it and allow tension to be created.

A slight change has been made to the overall footprint of the top bearing housing. To make machining more efficient, the curved sides have been replaced by several straight sides at different angles to make a hexagon. This shape is much quicker to machine and stronger with a slight increase in weight. See drawing number 1120 in Appendix I for the detailed drawing of this component. Figure 34 depicts the new top bearing housing.

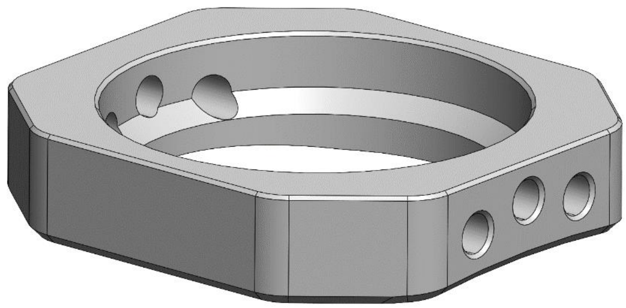


Figure 34: *New Top Bearing Housing Design*

Another slight change has also been made to the top cup where the rails on the ends have been extended slightly and kept flat on top instead of curved. This makes machining more efficient. More chamfers and fillets have also been added to decrease the sharpness of edges and improve the safety for riders. Figure 35 depicts the new top cup design while a detailed drawing is found in drawing 1110 in Appendix I.

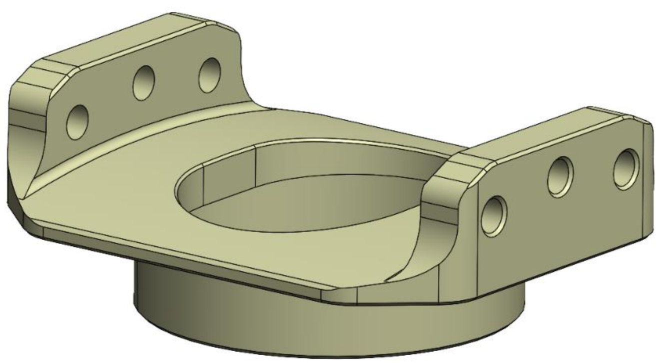


Figure 35: *Verification Prototype Top Cup Design*

Finally, we determined by availability and a definite increase in strength, to manufacture the bottom cup and spherical bearing holder from steel rather than aluminum. First, due to incorrect labelling on their website, the cane creek bottom cup will not work for our design as it is made for a straight steerer tube. Therefore, we determined to move forward with manufacturing a bottom cup and spherical bearing holder in house and made for the 51 mm bearing so we could design with more wall thickness to this assembly compared to a 52 mm bearing design. Plentiful steel stock was available for manufacturing of this bottom assembly, and compared to aluminum, steel provides more strength with a small increase in weight. This weight increase is acceptable because the steel provides more confidence to the rider that the bottom assembly will not fail and increases the factor of safety which the team believes is the best choice.

Figure 36 displays the current final assembly CAD of our design and reflects the parts that will now be manufactured.

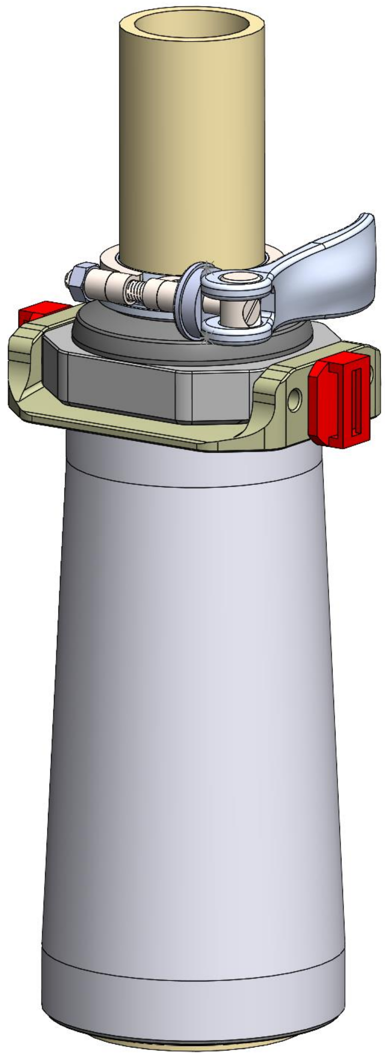


Figure 36: *Assembly CAD going into manufacturing of verification prototype.*

5.8 Design Specification Testing

We were able to confirm that our design will meet many of our design specifications by testing the structural prototype. We confirmed that our 20 second adjustment time is possible with the current design by timing the adjustment procedure. We confirmed that our design will not require any tools to adjust once we implement the cam handle clamping mechanism. We were able to see the design installed on a real bike which allowed for aesthetic comparisons to be made to standard headsets. While certainly larger and more obtrusive than a standard headset, we do not believe our design to be an eyesore. We are content with our resemblance to a normal headset and will only improve the aesthetics in the future. While we did not accurately measure our range of adjustment, we were able to confirm that our desired ±2˚ of adjustment is certainly attainable. A low-fidelity angle finding application on a smart phone told us that we were within our target range. Visually, the steerer tube angle moved more than we expected it to. Finally, we were able to confirm that our headset did not impede the handlebars' rotation.

By summing the listed weights of our purchased parts and CAD-generated weights of our custom parts, we were able to confirm that our design will weigh less than 250 grams with an estimated weight of 192 grams. Our toolpath simulations for the CNC machined parts confirmed that our parts are manufacturable. Our cost analysis confirmed that we will complete our project underbudget. Our analysis also confirmed that our headset will withstand the loads we predict it encountering.

The rest of our design specifications cannot be tested by our 3D printed components. We need to manufacture and test components before we can verify the test riding and maintenance specifications.

5.9 Safety, Maintenance and Repair Considerations

Throughout the design process, safety was our top priority. The team investigated the possible modes of failure through the completion of Failure Modes and Effects Analysis (Appendix L) as well as a Design Hazard Checklist (Appendix M). Possible risks were also assessed in Appendix N. We focused on the most important aspects in the following sections.

The first consideration is the quick release preload which has been designed with speed-of-adjustment in mind. If this quick release were to be caught during riding, or released by hand, or failed in some other way while the user is on the bike, the preload would be lost but no catastrophic failure would result. The top bearing would become unloaded axially without the preload, and the steerer tube may knock or wobble because some small gaps would open between the bearing, bearing housing, and top cup. The locating pins would still hold the steerer tube in its indicated position. Minimal damage would be possible, and the rider would have to dismount and reapply the preload before continuing riding. The stem and top cap would still be fully tightened and there would be no possibility of the steerer tube falling out of the headtube.

The most likely failure we believe might appear is of the pin holes on the top bearing housing. If failure occurs at the top bearing housing, the top of the steerer tube will no longer be constrained forwards and backwards, so the steerer tube would slop to the slackest position and rest against the top headset cup. Still, the stem and top cap are secured, so there is no risk of the steerer tube falling out of the frame. The steerer tube would no longer be held in a fixed position, and the steerer tube would be contacting the top cup directly rather than through the top bearing. Steering would still be possible, but effort required to steer may increase. This would be immediately noticeable to the rider, who would immediately stop riding.

A third failure would be created by the bottom cup not having enough material to withstand an axial force through the fork. The bottom spherical bearing housing would pass through the bottom cup. The fork crown could contact the bottom of the headtube and bind, preload would be lost. The distance between the fork crown and bottom of the headtube is very small even when assembled correctly and the movement of the headtube to contact the fork crown would take place over a very small distance. The fork crown would rest on the headtube, and the angular position at the top of the headtube would not be affected and will stay in position. A new bottom cup would be required.

Edges were rounded or chamfered to reduce the risk of scraping in a fall. Impairment to the rider's field of vision is negligible. The top headset cup extends 5mm beyond a standard headtube and is in the same area blocked by the front forks and fork crown anyway.

Maintenance other than that of a normal headset (closing/opening quick release, removing/replacing pins, and sliding top bearing housing to different positions) will be limited because the bearings and interior crevices will be protected by dust covers. A slight amount of grease will be applied to contacting surfaces, and this will attract some dust. A quick reapplication of fresh grease after wiping off the old will solve this. However, riding in extreme conditions of rain, mud and other weather which would increase the ingression of contaminants into the assembly will increase the frequency of required maintenance.

The risk assessment exercise determined the correct warnings and notes, as well as the correct methods for use and assembly as described in the User Manual (Appendix O.)

Our design is modular and inexpensive enough that repairing any component will not be sensible. If a component requires repair, the user will purchase or machine a new part.

5.10 Cost Analysis and Procurement

All our components, except for the top headset cup, bearing housing, bottom cup, and spherical bearing housing, will be purchased with minimal modifications required. The only local purchases we will make will be from Ace Hardware. We will purchase nuts and other small parts, if needed, from them. The rest of the purchases will be made online through the senior project purchasing process.

We will use Cane Creek headset components for every cross-compatible part between our headset and their standard options. We receive a large Cane Creek discount through Cal Poly Bike Builders, making purchasing through them the cheapest option for quality components.

We will purchase our cam handle, pins, stud spacers, and metal for the retention band from McMaster Carr. Their cam handles suit our compression assembly well by providing an M4 threaded stud to clamp on. They are priced similarly to other sources, but McMaster provides far more technical documentation. This documentation caused us to buy the pins and spacers from them as well. The selection of dimensions, materials, and other options makes McMaster a smart choice. The Velcro band was purchased through Amazon.com while the plastic pin connector pieces were 3D printed in Cal Poly's Mustang 60 shop with donated plastic from the shop.

Using 7075 aluminum is not ideal for our budget but is necessary for our design purposes. We chose to use Buymetal.com for obtaining our 7075 aluminum stock because of their pricing and available stock sizes. We want either 3” x 3” square stock or 1.25” x 3” rectangular stock to minimize wasted material. The minimum stock length most vendors will sell is 12”. Buymetal.com offers half the price per cubic inch as competitors, but with a $25 flat rate shipping fee. After estimating how much stock we will use for our senior project, we decided upon 12” of 3” x 3” square 7075 aluminum stock.

We are not including machine shop costs in our analysis because we believe we can machine our parts ourselves using existing tooling. Outside of a senior project, the labor, software, and machine access would be incredibly expensive. We are lucky enough to have access through Cal Poly, so the only cost is our time.

Looking at cost as marginal per additional headset manufactured, the cost of each headset will be roughly $180. We believe this is more likely to be an overestimate than an underestimate because we are being conservative with our predicted shipping costs. The total project cost will be higher than this if we only manufacture one headset because the 7075 aluminum stock is a sunk cost. A summary of each component’s cost is shown below in Table 4.

Table 4. *Component Cost Summary.*

Subassembly	Component	Cost	Source
Top Headset Cup Assembly	Top Headset Cup	$12.00	Custom Machined
	Top Bearing Housing	$6.00	Custom Machined
	Top Bearing	$10.50	Cane Creek
	Compression Ring	$5.00	Cane Creek
	Shim Spacers	$3.00	Cane Creek
	Dust Cover	$14.00	Cane Creek
Locating Pin Clip	Pins	$1.00	McMaster Carr
	Velcro Band	$5.00	Amazon.com
Compression Assembly	OneUp Conical Spacer	$25.00	Backcountry
	Cam Handle	$13.58	McMaster Carr
	Stud Spacers	$4.50	McMaster Carr
	Nut	$0.20	Ace Hardware
Bottom Headset Cup Assembly	Bottom Headset Cup	$29.00	Cane Creek
	Bottom Bearing Housing	$16.00	Cane Creek
	Bottom Bearing	$18.00	Cane Creek
	Crown Race	$12.00	Cane Creek

This table shows the cost of each component in our headset. The prices shown include predicted shipping costs. Prices for the top headset cup and top bearing housing were calculated by dividing the total stock price according to how much stock is predicted to be used in machining the component.

6. Manufacturing

We used a blend of off-the-shelf, custom machined, and modified purchased components. We used as many off-the-shelf components as possible to simplify the design and manufacturing process. Our custom machined components were necessary because no product, or assembly of products, exist that would meet our design specifications.

The final cost of our project came out to $327.32 which is well under our budget of $700. Meanwhile the cost we applied for one full assembly was $131.53. The low cost for each assembly as well as the entire project was possible with a great deal of donated stock for the entire testing fixture and the bottom cup assembly from Cal Poly Bike Builders. Table 5 gives a concise breakdown of these costs. A full budget is available in Appendix J.

Table 5. *Budget summary*.

Cost for one full assembly	$131.53
Total cost of project including leftover materials	$327.32

6.1 Custom or Modified Components

We will describe how each custom part was machined and how each modified component was changed. Components that did not require modification appear in the assembly/installation section.

6.1.1 Top Cup

Manufacturing the top cup started with squaring a piece of stock AL 7075-T351, acquired from BuyMetal.com, cut off with the horizontal bandsaw from a larger billet, sized to 3” x 3” x 1.25”. The cut piece was squared and sized on a manual mill. We utilized a 3-axis CNC mill, Haas VF2 with squared vise, to complete all machining for the top cup. Beginning with the top side of the cup roughing and finishing all surfaces and exterior profile. The depth from the top of the cup was to just below the ledge of the top cup, mating surface with the head tube, so the next operation would mesh smoothly without any cutting lines. The finished roughing part is shown in Figure 37, below. The slot for the steer tube was cut along with a central bore, not specific to the final part, that was used as a datum to reference the x-y position for the second operation, the bottom half. We used the top of the milled surface, top of the shoulders which house the pin holes, as the z datum for the bottom operation. To complete the top cup, the pin holes on each side were drilled and reamed. Since the part was symmetric, this was programmed as a single operation, with the part just being flipped over and run again. The benefit of our rectangular design allowed for referenceable features which do not require the use of soft jaws throughout our manufacturing process. This was taken advantage of by using the opposing sides as the z datum and the top of the shoulders as the y datum, the x datum was then measured off the edge of the shoulder as a midline datum. Due to the shoulder’s protrusion, this creates a bridge feature that is not capable of applying proper torque to grip the part. To rectify this, a soft block of wood was placed between the shoulders contacting the curved surface allowing a direct load transfer through the bottom cylindrical feature of the part.

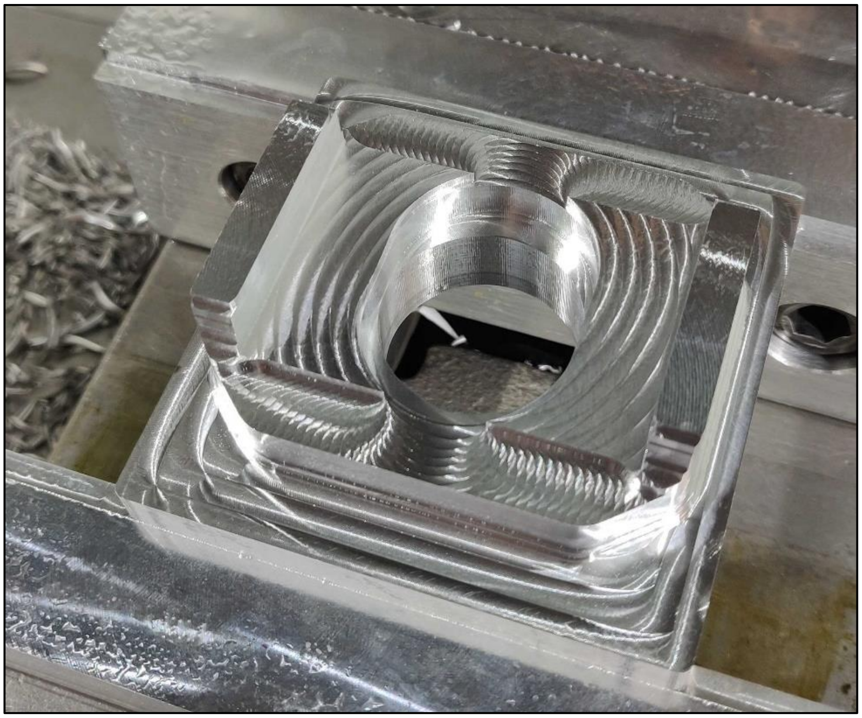


Figure 37: *Top cup after first operation.*

6.1.2 Top Bearing Housing

The top bearing housing was a 3-axis CNC part comprising of 4 operations not including soft-jaw manufacturing. Primarily, stock machining to square part and face edges occurred after stock was cut from billet AL 7075-T351, acquired from BuyMetal.com, done on the CNC mill. The next operation started with machining the bottom of the top bearing house. Exterior contour of the housing, then the concave 3D surface machining. The bore for the steer tube was machined, then the part was removed and flipped over. The part's exterior profile had 2 opposing parallel faces which grabbed the machined bottom of the part. Exterior profile of the top half. Then the bore for the bearing seat was machined. The next operation was to drill the pin holes on each side of the part; due to the parallel faces of the top and bottom and side to side, we had referenceable features to hold the part. Utilizing the side as the bottom reference, we drilled the opposing side pin holes, then repeated on the opposite side. Figure 38 shows the completed top bearing housings.

Figure 38: *Completed top bearing housings.*

We machined extra top bearing housings for load testing to have numerous test samples to apply different load cases to.

6.1.3 Pins and Pin-Retention System

The pins and pin-retention system comprise of two stainless steel pins that were ordered to diameter stock, then trimmed to designed length via hacksaw and sanding square. The Velcro, purchased from Amazon.com, was trimmed to length and one end was looped thru the bridges of the 3D printed components. The Velcro was wrapped around the top cup and over itself, securing the pins into the top cup. The pins were connected to the plastic components by heating the pins to melt the plastic around it as it was inserted into the hole. The new system is pictured in Figure 39.

Figure 39: *Pin retention system installed on the headset.*

6.1.4 Compression Assembly

The compression assembly consisted of the OneUp EDC preload kit conical spacer, a McMaster- Carr cam handle, nut, and some spacers. This assembly is shown in Figure 40.

Figure 40: *Compression assembly.*

The threads on the conical spacer's compression ring were drilled out so the cam handle's passes through both ends of the compression ring smoothly. We used a drill press with a 4mm drill bit to drill the threads out. A 7mm spacer was placed between the ring and cam handle base for clearance. We slid the 7mm spacer onto the cam handle stud, slid the stud through the conical spacer's holes, slid 4mm of spacers on the stud, and finally threaded a nut onto the remaining stud. To fine tune spacing for a certain stem, a few washers can be added on either end of the bolt providing clearance for the cam-washer.

6.1.5 Bottom Bearing Housing

This component required CNC machining because of its external spherical surface. For our verification prototype, we machined the bottom bearing housing from steel due to stock availability. We used a Haas TL-1 lathe, shown in Figure 41 below.

Figure 41: *Haas TL-1 lathe.*

We began by facing the stock, donated to the project by the Cal Poly Bike Builders Club. Next, we drilled a 1” hole to create clearance for the boring bar. Next, we used the boring bar to create the bearing seat profile. We used a grooving tool to rough the external spherical profile and a left-handed toolholder to finish the spherical profile. The finished bottom bearing housing is shown below in Figure 42.

Figure 42: *Bottom bearing housing and its bearing.*

We machined the bottom bearing housing to accept a 51mm bearing to provide more wall thickness, but upon inspection and testing, we could change our design to accept a more common 52mm bearing.

6.1.6 Bottom Cup

This component required CNC machining because of its external spherical surface. For our verification prototype, we machined the bottom bearing housing from steel due to stock availability. Same as for the bottom bearing housing, we used a Haas TL-1 lathe.

We began by facing the stock, also donated to the project by the Cal Poly Bike Builders Club. Next, we used a grooving tool to profile the exterior press-fit interface and lip. We then drilled a 1” hole to create clearance for the boring bar and used a boring bar to profile the internal spherical surface. The finished bottom cup is shown below in Figure 43.

Figure 43: *Bottom headset cup.*

The fit between the bottom cup and bottom bearing housing was nearly perfect. Because tool marks are made along the parts’ circumferences, they required polishing to reduce sliding friction. We polished the mating surfaces in a vertical direction to create the least friction possible.

6.1.7 Top Bearing Housing Test Fixture

The test fixture was designed to interface with the Instron tensile test machine in the Cal Poly composites laboratory. It has two steel yokes that were clamped by the Instron. One yoke supported the top bearing housing by simulating the top bearing and the other yoke simulated the pins and top headset cup. Each yoke was machined on a mill according to the engineering drawings in Appendix I, drawings 2100-2200. All stock for this fixture was donated to the project by the Cal Poly Bike Builders Club. For the top yoke, a tab was welded on the yoke which is gripped by the Instron machine. Considerations to welding skew were adjusted with heat and manual force. The bottom piece was machined from a solid piece of stock with a CNC mill to achieve surface finish and required positional tolerances. The upper yoke was machined on a manual mill by squaring the sides and then milling the material between the two arms. The lower yoke was first squared on a manual mill then a 3 Axis CNC mill was used to create the circular impression which holds the mock bearing. The mock headset bearing was turned on a manual lathe; one for the slack or steep position and one for the neutral position. The yoke pins were turned from a steel dowel. These pins have bigger radii on the outer ends, and a groove for a locating clip inside the yoke so the pins cannot move relative to the yoke. These lathe parts will also be machined per engineering drawings previously described. The bolt, nut, and washer will be purchased locally from Ace Hardware. The CAD is pictured in Figure 44.

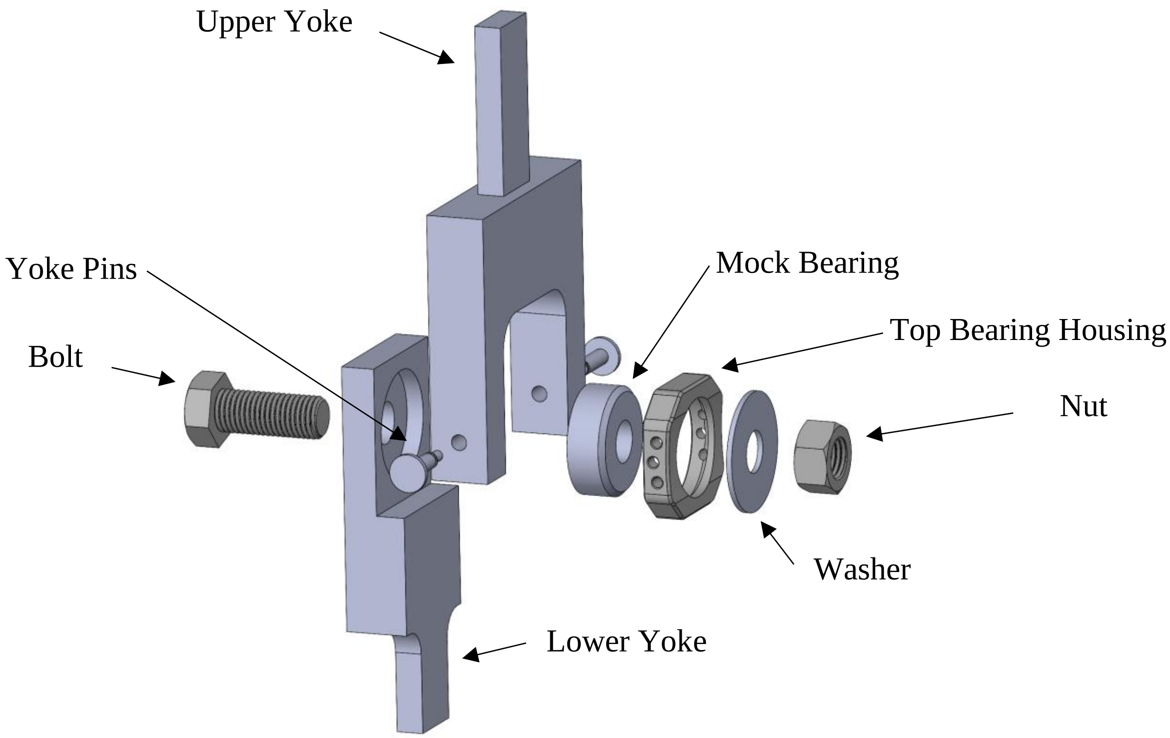


Figure 44: *Top bearing housing test fixture exploded view.*

To assemble the test fixture, the bolt was inserted into the yoke's hole and the mock bearing, top bearing housing, washer, and nut were placed on the bolt. Next, the other yoke was placed around the top bearing housing. The pins were be pushed into the test fixture and into the top bearing housing's holes and held in place by c clips. The complete assembly is shown below in Figure 45.

Figure 45: *Assembled bearing housing test fixture.*

The yoke tangs on the ends of the assembly were inserted into the Instron's grips. The grips were tightened, and the test was performed.

6.2 Assembly and Installation

While many of our components did not require modification, they still required correct installation onto a bike to function correctly. The following paragraphs describe how we installed our headset onto a bike.

All prior headset components were removed from the bike before installing our headset. The first step in installing the adjustable headtube angle headset onto a bike was pressing the headset cups into the frame. We pressed the bottom headset cup into the frame as described in the headset press' instructions. Next, the top headset cup was aligned so that the steerer tube slot and pin hole tabs were parallel with the bike's centerline. The top headset cup was then pressed into the frame as described in the headset press' instructions, as shown below in Figure 46.

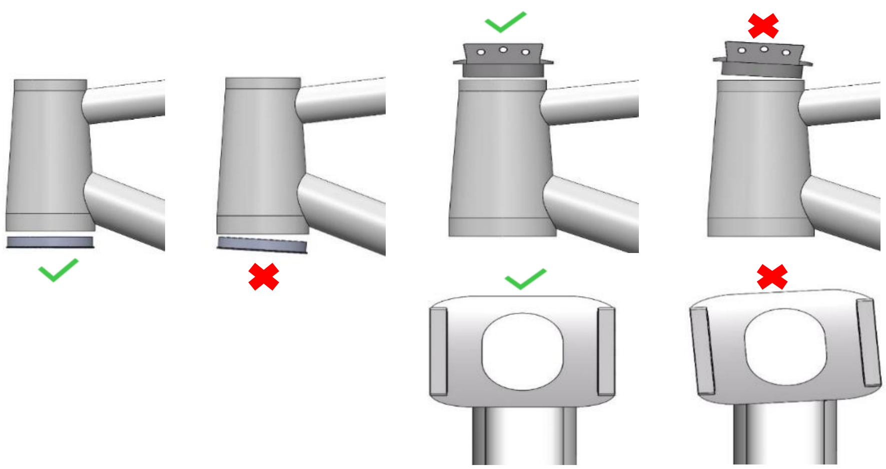


Figure 46: *Headset cup installation diagram.*

Next the crown race was placed on the fork. A thin layer of grease was applied onto the crown race. The bottom headset bearing was placed on the crown race with a thin layer of grease applied to the bearing's outer diameter and beveled edge. The bottom bearing housing was fitted on the bearing with more grease on the bottom bearing housing's exposed spherical surface. We slid the fork's steerer tube into the bike's headtube, making sure that the bearing housing was seated within the bottom headset cup, as shown below in Figure 47.

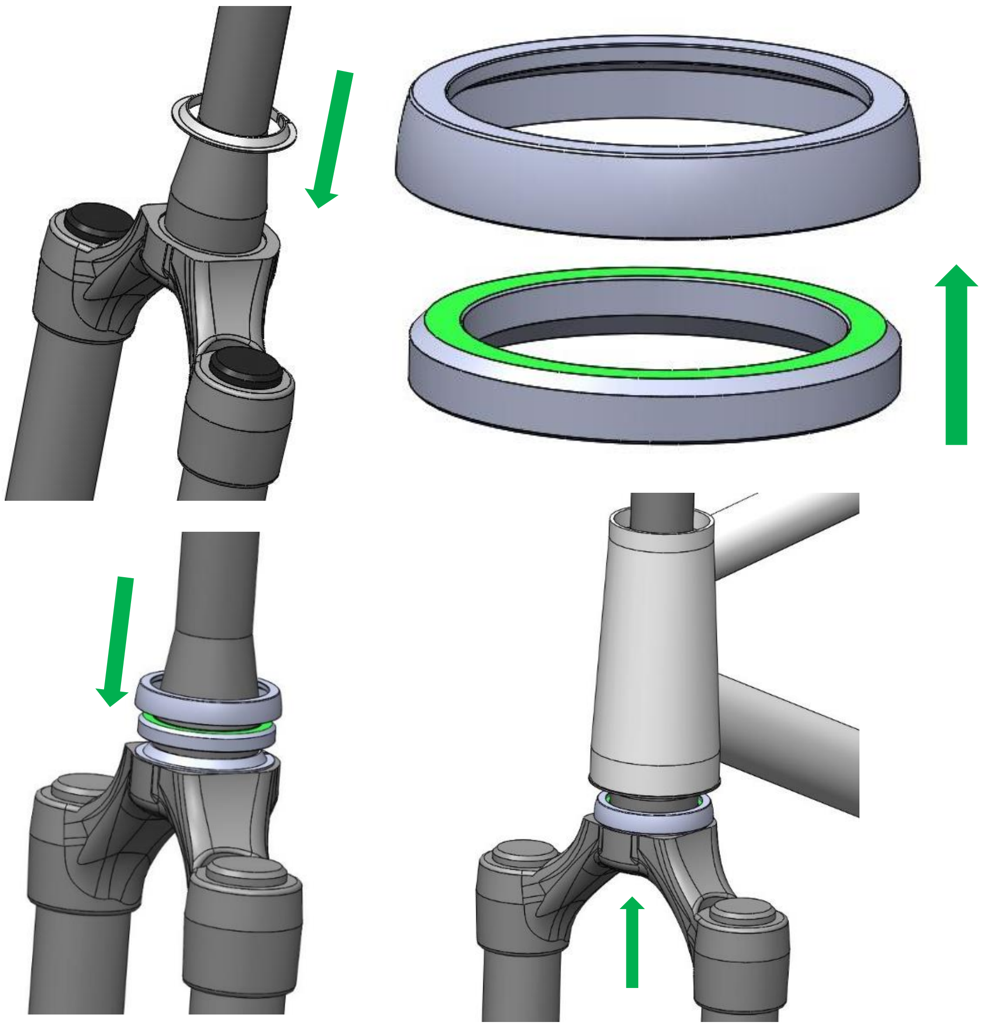


Figure 47: *Bottom cup assembly installation diagram.*

A thin layer of grease was applied to the top bearing housing's curved bottom surface and bearing seat. The top bearing housing was slid onto the steerer tube, ensuring the pin hole tabs were aligned with and held between the top headset cup's tabs. The top headset bearing was placed into the top bearing housing after applying a thin layer of grease to the inside and outside races of the bearing. With a thin layer of grease to the compression ring's outer surface, it was placed on the bearing's beveled edge. The dust cover was then set on the compression ring.

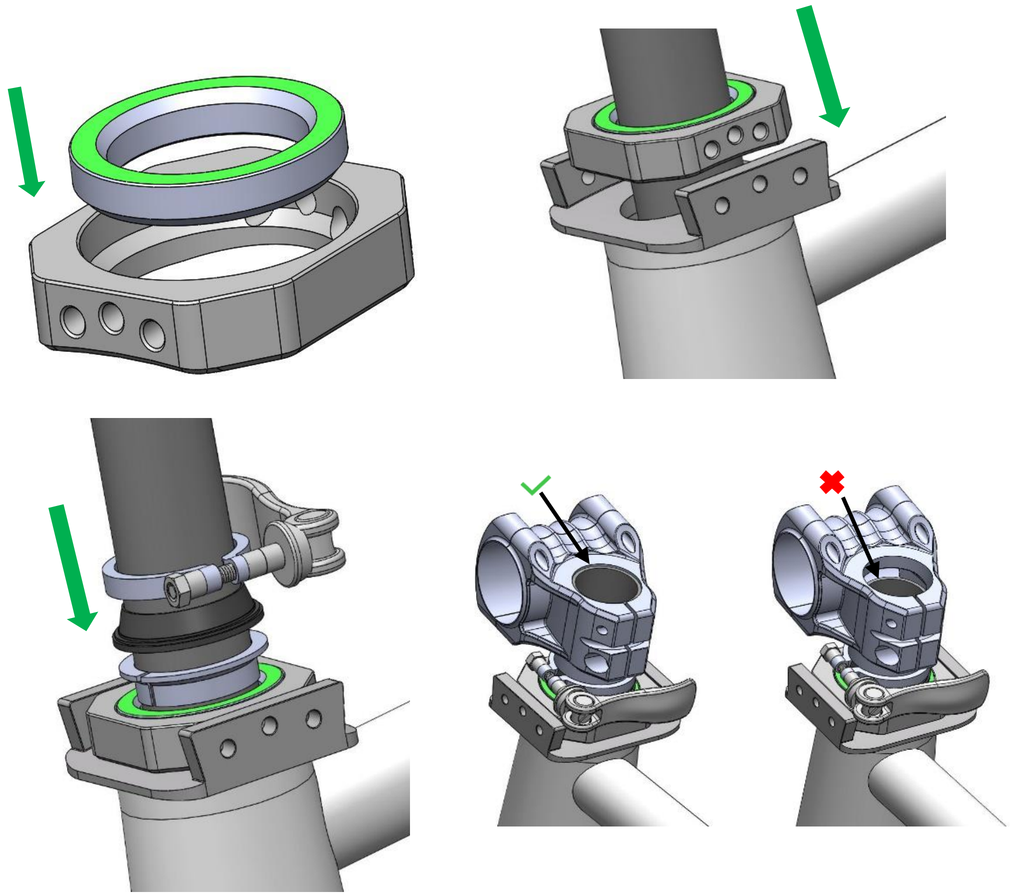


Figure 48: *Top cup assembly installation diagram.*

We ensured the nut on the cam handle's stud was loose when the handle was in the clamped position and slid the compression assembly on top of the dust cover. The black conical ring was placed on first with the silver ring and attached cam handle sitting on top. With the cam handle still in the clamped position, the nut was threaded on the cam handle's stud until it contacted the spacer. The nut was used to remove the stud's free play, but not tighten the ring. The correct sized spacers were then added to provide adequate seating of the stem and the stem was then assembled on the steer tubes with the top cap securing the entire assembly. These steps are shown above in Figure 48.

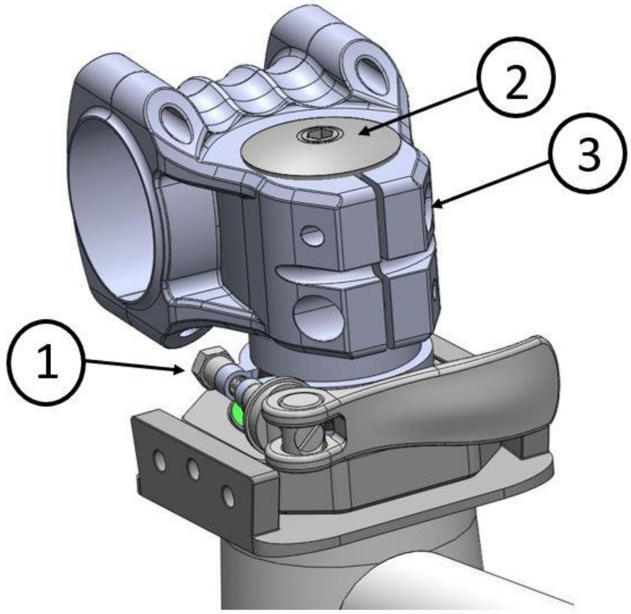


Figure 49: *Tightening order for headset assembly.*

The top cap bolt was tightened into the steerer tube until it contacted the top cap. Tightening was stopped when play was just barely removed from the assembly, but not yet preloaded. The stem was aligned in its final position and the stem bolts tightened to the manufacturer's torque specifications. The order is shown in Figure 49.

The Velcro was undone to allow slack to insert the pins. The pins were aligned with the holes on the top headset cup and then the Velcro tightened and applied to itself so it held slight tension and kept the pins inserted fully. The top bearing housing was aligned so the pins passed through the top bearing housing's holes and locked the steerer tube into place.

The cam handle's lever was pulled to the unclamped position and the nut turned a full turned clockwise to tighten it. The cam handle was then closed so all play was removed from the assembly and it was properly preloaded. In the case of play in the assembly, we opened the cam handle's lever and tightened the nut another turn until there is no play when the cam handle is closed.

6.3 Adjusting the Headset

These instructions describe how the headset was adjusted once it was already installed on the bike. The user dismounted from the bike or straddled the top tube. Once all body weight was removed from the bike, the cam handle's lever was opened to the unclamped position. The Velcro strap was released and the pins were pulled from the assembly. At some times, the user needed to lift the frame, relieving the binding forces created by the bike's weight. The pins were removed from the top bearing housing, and the user lifted the frame to change the headtube angle. The pins were inserted partway into the desired location and with slight pressure added.

The user rotated the steerer assembly until the pins fit in fully, locking the position. The Velcro was reapplied with slight tension and the compression assembly was clamped down to apply preload. If the clamping effort required was noticeably too high or could not be achieved, the user unclamped the lever and unthreaded the nut a turn before re-clamping. If the clamping effort was noticeably too low or the assembly still had play, the lever was unclamped, and the nut tightened a turn before re-clamping. Figure 50 gives a diagram of this action.

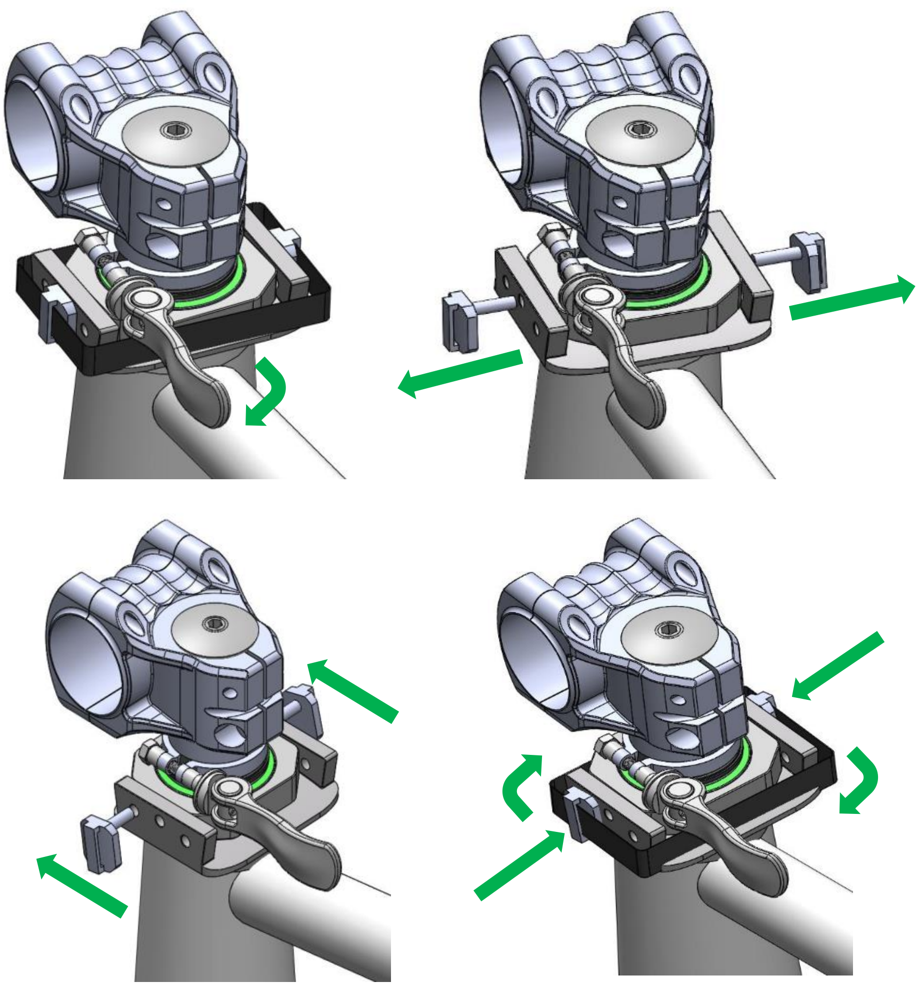


Figure 50: *Headset position adjustment diagram.*

6.4 Challenges and Lessons Learned

We found that ensuring all components fit together as well as possible was challenging. Any clearances between contacting surfaces resulted in a feeling of looseness in the final assembly. It was also challenging to maintain the smallest stack height possible.

We learned through our CNC machining to be more efficient in the future. We learned about how our headset interfaces with the user and bike, and what press-fit values worked well for our bikes.

6.5 Recommendations for Future Production

The bearing seat on our verification prototype's bottom bearing housing needed a smaller radius between the vertical walls and chamfer contact surface. This could be solved by using an insert with a smaller nose radius or extending the wall's toolpath further into the chamfered surface allowing the bearing to contact the housing evenly along the chamfered surface. The bottom headset cup and bearing housing could also be machined from AL 7075 instead of steel for weight reduction.

A dust cover with the lowest possible stack height would seal the top bearing and occupy less space on the steer tube. In addition to this, the design and manufacturing of a supple dust shield which would cover the top cup and top bearing housing, mating flush with the dust cover above these, would keep dust out of the top cup and top bearing housing extending the life and maintenance interval of the headset.

The top cup could have notches machined into the walls or ledges to guide the retention band. This would help ensure that the band does not slip up into the area of motion of the assembly when adjusting the headset or when turning the handlebars. When the handlebars are turned, the cam handle and compression assembly also rotate creating an area where the Velcro could be damaged during riding. Keeping it out of this area is paramount and a small redesign of the top cup could solve this issue.

Another aspect to improve would be the range of adjustment of the effective headtube angle. The top cup bore could be extended closer the walls of the headtube so that the steerer tube can pivot further in its rotation, this would yield greater effective headtube angle changes and was something that we did not fully pursue because we were looking for ± 2 degrees of rotation. It is possible that the bore could be extended but definite analysis into this extension on the strength of the top cup must be done before enacting this design change. As will become apparent in the next chapter, during testing we realized we had designed the headset for ± 2 degrees of rotation with reference to the headtube. This is different from relating the effective headtube angle to the ground. When the angle of the steerer tube and front fork changes, it increases the height of the headtube and changes the angle of the headtube and frame referenced to the ground. This counteracts the effect of the steerer tube pivoting in the headtube and yields an effective headtube angle change of less than ± 2 degrees even though the steerer tube changes angle with the headtube by ± 2 degrees. Our oversight, but with the analysis mentioned above and spacing out the holes in the top cup further, the range of effective headtube angle adjustment could be increased.

7. Design Verification

Verification of our design is crucial to the safety of riders and to gauge our success at meeting our design specifications. Using specifications determined in our QFD House of Quality, shown in Appendix D, we developed tests to measure our headset's capability of each specification. Table 6 provides an overview of the tests completed. See Appendix Q for all completed test procedures.

Table 6: *Summary of tests.*

Test Name	Description	Completed?
Top Bearing Housing Instron Test	Test top bearing housing to our loading case in all pin positions.	Yes
Adjustment Time	Test if adjustment of headset takes less than 20 seconds.	Yes
Tools Needed to Adjust	Test how many tools are needed to adjust the headset.	Yes
Weight	Test if our designed headset weighs less than target 250 grams.	Yes
Resemblance to Normal Headset	Determine aesthetic qualities of headset by survey sent out to mountain bikers.	Yes
Real-World Test Rides	Test headset as it would be used as a product on trails around SLO documenting observations.	Yes
Range of Adjustability	Determine if headset allows ± 2 degree adjustment from original headtube angle.	Yes
Production Planning Meeting with Manufacturer	Meeting with Trian Georgeou to determine manufacturability of design.	Yes
Rotation of Handlebars	Determine if headset allows full necessary use of handlebars 90 degrees each way from straight on.	Yes
Maintenance	Taking headset apart after frequent use to determine maintenance interval and life of design.	Yes

7.1 Top Bearing Housing Instron Test

Before we tested the headset on our own bikes, we verified the pin hole locating mechanism could withstand the forces we predicted it would encounter. We used an Instron tensile test machine to measure the force require to cause the top bearing housing to yield. We tested this component in this way because it is part of the only assembly unproven in the marketplace and we viewed it as the most likely failure point of the design. Because the spacing between holes is smaller on the top bearing housing than the top headset cup, it will fail before the top headset cup. If the top bearing housing can withstand a 3771N load, we will feel confident installing the entire assembly on one of our bikes.

Figure 51: *Images of Instron load test conducted on the Top Bearing Housing.*

The testing took place in the Cal Poly composites laboratory with the guidance of Graduate Student Marius Jatulis. Using Instron tensile test machine and our custom testing fixture, we slowly increase the load until double our predetermined load for a total of 7000 Newtons. We observed the following stress-strain plots for the three position location holes for neutral, steep, and slack positions.

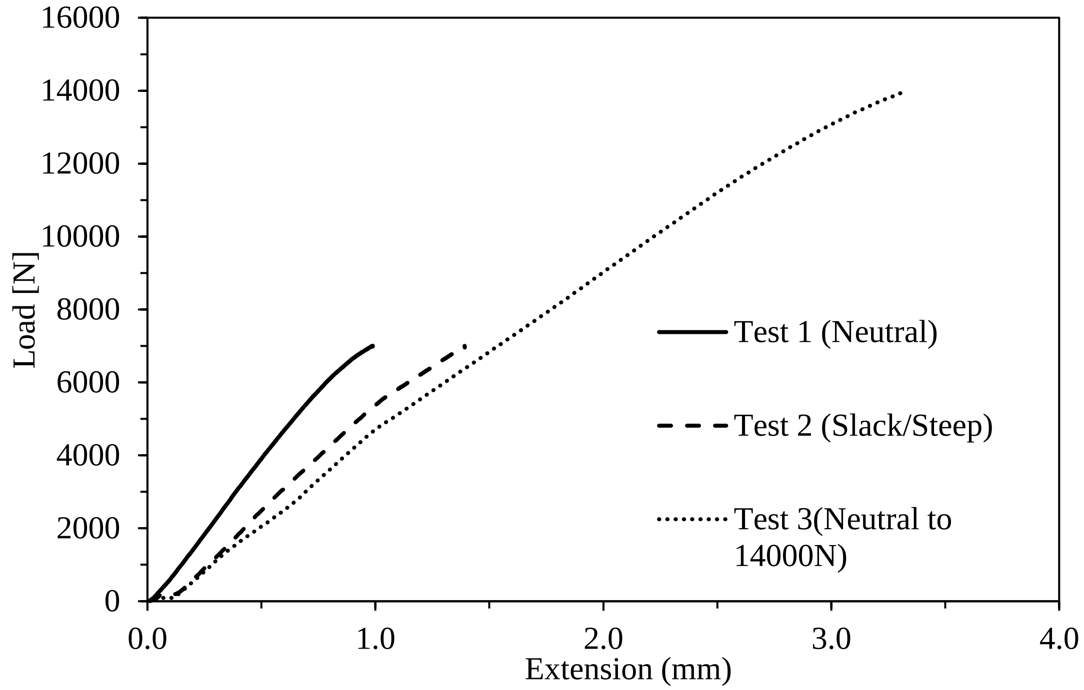


Figure 52: *Stress vs. Strain curves for the Instron test loading of the top bearing housing.*

The first test was set in the neutral position holes and loaded to 7000 newtons which corresponded to about 1 mm of strain. While at the end of the test, the plot begins to tip downward indicating plastic deformation, this test bolstered confidence as the housing did not fail catastrophically at this maximum load case. Visual inspection yielded no deformation.

The second test concerned the slack/steep case. Because the bearing holder is symmetric, we tested one side of it, in the slack position and can easily apply this to the other side, the steep position. Here we reached the 7000-newton load case with no failure at closer to 1.4 mm strain. A similar presence of slight plastic strain is evidenced by the downward curvature at the end of the curve. Still, this result is positive as there is no failure at our test load case in the slack or steep position. The increase in strain at this position could be due to a different position of the holes along the height of the housing. Visual inspection yielded no deformation.

Finally, for our third test, we used a new bearing housing and put it in the neutral position once again and doubled the load to 14000 Newtons or about 3000 pounds of force. The curve in this case appears to not curve upwards or downwards much until the 12000-newton mark indicating a greater range of elastic deformation for this test which is positive. The strain in this case totaled 3.3 mm. The housing did not fail catastrophically even to double our testing case. After the test, visual inspection showed the test pins bent or were shifted but there was no visible deformation to the bearing housing.

To further analyze the tested components, we utilized an optical CMM to analyze the circularity of the pin holes; we used a Micro-Vu Vertex provided in Mustang 60 Machine Shop. Assuming untested parts are uniform a repeated measures ANOVA (analysis of variance) indicates there is no statistical differences in circularity with 95% confidence; with a P-value greater than 0.05, see Appendix Q. Further testing is suggested to verify this. The results used are the mean circularity for all 6 holes on each test piece. The Figure 53 shows the mean circularity with standard error while Figure 54 shows the test piece on the CMM.

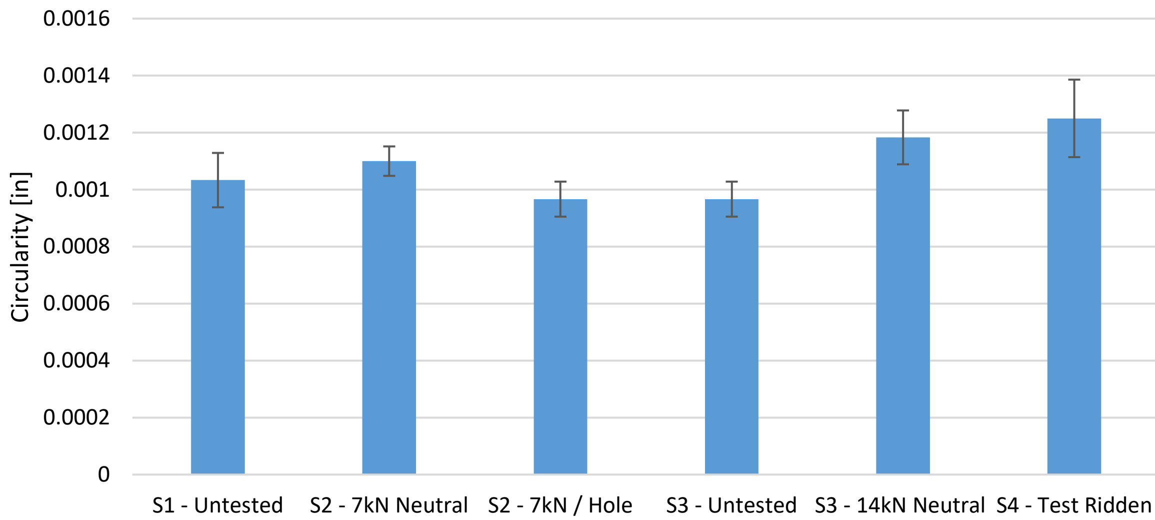


Figure 53: *Average circularity of each test sample pin holes with standard error bars.*

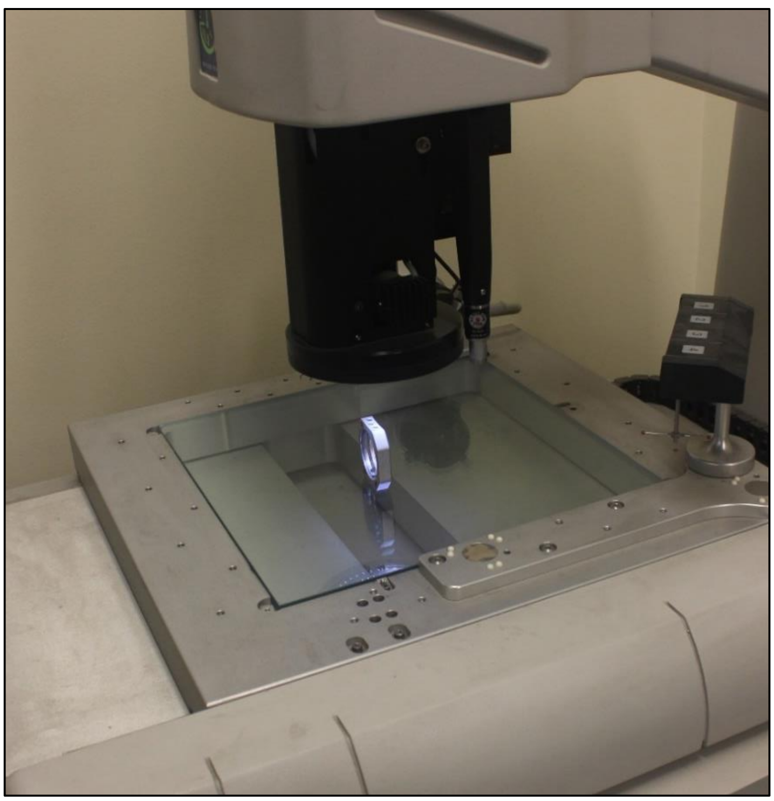


Figure 54: *Image of tested Top Bearing Housing on CMM.*

7.2 Design Specification Testing

We tested our headset on our own bikes on mountain bike trails in the San Luis Obispo area. Our complete design verification test plan with results and notes is attached in Appendix N.

Our adjustment time (1) specification was a measure of how long it took to adjust the headset from one position to the desired position. The headset has 3 possible positions, which means there are 6 possible adjustment moves. The testing took place on a Glenn's Mountain Bike with a rider on it. Each team member did these 6 possible position changes one at a time while being timed by a second individual with a stopwatch. The desired adjustment time is less than 20 seconds. The adjustment time during testing was on average about 8 seconds which positively is much less than 20 seconds. All components were at the verification prototype level for this test. The test was conducted 4 times, once for each group member. The accumulated test data was analyzed to create a sample mean and standard deviation to create a population mean adjustment time. This mean adjustment time was 14.7 seconds. See results in Table 7.

Table 7. *Headset Adjustment time data.*

	Trial 1	Trial 2	Trial 3
Dylan	15.84	16.18	19.33
Josh	11.72	18.08	15.75
Ben	16.35	15.03	15.72
Glenn	7.68	11.62	13.26

Figure 55: *Headset assembly for the time and tools to adjust tests.*

Our tools needed to adjust (2) specification was a simple test of how many tools it takes to make an adjustment. The desired number is less than one tool and after completing this test in unison with the above adjustment time test, we concluded no tools were needed to adjust the headset, passing this test.

