Preliminary Design Review Report

Perforated Groove Cam Lock
Lunar Surface Operations – EVA Dust-Tolerant Handle Extension Mechanism

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I. Technical Details

A. Abstract

NASA Artemis III astronauts need a way to attach and detach various tools to an extension handle to be used during lunar EVA sample collection. Because lunar dust is so harsh and abundant, mechanisms must be designed to function regardless of the number of contact particulates. Past designs used on the Apollo missions proved to be problematic for their operators, opening the door for innovative improvement. The Lunar Lads have designed a new mechanism that directly addresses the performance issues of the original handle extension mentioned in NASA's Apollo mission reports. The new mechanism boasts an open design that promotes dust tolerance while maintaining operational simplicity. The device contains two primary components: a cylindrical, insert with a notched groove, and a perforated socket paired with a cam latch. The notches in the insert have selective permeability, allowing lunar dust to pass through the negative space without sacrificing contact stability. A similar effect is achieved by the perforations in the socket. The assembly meets all Neutral Buoyancy Lab (NBL) standards and is intended for use with EVA gloved hands. An initial assessment supports the viability of this design – from both function and production perspectives. A full assessment plan is included and will be conducted throughout the remainder of the design process.

B. Design Description

In-depth overview of design features, research and manufacturing choices supported by visual representations. Detailed drawings are presented in Appendix A.

1. Design Overview

The mechanism is inspired from a cam and groove hose fitting, and modified to provide torsional stability, EVA ergonomics, and dust tolerance.

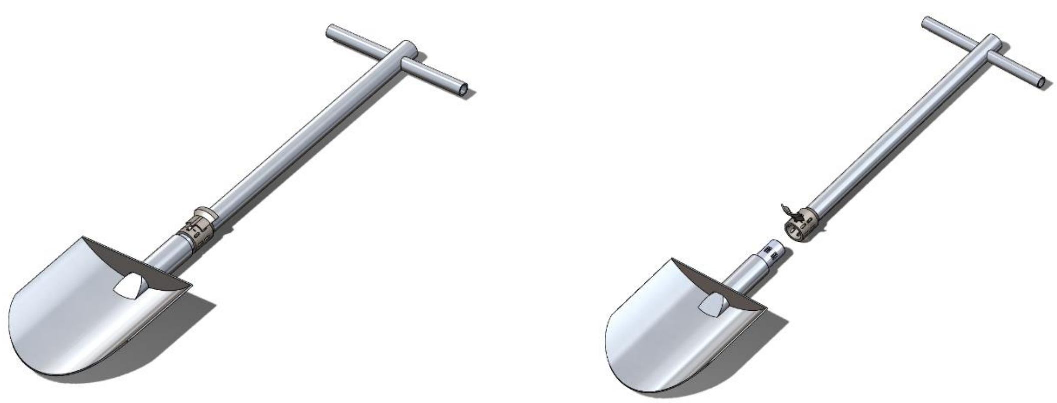

Figure 1. Fully assembled mechanism. (a) engaged, (b) disengaged

Key design features:

- Perforated receiver evacuates large amounts of lunar regolith after being buried and reduces weight.
- Notched “groove” design with dust relief slot provides torsional stability at multiple installation positions while giving dust a path to escape
- Cam with ergonomic lever designed to provide significant mechanical advantage to the user while being easy to use with EVA gloves
- Hollow internal features for increased dust tolerance and reduced weight

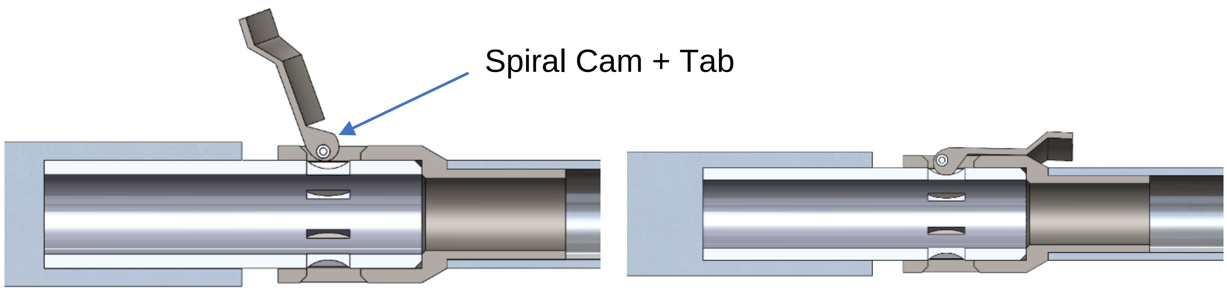

Figure 2. Cross-section views. (a) cam open, (b) cam closed

While the cam is open, the tool slides in or out of the extension handle. Once closed, the tool is locked in place and can support axial, torsional, and bending loads.

Cam & Receiver

The spiral cam design provides continuous clamping force as the cam is tightened. To reduce the occurrence of binding as the cam rotates around the pin, a drill bushing is press fit into the cam and rotates around a tight tolerance drill rod. The drill bushing fits inside the receiver as a tight slip fit, keeping dust away from the interior of the bushing.

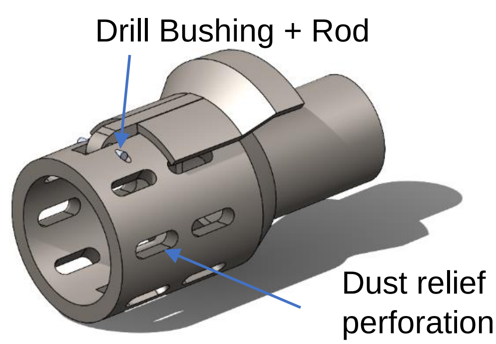

Figure 3. Cam & Receiver

A major risk that has been recognized is the possibility of an astronaut catching a glove or part of their suit in the mechanism and sub-assemblies. Conscious effort has been put in to create a solution that emphasizes safety. To be easily used by gloved hands, the cam features a large tab. There is a large pad that allows force to be applied easily while locking the tool. While prying, a small tab might otherwise be difficult with thick gloves, a raised tab extension allows fingers to fit under it. In addition, the tab has been designed without the need for spring-back force - preventing finger entrapment.

Tool-end Insert

The tool-end insert can be secured by the cam at any of the six installation positions. The notched groove pattern allows for additional torsional support and locational accuracy when attaching the tool by acting as a keyway. While a scoop tool's main loading mode is axial and bending, the extension handle can be used with a variety of attachments including a coring tool, which provides a higher torsional load.

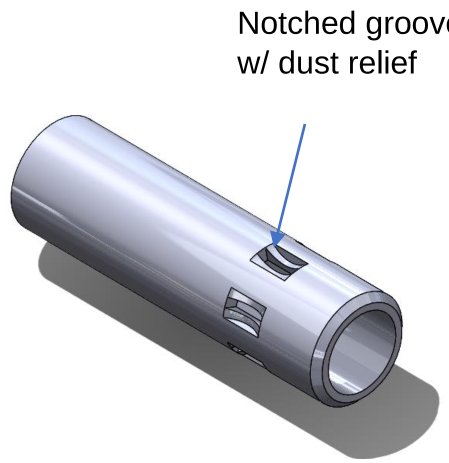

Figure 4. Tool-end Insert

Handle & Scoop Tool

The handle and scoop tools were designed similarly to those used in the Apollo 12 mission, as the focus of this design challenge is on the attachment mechanism.

2. Design Research and Ideation

Seven different designs were compared before a final direction was decided upon. Each mechanism has unique advantages that demonstrate a creative approach to a solution for the dust tolerant extension handle. Each design was ranked numerically using a weighted decision matrix with criteria: ease of use, dust tolerance, weight, stability, manufacturability, innovation.

- Compression Fit: Tool-end shaft is inserted into the extension handle with rubber gaskets to evacuate dust and provide a substantial frictional force to secure the tool.
- Cam and Groove: Modified cam and groove (aka. "Cam Lock") fitting to provide torsional stability, ease of use, and dust tolerance.
- Jaw and Latch: Radial "jaws" mesh together at the point of contact to provide torsional stability and are secured with an external latching system.
- Magnetic Base: Tool is secured to the extension handle with a magnet that is activated with a switch. (Usiskin)

- Taper and Pull Stud: Common tool-holding mechanism that provides stability in all directions.
- Snap-Together: Spring-loaded levers with “grabbers” are actuated when the tool is inserted into the handle and clamp down once the part is located.
- Collar: External collar is latched around the tool and extension handle, securing the tool in place.

Table 1. Weighted Decision Matrix

Design:		Compression Fit		Cam and Groove		Jaw and Latch		Magnetic Base		Taper and Pull Stud		Snap Together		Collar	
Criteria	Weight	Value	Weighted	Value	Weighted	Value	Weighted	Value	Weighted	Value	Weighted	Value	Weighted	Value	Weighted
Ease of Use	4	4	16	4	16	3	12	4	16	3	12	5	20	3	12
Dust Tolerance	4	3	12	4	16	3	12	4	16	1	4	4	16	3	12
Stability	5	3	15	5	25	4	20	3	15	5	25	4	20	4	20
Manufacturability	2	3	6	4	8	2	4	3	6	2	4	4	8	3	6
Innovation	1	4	4	3	3	5	5	2	2	3	3	3	3	2	2
Weight	3	3	9	3	9	2	6	2	6	1	3	3	9	2	6
Total Score:		62		77		59		61		51		76		58	

Table 2. Criteria Ranking Breakdown

Ease of Use		Dust Tolerance		Weight	
Ranking	Description	Ranking	Description	Ranking	Description
1	Requires use of fingertips, many steps	1	many parts, tight tolerances, trap dust	1	Solid Steel
2	small features, multiple steps	2	may trap dust, tight toleances	2	Solid Aluminum
3	medium features, few steps	3	dust can escape	3	Hollow Steel
4	large features, 2 hands	4	Multiple dust-tolerant features	4	Partially Hollow Aluminum
5	Requires one hand, minimal force	5	open design, dust escape, use frees dust	5	Hollow Aluminum

Stability		Manufacturability		Innovation	
Ranking	Description	Ranking	Description	Ranking	Description
1	Not Constrained	1	broaches, multiprocess, contours, jigs, grinding	1	Can buy online
2	1 Direction	2	4 of above	2	Can buy and modify
3	2 Directions	3	3 of above	3	References key traits of available designs
4	3 directions, loose tolerance	4	easily made with mustang 60 stuff	4	Vaguely similar to online options
5	3 directions, tight tolerance	5	easily made no tight tolerances	5	Can't find similar designs online

The weighted decision matrix provides a quantitative analysis of each design option, leaving “Cam & Groove” and “Snap Together” as the optimal solutions.

Past Design Research

The extension handle used on the Apollo 12 mission, shown in figures 6 and 7, was designed to collect soil samples and conduct trenching operations. To accommodate use within an EVA suit, the handle length was intended to be used without the astronaut bending down. For simple and effective torque, radial arm grips were added that could be grasped with thick gloves. The primary issues that arose during the lunar surface EVA sample collection related to mechanism binding, and length requirement failure. Astronauts reported that the extension handle was “from 3 to 5 inches too short” and that “the locking collar for the shover or core tube was binding slightly…probably because of dust collection in the mechanism” (Apollo 12 Mission Report sec. 9.10.7).

