

NICK'S PRECISION MACHINING COMPANY

PRODUCTION JOB TRAVELER

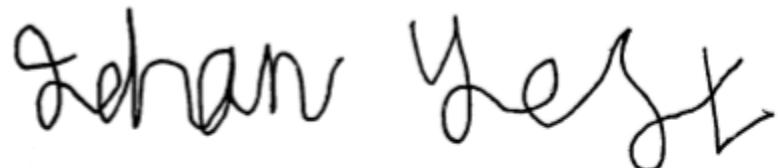
Manufacturing Engineer: Johan Yost

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Part 1: Academic integrity signature page

My signature below constitutes my pledge that I have followed this midterm policy for academic integrity as well as the specific instructions for this exam. I affirm that this exam represents my own work, without the use of any unpermitted aids or resources. I understand that there will be no tolerance towards academic dishonesty, and that cheating can and will lead to automatic failure on this exam and additional academic discipline as deemed necessary by the instructor.

A handwritten signature consisting of a large, bold 'X' followed by the name 'Johan Yost' in a cursive script.A handwritten signature consisting of a large, bold 'X' followed by the name 'Johan Yost' in a cursive script.

CSU Mechanical Engineering Student

Part 2: Email Exchange with AI Customer

Note: I asked ChatGPT to address me as "John Brown."

ChatGPT Prompt:

You are Chad Chaddzwick from NNM Optics Inc., waiting impatiently on the delivery of custom optical rails from Nicks Precision Machining Co. These rails are essential for your laser alignment testing system prototype, and any delays could seriously impact your development schedule. You're frustrated about potential delays and skeptical of the explanations provided so far. Firmly ask specific questions regarding the status of the rails, the exact reasons for delays, the expected impact on your timeline, potential extra costs, and what concrete steps they're taking to get the project back on track. Maintain a demanding and somewhat uncooperative tone.

Format your inquiry as an email with the following:

To: John Brown, jbrown@npmc.com
From: Chad Chaddzwick, chad.chaddzwich@nnmoptics.com
Date: March 25, 2025
Subject: Urgent Status Update Required on Custom Optical Rails, Order 15505

To: John Brown, jbrown@npmc.com
From: Chad Chaddzwick, chad.chaddzwich@nnmoptics.com
Date: March 25, 2025
Subject: Urgent Status Update Required on Custom Optical Rails, Order 15505

John,

I'm following up once again regarding the custom optical rails for our laser alignment testing system (Order 15505). As you know, these rails are absolutely critical to our project, and the

continued delays are unacceptable. The vague explanations we've been provided so far have only added to my frustration, and it's now beyond time for clear, concrete answers.

To avoid any further miscommunication or misunderstandings, I need you to provide specific answers to the following questions:

1. **What exactly is causing the delay with the rails?** I've heard multiple reasons, but none of them seem to align. I need an honest and precise explanation for what's going on.
2. **How will this delay impact our overall timeline?** We're already behind schedule, and I need to know exactly how much longer this will push us back. How far behind are we, and what specific dates can you guarantee for delivery?
3. **What additional costs are we looking at due to this delay?** If this pushes back our testing or requires us to make any adjustments, we need a clear breakdown of potential extra expenses. Who is covering these costs, and how are you addressing them?
4. **What immediate actions are being taken to resolve this?** I need to know what specific steps are being taken right now to expedite this order. Don't give me generic answers — tell me what's being done at this moment to ensure we don't lose any more time.

The lack of urgency and transparency on your end is becoming a serious concern. We cannot afford any further delays, and I expect a detailed response addressing all of the above points *today*.

Regards,
Chad Chaddzwick
NNM Optics Inc.

To: Chad Chaddzwick, chad.chaddzwick@nnmoptics.com

From: John Brown, jbrown@npmc.com

Date: March 25, 2025

Subject: Urgent Status Update Required on Custom Optical Rails, Order 15505

Hello Chad,

I hope you have been enjoying the beautiful weather this week. Thank you for contacting me directly regarding the status of your optical rail order. I am sorry for your frustration. I am the manufacturing engineer for your order and will strive to alleviate your concerns with complete transparency. Please be assured that I aim to deliver your precision optical rails at the timeliness and quality NPMC is known for. I will address your questions in the order you have asked.

- 1. *What exactly is causing the delay with the rails? I've heard multiple reasons, but none of them seem to align. I need an honest and precise explanation for what's going on.***

Due to the industry-wide shortage of O1 tool steel, our supplier placed our raw material order on backorder. They initially quoted delivery within five business days but estimated the backorder would delay delivery by an additional week. I contacted our sales engineer there. She said the shortage is growing daily and would classify it as a complete global shortage of O1 tool steel. She was not confident they could even meet their new estimated delivery date. However, we found a fantastic solution. Instead of waiting for our supplier to receive 12-foot-long bars of raw stock from their foundry, we will use "cut-offs" they have on hand. "Cut-offs" are the remaining ends of 12-foot-long bars their warehouse has from custom-length orders. Their warehouse will size these "cut-offs" to 12.500" -0' / +0.125" [1], a size we can put directly into our mill to machine your optical rails.

2. ***How will this delay impact our overall timeline? We're already behind schedule, and I need to know exactly how much longer this will push us back. How far behind are we, and what specific dates can you guarantee for delivery?***

Despite the worrisome global shortage of O1 tool steel, your overall timeframe will not be affected. We are scheduled to deliver your order on time as promised. We will receive the “cut-offs” from our supplier tomorrow, March 26, one day later than our supplier initially quoted the 12’ raw stock bars. I asked our supplier to send three additional “cut-offs” to provide a buffer in case of any “cut-off” measurement errors. As is the procedure of our ProtoForge Lab, we build in a 15% safety stock on all low-production prototype orders to account for errors, defects, and unforeseen issues [2]. Therefore, our internal work order specifies 23 rails, so no time is lost. Finally, because our ProtoForge Lab does not need to cut 12’ raw stock before it is milled, our machining time was reduced, allowing us to make up for the day lost due to the delivery delay. You will receive your order on April 1, the agreed-upon date.

3. ***What additional costs are we looking at due to this delay? If this pushes back our testing or requires us to make any adjustments, we need a clear breakdown of potential extra expenses. Who is covering these costs, and how are you addressing them?***

This raw stock change does not incur additional costs to you. Our supplier provided the additional three bars at no charge to compensate for their delivery delay. It was more expensive to purchase the “cut-offs” and have them sized to 12.5”; however, this cost increase was offset by the fact that our ProtoForge Lab did not have to cut 12’ bars as

budgeted. Therefore, you will not see a change in cost.

4. ***What immediate actions are being taken to resolve this? I need to know what specific steps are being taken right now to expedite this order. Don't give me generic answers — tell me what's being done at this moment to ensure we don't lose any more time.***

As I mentioned, I worked with our supplier to find a solution to the O1 tool steel shortage. Our supplier's warehouse expedited cutting the "cut-offs" into 23 bars of 12.5" length. While waiting for this raw stock, I have been preparing for machining and post-production efficiency. First, I procured the custom 0.33" and 0.53" drill bits for the rail slots. Next, I printed a 3D model of your optical rail. I used this model to verify tooling for the mill, instruct our ProtoForge Lab on the finishing procedure, and train our Quality Assurance inspectors to inspect your optical rails. Here is the model:



[3]

As each rail finishes on the mill, it will go straight to QA. Once 20 rails have passed inspection, we will ship your order for receipt no later than April 1.

I hope I have addressed your concerns with the details you requested. NPMC strives for excellence and thrives on our relationships with our customers. Please let me know if you have further questions. Thank you for allowing us to assist you with your laser alignment testing system prototype.

Kind Regards,
John Brown
Manufacturing Engineer
NPMC

To: John Brown, jbrown@npmc.com

From: Chad Chaddwick, chad.chaddwick@nnmoptics.com

Date: March 25, 2025

Subject: Urgent Status Update Required on Custom Optical Rails, Order 15505

Hi John,

I've reviewed your response, and while I appreciate your detailed explanation, I remain extremely skeptical. You claim that the timeline won't be impacted, yet I'm still seeing a number of potential risk factors that leave me concerned about further delays.

First, your explanation about the O1 tool steel shortage is noted, but the industry-wide shortage was already something you should have anticipated. It's hard to believe this situation is still causing significant disruption at this point. Why wasn't a backup plan in place before the delay was even announced? The "cut-offs" solution sounds like a temporary workaround, but I'm left questioning why it wasn't even considered earlier in the process if it was viable all along.

Second, while I'm being told the final delivery will be April 1, that still doesn't make up for the uncertainty surrounding whether everything goes according to plan. If there's any chance of another slip-up — even one more day — this whole project could be in jeopardy. What guarantees can you provide that the new stock won't encounter further issues, and that this will 100% be delivered by the promised date?

Third, the issue of costs is also far from settled in my mind. You state that there will be no cost increase, but I still don't see any clear breakdown on how those extra three bars you ordered were accounted for. Given the shifting factors here, what assurances do I have that this won't come back to bite us in additional costs down the line?

Finally, I want to hear more about the steps being taken right now to avoid any more hiccups.

You've mentioned several actions, but I don't get a real sense of urgency from your description.

What immediate actions are being taken to track this and ensure every piece is in place for the April 1 deadline?

I expect clear, unambiguous answers to these questions. Given the impact on our development schedule, I need more than just reassurances — I need to see tangible evidence that this is being managed properly at every level.

Best regards,
Chad Chaddzwick
NNM Optics Inc.

To: Chad Chaddzwick, chad.chaddzwich@nnmoptics.com
From: John Brown, jbrown@npmc.com
Date: March 25, 2025
Subject: Urgent Status Update Required on Custom Optical Rails, Order 15505

Hi Chad,

Thank you for your candid reply. I truly wish to alleviate the concerns that arose from your communication with our sales team. I feel it's always good to get information straight from the source and that is who I am for your project. This is also why I have spoken directly with our steel supplier once I learned about the backorder from our purchasing team and why I am working diligently with our ProtoForge Lab and QA team. Please rest assured that I am managing your project with utmost direct communication with those critical to minimize all risks that could compromise your crucial April 1 delivery date.

We have used our steel supplier for more than 25 years. They said they have never experienced

a steel shortage of this global magnitude before. While they anticipated it and stockpiled as much as possible, some of their orders are unfortunately still being impacted. As a much smaller company, NPMC just cannot stockpile steel. As a backup plan, our purchasing team attempted to source elsewhere. However, no one could beat the delivery estimates given by our primary supplier. As soon as I was aware of the situation, I worked diligently to expedite a solution. We were incredibly fortunate to have earmarked some of our supplier's "cut-offs" to complete your order. They were generous so as not to charge extra for the additional machining and to include three extra bars.

We do not order "cut-offs" due to their higher cost. Here is a comparison for you:

Qty	Part	Cert Required	Description	Dimensions	Via	Weight	Price	Line Price
11 PC	02565650 Ø	Yes	7/8 X 4 O-1 DCF,8-12 FT R/L'S	12.5 IN	UPS	143 lbs	\$120.46	\$1,325.09
1 PC	02565650 Ø	Yes	7/8 X 4 O-1 DCF,8-12 FT R/L'S	120 IN	CC	125 lbs	\$1,117.25	\$1,117.25

These prices are from our supplier's website [4] before any discounts that we receive on 12' bars. We can make 11 optical rails from one 12' bar of raw stock. That 12' bar costs \$1117, again before any discounts. It costs \$208 more for 11 bars that are custom cut to 12.5". It is cheaper for us to make these cuts in-house. However, since our supplier made these cuts free of charge for your order, "cut-offs" became a viable solution. Because I had already built time into the production schedule to machine 23 bars, there will not be a delay in machining. The three extra bars would have been made from the "cut-offs" we would have had from the 12' raw stock bars. Therefore, the manufacturing and material costs were already accounted for.

Regarding your second concern about uncertainty about everything going according to plan, the 15% overproduction (the three extra rails) will provide enough buffer for any unforeseen

material or manufacturing errors. This percentage is determined from the formula for final yield: final yield equals 100% multiplied by the number of parts that pass inspection divided by the number of parts manufactured [2]. Decades of our manufacturing data have shown our final yield for orders of your type to be 98%. That would suggest we only need one extra part, but I increased this to three to ensure we meet your tight timeframe. Additionally, I can guarantee that I've thoroughly conveyed all aspects of your design and timeframe to the machinists and QA inspectors. Everyone is on high alert to ensure we meet your delivery date. Lastly, the raw stock has indeed been shipped from the supplier, and I have a tracking number. Delivery is expected by 3:00 PM tomorrow, March 26.

I understand your concern about the issue of cost. I was explicit in my communication with our supplier, insisting that we have it in writing that we would not be charged anything further for them to provide 23 "cut-offs" sized to 12.5" lengths. I received that in writing, and now I am providing it to you in writing: you will not be charged anything extra for us to complete your order as originally agreed. I hope this fully reassures you about the cost.

Precision parts are our specialty, as highlighted in our company name. We have a solid reputation for quality and on-time deliveries, as noted in our Better Business Bureau listing and five-star Google and Yelp ratings. I am confident we will deliver 100% of your order by April 1. I have provided our ProtoForge Lab and QA team with a Job Traveler detailing the machining and inspection processes down to the mill tooling required, plus feeds and speeds, metrology details for inspection measurements and tolerances, plus the use of our new Taylor Hobson Form Talysurf® LASER profilometer [5] for measuring your precision surface finish. Our team is eagerly

awaiting the arrival of the raw stock and is prepared to launch into production immediately upon its delivery.

I am excited to share that we have placed cameras on the mill and the Form Talysurf® LASER profilometer so you can follow your project as it progresses through the ProtoForge Lab. Your personalized link is: www.npmc.com/customercams/NNMOptics. The link will go live when the first rail is on the mill.

I hope I have conveyed the steps being taken right now to avoid any hiccups. The entire NPMC team is dedicated to meeting your timeline with thorough transparency.

Kind regards,
John Brown
Manufacturing Engineer
NPMC

To: John Brown, jbrown@npmc.com
From: Chad Chaddwick, chad.chaddwick@nnmoptics.com
Date: March 26, 2025
Subject: Urgent Status Update Required on Custom Optical Rails, Order 15505

Hi John,

Thank you for your thorough and detailed response. I truly appreciate the transparency you've provided, especially with the additional information regarding the O1 tool steel shortage and the steps you've taken to manage the situation. It's clear that you've worked hard to come up with a solution that ensures we stay on track despite the challenges.