Figure 56: *Image of components on scale for weight specification.*

Our weight (3) specification was the total weight of all components in our final design assembly: compression system, top bearing housing, Velcro band and pins, top headset cup, bottom headset cup, and bottom bearing gimbal. The ideal weight is less than a total of 250 grams. This test was completed using Mustang 60 Student Machine Shops scale and found the total of components weights to be 236 grams which is under our target.

The subjective specification, resemblance to normal headset (4), was judged with a survey of mountain bikers. The goal was to gauge users' perception of the headset in comparison to a standard headset. We were aiming for most responses reacting positively to the design. The final design CAD and image/video of the final assembly on a bicycle was used for this test. The results displayed a positive reaction by 68% of those participating in the survey.

Figure 57: *Image of Glenn test riding headset at Costco Jumps in SLO.*

Our real-world test rides (5) specification was designed to provide an understanding of headset's real-world usability and reveal any shortcomings or design flaws. A complete assembly of the adjustable angle headset was installed on a mountain bike and ridden on increasingly aggressive terrain. Any noise (creaking), part failure and any other observations were documented. Subsequent disassembly and documentation for wear was also completed after a period of approximately 200 miles of riding mountain bike trails. The headset was taken on jumps, bumpy terrain, fast downhill and grueling uphill climbs, courtesy of the biking trails around San Luis Obispo. Throughout all tests on a single assembly, no part failure occurred, and no noises or creaking were documented while riding.

The riding experience that this headset offers is incredibly unique. It is like always having three different bikes with you. Each adjustment position offers extremely noticeable differences to ride characteristics that are easily applied to different trail conditions. Adjusting the headset was never annoying, and it went unnoticed by other riders for the entirety of our test period. When riding, the headset disappeared underneath us by functioning identically to a normal headset. It was easy to forget that it was even installed on our bikes. For riders who run their stems with minimal spacers underneath, the increase in stack height will be noticeable. The slight slackening of the head tube angle due to the increased stack height beneath the head tube will also be noticeable. But once acclimated to these factors, the adjustable headset offers a radical improvement to the riding experience by enabling riders to change their bikes' geometry to suit the terrain in front of them.

Our range of adjustability (6) specification test was of how far our headset can adjust the steerer tube angle from the stock headtube angle. This required the complete assembly to be installed on a bike. Angle measurements at the 3 positions were taken with a digital angle finder positioned on the top of the top cap.

Figure 58: *Range of adjustment testing.*

The angle at each of the 3 positions was measured 3 times. During this test, we discovered that the change in angle with reference to the ground when the bike is resting on its wheels is different from the change in angle with reference to the frame. When the wheels are on the ground, the change to a slacker position moved the front wheel forward and drops the handlebar height while change to a steeper position raises the handlebar height. This in turn changes the angle of the frame, and existing headtube, relative to the ground. Because we were measuring the change in angle relative to the original headtube and frame, the angle change measurement with wheels on the ground is less than expected because the change in angle of the frame offsets a slight amount of the effective headtube angle change. This is about 0.3 of a degree. See Table 8 our results measured relative to the ground.

Table 8. *Range of adjustability data summary.*

Bike #1 - Commencal		Bike #2 – YT Capra	
Headtube Length	115 mm	Headtube Length	120mm
Adjustment Position, Trial	**Effective Headtube Angle**	**Adjustment Position, Trial**	**Effective Headtube Angle**
Neutral, 1	66.1	Neutral, 1	63.3
Slack, 1	64.4	Slack, 1	61.9
Steep, 1	67.6	Steep, 1	64.9
Neutral, 2	66	Neutral, 2	63.5
Slack, 2	64.3	Slack, 2	61.9
Steep, 2	67.5	Steep, 2	65
Neutral, 3	66.1	Neutral, 3	63.4
Slack, 3	64.3	Slack, 3	61.9
Steep, 3	67.6	Steep, 3	65
Mean Neutral	66.07	Mean Neutral	63.4
Mean Slack	64.33	Mean Slack	61.9
Mean Steep	67.57	Mean Steep	64.96667

The CNC (Computer Numerical Control) machining review (7) with Professor Trian Georgeou helped us gain perspective towards the manufacturability of our parts and the potential concerns with our designed tolerances. This also helped us gauge our machining time for our manufacturing process and improve our decisions for the selected methods.

Figure 59: *Test rotation of handlebars.*

Our rotation of handlebars (8) specification measured any restrictions on steering angle imposed by our headset. The goal was to have our product not inhibit any natural rotation of the handlebars when properly installed. The handlebars had to be able to be rotated 90 degrees clockwise and counterclockwise from a neutral position steered forward. This also tested for any roughness or excessive friction in the steering feel. This subjective test was conducted by the same individuals during the adjustment test to compare our headset to standard ones. We found that our headset did not seem to create any roughness of friction in use and turning and fully allowed 90 degrees of turn in both directions from straight ahead. It did not affect the steering angle at all from the original bike.

Figure 60: Images of components during maintenance disassembly.

Our maintenance specification (9) was designed to compare our product to a standard headset. Our product should not increase the effort to maintain the bicycle and should endure all environments a rider would otherwise be comfortable to ride in with a normal headset. Post real-world test riding, we disassembled the headset and inspected it for wear, surface marring, and dust ingress in the assembly. There was gunk and dust ingress into the headset and moderate marring. Our headset passed this test because it did not affect operation. With a proper dust shield, the dust accumulation we see on the greased surfaces would be diminished. Further the wear we see on the top cup could be remedied with the lack of gunk build up. It is recommended for future design to create a dust shield for the top cup and top bearing housing assembly.

Table 9 gives a summary of results of the tests completed during the testing phase of this project.

Table 9: *Test results summary.*

Test Name	Results	Passed?
Top Bearing Housing Instron Test	Top bearing housing was loaded to full load case and double to 14000N with no catastrophic failure. Stress strain curves indicate little plastic deformation, deformation found in pins with little in housing.	Yes
Adjustment Time	Average time for team members to adjust was 10 seconds.	Yes
Tools Needed to Adjust	No tools were needed to adjust the headset between angular positions.	Yes
Weight	Headset weight 236 grams in total.	Yes
Resemblance to Normal Headset	Most survey respondents said the headset was aesthetically pleasing.	Yes
Real-World Test Rides	Headset was ridden on 40 miles of trail with no failures.	Yes
Range of Adjustability	Headset allows +/- 2 degrees from original headtube angle when measured relative to frame. When measured relative to the ground plane it offers a range of +/- 1.63 degrees due to frame trimming up and down for different positions.	Yes
Production Planning Meeting with Manufacturer	Trian Georgeou supported the manufacturability of our design.	Yes
Rotation of Handlebars	Headset did not impact angle of rotation achieved or feel of rotation compared to original headset.	Yes
Maintenance	Minimal particle ingress was noted in assembly, minimal surface marring or scratching was evident after 40 miles ridden.	Yes

7.3 Challenges and Lessons Learned

We designed our headset to adjust the head tube angle ±2˚ from neutral in relation to the bike frame. During testing, we discovered that the additional geometry changes resulting from changing the head tube angle reduced the adjustment range when measuring the head tube angle with both wheels on the ground. We would like to update our design to account for these effects to provide a full ±2˚ of adjustment with wheels on the ground.

Most of our testing was quickly repeated, but we cannot replicate years of real-world riding in our limited testing time window. We found areas of preliminary wear and abrasion, but other maintenace issues are surely hidden by time. More testing time would allow for these issues to be found and corrected.

8. Project Management

We worked through three quarters of research, design, manufacturing, and testing including milestones of preliminary design review, critical design review, project expo and final design review including a working verification prototype.

The first quarter of work prepared for the PDR. Extensive research was carried out to understand our customer requirements and other solutions already developed. Once we acquired background knowledge, the relevant requirements and the methods which would be used to determine if our product met those requirements were developed in the House of Quality (Appendix D).

Idea generation began with creating as many ideas as possible without thought of feasibility or critique. We used several methods, including brainwriting and brainstorming, to create ideas from other ideas and end up with more concepts. We created Pugh, morphological and weighted decision matrices to determine the best solutions to functions, most effective combinations of these functions, and several possible complete system designs. This phase finished with the determination of a design direction, creating a concept prototype, CAD model, and presenting our findings and accomplishments to date in the PDR presentation and report.

Upon approval and critiques from our sponsor on our design direction, we began analysis using prototypes, models and various failure and design theories. Drawings and manufacturing plans were documented, and a fully detailed CAD model was completed for the Critical Design Review. The sponsor once again submitted feedback based on our design and gave us the go-ahead to begin manufacturing.

Based on our final design, parts were ordered, and manufacturing of the verification prototype began and was completed. Testing, documentation, and reworking dominated the spring quarter. Our unique perspective of being both a customer and designer gave us the advantage of being able to test our design and obtain direct feedback into our design process. We installed the headset onto our own bikes to experience every stage of the design process, from customer to manufacturer.

At the end of the quarter, we presented our project at Design Expo as well as documented and submitted the entirety of our findings, the process, and the verification prototype to our sponsor, Dr. Kean. See Table 10 for a summary of time expended on each task of the project.

Table 10: *Summary of time expended*.

Task	Hours Spent
Problem definition, Background research	30
Idea generation and decision making	35
Concept prototypes, CAD models, PDR	25
Detailed CAD, drawings, and models	35
Analysis and manufacturing plans, CDR	65
CAM, Manufacturing	80
Testing, User Manual	35
Expo Website, FDR	20

9. Conclusion and Recommendations

This final design report is intended to highlight our concept design, decision-making process, final design, manufacturing, and testing. It also addresses our customer and background research and describes our project's objectives.

Through design, manufacturing, and testing of our headset, we felt proud and accomplished to have met the goals we created in the Fall. Our adjustable headset is tool-free, adjustable within 20 seconds, and offers a wide adjustment range for mountain bikers to change their bikes' geometry to suit the terrain in front of them. Along with a project we feel proud of, we also were able to learn a tremendous amount about mountain bike design.

We did not achieve perfect resemblance to existing headsets. Based on user feedback and survey results, users were not deterred by the headset's appearance and would ride their bikes with our headset. An ideal headset functions as intended and should never cross the rider's mind. With our headset, its appearance and performance are intentionally considered by the rider. A fully integrated, contained solution would solve this issue and be the ideal appearance while including adjustability features.

If future work were to be done with the findings we have made and the prototype we manufactured, we suggest improving the pin retention system. Our current design works and adequately secures the pins into the selected head angle position, but it is not the ideal solution. Currently, both hands are required to adjust the pins on either side of the headset which involves an awkward method of suspending the weight of the bike during adjustment with wrists or palms. Ideally, the rider could pick up the front of the bike with one hand then secure the adjustment and preload with their other hand. We believe this to be a major revision of our design and possesses the potential to fulfill another inspired group's senior project.

Slight modification to the bottom cup and bearing housing's designs would decrease the stack height beneath the headtube, reducing the difference in head tube angles between the stock and neutral positions. Slight modification to the top cup and bearing housing's designs by changing the holes' spacing would increase or decrease the adjustment range as desired. A design we began working towards but never implemented was a consideration to the band retention on the cup. The current design relies on friction to hold the Velcro strap axially in line with the pins, we redesigned the top cup adding shoulders to provide a lip to hold that band down.

Another aspect to undertake would be to design either a new system or a dust cover which would encase the top cup all the way up to the existing dust cover to keep particles from entering the contacts between components in between the top cup and the existing dust cap. This would increase smooth operation and decrease marring on these contacting surfaces.

Further work may be done to manufacture both the top bearing housing and top cup more efficiently. We used basic 3-axis CNC manufacturing methods due to availability of skill, cost, and time. A more efficient option regarding time, especially considering the manufacturing cost, would be to utilize a multi-axis option to reduce the number of setups and operations required to produce a final component. This would be an enhancement for both the top cup and top bearing housing.

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Appendices

A. Survey Results
B. Full Customer Needs/Wants List
C. ZS44/ZS56 Dimension Standards
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E. Idea List (all ideas developed during ideation)
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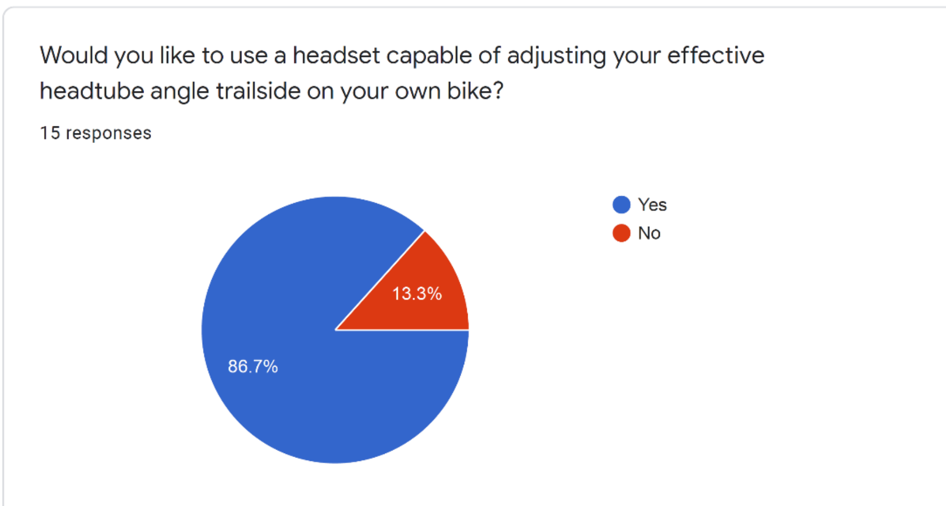
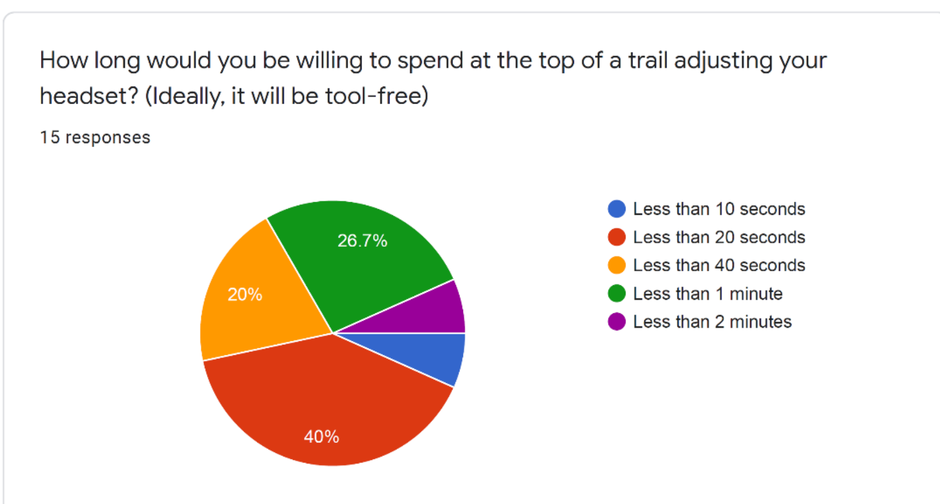
Appendix A) Survey Results

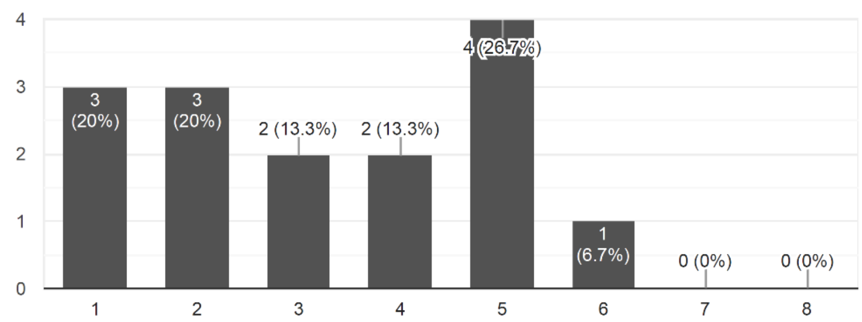
We published a survey and sent to the Cal Poly mountain biking community to obtain information on relevant wants and needs from serious, experienced mountain bikers. The survey covered topics such as range of adjustability, price, and necessary tooling. We learned that there is a large interest in a headset that will allow the user to change their effective head tube angle up to 5 degrees steeper or slacker. Maintaining a neutral position was highly valued. Other notable needs are a price of less than 150 dollars and an adjustment time of less than 20 seconds with or without a tool needed. We used these results along with our sponsor’s requirements to determine the relevant wants and needs we would design for.





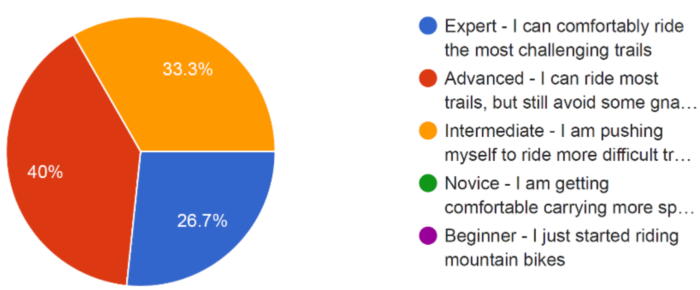
How many degrees of adjustment would you like available to steepen your steering axis?

15 responses



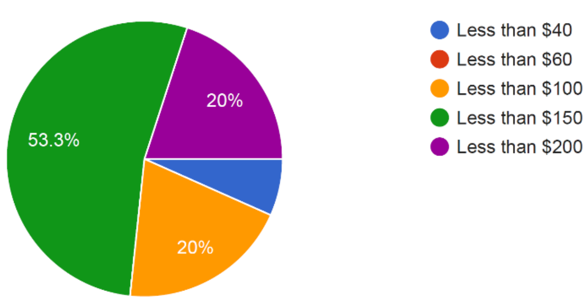
Describe your experience level

15 responses



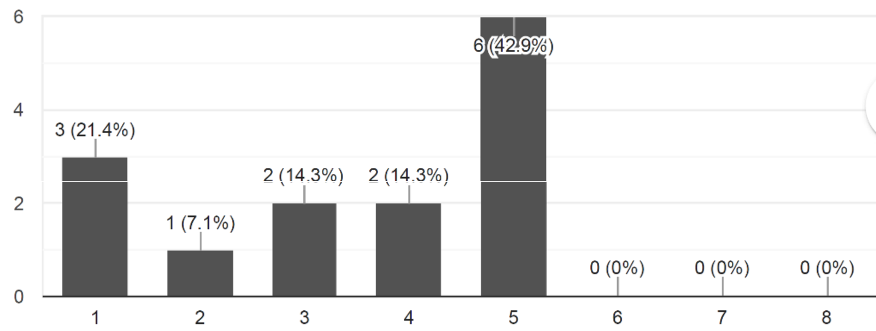
If this were a product on the consumer market, how much would you be willing to pay for it?

15 responses



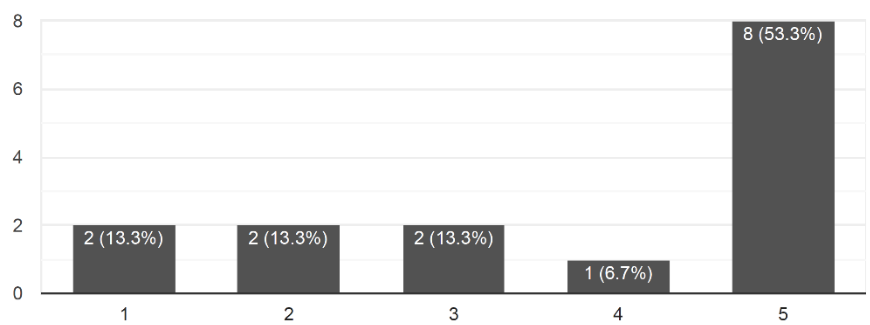
How many degrees of adjustment would you like available to slacken your steering axis?

14 responses



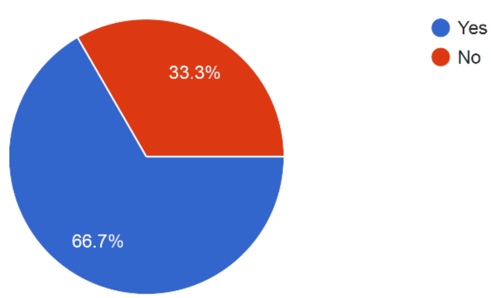
How important is having a neutral position - i.e., having a 0 degree position in addition to +/- 2 degrees of adjustment?

15 responses



Would you still be interested in using the adjustable headset if it required a multi-tool to adjust?

15 responses



Appendix B) Full Customer Needs/Wants List

- Tool-free adjustment. If tools are necessary, they should be found on common biking multi-tools.
- Quick adjustment. Preferably done in less than 20 seconds.
- Settings for a neutral, steeper, and slacker head tube angle.
- Silent, creak-free operation.
- Cannot slip or change positions while riding.
- Varies head tube angle by at least 2 degrees in both the slacker and steeper directions.
- Low-profile, lightweight, sleek design mimicking modern headset appearance.
- Must not increase riders’ risk of accident or injury.
- Similar maintenance schedule to current headsets.
- Must not limit the rotary motion of headset about steering axis.

Appendix C) ZS44/ZS56 Dimension Standards

Zero-Stack Dimensions

Common name	SHIS name	Bore inside diameter (mm)	Cup outside diameter (mm)
1 in semi-integrated	ZS41	41.35 – 41.4	41.45 – 41.5
1-1/8 in semi-integrated	ZS44	43.95 – 44	44.05 – 44.1
1-1/2 in semi-integrated	ZS49	49.57 – 49.61	49.7 - 49.75
1-1/2 in semi-integrated	ZS55	54.9 – 54.95	55.05 – 55.1
1-1/2 in semi-integrated	ZS56	55.9 – 55.95	56.05 – 56.1

External Cup Dimensions

Common name	SHIS name	Bore inside diameter (mm)	Cup outside diameter (mm)
1 in JIS	EC29	29.85 – 29.9	30 – 30.1
1 in Pro	EC30	30.05 – 30.1	30.2 – 30.3
1 in BMX	EC33	32.6 – 32.7	32.8 – 32.9
1-1/8 in external	EC34	33.9 – 33.95	34.05 – 34.15
1-1/4 in external	EC37	36.9 – 36.95	37.05 – 37.15
1.5 in external	EC44	43.95 – 44	44.1 – 44.15
1.5 in external	EC49	49.57 – 49.61	49.7 – 49.75
1.5 in external	EC56	55.9 – 55.95	56 – 56.05

Integrated Dimensions

Common name	SHIS name	Bore inside diameter (mm)	Bearing outside diameter (mm)	Bore depth (mm)
1 in IS (Cane Creek)	IS38	38.15 – 38.25	38	3.1 – 3.2 (top) / 6.9 – 7 (base)
1-1/8 in IS (Cane Creek)	IS41	41.1 – 41.2	41	3.1 – 3.2 (top) / 6.9 – 7 (base)
1-1/8 in Italian	IS42	41.95 – 42.05	41.8	2.8 – 3.0 (top) / 6.6 – 6.8 (base)
1-1/4 in IS (lower only)	IS47	47 – 47.1	47	49.1 – 49.2 (base)
1-3/8 in IS (lower only)	IS49	49.10 – 49.2	49	51.1 – 51.15 (base)
1-1/2 in IS (lower only)	IS52	52.05 – 52.15	52	7.3–7.5 (base)

Appendix D) QFD House of Quality

Correlations	
Positive	+
Negative	−
No Correlation	

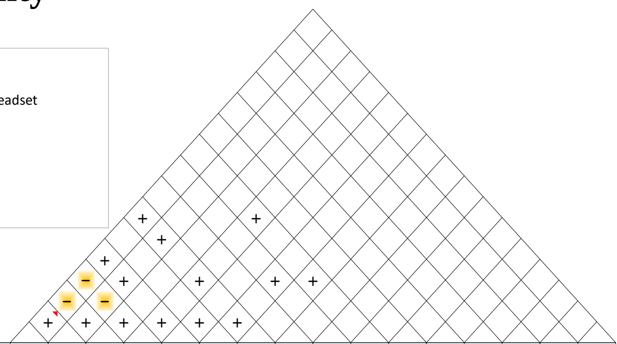
Relationships	
Strong	●
Moderate	○
Weak	▽

Direction of Improvement	
Maximize	▲
Target	◇
Minimize	▼

QFD House of Quality

Project: F64 - Adjustable Headtube Angle Headset
Ben Harper
Josh Martin
Glenn Petersen
Dylan Prins

Revision Date: 10/8/2020



Row #	Weight Chart	Relative Weight	Avid Mountain biker	Enthusiast bikers	Local Bike shops	Product Manufacturer	Maximum Relationship	WHAT: Customer Requirements (Needs/Wants) \ HOW: Engineering Specifications (Tests)	1 Adjustment Time	2 Tools Needed to Adjust	3 Weight	4 Resemblance to Normal Headset (Survey)	5 Real-World Test Rides	6 Range of Adjustability Test	7 Repeated Testing	8 Production Planning Meeting with Manufacturer	9 Test Rotation of Handlebars	10 Maintenance Test	11	12	13	14	15	16	Normal Headset	VP Varial	Cane Creek AngeSet	Slackerizer Angle Headset	Canyon ShapeShifter	Row #
								Direction of Improvement	▼	▼	▼	▲	◇	▲	◇	◇	◇													
1		6%	7	8	4	4	9	Tool-free adjustment	○	●			○												0	0	0	0	5	1
2		8%	10	10	5	4	9	Quick Adjustment	●	○			○												0	3	1	1	5	2
3		8%	8	8	10	3	9	Multiple Settings					○	●											0	5	3	1	2	3
4		7%	6	7	9	3	9	Wide Range of Adjustability					○	●											0	4	3	3	5	4
5		8%	8	7	7	5	9	Durable (tough)					▽		●										5	3	3	4	3	5
6		9%	9	9	8	5	9	Low-profile				●													5	1	5	5	2	6
7		9%	10	10	8	5	9	Reliable (changing setting)					▽		●										5	2	2	3	3	7
8		5%	5	6	3	3	9	light weight			●														5	2	4	4	1	8
9		10%	9	9	8	8	9	Low Risk					▽		●										5	4	4	4	4	9
10		9%	9	9	7	7	9	Low Maintenance					▽		●			●							5	3	5	5	2	10
11		8%	9	8	7	5	9	Functionality Identical to Normal Headset					●		●		●								5	5	5	5	5	11
12		5%	1	1	1	10	9	Ease of Production								●									5	1	2	4	0	12
13		8%	10	10	8	2	9	Silent, Creak Free					○		●										5	2	2	3	4	13
14		0%																												14
15		0%																												15
16		0%																												16

Column #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
HOW MUCH: Target Values	20 sec	0 tools	250 grams	results show low profile characteristics or does not extend further than VP	acceptable review from rider	must change angle ±2 and have atleast 5 positions	Performs effectively as a headset over as many test rides as possible	Manufacturable	Minimum rotation of 300 degrees with minimal effort	Must take 5 rides before necessary maintenance						
Max Relationship	9	9	9	9	9	9	9	9	9	9						
Technical Importance Rating	90.93	81.77	42.86	78.66	222.5	135.7	471.1	42.24	73.8	83.04	0	0	0	0	0	0
Relative Weight	7%	6%	3%	6%	17%	10%	36%	3%	6%	6%	0%	0%	0%	0%	0%	0%
Curr. Products: Normal Headset	5	5	5	5	5	0	5	5	5	5						
VP Varial	1	1	5	3	3	3	3	3	5	4						
Cane Creek AngeSet	0	0	5	5	3	0	3	3	5	5						
Slackerizer Angle Headset	0	0	5	5	4	0	4	4	5	5						
Canyon ShapeShifter	5	5	5	4	4	0	4	4	5	4						
Column #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16

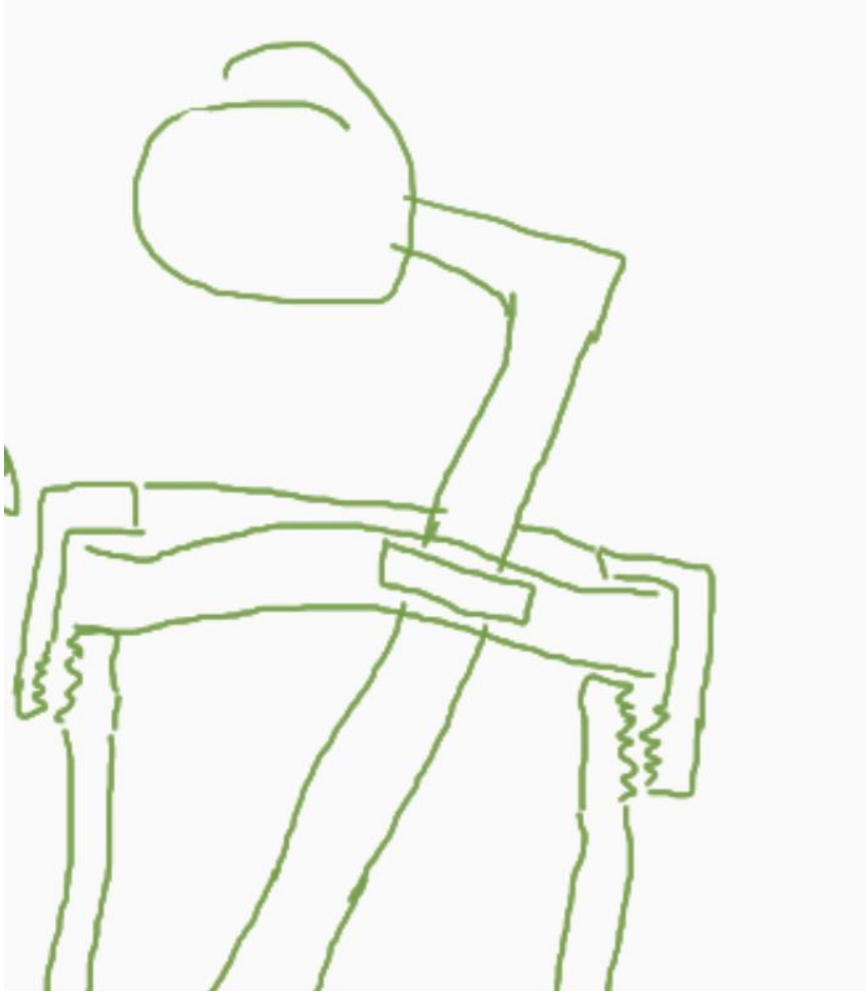
Appendix E) Idea List

E-1: Applying Assembly Preload – Eccentric Notch/Slot Lock

E-2: Applying Assembly Preload – Threaded Spacer

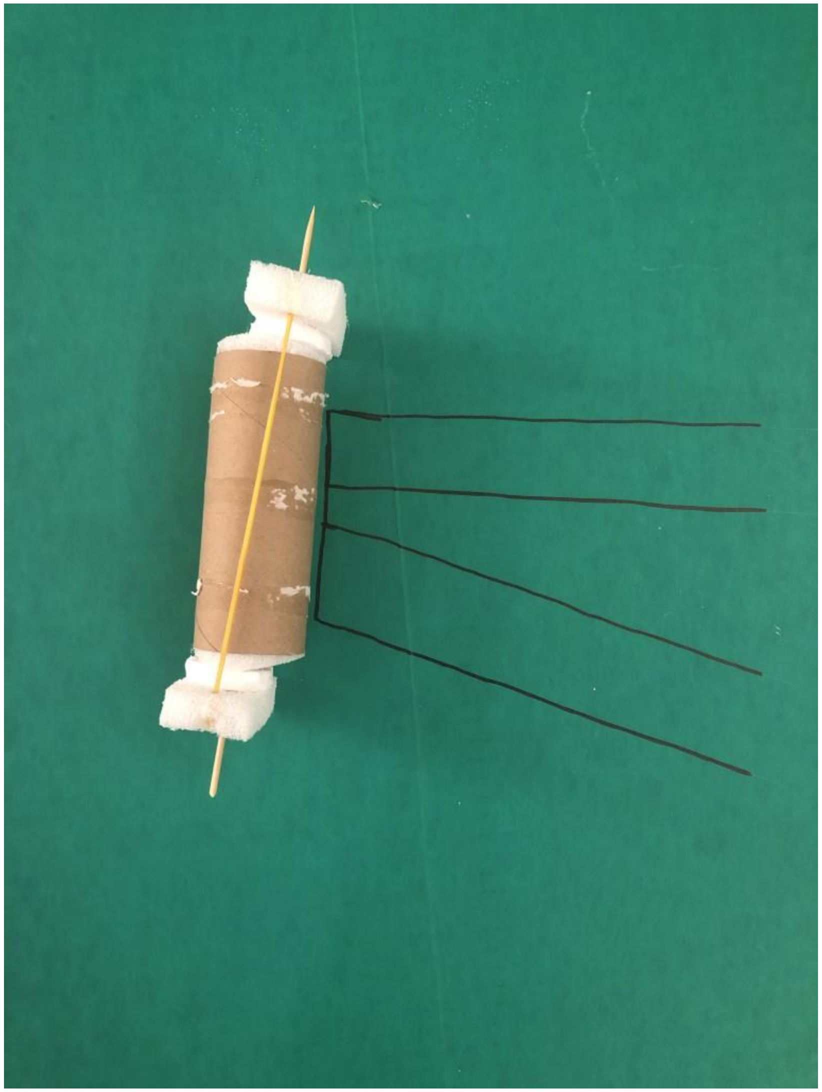
E-3: Applying Assembly Preload – Over - Center Lock

E-4: Applying Assembly Preload – Threading on Cup



E-5: Freely Adjusting – Rotating Eccentric Cups

E-6: Freely Adjusting – Convex Cups

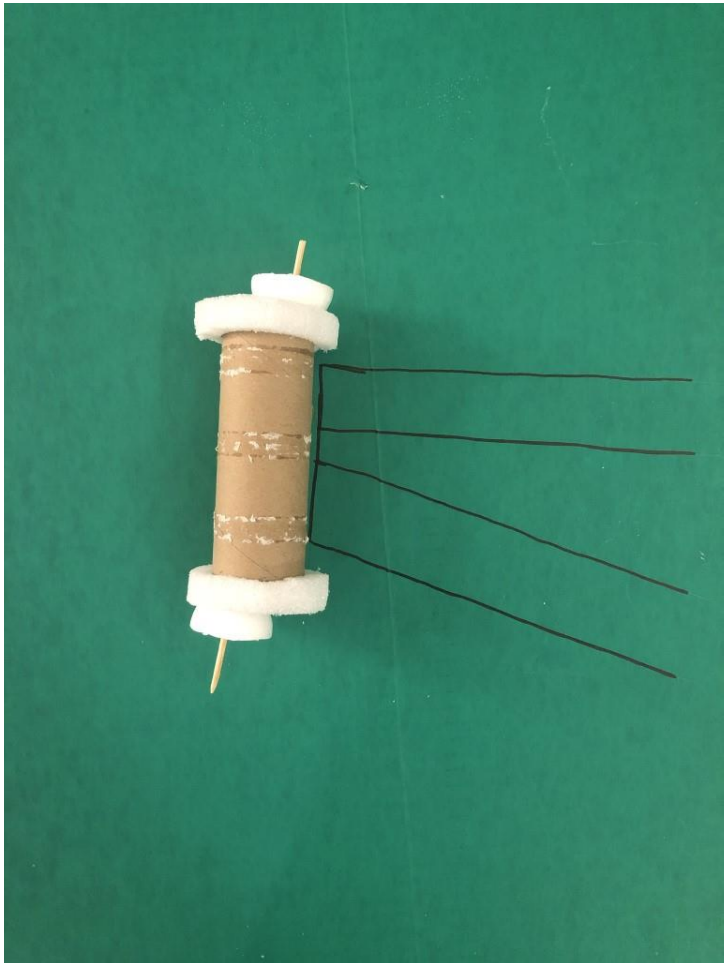


E-7: Freely Adjusting – Pinned Pivoting Bearing Housing

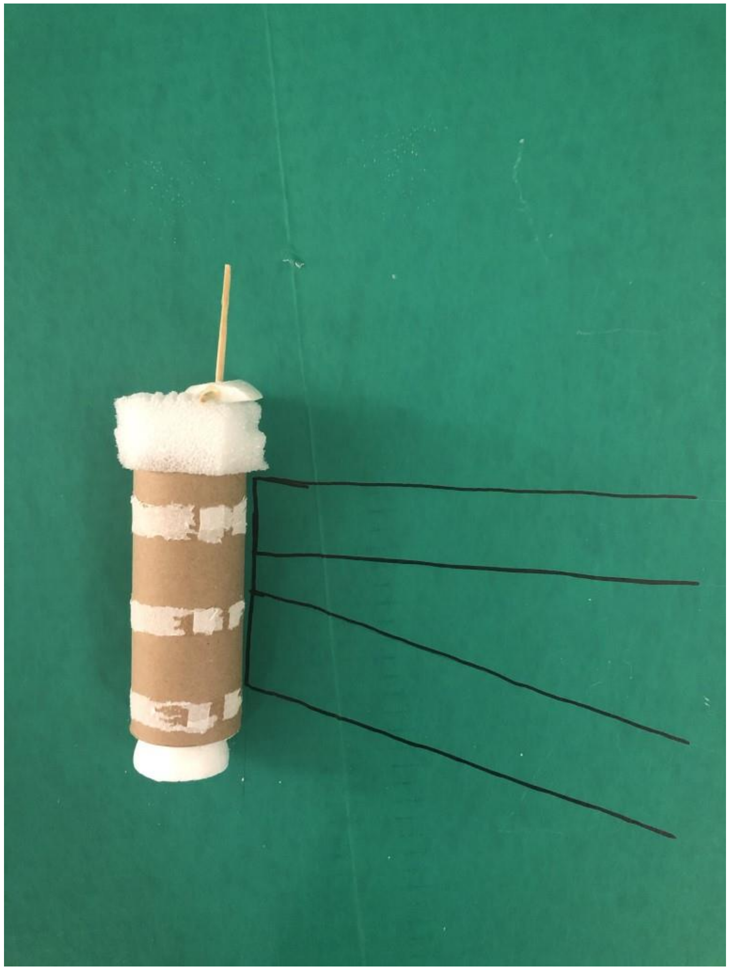
E-9: Freely Adjusting – Inner Head tube Assembly

E-10: Locating Mechanism – Eccentric Cups

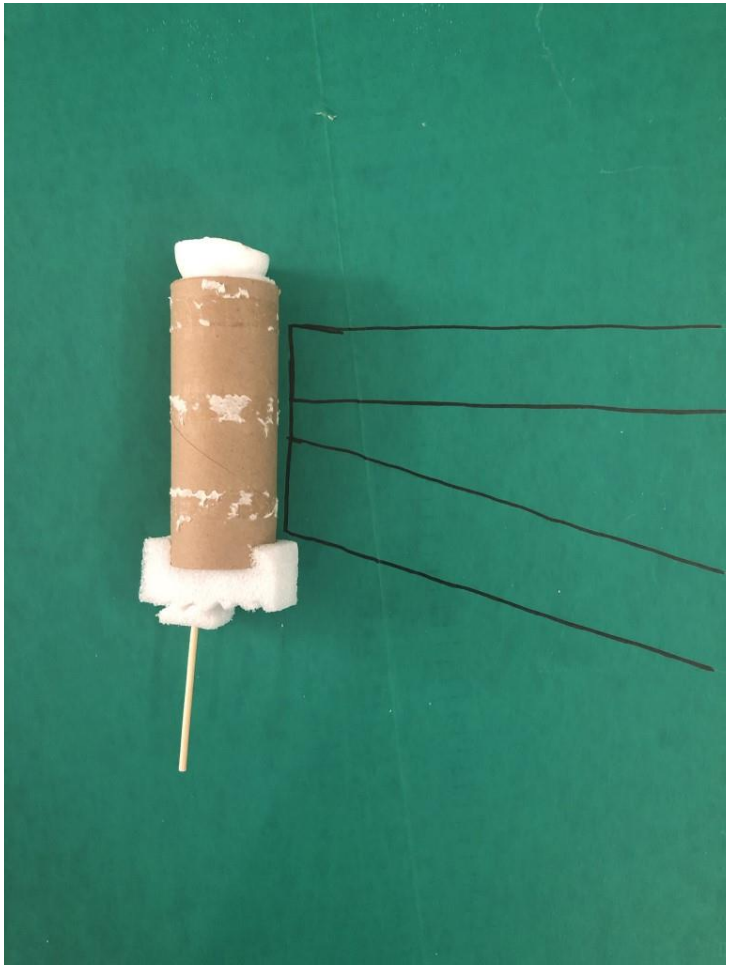
E-8: Freely Adjusting – Spherical Bearing (top or bottom cup)



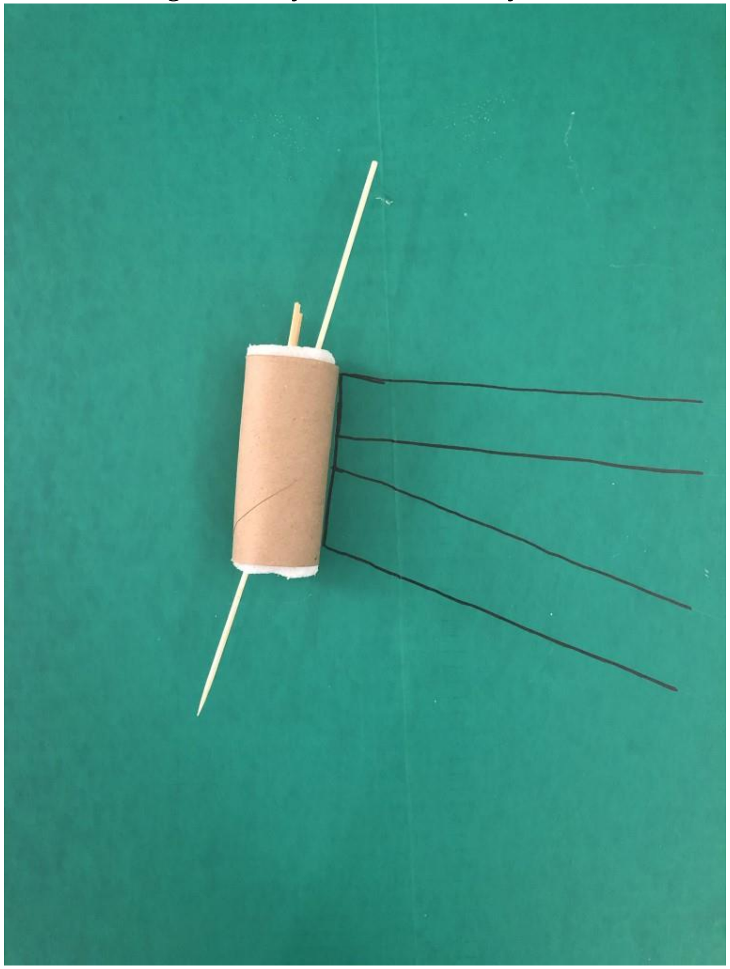
E-11: Locating Mechanism – Pin and Notches (Single Point)



E-12: Locating Mechanism – Teeth (Multipoint)

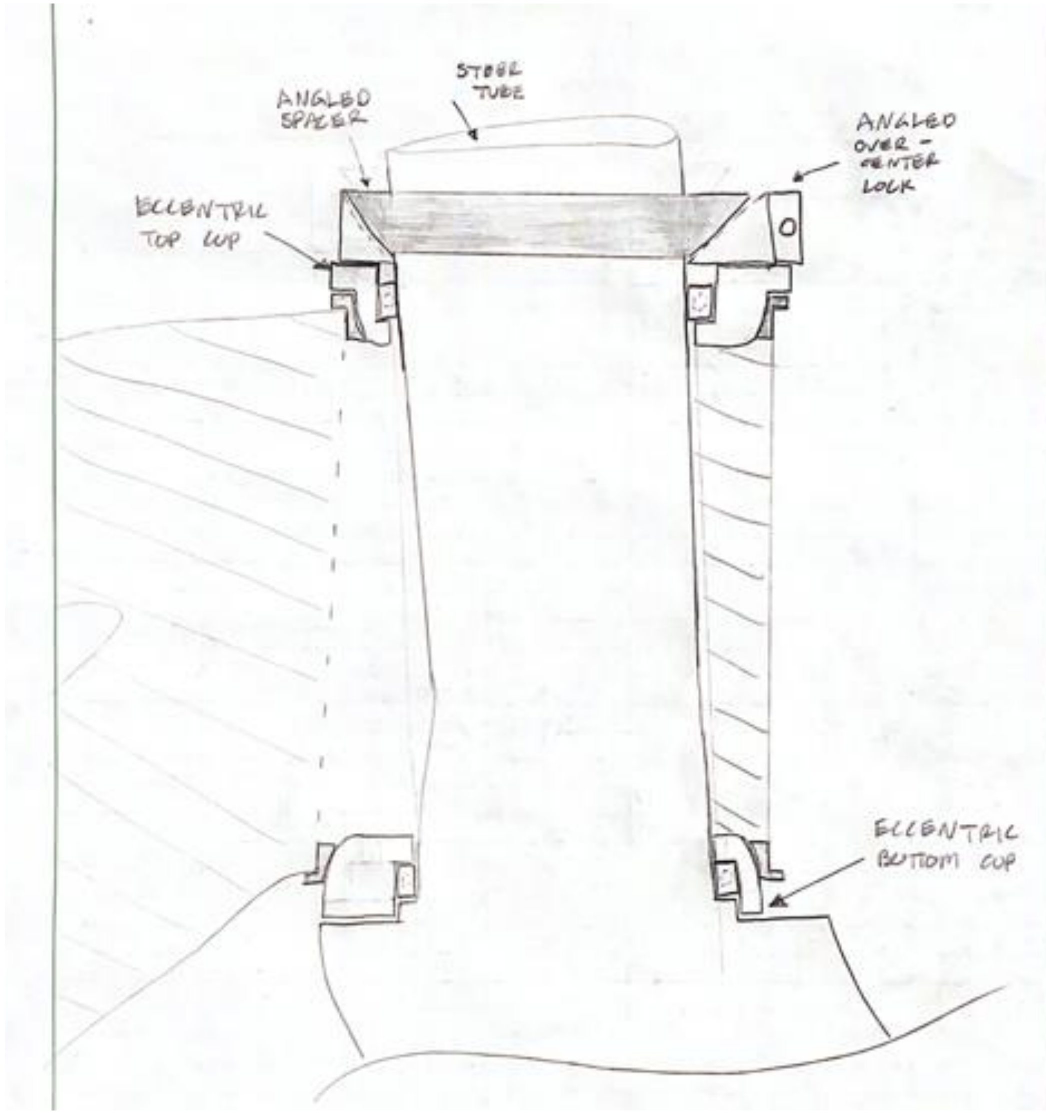


E-13: Locating Assembly – Inner Assembly

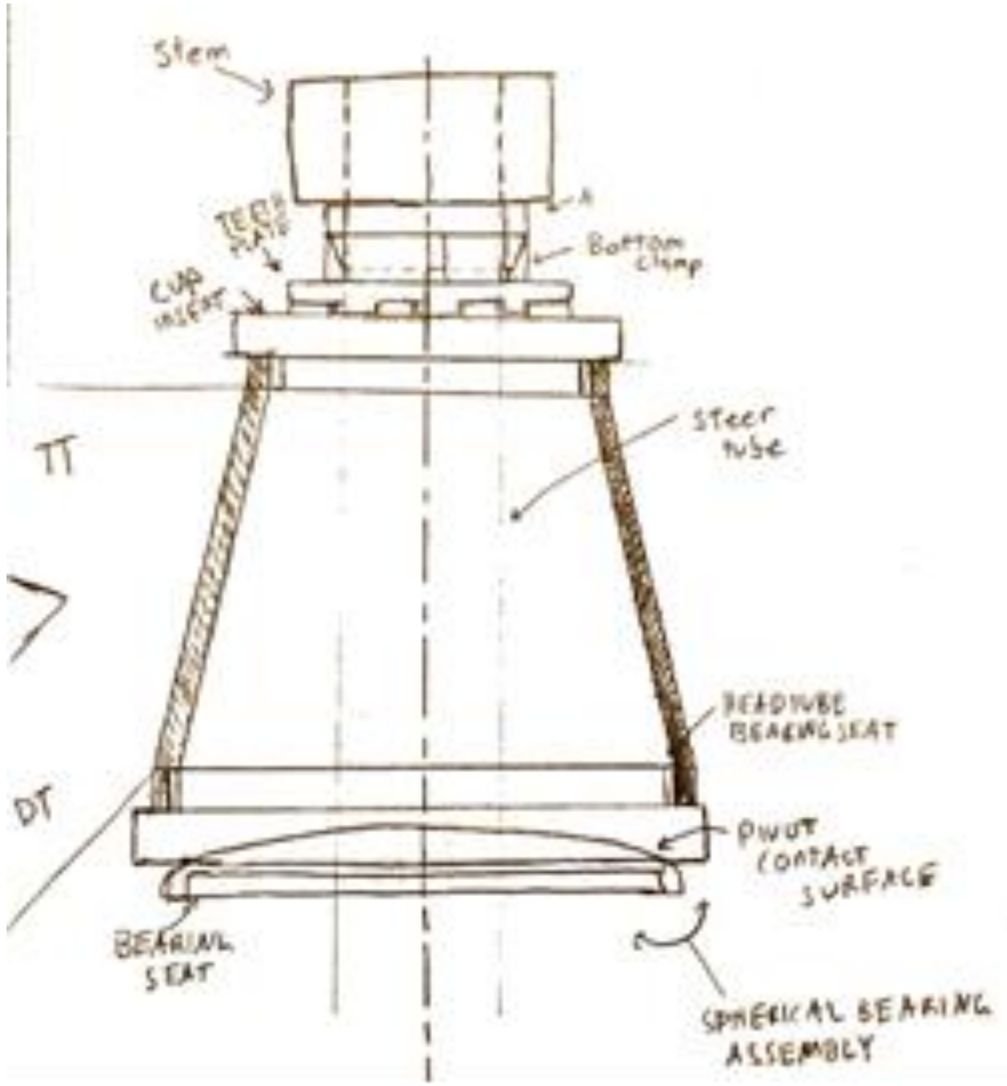


System-Level Ideas

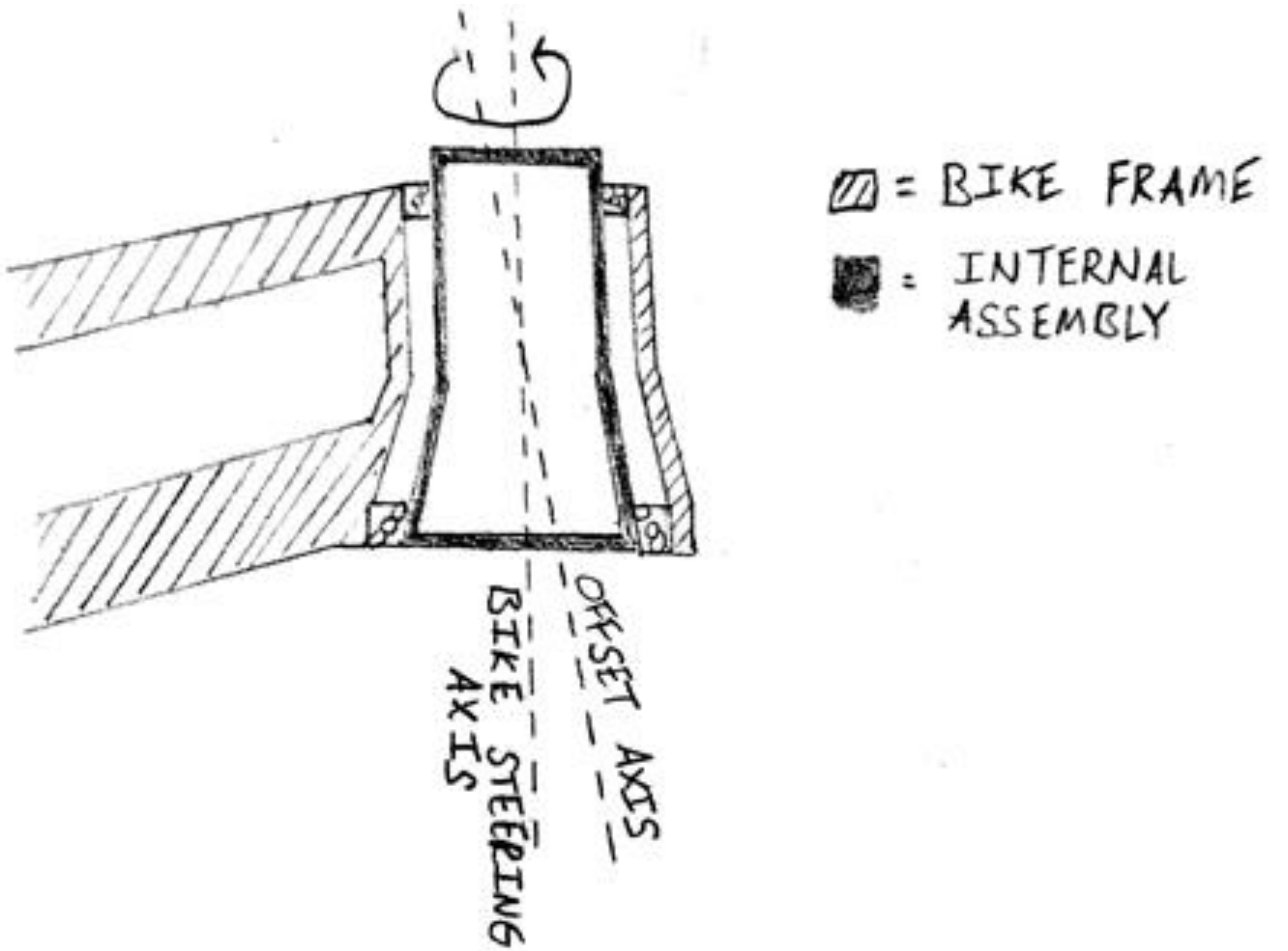
E-14: Rotating Eccentric Cups with Over-Center Lock