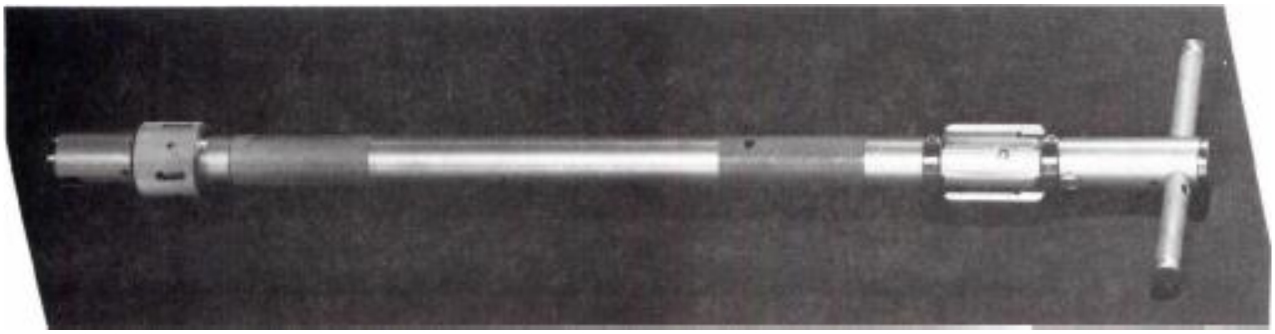

Figure 5. Extension Handle used on Apollo 12 Mission

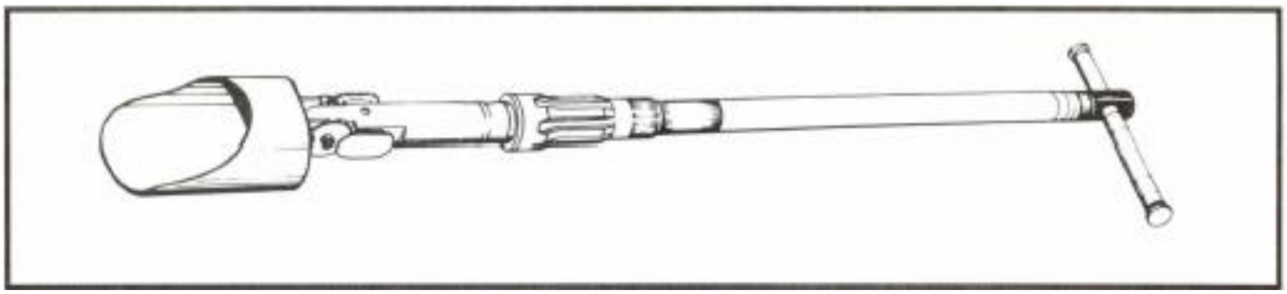

Figure 6. Extension Handle used on Apollo 12 Mission

Similar Products

The connection between the extension handle and tool is similar to a pipe or hose coupling. A wide range of pipe and hose fitting concepts were used to inspire a mechanism that would be applicable in a lunar EVA setting.

The proposed mechanism is inspired from a cam and groove coupling, classically used to join hoses and pipes in high pressure settings. US Patent No. US11187363 B2 represents a “Cam Lock Fitting with Vent and Safety Lock”. It describes the fitting as an improved “rotatable safety cam lock fitting with an air vent”.

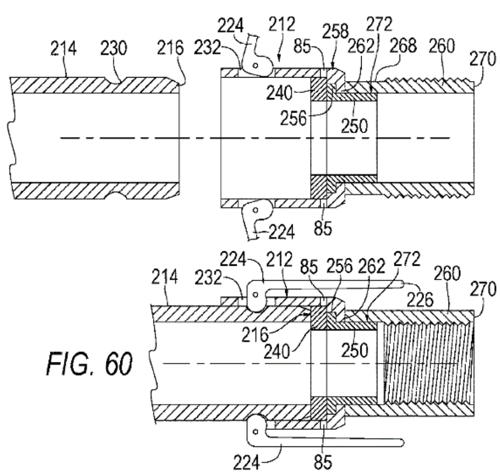

Figure 7. Patent No. US11187363, Cam Lock Fitting with Vent and Safety Lock

The design considerations for this Cam Lock design (Hartman) are very similar to those of the EVA Dust-Tolerant Extension Handle. Both mechanisms are designed with axial loading and ergonomic design in mind. Due to the nature of pipe and hose applications, the Cam Lock fitting must ensure that all contact faces are firmly held together, maintaining a seal to prevent fluid leakage. While the extension handle doesn't support fluid transfer, the ease of use, mechanical connection strength, and high reliability of the cam lock design are appealing traits. Modifications to the Cam Lock mechanism must be made to promote torsional stability, EVA glove ergonomics, and dust tolerance.

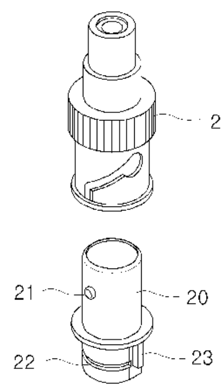

Figure 8. Patent No. KR100948561B1, BNC Connector

The BNC connector was a great starting point for ideation (Moon-Won). It is a simple and effective design, as it does not require any tertiary parts—the insert and receiver are the only requirements. Other than its simplicity, the BNC connector is also stable for a variety of load cases. The "locking" mechanism created by the open path on the receiver side of the connector allows for stability in tension and compression, as well as torsion. However, the decision was made to move away from this concept as it did a poor job of combating the problem of lunar dust—the most important design constraint. The mechanism is a closed design with moderately tight tolerances, allowing for the possibility of dust to be trapped in the connector which could increase friction between the mating pieces causing operating difficulties.

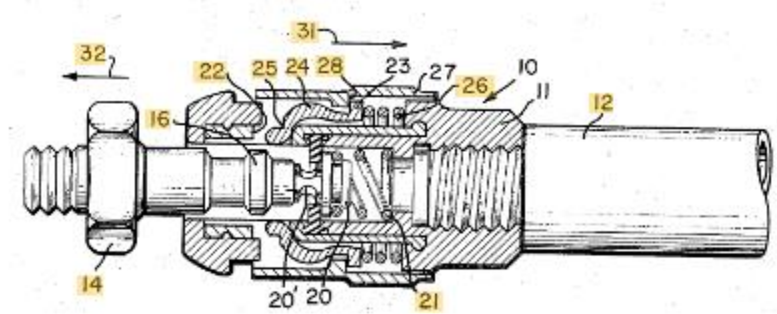

Figure 9. Patent No. US3873062A, Air Hose Quick Coupler

Air hose couplers contain many desirable traits for an EVA friendly attachment mechanism (Johnson and Adams). The device uses a slide collar to change the diameter of its latching mechanism, labeled in figure 9 at points 25 and 24. This provides a stable connection in both tension and compression. However, this product does not allow for any torsional stability, and the closed design is not dust tolerant enough for lunar applications.

Preliminary Analysis and Material Selection

Weight and durability are important factors to consider when designing a device intended for the moon. For this reason, the shaft is comprised of 6061 T6 aluminum and the scoop tool is 8356 cast aluminum. Aside from its low price compared to other engineering metals, aluminum has a high specific strength and is easy to machine and weld--three significant advantages when considering NASA's design constraints. Since aluminum is not very dense, but has a high specific strength, we can feel confident that the shaft and scoop possess the appropriate failure mode resistance for their respective load cases. The high specific strength allows for a reliance on design geometry for greater stiffness while retaining the same level of strength. Machinability is vital for time efficient manufacturability and its abundance means that it will be readily sourced.

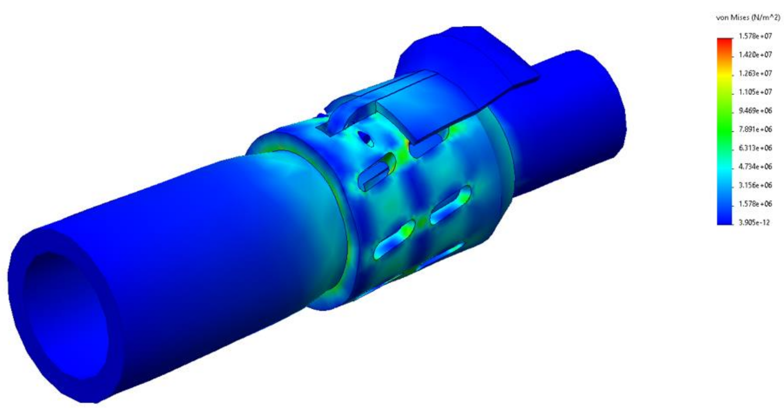

Figure 10. FEA model of mechanism with a 30 N-m torque applied to the cylindrical insert connector demonstrating stress concentrations on the receiver

Considering the high level of surface abrasion that the lunar dust will induce, 440C stainless steel has been selected for the cam and cam receiver. These parts, along with the adjustable lever, will experience the highest stress concentration under a torsional load—they have small area and thickness which makes materials with high shear strength best for the application. A preliminary FEA analysis on the SolidWorks assembly supports this assumption. As seen in figure 10, the cam receiver experiences high stress relative to the rest of the part. Similarly on the tool-side insert, large volumes of dust will abrade the divots, causing surface fatigue that can lead to mechanism failure. Since steel alloys are more wear resistant than most metals, especially when compared to aluminum, it offers the best physical properties for its intended application.

In terms of surface finish, a powder coating will be applied to the shaft and exterior of the attachment mechanism. Powder coated metals have a higher resistance to static charge, which will improve dust repellence of the extension handle body. Large quantities of electrostatically charged lunar dust particulates will be contacting the tool. Due to the nature of Micro-gravity environments, these contact points will not be limited to specific areas of the tool—making powder coating a viable option to combat this issue.

Manufacturing Plan

Cal Poly SLO offers a limited selection of manufacturing methods to its students. Therefore, the manufacturability of each part of the extension handle must be evaluated.

The aluminum scoop tool will be cast with 8356 aluminum ingots using a lost foam process. The foam mold will be machined using a 4-axis HAAS CNC mill. The aluminum ingots will be provided by the university. Delivery time of less than a month can be expected. The foam milling and casting will take place in the industrial manufacturing lab and can be completed within a two-hour window.

The shaft will be cut from 6061 T6 aluminum tube stock using a table saw with a tungsten carbide tip. It will be important to factor in the width of the blade when cutting to avoid violating length tolerances. The saw can be accessed in the Mustang 60 machine shop, where a cross-sectional cut can be achieved. The tube stock can be shipped in one to two business days.

The 440C stainless steel cam and receiver will both be machined on a 4-axis HAAS CNC mill. This will be the most expensive process, since a lot of steel material will be lost in the form of chips. Cylindrical billets must be ordered online with an expected shipping time of 1-2 business days.

The cam and receiver will be manually assembled using a press-fit drill bushing and a tight-tolerance multipurpose oil-hardening O1 tool steel rod to allow for hinged motion. The assembly process can be achieved using a standard press in the Cal Poly machine shop. The bushing and steel rod must be ordered online, with an expected shipping time of 1-2 business days.

Factoring in buffer time, all materials can be obtained within a month. Most manufacturing processes can be completed within a day—depending on lab availability.

Material cost estimates are provided in section III, article E.

3. Requirement Compliance

Figure 3. Requirement Compliance Table

No.	Requirement	Status	Explanation if Applicable
1	An extension handle with integrated tool attachment mechanism; a scoop tool to attach to the mechanism; and a second, standalone tool attachment mechanism shall be produced.	Intend to comply	Manufacturing resources are available to meet this requirement
2	If the mechanism design includes a receptacle for a mating part, place the receptacle end on the extension handle.	Complies	
3	Torque required to actuate the tool attachment mechanism shall not exceed 30 in-lb. (3.4 Nm)	Intend to comply	Will conduct detailed mechanical design
4	Extension handle, mechanism, and scoop shall maintain structural integrity when interfaced together and used to scoop soil samples.	Intend to comply	FEA, mechanical design, and regolith simulant testing will be conducted
5	The tool attachment mechanism shall restrain the scoop tool and eliminate wobbling of the tool.	Complies	
6	The tool attachment mechanism shall be dust-tolerant and remain operable after burial in lunar regolith simulant.	Intend to comply	Prototype testing will be conducted with lunar regolith simulant BP-1
7	The proposed design shall specify all materials the provided hardware will be made from.	Complies	
8	The extension handle and non-interfacing part of the scoop may be plastic or 3D printed out of NBL-accepted materials. A waiver may be granted on a case-by-case basis. *(No regular PLA. Tough PLA is okay.)	Complies	Materials are specified in the BOM provided
9	All components of the tool attachment mechanism and the interfacing part of the scoop shall be made of metal.*	Complies	
10	The total length of the extension handle with mechanism shall be 28-32 inches, not including the scoop.	Complies	
11	The total weight of the extension, handle, and mechanism (not including scoop tool) shall be less than5 lbs.	Complies	
12	The length of the scoop should be 13-16 inches.	Complies	
13	The weight of the scoop should be less than 3lbs	Complies	
14	The tool attachment mechanism must be operable with EVA gloved hands (like heavy ski gloves).	Intend to Comply	Testing will be conducted with welding/ski gloves
15	The extension handle, tool attachment mechanism, and scoop tool shall use only manual power.	Complies	
16	There shall be no holes or openings which would allow/cause entrapment of fingers on the device.	Intend to Comply	Prototype testing will be conducted to confirm compliance
17	There shall be no sharp edges on the device.	Complies	

C. Operations Plan

Step by step instructions for mechanism testing and use in dry and NBL environments.

1. Operation Procedures

Mechanism Engagement

1. Grasp shaft and check that cam receiver tab is flipped to the open position.
2. Grasp tool head with free hand.
3. Place base of tool head concentrically with the cam receiver.
4. Line up notched groove with opened tab.
5. Slide tool head base into cam receiver.
6. Close mechanism by flipping cam receiver tab to the closed position.