I understand now why the "cut-offs" weren't part of the initial plan, and I'm glad to see that you've been proactive in securing them as an alternative. I appreciate the effort you put into

mitigating the impact of this issue and the steps you've taken to avoid further delays.

It's also reassuring to know that the 15% buffer will cover any unforeseen issues and that you've already communicated the timeline and requirements to your team in great detail. The extra three bars as a precautionary measure also help to provide more confidence in meeting the April 1 delivery date.

The additional transparency with the live camera feed is a great initiative. Being able to monitor the process in real time will certainly help alleviate my concerns, and I truly appreciate this level of visibility. It's reassuring to see that you're keeping everything in check and moving forward with such precision.

Overall, I feel much more comfortable with the situation now, and I'm confident that with the steps you've outlined, we will be able to meet the original deadline. Thanks again for your clear communication, and I'll keep an eye on the live feed as things move forward. I am relieved to have you monitoring our project as you do appear to be on top of things.

Best regards,
Chad Chaddzwick
NNM Optics Inc.

To: Chad Chaddzwick, chad.chaddzwich@nnmoptics.com
From: John Brown, jbrown@npmc.com
Date: March 26, 2025
Subject: Urgent Status Update Required on Custom Optical Rails, Order 15505

Hi Chad,

Thank you for your trust. I will ensure I continue to earn it.

I'm tracking the steel raw stock order and it is out for delivery, still scheduled to arrive by 3:00 PM this afternoon. I will let you know when it arrives. I'll also let you know when the first bar is on the mill so you can tune into the live camera feed.

We are very proud to be working with you on this project.

Kind regards,
John Brown
Manufacturing Engineer
NPMC

To: John Brown, jbrown@npmc.com
From: Chad Chaddwick, chad.chaddwick@nnmoptics.com
Date: March 26, 2025
Subject: Re: Update on Custom Optical Rails Order 15505

Hi John,

Thank you for the update. I appreciate your ongoing communication and the transparency you've provided throughout this process.

I'll keep an eye out for the live camera feed and look forward to seeing the progress as the first bar hits the mill. Please do keep me posted on the arrival of the raw stock and let me know if there are any further developments.

It's good to hear that everything is on track, and I'm confident that your team will deliver as promised.

Kind regards,
Chad Chaddwick
NNM Optics Inc.

To: Chad Chaddzwick, chad.chaddzwich@nnmoptics.com
From: John Brown, jbrown@npmc.com
Date: March 26, 2025
Subject: Urgent Status Update Required on Custom Optical Rails, Order 15505

Hi Chad,

We received the raw stock as scheduled this afternoon. The first bar is on the mill, and your camera feed is live. Please reach out with any questions or concerns.

Kind regards,
John Brown
Manufacturing Engineer
NPM

To: John Brown, jbrown@npmc.com
From: Chad Chaddzwick, chad.chaddzwich@nnmoptics.com
Date: March 26, 2025
Subject: Re: Update on Custom Optical Rails Order 15505

Hi John,

Thank you for the update. I've tuned into the camera feed and can see the first bar on the mill — it's good to see things moving forward.

I'll be keeping an eye on the progress. I appreciate your diligence in keeping things on track, and I'll reach out if I have any further questions or concerns.

Looking forward to seeing the finished product by the agreed-upon date.

Kind regards,
Chad Chaddzwick
NNM Optics Inc.

Part 3: Safety Briefs

Part 3A – ProtoForge Lab Safety Brief

Part 3B – JET Vertical Mill Safety Brief

Part 3C – Taylor Hobson Form Talysurf® LASER Profilometer Safety Brief

Part 3A – ProtoForge Lab Safety Brief

 <p>NICK'S PRECISION MACHINING COMPANY</p>	
<h2>Safety Brief</h2> <h3>ProtoForge Lab</h3>	
<h4>Know Your Rights</h4>	
Description	Signage & Location
<p>Under federal law, you have the right to a safe working environment. Your employer is obligated to ensure that the workplace is free from recognized health and safety risks. If you have any concerns, you can raise them without the fear of retaliation. Additionally, you have the following rights:</p> <ul style="list-style-type: none"> • Receive training in a language you understand • Work with equipment that is safe to use • Be provided with necessary safety equipment, such as gloves or fall protection gear like a harness and lifeline • Be protected from exposure to harmful chemicals • Request an OSHA inspection and communicate with the inspector • Report any workplace injuries or illnesses and receive copies of your medical records • Access the workplace injury and illness log • Review records of work-related injuries and illnesses • Obtain copies of any test results related to workplace safety 	 <p>Job Safety and Health IT'S THE LAW!</p> <p>Employers must:</p> <ul style="list-style-type: none"> • Provide employees a workplace free from recognized health and safety hazards. To begin to violate an employee's right to use any of their rights under the law, including raising a health and safety concern with OSHA, or report a work-related injury or illness. • Comply with all applicable OSHA standards. • Notify OSHA within 8 hours of a workplace fatality or if an employee has suffered a repeated hospitalization, amputation, or loss of an eye. • Provide required training to all workers in a language and vocabulary they can understand. • Prominently display this poster in the workplace. • Post OSHA citations at or near the place of the alleged violation. <p>This poster is available free from OSHA.</p> <p>Contact OSHA. We can help.</p> <p>1-800-321-OSHA (6742) • TTY 1-877-889-5627 • www.osha.gov</p> <p>[6]</p> <p>Poster mounted on the west wall</p>

ProtoForge Lab Emergency Protocols

In any emergency, people's safety should always come first. While it's important to protect equipment and the facility, your primary focus should be helping those injured or in danger. Ensure to tend to people immediately, and only after that should you address any damage to equipment or the facility.

Protocol	Location	Instructions	Signage
1. Two Person Rule	Sign on west wall	When operating machinery, two people must be in the lab in case of an emergency. [7]	 [8]
2. Emergency Phone	Phone on shelf by north entrance	Call 9-1-1 in case of an accident or medical emergency.	 [9]
3. First Aid Kit & Eye Wash & Shower	First Aid Station by north entrance	<ul style="list-style-type: none"> Use First Aid Kit for minor injuries or as instructed by the 9-1-1 operator. Use the Eye Wash Station to rinse eyes as instructed. Use the Emergency Shower to rinse body in the event of a spill, as instructed. Alert the lab manager when supplies are used so they can be replenished. 	 [10]

4. Fire Extinguisher & Fire Blanket	Red cabinet by south entrance	<ul style="list-style-type: none"> Follow instructions on extinguisher and blanket packaging Alert the lab manager if used so they can be refilled/replaced.. 	 [11]
5. Emergency Power Shut-Off	Inside the labeled cabinet by south entrance	<ul style="list-style-type: none"> Break the seal by pulling the cabinet door open. Flip the switch to the OFF position. Alert the lab manager that the seal was broken so it can be replaced. 	 [12]

ProtoForge Lab Personal Protection Equipment



[13]

PPE	Instructions
Safety Glasses	Safety glasses rated ANSI/ISEA Z87.1–2010 must always be worn [14, p. 16085].
Hearing Protection	<ul style="list-style-type: none"> Earplugs and earmuffs must be worn as indicated by OSHA's Hearing Protection Regulations 29 CFR 1910.95 [15]. Protection must comply with ANSI S3.19 and ANSI/ASA S12.6 standards [15]. Protection must have the appropriate NRR rating as

	determined by NPMC [16].
Foot Protection	Closed-toed, closed-heeled, and sturdy shoes are required [7].

ProtoForge Lab Shutdown Procedures

1. Immediate Response	<ul style="list-style-type: none"> ● Stay Calm: Assess the situation. ● Alert Others: Warn nearby workers. ● Press Emergency Stop: Hit the emergency stop button on the affected machine.
2. De-Energize Equipment	<ul style="list-style-type: none"> ● Turn Off Power: Switch off the power to the affected machine. If necessary, shut off the main power supply to the entire shop – open the cabinet by the south entrance and flip the switch to OFF. ● Lockout/Tagout: Secure the machine using lockout/tagout procedures.
3. Clear the Area	<ul style="list-style-type: none"> ● Evacuate: Move workers away from the affected area. ● Secure Hazards: Contain any hazardous materials like oil or coolant.
4. Assess the Situation	<ul style="list-style-type: none"> ● Look for Hazards: Check for electrical, mechanical, or fire risks. ● Do Not Touch: Avoid fixing equipment until safe.
5. Notify Management	<ul style="list-style-type: none"> ● Report: Inform supervisors about the issue. ● Call Emergency Services: Contact fire, medical, or other emergency personnel if needed.
6. Follow-Up Actions	<ul style="list-style-type: none"> ● Inspect: Check the machine for the cause of failure. ● Repair: Do not restart until fixed or inspected by a professional.
7. Documentation	<ul style="list-style-type: none"> ● Log Incident: Record the shutdown details (time, cause, actions taken). ● Review Safety: Analyze the event to improve safety measures.
8. Restarting Equipment	<ul style="list-style-type: none"> ● Ensure Safety: Confirm all hazards are addressed. ● Test Run: Start at low speeds to check for issues.

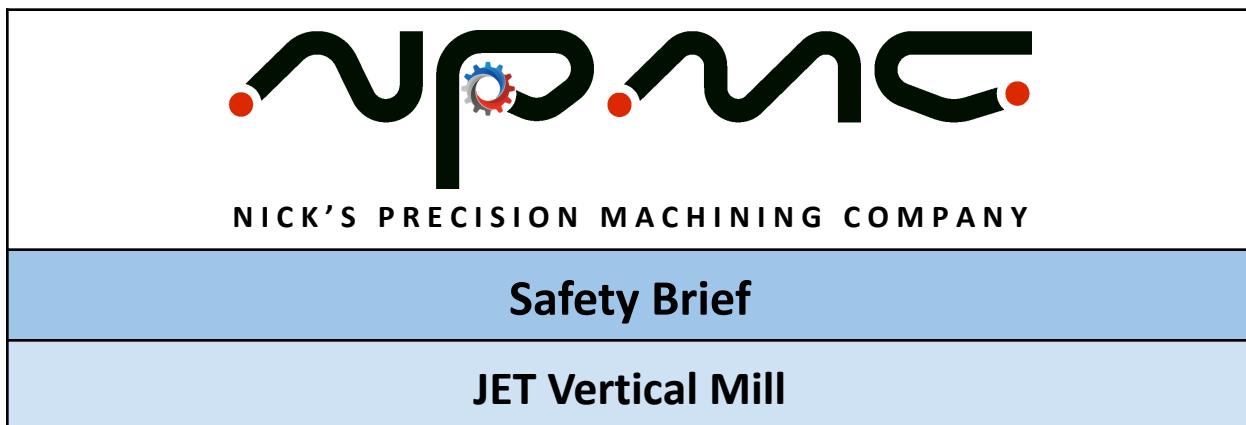
ProtoForge Lab Inspection and Maintenance Guide	
<p>These maintenance and inspection guidelines provide general instructions for ensuring the safety and proper functioning of equipment in the ProtoForge Lab. However, the specific maintenance and inspection procedures outlined for individual machines take precedence over these general guidelines. Always follow the manufacturer's recommendations for each machine to ensure optimal performance and safety.</p>	
1. Safety First	<ul style="list-style-type: none">● Wear PPE.● Follow lockout/tagout procedures before maintenance.● Turn off power before servicing machines.● Know emergency shutdown procedures.
2. Daily Checks	<ul style="list-style-type: none">● Visual Inspection: Look for leaks, cracks, or loose parts.● Cleanliness: Keep machines and work areas clean.● Functionality: Check that the machines start, run smoothly, and calibrate properly.● Coolant Systems: Verify coolant levels and flow.
3. Weekly Checks	<ul style="list-style-type: none">● Mechanical Components: Inspect belts, chains, bearings, and motors for wear or damage.● Lubrication: Ensure moving parts are properly lubricated.● Electrical: Check wires, connections, and control panels for issues.● Fuses/Circuit Breakers: Ensure they are in good working condition.
4. Monthly Checks	<ul style="list-style-type: none">● Hydraulics/Pneumatics: Check fluid levels, hoses, and pressure.● Cutting Tools: Inspect for wear, chips, or damage. Replace or sharpen as needed.● Tool Holders/Chucks: Ensure they're clean and properly mounted.
5. Quarterly Checks	<ul style="list-style-type: none">● Structural Integrity: Look for cracks or damage to the machine frame.● Alignment: Check that machines are properly aligned.● Performance Test: Run machines to ensure consistent performance and accuracy.

6. Annual Maintenance	<ul style="list-style-type: none">● Deep Cleaning: Clean internal components, including motors and fans.● Lubrication/Fluids: Replace oil and coolant, lubricate moving parts.● Component Replacement: Replace worn-out parts (e.g., bearings, seals).
7. Documentation	<ul style="list-style-type: none">● Log Maintenance: Record all inspections, repairs, and part replacements.● Machine History: Track operational hours and service intervals.● Follow Manufacturer's Guidelines: Stick to recommended schedules.
8. Troubleshooting	<ul style="list-style-type: none">● Identify Issues: Look for abnormal sounds, movements, or error codes.● Consult Manual: Refer to the manual for troubleshooting steps.● Repairs: Make minor repairs yourself; contact a technician for major issues.

ProtoForge Lab Hazards & Mitigation

Please see Safety Briefs for specific equipment for potential hazards and operating procedures that mitigate risk.