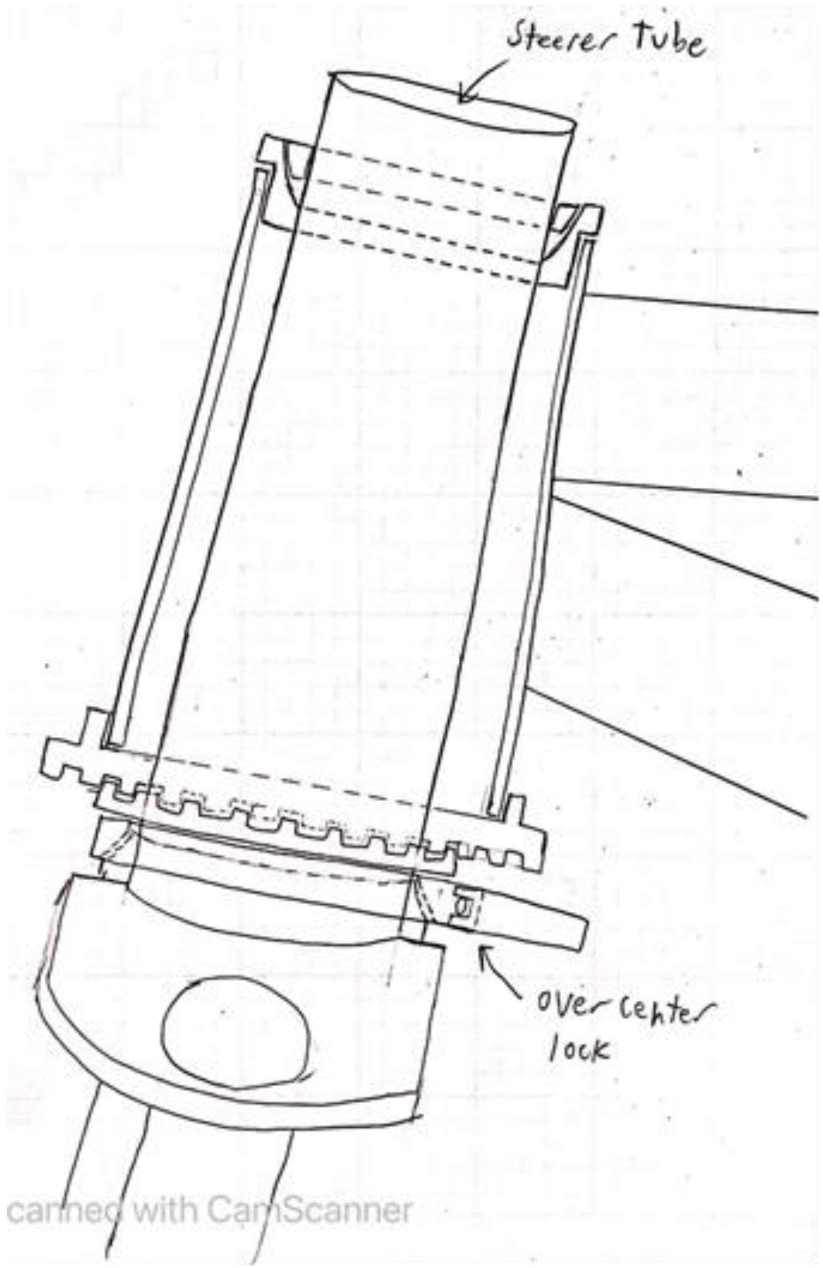
E-15: Spherical Bottom Bearing with Over-Center Lock and Locating Teeth



E-16: Inner Head tube Assembly with Locating Notch/Slot

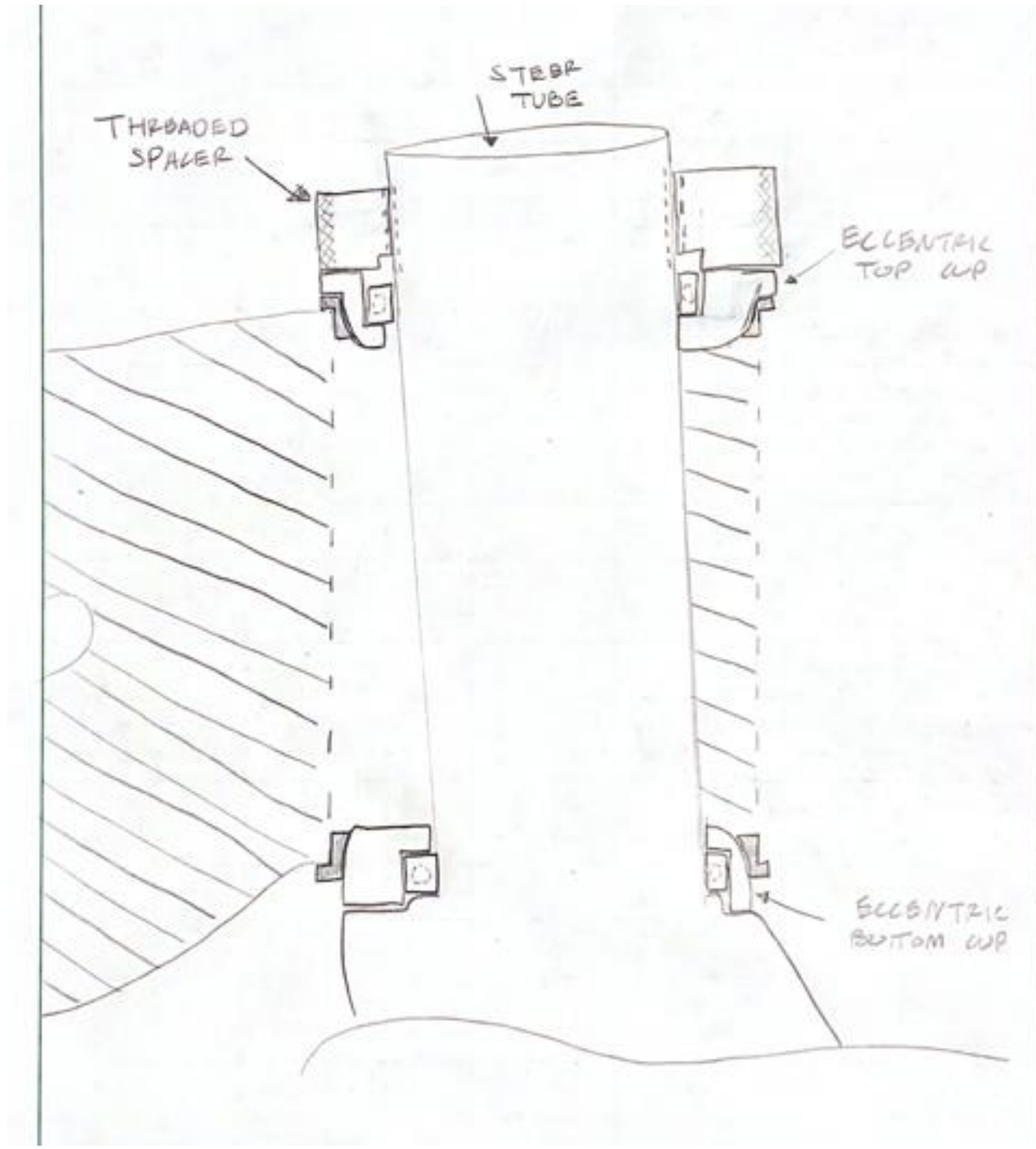


E-17: Spherical Top Bearing with Over-Center Lock and Locating Teeth

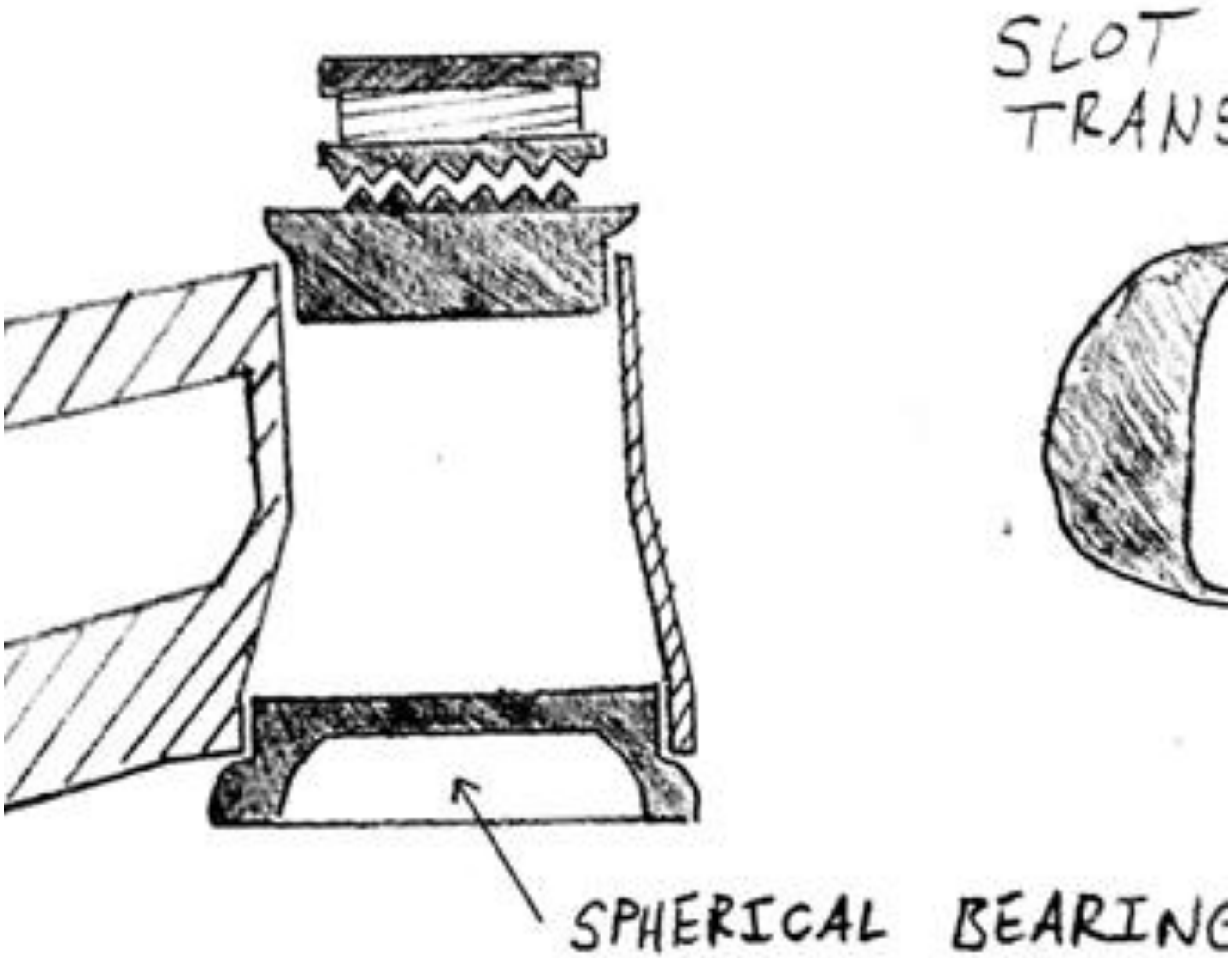


canned with CamScanner

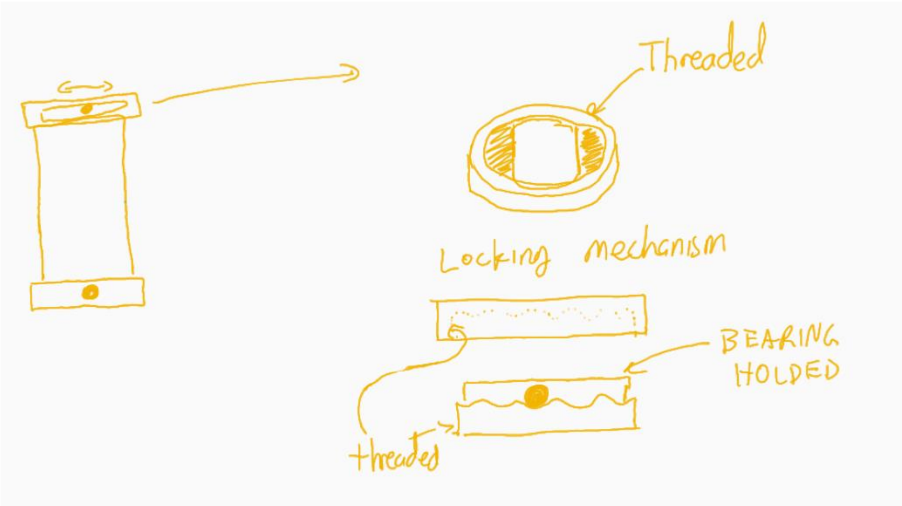
E-18: Rotating Eccentric Cups with Threaded Headset Spacer

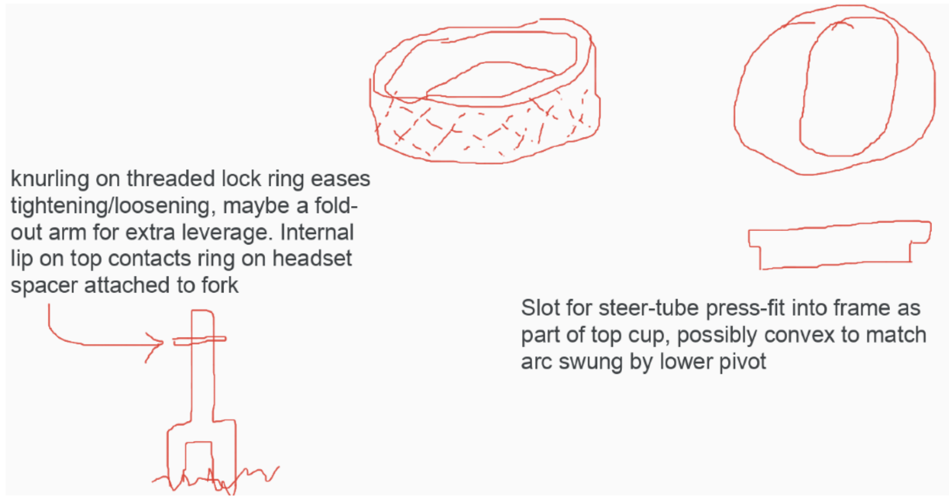


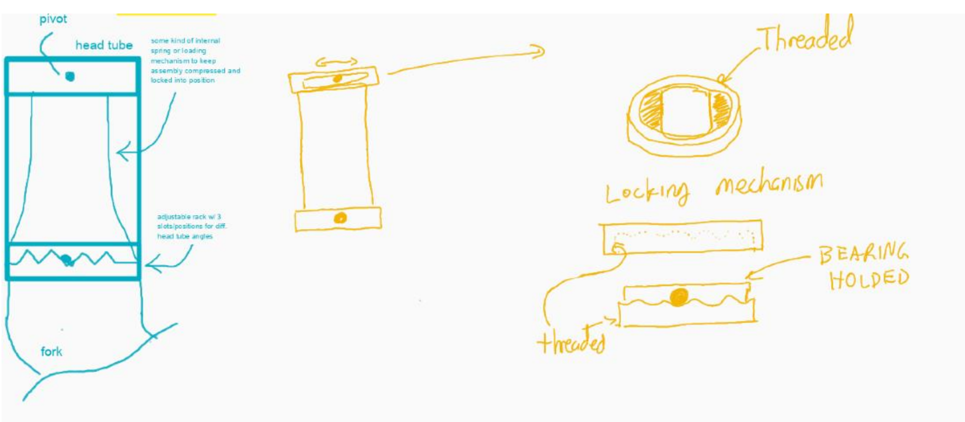
E-19: Spherical Bottom Bearing with Threaded Spacer and Locating Teeth


SLOT
TRANS
SPHERICAL BEARING

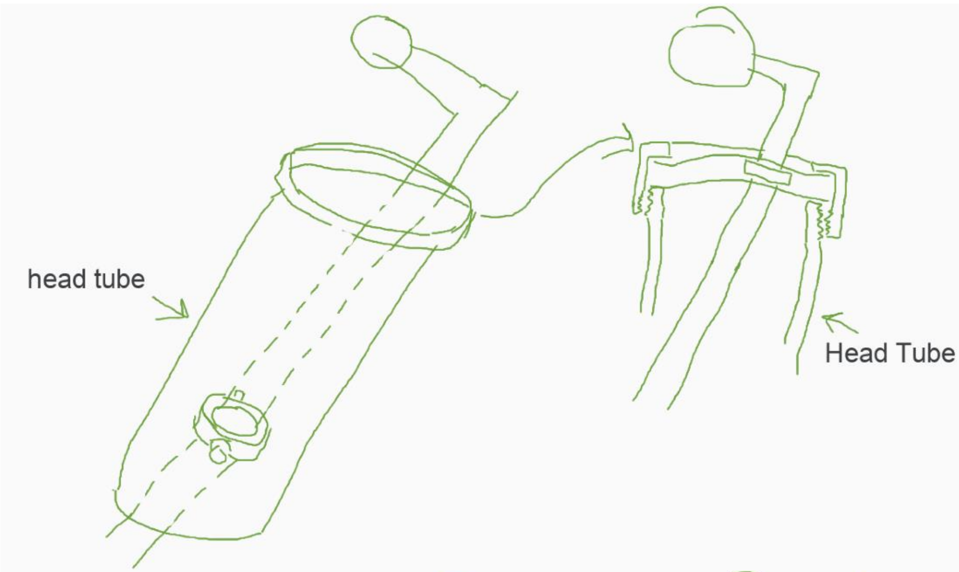
Appendix F) Brainwriting Sketches
Glenn's Idea

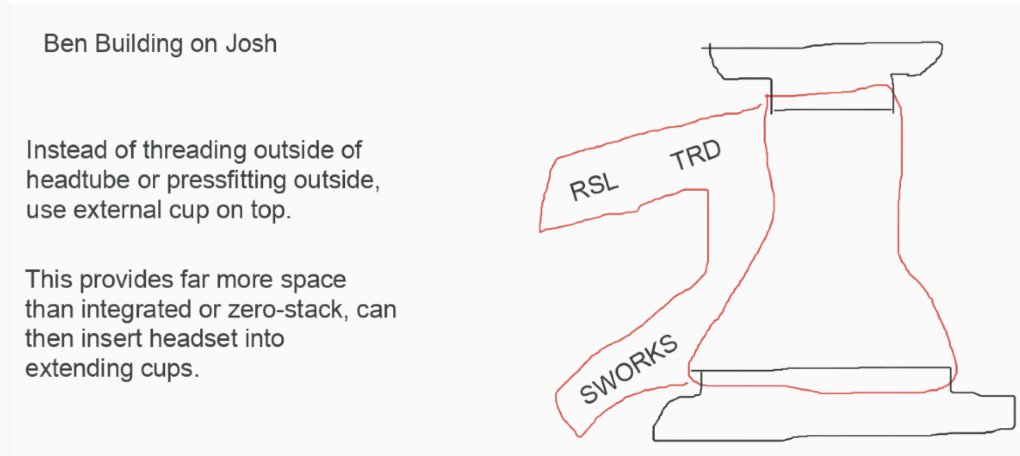


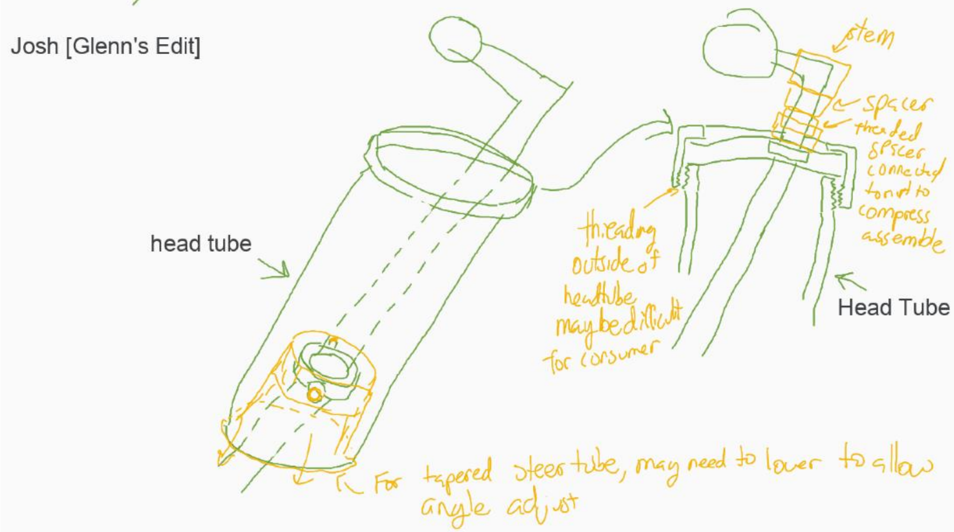


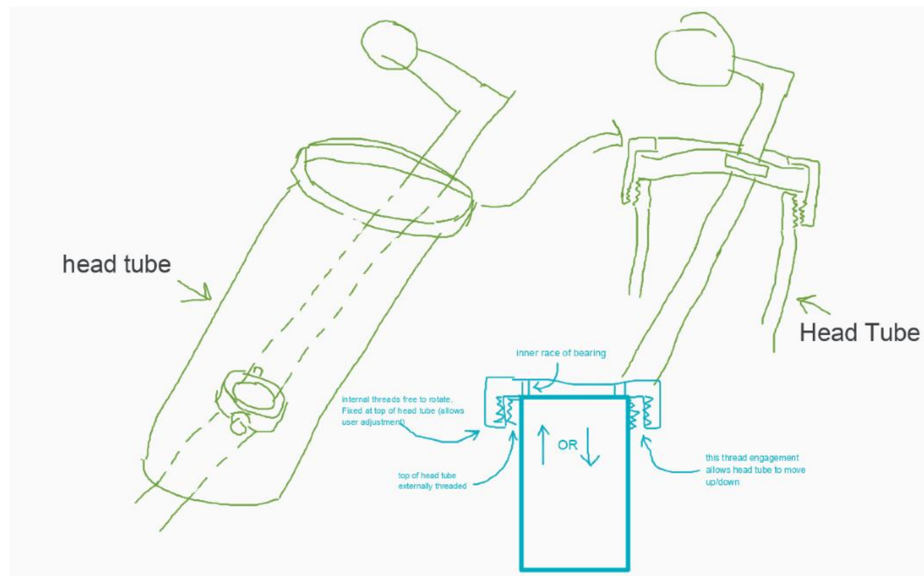


Josh’s Idea

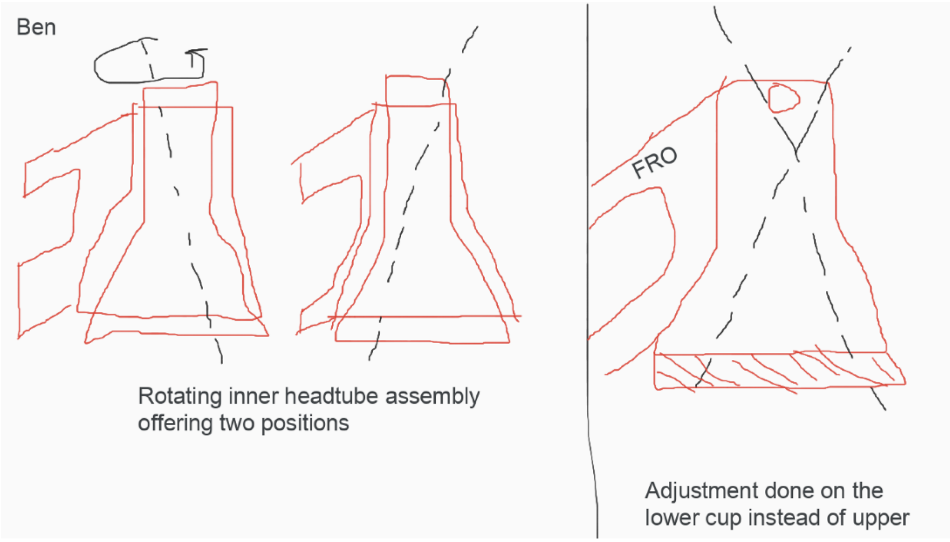

head tube
Head Tube

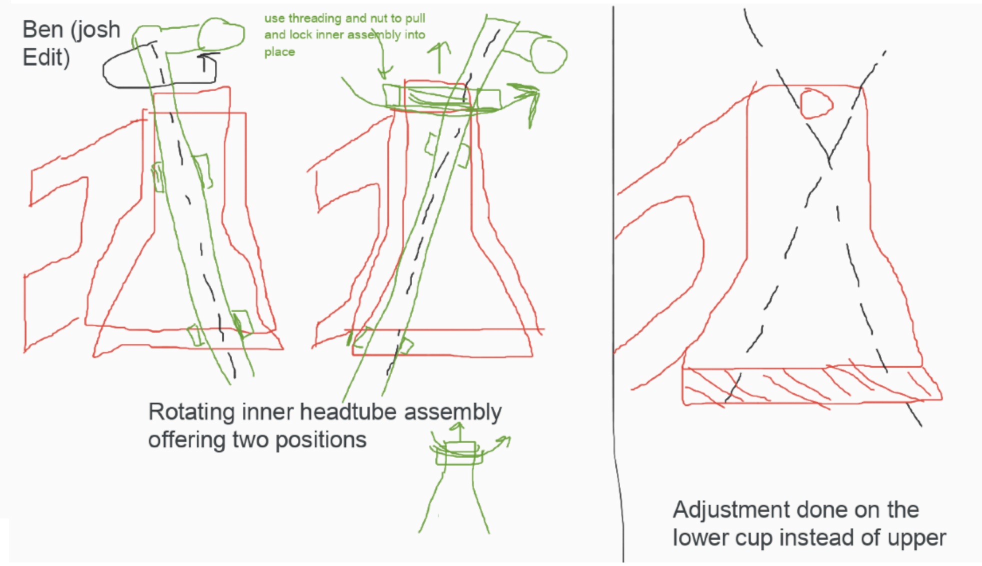

Ben Building on Josh
Instead of threading outside of headtube or pressfitting outside, use external cup on top.
This provides far more space than integrated or zero-stack, can then insert headset into extending cups.
RSL
TRD
SWORKS

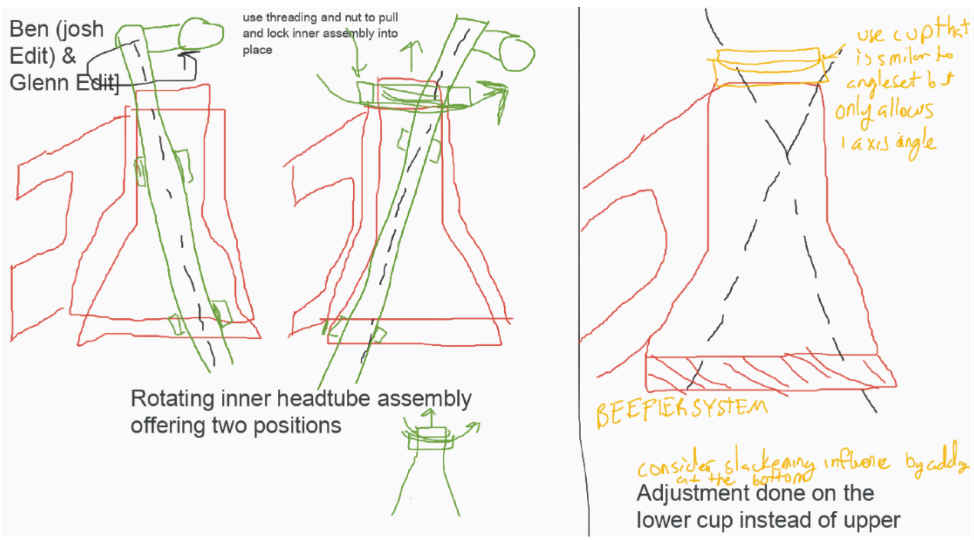

Josh [Glenn's Edit]
head tube
Head Tube
stem
spacer
threaded spacer connected to rod to compress assemble
threading outside of headtube may be difficult for consumer
For tapered steer tube, may need to lower to allow angle adjust

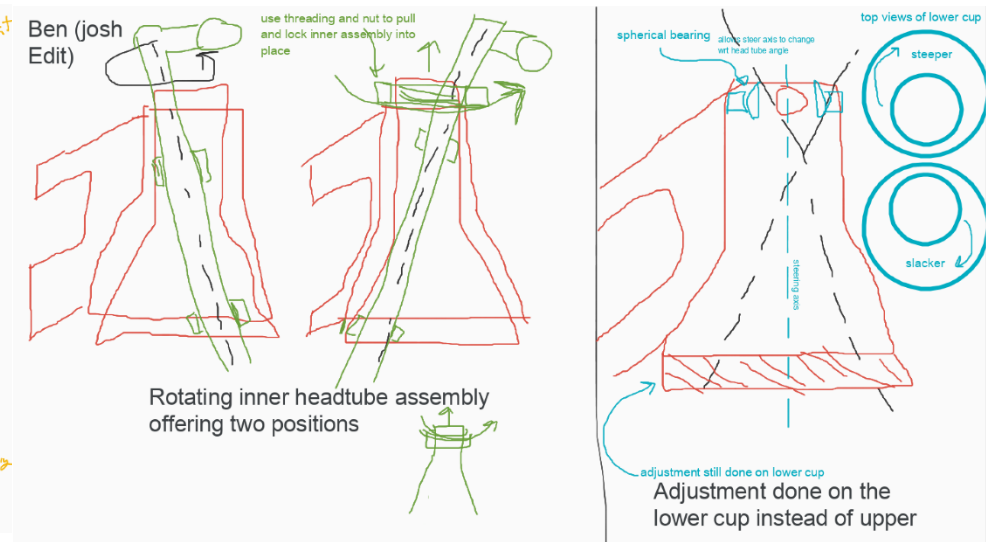

head tube
Head Tube
inner race of bearing
internal threads free to rotate. Fixed at top of head tube (allows user adjustment)
top of head tube externally threaded
OR
this thread engagement allows head tube to move up/down

Ben’s Idea

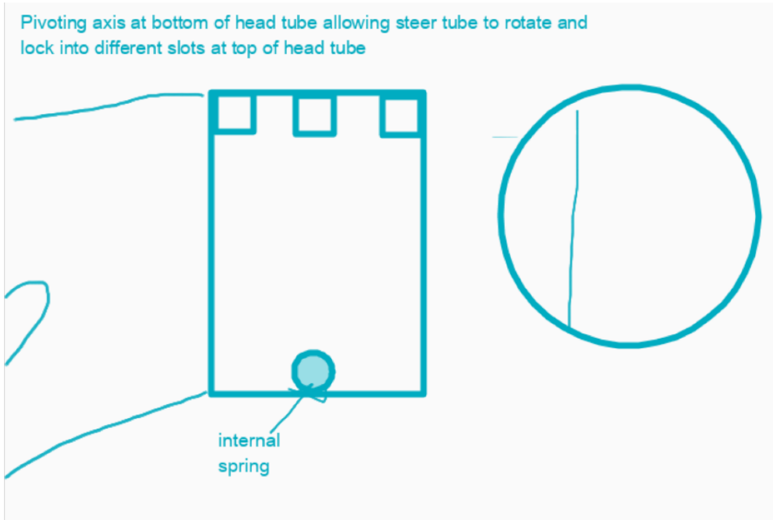

Ben
FRO
Rotating inner headtube assembly offering two positions
Adjustment done on the lower cup instead of upper


Ben (josh Edit)
use threading and nut to pull and lock inner assembly into place
Rotating inner headtube assembly offering two positions
Adjustment done on the lower cup instead of upper

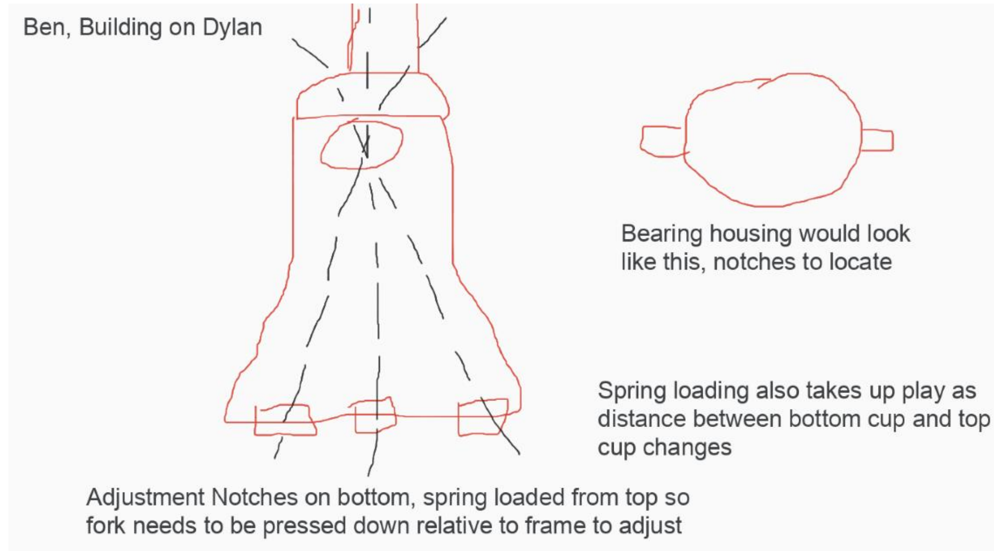

Ben (josh Edit) & Glenn Edit]
use threading and nut to pull and lock inner assembly into place
Rotating inner headtube assembly offering two positions
use cup that is similar to angleset but only allows 1 axis angle
BEEFIER SYSTEM
consider slackening influence by adding at the bottom
Adjustment done on the lower cup instead of upper


Ben (josh Edit)
use threading and nut to pull and lock inner assembly into place
Rotating inner headtube assembly offering two positions
spherical bearing
allows steer axis to change wrt head tube angle
top views of lower cup
steeper
slacker
steering axis
adjustment still done on lower cup
Adjustment done on the lower cup instead of upper

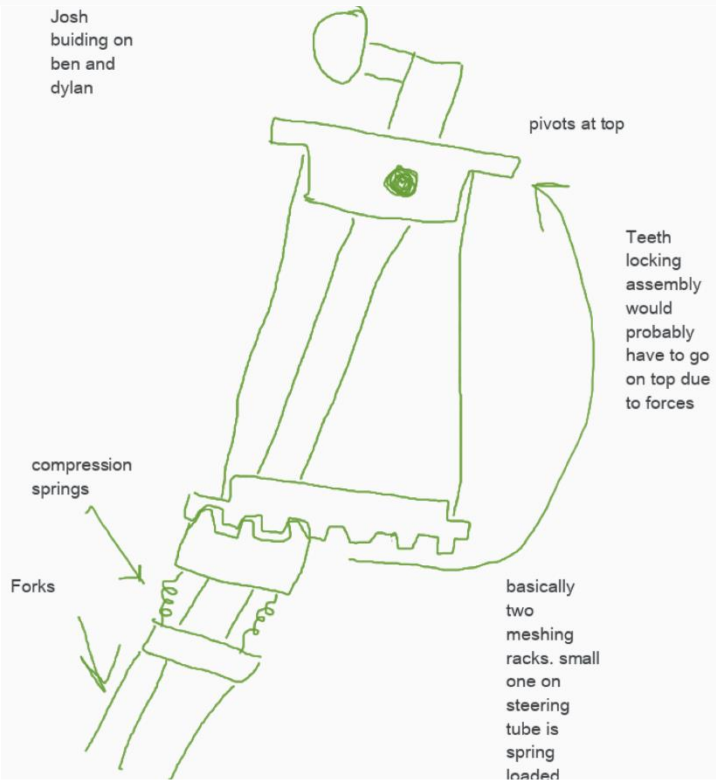
Dylan's Idea



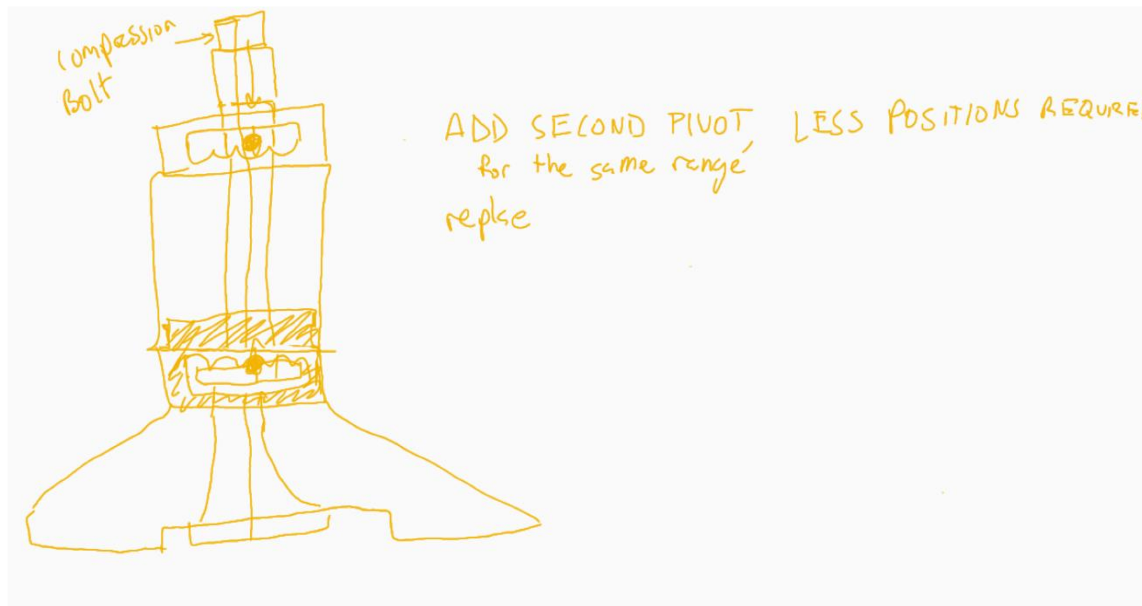
Pivoting axis at bottom of head tube allowing steer tube to rotate and lock into different slots at top of head tube
internal spring



Ben, Building on Dylan
Bearing housing would look like this, notches to locate
Spring loading also takes up play as distance between bottom cup and top cup changes
Adjustment Notches on bottom, spring loaded from top so fork needs to be pressed down relative to frame to adjust



Josh buiding on ben and dylan
pivots at top
Teeth locking assembly would probably have to go on top due to forces
compression springs
Forks
basically two meshing racks. small one on steering tube is spring loaded



compression Bolt
ADD SECOND PIVOT LESS POSITIONS REQURED
for the same range

Appendix G) Pugh Matrices

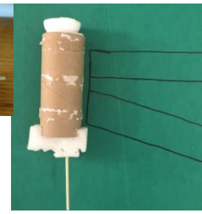
Function is preloading the assembly

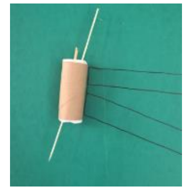
					
	Screws	Eccentric Notch/Slot Lock	Threaded Spacer	Over-Center Lock	External Threading on Cup
Tool Free Adjustment	Datum	+	+	+	+
Quick Adjustment		+	+	+	+
Durable		+	s	+	+
Light weight		-	-	-	-
Ease of Production		s	-	s	-
Silent, Creak free		+	s	+	s
Reliable		s	s	+	+
Totals		3	0	4	2

Function is Freely Adjusting

		Concept					
		VP Varial Spherical Bearing Bottom Cup	Rotating Eccentric Cups	Convex Cups	Pinned Pivoting Bearing Housing	Spherical Bearing (Top or Bottom Cup)	Inner Headtube Assembly
							
Criteria	Aesthetic/Low-Profile	Datum	+	S	S	S	-
	Multiple Adjustment Settings		-	S	S	S	-
	Ease of Production		S	+	+	S	+
	Range of Adjustment		+	S	S	S	+
	Adjustment Time		-	S	S	S	+
	Durability/Inherent Strength		+	-	-	S	+
	TOTAL		**1**	**0**	**0**	**0**	**2**

Function is Locating Mechanism

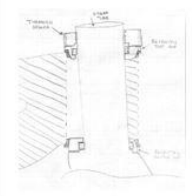
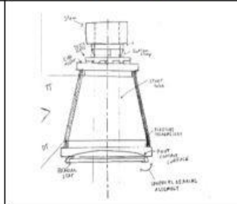
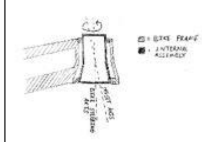
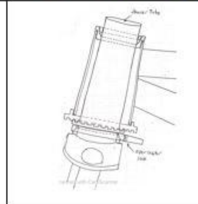
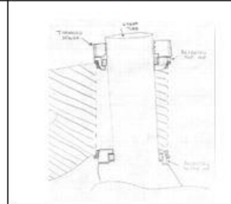
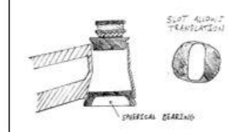





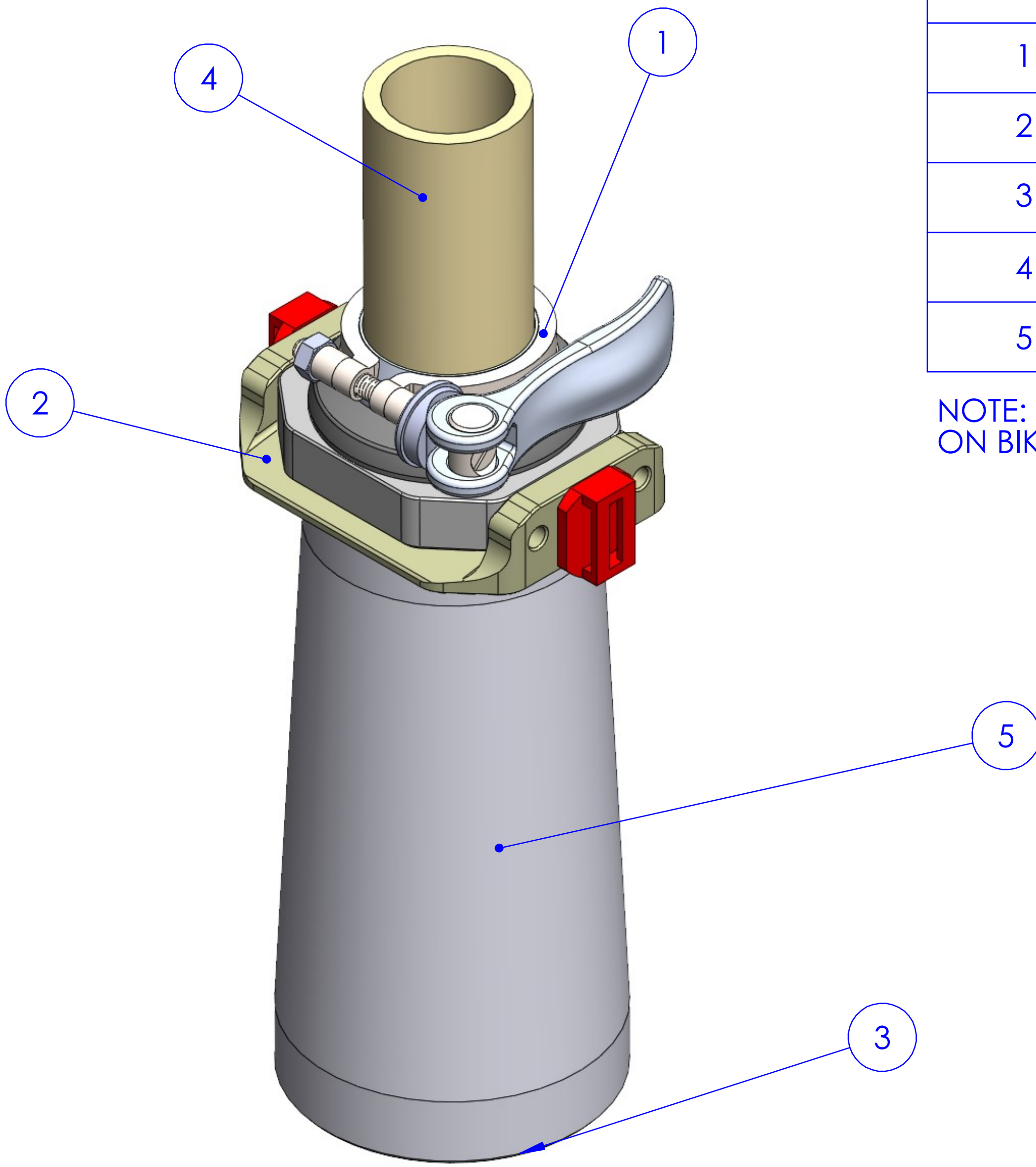
	VPVarial Eccentric Cup	Rotating eccentric cups	Bottom Notches/Referen	Bottom Pin on Notches	inner assembly	Indexed positions top	Top pin on notches
Tool Free Adjustment		+	+	+	+	+	+
Quick Adjustment		S	S	+	S	S	S
Durable		S	-	-	+	+	-
Light weight		S	+	+	-	S	S
Ease of Production	Datum	S	-	-	-	-	-
Silent, Creak free		S	+	S	-	+	+
Reliable		-	+	+	S	+	+
∑+		1	4	4	2	4	3
∑-		1	2	2	3	1	2
∑S		5	1	1	2	2	2

	VP Varial Headset	Eccentric Cups	Pin and Notches (Single Point)	Teeth (Multipoint)	Inner Assembly
Tool Free Adjustment	D A T U M	+	+	+	+
Quick Adjustment		+	+	+	+
Durable		S	-	S	+
Light weight		S	-	-	-
Ease of Production		S	-	-	-
Silent, Creak free		S	-	-	-
Reliable		S	-	-	-
TOTALS		**2**	**-3**	**-2**	**1**

Appendix H) Weighted Decision Matrix

		Idea 1	Idea 2	Idea 3	Idea 4	Idea 5	Idea 6
		Rotating Eccentric Cups with Over-Center Lock	Spherical Bottom Bearing with Over-Center Lock and Locating Teeth	Inner Headtube Assembly with Locating Notch/Slot	Spherical Top Bearing with Over-Center Lock and Locating Teeth	Rotating Eccentric Cups with Threaded Headset Spacer	Spherical Bottom Bearing with Threaded Spacer and Locating Teeth
							
Criteria	**Weight**	**Score**	**Score**	**Score**	**Score**	**Score**	**Score**
Tool-Free Adjustment	6%	5	5	5	5	5	5
Quick Adjustment	8%	2	4	5	4	1	3
Multiple Settings	8%	3	4	1	4	3	4
Wide Range of Adjustability	7%	5	4	4	4	5	4
Durable (Tough)	8%	3	3	3	2	3	3
Low-Profile	9%	4	4	4	4	4	4
Reliable (Holds Adjustment)	9%	5	4	5	4	5	4
Light Weight	5%	3	3	3	3	3	3
Low Risk	10%	5	4	5	3	4	4
Low Maintenance	9%	3	4	4	4	3	4
Functionality Identical to Normal Headset	8%	3	3	3	3	3	3
Ease of Production	5%	4	5	3	5	4	5
Silent, Creak Free	8%	3	5	4	5	3	5
Totals		**3.69**	**3.96**	**3.82**	**3.79**	**3.51**	**3.88**

Assembly Level	Part Number	Description				Quantity	Cost	Source	More Information
		Level 0	Level 1	Level 2	Level 3				
0	1000	Final Assembly				1			
1	1100		Top Headset Cup Assembly			1			
2	1110			Top Headset Cup		1	-	Custom	CNC Milled from 7075 Al
2	1120			Top Bearing Housing		1	-	Custom	CNC Milled from 7075 Al
2	1130			Top Bearing		1	$20	Enduro Bearings	ACB 3645 BOCC
2	1140			Locating Pin Clip		1			
3	1141				Pins	2	$1	McMaster Carr	Purchased Alloy steel stock
3	1142				Retention Strap	1	$5	Amazon.com	Rubber/Velcro band
2	1150			Compression Ring		1	$5	Cane Creek	AAA0001B
2	1160			Dust Cover		1	$14	Cane Creek	BAA0726K
2	1170			Shim Spacer		1	$3	Cane Creek	HSS2050
1	1200		Compression Assembly			1			
2	1210			One-Up EDC Preload Kit Top Ring		1	$20-30	Backcountry.com	Item #OUC0013
2	1220			One-Up EDC Preload Kit Bottom Ring		1		Jensonusa.com	Item #: TL001008
2	1230			Cam Handle		1	$13.48	McMaster Carr	Part # 5720K281
2	1240			Cam Spacer		1	$1.38	McMaster Carr	Part # 92871A308
2	1250			Nut Spacer		1	$1.38	McMaster Carr	Part # 94669A008
2	1260			Nut		1	$0.20	Ace Hardware	M4
1	1300		Bottom Headset Cup Assembly			1			
2	1310			Bottom Headset Cup		1	-	Custom	From donated stock
2	1320			Bottom Bearing Housing		1	-	Custom	From donated stock
2	1330			Bottom Bearing		1	$30	Enduro Bearings	ACB 6808 SS
2	1340			Crown Race		1	$12	Cane Creek	BAA0173A
0	2000	Testing Fixture Assembly				1			
1	2100		Upper Yoke			1	-	Custom	From donated stock
1	2200		Bottom Tang			1	-	Custom	From donated stock
1	2300		Slack Bearing Spacer			1	-	Custom	From donated stock
	2400		Neutral Bearing Spacer			1	-	Custom	From donated stock
1	2500		Bolt			1	$1.00	Ace Hardware	
1	2600		Washer			1	$0.25	Ace Hardware	
1	2700		Nut			1	$0.50	Ace Hardware	
2	2800		Pin Design			2	-	Custom	From donated stock



ITEM NO.	PART NO.	DESCRIPTION
1	1200	Preload Assembly
2	1100	Top Headset Cup Assembly
3	1300	Bottom Headset Cup Assembly
4	-	Steerer Tube
5	-	Head Tube

NOTE: HEAD TUBE AND STEERER TUBE ARE EXISTING ON BIKE FRAME AND NOT PURCHASED NOR DESIGNED

F64 Adjustable Head Tube Angle Headset			Title: Full Assembly	Drwn. By: Josh Martin
	Dwg. #: 1000		Date: 5/31/2021 Scale: 4:5	Checked by: Ben Harper

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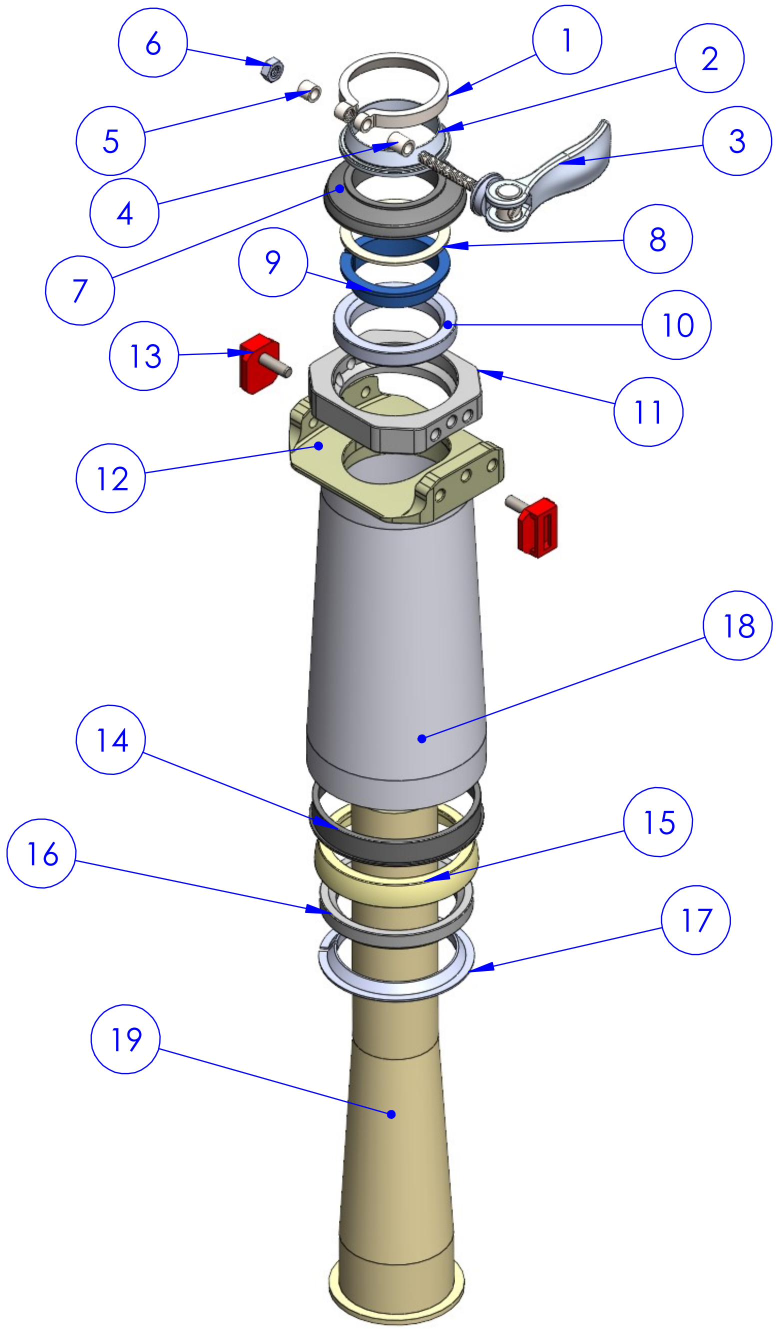


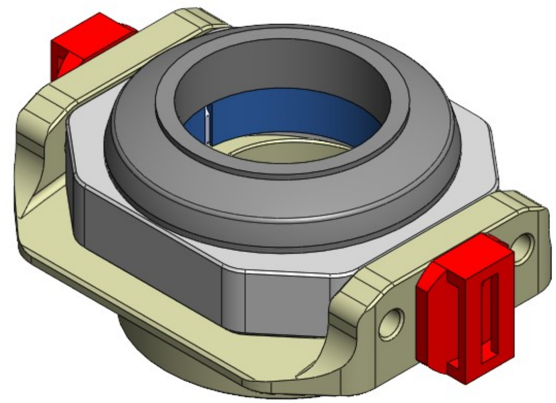
ITEMNO.	PART NO.	DESCRIPTION
1	1210	One-Up Stem Preload Kit Upper Ring
2	1220	One-Up Stem Preload Kit Bottom RIng
3	1230	Cam Handle
4	1240	Cam Spacer
5	1250	Nut Spacer
6	1260	M4 Nut
7	1160	Dust Cover
8	1170	Shim Spacer
9	1150	Compression Ring
10	1130	Top 44mm Bearing
11	1120	Top Bearing Housing
12	1110	Top Headset Cup
13	1140	Locating Pin Clip
14	1310	Bottom Headset Cup
15	1320	Bottom Bearing Housing
16	1330	Bottom 51mm Bearing
17	1340	Crown Race
18	-	Headtube
19	-	Steerer Tube

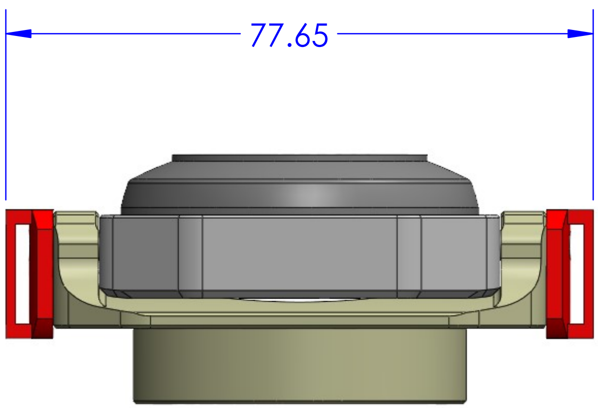
NOTE:
1. HEAD TUBE AND STEERER TUBE ARE EXISTING ON BIKE FRAME AND NOT PURCHASED NOR DESIGNED
2. VELCRO IS A PART OF PIN SYSTEM. LOOPED THROUGH THE TWO PIN CLIPS PICTURED

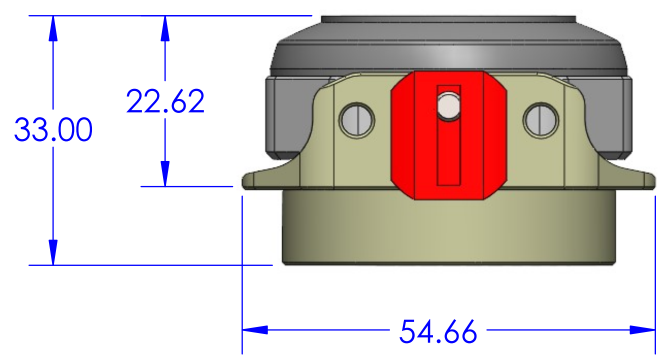
F64 Adjustable Head Tube Angle Headset			Title: Full Assembly Exploded		Drwn. By: Josh Martin
	Dwg. #: E1000		Date: 5/31/2021	Scale: 2:5	Checked by: Ben Harper

SOLIDWORKS Educational Product. For Instructional Use Only.