Mechanism Disengagement

1. Grasp shaft and check that cam receiver tab is in the closed position.
2. Use free hand to move tab to the open position.
3. Orient the assembly to the horizontal position.
4. Place one hand on shaft, and one hand on the tool head base.
5. Pull shaft and tool head in opposite directions to disengage.

2. Testing Procedures

Weight and Length Test

1. Detach the scoop tool from the mechanism.
2. Measure length of mechanism and extension handle shaft from the base of the receiver to the top of the torque handle using a tape measure.
3. Confirm that length is between 28-32 inches using a tape measure.
4. Measure the weight of the mechanism and extension handle using an electric scale.
5. Confirm that the weight of the shaft and mechanism is under 5 lbf.
6. Measure length of the scoop from the base to the tip using a tape measure.
7. Confirm that scoop length is within 13-16 inches.
8. Measure the weight of the scoop using an electric scale.
9. Confirm that the weight of the scoop head is under 3 lbf.
10. Record results and observations.

NBL Test

1. Astronaut will be provided with a scoop tool head and an extension handle shaft.
2. Astronaut will descend to the bottom of the NBL pool (Lunar Surface Substitute)
3. Astronaut will attach and detach the scoop tool to the extension handle using the provided operations procedure.
    a. EVA gloves should be worn to assess the practicality of the design

    b. Reattachment process should be repeated a minimum of five times to highlight repeatability.
4. Once the reattachment test is completed, the astronaut will then proceed to put the extension handle through three different load cases.
    a. Tensile test
        i. Place one hand on extension handle shaft.
        ii. Place one hand on scoop tool base and pull
    b. Torsional test
        i. Scoop tool should be submerged into pool floor.
        ii. Place one hand on each extension handle.
        iii. Rotate counterclockwise.
        iv. Repeat several times.
    c. Compression Test
        i. Scoop tool should be pressed against pool floor.
        ii. Place one hand on each extension handle and push down.
5. After the load cases are tested, the entire process should be repeated with a new volunteer to further test the mechanism's ease of use.
6. Record results and observations.

<u>Dry Test</u>

The standalone mechanism will undergo two separate burial tests: an engaged burial test and a disengaged burial test.

Engaged Burial

1. Engage locking mechanism by following the operations procedure.
2. Bury mechanism horizontally and ensure that lunar simulant is dispersed across entire surface area
3. Recover the mechanism.
4. Disengage latch, separate tool from handle before reconnecting and repeat the operations procedure three times.
5. Repeat process for a minimum of three times to account for operating variability.
6. Record results and observations.

Detached Burial

1. Disengage mechanism and separate the insert and receiver apparatuses.
2. Bury both devices separately in a horizontal configuration to ensure that lunar simulant is dispersed across the entire surface area.
3. Recover the apparatuses.
4. Engage mechanism by following the operations procedure.
    a. Mechanism should be engaged and disengaged three times
5. Repeat burial process three times to account for operating variability.
6. Record results and observations.

D. Safety

Appendix C table 6 contains the hazard assessment for the following hazards: finger entrapment, suit puncture, hand fatigue, and mechanical failure. The highest scoring risk is suit puncture by one of the tools used with the extension handle. Since this is an inherent risk with all lunar EVA operations, it does not warrant further risk assessment related to our mechanism.

Risks associated while operating the mechanism all received acceptable hazard scores. The dust relief perforations are too small to allow finger entrapment. The latch is designed without the need for spring back force to maintain mechanism closure--it can be moved with a low force application from the operator.

Considering safety in an NBL environment, all sharp surfaces and edges are removed from the handle extension assembly. All holes and or circular profiles must undergo a deburring treatment to prevent suit tears or fabric catching.

No materials that cause harmful reactions with chlorine exist in the assembly. Powder coating surface treatments on the aluminum surfaces prevent corrosion and oxidization.

E. Future Work

The next immediate steps are making prototypes with a 3D printer and testing the functionality of the design. These prototypes will be simplified models comprised only of the latching mechanism. Initial prototypes will test things such as clearances, actuation, and basic functionality of the mechanism. Preliminary tests of a functional mechanism will focus on the application of load cases on the part: tension, compression, torsion and bending. Each test can be applied by hand, as quantitative stress response is not required at this stage. Component failures will be recorded and used to create new prototypes to address the relative issues. Each consecutive prototype will verify vital concepts of the mechanism which can be easily adapted to meet NASA's engineering specifications. After several iterations of concept verification, a complete assembly will be manufactured and tested to simulate functionality in the NBL and lunar dust environment. The assembly must be functional underwater, so load cases and mechanism engagement will be tested and recorded in an aquatic environment. To simulate lunar dust, the mechanism will also be buried in beach sand and operated after being uncovered.

All tests performed from this stage onward will revolve around the NASA test environments. Tests will identify design flaws in the assembly that should be addressed. After several adjustments, the most compliant assembly will be selected for further development. This assembly will be the focus of the next PDR—a more in-depth report that will be submitted to the Micro-g sponsors at NASA. The goal of the next PDR is to verify that the selected design direction meets the necessary qualifications to be tested at the Johnson Space Center in June.

Considering that the PDR contents submitted to NASA line up with class CDR deliverables, the same structural prototype will be used in that report. Manufacturing materials will be ordered in the coming weeks to allow for enough lead time to machine a full assembly prototype. Material choice has been informed by not only strength, but availability and machinability conducive to minimizing lead times and expediting manufacturing speed. Lead time is the most significant, as team productivity will be dependent on the arrival of the construction materials. Beyond that, spare materials must be ordered in the event of process failure. NASA advises all Micro-g teams to purchase back-up parts so structural prototypes can be made in quick succession. Back-up materials save valuable time when production changes are made by allowing for proper trial and error periods.

Further emphasis will then be put on the manufacturing plan for this design. Once the proper materials are secured, many machining processes will be adjusted off the successes and failures of the structural prototypes. Cal Poly offers a large variety of manufacturing resources; however, it may become apparent that the current manufacturing plan is not realistic. As it stands, the scoop tool will be casted while the shaft will be cut from readily available aluminum tube stock. The mechanism itself will be machined using a CNC mill, but the taper on the part may yield the wrong results. A finalized plan will be recorded in the CDR once the relevant manufacturing obstacles are identified.

A detailed breakdown of these plans can be found in a Gantt chart in appendix D. The proper timeline of each design cycle is clearly labeled, giving the sponsor realistic expectations while maintain team productivity.

F. Conclusion

The NASA Artemis III astronauts need a new mechanism to attach various tools to a handle extension. Previous attempts have had suboptimal results with the mechanism beginning to bind after some use in the dusty lunar surface. Many existing solutions for quick connecting mechanisms have been analyzed for their usability and have been deemed inadequate. Our team designed a new mechanism based on a cam and groove locking mechanism used in high pressure hose connections. This design has perforations in the housing and in the grooves themselves to allow dust to travel through it and not damage the mechanism. The grooves are also cut such that they give additional torsional resistance in addition to the resistance due to friction.

For this new design our team will run through many rounds of prototyping and testing. We will start with simpler 3D printed models to check fits and viability, also assessing the effectiveness of our mechanism. After at least two 3D printed models we will switch to a machined model where we will begin to refine our manufacturing process and test more accurately fits and the various specs set forth in our Scope of Work document. This will lead to further rounds of 3D printing and machined prototypes that will bring us closer to our final product.

Our final product will be taken to NASA’s Neutral Buoyancy Lab (NBL) where it will be tested further in the simulated lunar surface. Our team will direct the divers of the NBL in a series of tests which we have developed. This will allow us to better understand how effective our design is and its viability as a replacement for the previous design.

G. Technical References

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II. STEM Engagement

A. Outreach Plan

STEM, and specifically engineering, is a fantastic field to be passionate about. Many who actively participate in the STEM community were first introduced in an educational environment. Those fortunate enough to attend schools with the proper infrastructure are provided opportunities to learn and participate in STEM activities at a young age. Unfortunately, many students do not pursue these fields even if they possess the ability to positively impact them. There is a clear need to inspire young, culturally, and economically diverse demographics to pursue interests in engineering and stem-related fields.

Our team has taken it upon ourselves to correct misconceptions about STEM and engineering on a professional and amateur level. According to recent studies, there has been a noticeable increase in the correlation between a student's beliefs about their academic abilities and their academic persistence in STEM related fields. A research book published by the National Academies Press titled, *Barriers and Opportunities for 2-Year and 4-Year STEM Degrees: Systemic Change to Support Students' Diverse Pathways,* highlights a concept called 'Ability Cues'. Ability cues are essentially internal acknowledgements of what ability looks like, and the assumption of who has it:

> These cues can influence students' views of their own ability. Research on implicit beliefs about ability show that students who think of ability as fixed respond to academic settings in different ways than those who think of ability as malleable… Students with fixed beliefs about ability are more likely to avoid challenging tasks and to view challenge as more threatening to their self-concepts. They are more likely to respond to challenge or failure by feeling helpless, avoiding help-seeking, and ultimately, disengaging. In contrast, students who view ability as malleable view failures as opportunities to learn, are persistent in the context of challenge or failure, and are more likely to seek help… [1]

It is far too common that you meet a bright kid who becomes discouraged from pursuing STEM related education because they feel that they do not possess the ability. They may have struggled with a subject area and misinterpreted failure as a sign that success isn't possible. We want to highlight the importance of failure—especially in engineering applications.

[1] National Academies of Sciences, Engineering, and Medicine. 2016. Barriers and Opportunities for 2-Year and 4-Year STEM Degrees: Systemic Change to Support Students' Diverse Pathways. Washington, DC: The National Academies Press. https://doi.org/10.17226/21739.

To begin our sessions, we will present a variety of human achievements within engineering—the lightbulb, the first planes, the first rockets, etc. The idea is to get the group engaged by showing the worlds “perfect” inventions, then we will contrast this with the long list of failures that were used as building blocks for success. Once the group starts to understand that perfection is impossible, we will then proceed to a group activity—a mini design challenge.

The group design challenge will serve multiple purposes. The first is to promote hands on engagement. The group will have an open-ended problem that they get to solve whatever way they see fit. During this time, we will actively encourage ideation and share valuable brainstorming techniques that we have learned as Cal Poly engineers. After the first ‘prototypes’ are made, we will conduct a small performance test, and then re-evaluate the designs—a great introduction to the iterative design process. This will allow us to transition into a discussion, drawing parallel to what we are currently working on with the Micro-g NExT Design Challenge. We will get feedback from the instructor and the students to see if there are any improvements possible for our design.

To include a broader community in our outreach efforts than we are physically capable of reaching, an Instagram account will be created to document various aspects of our sessions. Pre- and post-discussion interviews will be conducted to assess the effectiveness of our activities—these will consist of short questions that will gauge the excitement level of the student, promoting peer to peer communication on a large scale. Note that we plan to obtain parental and student consent before recording any interviews. The design activities and brainstorming processes will also be shared on the social media account to stimulate engagement and STEM awareness with our virtual audience.

1. Current Progress

Multiple high schools have been contacted, as well as community organizations such as the local Boy and Girl Scout Councils, describing the plan for our outreach efforts. Responses from three groups who plan to participate have been received: Templeton High School, Morro Bay High School, and the Girl Scouts of California’s Central Coast. Approval to present to the Boy Scouts of America - Los Padres Council, and San Luis Obispo High School is still pending. Only Templeton High School has sent their letter of agreement, letters from Morro Bay High School and the Girl Scouts are still pending.

To Whom It May Concern,

By signing this Letter, I, Jason Diodati, faculty at Templeton High School, have agreed to allow the EVA Dust-Tolerant Extension Handle Team to present to my students. They will perform a presentation and accompanying interactive activity. It will serve to introduce STEM applications to the students and provide hands-on exposure to the engineering design process.

Sincerely,

Jason Diodati
jdiodati@templetonusd.org

III. Administrative Details

A. Mentor Request

We do not currently have a mentor contact with NASA, but we would like to be paired with a Johnson Space Center engineer or scientist.

B. Institutional Letter of Endorsement

CAL POLY

Mechanical Engineering Department
College of Engineering

Office: 805-756-1334
Fax: 805-756-1137
jwidmann@calpoly.edu
me.calpoly.edu

October 19, 2022

Micro-g NExT Program
NASA Johnson Space Center

Dear Micro-g NExT Coordinators,

This letter confirms that the Mechanical Engineering Department of California Polytechnic State University, San Luis Obispo (Cal Poly SLO) supports our student teams competing in the 2023 Micro-g NExT Challenge. The team focusing on the EVA Dust-Tolerant Extension Handle challenge includes team members Sam Potter, Matt Redmond, Andrew Reese, and Dylan Weiglein, working with faculty advisor Peter Schuster.