Part 3B – JET Vertical Mill Safety Brief



General Safety Statement for JET Vertical Mill

The JET vertical mill is a rotating machine and should always be handled with caution. The spinning spindle can be dangerous if clothing or body parts become caught. There's also a danger of tools being thrown if they aren't properly secured in the spindle's tool holder. It's important to be aware of this risk and take extra precautions while working with the mill. [6, 7]

Hazards & Mitigation for JET Vertical Mill [6, 7, 17]

Potential Hazard	Risk Mitigation
1. Neglecting lockout/tagout procedures can result in accidental machine startup, causing serious harm to the operator or others nearby.	Follow lockout/tagout procedures during service and maintenance activities.
2. Reaching around a moving cutter can lead to severe injuries, including amputations, or could result in the machine malfunctioning.	Never reach around the cutter or hob to remove chips while the machine is in motion or not locked/tagged out.
3. Rotating tools can cause serious, even fatal injuries.	Don't stop a rotating tool by hand. Always allow the tool to naturally slow and stop before reaching into the machine to adjust or handle any components.
4. Don't adjust gear settings while the mill is running. Tools can break, and other damage and injury can occur.	Always ensure the mill is powered off before making gear adjustments.
5. An unsecured workpiece can spin or be thrown, causing injury or damage to the machine.	Before starting the cut, ensure the workpiece is securely fastened, and the mill is set to the correct speed and feed.
6. Failing to properly position the locking mechanism can damage the cutter or create a dangerous situation with flying debris.	Position the jig or vise-locking mechanism so that the force is directed away from the cutter.
7. Leaving the wrench on the drawbar can cause it to be accidentally knocked off, causing injury or damaging the machine.	If the drawbar wrench is not placed in the toolbox, always keep your hand on it, and never leave it on the drawbar.
8. Handling chips by hand can lead to cuts	Use a brush to remove chips instead of using

and serious injuries due to their sharp edges.	your hands, as chips can be sharp.
9. Long, spinning chips can trap the brush and cause injury or damage to the machine.	Do not remove long, spinning chips while the mill is in motion to avoid entanglement with the brush.
10. Lifting heavy components improperly can lead to serious injury, including muscle strains or crushed body parts.	Lift heavy components cautiously, as metal parts can be challenging to handle.
11. Tools left on the machine can cause severe cuts or injuries due to their sharpness.	Remove unused tools from the machine and store them properly to avoid accidents.
12. Keeping the work-holding device too close to the rotating cutter can cause serious injury or damage to the machine.	Move the work-holding device to a safe distance when loading, unloading, or measuring the work while the cutter is still rotating (unless the cutter is guarded).
13. A cluttered work area increases the risk of accidents and injuries, as it can cause tripping hazards or obstruct safe operation.	Keep your workspace clean and free of clutter to maintain a safe environment.
14. Distractions or lack of awareness can lead to accidents, injuries, or damage to the machine.	Stay alert and focused while operating the mill; avoid distractions and be mindful of your surroundings.

Personal Protection Equipment for JET Vertical Mill

PPE	Instructions
Safety Glasses	Safety glasses rated ANSI/ISEA Z87.1–2010 must always be worn [14, p. 16085].
Hearing Protection	<ul style="list-style-type: none"> Earplugs and earmuffs must be worn as indicated by OSHA's Hearing Protection Regulations 29 CFR 1910.95 [15]. Protection must comply with ANSI S3.19 and ANSI/ASA S12.6 standards [15]. Protection must have the appropriate NRR rating as determined by NPMC [16].
Foot Protection	Closed-toed, closed-heeled, and sturdy shoes are required. [7]

Hazards & Mitigation Solved with Personal Protection Equipment [6, 7, 17]	
Potential Hazard	Risk Mitigation
1. Loose clothing can get caught in machinery and cause serious injury.	Close-fitting/protective clothing is required to be worn.
2. Jewelry can get caught in machinery and cause serious injury, including strangulation and amputation.	No jewelry may be worn while operating machinery or equipment, including but not limited to rings, necklaces, bracelets, and earrings.
3. Gloves can get caught in machinery, causing serious injury.	No gloves may be worn while operating machinery or equipment.
4. Long or loose hair can get caught in machinery and cause serious injury.	Long and loose hair must be secured while operating machinery or equipment.

Emergency Protocols for JET Vertical Mill	
1. Immediate Response	<ul style="list-style-type: none"> Stop the Machine: Press the emergency stop button on the mill to halt all operations immediately. Turn Off Power: Switch off the power to the machine using the main power switch. Alert Others: Notify nearby personnel about the emergency and clear the area if necessary.
2. De-Energize Equipment	<ul style="list-style-type: none"> Lockout/Tagout: Apply lockout/tagout procedures to prevent the machine from being accidentally turned on during troubleshooting or repairs. Turn Off Air/Water Supply: If applicable, shut off the air or water supply connected to the mill.
3. Evacuate and Secure Area	<ul style="list-style-type: none"> Evacuate Personnel: If there's a risk of fire, electrical hazard, or injury, evacuate workers from the vicinity. Secure Hazardous Materials: If coolant, oil, or other hazardous materials are leaking, contain them immediately and report them to safety personnel.
4. Assess the Situation	<ul style="list-style-type: none"> Check for Hazards: Identify any immediate dangers (fire, electrical issues, mechanical failures, etc.). Do Not Attempt Repairs: Avoid attempting repairs unless you are trained and it's safe.

5. Accident/Injury Assessment and Care	<ul style="list-style-type: none"> ● Assess Injuries: Quickly evaluate the condition of any injured personnel. Prioritize serious injuries. <ul style="list-style-type: none"> ○ For minor injuries: Administer first aid (e.g., bandage cuts, apply cold compresses to minor bruises). ○ For major injuries: Do not move the injured person unless in immediate danger (fire, electrical hazard). ● Call for Medical Help: Contact emergency medical services (EMS) immediately if the injury is severe (broken bones, unconsciousness, bleeding, etc.). ● Provide First Aid: If trained, administer first aid while waiting for EMS, including CPR if necessary. ● Monitor for Shock: Keep the injured person calm, warm, and lying down if they are in shock. ● Document the Incident: Record the nature of the injury and actions taken. Provide this information to emergency responders.
6. Notify Management and Emergency Services	<ul style="list-style-type: none"> ● Report the Incident: Notify the supervisor or machine shop manager about the situation. ● Call Emergency Services: If the situation involves fire, injury, or other severe hazards, immediately contact emergency services (fire, medical, etc.).
7. Inspect and Repair	<ul style="list-style-type: none"> ● Check for Damage: Once the mill is completely powered down and de-energized, inspect the machine for any signs of damage or malfunction. ● Document the Issue: Record the cause of the emergency and any actions taken during shutdown.
8. Restarting the Machine	<ul style="list-style-type: none"> ● Ensure Safety: Verify that all issues have been addressed and that it is safe to restart the machine. ● Test the Machine: Start the machine at a low speed to check for normal operation and confirm no further issues.
9. Follow-Up Action	<ul style="list-style-type: none"> ● Review Incident: After the emergency is resolved, conduct a review of the situation to prevent future occurrences. ● Inspect Safety Systems: Ensure all safety features, like emergency stops and guards, are functioning properly. ● Schedule Maintenance: If the emergency was caused by wear or damage, schedule maintenance or part replacements as needed.
<p>NOTE: Always follow the JET Vertical Mill's user manual and safety guidelines for handling specific emergencies.</p>	

Inspection and Maintenance Guide for JET Vertical Mill	
1. Daily Checks	<ul style="list-style-type: none"> • Clean Machine: Remove chips, dust, and debris from the mill. • Lubrication: Check and apply oil to the spindle, table, and other moving parts. • Coolant Level: Ensure coolant reservoir is full. • Visual Inspection: Look for leaks, loose bolts, or unusual wear.
2. Weekly Checks	<ul style="list-style-type: none"> • Vibration: Check for excessive vibrations during operation. • Belt Tension: Inspect belts for proper tension and wear. • Way Lubrication: Ensure the slideways and table are properly lubricated. • Tooling: Inspect and clean tool holders, collets, and cutting tools.
3. Monthly Checks	<ul style="list-style-type: none"> • Spindle Bearings: Listen for unusual sounds; lubricate bearings as per the manual. • Table Movement: Test smoothness of X, Y, and Z axes movement. • Safety Features: Check emergency stop and safety guards for proper function. • Electrical Connections: Inspect wires and connections for wear or damage.
4. Quarterly Checks	<ul style="list-style-type: none"> • Machine Alignment: Verify alignment of the table and spindle using a dial indicator. • Drive System: Inspect motor and drive belts for wear. • Hydraulic System: Check hydraulic fluids and pressure, if applicable. • Power Supply: Test circuit breakers and fuses for functionality.
5. Annual Maintenance	<ul style="list-style-type: none"> • Deep Cleaning: Clean interior components (spindle, drive system, etc.). • Replace Worn Parts: Replace bearings, seals, or other worn components. • Lubricant Change: Replace oils in the gearboxes and motors. • Inspect Electrical Components: Check for wear and replace any faulty electrical parts.
6. Documentation	<ul style="list-style-type: none"> • Log Inspections: Record daily, weekly, and monthly inspections. • Track Repairs: Document any repairs or parts replacements.
NOTE: Always follow JET's user manual for specific lubrication and maintenance intervals.	

Emergency Shutdown Procedure for JET Vertical Mill	
1. Press Emergency Stop	• Hit the emergency stop button on the mill to immediately halt operations.
2. Turn Off Power	• Switch off the machine's power at the main power switch to cut all electrical power.
3. Activate Lockout/Tagout	• Apply lockout/tagout procedures to ensure the machine cannot be accidentally restarted.
4. Evacuate Area	• Clear the area of personnel if there's a risk of fire, injury, or further hazards.
5. Assess Hazards	• Look for Hazards: Check for electrical, mechanical, or fire risks to ensure the area is safe.
6. Notify Management	• Inform the supervisor or manager of the emergency situation for further action.
7. Call Emergency Services	• Contact emergency personnel (fire, medical) if there are injuries, fire, or immediate danger.
8. Inspect for Damage	• After ensuring safety, inspect the mill for any signs of damage or malfunction.
9. Do Not Restart	• Do not restart the mill <i>until</i> the issue is fully resolved and the machine is safe to operate.

Part 3C – Taylor Hobson Form Talysurf® LASER Profilometer Safety Brief



NICK'S PRECISION MACHINING COMPANY

Safety Brief

Taylor Hobson Form Talysurf® LASER Profilometer

General Safety Statement

When working with measurement devices that use lasers, always wear appropriate eye protection to prevent eye injury from direct or reflected laser beams. Measurement devices typically use Class 1, Class 2, or Class 3R lasers. Class 1 lasers do not require eye protection. Class 2 lasers usually do not require eye protection except in cases of prolonged use. Class 3R lasers require safety glasses with an appropriate optical density (OD) specific to the laser's wavelength and power. The need for laser safety glasses depends on the particular measurement device and its laser classification. Follow all manufacturer guidelines, safety protocols, and regulatory standards to ensure safe operation and handling of laser equipment. [18, 19]

Hazards & Mitigation for Talysurf® LASER Profilometer

Potential Hazard	Risk Mitigation
1. Laser Exposure: Risk of eye injury from the laser beam.	<ul style="list-style-type: none">Never look directly into the laser.Ensure proper laser alignment and shielding.Display visible warning signs in the laser area.
2. Electrical Shock: Risk of electrical shock from exposed wiring or faulty connections.	<ul style="list-style-type: none">Ensure proper grounding of the machine.Disconnect the power supply before maintenance.Inspect power cords regularly for wear or damage.Only trained personnel should handle electrical components.
3. Mechanical Injury (Moving Parts): Risk of electrical shock from exposed wiring or faulty connections.	<ul style="list-style-type: none">Keep hands and loose clothing away from moving parts.Use safety interlocks and shields on moving components.Power down the machine before maintenance (lockout/tagout).
4. Overheating: Risk of machine malfunction or fire due to overheating.	<ul style="list-style-type: none">Ensure proper ventilation around the machine.Regularly monitor operating temperatures.Shut down if overheating occurs and allow cooling before restarting.
5. Slip, Trip, and Fall: Risk of accidents due to	<ul style="list-style-type: none">Keep workspace clean and organized.

cluttered or wet floors.	<ul style="list-style-type: none"> • Use non-slip mats and clean up spills immediately. • Secure cables to prevent trip hazards.
6. Improper Use or Setup: Incorrect operation or setup could lead to machine damage or inaccurate results.	<ul style="list-style-type: none"> • Train operators on correct setup and operation. • Always follow the manufacturer's operating and calibration guidelines. • Perform routine checks and calibrations.

Personal Protection Equipment for Talysurf® LASER Profilometer

PPE	Instructions
Safety Glasses	<ul style="list-style-type: none"> • Regular Safety glasses rated ANSI/ISEA Z87.1–2010 must always be worn [14, p. 16085]. • The Taylor Hobson Form Talysurf® LASER Profilometer has a Class 1 laser, so laser safety glasses are not required [19].
Foot Protection	Closed-toed, closed-heeled, and sturdy shoes are required.

Hazards & Mitigation Solved with Personal Protection Equipment [6, 7, 17]

Potential Hazard	Risk Mitigation
1. Loose clothing can get caught in machinery and cause serious injury.	Close-fitting/protective clothing is required to be worn.
2. Jewelry can get caught in machinery and cause serious injury, including strangulation and amputation.	No jewelry may be worn while operating machinery or equipment, including but not limited to rings, necklaces, bracelets, and earrings.
3. Gloves can get caught in machinery, causing serious injury.	No gloves may be worn while operating machinery or equipment.
4. Long or loose hair can get caught in machinery and cause serious injury.	Long and loose hair must be secured while operating machinery or equipment.