NOTE:
1. ALL DIMENSIONS IN MILLIMETERS







F64 Adjustable Head Tube Angle Headset			Title: Top Headset Cup Assembly	Drwn. By: Josh Martin
	Dwg. #: 1100		Date: 5/31/2021 | Scale: 1:1	Checked by: Ben Harper

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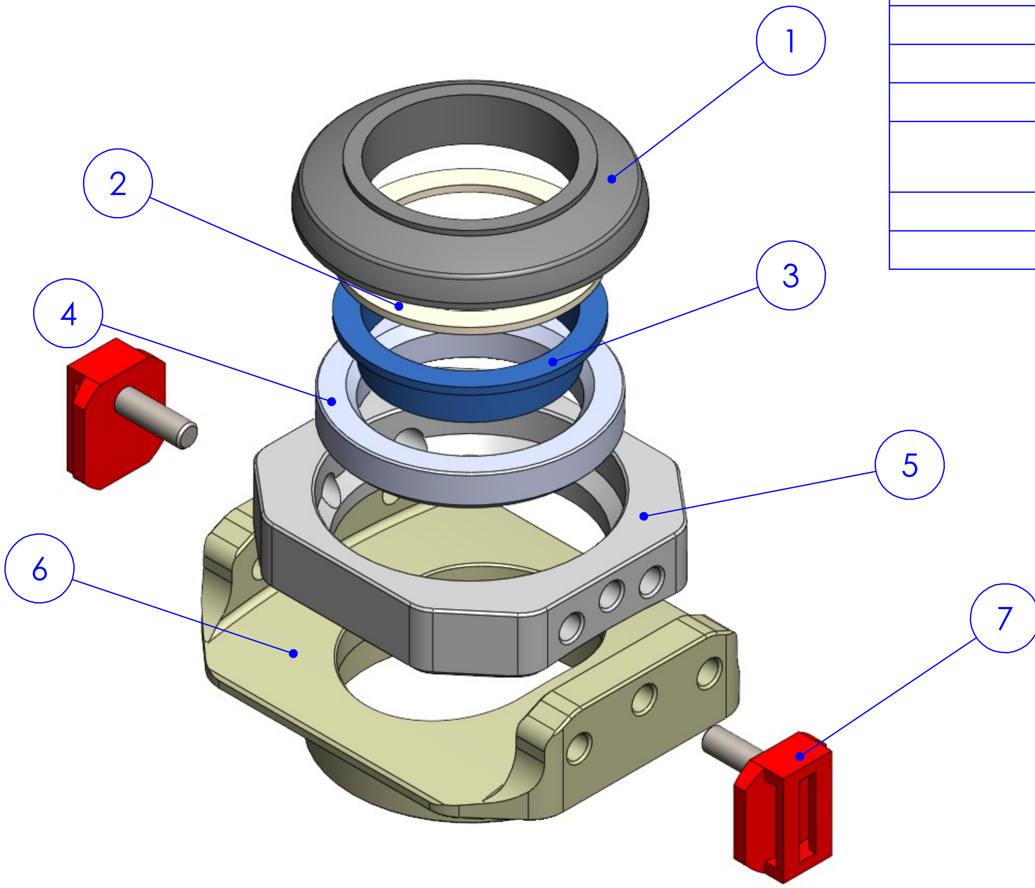

ITEM NO.	PART NO.	DESCRIPTION
1	1160	Dust Cover
2	1170	Shim Spacer
3	1150	Compression Ring
4	1130	Top 44 mm Bearing
5	1120	Top Bearing Housing
6	1110	Top Headset Cup
7	1140	Locating Pins

F64 Adjustable Head Tube Angle Headset			Title: Top Headset Cup Assembly	Drwn. By: Josh Martin
	Dwg. #: E1100		Date: 5/31/2021 Scale: 1:1	Checked by: Ben Harper

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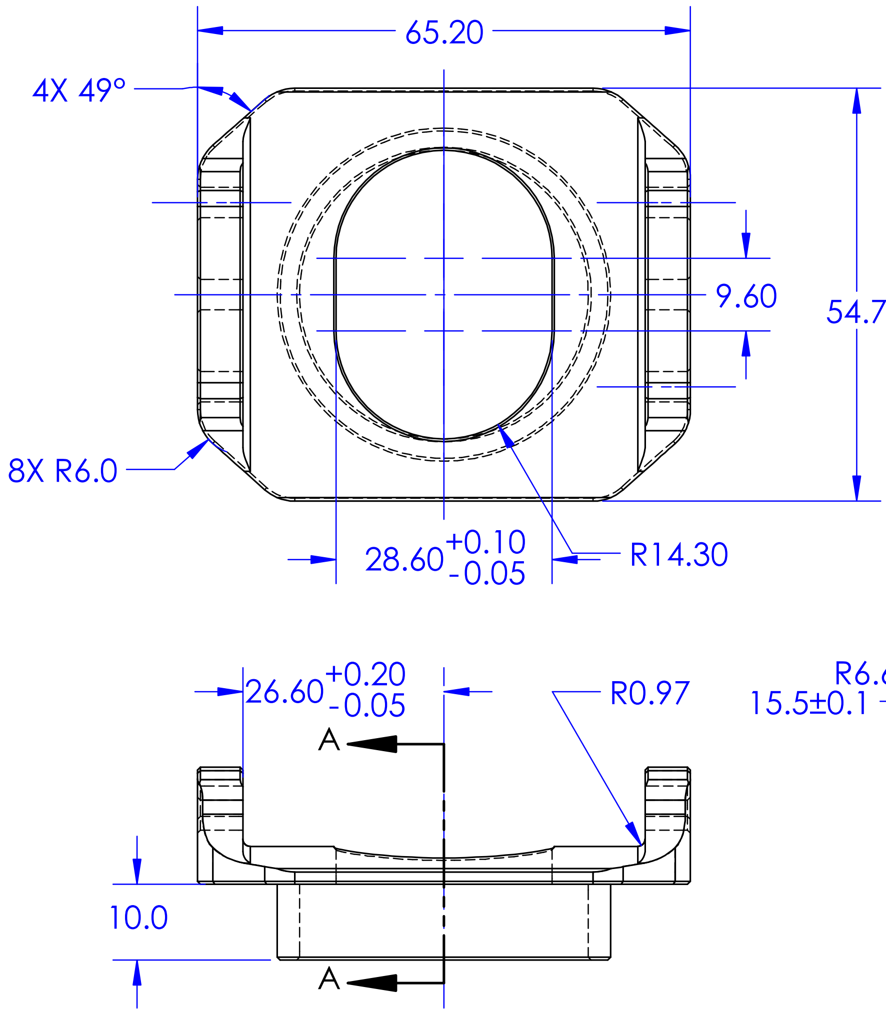

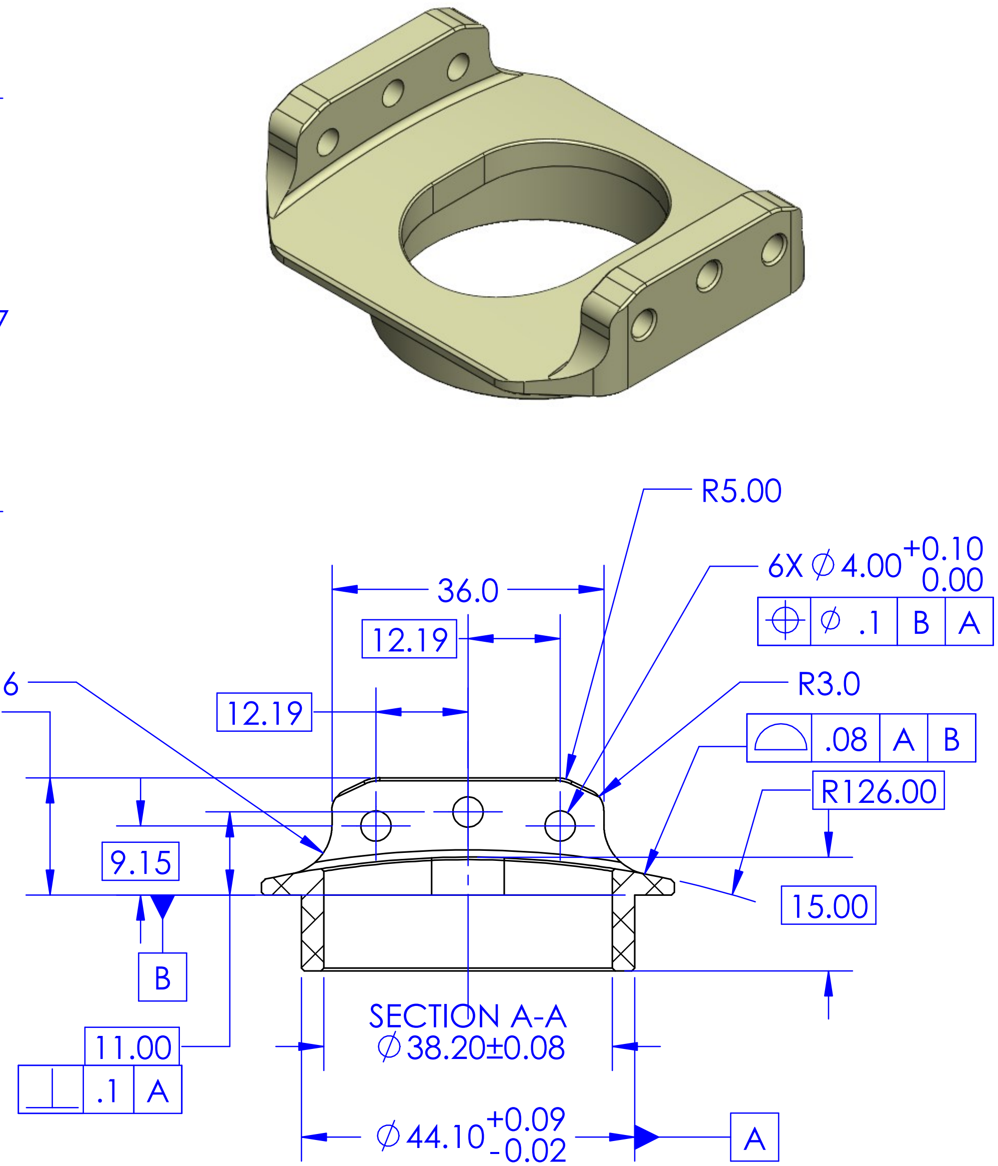

NOTE:
UNLESS OTHERWISED SPECIFIED
1. BREAK EDGES 0.381 MM X 45° (.015 IN X 45°) MAX
2. DIMENSIONS ARE IN MILLIMETERS
3. TOLERANCES:
   ONE PLACE DECIMAL ± .1
   TWO PLACE DECIMAL ± .01
   THREE PLACE DECIMAL ± .005

F64 Adjustable Head Tube Angle Headset			Title: Top Cup		Drwn. By: Glenn Petersen
	Dwg. #: 1110		Date: 3/4/2021	Scale: 1:1	Chkd. By: Josh Martin

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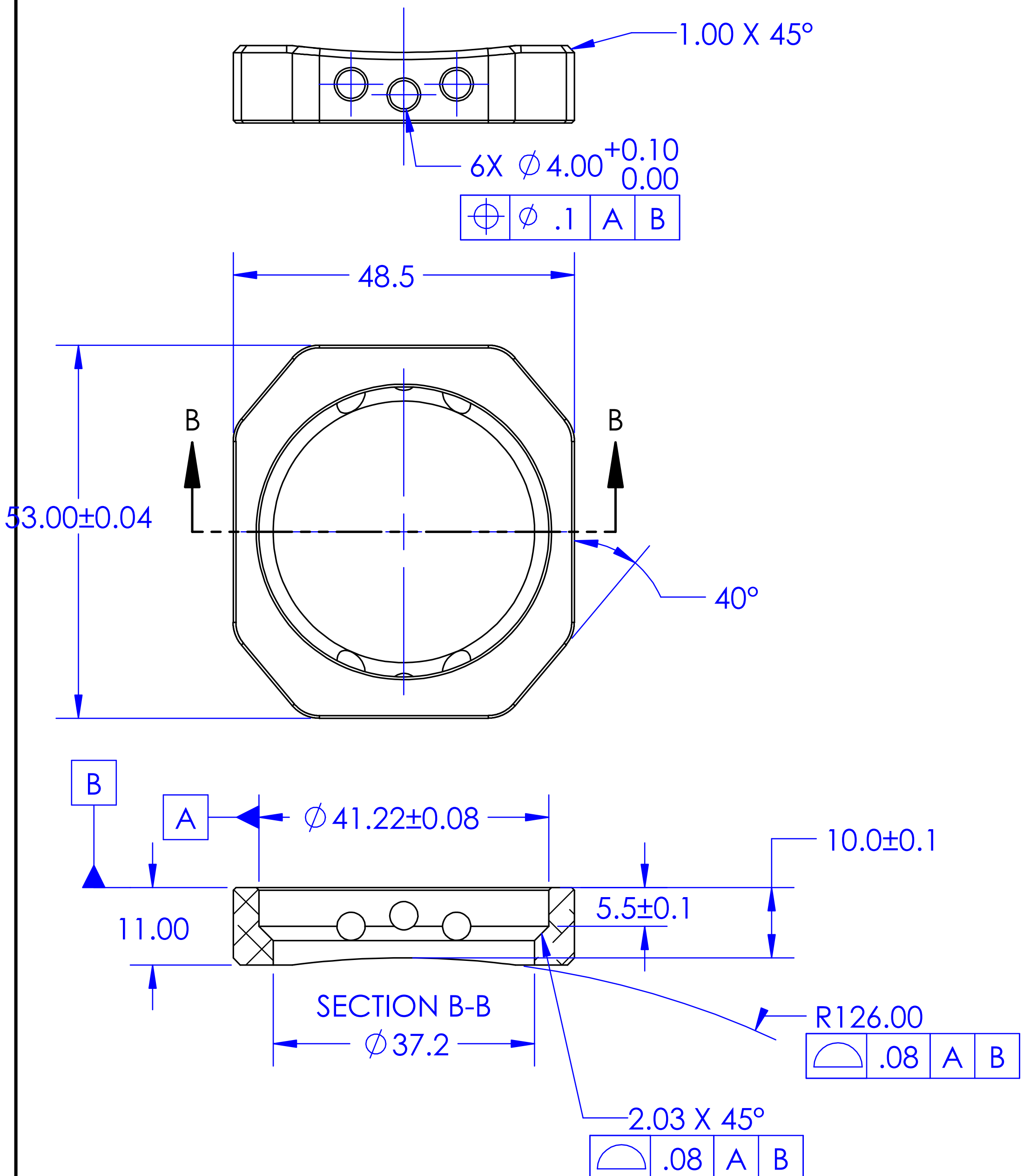

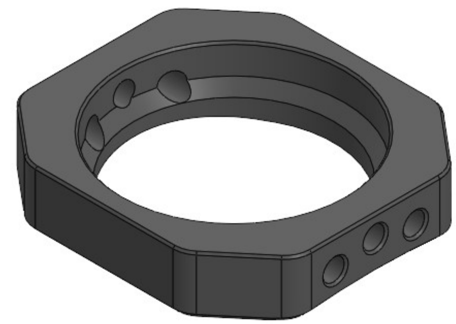

NOTE:
UNLESS OTHERWISED SPECIFIED
1. BREAK EDGES 0.381 MM X 45° (.015 IN X 45°) MAX
2. DIMENSIONS ARE IN MILLIMETERS
3. TOLERANCES:
   ONE PLACE DECIMAL ± .1
   TWO PLACE DECIMAL ± .01
   THREE PLACE DECIMAL ± .005

F64 Adjustable Head Tube Angle Headset			Title: Top Bearing Housing	Drwn. By: Glenn Petersen
	Dwg. #: 1120		Date: 3/4/2021 | Scale: 1:1	Chkd. By: Josh Martin

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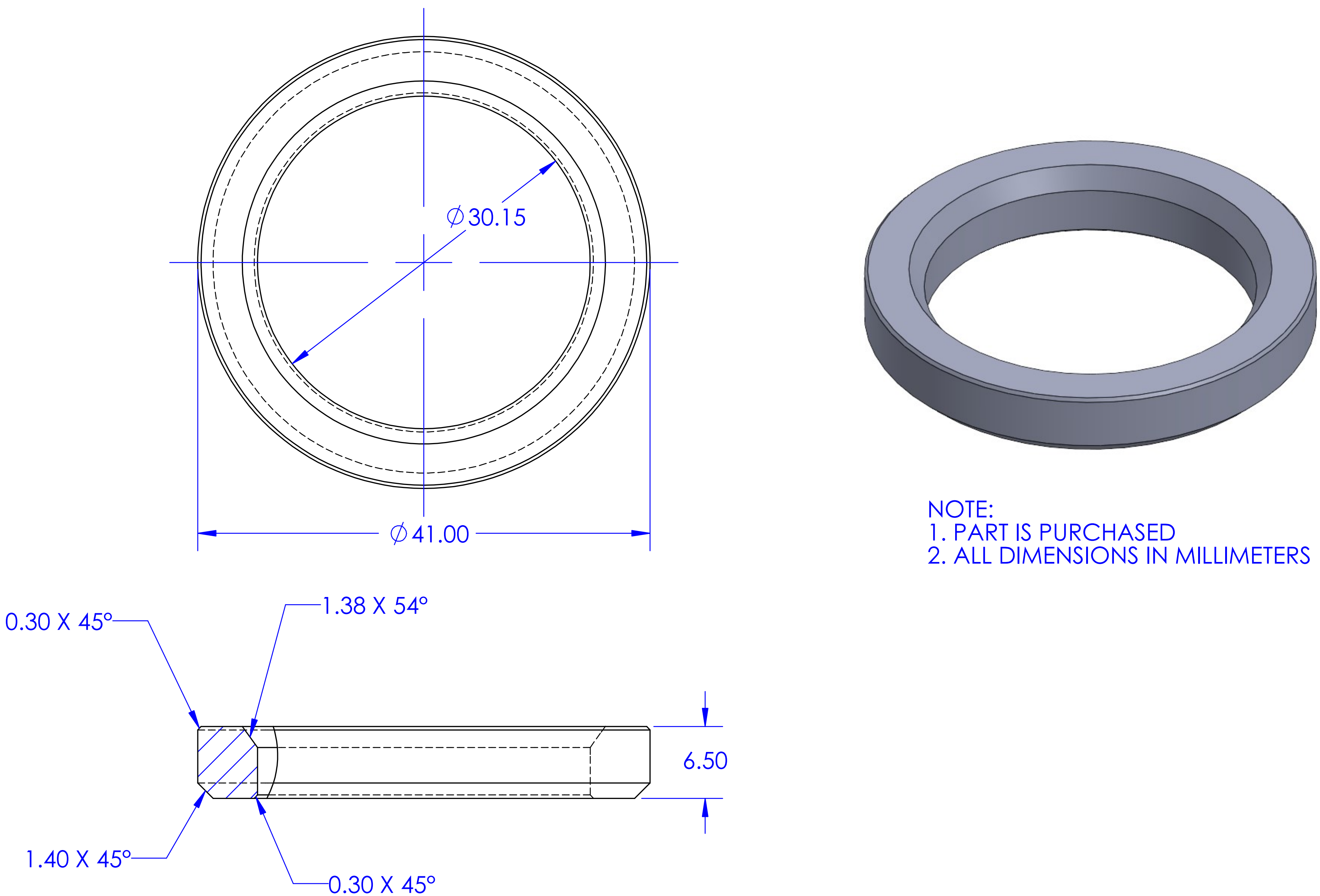

NOTE:
1. PART IS PURCHASED
2. ALL DIMENSIONS IN MILLIMETERS

F64 Adjustable Head Tube Angle Headset			Title: Top Bearing		Drwn. By: Josh Martin
	Dwg. #: 1130		Date: 2/5/2021	Scale: 2:1	Checked by: Ben Harper

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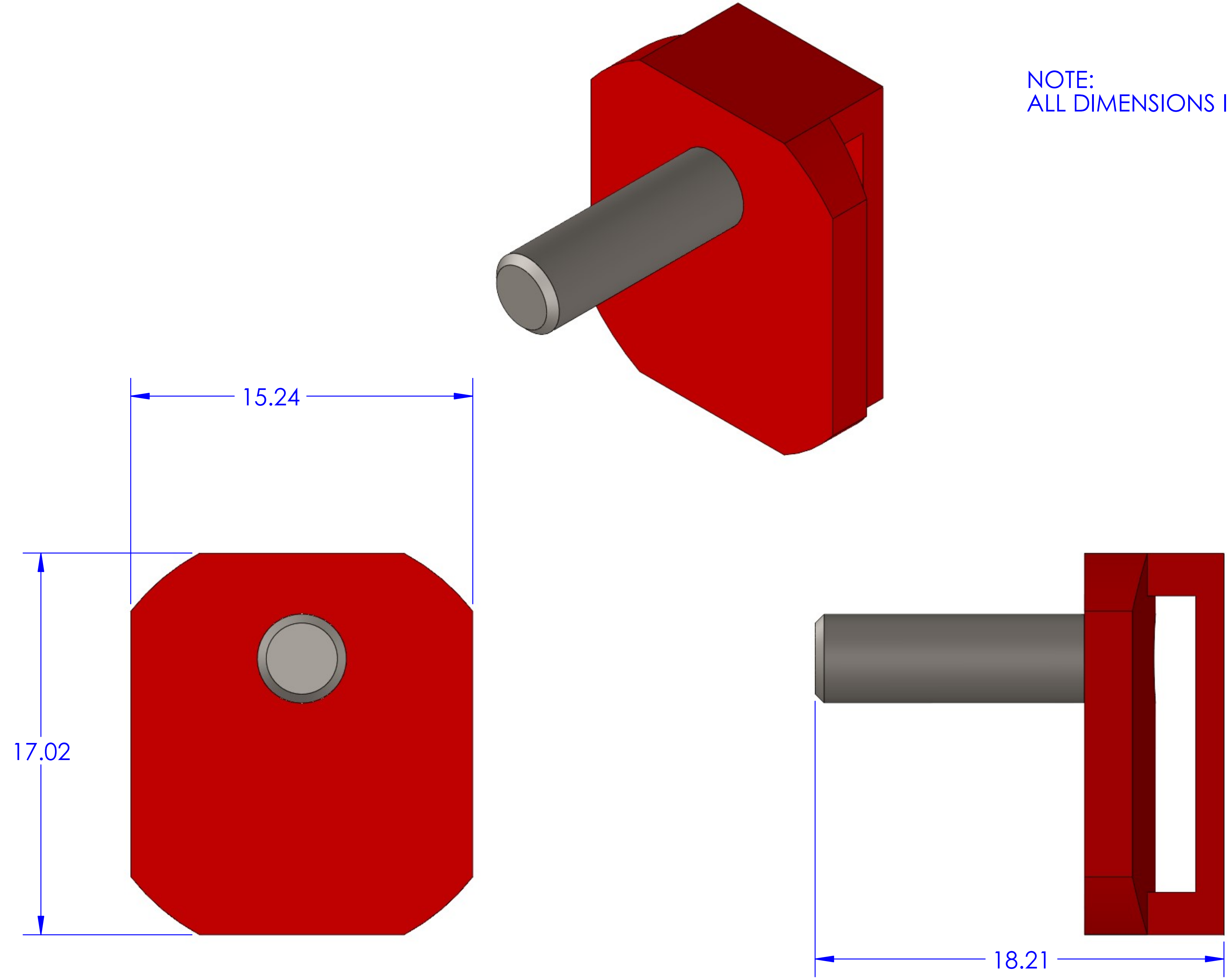
NOTE:
ALL DIMENSIONS IN MILLIMETERS



F64 Adjustable Head Tube Angle Headset			Title: Pin Connector	Drwn. By: Josh Martin
	Dwg. #: 1140		Date: 5/31/2021 / Scale: 4:1	Checked by: Ben Harper

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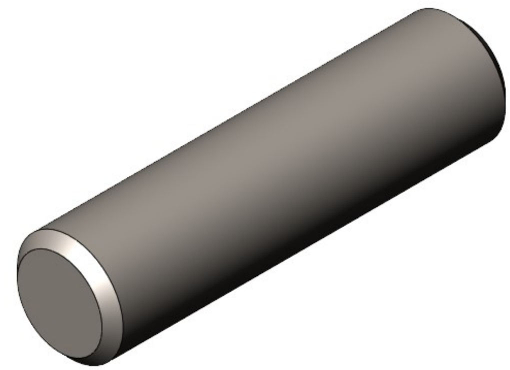
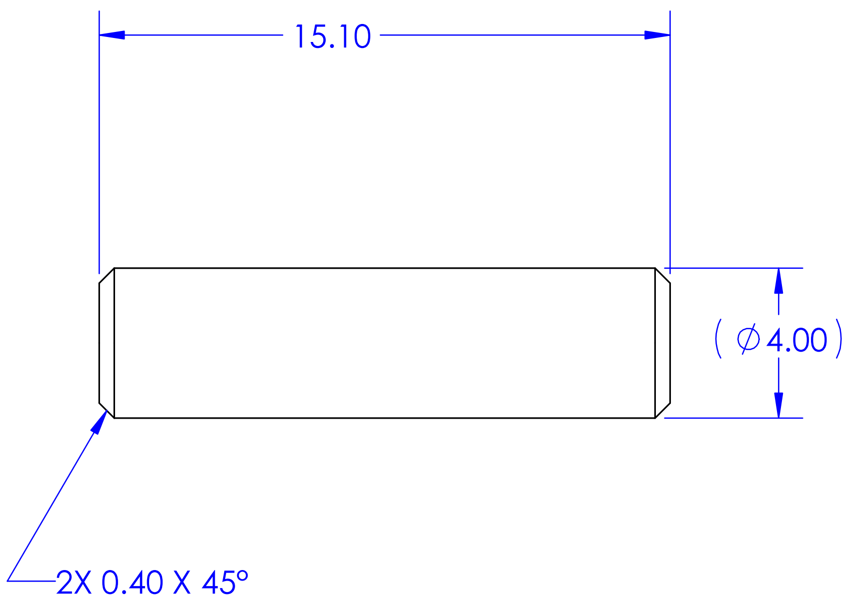
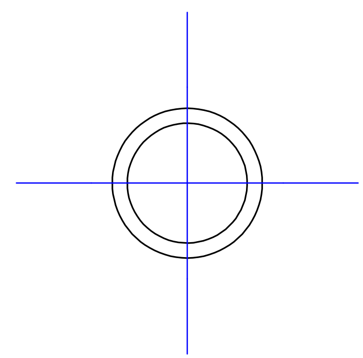
NOTE:
1. PART IS PURCHASED AS BAR STOCK AND CUT TO LENGTH
2. ALL DIMENSIONS IN MILLIMETERS







F64 Adjustable Head Tube Angle Headset			Title: Pin	Drwn. By: Josh Martin
	Dwg. #: 1141		Date: 2/5/2021 / Scale: 5:1	Checked by: Ben Harper

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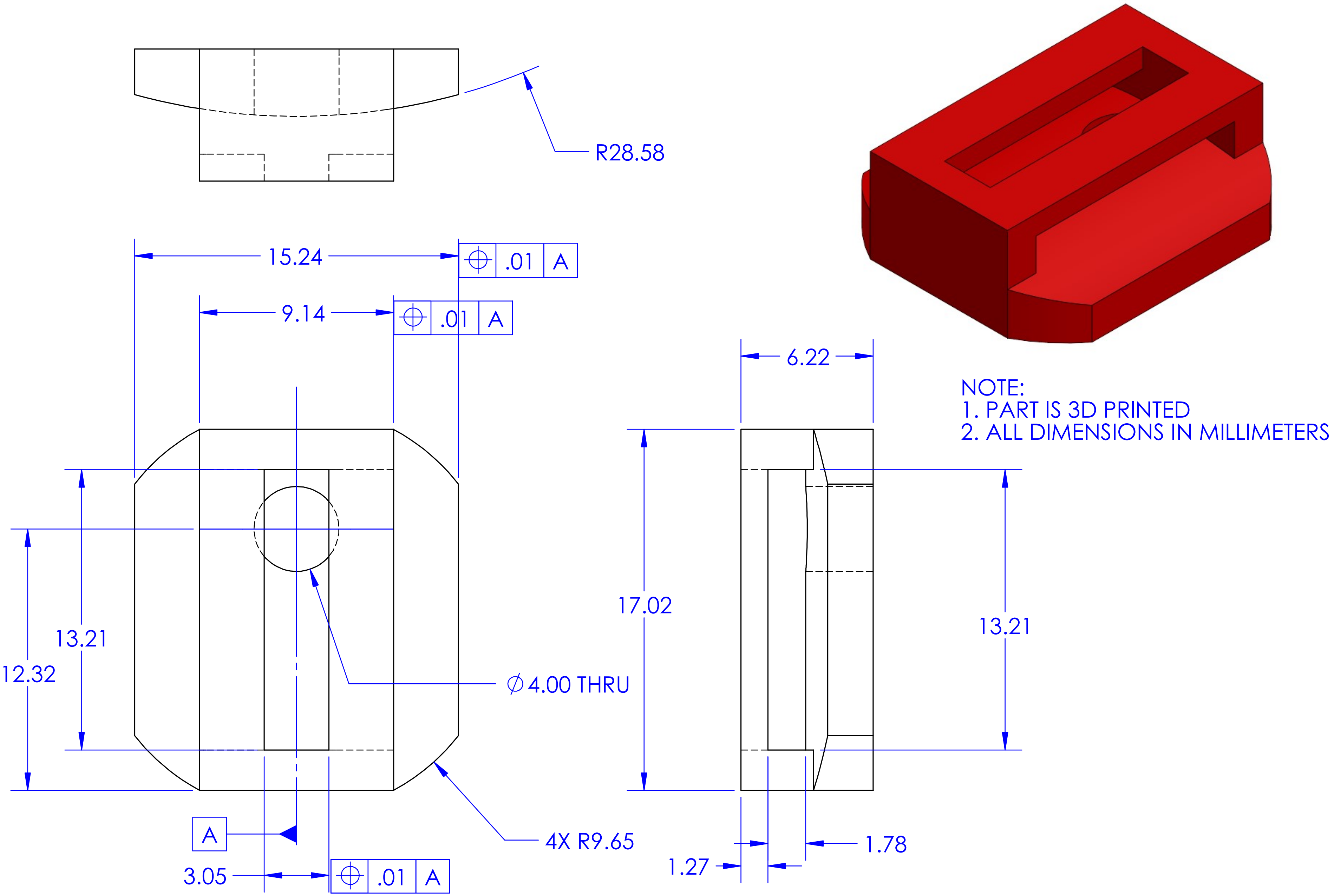

NOTE:
1. PART IS 3D PRINTED
2. ALL DIMENSIONS IN MILLIMETERS

F64 Adjustable Head Tube Angle Headset			Title: Pin Connector		Drwn. By: Josh Martin
	Dwg. #: 1142		Date: 5/31/2021	Scale: 4:1	Chkd. By: ME STAFF

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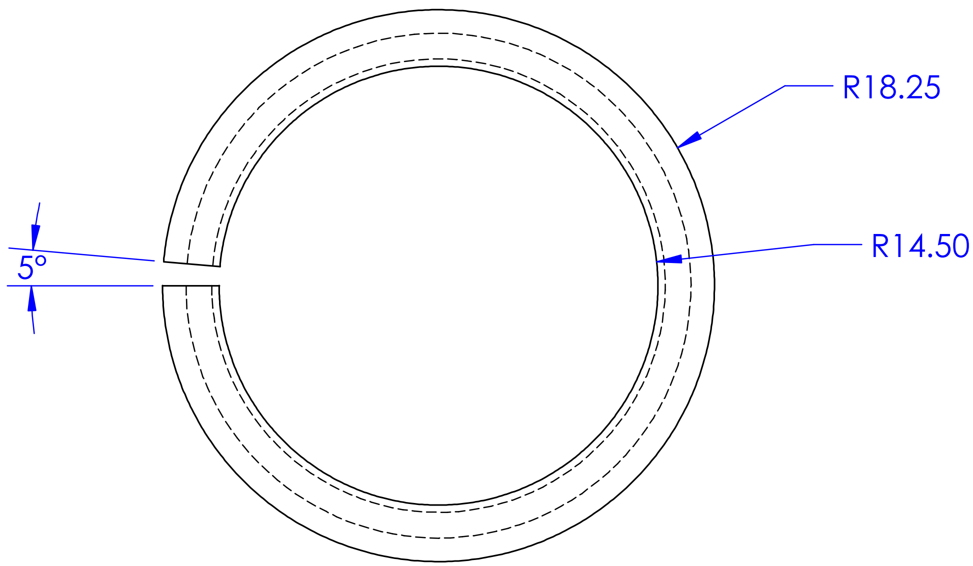
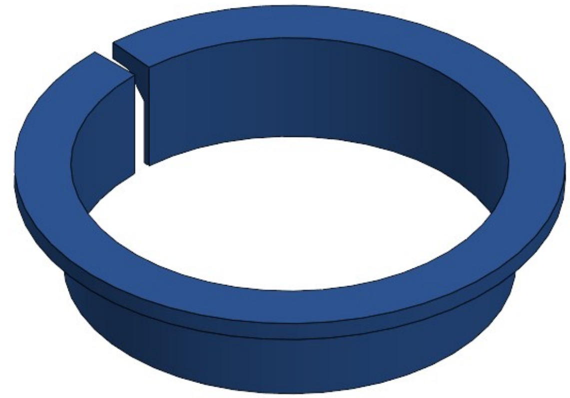
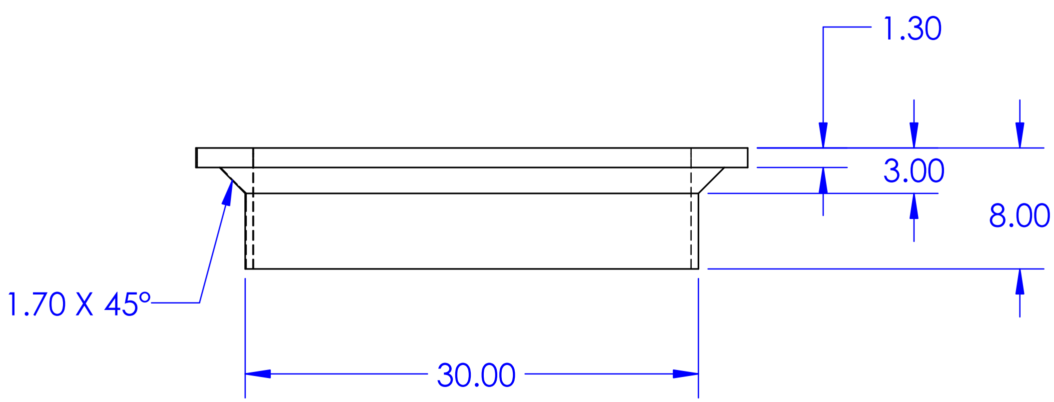




NOTE:
1. PART IS PURCHASED
2. ALL DIMENSIONS IN MILLIMETERS



F64 Adjustable Head Tube Angle Headset			Title: Compression Ring	Drwn. By: Josh Martin
	Dwg. #: 1150		Date: 2/5/2021 / Scale: 2:1	Checked by: Dylan Prins

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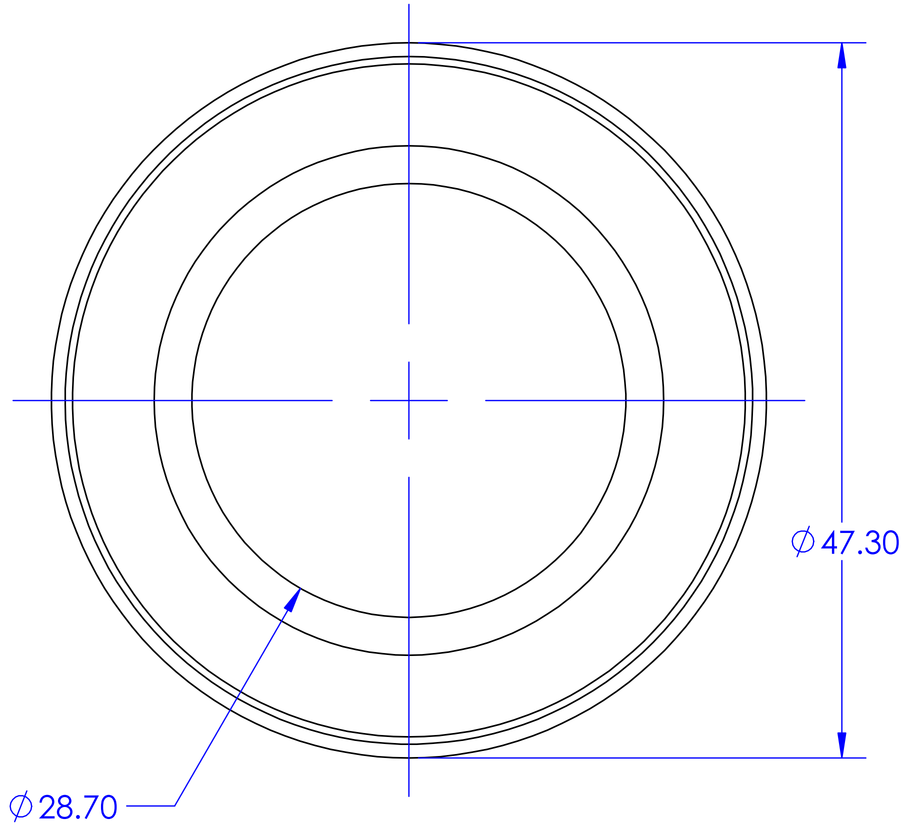
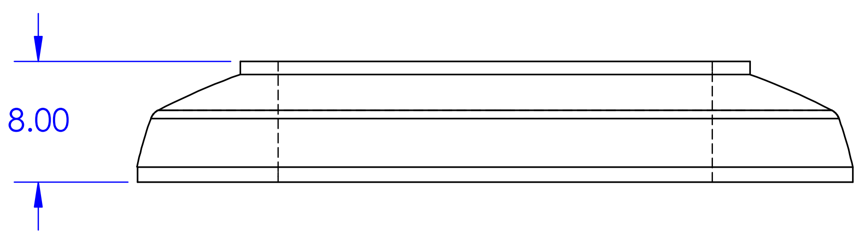


NOTE:
1. PART IS PURCHASED
2. ALL DIMENSIONS IN MILLIMETERS



F64 Adjustable Head Tube Angle Headset			Title: Dust Cover		Drwn. By: Josh Martin
	Dwg. #: 1160		Date: 2/5/2021	Scale: 2:1	Checked by: Dylan Prins

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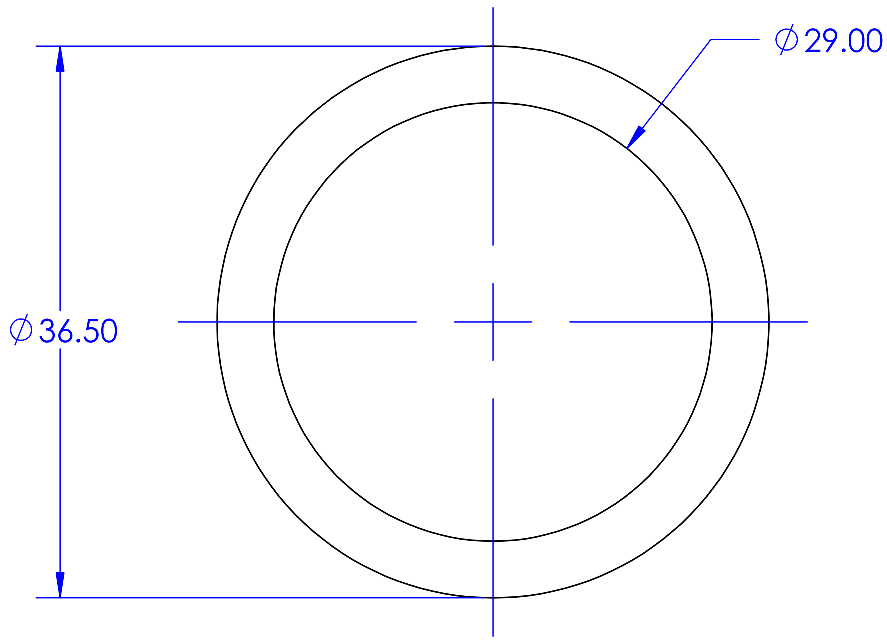

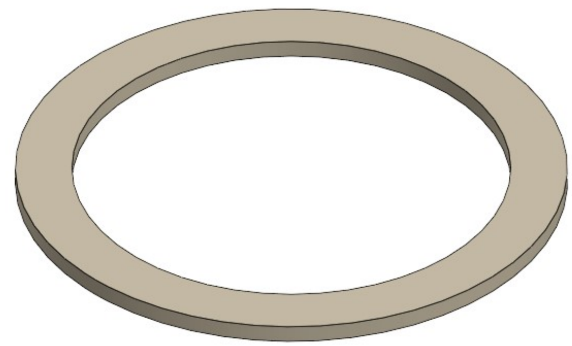

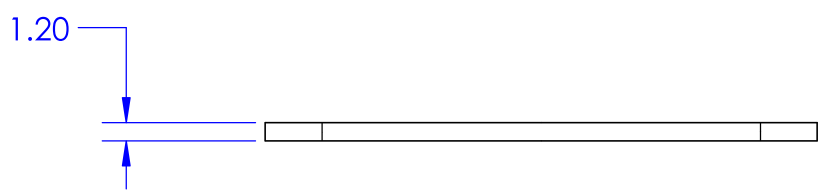

NOTE:
1. PART IS PURCHASED
2. ALL DIMENSIONS IN MILLIMETERS

F64 Adjustable Head Tube Angle Headset			Title: Shim Spacer		Drwn. By: Josh Martin
	Dwg. #: 1170		Date: 2/5/2021	Scale: 2:1	Checked by: Dylan Prins

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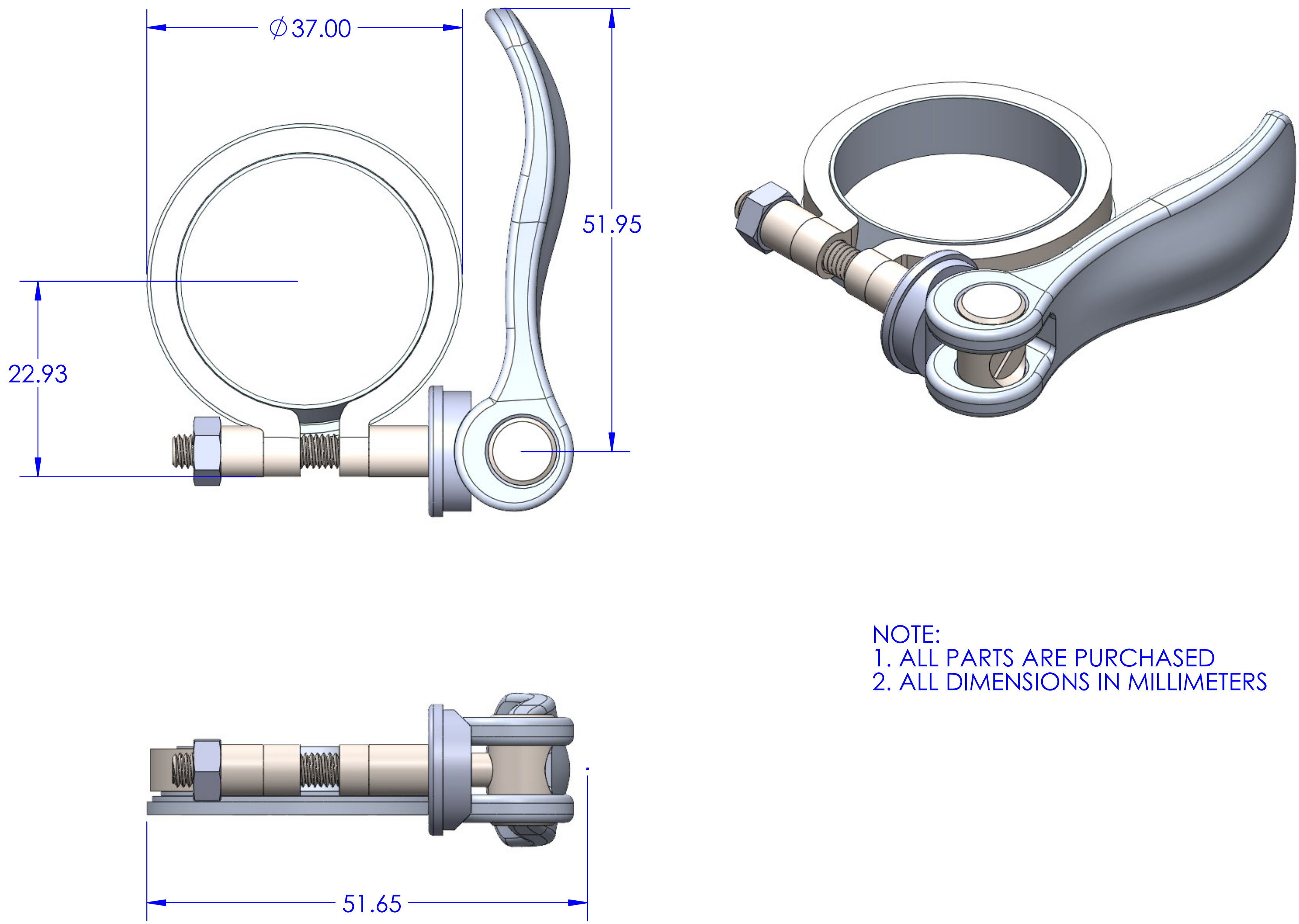

NOTE:
1. ALL PARTS ARE PURCHASED
2. ALL DIMENSIONS IN MILLIMETERS

F64 Adjustable Head Tube Angle Headset			Title: Compression Assembly		Drwn. By: Josh Martin
	Dwg. #: 1200		Date: 2/4/2021	Scale: 3:2	Checked by: Dylan Prins

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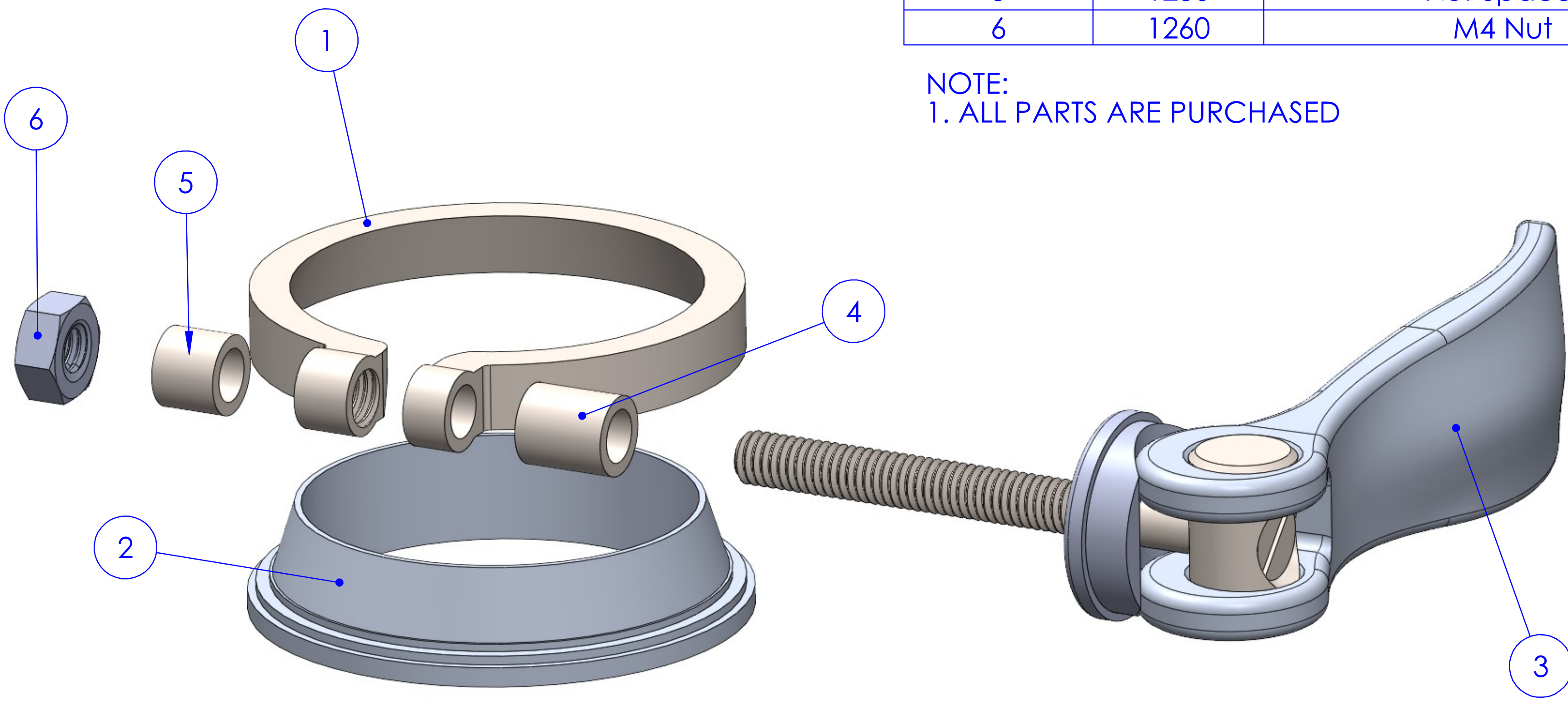
ITEM NO.	PART NO.	DESCRIPTION
1	1210	One-Up Preload Kit Top RIng
2	1220	One-Up Preload Kit Bottom Ring
3	1230	Cam Handle
4	1240	Cam Spacer
5	1250	Nut Spacer
6	1260	M4 Nut

NOTE:
1. ALL PARTS ARE PURCHASED



F64 Adjustable Head Tube Angle Headset			Title: Compression Assembly		Drwn. By: Josh Martin
	Dwg. #: E1200		Date: 2/3/2021	Scale: 2:1	Checked by: Dylan Prins