Facilities, equipment and a faculty advisor at the university will be made available to the student team as needed to successfully design, build, test, and deliver a functioning prototype system that can compete in this challenge.

Sincerely,

Jim Widmann
Professor and Chair
Mechanical Engineering Department
California Polytechnic State University

1 GRAND AVENUE • SAN LUIS OBISPO • CALIFORNIA • 93407 • 805-756-1111 CALPOLY.EDU

C. Statement from Supervising Faculty

CAL POLY

Mechanical Engineering Department
College of Engineering

Office: 805-756-1334
Fax: 805-756-1137
pschuste@calpoly.edu
me.calpoly.edu

October 24, 2022

Micro-g NExT Program
NASA Johnson Space Center

To whom it may concern,

As the faculty advisor for the "EVA Dust-Tolerant Handle Extension Mechanism" project proposed by Andrew Reese, Dylan Weiglein, Sam Potter, Matt Redmond, a team of undergraduate students from California Polytechnic State University, San Luis Obispo (Cal Poly SLO), I concur with the concepts and methods by which this project will be conducted. I will ensure that all reports and deadlines are completed by the student team members in a timely manner. I understand that any default by this team concerning any Program requirements (including submission of final report materials) could adversely affect selection opportunities of future teams from Cal Poly SLO.

Sincerely,

Peter Schuster
Professor
Mechanical Engineering Department
California Polytechnic State University

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D. Statement of Rights of Use

As a team member for a proposal entitled Perforated Groove Cam Lock proposed by a team of undergraduate students from California Polytechnic University, San Luis Obispo, I will and hereby do grant the U.S. Government a royalty-free, nonexclusive and irrevocable license to use, reproduce, distribute (including distribution by transmission) to the public, perform publicly, prepare derivative works, and display publicly, any data contained in this proposal in whole or in part and in any manner for Federal purposes and to have or permit others to do so for Federal purposes only.

As a team member for a proposal entitled Perforated Groove Cam Lock proposed by a team of undergraduate students from California Polytechnic University, San Luis Obispo, I will and hereby do grant the U.S. Government a nonexclusive, nontransferable, irrevocable, paid-up license to practice or have practiced for or on behalf of the United States an invention described or made part of this proposal throughout the world.

Andrew Reese (Team Leader)	Dylan Weiglein (Team Member)	Matt Redmond (Team Member)	Sam Potter (Team Member)	Peter Schuster (Advisor)

E. Funding and Budget Statement

Cal Poly SLO provides a stipend of $1,000 to every senior project group, this will be the base of the funding for materials and supplies. The budget is broken down in the following table:

Table 4. Project expense breakdown and total.

Item	Cost
Materials and Supplies	
Aluminum stock	$50
440C SST Round Stock	$163
440C SST Bar Stock	$56
Press-Fit Drill Bushing Qty. 4 (McMaster-Carr 96511A366)	$55
Tight Tolerance Drill Rod (3ft) (McMaster-Carr 8893K131)	$5
Powder Coating (Jet Black, Powder by the Pound)	$12
Manufacturing Costs	
Provided by school	--
Travel	
Round trip plane tickets to Houston Qty. 4	$2,668
Hotel	$528
Transport	$1,000
Food	$600
Miscellaneous	$400
Total	$5,537

To cover travel expenses, the Lunar Lads plan to reach out to Cal Poly Alumni with fund raising assistance for the remaining $4,537 that will not be provided by the University. Our team possesses memberships to multiple organizations that contain a network of highly motivated individuals who are willing to provide resources to undergraduate students.

These organizations include:

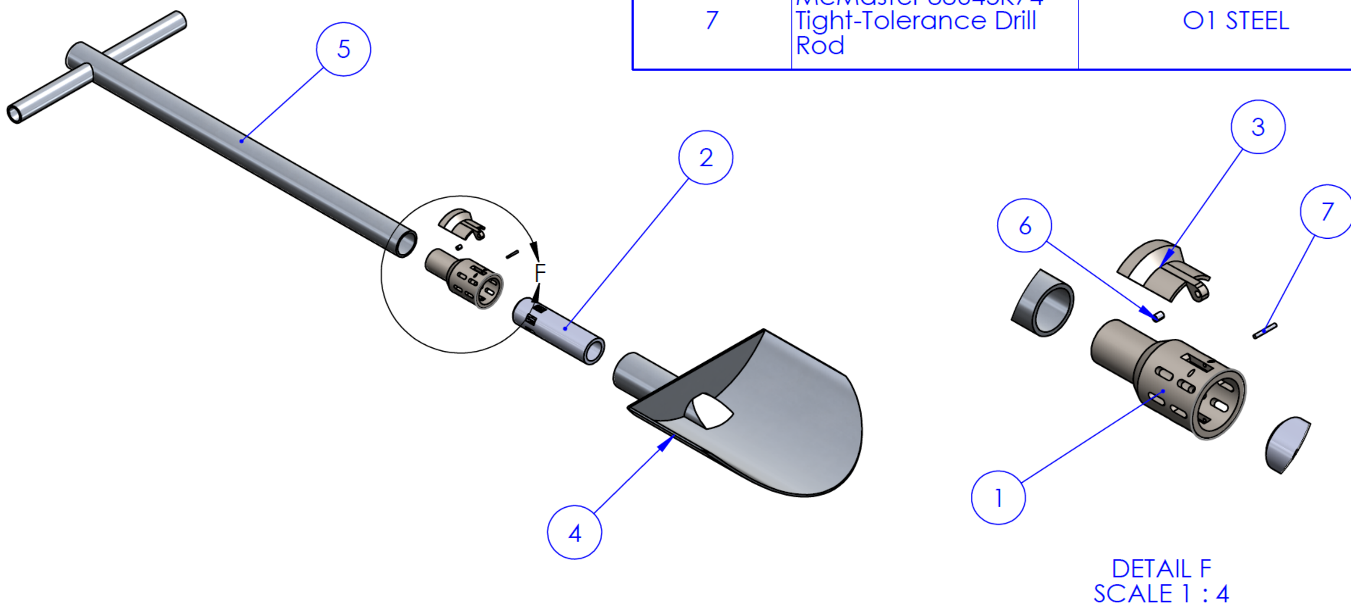
- Cal Poly SLO – Men's Water Polo Club
- Delta Upsilon International Fraternity – Cal Poly Chapter
- Cal Poly American Society of Mechanical Engineers

If the team fails to raise the remaining funds through this method, then the difference will be covered equally by each of the team members.

IV. Appendices

A. Engineering Drawings

ITEM NO.	PART NUMBER	MATERIAL	QTY.
1	Cam_Receiver	440C SST	1
2	Tool_Side_Groove	6061 T6 ALUMINUM	1
3	Cam	440C SST	1
4	Scoop	8356 ALUMINUM	1
5	Handle	6061 T6 ALUMINUM	1
6	96511A366_Press-Fit Drill Bushing.step	STEEL	1
7	McMaster 88645K74 Tight-Tolerance Drill Rod	O1 STEEL	1

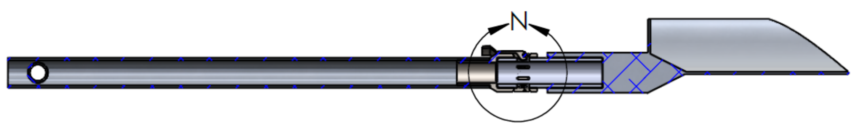


Cal Poly Mechanical Engineering	Dwg. #: 1	Title: EXTENSION HANDLE		Drwn. By: DYLAN WEIGLEIN
		Date: 10/25/22	Scale: 1:8	Chkd. By: ANDREW REESE

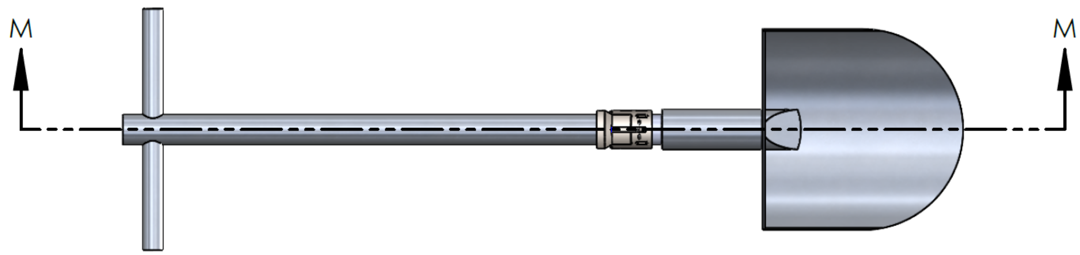
NOTES
UNLESS OTHERWISE SPECIFIED:

1. ALL DIMENSIONS IN INCHES
2. TOLERANCES:
   X.XX = ±.01
   X.XXX = ±.002
   ANGLES = ±1°
3. INSIDE TOOL RADIUS .01 MAX
4. BREAK SHARP EDGES .02 MAX

DETAIL N
SCALE 1 : 1.5



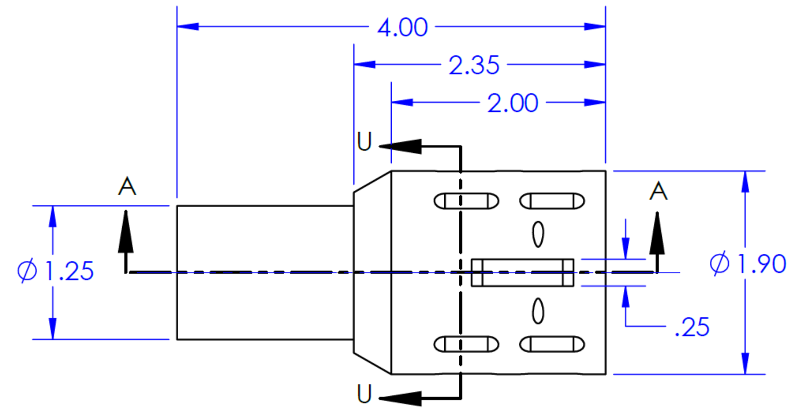
SECTION M-M
SCALE 1 : 8

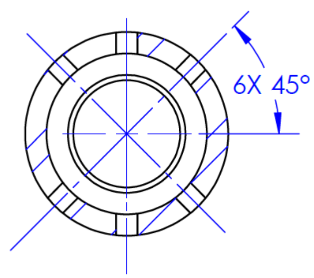


Cal Poly Mechanical Engineering	Dwg. #: 1	Title: MECHANISM DETAIL VIEW	Drwn. By: DYLAN WEIGLEIN
		Date: 10/25/22 / Scale: 1:8	Chkd. By: ANDREW REESE

NOTES
UNLESS OTHERWISE SPECIFIED:

1. ALL DIMENSIONS IN INCHES
2. TOLERANCES:
   X.XX = ±.01
   X.XXX = ±.002
   ANGLES = ±1°
3. INSIDE TOOL RADIUS .01 MAX
4. BREAK SHARP EDGES .02 MAX





SECTION U-U
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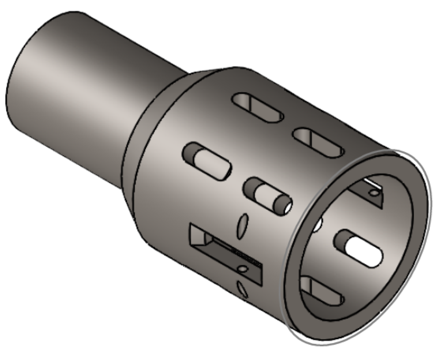

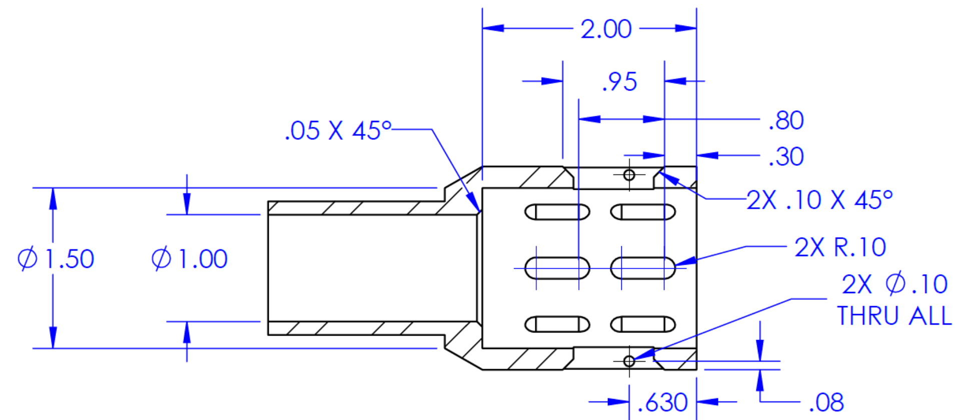

SECTION A-A
SCALE 1 : 1.5

Cal Poly Mechanical Engineering	Dwg. #: 1	Title: CAM_RECEIVER	Drwn. By: DYLAN WEIGLEIN
		Date: 10/25/22 | Scale: 1:1.5	Chkd. By: ANDREW REESE