Emergency Protocols for Talysurf® LASER Profilometer	
1. Immediate Response	<ul style="list-style-type: none"> ● Stop the Machine: Press the emergency stop button on the mill to halt all operations immediately. ● Turn Off Power: Switch off the power to the machine using the main power switch. ● Alert Others: Notify nearby personnel about the emergency and clear the area if necessary.
2. De-Energize Equipment	<ul style="list-style-type: none"> ● Lockout/Tagout: Apply lockout/tagout procedures to prevent the machine from being accidentally turned on during troubleshooting or repairs. ● Turn Off Air/Water Supply: If applicable, shut off the air or water supply connected to the mill.
3. Evacuate and Secure Area	<ul style="list-style-type: none"> ● Evacuate Personnel: If there's a risk of fire, electrical hazard, or injury, evacuate workers from the vicinity. ● Secure Hazardous Materials: If coolant, oil, or other hazardous materials are leaking, contain them immediately and report them to safety personnel.
4. Assess the Situation	<ul style="list-style-type: none"> ● Check for Hazards: Identify any immediate dangers (fire, electrical issues, mechanical failures, etc.). ● Do Not Attempt Repairs: Avoid attempting repairs unless you are trained and it's safe.
5. Accident/Injury Assessment and Care	<ul style="list-style-type: none"> ● Assess Injuries: Quickly evaluate the condition of any injured personnel. Prioritize serious injuries. <ul style="list-style-type: none"> ○ For minor injuries: Administer first aid (e.g., bandage cuts, apply cold compresses to minor bruises). ○ For major injuries: Do not move the injured person unless in immediate danger (fire, electrical hazard). ● Call for Medical Help: Contact emergency medical services (EMS) immediately if the injury is severe (broken bones, unconsciousness, bleeding, etc.). ● Provide First Aid: If trained, administer first aid while waiting for EMS, including CPR if necessary. ● Monitor for Shock: Keep the injured person calm, warm, and lying down if they are in shock. ● Document the Incident: Record the nature of the injury and actions taken. Provide this information to emergency responders.
6. Notify Management and	<ul style="list-style-type: none"> ● Report the Incident: Notify the supervisor or machine shop

Emergency Services	<p>manager about the situation.</p> <ul style="list-style-type: none"> ● Call Emergency Services: If the situation involves fire, injury, or other severe hazards, immediately contact emergency services (fire, medical, etc.).
7. Inspect and Repair	<ul style="list-style-type: none"> ● Check for Damage: Once the mill is completely powered down and de-energized, inspect the machine for any signs of damage or malfunction. ● Document the Issue: Record the cause of the emergency and any actions taken during shutdown.
8. Restarting the Machine	<ul style="list-style-type: none"> ● Ensure Safety: Verify that all issues have been addressed and that it is safe to restart the machine. ● Test the Machine: Start the machine at a low speed to check for normal operation and confirm no further issues.
9. Follow-Up Action	<ul style="list-style-type: none"> ● Review Incident: After the emergency is resolved, conduct a review of the situation to prevent future occurrences. ● Inspect Safety Systems: Ensure all safety features, like emergency stops and guards, are functioning properly. ● Schedule Maintenance: If the emergency was caused by wear or damage, schedule maintenance or part replacements as needed.
<p>NOTE: Always follow the Talysurf® LASER Profilometer's user manual and safety guidelines for handling specific emergencies.</p>	

Inspection and Maintenance Guide for Talysurf® LASER Profilometer

1. Daily Checks	<ul style="list-style-type: none"> ● Clean Machine: Remove chips, dust, and debris from the mill. ● Lubrication: Check and apply oil to the spindle, table, and other moving parts. ● Coolant Level: Ensure coolant reservoir is full. ● Visual Inspection: Look for leaks, loose bolts, or unusual wear.
2. Weekly Checks	<ul style="list-style-type: none"> ● Vibration: Check for excessive vibrations during operation. ● Belt Tension: Inspect belts for proper tension and wear. ● Way Lubrication: Ensure the slideways and table are properly lubricated. ● Tooling: Inspect and clean tool holders, collets, and cutting tools.
3. Monthly Checks	<ul style="list-style-type: none"> ● Spindle Bearings: Listen for unusual sounds; lubricate bearings as per the manual. ● Table Movement: Test smoothness of X, Y, and Z axes

	<p>movement.</p> <ul style="list-style-type: none"> • Safety Features: Check emergency stop and safety guards for proper function. • Electrical Connections: Inspect wires and connections for wear or damage.
4. Quarterly Checks	<ul style="list-style-type: none"> • Machine Alignment: Verify alignment of the table and spindle using a dial indicator. • Drive System: Inspect motor and drive belts for wear. • Hydraulic System: Check hydraulic fluids and pressure, if applicable. • Power Supply: Test circuit breakers and fuses for functionality.
5. Annual Maintenance	<ul style="list-style-type: none"> • Deep Cleaning: Clean interior components (spindle, drive system, etc.). • Replace Worn Parts: Replace bearings, seals, or other worn components. • Lubricant Change: Replace oils in the gearboxes and motors. • Inspect Electrical Components: Check for wear and replace any faulty electrical parts.
6. Documentation	<ul style="list-style-type: none"> • Log Inspections: Record daily, weekly, and monthly inspections. • Track Repairs: Document any repairs or parts replacements.
<p>NOTE: Always follow the Talysurf® LASER Profilometer user manual for specific lubrication and maintenance intervals.</p>	

Emergency Shutdown Procedure for Talysurf® LASER Profilometer

1. Press Emergency Stop	<ul style="list-style-type: none"> • Hit the emergency stop button on the mill to immediately halt operations.
2. Turn Off Power	<ul style="list-style-type: none"> • Switch off the machine's power at the main power switch to cut all electrical power.
3. Activate Lockout/Tagout	<ul style="list-style-type: none"> • Apply lockout/tagout procedures to ensure the machine cannot be accidentally restarted.
4. Evacuate Area	<ul style="list-style-type: none"> • Clear the area of personnel if there's a risk of fire, injury, or further hazards.
5. Assess Hazards	<ul style="list-style-type: none"> • Look for Hazards: Check for electrical, mechanical, or fire risks to ensure the area is safe.
6. Notify Management	<ul style="list-style-type: none"> • Inform the supervisor or manager of the emergency

	situation for further action.
7. Call Emergency Services	<ul style="list-style-type: none"> ● Contact emergency personnel (fire, medical) if there are injuries, fire, or immediate danger.
8. Inspect for Damage	<ul style="list-style-type: none"> ● After ensuring safety, inspect the mill for any signs of damage or malfunction.
9. Do Not Restart	<ul style="list-style-type: none"> ● Do not restart the mill <i>until</i> the issue is fully resolved and the machine is safe to operate.

Part 4: Process Sheet

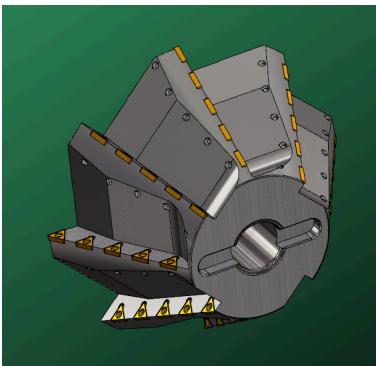
 NICK'S PRECISION MACHINING COMPANY	
Process Sheet	
ProtoForge Lab	
NPMC Team	ProtoForge Lab, 970-555-8484, protoforgelab@npmc.com
Manufacturing Engineer	Johan Yost, 970-214-6987, johan.yost@colostate.edu
Date of Request	March 20, 2025
Date of Completion	March 31, 2025
Delivery Date	April 1, 2025
Customer	NNM Optics Inc.
Order Number	15505
Part Number	808

Drawing No. & Revision	808 REV A			
Description	Precision Optical Rail			
Order Quantity	20 Rails			
Bill of Materials				
Raw Stock				
Part Number	800			
Drawing No. & Revision	800 REV A			
Description	12.5" x 4" x 0.875" O1 Tool Steel Blank			
Quantity	23 bars (20 bars for customer order plus a safety stock of 3)			
Material	O1 Tool Steel			
Size	Length: 12.500" -0 / +0.125" Width: 4.000" +0.035" / +0.077" oversize Thickness: 0.875" +0.015" / 0.035" oversize			
Supplier	Alro Steel Corp. 4321 N Garnett Rd, Tulsa, OK 74116 (918) 439-1000 Online Store: https://www.myalro.com/ Contact: Julie, Inside Sales			
Lead Time	6 days <ul style="list-style-type: none"> ● Typical lead time is 5 days ● Delay of 1 day to switch from 12' bars to "cut-offs" sized to 12.5" in length ● Revised delivery date: March 26, 2025 			
Tooling				
Standard Tooling: Obtain from NPMC Tool Crib				
Tool	Material / Rationale	Description / Purpose		
#3 Center Drill	<ul style="list-style-type: none"> ● High-Speed Steel (HSS): chosen because this is an intermediary operation 	Center drill the location where the holes will be drilled		

 <p>[20] 0.109" tip diameter 1/4" shank diameter</p>	<p>where the finish is not critical.</p>	
<p>0.31" Drill Bit</p>	<ul style="list-style-type: none"> • HSS: chosen because this is an intermediary operation where the finish is not critical. 	<p>Pre-drill for 0.33" end mill</p>
<p>45° Backside Chamfer End Mill</p>  <p>[21] 1" diameter 4 Flutes</p>	<ul style="list-style-type: none"> • Carbide: chosen because this operation will create a precision finished surface. 	<p>Create backside chamfer slots per drawing</p>
<p>1" End Mill 2 Flutes</p>	<ul style="list-style-type: none"> • Carbide: chosen because this operation will create a precision finished surface. 	<ul style="list-style-type: none"> • Mill two 1.00" channels on the bottom • Finish same two channels on the bottom to $Ra = 16\mu\text{in}$ per drawing
<p>3" Wide Fly Cutter</p>  <p>[22]</p>	<ul style="list-style-type: none"> • HSS Body with Carbide Inserts • Carbide was chosen because this operation will create a precision finished surface. • A HSS body is more affordable. The carbide cutter is replaceable. 	<p>Finish the 2.18" wide section on the top to $Ra = 16\mu\text{in}$ per drawing</p>

<p>2" Wide Fly Cutter</p>  <p>[23]</p>	<ul style="list-style-type: none"> • HSS Body with Carbide Inserts • Carbide was chosen because this operation will create a precision finished surface. • A HSS body is more affordable. The carbide cutter is replaceable. 	<ul style="list-style-type: none"> • Finish the 1.20" wide section on the top to $Ra = 16\mu\text{in}$ per drawing • Finish the two 0.465" wide sections on the bottom to $Ra = 16\mu\text{in}$ per drawing • Finish the center 1.00" section on the bottom to $Ra = 16\mu\text{in}$ per drawing
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Custom Tooling: Obtain from Manufacturing Engineer

Tool	Material	Description / Purpose / Supplier
<p>14.71° Chamfer End Mill Custom 10 flutes</p>  <p>[24]</p>	<ul style="list-style-type: none"> • Carbide: chosen because this operation will create a precision finished surface. 	<ul style="list-style-type: none"> • Machine angled chamfer features as shown in drawings • Supplier: CARAY Dezhou Jiarui Precision Machinery Co., Ltd. East end of Nan Huan Road Pingyuan County Dezhou City, Shandong Province China WhatsApp: +86 18953480990 grace@caraytools.com
<p>0.33" Custom End Mill</p>  <p>[25]</p>	<ul style="list-style-type: none"> • Carbide: chosen because this operation will create a precision finished surface. 	<ul style="list-style-type: none"> • Finish cutting oval slot through the part • Supplier: Harvey Tool Company 428 Newburyport Turnpike Rowley, MA 01969 800-645-5609 harveysales@harveyperformance.com
<p>0.53" Custom End Mill</p>	<ul style="list-style-type: none"> • Carbide: chosen because this operation will create 	<ul style="list-style-type: none"> • Cut to the depth of the pockets then cut the ovals to

 [25]	a precision finished surface.	size • Supplier: Harvey Tool Company 428 Newburyport Turnpike Rowley, MA 01969 800-645-5609 harveysales@harveyperformance.com
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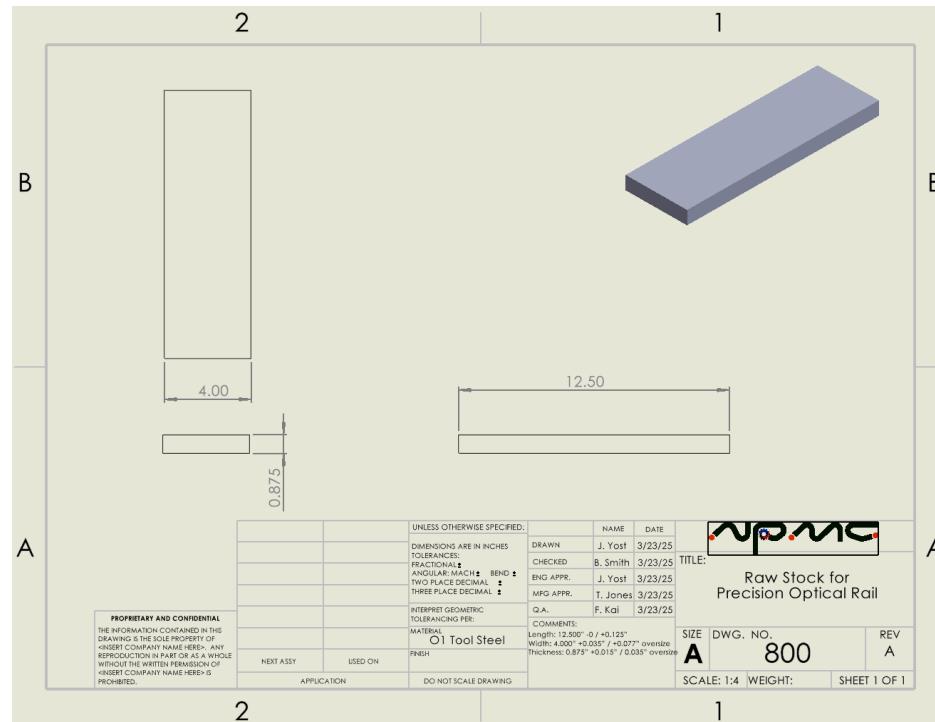
Additional Supplies

Item	Description/Purpose
Coolant	<ul style="list-style-type: none"> • Coolant and water mixture • Reduce heat, lubricate the cutting area, and remove chips
Dual-size box end wrench size $\frac{1}{2}$ and $\frac{3}{4}$	<ul style="list-style-type: none"> • Used to tighten the spindle onto the mill
Jacobs Chuck & Key	<ul style="list-style-type: none"> • Secures drill bits and center drill in the mill spindle • Use Jacobs key to tighten the chuck
R8 Collets	<ul style="list-style-type: none"> • Secures endmills and chamfer tools in the mill spindle
Machinists Vise	<ul style="list-style-type: none"> • Holds the workpiece on the mill
Parallel Bars	<ul style="list-style-type: none"> • Holds the workpiece flat in the vise
Orange Rubber Mallet	<ul style="list-style-type: none"> • Used to tap the workpiece firmly into the parallel bars
Dial Indicator	<ul style="list-style-type: none"> • Used to align the vise

Operational Steps

Process Step 1 | Obtain Raw Stock

- Obtain the required quantity and material as specified in the **Bill of Materials (BOM)**.
- Note: No raw stock preparation is required, as raw stock bars will be sized to go directly onto the mill.
- Refer to **Appendix A** for full-size drawing:



Process Step 2 | Set Up Mill for Operations

1. Mount the Machinist Vise

- Place a **machinist vise** on the mill bed.
- **Tram (square)** the vise to the spindle to ensure it's aligned with the mill's travel.
 - Use a **dial indicator** and sweep across the fixed jaw of the vise for alignment.