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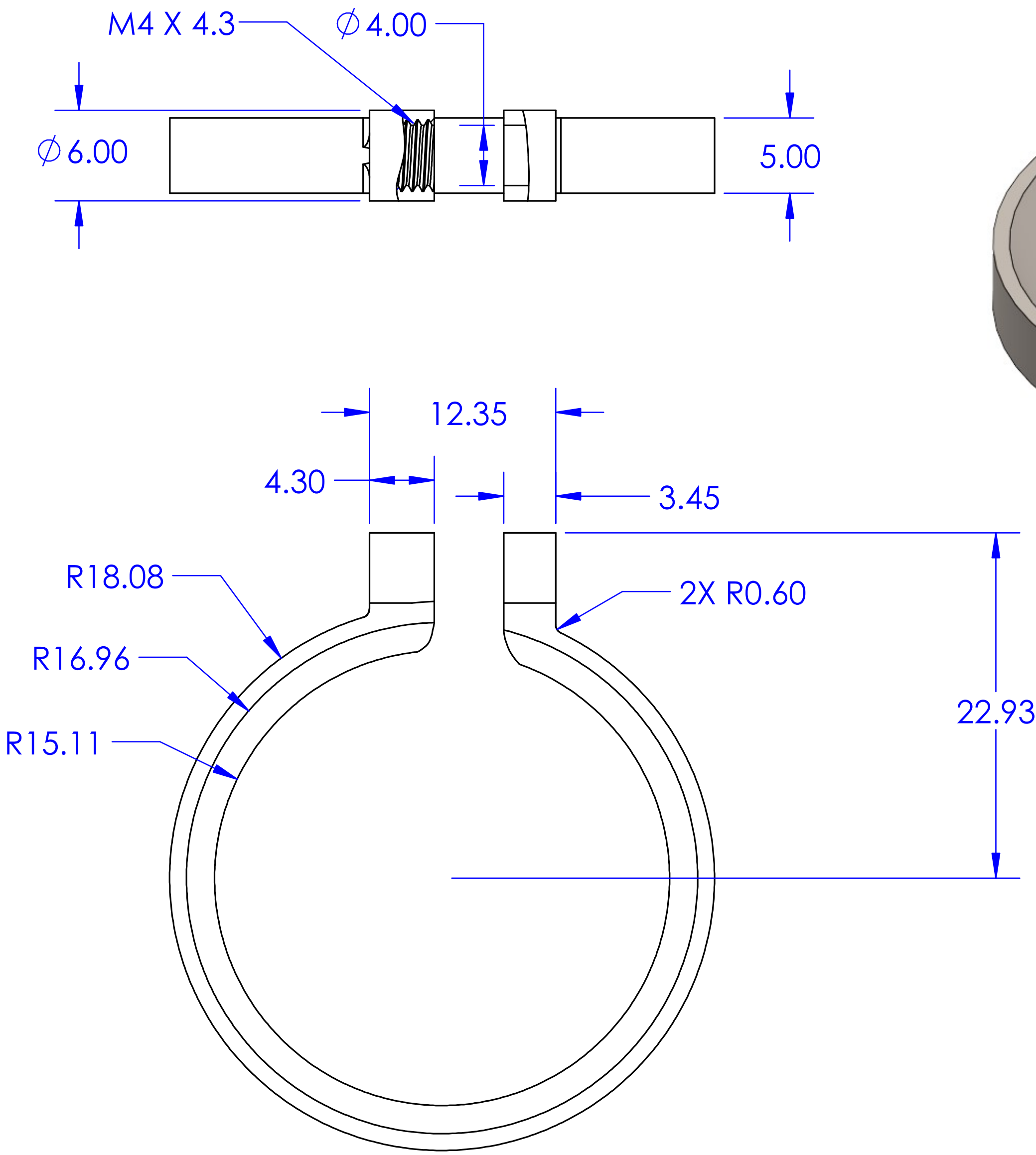

NOTE:
1. PART IS PURCHASED
2. ALL DIMENSIONS IN MILLIMETERS

F64 Adjustable Head Tube Angle Headset			Title: Top Ring		Drwn. By: Josh Martin
	Dwg. #: 1210		Date: 2/4/2021	Scale: 2:1	Checked by: Dylan Prins

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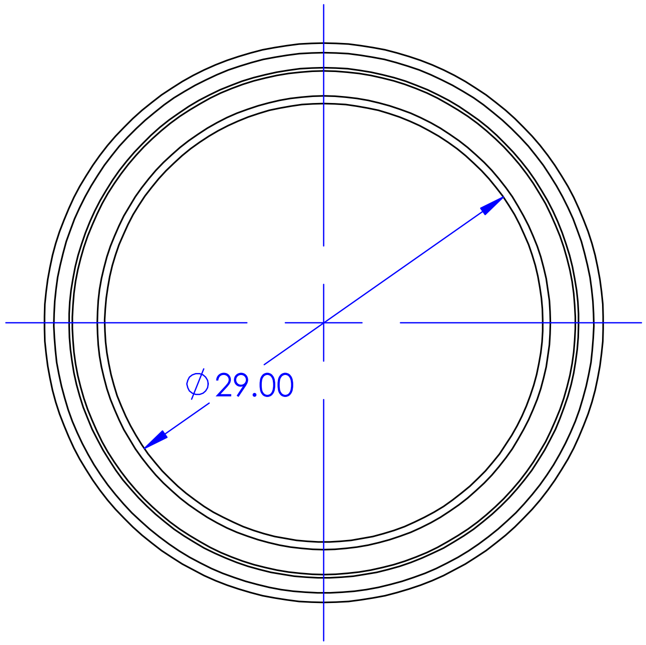

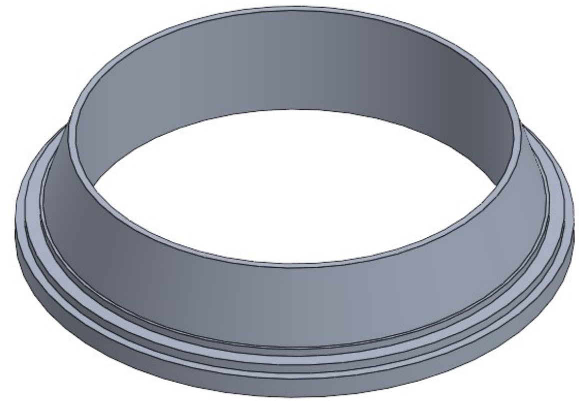

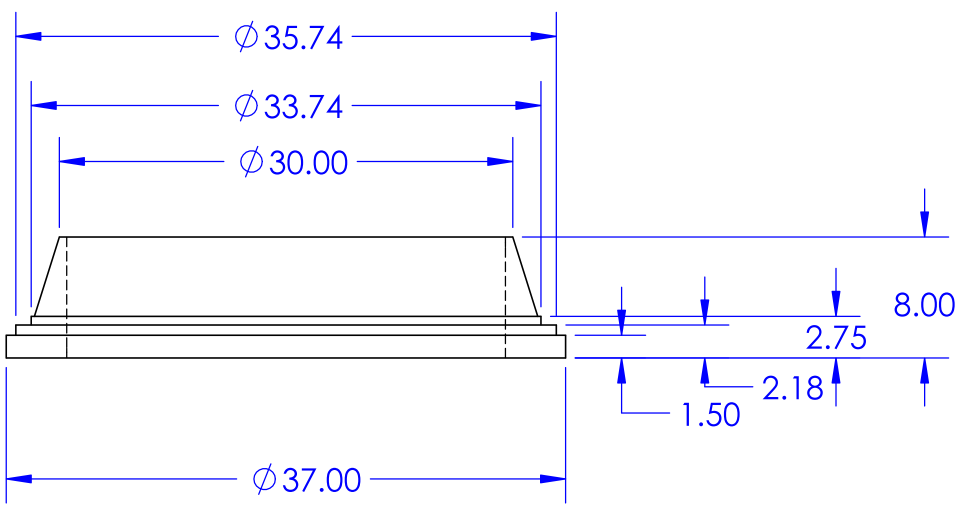

NOTE:
1. PART IS PURCHASED
2. ALL DIMENSIONS IN MILLIMETERS

F64 Adjustable Head Tube Angle Headset			Title: Bottom Ring		Drwn. By: Josh Martin
	Dwg. #: 1220		Date: 2/3/2021	Scale: 2:1	Checked by: Glenn Petersen

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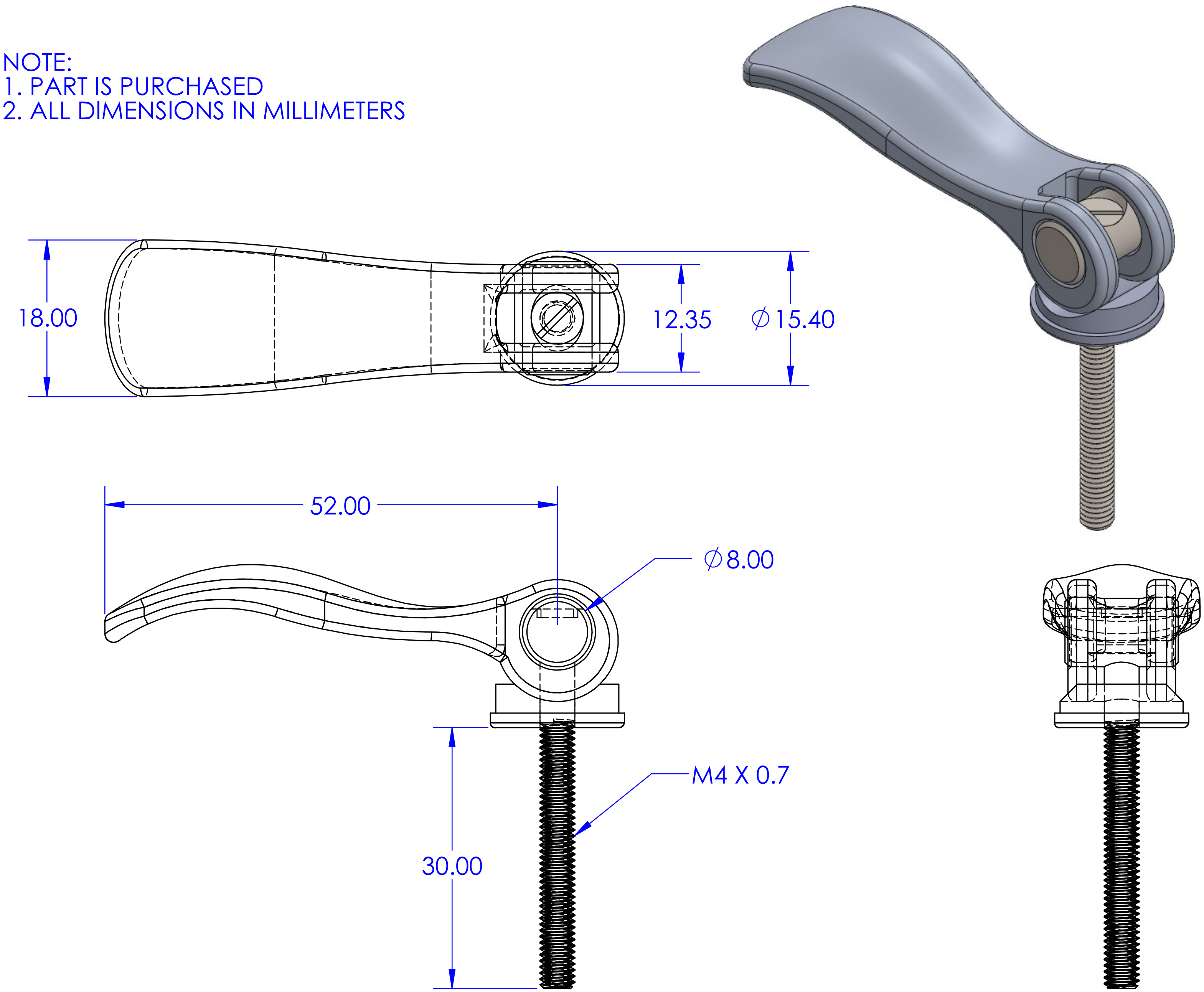
NOTE:
1. PART IS PURCHASED
2. ALL DIMENSIONS IN MILLIMETERS



F64 Adjustable Head Tube Angle Headset			Title: Cam Handle	Drwn. By: Josh Martin
	Dwg. #: 1230		Date: 2/5/2021 / Scale: 2:1	Checked by: Glenn Petersen

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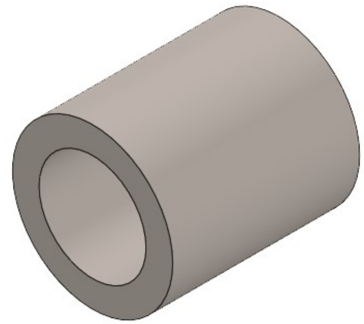
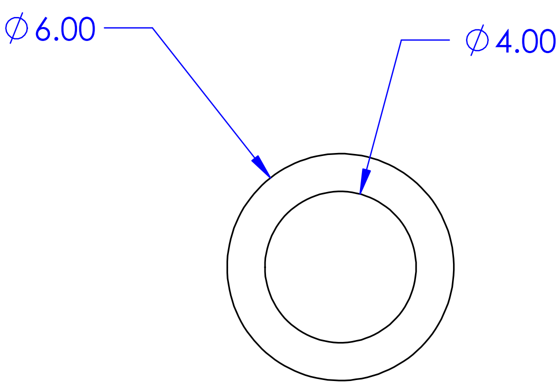
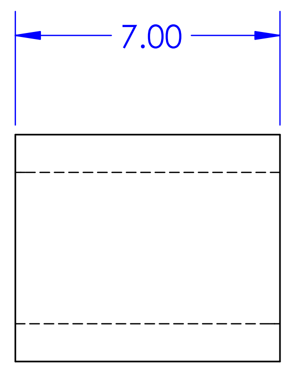
NOTE:
1. PART IS PURCHASED
2. ALL DIMENSIONS IN MILLIMETERS







F64 Adjustable Head Tube Angle Headset			Title: Cam Spacer	Drwn. By: Josh Martin
	Dwg. #: 1240		Date: 2/3/2021 / Scale: 5:1	Checked by: Glenn Petersen

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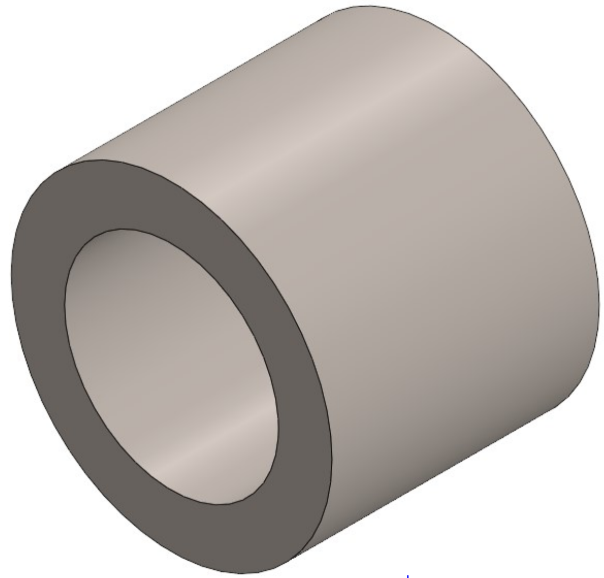
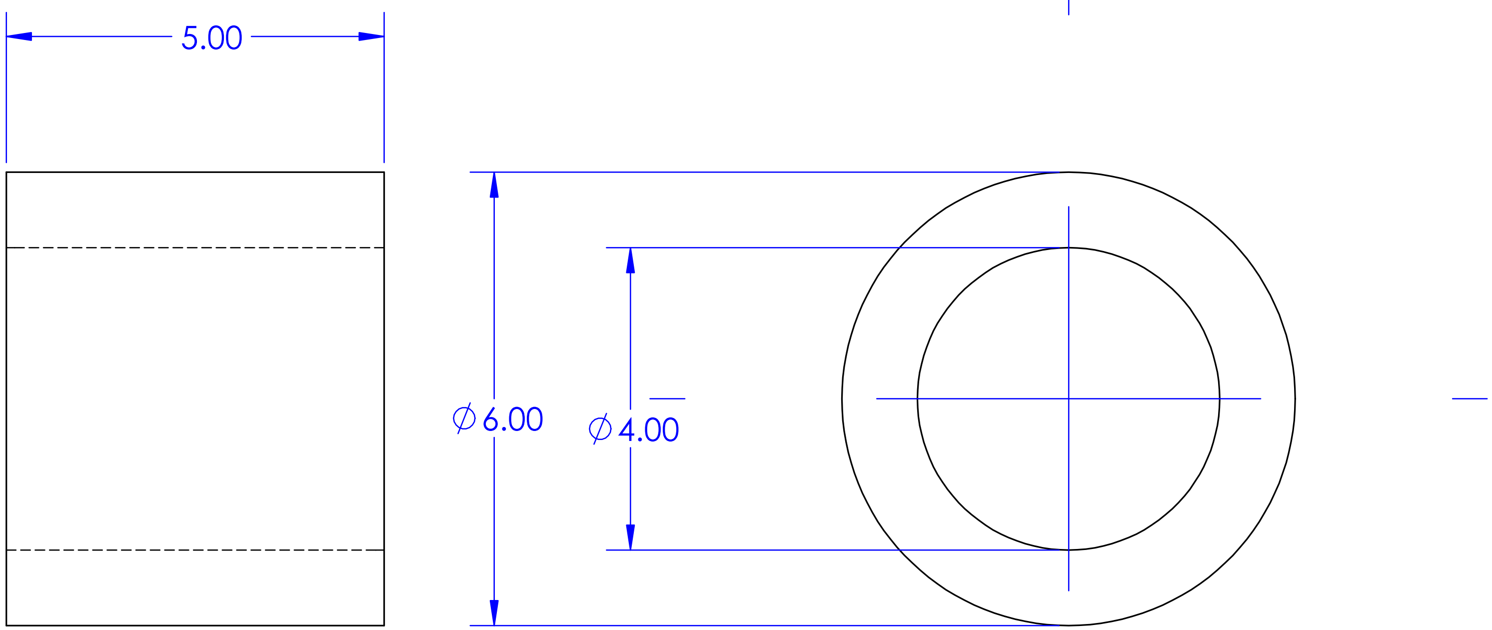
NOTE:
1. PART IS PURCHASED
2. ALL DIMENSIONS IN MILLIMETERS





F64 Adjustable Head Tube Angle Headset			Title: Nut Spacer		Drwn. By: Josh Martin
	Dwg. #: 1250		Date: 2/5/2021	Scale: 8:1	Checked by: Glenn Petersen

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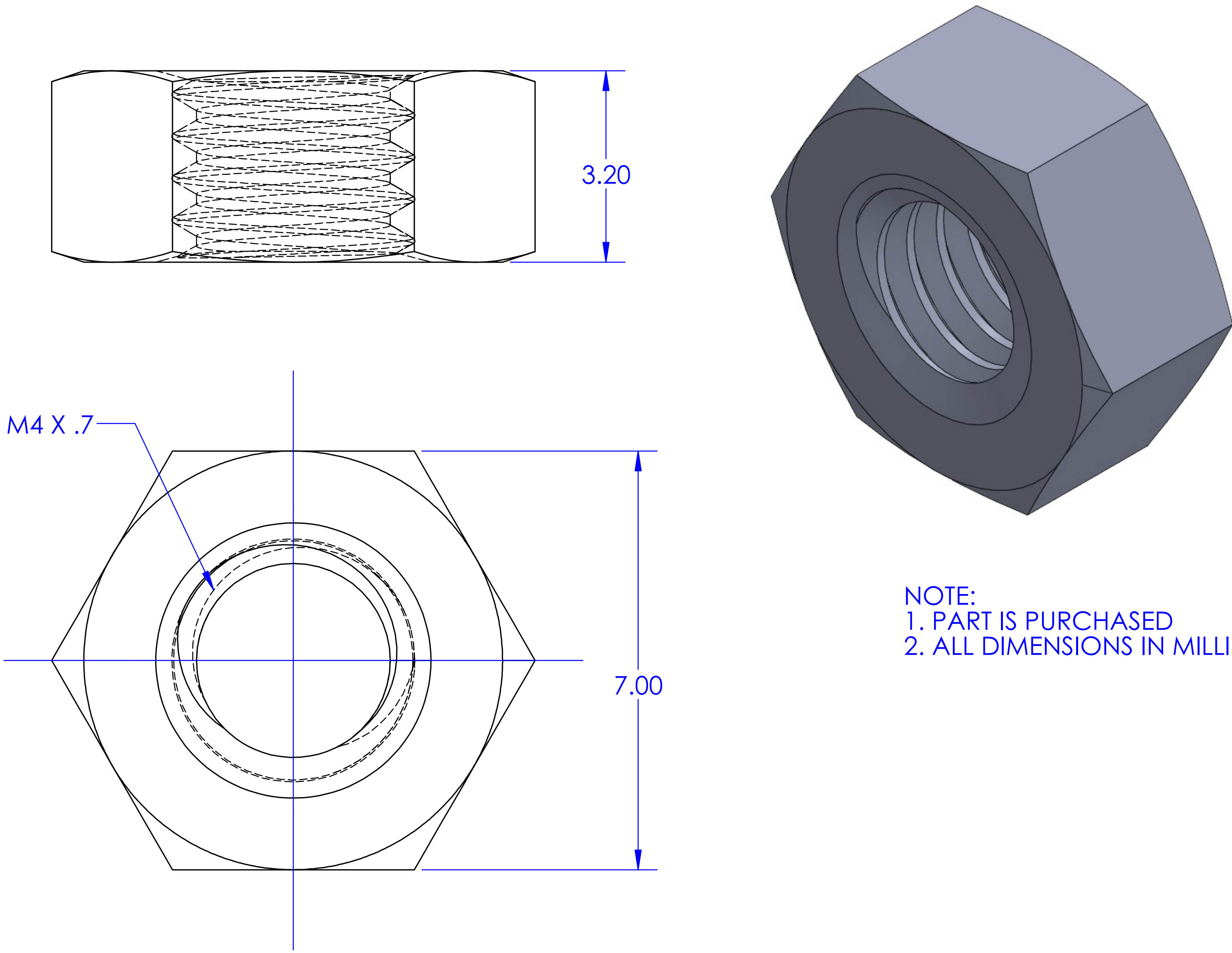

NOTE:
1. PART IS PURCHASED
2. ALL DIMENSIONS IN MILLIMETERS

F64 Adjustable Head Tube Angle Headset			Title: M4 Nut		Drwn. By: Josh Martin
	Dwg. #: 1260		Date: 2/5/2021	Scale: 8:1	Checked by: Glenn Petersen

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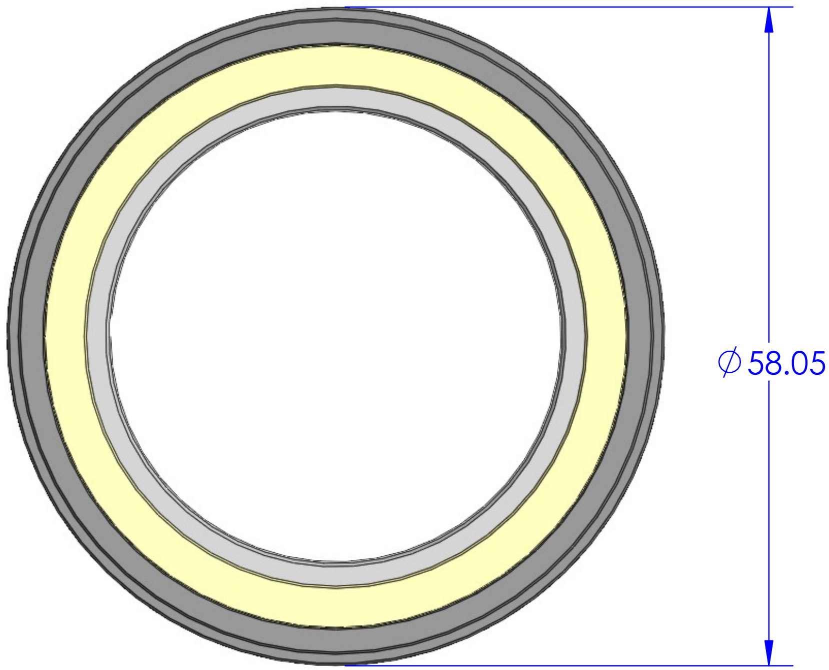
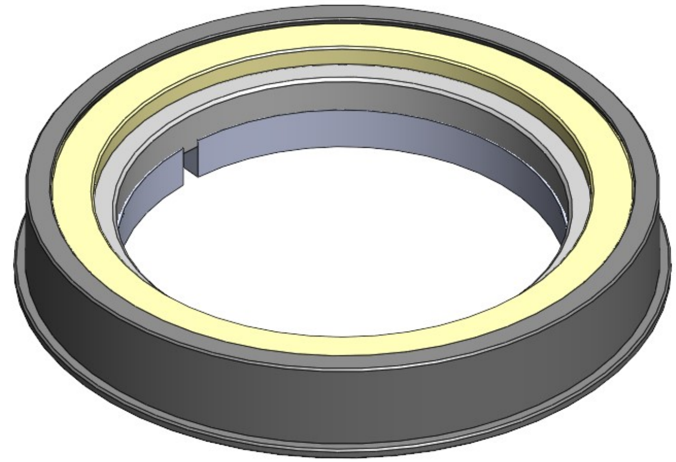
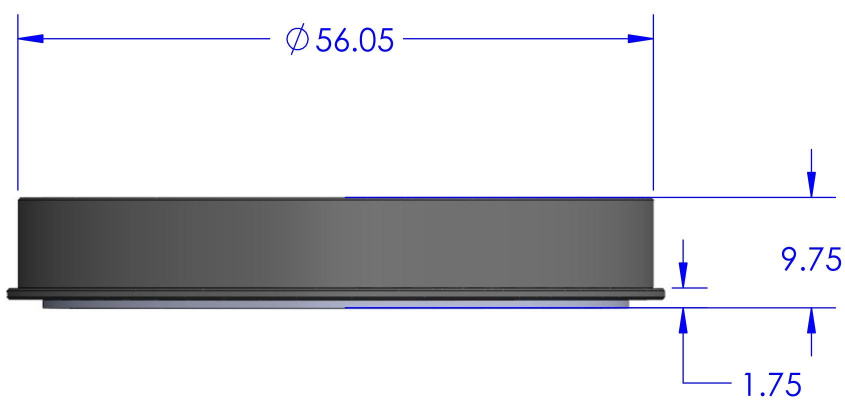




NOTE:
1. ALL PARTS ARE PURCHASED
2. ALL DIMENSIONS IN MILLIMETERS



F64 Adjustable Head Tube Angle Headset			Title: Bottom Headset Cup Assembly	Drwn. By: Josh Martin
	Dwg. #: 1300		Date: 2/4/2021 Scale: 3:2	

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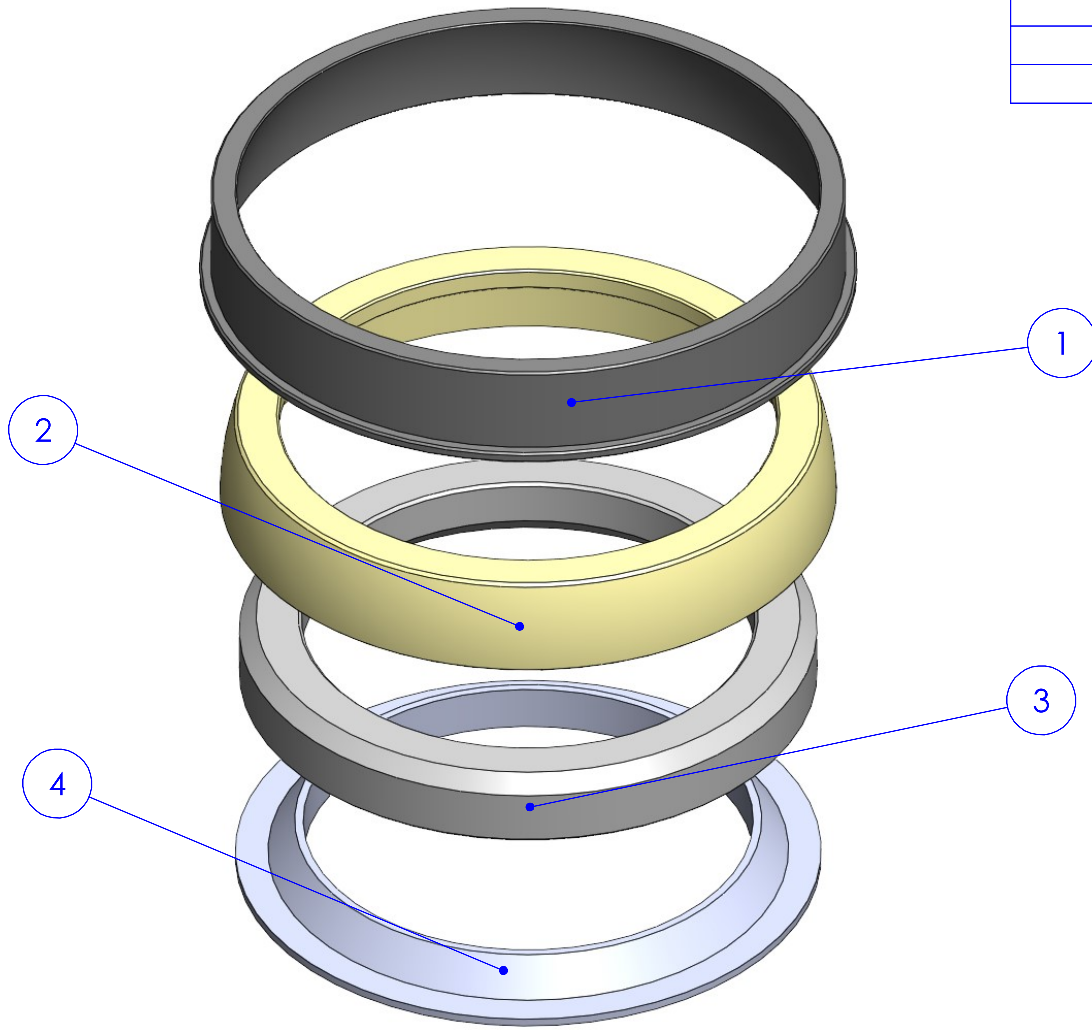
ITEM NO.	PART NO.	DESCRIPTION
1	1310	Bottom Headset Cup
2	1320	Bottom Bearing Housing
3	1330	Bottom Bearing
4	1340	Crown Race

NOTE:
1. ALL PARTS ARE PURCHASED



F64 Adjustable Head Tube Angle Headset			Title: Exploded Bottom Headset Cup Assembly	Drwn. By: Josh Martin
	Dwg. #: E1300		Date: 2/4/2021	Scale: 3:2

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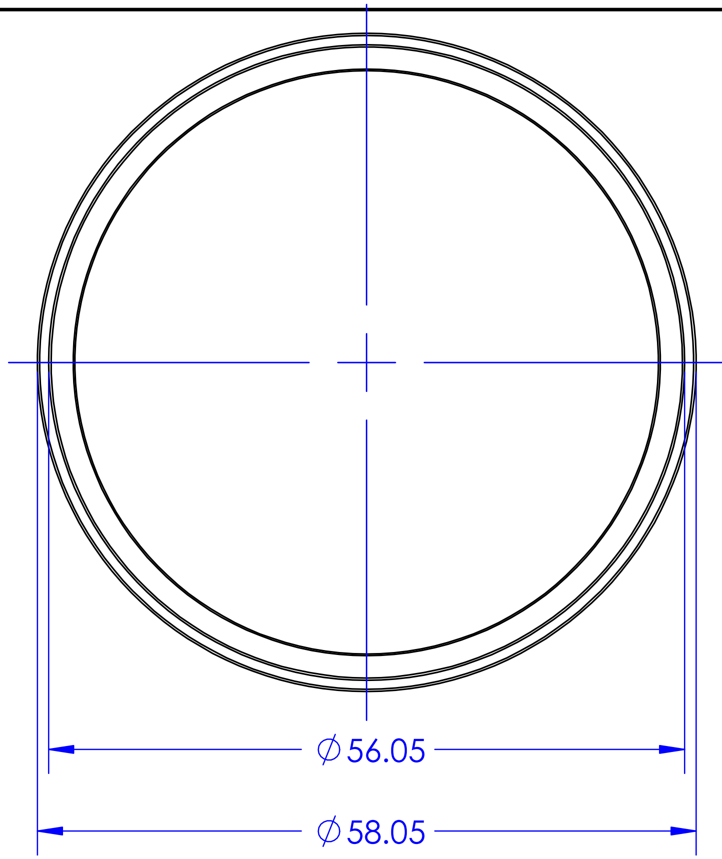
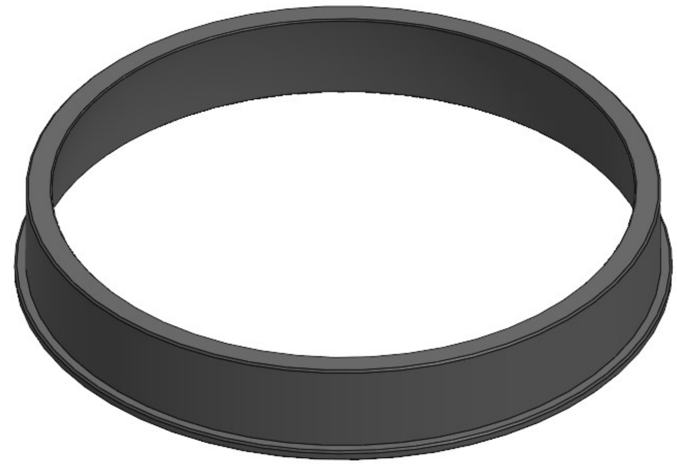
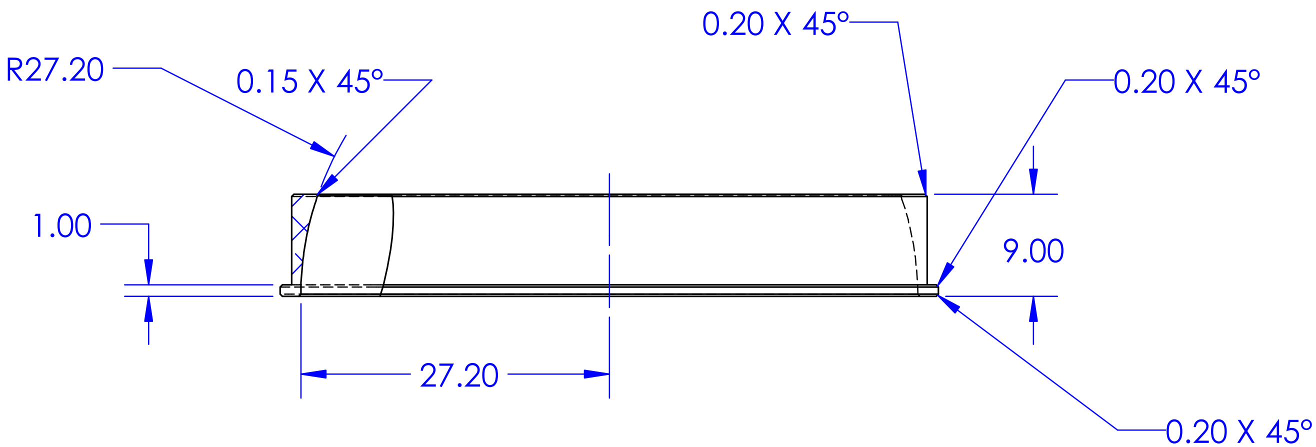




NOTE:
1. PART IS PURCHASED
2. ALL DIMENSIONS IN MILLIMETERS



F64 Adjustable Head Tube Angle Headset			Title: Bottom Headset Cup	Drwn. By: Josh Martin
	Dwg. #: 1310		Date:2/4/2021 | Scale: 1:1	

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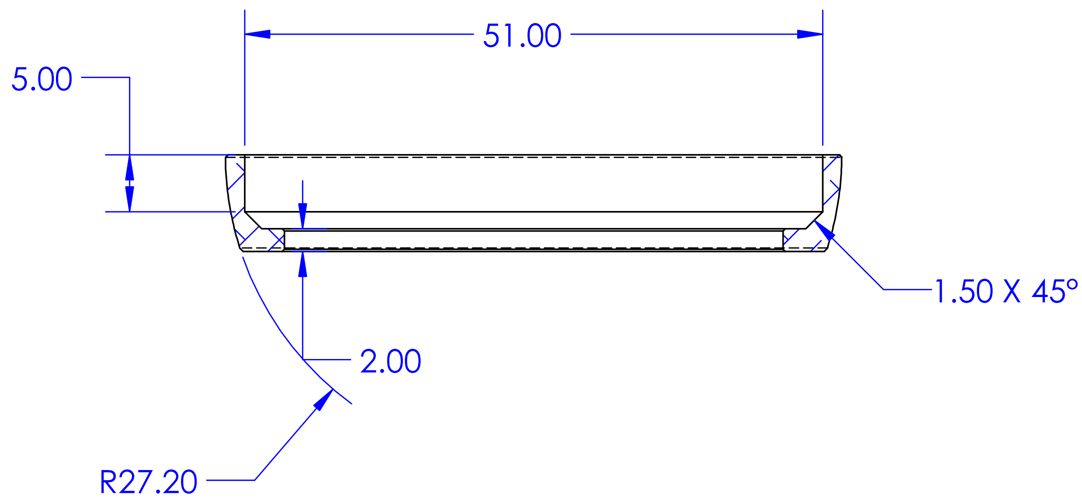
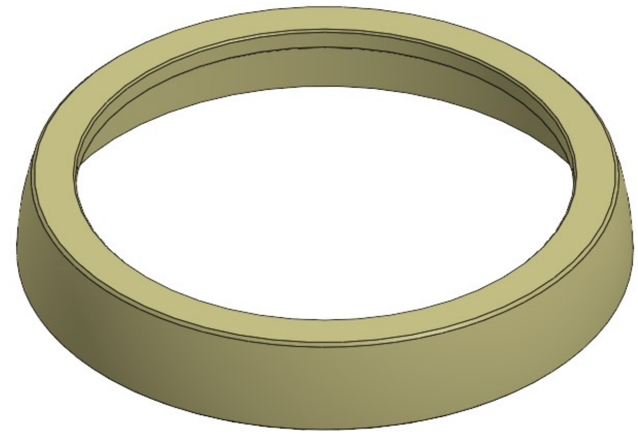
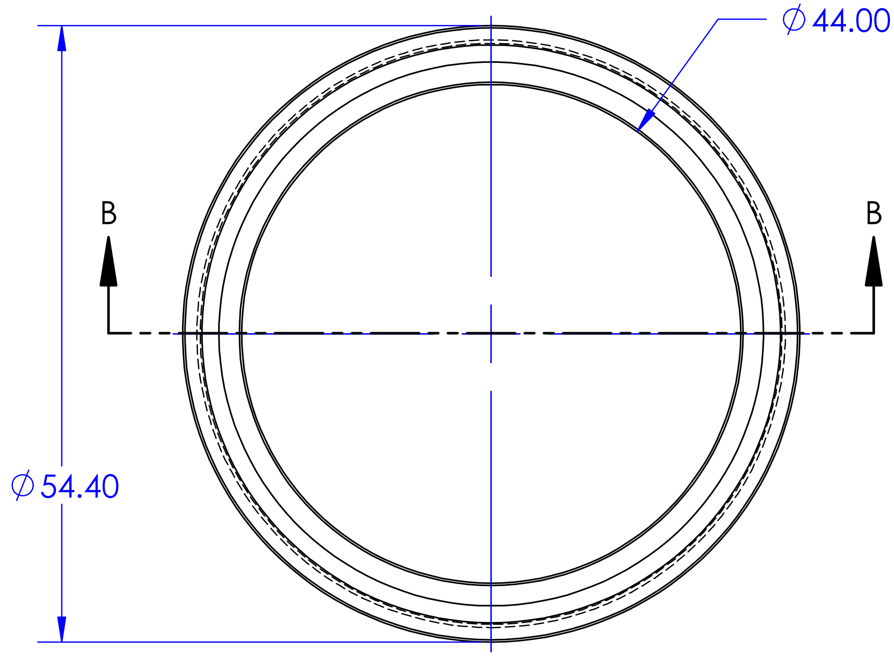




NOTE:
1. PART IS PURCHASED
2. ALL DIMENSIONS IN MILLIMETERS



F64 Adjustable Head Tube Angle Headset			Title: Bottom Bearing Housing	Drwn. By: Josh Martin
	Dwg. #: 1320		Date: 2/4/2021 / Scale: 1:1	

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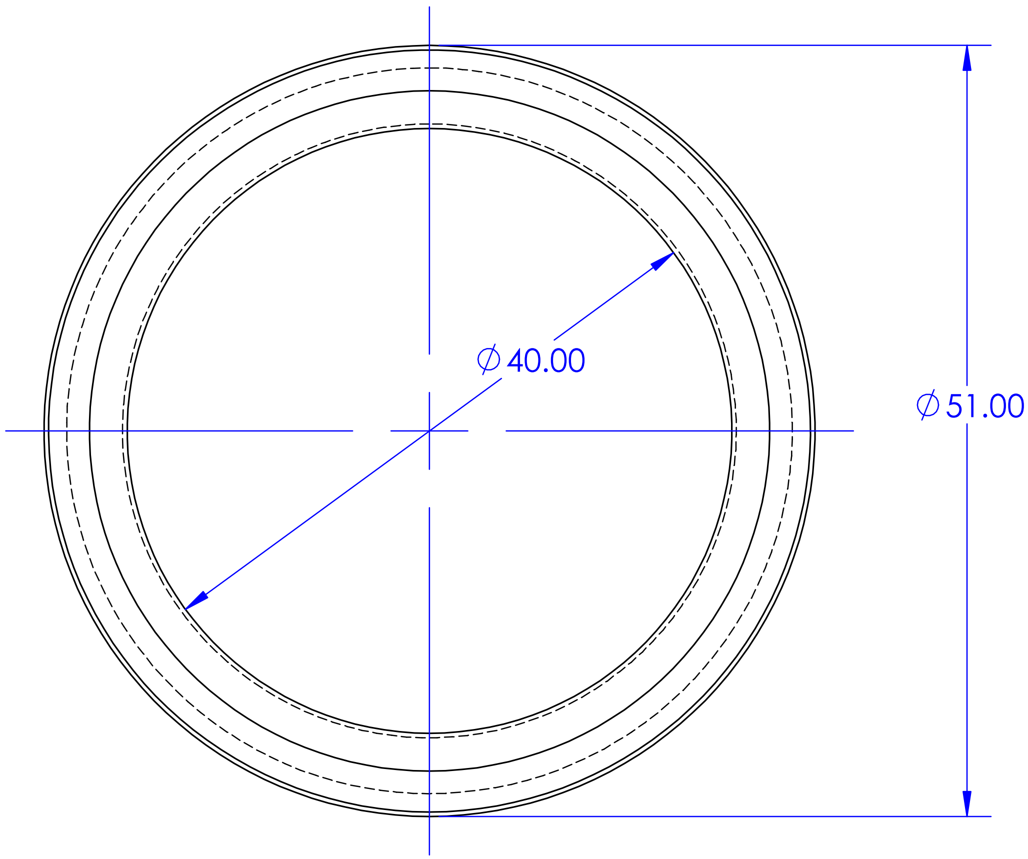
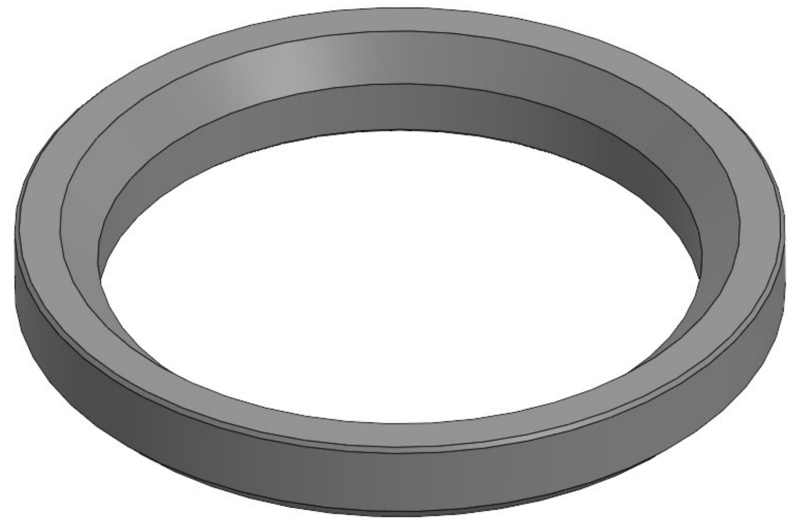
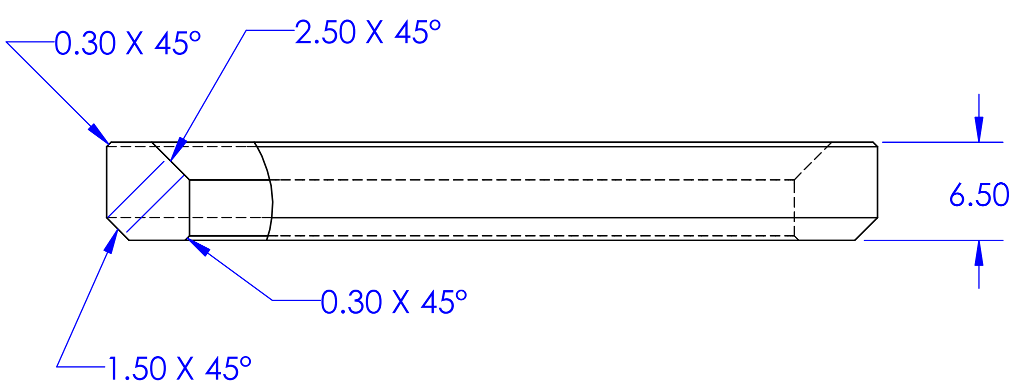




NOTE:
1. PART IS PURCHASED
2. ALL DIMENSIONS IN MILLIMETERS



F64 Adjustable Head Tube Angle Headset			Title: Bottom 52 mm Bearing		Drwn. By: Josh Martin
	Dwg. #: 1330		Date: 2/5/2021	Scale: 2:1	

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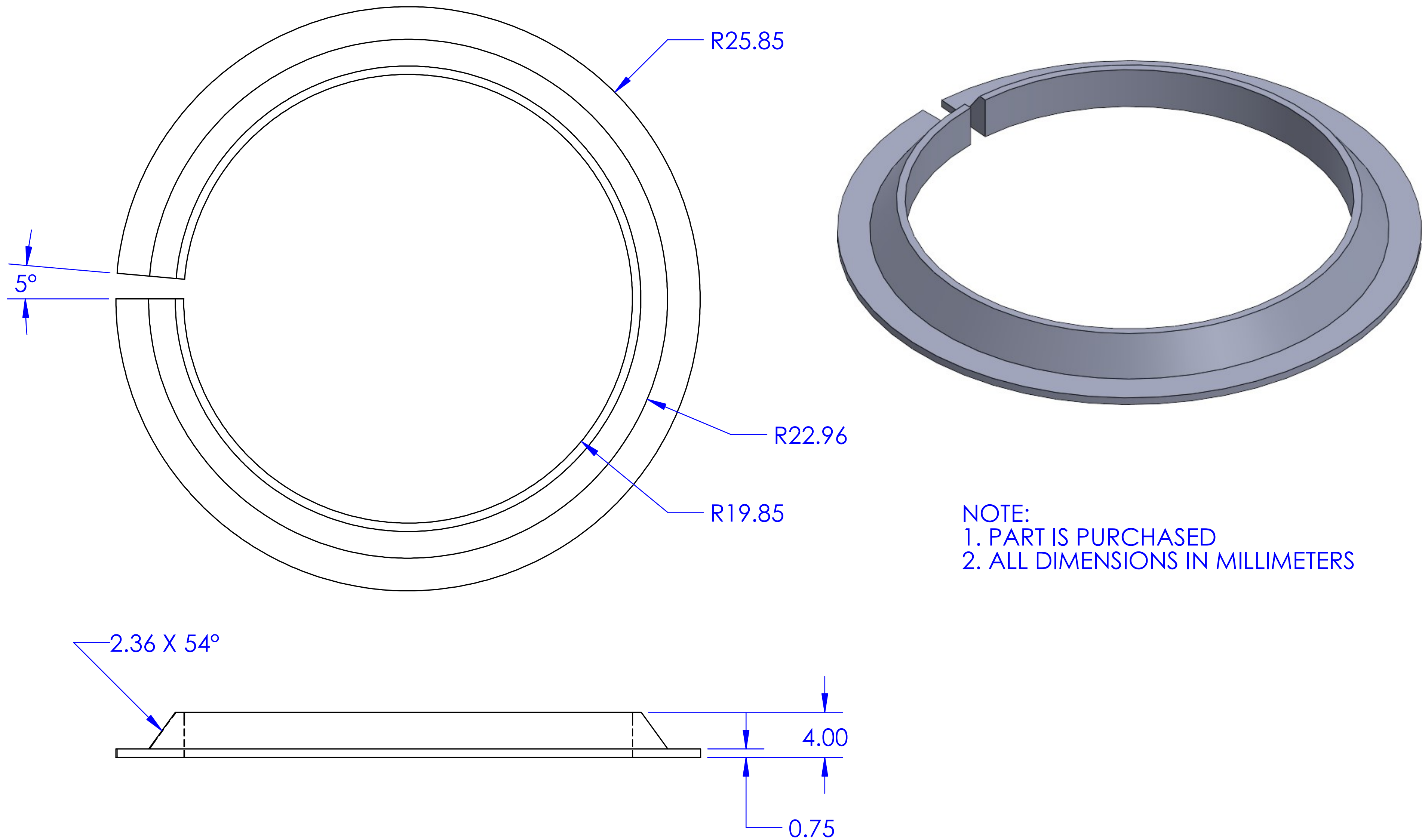

F64 Adjustable Head Tube Angle Headset			Title: Crown Race		Drwn. By: Josh Martin
	Dwg. #: 1340		Date: 2/5/2021	Scale: 2:1	

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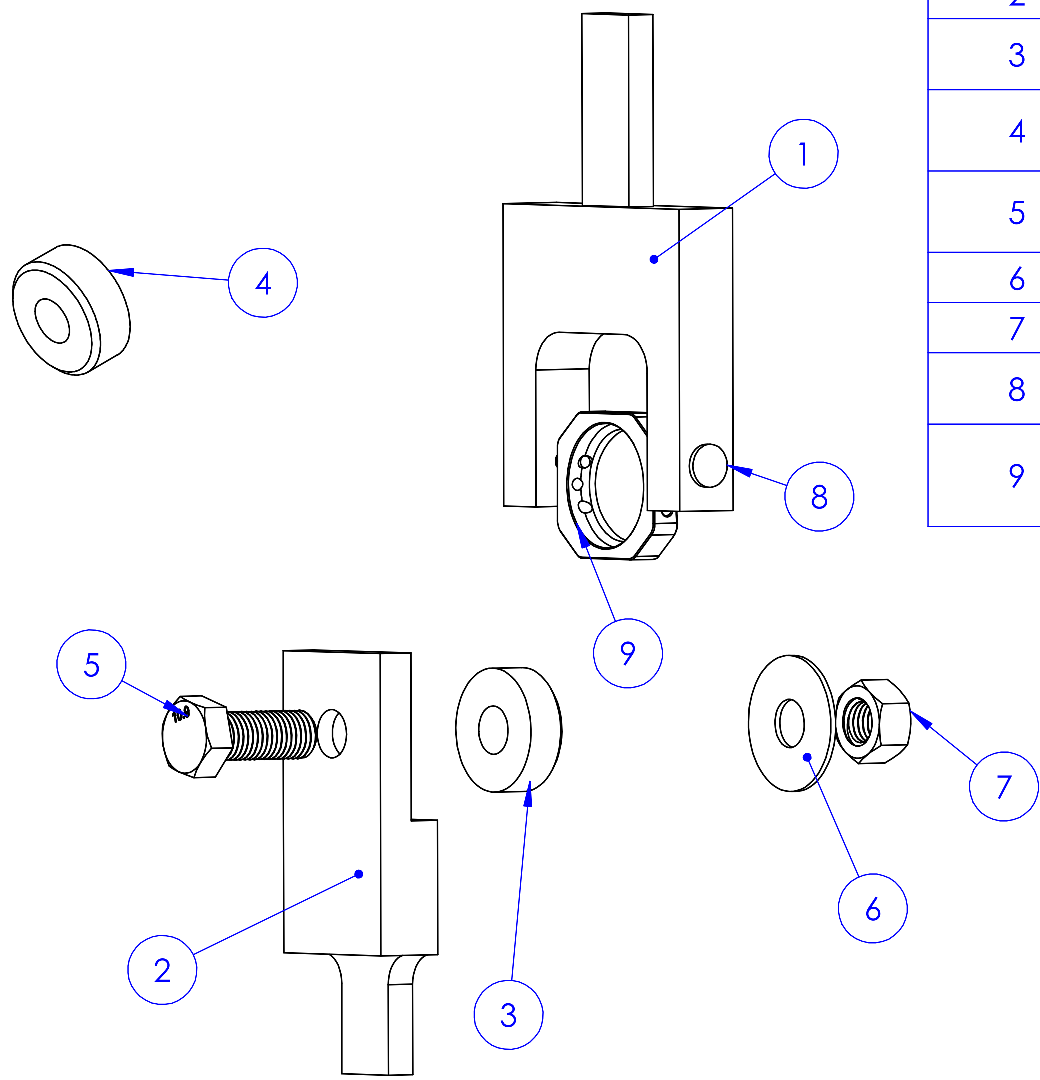

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	2100	TOP YOKE	1
2	2200	BOTTOM TANG	1
3	2300	SLACK BEARING SPACER	1
4	2400	NEUTRAL BEARING SPACER	1
5	2500	M16X2.0 X 40 HEX BOLT	1
6	2600	M16 WIDE WASHER	1
7	2700	M16 NUT	1
8	2800	TEST FIXTURE PIN	2
9	1120	TOP BEARING HOUSING	1

NOTE:
ITEM 3 AND ITEM 4 ARE INTERCHANGABLE IN FINAL ASSEMBLY IN EITHER A SLACK OR NEUTRAL SETUP

F64 ADJUSTABLE HEAD TUBE ANGLE HEADSET		Title: TOP BEARING TEST FIXTURE ASSEMBLY		Drwn. By: GLENN PETERSEN
	Dwg. #:E2000	Date: 6/1/2021	Scale: 2:5	Chkd. By: JOSH MARTIN