NOTES
UNLESS OTHERWISE SPECIFIED:
1. ALL DIMENSIONS IN INCHES
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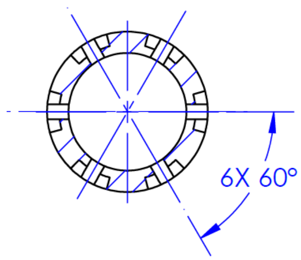
   X.XX = ±.01
   X.XXX = ±.002
   ANGLES = ±1°
3. INSIDE TOOL RADIUS .01 MAX
4. BREAK SHARP EDGES .02 MAX



SECTION V-V
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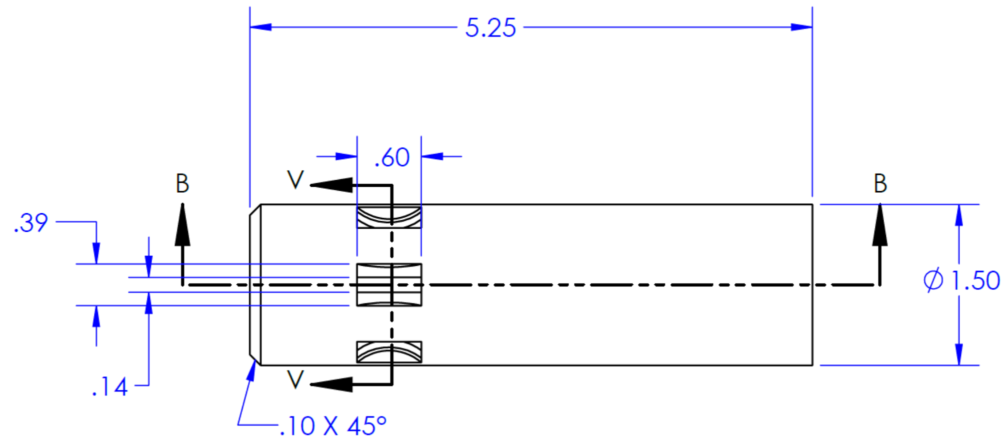

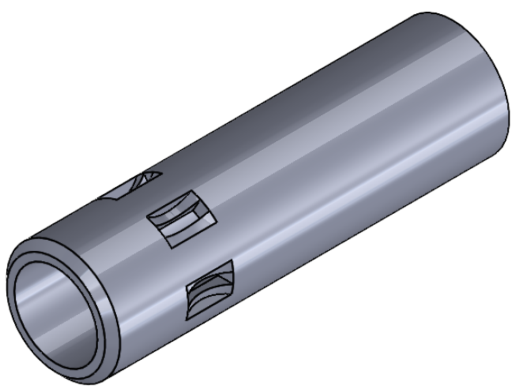

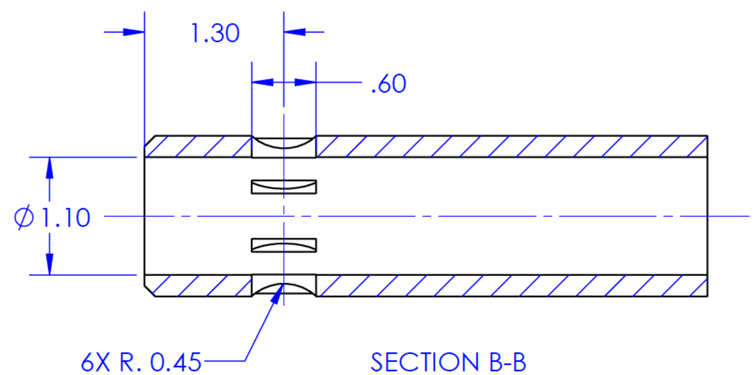

SECTION B-B
SCALE 1 : 1.5

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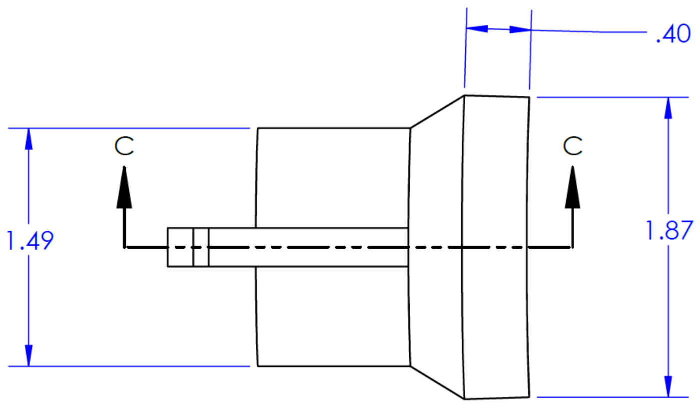
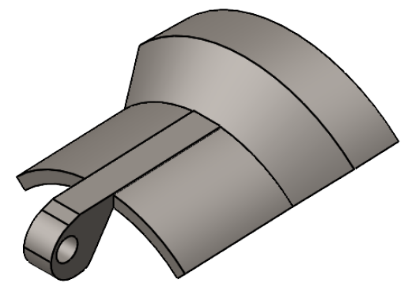
		Date: 10/25/22 / Scale: 1:1.5	Chkd. By: ANDREW REESE

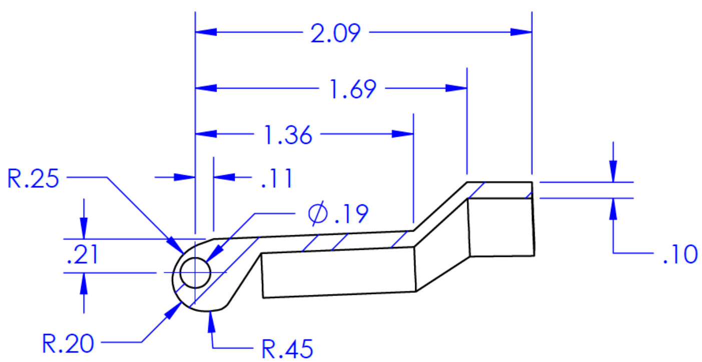


NOTES

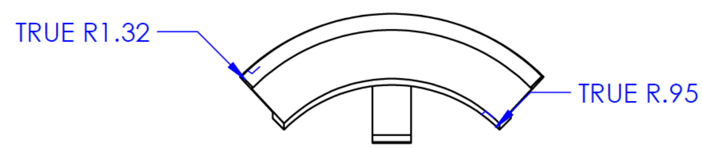
UNLESS OTHERWISE SPECIFIED:

1. ALL DIMENSIONS IN INCHES
2. TOLERANCES:
   - X.XX = ±.01
   - X.XXX = ±.002
   - ANGLES = ±1°
3. INSIDE TOOL RADIUS .01 MAX
4. BREAK SHARP EDGES .02 MAX





SECTION C-C



Cal Poly Mechanical Engineering	Dwg. #: 1	Title: CAM	Drwn. By: DYLAN WEIGLEIN
		Date: 10/25/22 / Scale: 1:1	Chkd. By: ANDREW REESE

NOTES
UNLESS OTHERWISE SPECIFIED:
1. ALL DIMENSIONS IN INCHES
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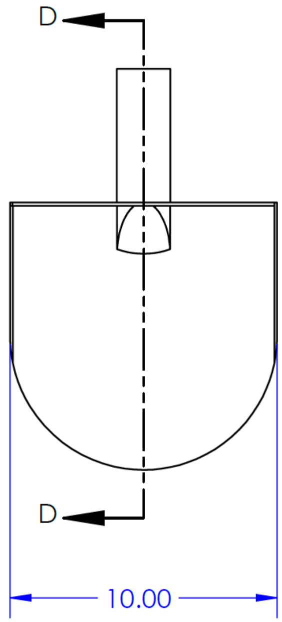
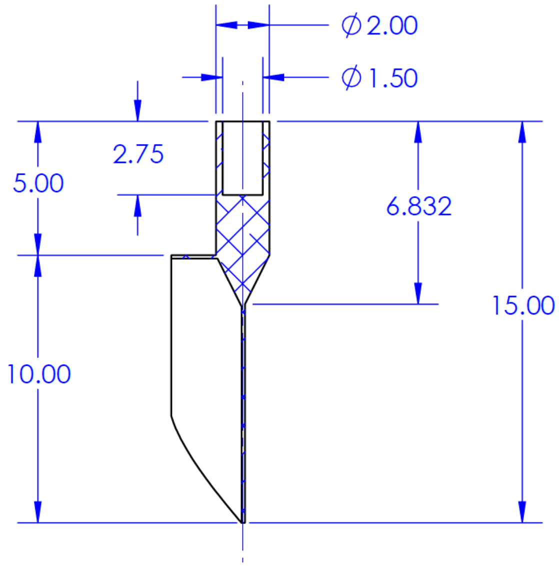
   X.XX = ±.01
   X.XXX = ±.002
   ANGLES = ±1°
3. INSIDE TOOL RADIUS .01 MAX
4. BREAK SHARP EDGES .02 MAX





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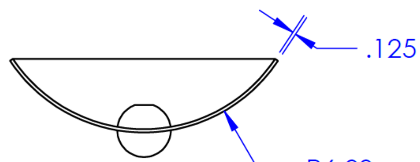
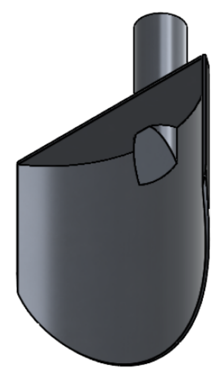
SCALE 1 : 6



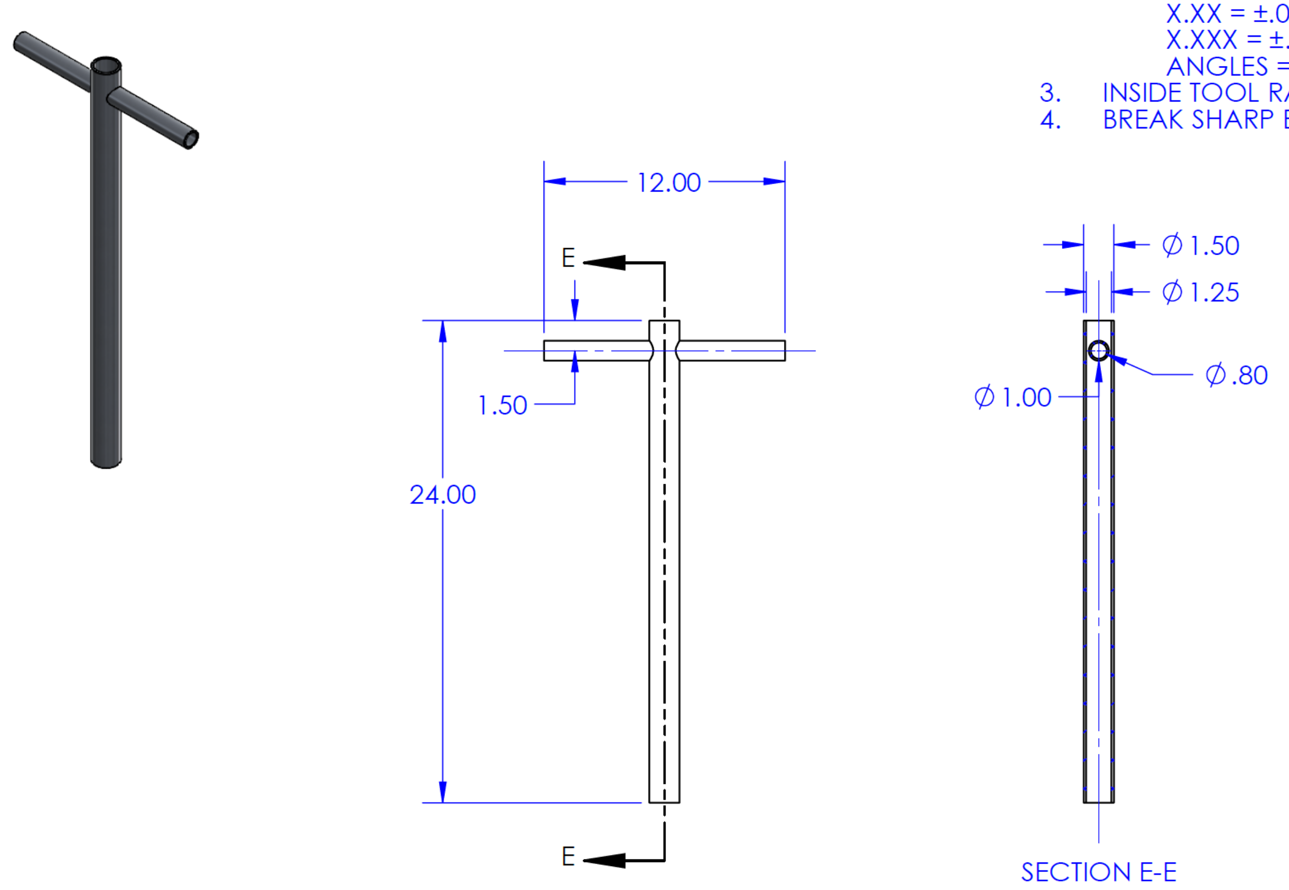


Cal Poly Mechanical Engineering	Dwg. #: 1	Title: SCOOP	Drwn. By: DYLAN WEIGLEIN
		Date: 10/25/22 / Scale: 1:6	Chkd. By: ANDREW REESE