2. Secure the Vise

- Carefully tighten the **T-slot nuts** to fasten the vise to the bed.
- After tightening, **recheck the tram** to ensure the vise did not shift during clamping.

3. Mount the Workpiece

- Place the **workpiece centered** in the vise.
- Use **parallels** to support the part off the bottom of the vise.
- Ensure the setup is **secure and rigid** to prevent movement during machining.

4. Final Setup Check

- **Gently tap the bar stock** down against the parallels with a soft mallet to ensure solid contact and proper seating.
- **Double-check** that the workpiece is level and evenly clamped.

Process Step 3 | Face Workpiece to Length

1. Tool Setup

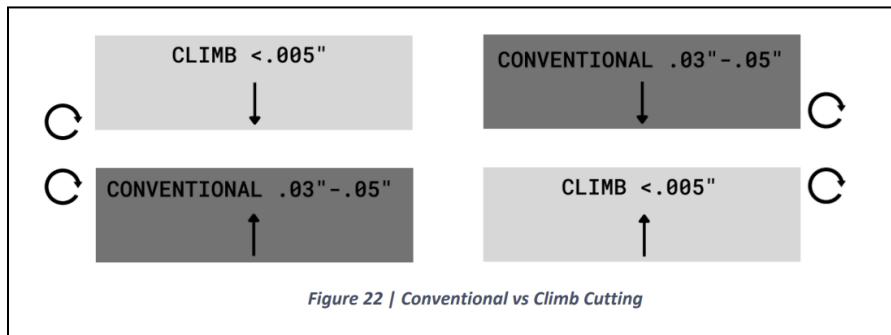
- Mount a **1" 2-flute HSS endmill** in the spindle using the appropriate R8 collet.

2. Set the **Speed and Feed** as follows:

1" 2-flute HSS Endmill		
RPM	Feed Rate	Depth of Cut
1079 RPM	11.92 IPM	0.910"

Note: Maximum depth of cut (DOC) is:

- **0.030"** in **conventional (standard)** milling
- **< 0.005"** in **climb** milling



[7, p.80]

3. Facing Pass (Conventional Milling)

- Position the mill for a **conventional milling pass** on the end of the workpiece.
- Lock the **quill** and the **X-axis**.
- Start the mill and apply **coolant** while facing the end of the workpiece.
- Stop the mill when the facing operation is complete.

4. Mill to Final Length (Opposite Side)

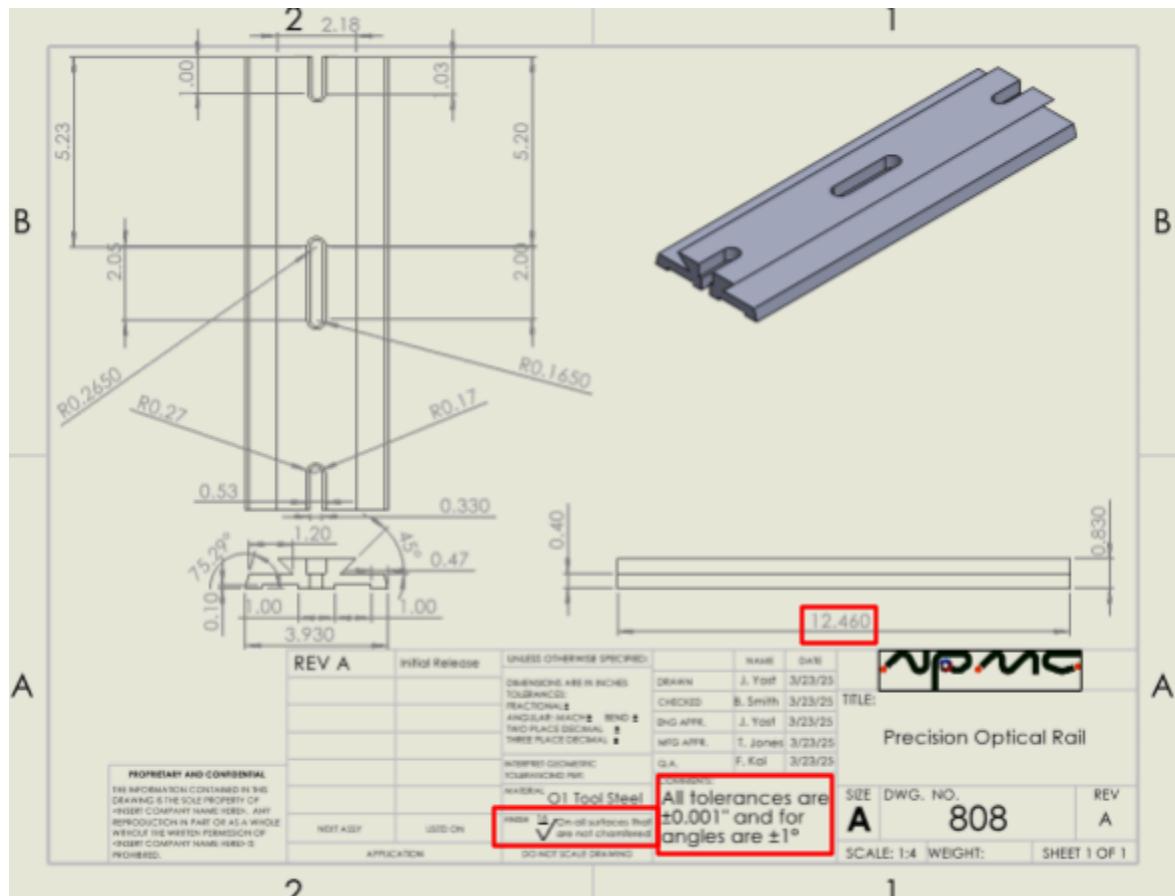
- Move the mill to the opposite end of the workpiece.
- Repeat step 2 to **mill the workpiece to its final length**.
- Use the **Digital Readout (DRO)** to track movement
 - **Be sure to account for the 1" endmill diameter** when setting coordinates with the DRO.

5. Quality Check

- **Take frequent caliper measurements** throughout the process.

6. Result

- Final Length: 12.460" +0.001" / -0.001"
- Surface Finish: Ra=16μin (or better)
- Refer to **Appendix A** for full-size drawing



Process Step 4 | Mill Channels on Bottom of Workpiece

1. Tool Setup

- Use the **1" 2-flute HSS endmill** from Process Step 3.

2. Set the **Speed and Feed** as follows:

1" 2-flute HSS Endmill		
RPM	Feed Rate	Depth of Cut
863 RPM	7.63 IPM	0.100"

3. Use the **Digital Readout (DRO)** to track movement

- **Be sure to account for the 1" endmill diameter** when setting coordinates with the DRO.

4. Mill the two channels per the drawing.

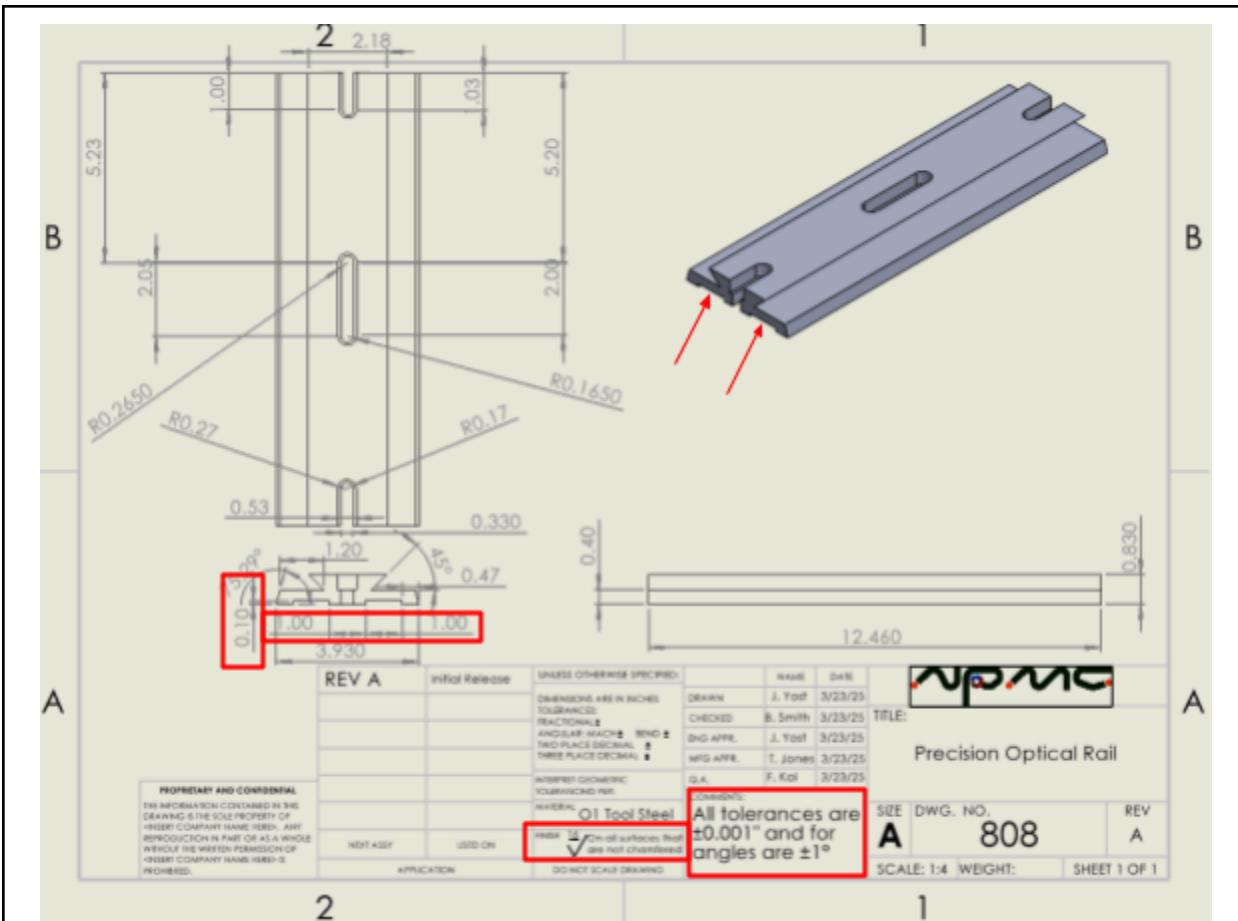
- Apply **coolant** while cutting.

5. **Quality Check**

- Take **frequent caliper measurements** throughout the process.

6. **Result**

- Final Channel Dimensions:
 - Length: 12.460" +0.001" / -0.001"
 - Width: 1.000" +0.001" / -0.001"
 - Depth: 0.100" +0.001" / -0.001"
- Surface Finish: Ra=16 μ in (or better)
- Refer to **Appendix A** for full-size drawing



Process Step 5 | Finish Surface on Bottom of Workpiece

1. **Tool Setup**
 - Mount the **2" wide Fly Cutter** in the spindle using the appropriate R8 collet.
2. Set the **Speed and Feed** as follows:

2" wide Fly Cutter		
RPM	Feed Rate	Depth of Cut
809 RPM	6.66 IPM	0.028"

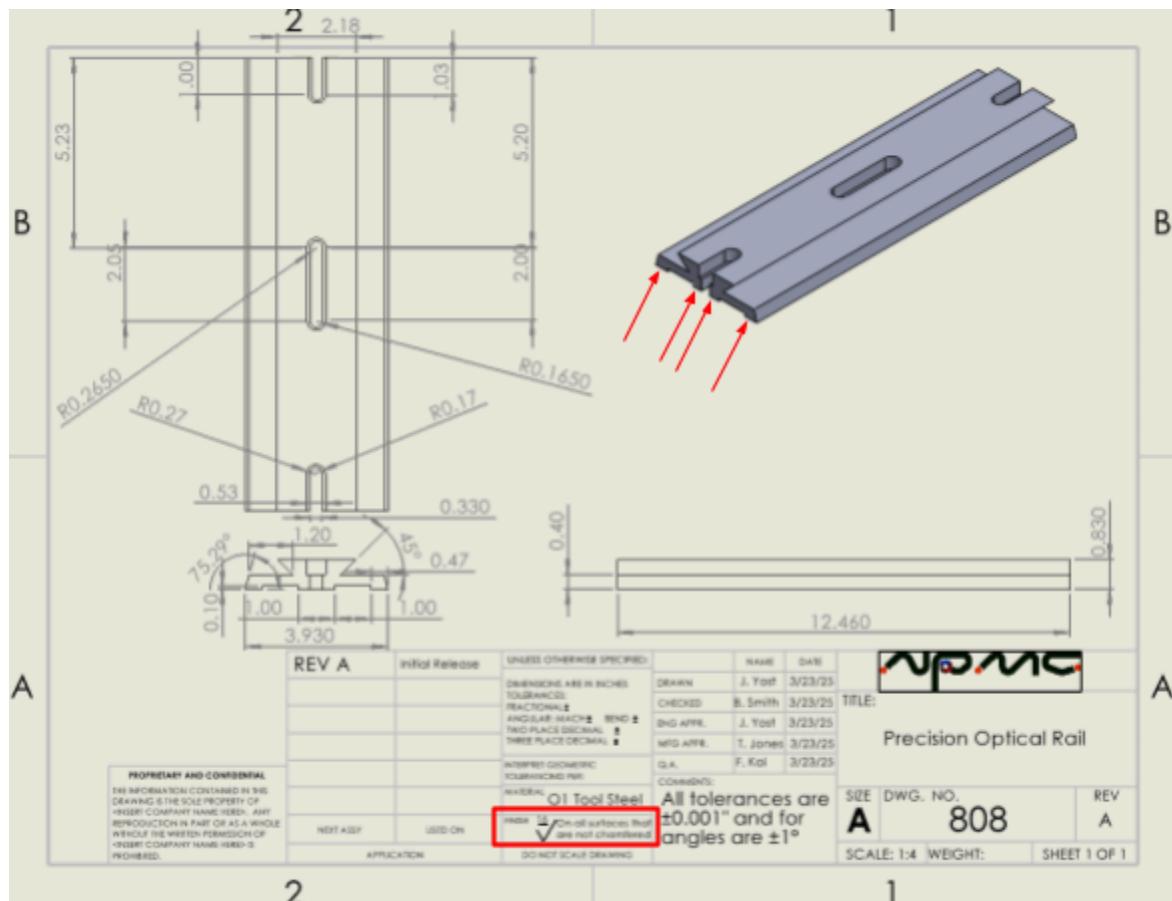
3. Use the **Digital Readout (DRO)** to track movement
 - **Be sure to account for the 2" fly cutter diameter** when setting coordinates with the DRO.
4. Mill the three bottom faces per the drawing.
 - **Apply coolant** while cutting.