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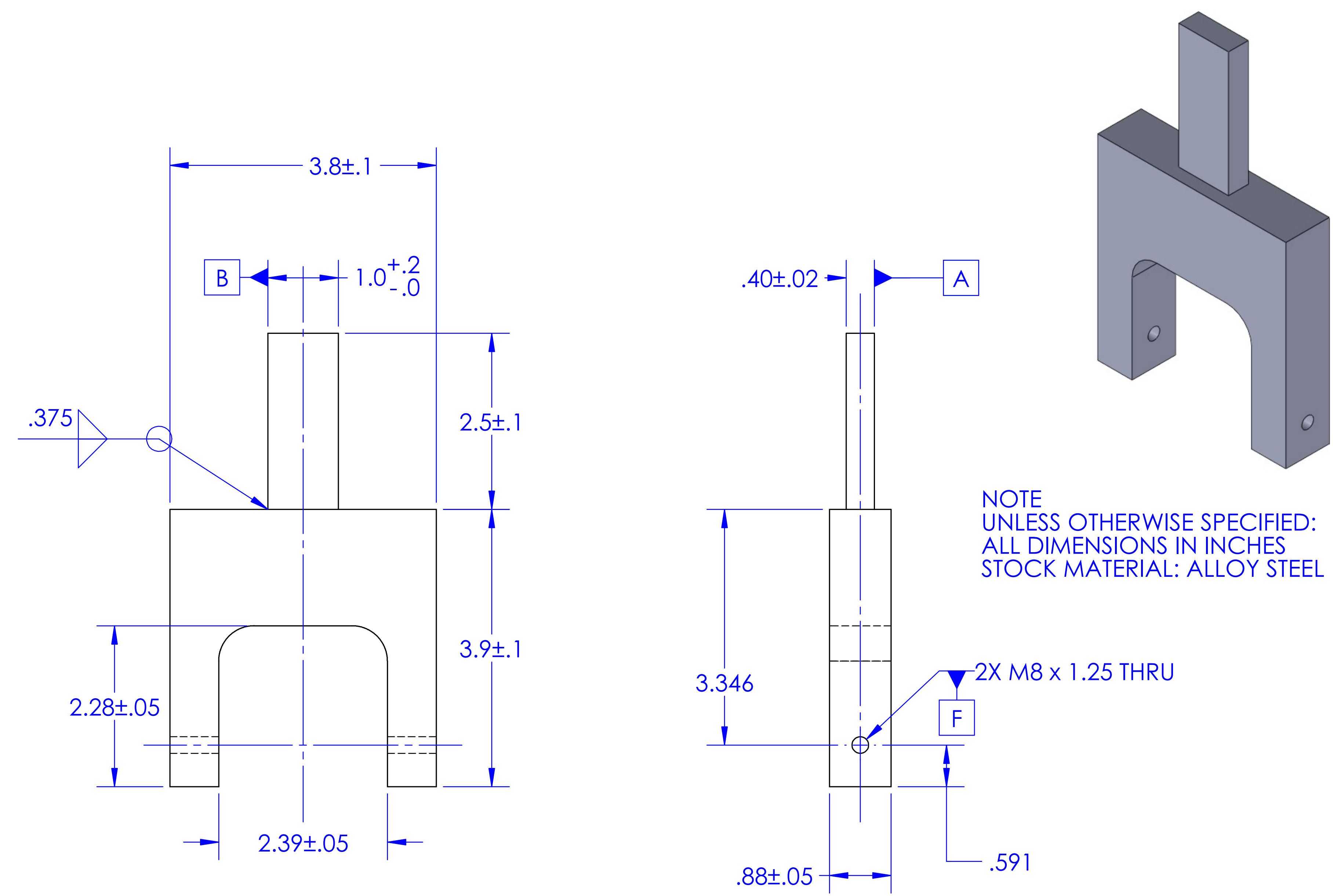

NOTE
UNLESS OTHERWISE SPECIFIED:
ALL DIMENSIONS IN INCHES
STOCK MATERIAL: ALLOY STEEL

F64 ADJUSTABLE HEAD TUBE ANGLE HEADSET			Title: TOP YOKE	Drawn By: GLENN PETERSEN
	Dwg. #:2100		Date: 6/1/2021 / Scale: 1:1	Chkd. By: JOSH MARTIN

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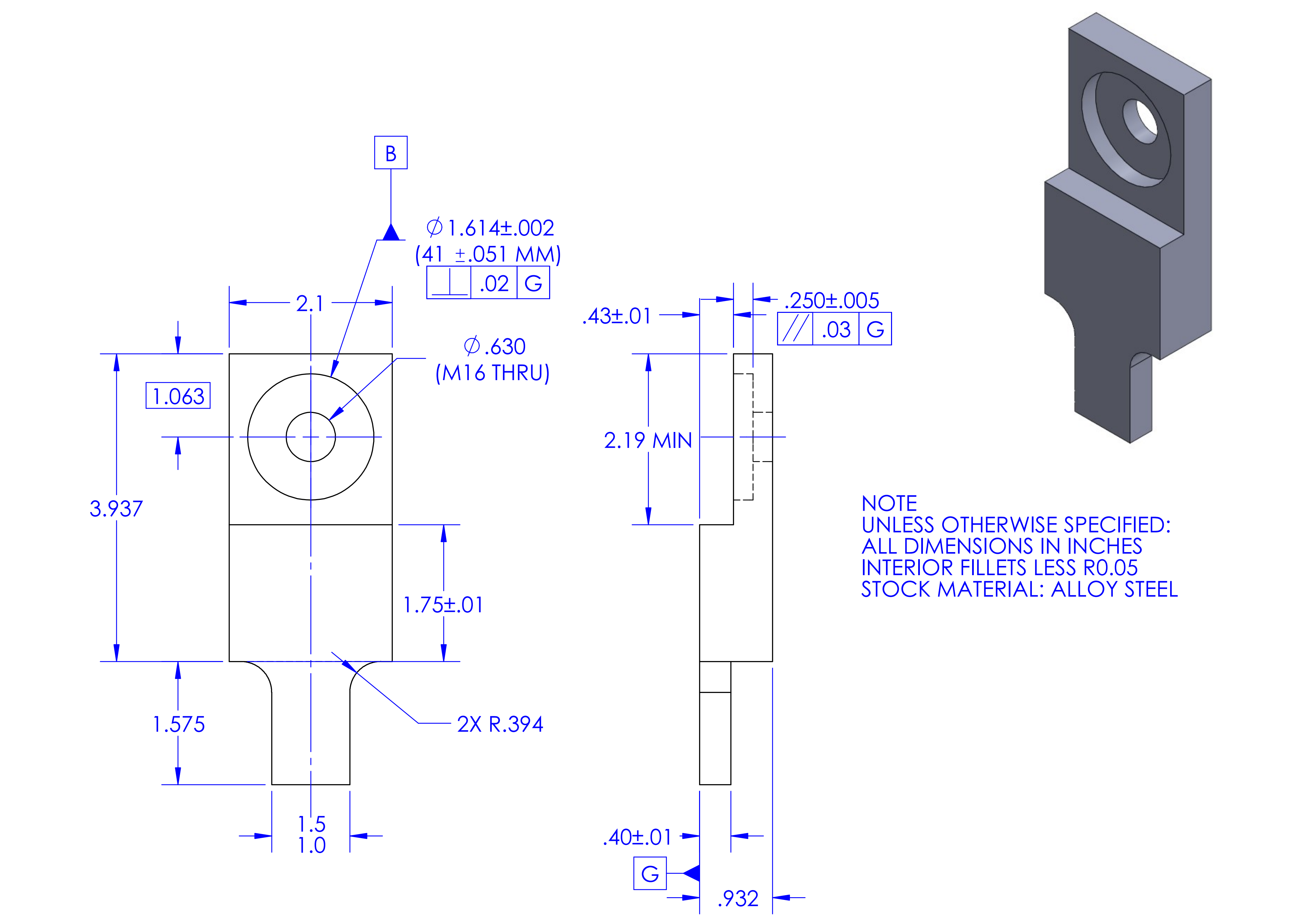

F64 ADJUSTABLE HEAD TUBE ANGLE HEADSET		Title: BOTTOM TANG			Drwn. By: GLENN PETERSEN
	Dwg. #:2200		Date: 6/1/2021	Scale: 3:5	Chkd. By: JOSH MARTIN

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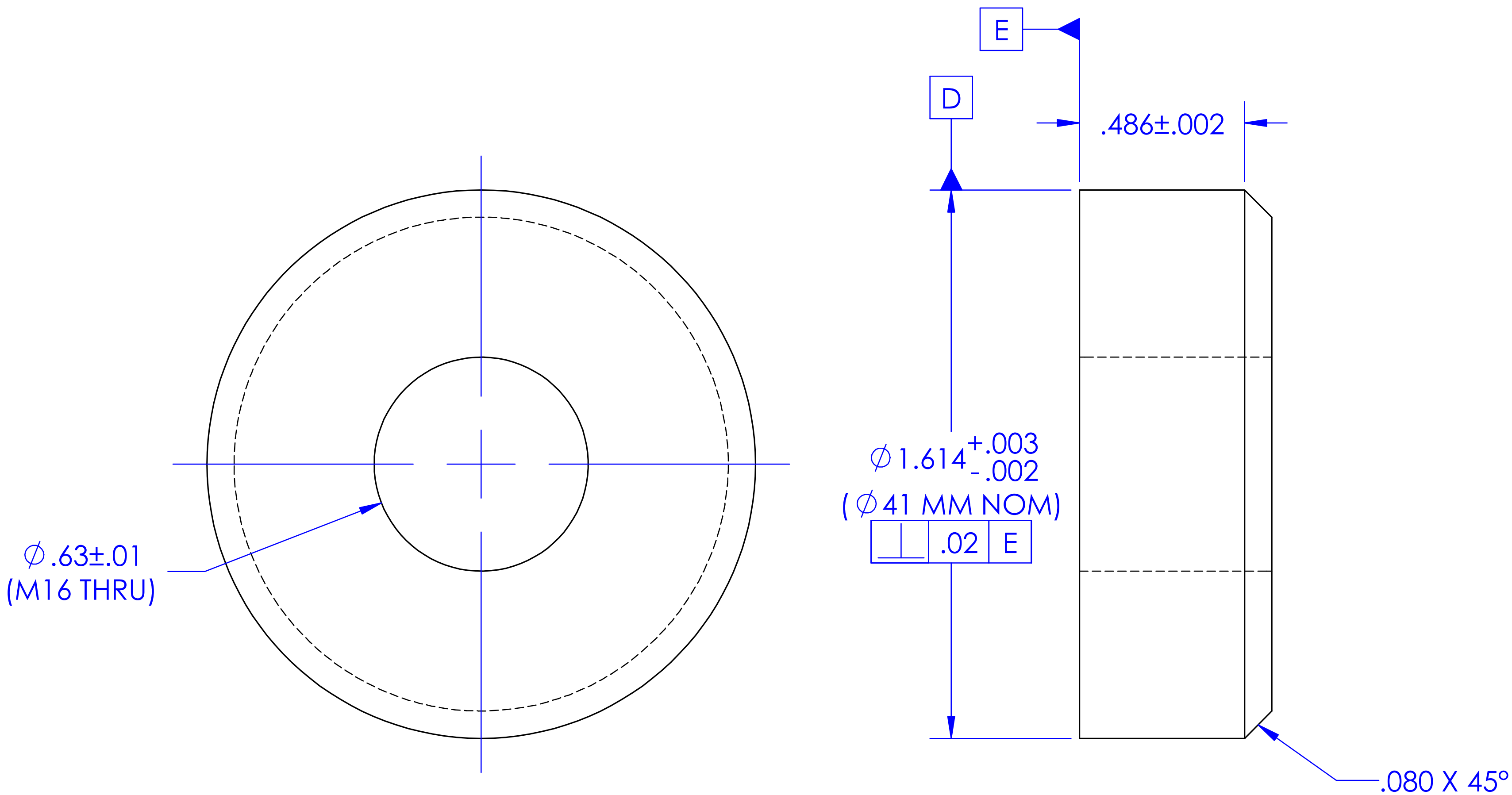

NOTE
UNLESS OTHERWISE SPECIFIED:
ALL DIMENSIONS IN INCHES
STOCK MATERIAL: ALLOY STEEL

F64 ADJUSTABLE HEAD TUBE ANGLE HEADSET		Title: SLACK BEARING SPACER		Drwn. By: GLENN PETERSEN
	Dwg. #:2300	Date: 6/1/2021	Scale: 2:1	Chkd. By: JOSH MARTIN

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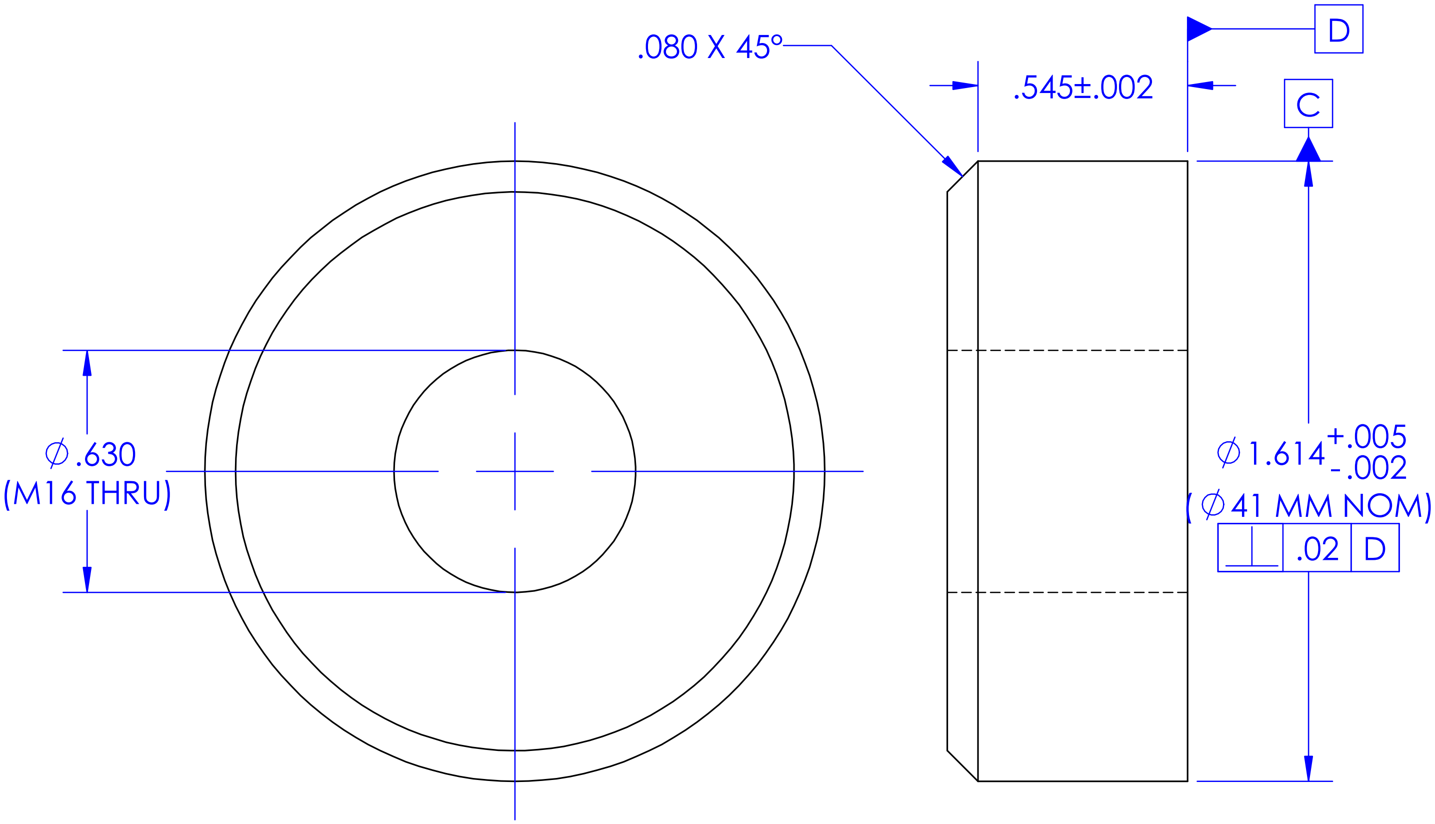

NOTE
UNLESS OTHERWISE SPECIFIED:
ALL DIMENSIONS IN INCHES
STOCK: ALLOY STEEL

F64 ADJUSTABLE HEAD TUBE ANGLE HEADSET		Title: NEUTRAL TOP BEARING SPACER			Drwn. By: GLENN PETERSEN
	Dwg. #:2400		Date: 6/1/2021	Scale: 2:1	Chkd. By: JOSH MARTIN

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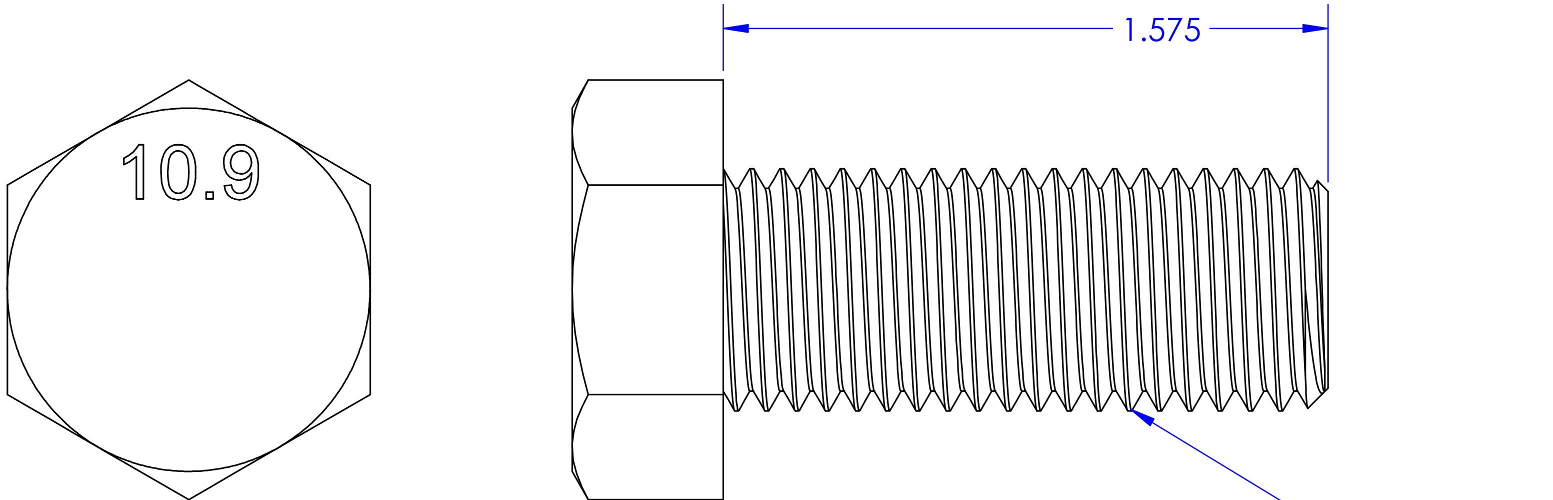
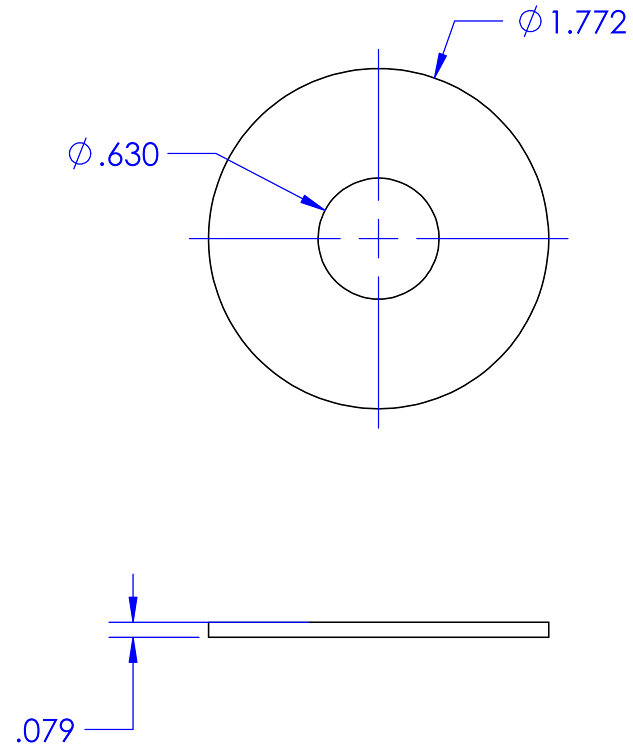


NOTE
THIS ITEM IS PURCHASED

F64 ADJUSTABLE HEAD TUBE ANGLE HEADSET		Title: M16X2.0X40 BOLT		Drwn. By: GLENN PETERSEN
	Dwg. #:2500		Date: 6/1/2021	Scale: 2:1	Chkd. By: JOSH MARTIN

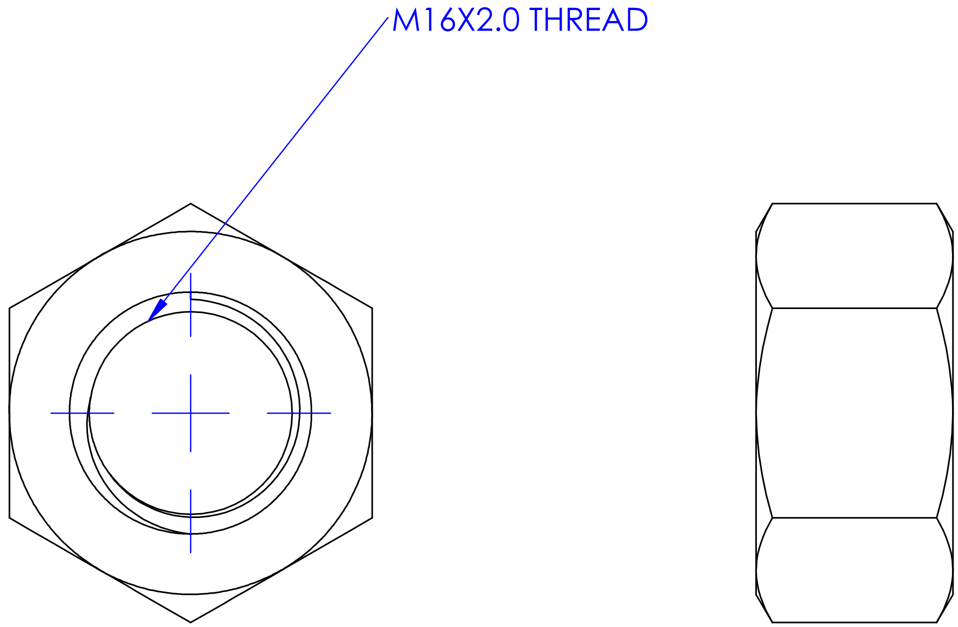
SOLIDWORKS Educational Product. For Instructional Use Only.



NOTE
UNLESS OTHERWISE SPECIFIED:
ALL DIMENSIONS IN INCHES
STOCK: ALLOY STEEL

F64 ADJUSTABLE HEAD TUBE ANGLE HEADSET		Title: M16 WIDE WASHER			Drwn. By: GLENN PETERSEN
	Dwg. #:2600		Date: 6/1/2021	Scale: 1:1	Chkd. By: JOSH MARTIN

SOLIDWORKS Educational Product. For Instructional Use Only.

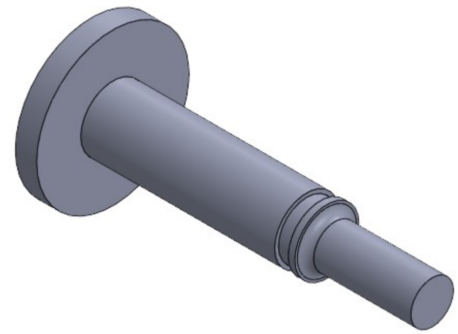


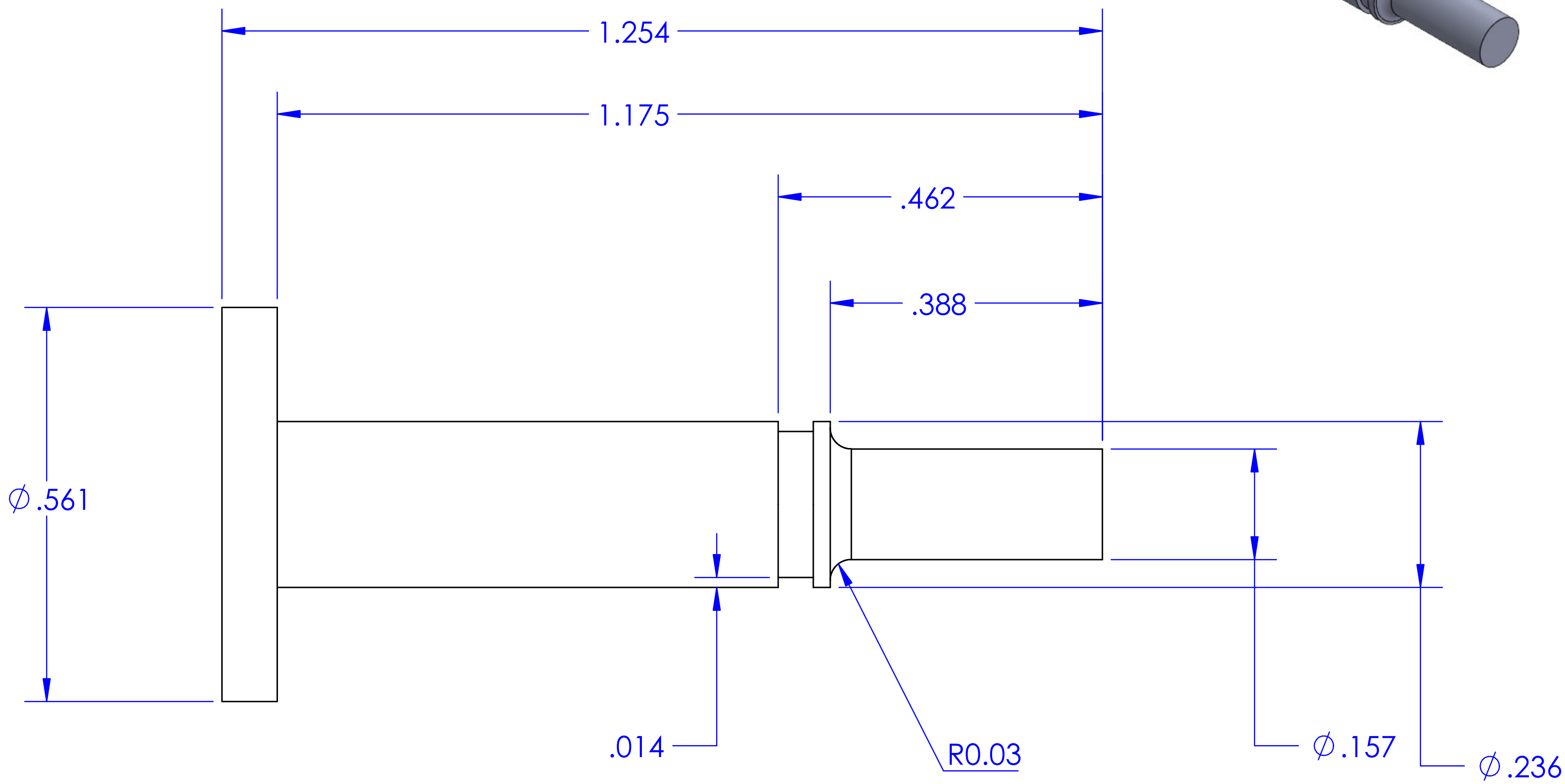
NOTE
THIS ITEM IS PURCHASED

F64 ADJUSTABLE HEAD TUBE ANGLE HEADSET		Title: M16 NUT			Drwn. By: GLENN PETERSEN
	Dwg. #:2700		Date: 6/1/2021	Scale: 2:1	Chkd. By: JOSH MARTIN

SOLIDWORKS Educational Product. For Instructional Use Only.

NOTE
UNLESS OTHERWISE SPECIFIED:
ALL DIMENSIONS IN INCHES
STOCK MATERIAL: ALLOY STEEL





F64 ADJUSTABLE HEAD TUBE ANGLE HEADSET			Title: PIN DESIGN		Drwn. By: DYLAN PRINS
	Dwg. #: 2800		Date: 6/2/2021	Scale: 2:1	Chkd. By: GLENN PETERSEN

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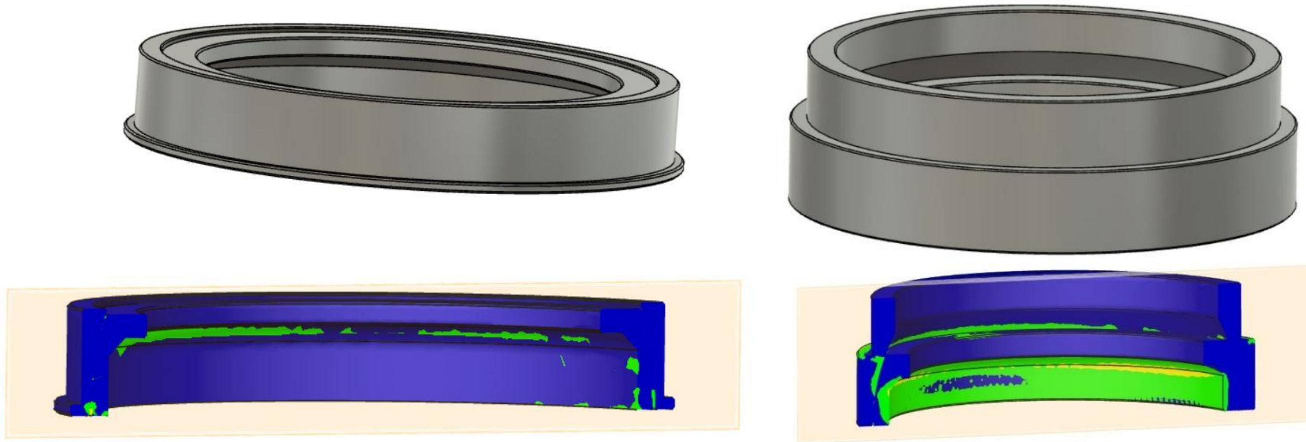
Appendix J) Project Budget

Subassembly	Component	Cost	Source
Top Headset Cup Assembly	Top Headset Cup	$12.00	Custom Machined
	Top Bearing Housing	$6.00	Custom Machined
	Top Bearing	$10.50	Cane Creek
	Compression Ring	$5.00	Cane Creek
	Shim Spacers	$3.00	Cane Creek
	Dust Cover	$14.00	Cane Creek
Locating Pin Clip	Pins	$1.00	McMaster Carr
	Velcro	$5.00	Amazon
Compression Assembly	OneUp Conical Spacer	$25.00	Backcountry
	Cam Handle	$13.58	McMaster Carr
	Stud Spacers	$4.50	McMaster Carr
	Nut	$0.20	Ace Hardware
Bottom Headset Cup Assembly	Bottom Headset Cup	Donated	Custom
	Bottom Bearing Housing	Donated	Custom
	Bottom Bearing	$18.00	Cane Creek
	Crown Race	$12.00	Cane Creek
Testing Fixture	Bolt	$1.00	Ace Hardware
	Washer	$0.25	Ace Hardware
	Nut	$0.50	Ace Hardware
	Upper Yoke	Donated	Custom
	Lower Yoke	Donated	Custom
	Mock Bearing	Donated	Custom
Total		$131.53	

Appendix K) Engineering Analyses

Top Cup FEA



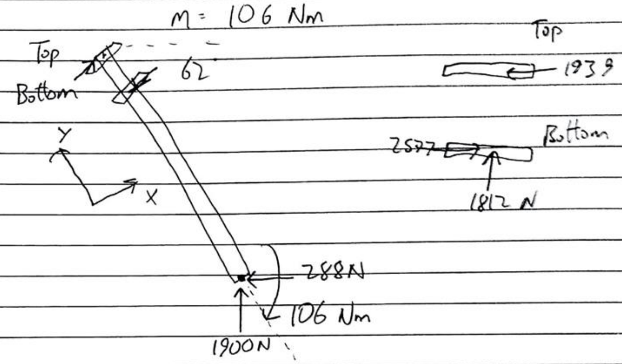
1995 Specialized FSR Load Case Model

From a study done by M. L. Hill, Professor of Mechanical Engineering and Chair of Bio medical Engineering at UC Davis, we found the magnitude of the maximum force seen by their experimental front wheel was 1900 N. This is equitable to five times their rider's body weight (75 kg). We assumed the testing conditions of their experiment to be directly applicable to our own. The trail they used was "fairly straight and continuously downhill of approximately 8 -percent slope whose surface was rutted, washed-out, and held exposed rock." Modelling our analysis after their experimental maximum force was validated by this assumption and under the presumption that most riders desiring an adjustable headset are aggressive off-road cyclists.

$F = ma$ $\qquad$ $M = Fr$

$F = (115\ kg)(2.5\ m/s^2)$ $\qquad$ $M = (288\ N)\left(\frac{.74m}{2}\right)$

$F = 288\ N$ $\qquad$ $M = 106\ Nm$



$\Sigma M_{top} = 0$

$(1900N)(\sin 28)(.592 + .14m) - (288N)(\sin 62)(.592 + .14m) - (106\ Nm) + (R_{bott})(.14m) = 0$

$R_{bottom_x} = \frac{652\ Nm - 186\ Nm - 166\ Nm}{.14m} = \boxed{2577N}$

$\Sigma F_x = 0 = (1900N)(\sin 28) - (288N)(\sin 62) - 2577 + R_{top\ x}$

$R_{top_x} = \boxed{1939\ N}$

$\Sigma F_Y = 0 = 1900\cos(28) + 288\cos(62) + F_{bottom_Y}$

$F_{bottom_Y} = \boxed{1812\ N}$

Without braking forces | $\Sigma M_{top} = 0$

$(1900N)(\sin 28)(.592 + .14) - (F_{bottom_x})(.14) = 0,$ $\qquad$ $F_{bottom_x} = \frac{652.M}{.14} = \boxed{4663\ N}$

$\Sigma F_x = 0 = (1900)\sin(28) - 4663 + R_{top\ x},$ $\qquad$ $R_{top\ x} = \boxed{3771}N$

~~$R_{bottom_y} = 1900\cos 28 = \boxed{1677N}$~~

In our model, we applied this load case to the front hub of a 29-inch bicycle wheel. The goal of our model was to compute the radial loads seen at the top and bottom cups of a 140-millimeter head tube. This head tube height would produce the highest reactive forces at the top and bottom headset bearings because it creates the largest reactive moment at the bottom headset bearing. We also included a load case with a braking force equivalent to a rider weighing 115 kilograms decelerating at a quarter the acceleration due to gravity (2.5 m/s^2). We found the worst-case loading was without the braking forces, so the non-braking scenario was considered for proceeding design direction and analyses. The concluding radial loads of this analysis at the top and bottom cup were 4663 newtons and 3771 newtons, respectively. These values were used in later calculations to evaluate factors of safety within the top cup and top bearing housing.

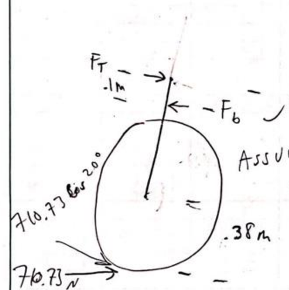
Pin Shear Calculations

The pins connected to our pin locating mechanism secure our bearing holder to the top cup after headset adjustments are made. After the preload from the expanding quick release is applied, the pins will bear any shearing forces translated at the top cup. These shear loads are shared between the locating pins, bearing holder and top cup. We performed various shear stress calculations in order to obtain reasonable diameters of the locating pins. Our model used a factor of safety of 2 and steel, with a yield strength of 669MPa, for our pin material. We applied an additional shearing force due to a maximum braking effort equivalent to a 115 kg cyclist decelerating at roughly 60% the acceleration due to gravity. From this analysis we found a pin diameter of 4 millimeters and proceeded with this value in our design.

maximum Braking effort

$.63g \to 6.1803\ m/s^2$

$(115\ kg)(6.1803\ m/s^2) = 710.73\ N$



Say 1m length mtb is .914 m

Assume Brake is locked

$M_T = 0 = 710.73 \cos 20° (1m) - F_b(.1m)$

$F_b = 6678.6N$

$F_T = F_b - 710.73 \cos 20°$

$F_T = 6010\ N$

Pin shear

Steel Yeild strength ≈ 669 Mpa

$\tau_{max} = \frac{4(V)}{3(A)} = \frac{4(6010N)}{3(\pi r^2)}$ want Fs of 2 for 2 pins

$\tau_{max} = (669\ Mpa/2) \times 2\ pins = 669\ Mpa$

$r^2 = \frac{4(6010N)}{(3)(\pi)(669\ Mpa)} = 3.8127 \times 10^{-6}\ m^2$

$r = 0.00195\ m \to D = r \cdot 2 = 0.0039\ m = D$

Scanned with CamScanner

Appendix L) Failure Modes and Effects Analysis

												Action Results			
System / Function	**Potential Failure Mode**	**Potential Effects of the Failure Mode**	**Severity**	**Potential Causes of the Failure Mode**	**Current Preventative Activities**	**Occurence**	**Current Detection Activities**	**Detection**	**RPN**	**Recommended Action(s)**	**Responsibility & Target Completion Date**	**Actions Taken**	**Severity**	**Occurence**	**Criticality**
Bottom Cup & Spherical Bearing / Allows Pivoting for Adjustment	High adjustment effort	User cannot adjust headset	7	1) Grease dissipates 2) Grease becomes contaminated	1) Define maintenance interval, design surfaces to hold grease 2) Seal the bearing	4	1) Test rides 2) Dissassembly and inspection	2	56						
	Does not allow for the fork to pivot	User cannot adjust headset	8	1) Spherical bearing deforms 2) Contaminants mar/interfere with mating surfaces 3) Manufacturing error	1) Stress analysis 2) Seal mating surfaces 3) Inspections	2	1) Loading testing 2) Test rides 3) FAIR	4	64						
Bottom Cup with Spherical Bearing / Accomodates Forces From the Fork	Fractures or deforms	Assembly Components Not Secured	9	1) Stress concentrations/fatigue 2) Improper assembly preload 3) Improper preload/installation	1) Stress Analysis 2) Calculations and design user instructions 3) Calculations and design user instructions	2	1) Test rides 2,3) Test ride and customer use test 4) Max load test fixture	3	54						
Equivalent Operation to Standard Headset / Allows free fork rotation	limits fork rotation	Doesn't allow for free fork rotation	9	1) improper bearing preload/housing 2) internal geometry limits fork rotation 3) Bulky design contacts stem/crown	1) adequate conical spacer height 2) validation of fits during manufacturing and assembly 3) Size compoenents within geometric restraints of fork and stem	2	Testing adjustments/bike rides	3	54						
Equivalent Operation to Standard Headset / Low Profile	bulkier than traditional headset	Large and bulky	3	1) Not excessively bulky 2) Size/geometry not optimized	1) provide adequate oversizing estimate with respect to traditional headset 2) sacrifice material selection/optimization	3	visual inspection	1	9						
Equivalent Operation to Standard Headset / Silent Operation	assembly/components create noise	Makes noise	6	Between mating surfaces: 1) introduction of contaminants 2) insufficient lubrication 3) insufficient contact pressure	1) ensuring assembly is sealed properly 2) proper and sufficient quantity of lubrication applied during assembly 3) Designing for correct conical surface angle on over-center lock and spacer	7	1) Test rides 2) disassembly	8	336	We will try to seal moving surfaces where possible, lubricate where possible, maintain tight tolerances, and ensure components are secured.	Josh, Jan 14,2021 (IDR)				
Over-Center Lock / Provides Axial Displacement	fails to provide adequate axial space for adjustment	Assembly Components Not Secured	7	1) Deformation or fracture 2) Improper spacer height/installation 3) Installation/user error 4) Contaminant clogging system	1) Stress analysis 2) Calculations and design user instructions 3) Design user instructions 4) Seal system from environment	3	1) Test Rides 2,3) Have other customers use device 4) Test rides	2	42						
Over-Center Lock / Provides Axial Force	Fails to maintain axial force	Assembly Components Not Secured	10	1) Preload kit fails 2) User error of cam lock 3) Incorrect conical surface angle 4) Not enough compression from the ring 5) High contact friction	1) Stress analysis 2) Design instructions 3) Calculations and analysis 4) Calculations and analysis 5) Calculations and keep contaminants from mating surface	6	1) Test Rides 2) Have other customers use device 3,4,5) Test rides	6	360	Perform stress and fatigue analysis with FEA, as well as design a testing fixture to validate our FEA results	Dylan, Jan 14,2021 (IDR)				
Top Cup & Pins / Creates Indexed Positions	Doesn't provided indexed positions	Cannot hold fixed positions	9	1) Holes deform/wear 2) Pins deform/wear 3) Pins don't fit into holes correctly	1) Design material selection and geometry for a specified cycle quantity 2) Consider the protection of the pins/holes from environement 3) Designate maintenance interval	3	1) Test rides 2) Visual Inspection 3) Disassembly & Inspection	1	27						
Top Cup & Pins / Guides Fork Adjustment	Doesn't constrain frok movement to a linear fore/aft path	Cannot hold fixed positions	7	1) Improper installation 2) Slot deforms/wears 3) Cup rotates in frame	1) consider adjustment cycle quantity in material selection 2) Verify proper fits for cup installation 3) Provide clear and coherent installation instructions	3	1) Test installations and rides 2) Disassembly & Inspection	1	21						

Appendix M) Design Hazard Matrix

Y	N	
	x	1. Will any part of the design create hazardous revolving, reciprocating, running, shearing, punching, pressing, squeezing, drawing, cutting, rolling, mixing or similar action, including pinch points and sheer points?
	x	2. Can any part of the design undergo high accelerations/decelerations?
x		3. Will the system have any large moving masses or large forces?
	x	4. Will the system produce a projectile?
	x	5. Would it be possible for the system to fall under gravity creating injury?
	x	6. Will a user be exposed to overhanging weights as part of the design?
	x	7. Will the system have any sharp edges?
	x	8. Will any part of the electrical systems not be grounded?
	x	9. Will there be any large batteries or electrical voltage in the system above 40 V?
	x	10. Will there be any stored energy in the system such as batteries, flywheels, hanging weights or pressurized fluids?
	x	11. Will there be any explosive or flammable liquids, gases, or dust fuel as part of the system?
	x	12. Will the user of the design be required to exert any abnormal effort or physical posture during the use of the design?
	x	13. Will there be any materials known to be hazardous to humans involved in either the design or the manufacturing of the design?
	x	14. Can the system generate high levels of noise?
x		15. Will the device/system be exposed to extreme environmental conditions such as fog, humidity, cold, high temperatures, etc?
x		16. Is it possible for the system to be used in an unsafe manner?
	x	17. Will there be any other potential hazards not listed above? If yes, please explain on reverse.

Description of Hazard	Planned Corrective Action	Planned Date	Actual Date
The headset is important to rider safety and will encounter large forces relative to the amount of material there is room to use.	A sufficient factor of safety and testing will be used to ensure the headset can accommodate any forces encountered during riding.	11/5 going forward	
Incorrect use of the preloading mechanism could result in a loose headset.	While this hazard is present in all threadless bicycle headsets, it is more likely when adjustments will be frequently made. Reminders could be labelled on the headset and provided in literature accompanying the headset. A dangerously loose headset will be immediately noticeable to riders of any experience level.	11/5 going forward	
Providing adjustment provides a gap for rain, moisture, and debris to be allowed into the bicycle headtube and device mechanism, this could accelerate wear and tear on device and bicycle frame	This is a hazard that can be accommodated for with rubber flashing and liners introduced into the design to cover the open side to prevent the entry of rain or debris. Also adding note in provided literature as warning to potential harm a misused or installed flashing could cause.	11/5 going forward	

Appendix N) Risk Assessment

designsafe Report

Application:	F64 Adjustable Headtube Angle Headset	Analyst Name(s):	Dylan Prins, Ben Harper, Glenn Petersen, Josh Martin
Description:		Company:	
Product Identifier:		Facility Location:	
Assessment Type:	Detailed		
Limits:			
Sources:			
Risk Scoring System:	ANSI B11.0 (TR3) Two Factor		

Guide sentence: When doing [task], the [user] could be injured by the [hazard] due to the [failure mode].

Item Id	User / Task	Hazard / Failure Mode	Initial Assessment Severity Probability	Risk Level	Risk Reduction Methods /Control System	Final Assessment Severity Probability	Risk Level	Status / Responsible /Comments /Reference
1-1-1	adult first use / test	mechanical : cutting / severing 90 degree metal edges that could be sharp	Moderate Unlikely	Low		Moderate		On-going [Daily] Josh /General: Primary risks come from part failure rather than misuse
1-1-2	adult first use / test	mechanical : pinch point pinching of bearing holder and top cup	Minor Remote	Negligible		Minor		On-going [Daily] Glenn
1-1-3	adult first use / test	mechanical : product instability cup rotation	Minor Unlikely	Negligible		Minor		On-going [Daily]
1-1-4	adult first use / test	mechanical : Impact Knees contacting assembly in fall	Moderate Unlikely	Low		Moderate		On-going [Daily] Ben
1-1-5	adult first use / test	slips / trips / falls : impact to / with body parts contacting assembly in fall	Moderate Unlikely	Low		Moderate		On-going [Daily] Dylan
1-2-1	adult normal use	mechanical : cutting / severing sharp edges	Minor Unlikely	Negligible		Minor		On-going [Daily] Ben
1-2-2	adult normal use	mechanical : pinch point parts moving against each other	Minor Unlikely	Negligible		Minor		On-going [Daily] Glenn

Privileged and Confidential Information

Item Id	User / Task	Hazard / Failure Mode	Initial Assessment Severity Probability	Risk Level	Risk Reduction Methods /Control System	Final Assessment Severity Probability	Risk Level	Status / Responsible /Comments /Reference
1-2-3	adult normal use	mechanical : product instability Cup rotating, Pin clip failing	Moderate Unlikely	Low		Moderate		On-going [Daily] Josh
1-2-4	adult normal use	mechanical : Impact body parts impacting assembly in fall or crash	Moderate Unlikely	Low		Moderate		On-going [Daily] Glenn
1-2-5	adult normal use	mechanical : Part failure Holes round, top bearing housing fails	Catastrophic Remote	Low		Catastrophic		Dylan
1-2-6	adult normal use	slips / trips / falls : impact to / with Impacting assemby in crash or fall	Moderate Unlikely	Low		Moderate		On-going [Daily] Ben
1-3-1	adult aggressive use	mechanical : cutting / severing Possible sharp metal edges	Moderate Unlikely	Low		Moderate		On-going [Daily] Dylan
1-3-2	adult aggressive use	mechanical : pinch point contact between bearing housing and top cup	Moderate Remote	Negligible		Moderate		On-going [Daily] Josh
1-3-3	adult aggressive use	mechanical : product instability rotation of top cup, failure of pin clip	Moderate Unlikely	Low		Moderate		On-going [Daily] Glenn
1-3-4	adult aggressive use	mechanical : Impact Impact of body parts with assembly in fall	Moderate Unlikely	Low		Moderate		On-going [Daily] Ben
1-3-5	adult aggressive use	mechanical : Part failure Holes round, top bearing housing fails	Catastrophic Unlikely	Medium	complete testing	Catastrophic		Action Item [5/12/2021] Ben

Item Id	User / Task	Hazard / Failure Mode	Initial Assessment Severity Probability	Risk Level	Risk Reduction Methods /Control System	Final Assessment Severity Probability	Risk Level	Status / Responsible /Comments /Reference
1-3-6	adult aggressive use	slips / trips / falls : impact to / with impact of body parts in fall	Moderate Unlikely	Low		Moderate		On-going [Daily] Dylan
1-4-1	adult maintenance / lubrication	mechanical : cutting / severing sharp edges	Minor Unlikely	Negligible		Minor		On-going [Daily] Josh
1-4-2	adult maintenance / lubrication	mechanical : pinch point contact between top bearing housing and top cup	Minor Unlikely	Negligible		Minor		On-going [Daily] Glenn
1-5-1	adult cleaning	mechanical : cutting / severing	Moderate Unlikely	Low		Moderate		On-going [Daily] Ben
1-6-1	adult assemble	mechanical : crushing could have crushing if using a mallet or punch to assemble	Moderate Unlikely	Low		Moderate		On-going [Daily] Dylan
1-6-2	adult assemble	mechanical : cutting / severing sharp edges	Minor Unlikely	Negligible		Minor		On-going [Daily] Josh
1-6-3	adult assemble	mechanical : pinch point contact between top bearing housing and top cup	Minor Unlikely	Negligible		Minor		On-going [Daily] Glenn
1-7-1	adult disassembly	mechanical : crushing possible crushing if using mallet or punch	Moderate Unlikely	Low		Moderate		On-going [Daily] Ben
1-7-2	adult disassembly	mechanical : cutting / severing sharp edges	Minor Unlikely	Negligible		Minor		On-going [Daily] Dylan

Item Id	User / Task	Hazard / Failure Mode	Initial Assessment Severity Probability	Risk Level	Risk Reduction Methods /Control System	Final Assessment Severity Probability	Risk Level	Status / Responsible /Comments /Reference
1-7-3	adult disassembly	mechanical : pinch point	Minor Unlikely	Negligible		Minor		On-going [Daily] Josh
1-8-1	adult misuse	mechanical : crushing contact points	Moderate Likely	Medium	warning label(s), provided instructions	Moderate		Action Item [4/21/2021] Glenn
1-8-2	adult misuse	mechanical : cutting / severing sharp edges	Serious Unlikely	Medium	round edges, deburr	Serious		Action Item [2/25/2021] Ben
1-8-3	adult misuse	mechanical : pinch point contact between top bearing housing and top cup	Serious Unlikely	Medium	warn users in provided instruction manual	Serious		Action Item [4/21/2021] Dylan
1-8-4	adult misuse	mechanical : product instability rotation of top cup if not set up correctly	Moderate Unlikely	Low		Moderate		On-going [Daily] Josh

Appendix O) User Manual

This manual includes instructions for how to assemble the adjustable headtube angle headset onto a bike and how to adjust the product on a ride or at any desired time.

<u>Important Notes:</u>

This product interfaces only with headtubes in accordance with ZS 44/56 tapered headtube standards (Cane Creek – Standardized Headset Identification System). See Appendix C. DO NOT attempt to assemble this product on a bike with a headtube that is not to this standard.

DO NOT attempt to release the preload by opening the compression assembly handle while riding on the bike or with any body weight on the bike.

Because of the extension of the forks and the location of applied forces occurring on this extension, large forces are seen at the headtube and by the headset under riding or loaded conditions. DO NOT attempt to remove the pins from the assembly while riding on the bike or with any body weight on the bike.

DO NOT attempt to change the angle of the headset while riding on the bike or with any body weight on the bike.

This product does not increase or decrease the risk of injury inherent to mountain biking or biking of any sort.

Safety Concerns:

- Use of this product will require use of PPE such as safety glasses for the assembly of the product on a bike when using a hammer or mallet. While riding and using this product, no PPE is required other than what the user would typically employ during riding such as helmet, gloves, safety glasses, pads, etc. Use of the product does not increase the need for PPE when used for riding.
- If not adjusted correctly, with pins inserted correctly, the product may fail to hold a certain angular position.
- In the event of a crash, additional injury may occur from contacting the top cup and compression assembly, though edges are chamfered and rounded to mitigate this.
- There are possible pinch points between moving parts. DO NOT place fingers into mating surfaces of headset.