NOTES

UNLESS OTHERWISE SPECIFIED:

1. ALL DIMENSIONS IN INCHES
2. TOLERANCES:
   - X.XX = ±.01
   - X.XXX = ±.002
   - ANGLES = ±1°
3. INSIDE TOOL RADIUS .01 MAX
4. BREAK SHARP EDGES .02 MAX



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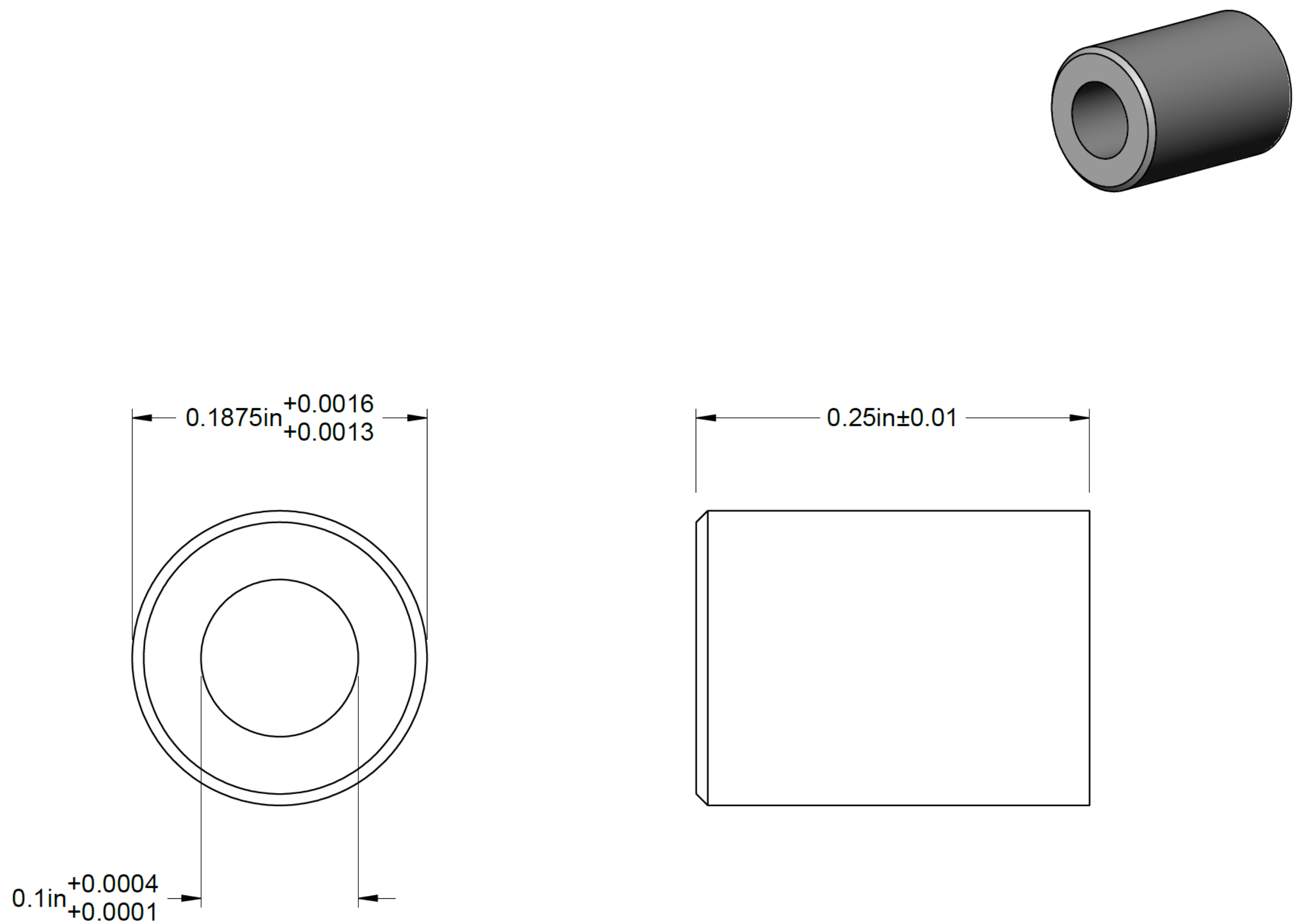
		Date: 10/25/22 / Scale: 1:8	Chkd. By: ANDREW REESE