5. Quality Check

- Take **frequent caliper measurements** throughout the process.
- Take caution to maintain the depth of the channels.

6. Result

- Surface Finish: $R_a=16\mu\text{in}$ (or better)
- Refer to **Appendix A** for full-size drawing



Process Step 6 | Chamfer Long Sides

1. Tool Setup

- Mount the custom **14.71° Chamfer End Mill** in the spindle using the appropriate R8 collet.

2. Set the **Speed and Feed** as follows:

14.71° Chamfer End Mill		
RPM	Feed Rate	Depth of Cut
539 RPM	23.3 IPM	0.250"

3. Use the **Digital Readout (DRO)** to track movement

- **Be sure to account for the 14.71° Chamfer End Mill** when setting coordinates with the DRO.

4. Chamfer the two long sides per the drawing.

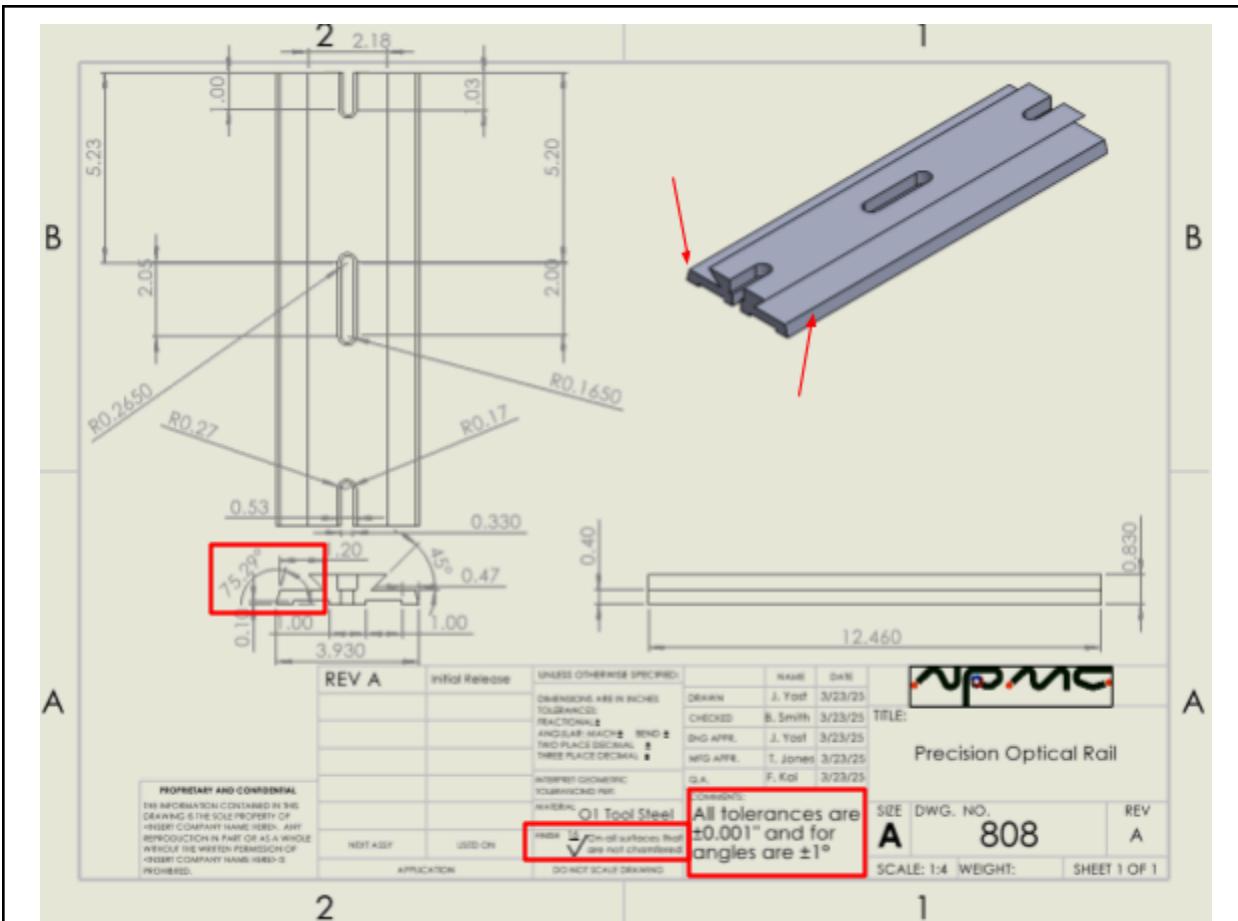
- Apply **coolant** while cutting.

5. Quality Check

- Take **frequent protractor measurements** throughout the process.

6. Result

- $75.29^\circ +1^\circ / -1^\circ$ open angle per drawing which defines the side chamfers
- Surface Finish: $Ra=16\mu\text{in}$ (or better)
- Refer to **Appendix A** for full-size drawing



Process Step 7 | Flip Workpiece Over & Remount

1. Remove the Workpiece from the vise.
2. Flip workpiece over so unworked side is up.
3. Mount the Workpiece
 - Place the workpiece **centered** in the vise.
 - Use **parallels** to support the part off the bottom of the vise.
 - Ensure the setup is **secure and rigid** to prevent movement during machining.
4. Final Setup Check
 - **Gently tap the bar stock** down against the parallels with a soft mallet to ensure solid contact and proper seating.

- **Double-check** that the workpiece is level and evenly clamped.

Process Step 8 | Create Top of Rail

1. Tool Setup

- Mount the **45° Backside Chamfer End Mill** in the spindle using the appropriate R8 collet.

2. Set the **Speed and Feed** as follows:

45° Backside Chamfer End Mill

RPM	Feed Rate	Depth of Cut
863 RPM	10.8 IPM	0.430"

3. Use the **Digital Readout (DRO)** to track movement

- **Be sure to account for the 45° Backside Chamfer End Mill** when setting coordinates with the DRO.

4. Make the two 45° chamfers per the drawing.

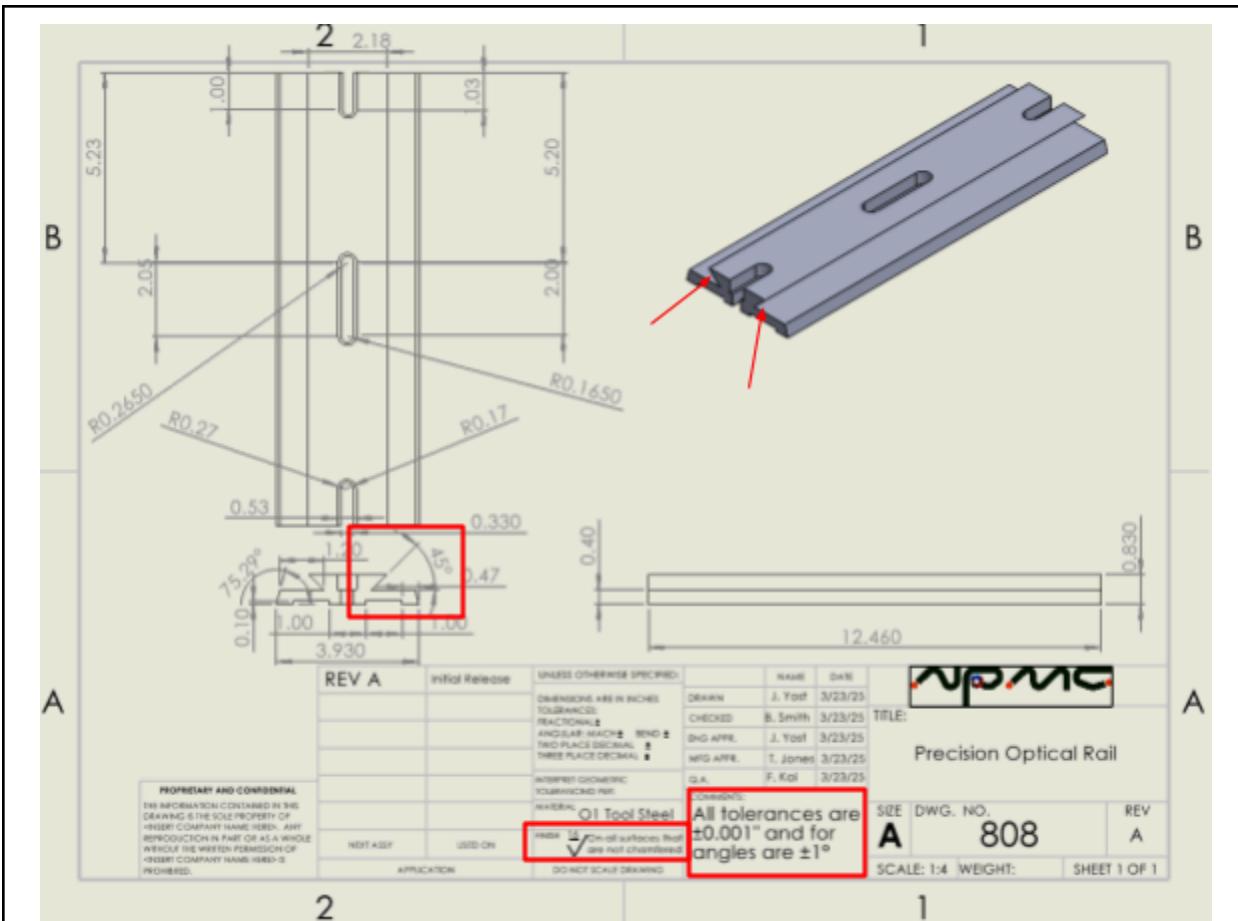
- Apply **coolant** while cutting.

5. Quality Check

- Take **frequent protractor measurements** throughout the process.

6. Result

- $45^\circ +1^\circ / -1^\circ$ chamfers per the drawing
- Surface Finish: $Ra=16\mu\text{in}$ (or better)
- Refer to **Appendix A** for full-size drawing



Process Step 9 | Drill the Small hole in the Center

1. Tool Setup

- Remove the R8 collet.
- Install a 3-jaw Jacobs chuck in the spindle.
- Mount the #3 Center drill in the Jacobs Chuck. (Do step ➤ only).
- After the center drill has been plunged, mount the 0.31" drill bit(undersized for the 0.33"endmill) into a R8 collet. Then (Do step ■ and on).
 - Center drill the first hole location.
 1. Apply coolant while cutting.
 - Drill through the entire part using a 0.31" drill bit (undersized for the 0.33" endmill).

2. Set the Speed and Feed as follows for the center drill:

Center Drill

RPM	Feed Rate	Depth of Cut
1963 RPM	3.49 IPM	0.5"

3. Set the **Speed and Feed** as follows for the **0.31" drill bit**

0.31" Drill Bit		
RPM	Feed Rate	Depth of Cut
592 RPM	1.39 IPM	0.830"

4. Use the **Digital Readout (DRO)** to track movement

- Be sure to account for the radius of the center drill when setting coordinates with the DRO.

5. Make the **center drill plunge**.

- Apply **coolant** while cutting.

6. Switch to the **0.31" drill bit** and drill fully through the material.

- Apply **coolant** while cutting.

7. Refer to **Appendix A** for full-size drawing.

Process Step 10 | Endmill the Center Slot

1. **Initial Setup**

- Remove the Jacobs chuck
- **Mount the 0.33" end mill** in the R8 Collet into the spindle

2. Set the **Speed and Feed** as follows for the **0.33" endmill**:

0.33" End Mill		
RPM	Feed Rate	Depth of Cut
1962 RPM	5.17 IPM	0.830"

3. Use the **Digital Readout (DRO)** to track movement

- Be sure to account for the radius of the end mill when setting coordinates with the DRO.

4. Make the **0.33" end mill plunge** fully through the material.

- Apply **coolant** while cutting.
- 5. Use the 0.33" end mill to cut the needed length of the slot.
- 6. Refer to **Appendix A** for full-size drawing

Process Step 11 | Drill the Large Slot in the Center

1. **Initial Setup**
 - **Mount the 0.53" end mill** in the R8 Collet into the spindle
2. Set the **Speed and Feed** as follows for the **0.53" endmill**:

0.53" End Mill		
RPM	Feed Rate	Depth of Cut
1221 RPM	4.65 IPM	0.43"

3. Use the **Digital Readout (DRO)** to track movement
 - Be sure to account for the radius of the end mill when setting coordinates with the DRO.
4. Make the **0.53" end mill plunge 0.43" deep** per the drawing.
 - Apply **coolant** while cutting.
5. Use the 0.53" end mill to cut the needed length of the slot.
6. Refer to **Appendix A** for full-size drawing

Process Step 12 | Drill the Large Slot on both sides

1. With the mill set up the same from **Process Step 11 no initial set up is needed**.
2. Use the **Digital Readout (DRO)** to track movement
3. Make the **0.53" end mill plunge 0.43" deep** per the drawing at the edge of the workpiece shown in the drawing.
 - Apply **coolant** while cutting.
4. Use the 0.53" end mill to cut the needed length of the slot on both sides.