Assembling Adjustable Headtube Angle Headset:

Necessary Tools/Materials/PPE:

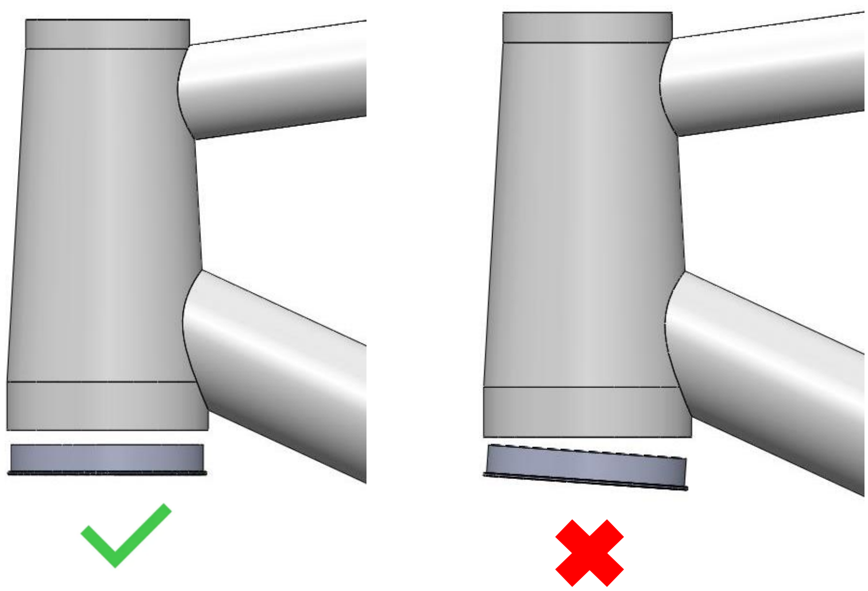
- Safety Glasses
- Standard Bike Component Grease
- Mallet and Post

Or

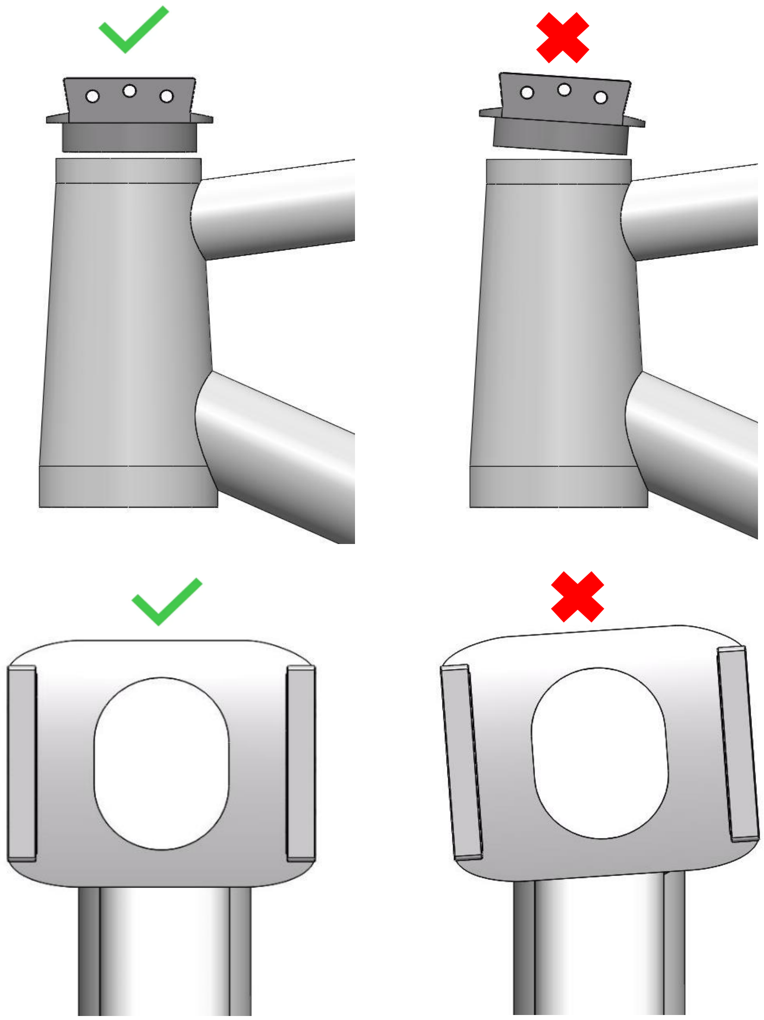
- Headset Cup Press

These instructions detail how to assemble the product on a bike with a ZS 44/56 headtube standard.

1. Grease the contact surfaces on the bottom cup and insert it into the bottom of headtube. Carefully seat it fully and evenly in the headtube using a cup press or mallet.

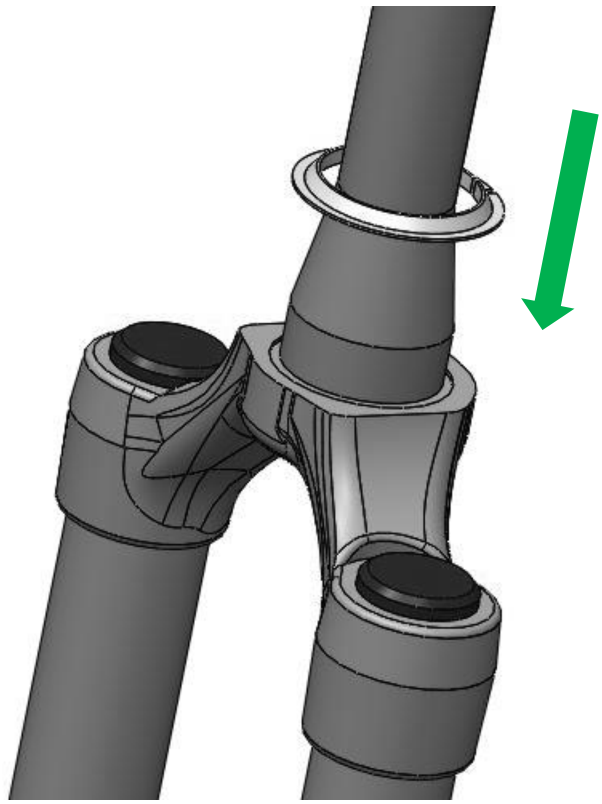


2. Grease the outer cylindrical contact of the top cup with the top of the headtube and insert it in the top of the headtube taking care to align the top cup so the planes on the sides of the upright tabs on the top cup are parallel to the bike frame plane. Use a cup press or mallet to slowly move it into the headtube till it is completely and evenly seated.

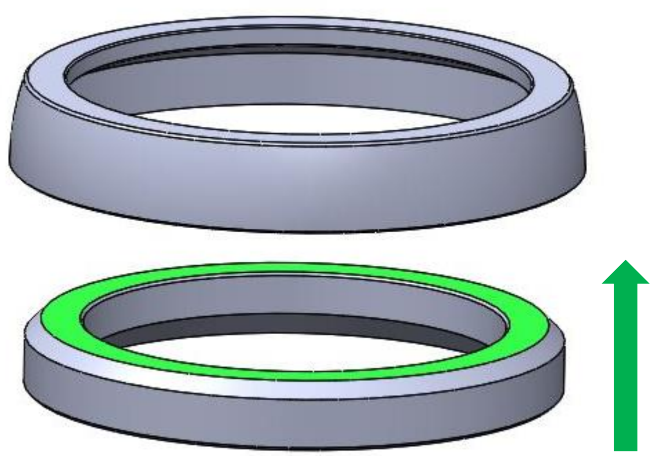


MAKE SURE THE TOP CUP IS ALIGNED CORRECTLY WITH THE FRAME.
Incorrect alignment could lead to instability of the bike.

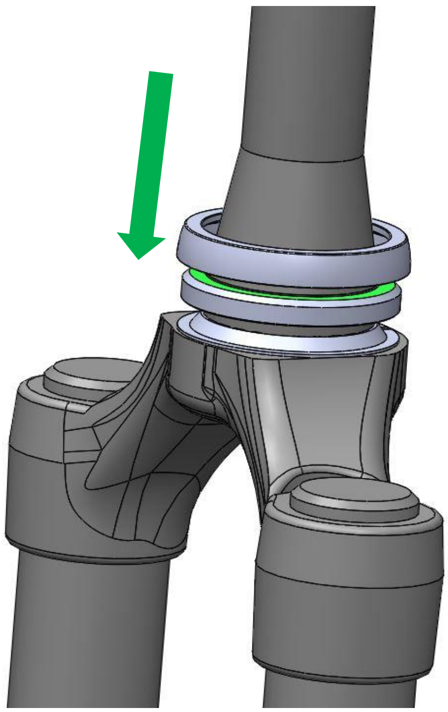
3. Slide the crown race onto the steerer tube.



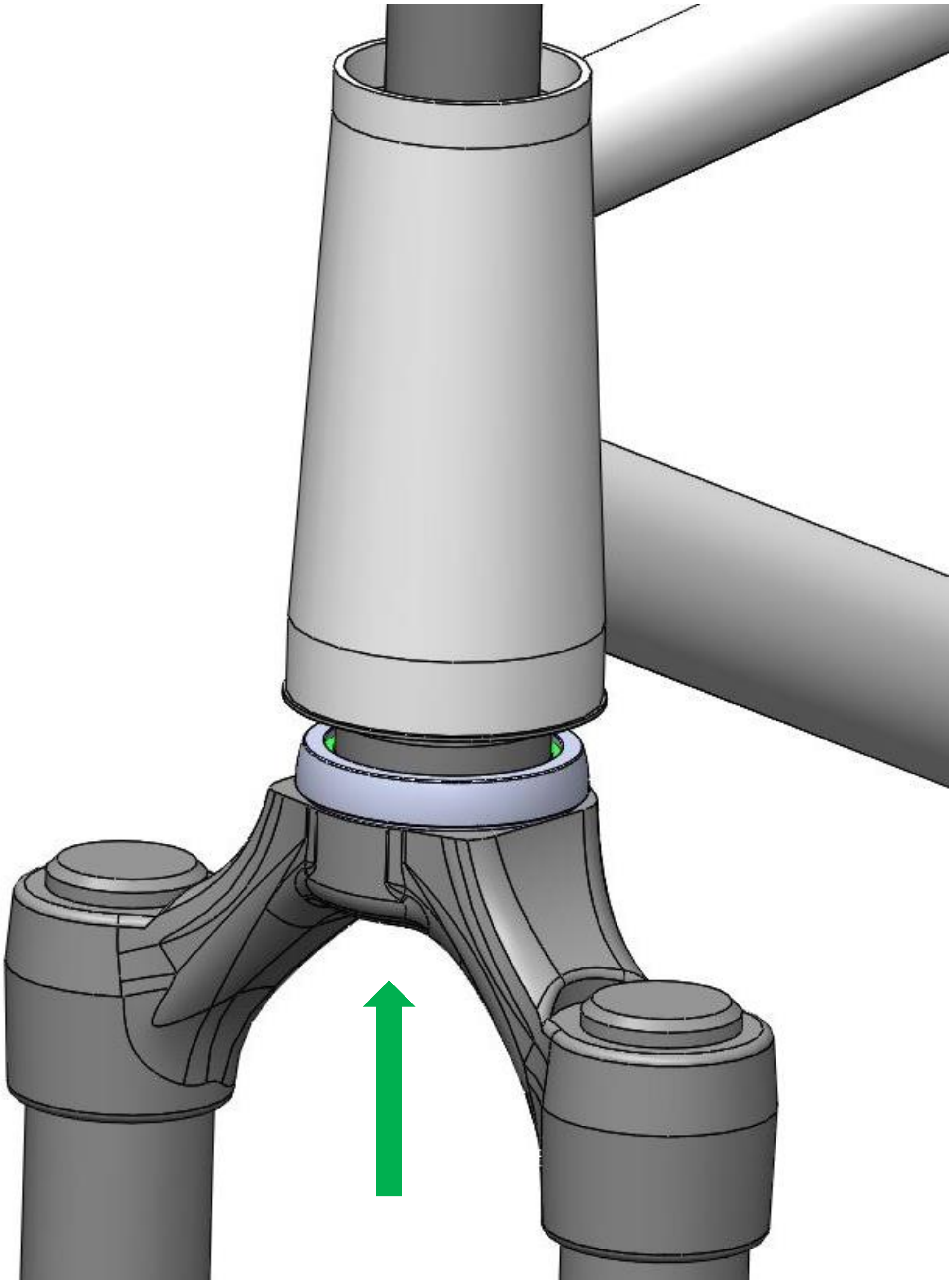
4. Grease the inner and outer races of the bottom bearing and place it in the bottom bearing housing so the outer chamfer seats into the chamfer in the bottom bearing housing.



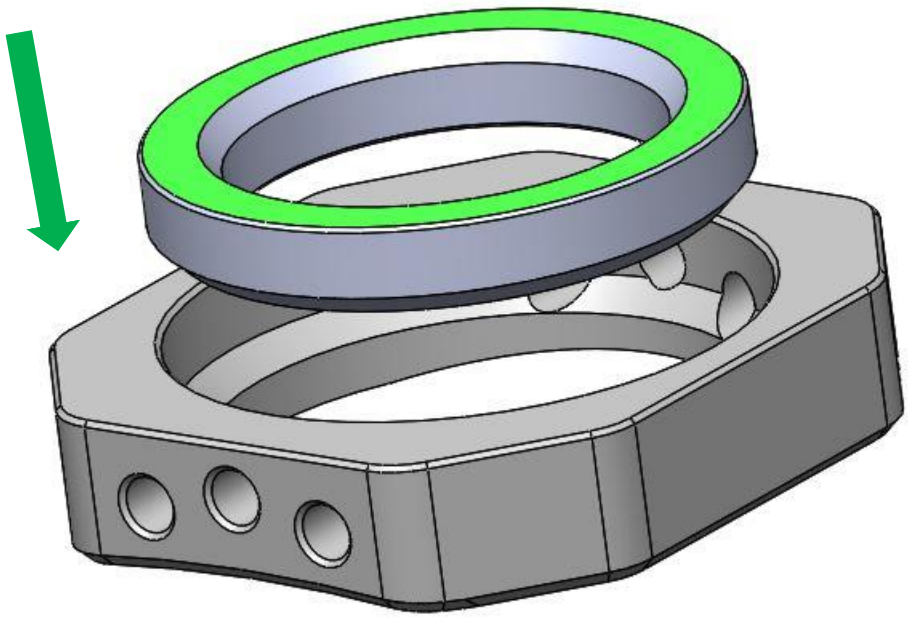
5. Place these onto the crown race so it contacts the inside of the bottom bearing with the spherical contact of the housing turned up to contact the spherical contact in the bottom cup.



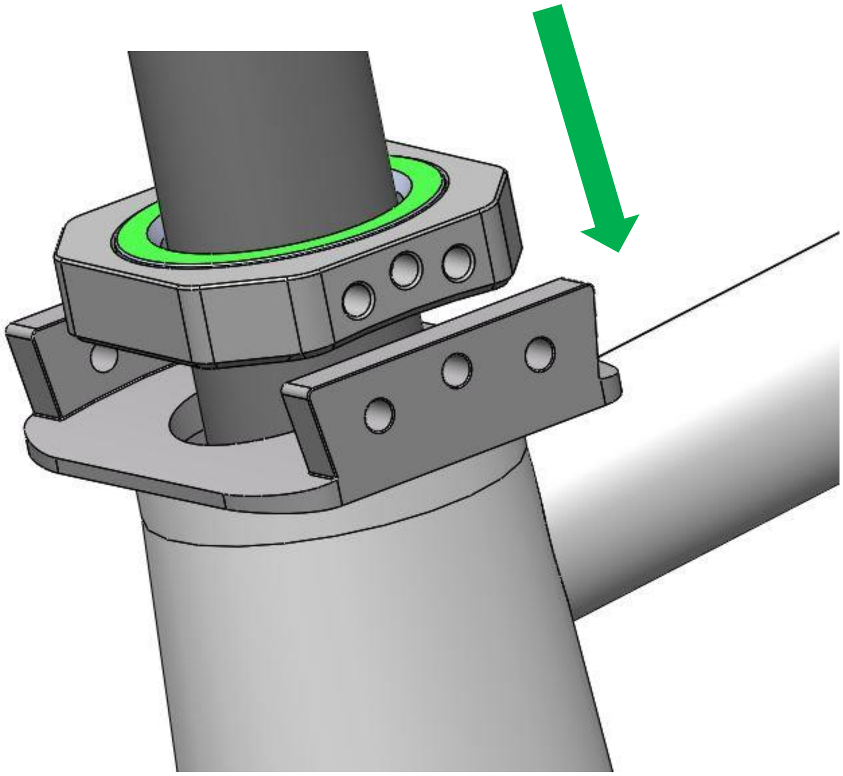
6. Add a thin layer of grease to the spherical contact on the bottom cup housing and slide the fork through the headtube and cups to its highest point and hold it there.



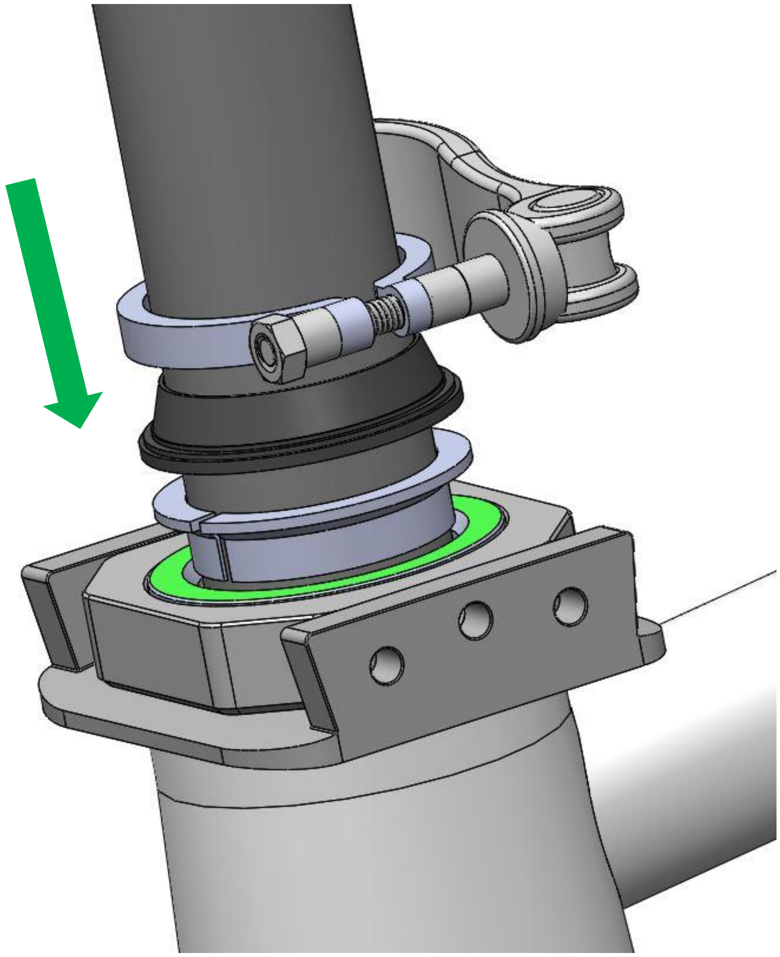
7. Grease the outer contact surface of the top bearing and seat it into the top bearing housing.



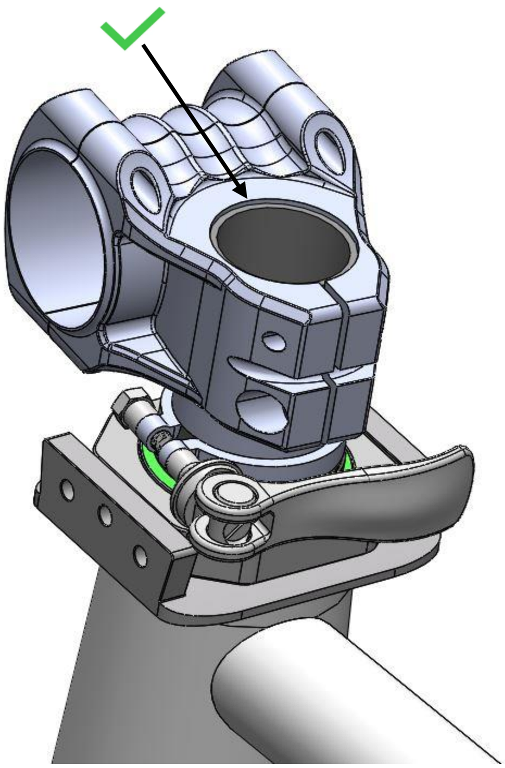
8. Slide the top bearing housing and bearing onto the steerer tube with the bearing facing up and align the housing within the top cup.

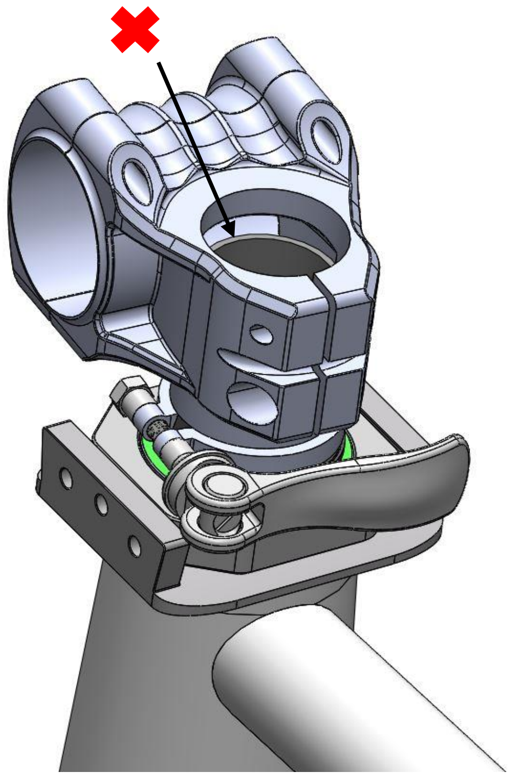


9. Slide the compression ring and compression assembly into place above this with the cone of the compression assembly contacting the compression ring.

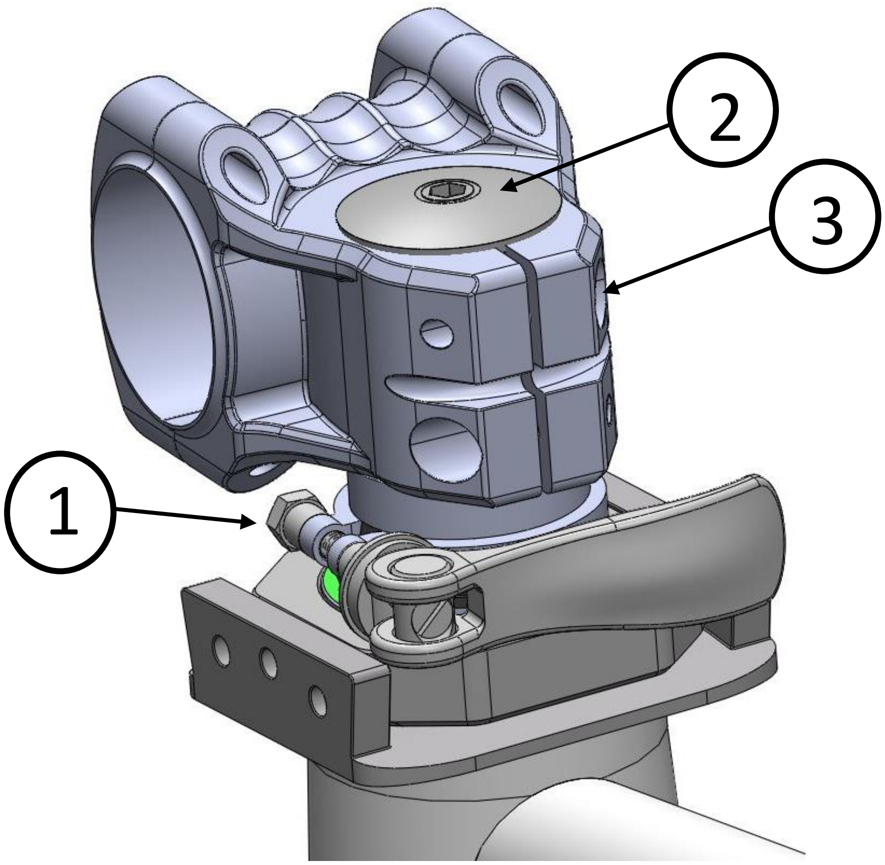


10. Slide on the correct amount of spacers using a guess and check method of sliding the stem onto the steerer tube and checking if the stem extends above the steerer tube by about a millimeter or two.

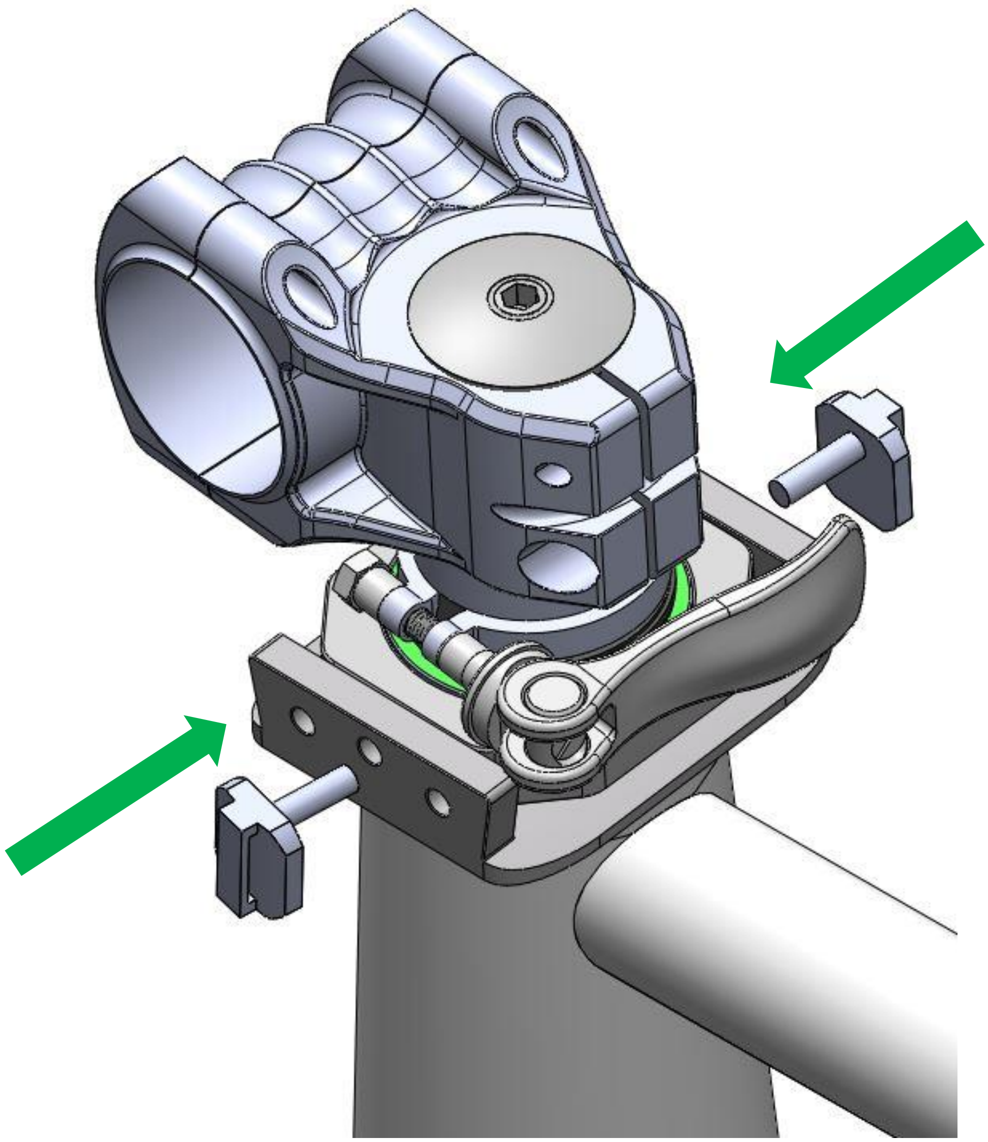




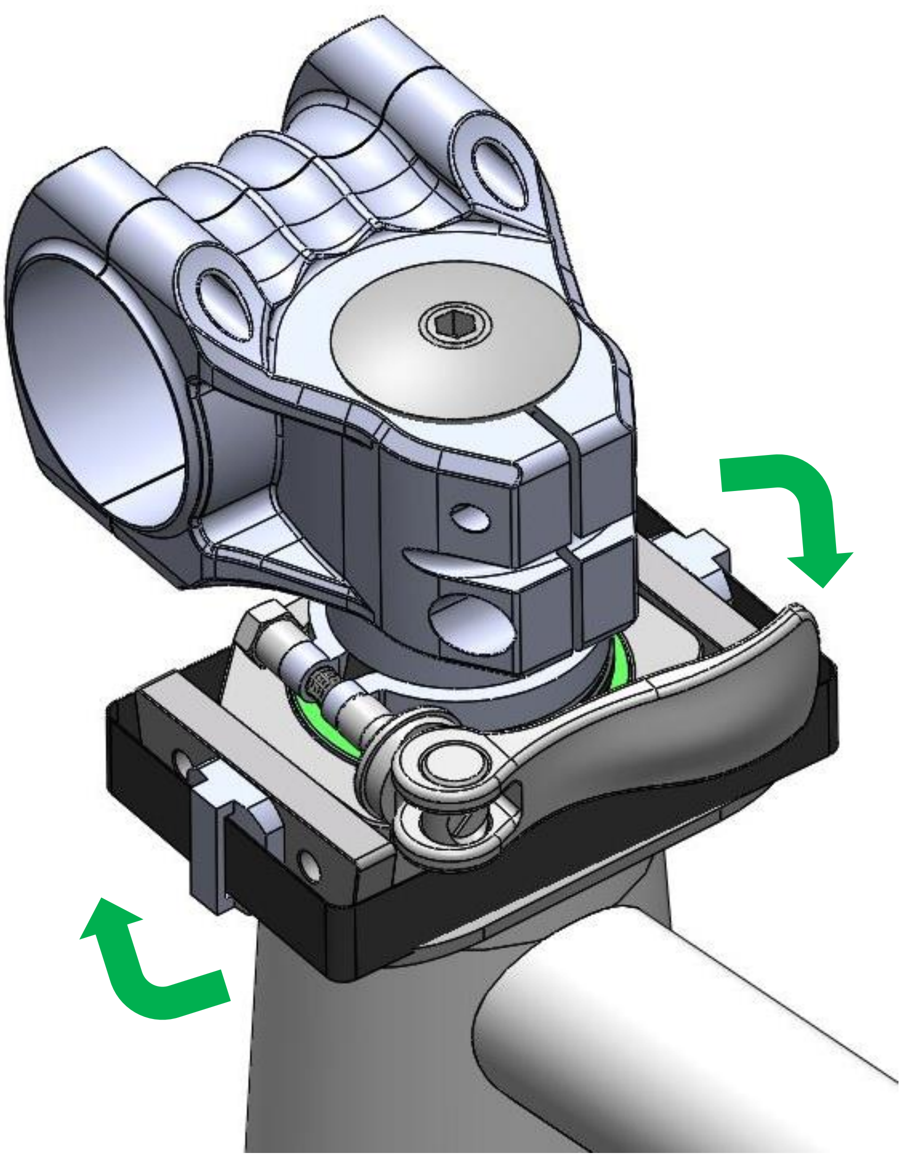
11. (1) Make sure the compression cam handle is closed and the nut is tightened sufficiently for contact.
(2) Tighten the top cap bolt to the torque desired or recommended for riding.
(3) Align the stem and tighten the stem bolts to their recommended torque.



12. Insert the pins in the position desired and put light pressure on them. Rotate the steerer assembly to this location until the pins slide in completely.



13. Tighten and press down the Velcro so it holds the pins in place.



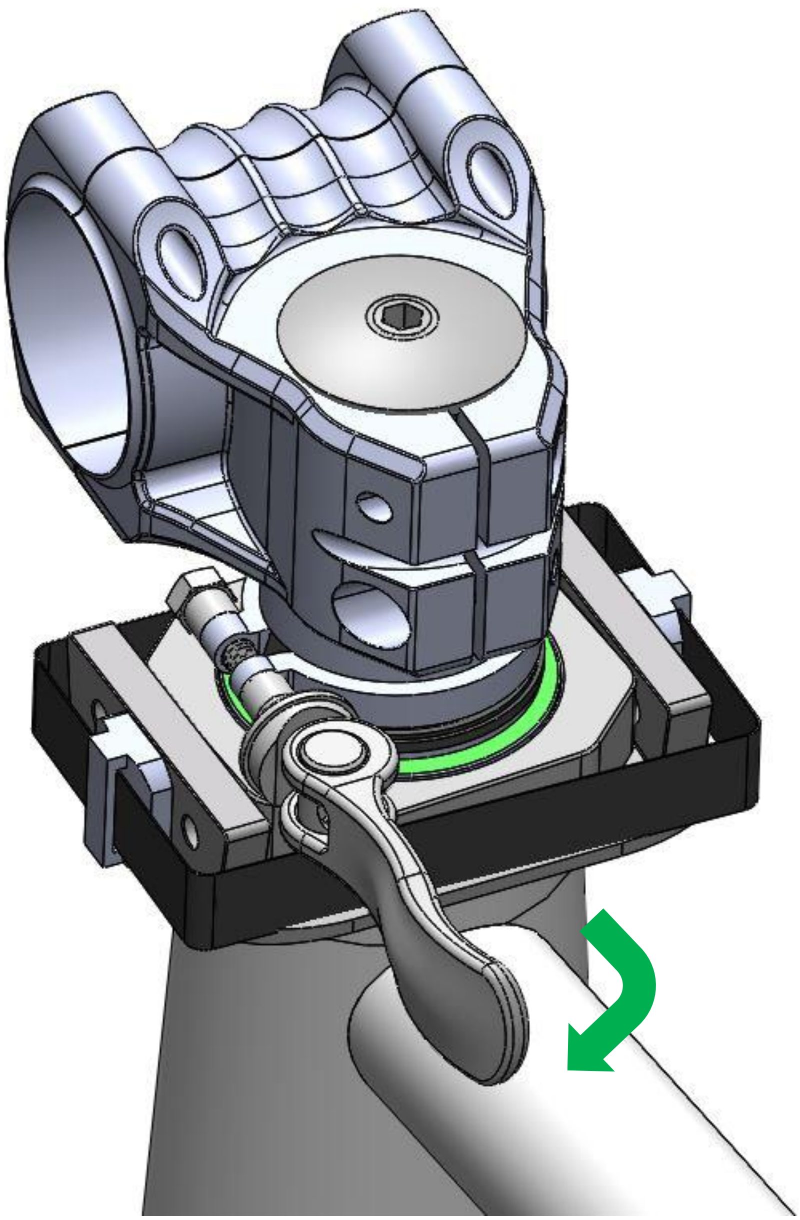
Adjusting the Angle:

Necessary Tools/PPE:

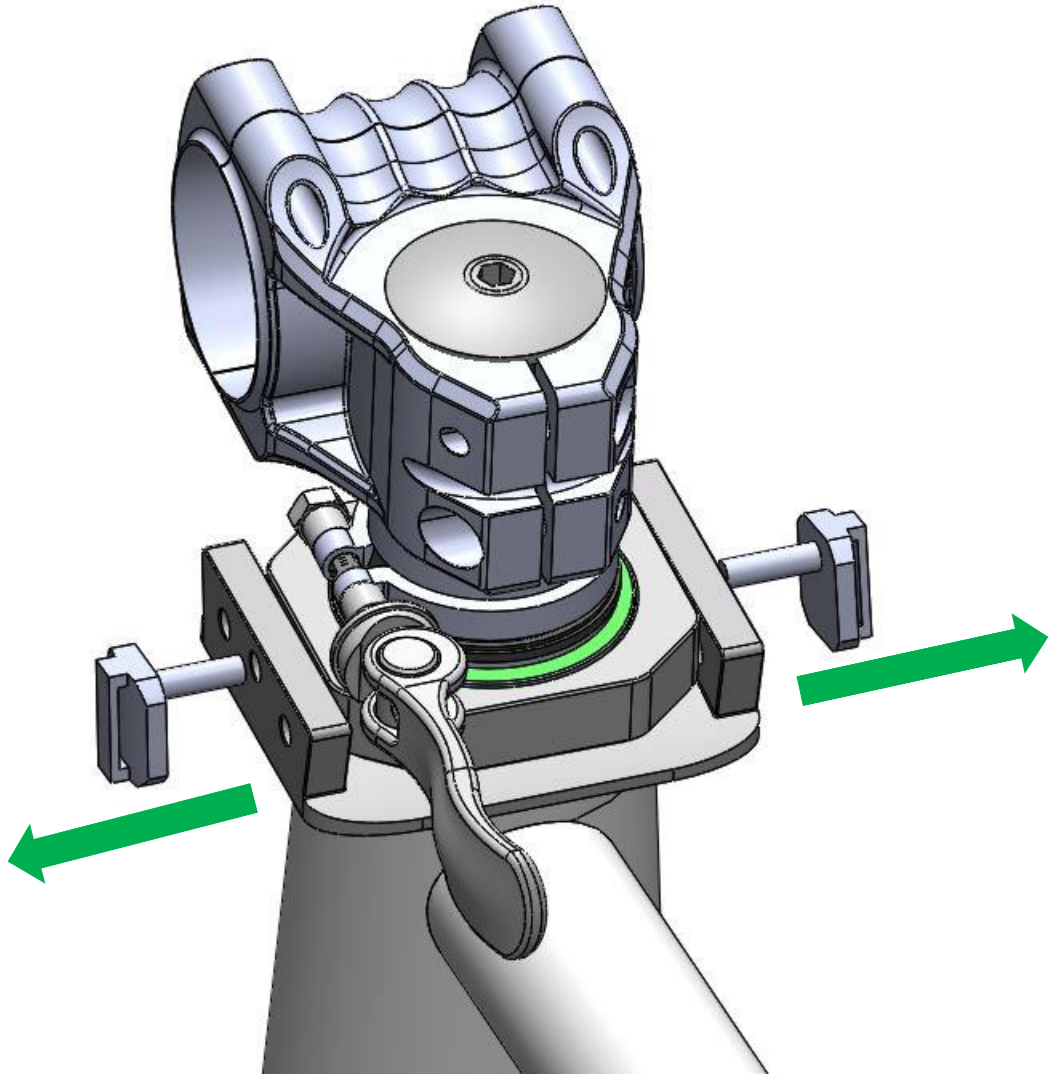
- No tools or PPE needed

These instructions describe how the headset can be adjusted once it is installed on a bike.

1. Dismount from the bike and straddle the top tube.
2. Remove all body weight from the bike and open the cam handle's lever to the unclamped position.

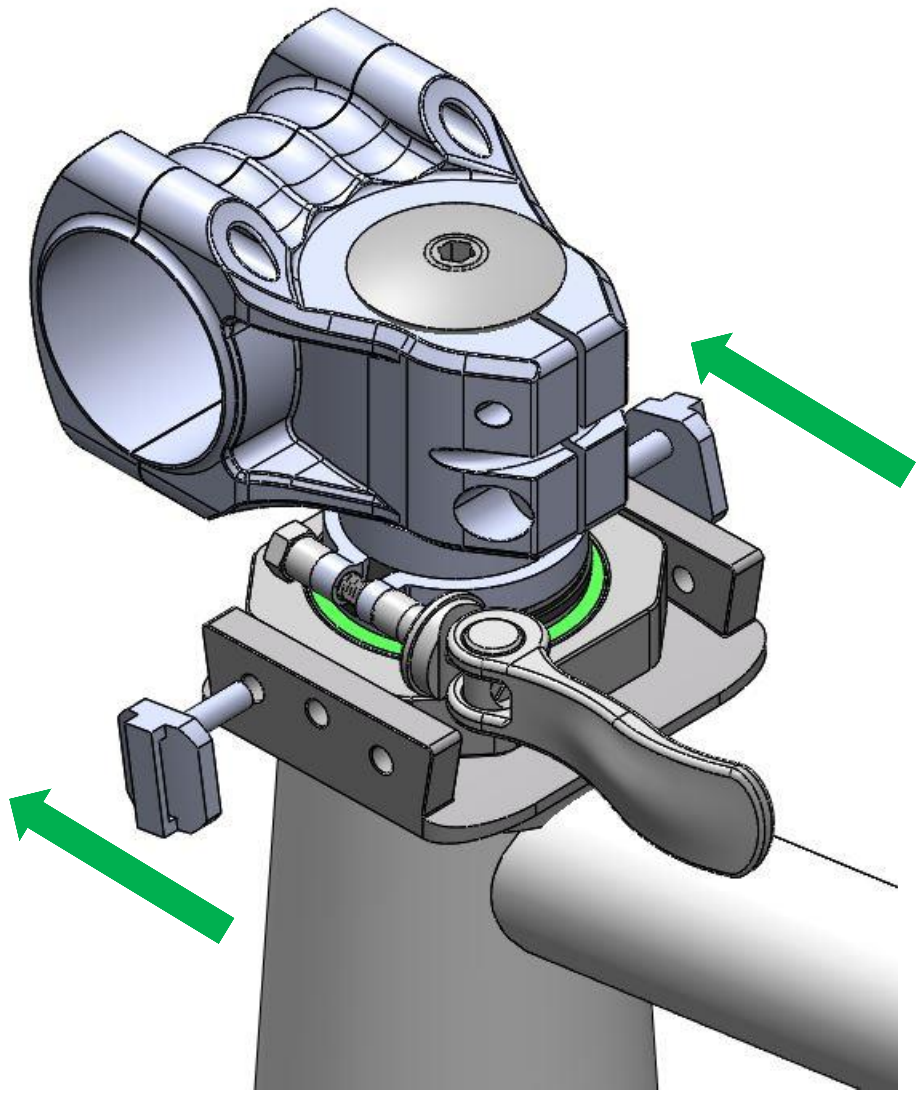


3. Undo the Velcro strap and create some slack in it between the pins. Pull the pins from the assembly.

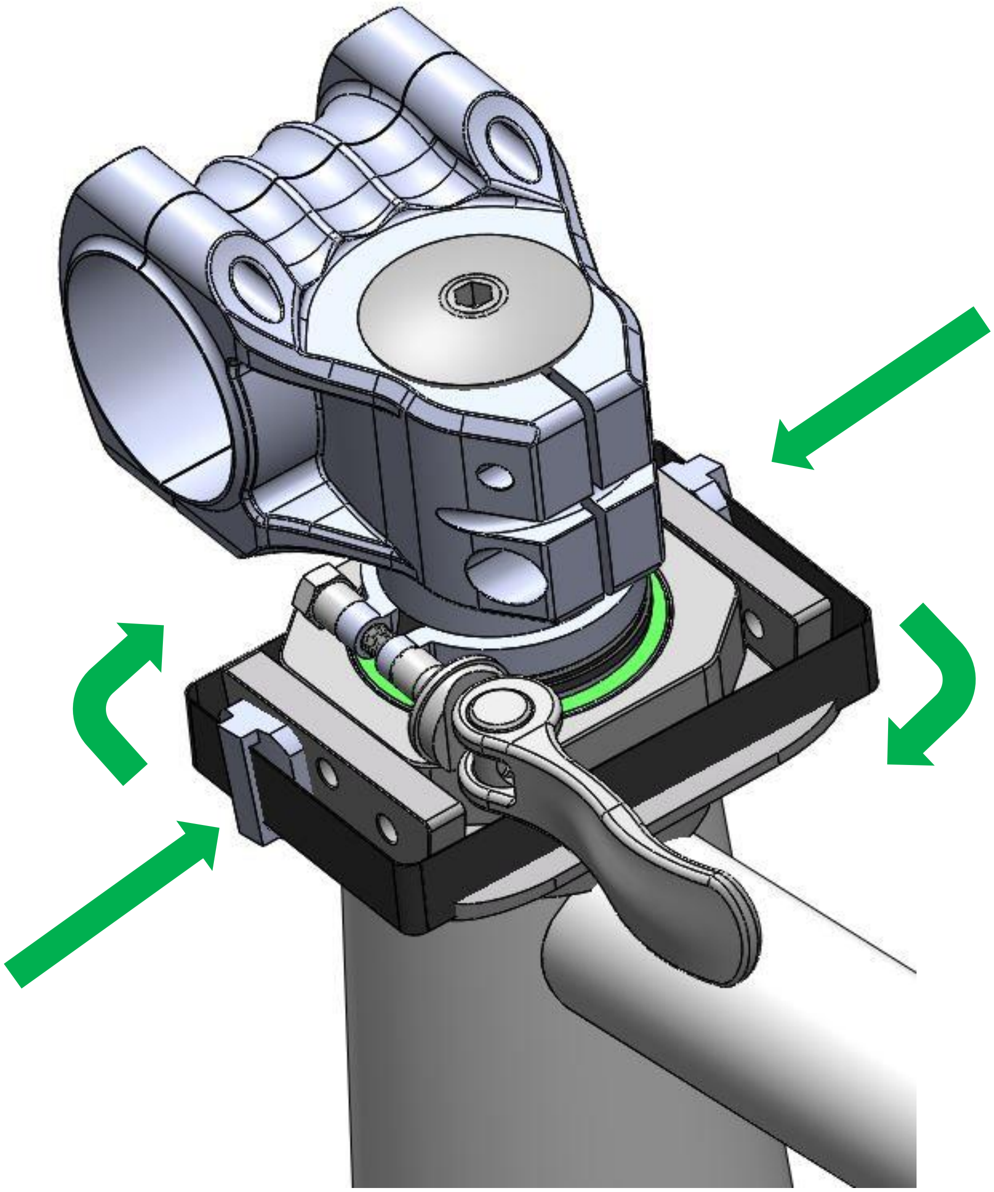


4. Remove the pins from the top bearing housing. It may be necessary to lift the frame, relieving the binding forces created by the bike's weight.

5. Insert the pins partway into the desired location and with slight pressure added. Then rotate the steerer assembly, using your wrists to push the handlebars or lift the front of the bike, until the pins fit in fully, locking the position.

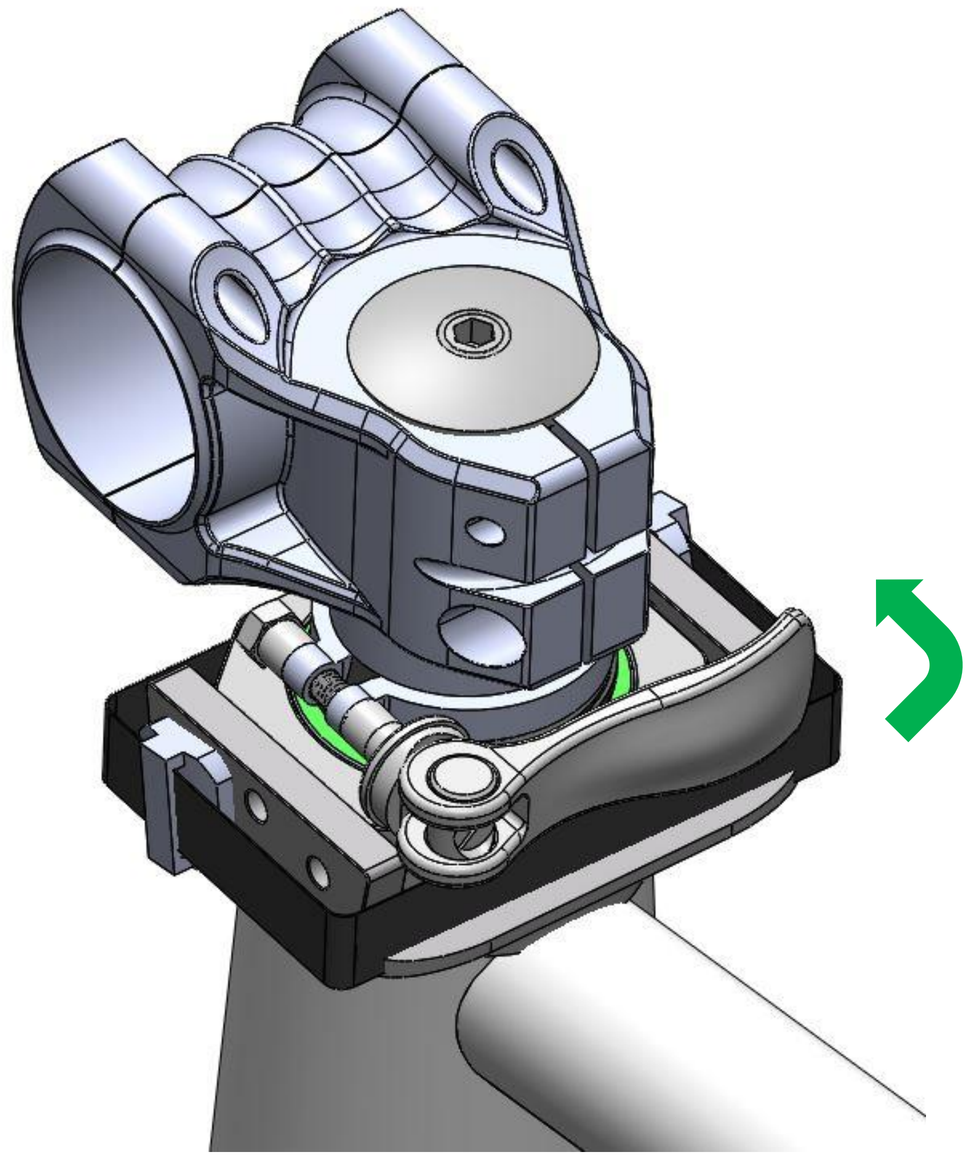


6. Pull the ends of the Velcro with slight tension and reapply the Velcro to itself to hold the pins in place.



7. Re-clamp the compression handle back down to apply preload.

Note: If the clamping effort required is noticeably too high or could not be achieved, unclamp the lever and unthread the nut a turn before re-clamping. If the clamping effort is noticeably too low or the assembly still has play, unclamp the lever and tighten the nut a turn before re-clamping.



Maintenance and Repair Guidelines:

Please follow these guidelines to extend the life of the product as much as possible.

Dry Conditions: perform this maintenance every 100 miles.

Wet Conditions: perform this maintenance every 50 miles.

Disassemble the headset assembly up to removing the cups from the headtube. Grease all contacts as explained in the assembly instructions in this manual.

During this disassembly, make sure to check the condition of all wear surfaces. These include, but are not limited to: the pins, pin holes in the top cup and top bearing holder, contact surfaces between top cup and top bearing housing, contact between bottom bearing housing and bottom cup. Look for scratches, deformation, bending, marring, etc.

For any parts in poor condition, replace them according to the parts list and sourcing on page O-21.

Troubleshooting:

Problem/Fault	Solution
Pins will not seat fully into position.	Attempt to remove all weight from the forks and rotate the steering assembly slightly in both directions (forward and backward) to align the holes while pushing on the pins moderately.
Pins will not come out of the assembly.	Make sure to unclamp the compression handle fully and remove all weight from the steering assembly and try to shift the steering assembly forward and backward to relieve any binding forces between the pins, top cup, and top bearing housing as you pull on the pins. This can also be done one pin at a time.
Assembly seems loose when the compression handle is clamped down.	Open the compression handle fully and tighten (clockwise) the nut half a turn and close the handle again. If the assembly continues to feel loose, repeat this process until it is not.
Compression handle will not close or requires too much force to close.	Open the compression handle fully and loosen (counter-clockwise) the nut half a turn and close the handle again. If the assembly continues to feel too tight or the handle will not close, repeat this process until the handle can be closed.
Creaking noise coming from headset.	Disassemble the assembly and remove and separate all parts. Wipe clean and then apply standard bike component grease to all contacting surfaces outlined in the assembly procedure at the beginning of this manual.

Parts List:

Source	Part Name	Part Number
Cane Creek	Compression Ring	AAA0001B
	Dust Cover	BAA0726K
	Shim Spacer	HSS2050
	Crown Race	BAA0173A
McMaster Carr	Cam Handle	5720K281
	Cam Spacer	92871A308
	Pins	Purchased Alloy steel stock
	Nut Spacer	94669A008
Ace Hardware	Nut M16 x 2.0	-
	Bolt M16 x 2.0 x 40	-
	Washer M16 Wide	-
Jenson USA	One-Up EDC Preload Kit Top Ring	TL001008
	One-Up EDC Preload Kit Bottom Ring	TL001008
Enduro Bearings	Top Bearing	ACB 3645 BOCC
	Bottom Bearing	ACB 6808 SS
Amazon	Retention Strap	Rubber/Velcro band
Custom Made	Top Headset Cup	Purchased 7075 Al
	Top Bearing Housing	Purchased 7075 Al
	Bottom Headset Cup	From donated stock
	Bottom Bearing Housing	From donated stock
	Upper Yoke	From donated stock
	Lower Yoke	From donated stock
	Mock Bearing	From donated stock

Appendix P) Design Verification Plan

DVP&R - Design Verification Plan (& Report)												
Project:	F64 Angle Adjust Headtube		Sponsor:	Dr. Kean						Edit Date: 6/1/2021		
TEST PLAN										TEST RESULTS		
Test/Spec. #	Specification	Test Description	Measurements	Acceptance Criteria	Required Facilities/Equipment	Parts Needed	Responsibility	TIMING		Numerical Results	Notes on Testing
								Start date	Finish date		
1	Adjustment Time	Measure how long headset adjustment takes.	Headset adjustment time	Less than 20 seconds adjustment time	Team garage/Stop watch	All components at VP level	Josh	May 11th, 2021	May 11th, 2021	Average of about 15 seconds between all team members	All team members performed test. Passed it will all trials under 20 seconds to adjust headset
2	Tools Needed to Adjust	Count how many tools are required to adjust the headset	Number of tools	Less than one tool needed	Team Garage	All components at VP level	Ben	May 11th, 2021	May 11th, 2021	0 Tools	No tools were needed. Done concurrently with test 1.
3	Weight	Weigh all components to find sum of headset assembly + preload Kit	Weight of parts	sum is less than 250 grams	Mustang 60/Scale	All components at VP level	Glenn	May 11th, 2021	May 11th, 2021	236 grams	Under weight target
4	Resemblance to Normal Headset (Survey)	Ask mountain bikers how closely they think our headset resembles a standard headset.	Popular opinion on resemblance to standard headset	Majority acceptance of design by biking community	N/A	CAD of final design and each part within it, and an image of all parts assembled on a bike	Dylan	May 3rd, 2021	May 26th, 2021	68% of riders would not let its appearance prevent them from running our headset	Surveyed cycling anf bike builders clubs' mountain bikers. Obtained favorable results.
5	Real-World Test Rides	Install the headset assembly on one of our moutnain bikes. Go on a bike ride with features that would test the integrity of our design.	Experience of headset on bike ride and Visual inspection of parts proceeding the removal of the headset.	Does not creek or fail to accomplish our adjustablilty requirements.	Personal mountain bike with correct headtube configuration, assembly tools, headset press and allen keys	All components at VP level	Dylan	May 11th, 2021	June 1st, 2021	Complete, around 200 miles ridden	Does not fail any adjustability requirements, but due to lack of of solid dust seal there is a slight creek
6	Range of Adjustability Test	Test how far the steerer tube can be adjusted steeper and slacker from neutral	Measure angle of offset of steerer tube centerline from headtube centerline	greater than or equal to 2 degrees of offset each way	Team Garage and digital angle gauge.	Full assembly and fitting mountain bike.	Ben	May 11th, 2021	May 11th, 2021	Referenced to frame: +/- 2 degrees Referenced to ground: +/- 1.63 degrees	We realized that the angle measured depended on reference to frame or reference to ground with both wheels on the ground. We designed using frame as reference and we met 2 degrees that way but not with reference to ground. Recommend to remanufacture top cup with holes spaced out further to limit.
7	Top Bearing Housing Load Test	Top Bearing Housing Structural Test: Load test of top bearing housing to failure to determine design factor of safety.	Stress-strain relationship providing part yield and failure loading.	Yield loading force is higher than our design criteria loading case.	Instron Tensile Test Machine - in Composites lab.	1) Test Fixture(yoke, bottom tang, bearing spacer, fixture pins, bolt/washer/nut) 2) Top bearing housing	Dylan	May 13th, 2021	May 13th, 2021	Instron tentile machine reached its load limit of 7000 lbf. No noticable defromation of pin holes or bearing failure.	Stress-strain curve began going into plastic (curved out) but the origin of the deformation is more likely to be in the pins supporting the assembly.
8	CNC Review Meeting With Professor	Discuss manufactured parts manufacturability as well as possible inspection capabilty. This includes the test fixture design. Consideration to optimal operation order with regard to achieving tolerances and speed.	Review part design and manufacturing CAM programs with Professor	Gauged optimal process plan.	N/A	CAD of final design and each part within it	Glenn	February 10th, 2021	February 10th, 2021	N/A	Professor Trian Georgeou determined that our design was complex but entirely feasible. He suggested that reducing some of the complex curvatures to make them simply straight edges would decrease manufacturing time and increase strength slightly.
9	Test Rotation of Handlebars	Measure fork rotation angles allowed by headset	Rotation angle, effort required to rotate (feeling in hand to experienced mechanic).	90˚ rotation in each direction, same effort to standard headset.	Team Garage/Protractor	All components at VP level	Dylan	May 11th, 2021	May 11th, 2021	90 degrees each way from straight on.	Test was passed and the handlebars could rotate more than 90 degrees each way.
10	Maintenance Test	Disassemble headset after testing to check for wear.	Bearing wear, surface marring, dust ingress.	Little to no scaring of components from dirt/dust ingress, no reduced performance due to above	Team garage/tools to dissassemble headset, headset press, allen keys	All components at VP level	Josh	May 1st, 2021	May 15th, 2021	No rounding of holes, no concerning wear, no dust/grit buildup.	Our testing was far from long-term, but we did not discover any concerning maintenance issues in our brief test span.