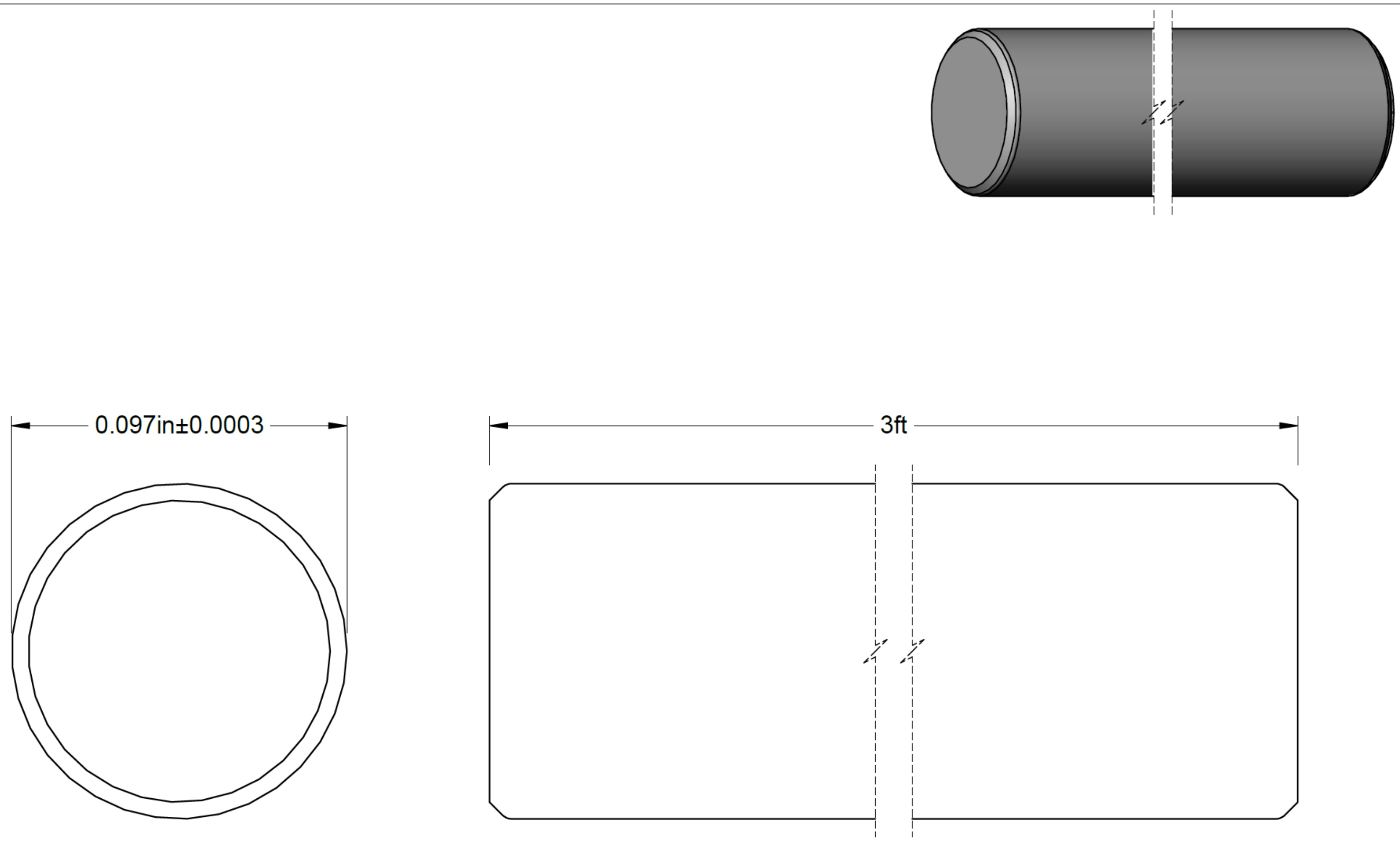


For No. 39 Drill Size

McMASTER-CARR® CAD

PART NUMBER 96511A366

Press-Fit Drill Bushing



McMASTER-CARR® CAD

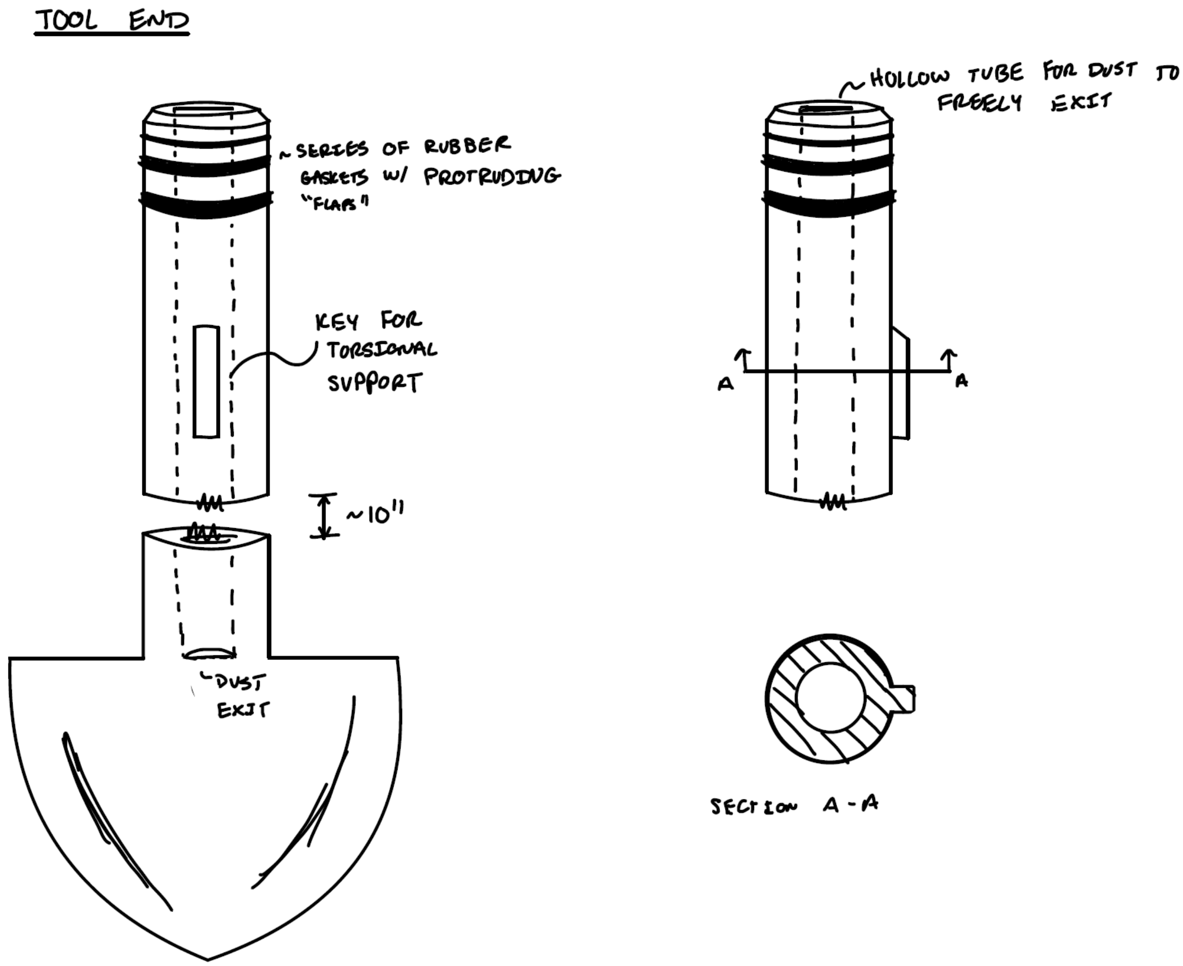
PART NUMBER **88645K74**

http://www.mcmaster.com

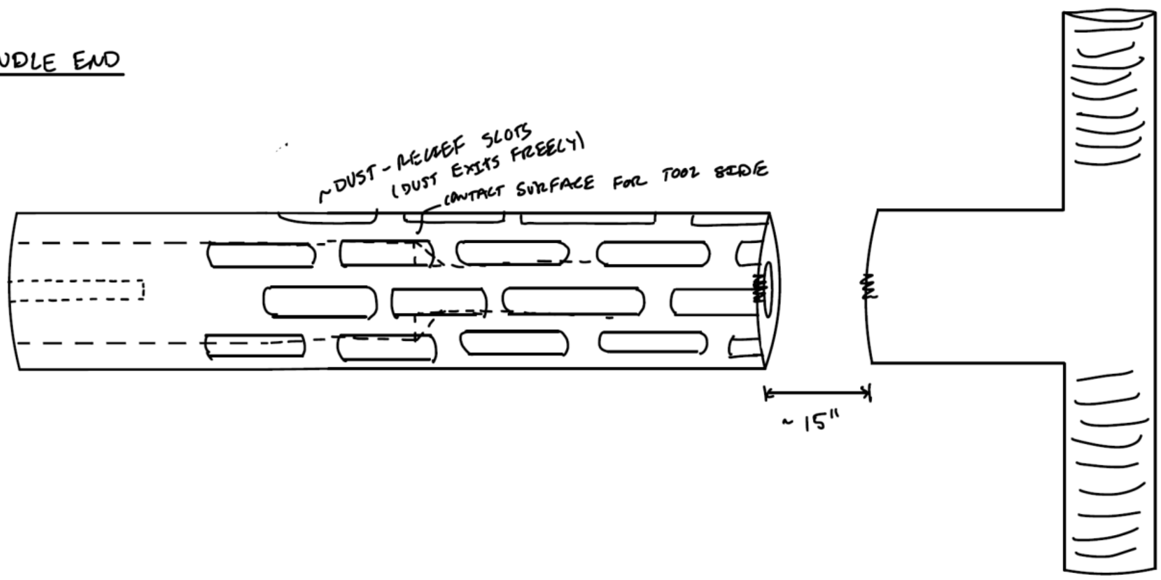
Tight-Tolerance Multipurpose O1 Tool Steel Rod