Process Step 13 | Drill the Small Slot on both sides

1. Initial Setup

- Mount the **0.33"** end mill in the R8 Collet into the spindle

2. Set the Speed and Feed as follows for the **0.33" endmill:**

0.33" End Mill		
RPM	Feed Rate	Depth of Cut
1962 RPM	5.17 IPM	0.830"

3. Use the **Digital Readout (DRO)** to track movement
4. Make the **0.33" end mill** at a height that will cut through the entire work piece.
 - Apply **coolant** while cutting.
5. Use the 0.33" end mill to cut the needed length of the slot.
6. Refer to **Appendix A** for full-size drawing

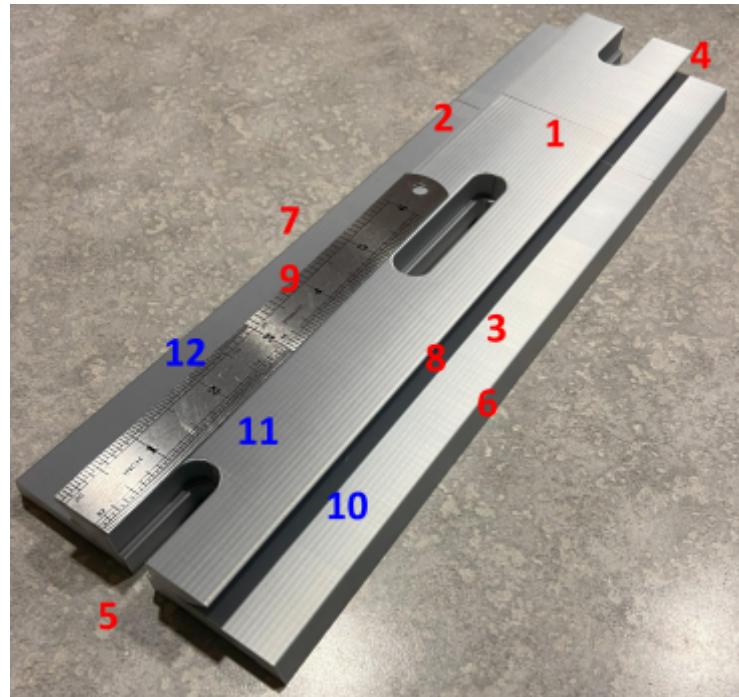
Part 5: Metrology

Metrology					
Instructions: Complete this form each part in the order.					
Feature	Dimension	Metrology Tool	Tolerance Band	Actual	Go/No-Go
Top Width	2.180"	Calipers	±0.001		
Length	12.460"	Calipers	±0.001		
Width of Bottom	3.930"	Calipers	±0.001		
Height	0.830"	Calipers	±0.001		
Channel Depth	0.1"	Calipers	±0.001		
Channel Width	1"	Calipers	±0.001		
Ovals are Centerd	1.965"	Calipers	±0.001		
Center Small Oval Diameter	0.33"	Calipers	±0.001		
Center Small Oval Length	2"	Calipers	±0.001		
Center Small Oval Length From Edge	7.28"	Calipers	±0.001		
Center Big Oval Diameter	0.53"	Calipers	±0.001		
Center Big Oval Length	2.05"	Calipers	±0.001		
Center Big Oval Depth	0.43"	Calipers	±0.001		
Center Big Oval Length From Edge	7.20"	Calipers	±0.001		
Both Side Big Ovals Diameter	0.53"	Calipers	±0.001		
Both Side Big Oval	1.265"	Calipers	±0.001		

Metrology				
Instructions: Complete this form each part in the order.				
Lengths From Edge				
Both Side Big Oval Depths	0.43"	Calipers	± 0.001	
Both Side Small Ovals Diameters	0.33"	Calipers	± 0.001	
Both Side Small Ovals Lengths From Edge	1.195"	Calipers	± 0.001	
Center Width of Bottom	1"	Calipers	± 0.001	
Both Sides of Bottom Widths	0.465"	Calipers	± 0.001	
Both Sides	1.2"	Calipers	± 0.001	
Backside Chamfer	45°	Protractor	$\pm 1^\circ$	
Chamfer	14.71°	Protractor	$\pm 1^\circ$	
The Surface Finish must be tested on all sides of the part. Below, document the measurements using the Taylor Hobson Form Talysurf® LASER profilometer [19] as they correspond to the diagram:				

Metrology

Instructions: Complete this form **each** part in the order.



[3]

Metrology**Instructions:** Complete this form **each** part in the order.

LASER Profilometer Probe

[27]

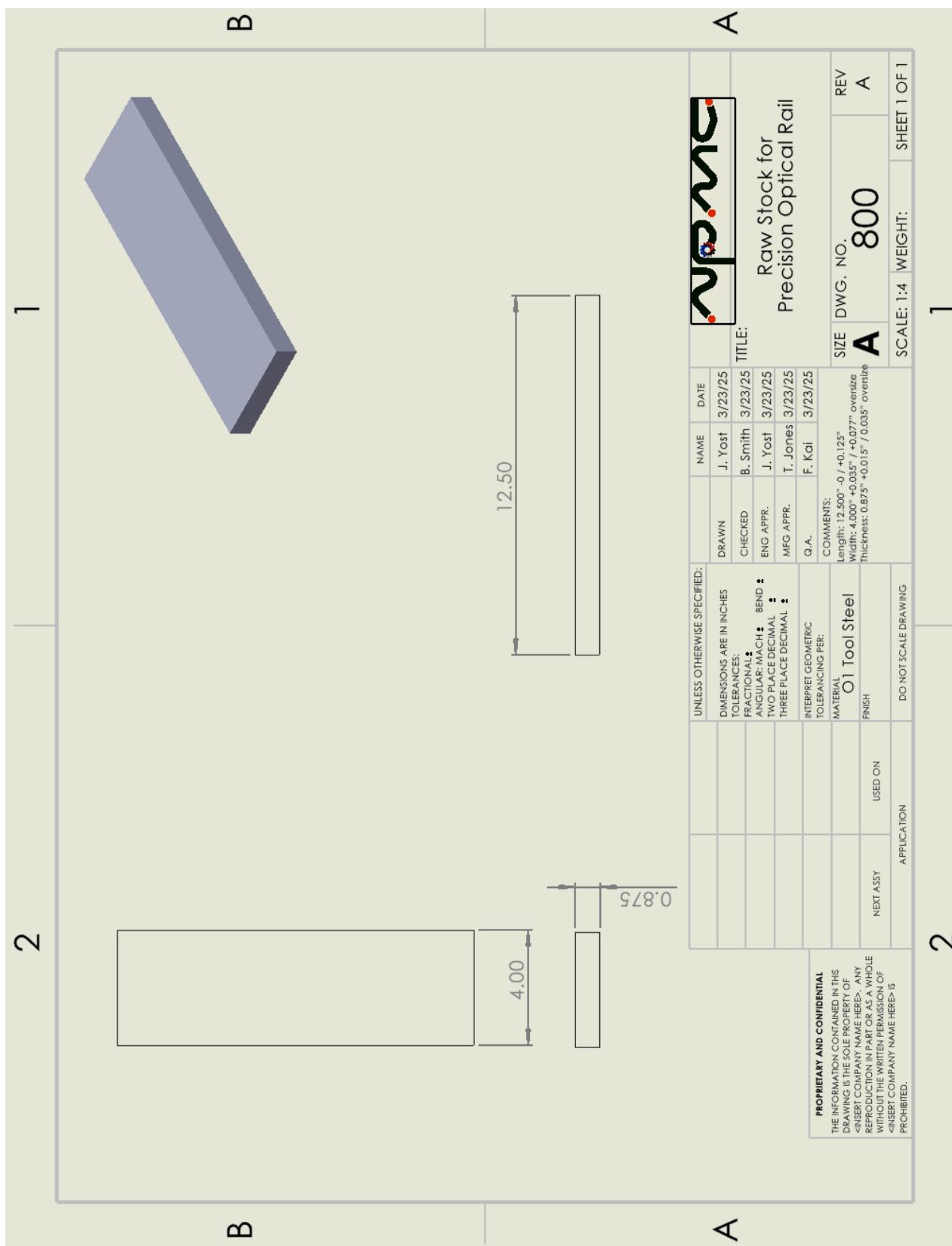
Surface Finish 1. Top	Ra = 16	Taylor Hobson Form Talysurf® LASER profilometer	Ra ≤ 16		
Surface Finish 2. Lower top	Ra = 16	Taylor Hobson Form Talysurf® LASER profilometer	Ra ≤ 16		
Surface Finish 3. Other Lower top	Ra = 16	Taylor Hobson Form Talysurf® LASER profilometer	Ra ≤ 16		

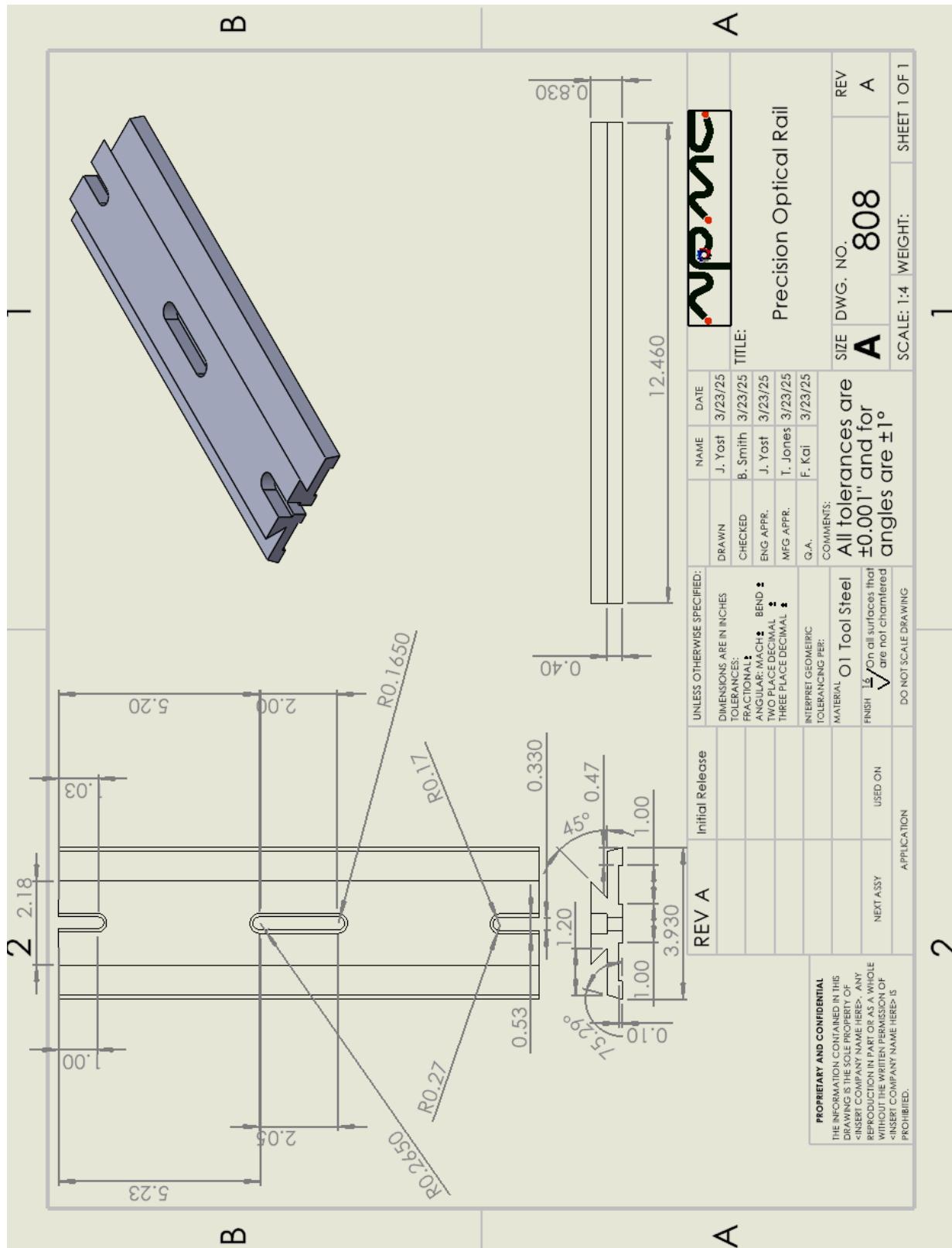
Metrology					
Instructions: Complete this form each part in the order.					
Surface Finish 4. Short edge	Ra = 16	Taylor Hobson Form Talysurf® LASER profilometer	Ra ≤ 16		
Surface Finish 5. Other short edge	Ra = 16	Taylor Hobson Form Talysurf® LASER profilometer	Ra ≤ 16		
Surface Finish 6. 14.71° chamfer edge	Ra = 16	Taylor Hobson Form Talysurf® LASER profilometer	Ra ≤ 16		
Surface Finish 7. Other 14.71° chamfer edge	Ra = 16	Taylor Hobson Form Talysurf® LASER profilometer	Ra ≤ 16		
Surface Finish 8. 45° chamfer edge	Ra = 16	Taylor Hobson Form Talysurf® LASER profilometer	Ra ≤ 16		
Surface Finish 9. Other 45° chamfer edge	Ra = 16	Taylor Hobson Form Talysurf® LASER profilometer	Ra ≤ 16		
Surface Finish 10. Bottom side	Ra = 16	Taylor Hobson Form Talysurf® LASER profilometer	Ra ≤ 16		
Surface Finish 11. Bottom cCenter	Ra = 16	Taylor Hobson Form Talysurf® LASER profilometer	Ra ≤ 16		

Metrology**Instructions:** Complete this form **each** part in the order.