Appendix Q) Test Procedures

Test Name: Adjustment Time Test

Planned Test Date(s): 4/30/21

Purpose: This test's purpose is to determine the average time to adjust between two different headtube angle positions while on a ride.

Scope: This test focuses on the top cup, top bearing housing and preload interface with the user. The function in question is the adjustment of the headtube angle and the time it takes to do this.

Hazards: Limited to possible pinch point between top cup and top bearing housing. Parts are all machined metal but will have rounded/chamfered edges.

Facility: Team garage or driveway.

Performed By: Team F64 – Adjustable Headtube Angle Headset

Equipment: Full headset assembly installed on a mountain bike. Stopwatch and notebook to record times.

PPE Requirements: Proper face covering for all present in accordance to Cal Poly's COVID-19 Health Requirements.

Procedure:

1) Test subject straddling bike frame facing forward on the bike as common after dismounting to take a break. Headtube is in neutral position.
2) Stopwatch is started.
3) Test subject removes all weight from bike (not sitting or leaning on frame at all).
4) Test subject removes preload by opening cam handle.
5) Test subject removes pins from top cup.
6) Test subject moves headtube from neutral position to steep position.
7) Test subject re-inserts the pins into the top cup and aligning top bearing housing holes.
8) Test subject closes cam handle to reapply preload, fine tuning nut to provide correct preload where headset has no "play".
9) Stopwatch is stopped.
10) Process is repeated from step one and the headtube is moved from steep to slack. Then repeated from step one and moving headtube from slack to neutral positions.
11) Record time for each adjustment. Average times of all three to determine Time to Adjust.

Results: Each team member will be the test subject for 3 trials. If the majority of these 12 trials are less than 20 seconds then the Adjustment Time Test has been passed. If fewer than the majority of the 12 trials are less than 20 seconds then the Adjustment Time Test has been failed.

Test Results:
We will place results in the following tables:

	Trial 1	Trial 2	Trial 3
Dylan	15.84	16.18	19.33
Josh	11.72	18.08	15.75
Ben	16.35	15.03	15.72
Glenn	7.68	11.62	13.26

	Avg. Trials 1-3
Dylan	17.12
Josh	15.18
Ben	15.70
Glenn	10.85

All team members completed their trials in under 20 seconds. This means the design passes this test. In addition, Ben and Glenn had been operating this design on their bikes and had experience with it. Meanwhile Dylan and Josh had not been operating it and had much less experience using it. Even so, the difference between the experienced users and less experienced users is not great. All users, experienced and not, achieve the test in under 20 seconds. It speaks to the usability of our design.

Both Ben and Glenn report that the 20 seconds or less of adjusting the headset at the top of a trail, from steep to slack setting, preparing for the downhill section, is a 20 second allowed break to catch their breath rather than a 20 second slowdown.

Image of Glenn performing the time to adjust test.

Test Name: Tools Needed to Adjust Headset

Test Date: 5/6/21

Purpose: The purpose of this test is to measure how many tools are needed to adjust the headset's position.

Scope: Measure the number of tools required to adjust the headset.

Hazards: No additional hazards exist outside of those associated with normal installation and use of our headset. The only hazard we predict is a possible pinch point when adjusting the headset.

Facility: Team member house or building 192 or 197.

Performed By: Team F64 – Adjustable Headtube Angle Headset

Equipment:

- Bike with our headset installed
- Any tools necessary to adjust the headset (idea is to have zero)

PPE Requirements:

- Mask.
- Safety glasses.

Procedure:

1. One team member shall take the full assembly installed on a mountain bike and adjust the headtube angle through all positions, slack, steep and neutral.
2. Meanwhile, another team member will record how many tools are needed to adjust the headset.

Note: this test may be performed concurrently with other adjustment tests

Pass/Fail Criteria: Our headset must not require any tools to adjust its position to pass the test. Otherwise, it will fail this test.

Test Results: We will place our test results into the following table:

Tools Required to Adjust Headset	0

Test Notes:
Performed in unison with the time to adjust test. No tools were needed to adjust the headset as it was effectively designed to be adjusted with no tools.

Test Name: Weight

Planned Test Date(s): 4/31/21

Purpose: This test's purpose is to measure the complete headset assembly's mass to compare to current headsets available.

Scope: Measure the headset's mass.

Hazards: No hazards for this test exist besides those associated with using a scale.

Facility: Mustang 60 Shop, Bonderson.

Performed By: Team F64 – Adjustable Headtube Angle Headset

Equipment:

- Complete headset assembly (excluding bicycle and fork)
- Scale – Mustang 60

PPE Requirements:

- Mask.
- Safety glasses.

Procedure:

1. Turn on scale and ensure units are grams (g).
2. Place all bottom cup components (including bearings), record in table.
3. Place all top cup components (including bearings), record in table.
4. Place all bottom and top cup components on scale, record in table.
5. Repeat step 2 for 4 trials and 3 assemblies.

Pass/Fail Criteria: Our headset's total mass must not exceed 250 grams, or it fails this test. Otherwise, it passes this test.

Test Results: We will place our test results into the following table:

Assembly	Bottom Cup Assembly Mass (g)	Top Cup Assembly Mass (g)	Complete Assembly Mass (g)
Mass	90	146	236

Comment: Plastic bag used as surface to place dirty components on clean scale, scale was tared prior to measuring.

Figure 1. Bottom cup assembly including: bottom cup, bottom bearing housing, and bottom bearing.

Figure 2. Top cup assembly including: top cup, top bearing housing, top bearing, dust cap, and compression ring.

Figure 3. Complete assembly including all components of bottom and top assemblies.

Test Name: Resemblance to Normal Headset

Performed By: Team F64

Test Date: 5/18/2021

Purpose: This test's purpose is to gauge popular opinion on our headset's resemblance to normal headsets and the likelihood of people using it on their own bike.

Scope: This test gauges a subjective measure of our headset's aesthetics.

Hazards: This test contains no hazards.

PPE Requirements: This test requires no PPE.

Facility: This test could take place at trailheads if Covid rules permit. Otherwise, it will take place online in a survey.

Equipment:

- Google survey with pictures

Procedure:

1. Create a survey that asks participants to rate the headset's aesthetics on a 1-10 scale.
2. Send the survey to mountain bike groups and ask other riders at trailheads to participate in the survey.
3. Analyze the test's results.

Pass/Fail Criteria: Our headset passes this test if more than 50% of riders surveyed approve of its aesthetics and would run it on their bike. We hope to survey at least 30 riders.

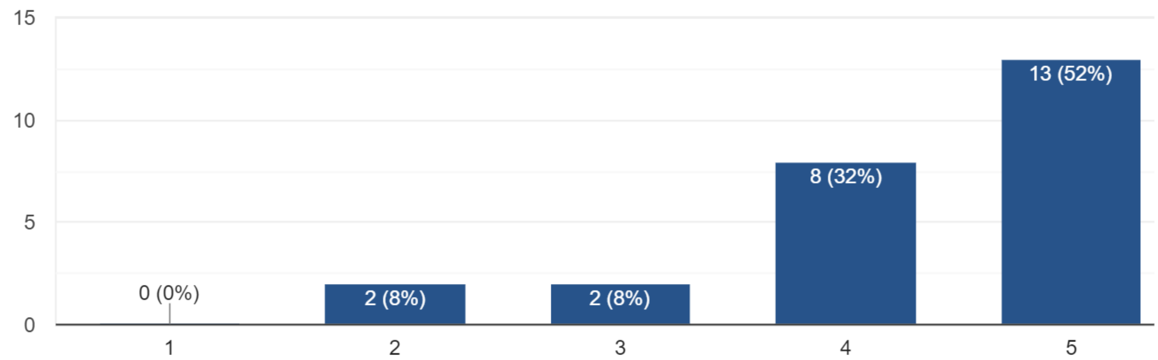
Test Results:

1 designates strongly disagree while 5 indicates strongly agree.

Based on the results of the survey, riders are likely to notice our headset if they are riding with someone who has it installed and less likely to notice it on a bike passing by. Most believe the appearance of our headset would not affect their decision to purchase it or not for their own use.

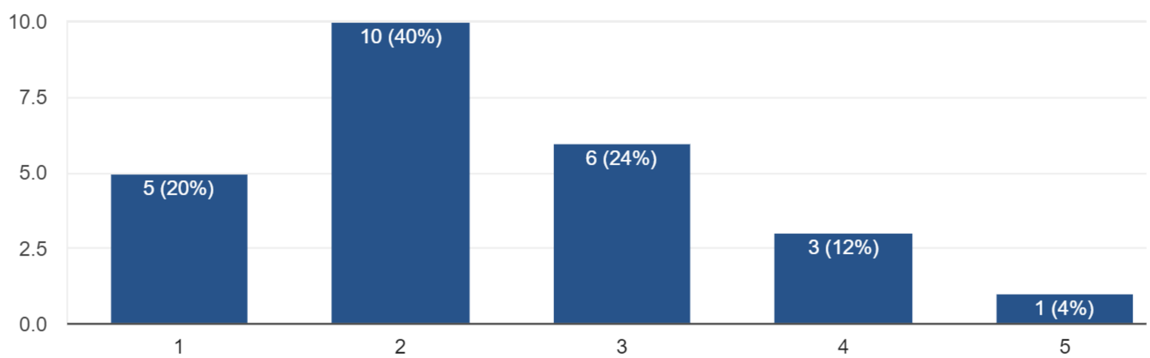
Do you think you would notice this headset on the bike of someone you're riding with?

25 responses



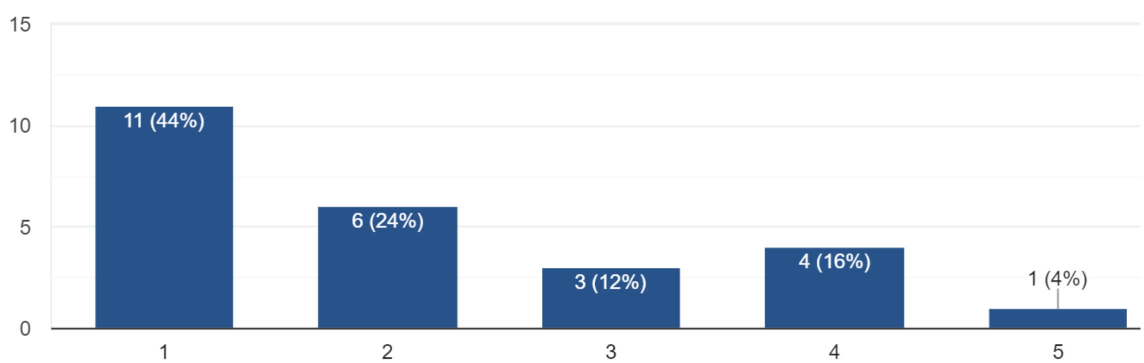
Do you think you would notice this headset on the bike of someone passing by?

25 responses



Would this headset's appearance prevent you from running it on your bike?

25 responses



Test Name: Real World Test Rides

Planned Test Date(s): Ongoing through spring quarter once the headset is completed (hopefully 4/30-5/25.

Purpose: This test's purpose is to confirm that our headset functions as designed when used in a real-world setting.

Scope: Confirm our headset's functionality in real-world use cases.

Hazards: In addition to the hazards associated with mountain biking, our headset introduces the potential for user error. Improper use of the headset could result in the steerer tube not being securely held within the frame. Headset failure would have the same result. While this would be alarming to the rider, it will be immediately noticeable and cause the rider to stop as soon as possible.

Facility: Trails around San Luis Obispo.

Performed By: Team F64 – Adjustable Headtube Angle Headset

Equipment:
- Bike with our full VP headset installed

PPE Requirements:
- Mask.
- Safety glasses.
- Mountain biking protective gear (helmet).

Procedure:
3. Install the headset onto a personal bike.
4. Ride like normal, adjusting the headset to suit the trail as designed.
5. Observe the headset for any abnormal behavior.
6. Record notes when thoughts arise for documentation.

Pass/Fail Criteria: Our headset must function as designed and, when locked into an adjustment position, have identical functionality to a normal headset to pass this test. That means it must not make noise, allow the preload to lessen, or allow the steerer tube to move out of position. Otherwise, it fails this test.

Test Results: We will have the rider record his/her thoughts in either voice recordings made during breaks while riding or on a notepad. Those will be transcribed and listed below as text.

Test Results

Test Rider: Glenn Petersen

Install date: 5/6/21

Rides:

1. Stomping around the hanger

Installed the headset and road the bike around for 20 minutes figuring it out on flat pavement. At this time, there was about 0.5 – 1 mm of free play that could be manually shifted by hand. This play was only capable when the preload was not set.

We began to stomp on it, videoed. This resulted in no visible or increase in the play felt during the non-preloaded setting. This led to more stomping and more vigorous stomping. No change in the capability of the headset. No further noise or shifting.

Condition: Sunny dry, pavement with some gravel.

2. Good and tasty [13 miles]

Road up via Stenner and shooters, to the top riding in the steep position. Then the fire road across down to good and tasty. The top of good and tasty is extremely steep. Riding in the slack position, I noticed a slight shifting under high front wheel braking. This shifting presented itself with a slight knocking under each stiff breaking pulse. Upon review, the preload was set properly, and all was fine with the headset. While riding the actual trail no noticeable knocking or noise or play was felt or heard.

Conditions during the ride were warm and dry. Dirt, gravel, and dust.

3. Stadium Park [7.6 miles]

Up the front side to the top, riding in neutral position. No creaking or shifting felt. Down the flow trail, up the ebike steeps, in the steep position, then down the jump track in the slack position. Back up the front side after taking the road around the exterior of the park (steep position up the front). Then down the flow trail in neutral. Similar experiences to the good and tasty test ride, small knocking or shifting felt during the steep downhill portions at slow speeds. A small rock garden at slow to moderate speed also did not provide a noise or shifting feeling. During normal speeds and moderate braking did not provide any noise or shifting feeling.

Conditions: Dry, sunny. Dusty and compact dirt; small rock section. Short section of pavement

4. Costco Jumps #1 [1.5 hours]

Large step, main table, long table, steep double to downhill landing, far west gap to small double parallel to main table. Set to neutral position the entire time. No noticeable effects while riding. Got a nice comment on the bike, no comment on the headset or noticing it.

Conditions: Evening time, windy, dirt jumps.

5. Shooters [15 miles]

Up shooters via stenner in steep setting, then slack down. Neutral through Poly Canyon. Prior to ride, I was practicing track stands in the meat processing plant parking lot. I noticed a slight creaking noise that occurred. It was minor, but it was there.

Conditions: Cool, windy, overcast. Dusty, dirt and gravel pack riding. Some loose gravel.

Test Results

Test Rider: Ben Harper

Install date: 5/18/21

Ride locations: West Cuesta Ridge, Montana do Oro, Madonna Mountain, and Irish Hills.

How it was used: I rode flat and climbing sections in the steepest position. I rode dedicated descents in the slackest position. I rode general rolling terrain in the neutral position.

Ride Impressions: The first things I noticed after installation was the higher handlebar position from the increased stack height and the slight slackening of the neutral position due to the increased stack height beneath the headtube. After riding the headset in the neutral position only to reset my baseline, I began experimenting with the other adjustment positions.

The steepest position made controlling the steering when climbing far easier. For lower speed riding and flat traversing, this position increased the ride quality by making turning feel better and reducing fork flop.

The slackest position offered more control when descending steep trails. Having the fork further out in front of me made sections of trail that were normally point-and-shoot far easier to remain controlled. The stability at high speeds was impressive. The force transmitted to my hands was reduced so much through technical terrain that I often felt like I could remove my hands from the bars. Coming to a stop after a descent, the low-speed instability was also noticeable.

The neutral position remained a good compromise on geometry for when the terrain was evenly split between climbs and descents, where adjusting the headset so frequently would be a nuisance.

I never felt any loose headset feedback or play while riding. It simply disappeared underneath me, as it should. Some creaks were made while tightening and loosening the cam handle while adjusting the headset, but I did not experience any noises while riding. I rode this headset enough to be very confident in its durability.

It was like having three different bikes with me at all times. It was a unique experience to be able to adjust my head tube angle to suit the trail in front of me. Adjusting the headset was quick and easy. It added so much more to the riding experience and I loved spending time on it.

Test Name: Range of Adjustment

Planned Test Date(s): 5/4/21

Purpose: This test's purpose is to measure our headset's achievable adjustment angles on bikes with different headtube lengths. This will verify our theoretical model of how headtube length impacts our headset's adjustment angles.

Scope: Measure the effective headtube angle in each adjustment position.

Hazards: No additional hazards exist outside of those associated with normal installation and use of our headset. The only hazard we predict is a possible pinch point when adjusting the headset.

Facility: Building 192 or 197.

Performed By: Team F64 – Adjustable Headtube Angle Headset

Equipment:

- Digital angle finder.
- Flat, rectangular object with positioning fixture for the digital angle finder.
- At least 2 bikes with ZS44/56 headtubes of different lengths.
- Flat ground.

PPE Requirements:

- Mask.
- Safety glasses.

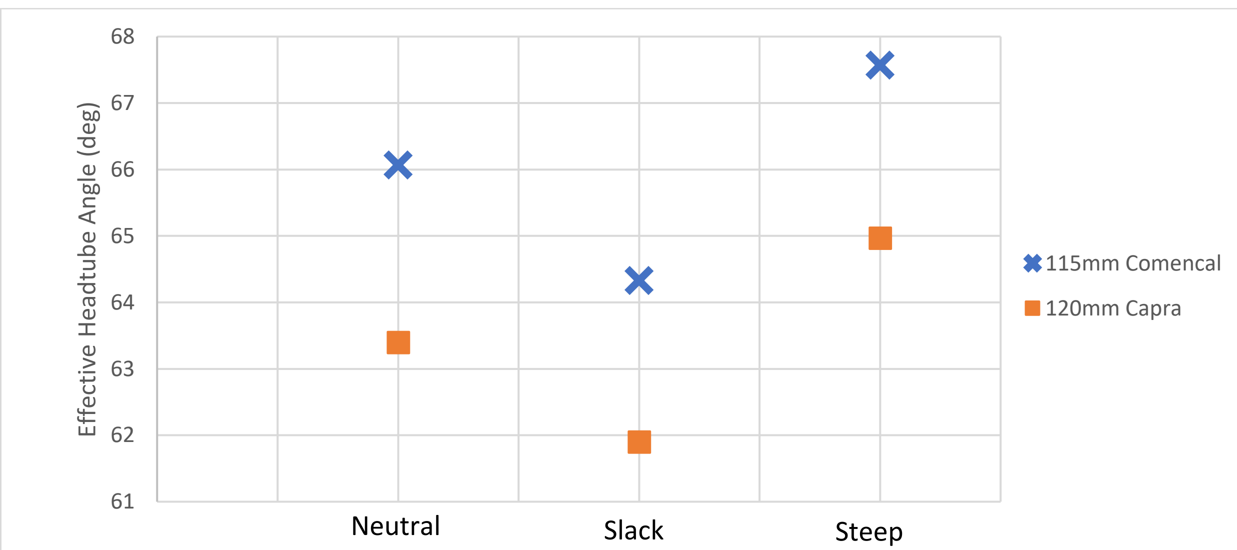
Procedure:

1. Find a flat floor in building 192 or 197.
2. One group member will square the fork to the frame and level the bike to a horizon.
3. Another group member will place the flat, rectangular object across the fork's stanchions.
4. Zero the digital angle finder to the floor.
5. Using the positioning fixture on the flat object, use the digital angle finder to measure the effective headtube angle.
6. Adjust the headset to each of the other adjustment positions and repeat steps 2-5.
7. Perform three trials of this procedure for each bike tested.

Pass/Fail Criteria: Our headset must provide at least ±2 degrees of effective headtube angle adjustment in either direction from neutral on our bikes tested. Our headset passes this test if it achieves these adjustment angles and fails the test if it does not. We will use the mean values for each adjustment position in our pass/fail criteria.

Test Results: We will place our test results into the following table:

Bike #1 - Commencal		**Bike #2 – YT Capra**	
Headtube Length	115 mm	Headtube Length	120mm
Adjustment Position, Trial	**Effective Headtube Angle**	**Adjustment Position, Trial**	**Effective Headtube Angle**
Neutral, 1	66.1	Neutral, 1	63.3
Slack, 1	64.4	Slack, 1	61.9
Steep, 1	67.6	Steep, 1	64.9
Neutral, 2	66	Neutral, 2	63.5
Slack, 2	64.3	Slack, 2	61.9
Steep, 2	67.5	Steep, 2	65
Neutral, 3	66.1	Neutral, 3	63.4
Slack, 3	64.3	Slack, 3	61.9
Steep, 3	67.6	Steep, 3	65
Mean Neutral	66.07	Mean Neutral	63.4
Mean Slack	64.33	Mean Slack	61.9
Mean Steep	67.57	Mean Steep	64.96667



Test Notes:

In the end, the 115 mm Commencal headtube allowed an effective headtube angle change of 3.27 degrees between slackest and steepest positions (+/- 1.63degrees), while the 120mm Capra gives a range of 3 degrees between slack and steep (+/- 1.5 degreeds). The design does not meet the +/- 2 degrees of angle change because we were designing it based on an angle relative to the headtube rather than to the ground. The effect of the change in angle between position raises the position of the headtube upward, moving from slack to steep. This change in position of the headtube trims the frame as well which changes the angle of the headtube, decreasing the change to the effective headtube angle measured relative to the ground.

When on a bike stand, the change in angle of the steerer tube is +/- 2 degrees when measured relative to the headtube, which is the preliminary analysis we did when designing. So, our design works as it should, but we had an oversight where we did not think about how the angle change of the steering assembly would impact the frame trim and decrease the change in the effective headtube angle to the ground rather than to the frame.

Images of the team performing the range of adjustment test.

Test Name: Top Bearing Housing Load Test

Planned Test Date(s): 4/30/21

Purpose: This test's purpose is to measure the top bearing housing's maximum load carrying capacity to compare our FEA results to experimental results.

Scope: Measure the top bearing housing's maximum radial load carrying capacity and effects of high loading.

Hazards: The hazards associated with using an Instron tensile test machine will be present. It is possible that our test fixture could fail. This would result in potential components of fixture to rupture and project out within the Instron tensile fixture protective enclosure. However, this is an intended aspect of safety enclosure and procedures by wearing protective safety glasses.

Facility: Composites Laboratory in Building 192.

Performed By: Team F64 – Adjustable Headtube Angle Headset with assistance from composite lab tech.

Equipment:

- Instron tensile test machine
- Top bearing housing
- Top bearing housing test fixture
    - Top yoke
    - Bottom tang
    - Fixture pins (2)
    - Spacer (neutral/slack)
    - Washer
    - Bolt and nut

PPE Requirements:

- Mask.
- Safety glasses.

Procedure:

7. Install the top bearing housing onto the test fixture by putting the top bearing housing into the yoke and inserting the fixture pins so they enter the top bearing housing holes in the middle holes.
8. Insert the cotter pins between the top bearing housing and the yoke to hold the pins in place.
9. Insert tall test spacer into the top bearing housing and pass the bolt through the spacer and top bearing housing and bottom tang. Put the washer on the bottom side of the top bearing housing and affix the nut below it. Tighten nut to 10 ft-lbs.
10. Install the test fixture into the Instron tensile test machine by affixing the clamps to both welded tabs on each end of the testing fixture.
11. Follow the Instron instructions to begin applying loads and capturing data.
12. Increase the load applied until the bearing housing fails or reaches 10,000 N.

13. Asses the state of the top bearing housing. If in good condition, repeat steps 1-6 with the steep and slacker position holes using the shorter spacer.

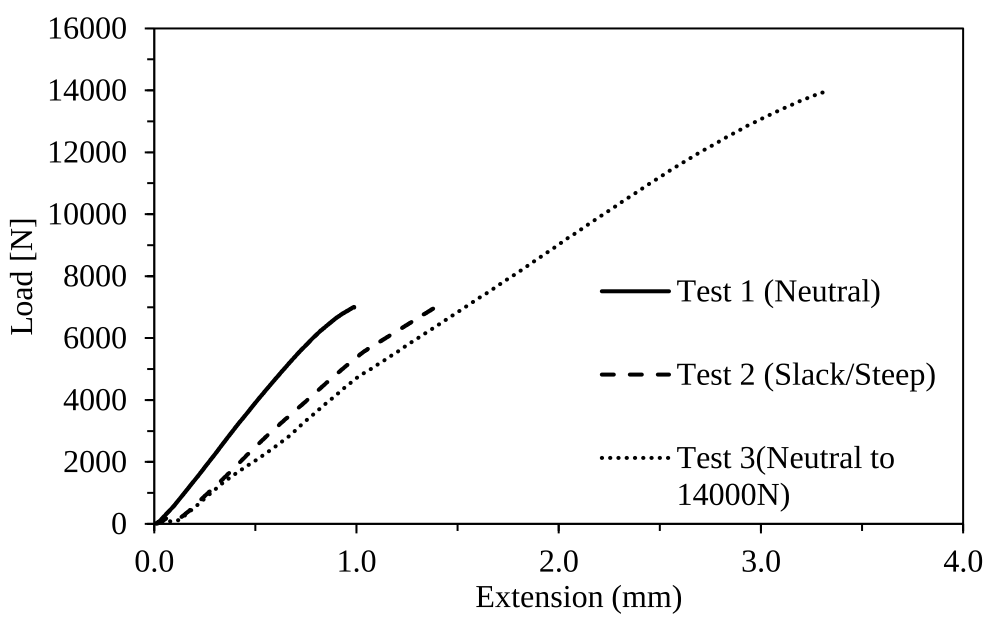
Pass/Fail Criteria: Our headset must accommodate a radial load of 5631 N to pass this test. Otherwise, it fails this test.

Test Results: We will place our test results into the following table:

Performed by: Ben Harper, Glenn Petersen, Josh Martin, Dylan Prins
Date: 5/13/2021, 5/18/2021

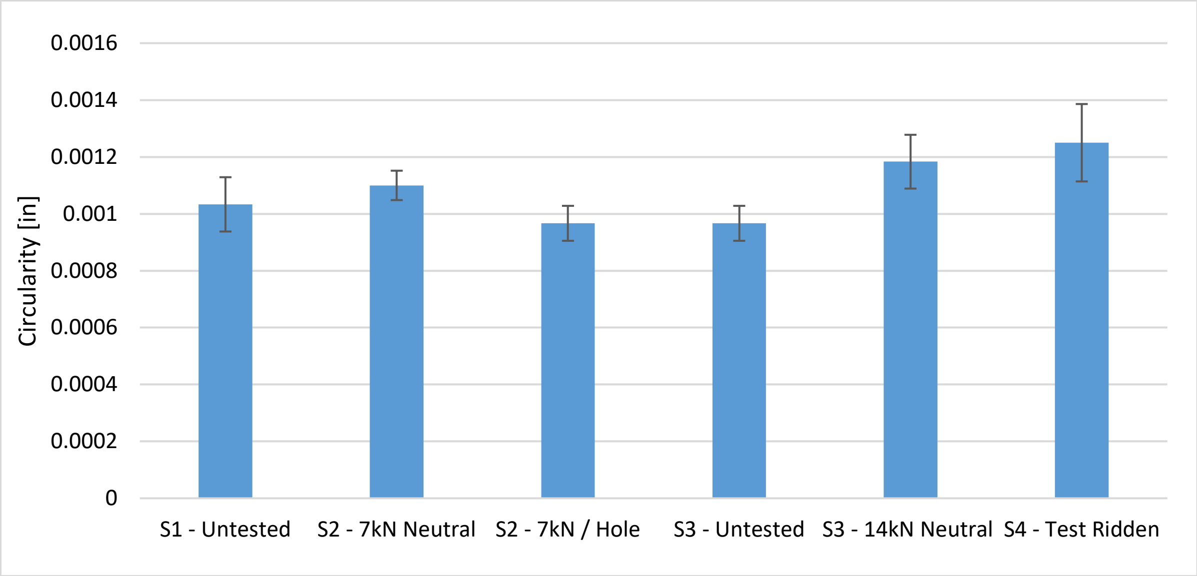
Runs	Maximum Load Accommodate by Top Bearing Housing [N]	Documented qualitative perspectives of damage to top bearing housing and/or fixture
Neutral	7000N	No damage seen
Slack/Steep	7000N	No damage seen
Neutral to 14000N	14000N	Test pins were bent but did not shear. Visually no change to bearing housing pin holes.

Stress v. Strain curves for above trials.

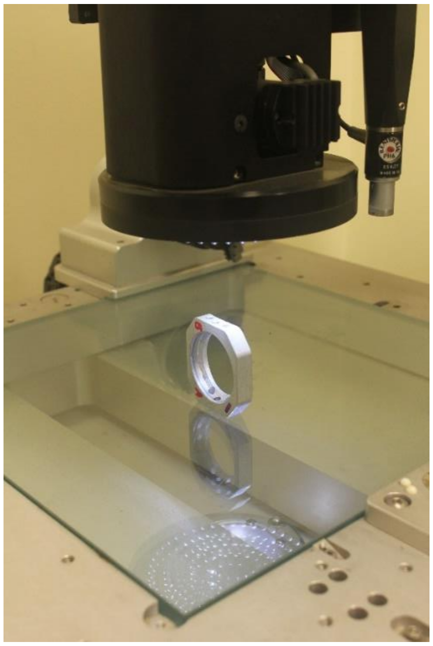


Optical CMM results of pin hole circularity:

Assuming untested parts are uniform a repeated measures ANOVA (analysis of variance) indicates there is no statistical differences in circularity with 95% confidence. Further testing is suggested to verify this. The results used are the mean circularity for all 6 holes on each test piece. The figure below shows the mean circularity with standard error.



The figure below shows a picture of the CMM scanning the end of a test sample.



General Linear Model:...

WORKSHEET 1

General Linear Model: Results versus Treatment

Method

Factor coding (-1, 0, +1)

Factor Information

Factor	Type	Levels	Values
Treatment	Fixed	6	14KnNeutral, P17kN/hole, P17kNNeutral, P2Untested, P3Untested, TestRidden

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Treatment	5	0.000000	0.000000	1.74	0.156
Error	30	0.000001	0.000000		
Total	35	0.000002			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
0.0002163	22.47%	9.55%	0.00%

Coefficients

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	0.001083	0.000036	30.05	0.000	
Treatment					
14KnNeutral	0.000100	0.000081	1.24	0.224	1.67
P17kN/hole	-0.000117	0.000081	-1.45	0.158	1.67
P17kNNeutral	0.000017	0.000081	0.21	0.838	1.67
P2Untested	-0.000117	0.000081	-1.45	0.158	1.67
P3Untested	-0.000050	0.000081	-0.62	0.540	1.67

Regression Equation

Results = 0.001083 + 0.000100 Treatment_14KnNeutral - 0.000117 Treatment_P17kN/hole
+ 0.000017 Treatment_P17kNNeutral - 0.000117 Treatment_P2Untested
- 0.000050 Treatment_P3Untested + 0.000167 Treatment_TestRidden

Figure of results of ANOVA, note P-value greater than 0.05 (indicating no statistically significant difference)

Test Name: CNC Review with Professor

Test Date: 3/10/21

Purpose: This test's purpose is to obtain feedback on our designs from an engineer experienced with designing parts to be manufactured using CNC machining.

Scope: Obtain feedback on our design's manufacturability.

Hazards: There are no hazards for this test.

Facility: Zoom meeting.

Performed By: Team F64 – Adjustable Headtube Angle Headset

Equipment:
- CAD models
- MasterCam models
- Computer to Zoom through

PPE Requirements:
- Computer to Zoom through.

Procedure:
1. Show the reviewing professor our designs.
2. Record his/her feedback.
3. Incorporate the feedback into our design.

Pass/Fail Criteria: Our headset components must be manufacturable using Cal Poly's tooling to pass this test. Otherwise, it fails this test.

Test Results: We will record the professor's feedback as text below:

Professor Trian Georgeou determined that our design was complex but entirely feasible. He suggested that reducing some of the complex curvatures to make them simply straight edges would decrease manufacturing time and increase strength slightly. We agreed and used these suggestions.

Test Name: Test Rotation

Test Date: 5/6/21

Purpose: This test's purpose is to measure how far our headset allows the fork to rotate within the frame and check for increased rotation resistance.

Scope: Measure how far our headset allows a fork to rotate and check for increased rotation resistance.

Hazards: No hazards exist for this test.

Facility: Team member house or building 192 or 197.

Performed By: Team F64 – Adjustable Headtube Angle Headset

Equipment:

- Bike with our headset installed
- Protractor

PPE Requirements:

- Mask
- Safety glasses

Procedure:

1. Rotate the handlebars as far as the headset, cables, and steering assembly allow in each direction from neutral.
2. Record if the headset allows a 90˚ rotation in either direction for neutral, and if not, measure the rotation angle.
3. While rotating the handlebars, check if the headset causes increased rotational friction from a standard headset and record observations.
4. Repeat steps 1-3 for each position of the headset (slack, steep, neutral).

Pass/Fail Criteria: Our headset must allow the fork to rotate 90˚ from neutral in either direction and without increased rotational friction to pass this test. Otherwise, it fails this test.

Test Results: We will place our test results into the following table:

	Slack	Steep	Neutral
Rotation Angle Achieved (Left)	90° +	90° +	90° +
Rotation Angle Achieved (Right)	90° +	90° +	90° +
Rotational Friction Feel	Negligible	Negligible	Negligible

Test Notes:

Headset allowed more than 90 degrees of rotation both right and left from straight ahead. It is reasonable to say that the adjustable headtube angle headset had no effect on the original rotation of the handlebars and no change to the achievable steering angles possible on a certain bike compared to a standard headset.

Test Name: Maintenance Test

Test Date: 5/20/2021

Purpose: To verify the extent of wear and required re-lubrication and cleaning the headset requires in comparison to a normal headset.

Scope: This test involves the full assembly of the test requiring a post ride assembly, gauging the effect normal riding has on the maintenance schedule.

Hazards: No additional hazards exist besides those normally encountered when mountain biking.

Facility: This test will take place either in the shops or at a member garage with the tools and space to disassemble their headset.

Performed By: Team F64 – Adjustable Headtube Angle Headset

Equipment: Mountain bike fitted with adjusted angle headset. Metric hex driver set. (Optional: Bike stand for ease of assembly)

PPE Requirements: Helmet (and other preferred mountain biking gear) during ride.

Procedure:

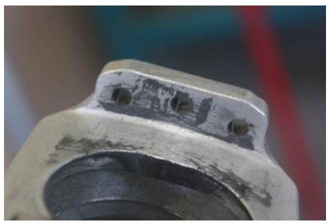
1) Ride mountain bike in normal conditions in multiple timelines (1 ride, 5 rides, 10 rides, etc.), note conditions, trail, duration, and comments about headset performance before ride and after.
2) Do not clean headset prior to removal.
3) Take pictures of the headset prior to removal.
4) Note performance of adjusting headset and anything including normal operation.
5) Remove headset from mountain biking, leaving top and bottom cup inserted in frame.
6) Take notes & pictures of the top and bottom cup left in frame.
7) Of components removed, take pictures of each component, and fill out form.
8) Clean components and note where dirt is located (should be shown in pictures) in comments section of form.
9) Reassemble properly per directions of assembly and lubrication.

Results: A pass will include that no further maintenance (cleaning, lubrication) is required than a normal headset to maintain adequate adjusting performance.
A failure would be maintenance is required after every ride to maintain adjustability.

Test Results:

Post Test Ride(s)	
Date	May 1 – May 14
Location	Cuesta Grade, Stadium Park
Trail(s)	Stenner system, Eucs, shooters, Firebreak, Morning Glory, Costco Jumps (all but large canyon), Stadium Park (jump and flow lines), Poly Canyon, Pin-it-you-fairy
Weather	Hot, dry, and sunny.
Trail Conditions	Dry Hard park, dusty, gravelly, rocky; never wet.
Performance before ride	Consistent and good
Performance after ride	Consisten and good, slight creak developed during track stands.

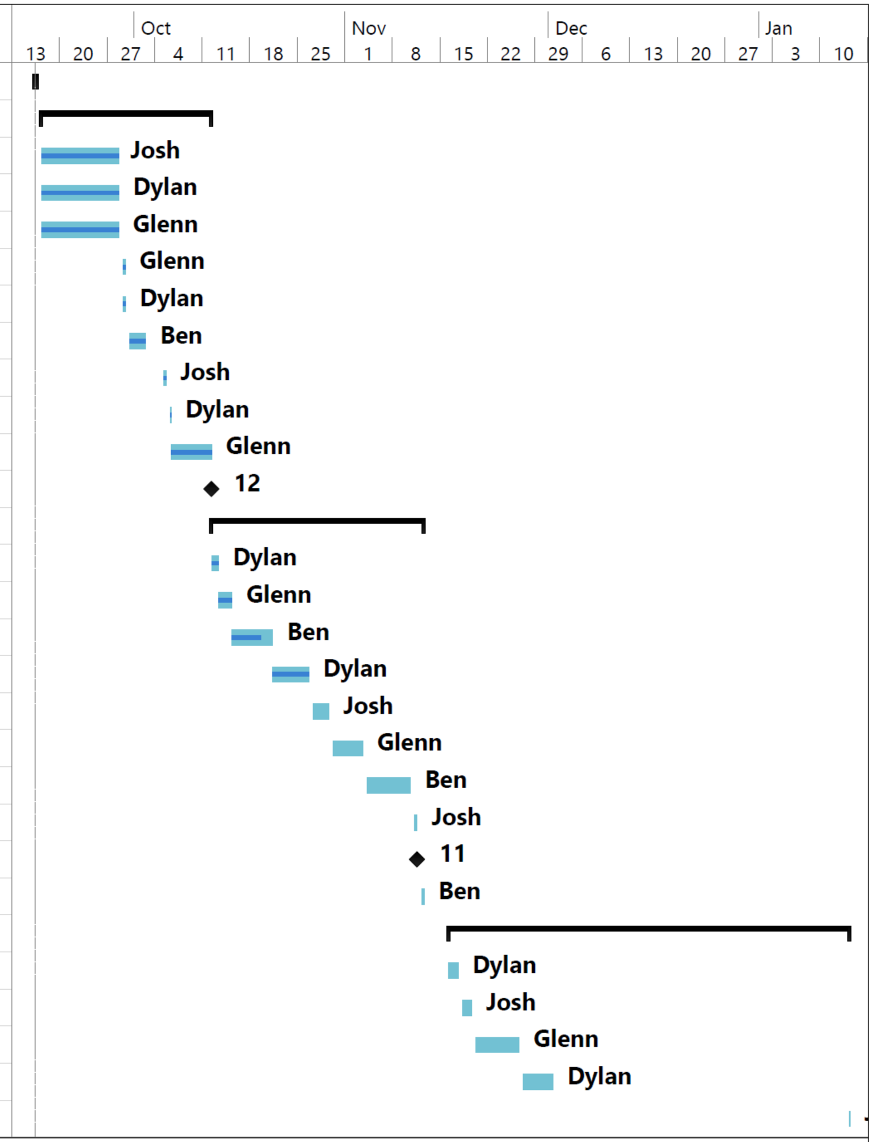
Comments: With a proper dust shield, the dust accumulation we see on the greased surfaces would be diminished. Further the wear we see on the top cup could be remedied with the lack of gunk build up.

Photos	Angle 1	Angle 2	Angle 3	Comments
Bottom Cup				Dirt and dust mixed with assembly grease (Gunk). No noticeable wear on contacting surface.
Top cup				Noticeable wear at the center of the top cup from the bearing housing contact.
Bottom bearing gimbal				Gunk present, but no wear.
Bottom bearing				Gunk present by no wear. No play in bearing or issues. No wear on the steer tube or crown race.

Top bearing housing				Wear at 4 corners of top bearing housing contact with top cup. Gunk present on exterior pin hole sides and sliding surface. No noticeable wear of pin holes.
Top bearing				Gunk present on bearing and on steer tube shim spacer.

Appendix R) Gantt Chart

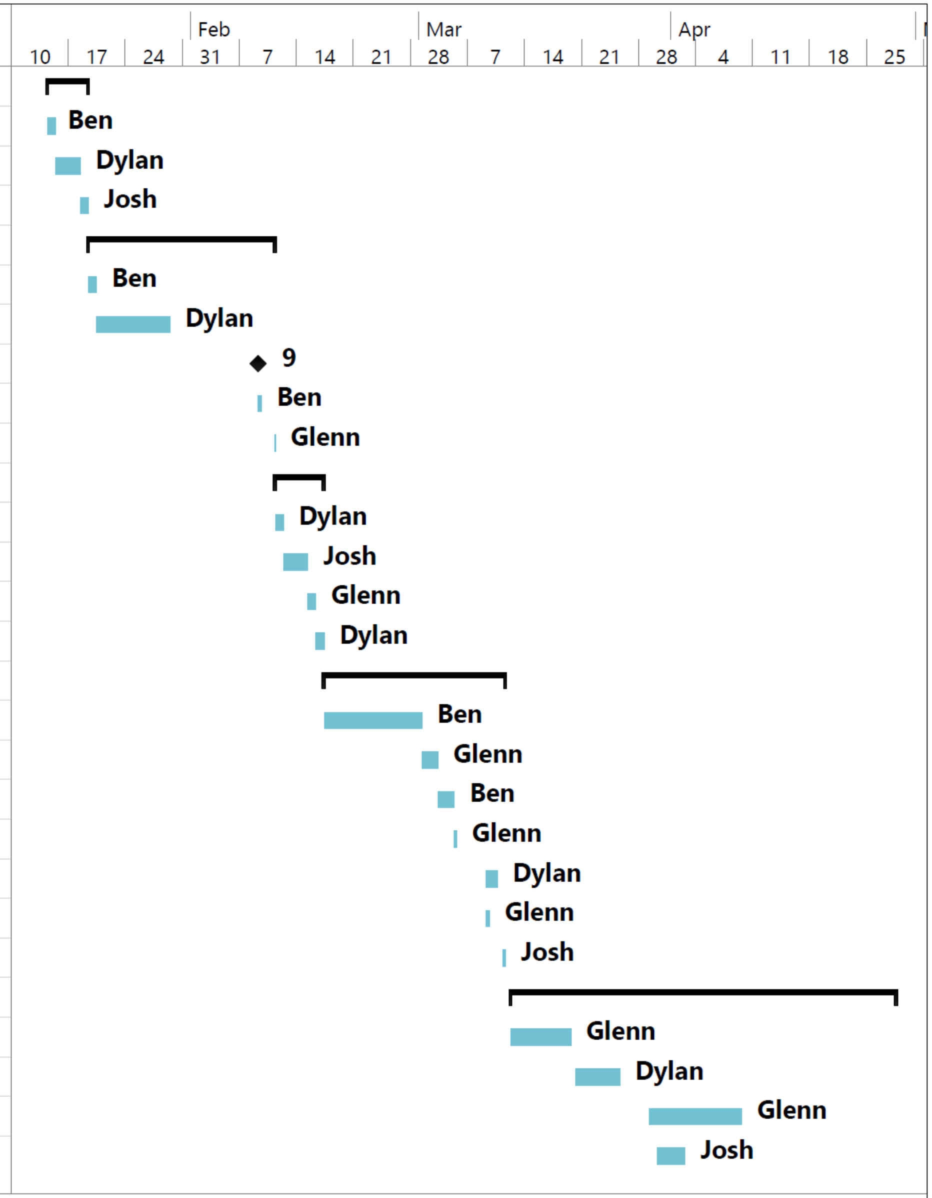
ID	Task Name	Person Assigned	Duration	Start
1	**Get Project**		**1 day**	**9/16**
3	**Scope of Work (SOW)**		**17.25 day**	**9/17**
4	Technical Research	Josh	8 days	9/17
5	Stakeholder Research	Dylan	8 days	9/17
6	Product Research	Glenn	8 days	9/17
7	Problem Statement	Glenn	1 day	9/29
8	Stakeholder Needs	Dylan	1 day	9/29
9	QFD House of Quality	Ben	3 days	9/30
10	Gantt Chart	Josh	1 day	10/5
11	Specifications Table	Dylan	2 hrs	10/6
12	Review and Edit SOW	Glenn	4 days	10/6
13	Deliver SOW to Sponsor	Ben	0 days	10/12
14	**PDR**		**23.75 day**	**10/12**
15	Functional Decomposition	Dylan	1 day	10/12
16	Ideation and Modeling	Glenn	2 days	10/13
17	Concept Selection	Ben	4 days	10/15
18	Preliminary Analysis	Dylan	3 days	10/21
19	CAD Preliminary Headset	Josh	3 days	10/27
20	Build Concept Prototype	Glenn	3 days	10/30
21	Create PDR	Ben	5 days	11/4
22	Review and Edit Report	Josh	1 day	11/11
23	PDR!!	Ben,Dylan,	0 days	11/11
24	Submit PDR to Sponsor	Ben	1 day	11/12
25	**IDR**		**43.38 day**	**11/16**
26	FMEA	Dylan	2 days	11/16
27	DFMA	Josh	2 days	11/18
28	Design Analysis	Glenn	5 days	11/20
29	Major Part Details	Dylan	3 days	11/27
30	IDR in Lab	Josh	3 hrs	1/14



Project: Gantt Chart
Date: 6/1

Task Milestone Summary

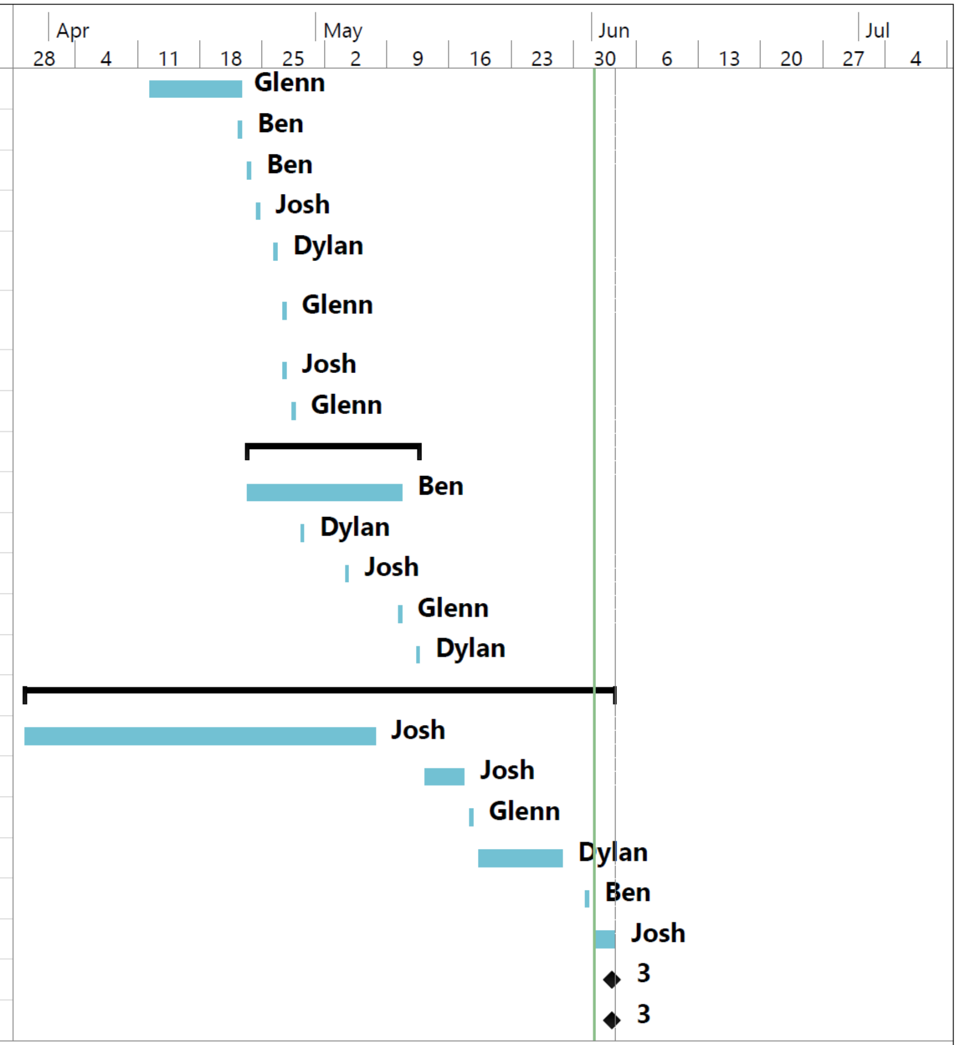
ID	Task Name	Person Assigned	Duration	Start
31	**Structural Prototype**		**3 days**	**1/14**
32	Begin Structural Prototype	Ben	1 day	1/14
33	Rough Build of Headset	Dylan	1 day	1/15
34	Perform Validation Testing	Josh	1 day	1/18
35	**Critical Design Review**		**16.88 day**	**1/19**
36	Bill of Materials (BOM)	Ben	1 day	1/19
37	Create CDR Deliverables	Dylan	7 days	1/20
38	CDR!!		0 days	2/9
39	Assess Critiques from CDR	Ben	1 day	2/9
40	Submit Written Report	Glenn	2 hrs	2/11
41	**Risk Assesment and Safety**		**4 days**	**2/11**
42	Identify Risks	Dylan	1 day	2/11
43	Prepare Assessment	Josh	1 day	2/12
44	Safety Technician Mtg	Glenn	1 day	2/15
45	Assess Comments	Dylan	1 day	2/16
46	**Manufacturing and Testing**		**16.75 day**	**2/17**
47	Order Parts and Begin Build	Ben	8 days	2/17
48	Update Test Plan	Glenn	2 days	3/1
49	Safety Checklist	Ben	2 days	3/3
50	Mill Top Bearing Housing	Glenn	1 day	3/5
51	Update Schedule	Dylan	2 days	3/9
52	Mill Top Cup	Glenn	1 day	3/9
53	M and T Review	Josh	1 day	3/11
54	**Verification Prototype Sign Off**		**36 days**	**3/12**
55	Top Bearing Housing Test Fixtu	Glenn	6 days	3/12
56	Test Top Bearing Housing on In	Dylan	5 days	3/20
57	Glenn Gets Lathe Cert	Glenn	10 days	3/29
58	Repeatability Test (Top Bearing Housing)	Josh	4 days	3/30



Project: Gantt Chart
Date: 6/1

Task | Milestone | Summary

ID	Task Name	Person Assigned	Duration	Start
59	Mfg. Bottom Cup and Gimbal	Glenn	9 days	4/12
60	Weight Test	Ben	1 day	4/22
61	Assemble Full Assembly on Bike	Ben	1 day	4/23
62	Perform Adjustment Time Test	Josh	1 day	4/24
63	Perform Tools Needed to Adjust Test	Dylan	1 day	4/26
64	Prepare Resemblence to Normal Headset Survey	Glenn	1 day	4/27
65	Get Prototype Sign Off	Josh	1 day	4/27
66	Design Verification Report	Glenn	1 day	4/28
67	**Testing Sign off**		**15 days**	**4/23**
68	Test Rides and Document	Ben	13 days	4/23
69	Handlebar Rotation Test	Dylan	1 day	4/29
70	Perform Angle Adjust Test	Josh	1 day	5/4
71	Maintenance Test	Glenn	1 day	5/10
72	Testing Sign Off	Dylan	1 day	5/12
73	**FDR**		**50 days**	**3/29**
74	Add to FDR report	Josh	31 days	3/29
75	Operators Manual	Josh	3 days	5/13
76	Update Drawings	Glenn	1 day	5/18
77	Complete Report	Dylan	8 days	5/19
78	Safety Review	Ben	1 day	5/31
79	Grading Time	Josh	3 days	6/1
80	Submit Expo Webpage	Glenn	0 days	6/3
81	Submit FDR to Sponsor (5pm)	Ben	0 days	6/3



Project: Gantt Chart
Date: 6/1

Task | Milestone ◆ | Summary