B. Alternate Design Sketches and Models

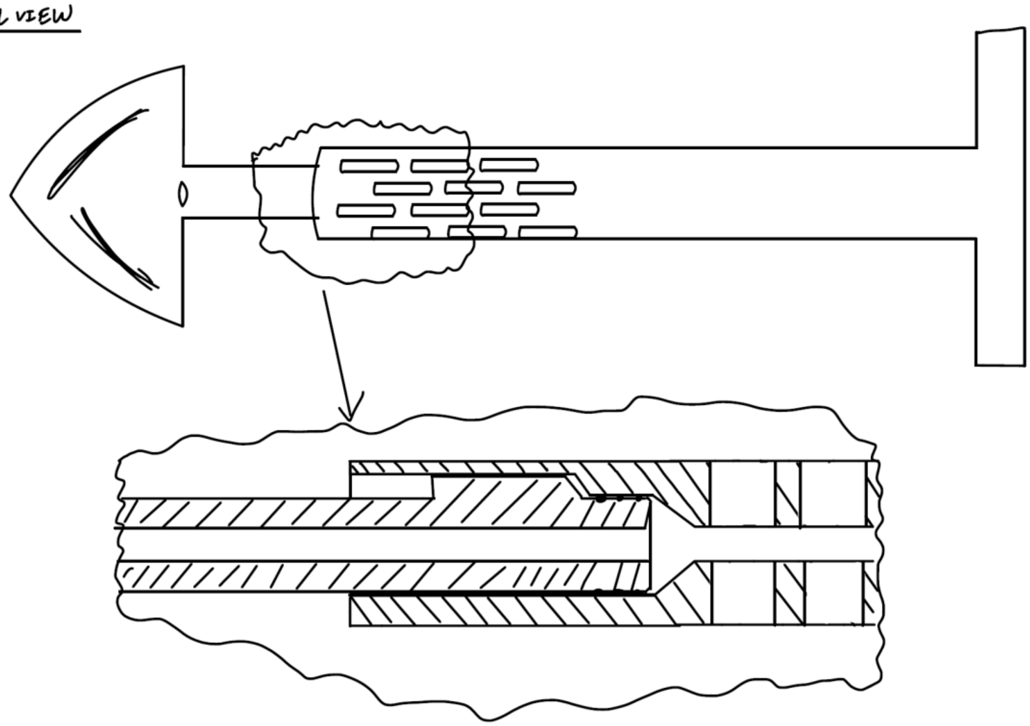
Compression Fit



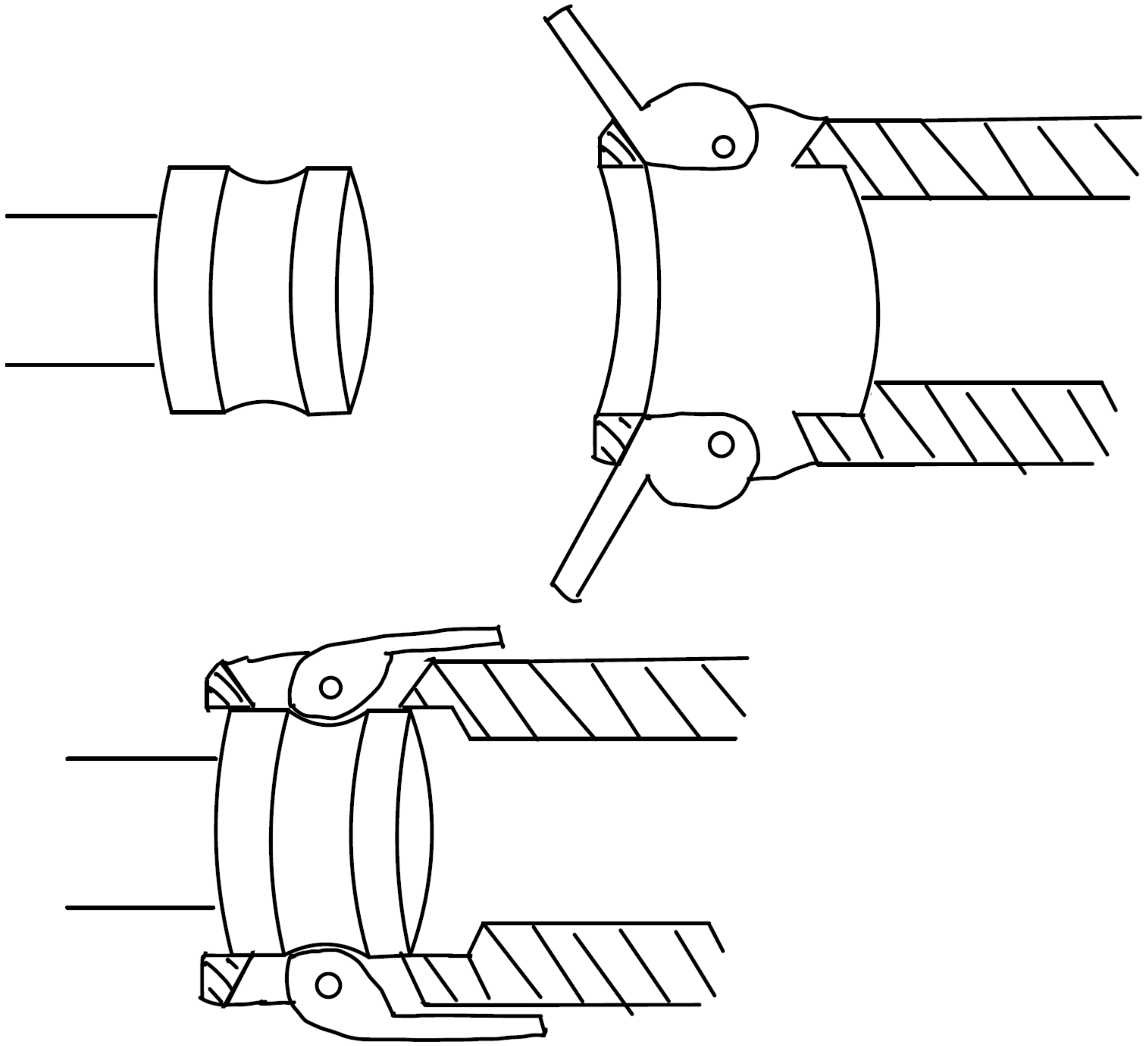
HANDLE END



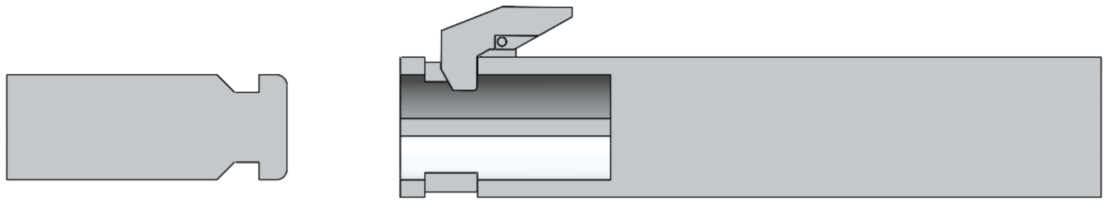
FULL VIEW

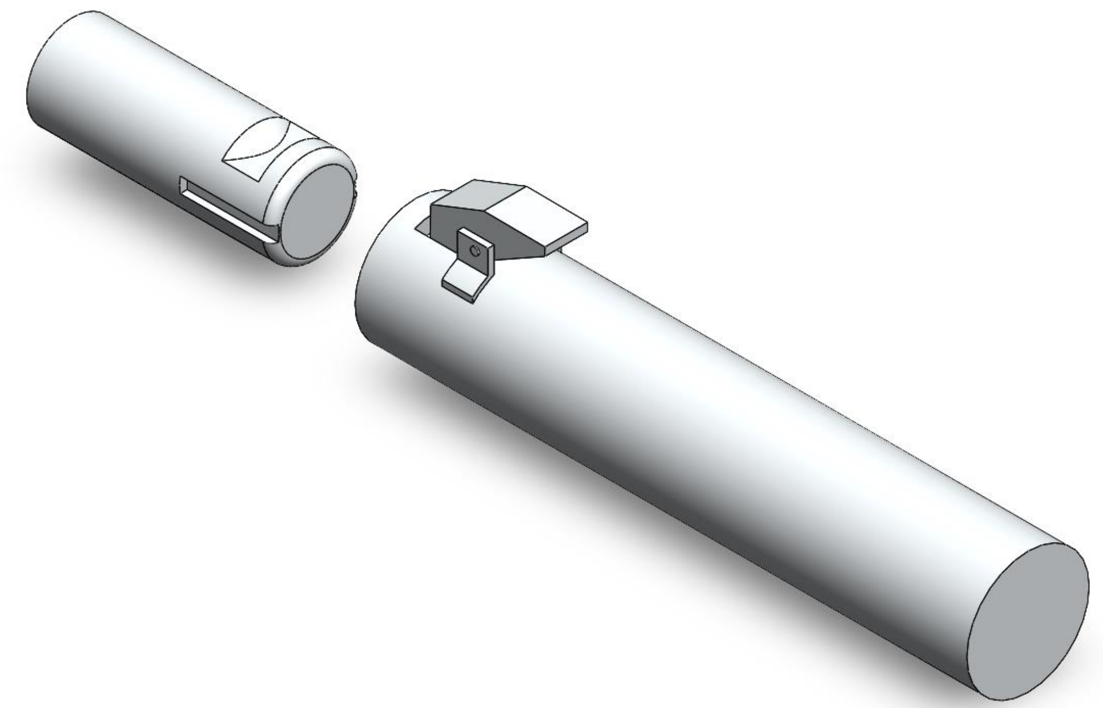


Cam and Groove

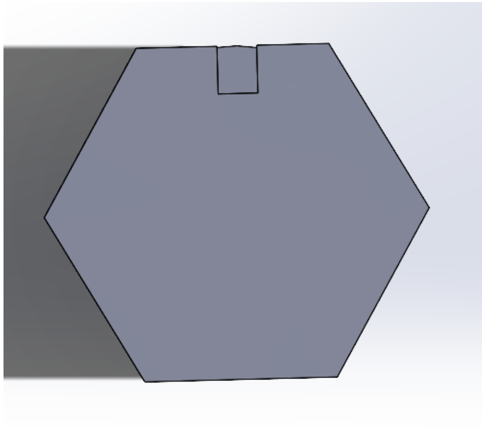


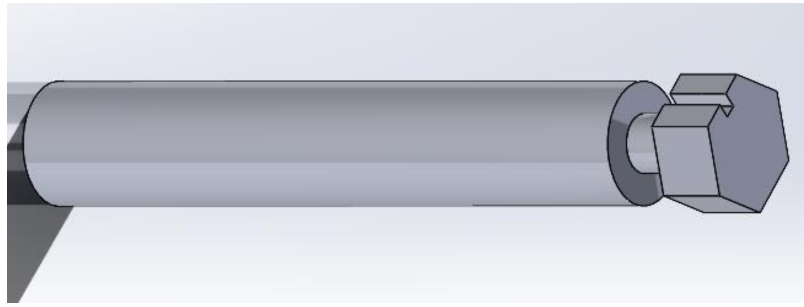
Snap Together

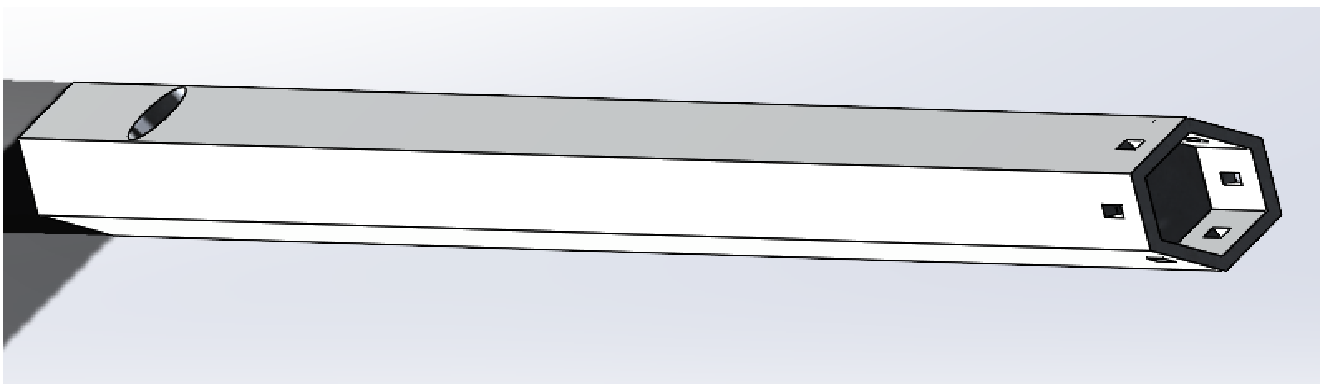


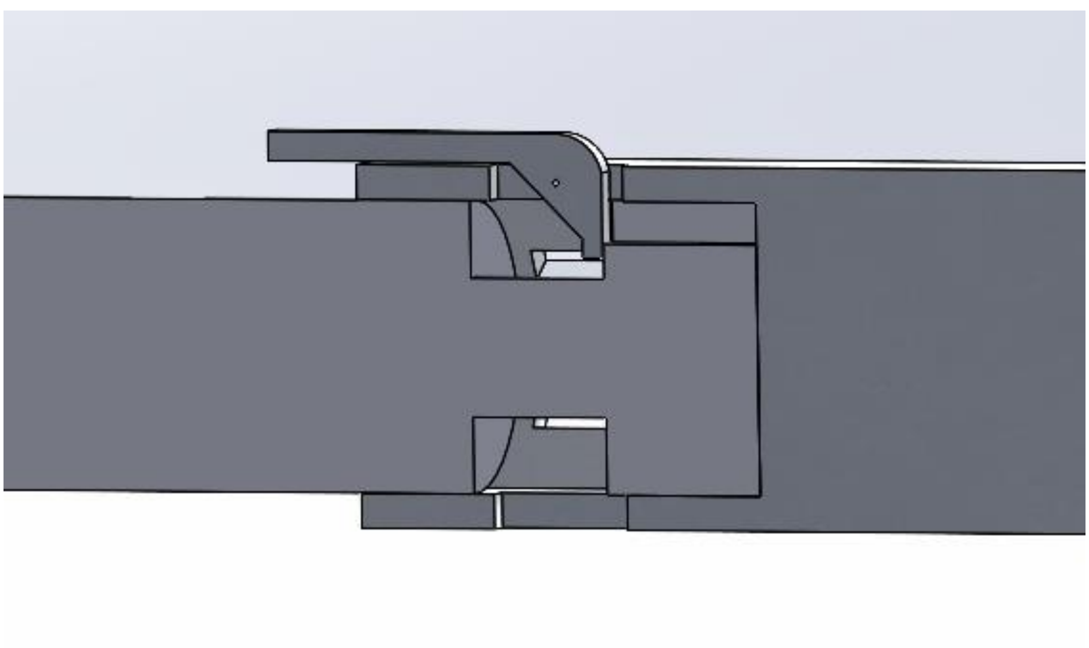


Hex Fit









C. Hazard Assessment

Table 5: Score description of various consequence categories [1]

CONSEQUENCE					
	1	2	3	4	5
Performance	Minimal consequence to objectives/goals	Minor consequence to objectives/goals	Unable to achieve a particular objective/ goal, but remaining objective goals represent better than minimum success or outcome	Unable to achieve multiple objectives/ goals but minimum success can still be achieved or claimed	Unable to achieve objectives/goals such that minimum success cannot be achieved or claimed
Safety Human	Discomfort or nuisance	First aid event per OSHA criteria	No lost time injury or illness per OSHA criteria	Lost time injury or illness per OSHA criteria	Loss of life
Asset	Minimal consequence: asset has no sign of physical damage	Minor consequence: asset has cosmetic damage and is repairable	Minor consequence: asset is damaged but repairable	Major consequence asset is substantially damaged but repairable	Destroyed: asset is compromised, and un-repairable: a total loss
Schedule	Minimal consequence	Critical path is not slipped; total slack of slipped tasks will not impact critical path in less than 10 days	Critical path is not slipped; total slack of slipped tasks is within 10 days of impacting the critical path	Critical path slips	Critical path slips and one or more critical milestones or events cannot be met
Cost	Minimal consequence	Minor cost consequence. Cost variance ≤ 5% of total approved FY baseline	Cost consequence. Cost variance > 5% but ≤ 10% of total approved FY baseline	Cost consequence. Cost variance > 10% but ≤ 15% of total approved FY baseline	Major cost consequence. Cost variance > 15% of total approved FY baseline

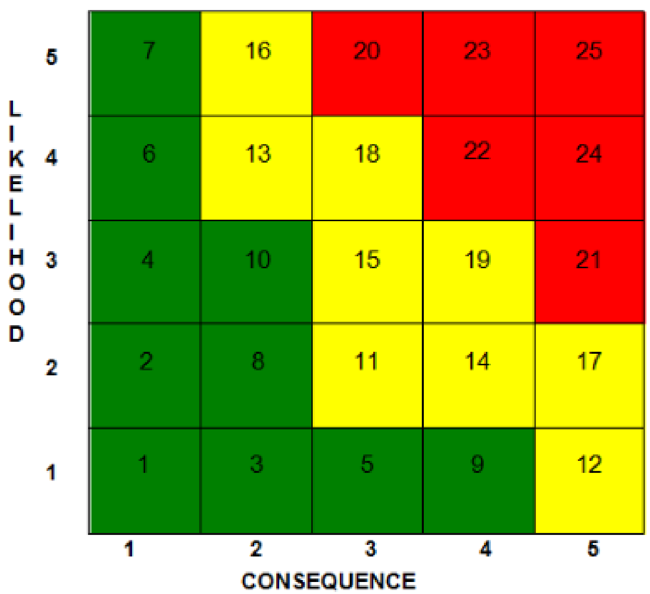


Figure 11: Hazard Assessment Score Chart [1]

[1] Benton, Scott "S3001: Guidelines for Risk Management: Version G". 16 October, 2017

Table 6: Scoring of risk analysis compared to a likelihood vs consequence table

Risk	Consequence Category	Consequence Score	Likelihood Score	Combined Score
Finger Entrapment	Human Safety	1	2	2
Suit Puncture	Human Safety	5	1	12
Hand Fatigue	Performance	2	2	8
Mechanical Failure	Asset	4	1	9

D. Project Timeline

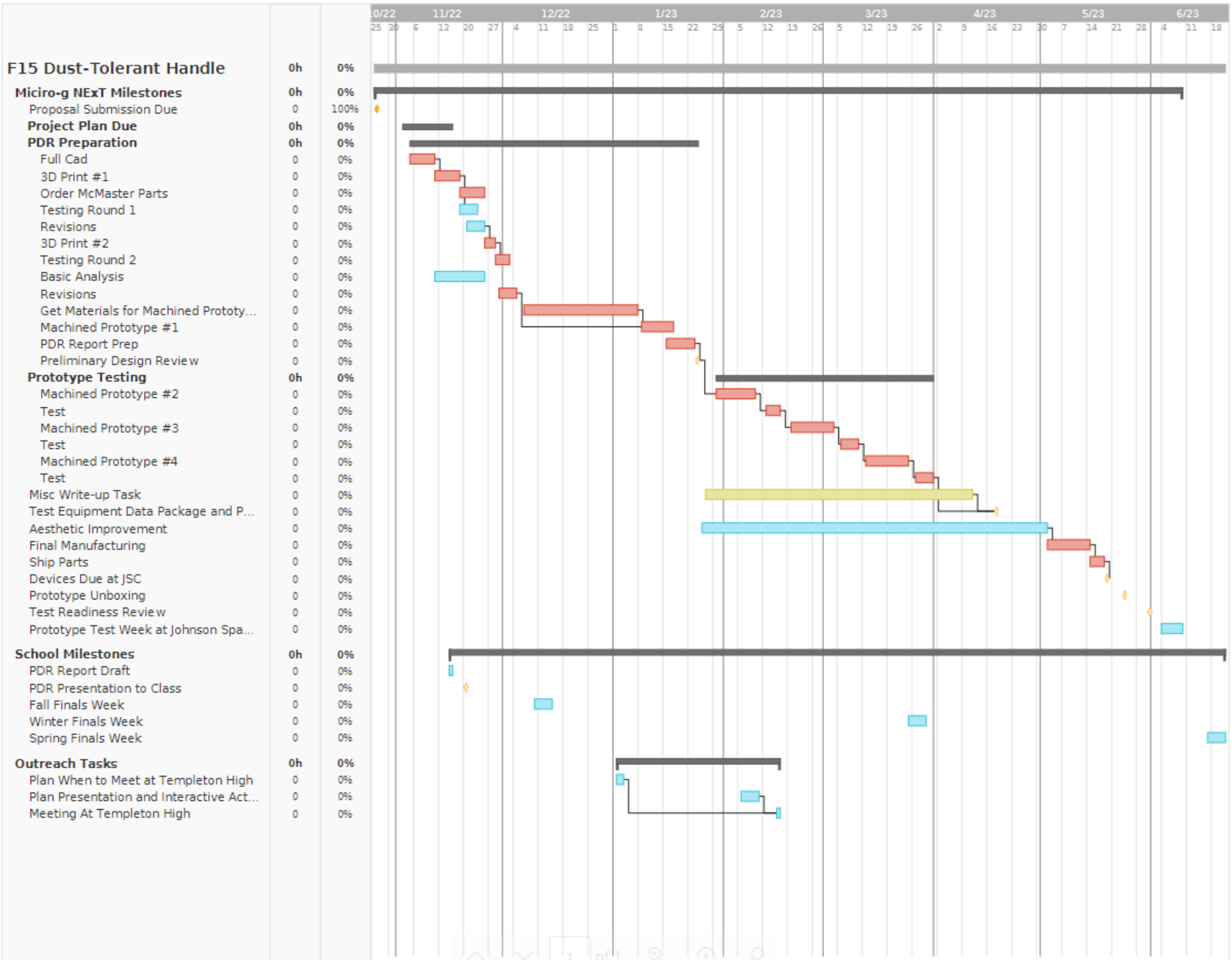


Figure 12: Color coded Gantt chart