Surface Finish 12. Other bottom side	Ra = 16	Taylor Hobson Form Talysurf® LASER profilometer	Ra \leq 16		
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Appendix A





Appendix B

Feed & Speed Calculations

Process Step 3 | Face Workpiece to Length

FSWizard Inputs [26]

Tool	Tool Material	Tool Coating	Tool Tip Diameter	Tool Number of Flutes
1" End Mill 2 Flutes	Carbide	Uncoated	1"	2
Material	Material Hardness	Depth of Cut	Width of Cut	
Normal Tool Steel	170-270 HB	0.910 in	0.065 in	

FSWizard Outputs



MENU

RPM: 1079

Feed: 11.92 in/min

Power: 0.68 HP

Vc: 282.3 f/min

fz: 0.0055 in/th

MRR: 0.7 in³/min

Normal tool steels. Hard-quenching and tempering steels. (170-270 HB)

Solid End Mill Carbide Uncoated

Size: 1 2 fl

Tool Type: Solid End Mill

Tool Material: Carbide

Coating: Uncoated

Units: **mm** **in**

Tip Diameter: **1** in

N# of Flutes: **2**

Tool Stickout: **2.5** in

Corner Radius: **0** in

BallNose: **0**

Flute Length: **2** in

Helix Angle: **30** degrees

Lead Angle: **90** degrees

Shank Diameter: **1** in

DOC: 0.91 WOC: 0.065

Depth Of Cut	0.91	in
Width Of Cut	0.065	in
Width Of Cut	7	%
Slotting		
Chip Thinning		
HSM		
Radial Thinning: 2.028		
Axial Thinning: 1		
Total Thinning: 1		

Process Step 4 | Mill Channels on Bottom of Workpiece

FSWizard Inputs

Tool	Tool Material	Tool Coating	Tool Tip Diameter	Tool Number of Flutes
1" End Mill 2 Flutes	Carbide	Uncoated	1"	2
Material	Material Hardness	Depth of Cut	Width of Cut	
Normal Tool Steel	170-270 HB	0.100 in	1 in	

FSWizard Outputs

RPM: 863 **Vc: 225.9 in/min**
Feed: 7.63 in/min **fz: 0.0044 in/th**
Power: 0.73 HP **MRR: 0.76 in³/min**

Normal tool steels. Hard-quenching and tempering steels. (170-270 HB)

Solid End Mill Carbide Uncoated
Size: 1 2 fl

Tool Type	Solid End Mill	
Tool Material	Carbide	
Coating	Uncoated	

Units **mm** **in**

Tip Diameter	1	in	N# of Flutes	2	Tool Stickout	2.5	in	
Corner Radius	0	in	BallNose		Flute Length	2	in	
Helix Angle	30	degrees	Lead Angle	90	degrees	Shank Diameter	1	in

DOC: 0.1 WOC: 1

Depth Of Cut	0.1	in	Width Of Cut	100	%	Slotting
Width Of Cut	1	in	Width Of Cut	100	%	Slotting

Chip Thinning
HSM

Radial Thinning: 1
Axial Thinning: 1
Total Thinning: 1

Process Step 5 | Finish Surface on Bottom of Workpiece

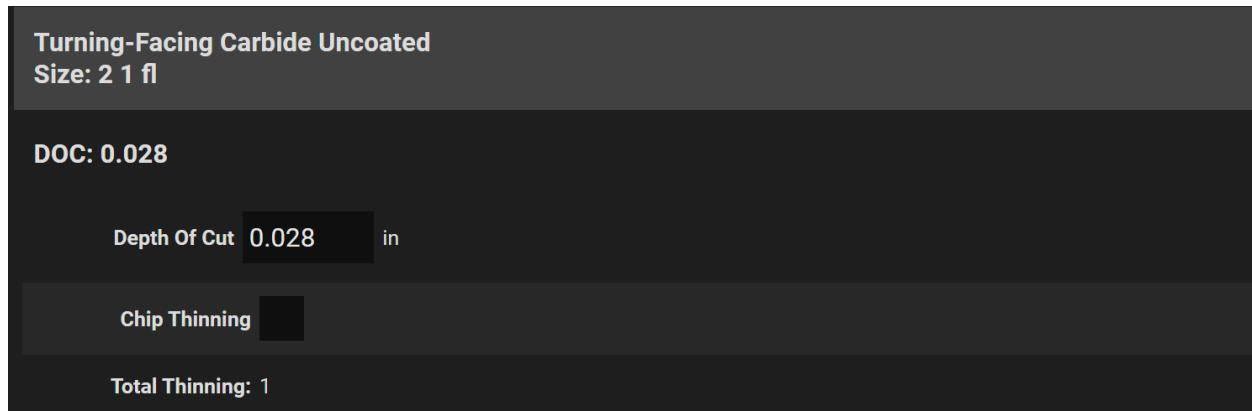
FSWizard Inputs

Tool	Tool Material	Tool Coating	Tool Tip Diameter	Tool Number of Flutes
2" Fly Cutter	Carbide	2	1"	1

Material	Material Hardness	Depth of Cut	Width of Cut
Normal Tool Steel	170-270 HB	0.100 in	1 in

FSWizard Outputs

MENU	RPM: 809	Vc: 423.5 f/min
	Feed: 6.66 in/min	fz: 0.0082 in/th
	Power: 1.13 HP	MRR: 1.18 in ³ /min
▼		
Normal tool steels. Hard-quenching and tempering steels. (170-270 HB)		
Turning-Facing Carbide Uncoated Size: 2 1 fl		
Tool Type Turning-Facing Tool Material Carbide Coating Uncoated		
Units mm in		
Turn Diameter 2 in Tool Stickout 1 in		
Corner Radius 0 in Insert Length 0.375 in		
Lead Angle 90 degrees Holder size 0.75 in		



Process Step 6 | Chamfer Long Sides

FSWizard Inputs

Tool	Tool Material	Tool Coating	Tool Tip Diameter	Tool Number of Flutes
1" End Mill 2 Flutes	Carbide	Uncoated	1"	2
Material	Material Hardness	Depth of Cut	Width of Cut	
Normal Tool Steel	170-270 HB	0.105 in*	0.3869 in	

*The FSWizard restricted the DOC to 0.25".

FSWizard Outputs

Normal tool steels.Hard-quenching and tempering steels. (170-270 HB)

Chamfer Mill Carbide Uncoated
Size: 2.5 10 fl

Tool Type: Chamfer Mill
Tool Material: Carbide
Coating: Uncoated

Units: mm in

Tip Diameter: 2.5 in
N# of Flutes: 10
Tool Stickout: 1 in

Lead Angle: 45 degrees
Shank Diameter: 0.5 in

DOC: 0.25 WOC: 0.3869

Depth Of Cut: 0.25 in
Width Of Cut: 0.3869 in
Width Of Cut: 15 %
Slotting:

Chip Thinning:
HSM:

Radial Thinning: 1.492
Axial Thinning: 1.414
Total Thinning: 1

Process Step 8 | Create Top of Rail

FSWizard Inputs

Tool	Tool Material	Tool Coating	Tool Tip Diameter	Tool Number of Flutes
45° Backside Chamfer End Mill	Carbide	Uncoated	1"	4
Material	Material Hardness	Depth of Cut	Width of Cut	
Normal Tool Steel	170-270 HB	0.430 in*	1.2 in	

*The FSWizard restricted the DOC to 0.25".

FSWizard Outputs

≡ MENU
RPM: 863
Vc: 338.8 f/min

Feed: 10.8 in/min
fz: 0.0031 in/th

Power: 4.14 HP
MRR: 3.24 in³/min

▼

Normal tool steels. Hard-quenching and tempering steels. (170-270 HB)

Chamfer Mill Carbide Uncoated
Size: 1 4 fl

Tool Type: Chamfer Mill

Tool Material: Carbide

Coating: Uncoated

Units: mm in

Tip Diameter: 1 in N# of Flutes: 4 Tool Stickout: 1 in

Lead Angle: 45 degrees Shank Diameter: 1 in

DOC: 0.25 WOC: 1.2

Depth Of Cut	0.25	in
Width Of Cut	1.2	in
Width Of Cut	120	%
Slotting		
Chip Thinning		
HSM		
Radial Thinning: 1		
Axial Thinning: 1.414		
Total Thinning: 1		

Process Step 9 | Drill the Small hole in the Center

FSWizard Inputs

Tool	Tool Material	Tool Coating	Tool Tip Diameter	Tool Number of Flutes
#3 Center drill	HSS	Uncoated	0.109"	2
Material	Material Hardness	Depth of Cut	Width of Cut	
Normal Tool Steel	170-270 HB	0.500 in	n/a	

FSWizard Outputs

RPM: 1963 **Vc: 56 f/min**
Feed: 3.49 in/min **fz: 0.0009 in/th**
Power: 0.03 HP **MRR: 0.03 in³/min**

Normal tool steels. Hard-quenching and tempering steels. (170-270 HB)

Spot Drill HSS (High Speed Steel) Uncoated
Size: 0.109 2 fl

Tool Type Spot Drill
Tool Material HSS (High Speed Steel)
Coating Uncoated

Units mm in

Tip Diameter	0.109	in	N# of Flutes	2	Tool Stickout	2.5
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FSWizard Inputs

Tool	Tool Material	Tool Coating	Tool Tip Diameter	Tool Number of Flutes
0.31" drill bit	HSS	Uncoated	0.31"	2
Material	Material Hardness	Depth of Cut	Width of Cut	
Normal Tool Steel	170-270 HB	0.830"	n/a	

FSWizard Outputs

MENU	RPM: 592	Vc: 48 f/min
	Feed: 1.39 in/min	fz: 0.0012 in/th
	Power: 0.13 HP	MRR: 0.11 in ³ /min
▼		
Normal tool steels. Hard-quenching and tempering steels. (170-270 HB)		
Straight Flute for hard metal HSS (High Speed Steel) Uncoated		
Size: 0.31 2 fl		
Tool Type: Straight Flute for hard metal		
Tool Material: HSS (High Speed Steel)		
Coating: Uncoated		
Units	mm	in
Tip Diameter	0.31	in
N# of Flutes	2	Tool Stickout 2

Process Step 10 | Endmill the Slot**FSWizard Inputs**

Tool	Tool Material	Tool Coating	Tool Tip Diameter	Tool Number of Flutes
0.33" end mill	Carbide	Uncoated	0.33"	2
Material	Material Hardness	Depth of Cut	Width of Cut	
Normal Tool Steel	170-270 HB	0.83 in	2.00 in	

FSWizard Outputs

MENU	RPM: 1962	Vc: 169.4 f/min
	Feed: 5.17 in/min	fz: 0.0013 in/th
	Power: 0.53 HP	MRR: 0.44 in ³ /min
▼		
Normal tool steels. Hard-quenching and tempering steels. (170-270 HB)		
Straight Flute for hard metal Carbide Uncoated		
Size: 0.33 2 fl		
Tool Type: Straight Flute for hard metal		
Tool Material: Carbide		
Coating: Uncoated		
Units	mm	in
Tip Diameter	0.33	in
N# of Flutes	2	
Tool Stickout	1.5	

Process Step 11 | Drill the Large Slot in the Center**FSWizard Inputs**

Tool	Tool Material	Tool Coating	Tool Tip Diameter	Tool Number of Flutes
0.53" end mill	Carbide	Uncoated	0.53"	2

Material	Material Hardness	Depth of Cut	Width of Cut
Normal Tool Steel	170-270 HB	0.83 in	2.00 in

FSWizard Outputs

RPM: 1221 **Vc: 169.4 f/min**
Feed: 4.65 in/min **fz: 0.0019 in/th**
Power: 1.22 HP **MRR: 1.02 in³/min**

Normal tool steels. Hard-quenching and tempering steels. (170-270 HB)

Straight Flute for hard metal Carbide Uncoated
Size: 0.53 2 fl

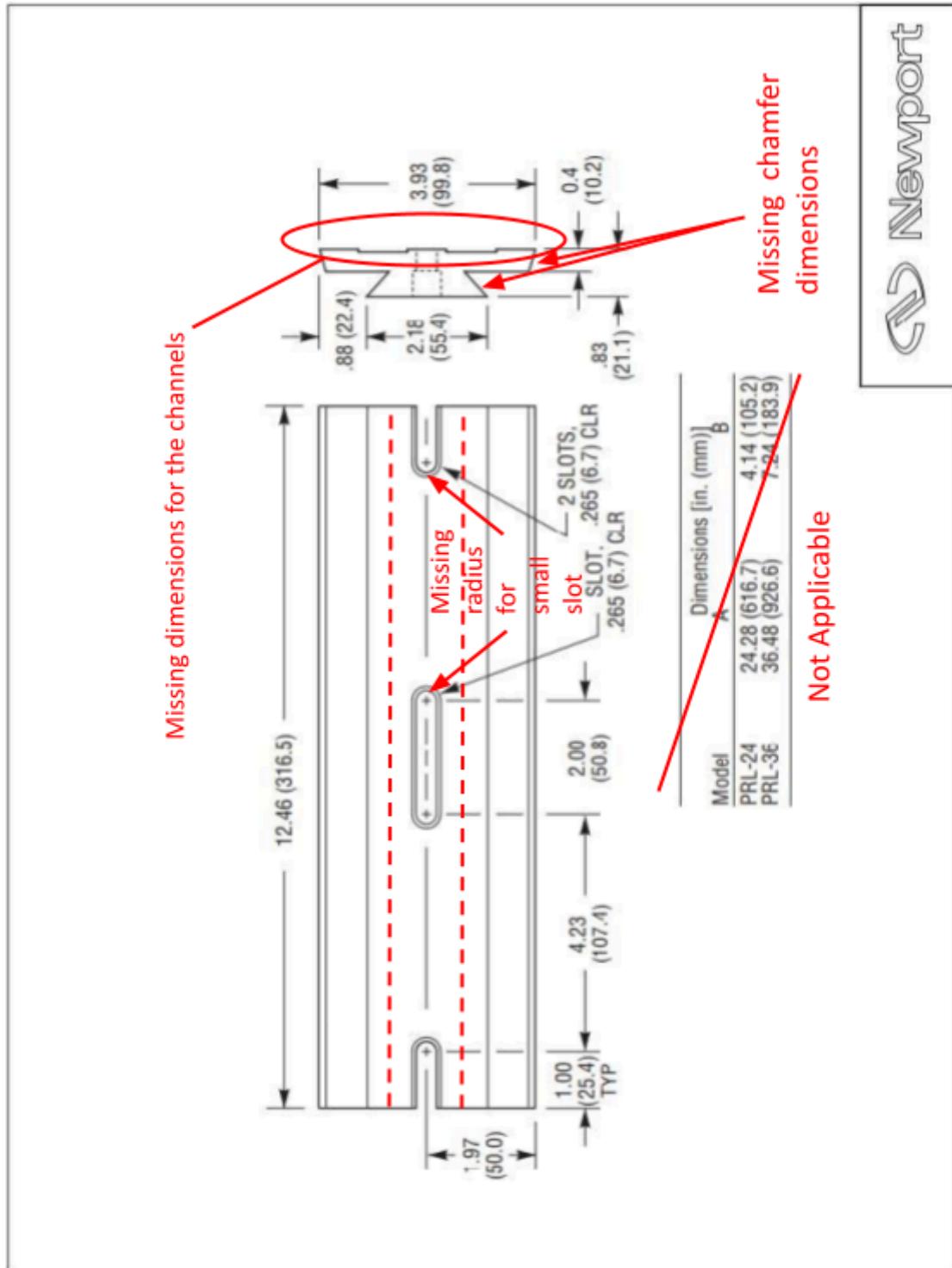
Tool Type Straight Flute for hard metal
Tool Material Carbide
Coating Uncoated

Units **mm** **in**

Tip Diameter **0.53** in **N# of Flutes 2** Tool Stickout **1.5**

Appendix C

Original Engineering Drawing Showing Missing Information



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