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Processes for Fabrication and Optimization of a 90° Tool Holder for Large-Caliber Sabot Machining

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and Marshal Childers

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14. ABSTRACT This technical note is a case study of how ARL's Experimental Fabrication Branch (EFB) collaborated with the Lethal Mechanisms Branch (LMB) to achieve program objectives for the Decisive Lethality mission program and improve processes and capabilities within the EFB Precision Machine Shop for future fabrication solutions. It details the process of engagement with EFB and the development effort to address manufacturability for realizing LMB designs. The procedures executed by the EFB Machine Shop for manufacturing, modification, and optimization for developing a custom 90° tool holder are presented. This tooling package supports LMB in reducing machining times for cutting grooves in large-caliber sabots. This technical note outlines the fabrication of the three-part 7075-T6 aluminum assembly comprising a quill-spindle-tooling profile, top clamp, and bottom clamp using computer numerical control (CNC) turning, CNC milling, and precision electrical discharge machining (EDM). It also chronicles four work packages completed under the project from May to August 2026, including the EDM bore enlargement of a legacy holder and tungsten carbide disc profiling. Finally, production bottlenecks are analyzed; and standardized guidance is provided to streamline setups, manage chips, and accelerate turnarounds for subsequent tooling runs.					
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1. Introduction*

1.1 Background and Objective

This technical note is a case study of how the U.S. Army Combat Capabilities Development Command (DEVCOM) Army Research Laboratory (ARL) Experimental Fabrication Branch (EFB) collaborated with the Lethal Mechanisms Branch (LMB) of the Terminal Effects Division to achieve program objectives for the Decisive Lethality mission program and improve processes and capabilities within the EFB Precision Machine Shop for future fabrication solutions. It details the process of engagement with EFB and the development effort to address manufacturability for realizing LMB designs.

LMB of ARL's Terminal Effects Division is currently developing an advanced machining methodology aimed at drastically reducing the cycle times associated with cutting high-tolerance grooves in large-caliber sabots. Large-caliber sabot manufacturing requires deep, repetitive grooving operations on high-strength materials. These operations typically generate substantial heat and tool deflection, resulting in prolonged production runs and accelerated tool wear. To operationalize and evaluate this new machining method, ARL EFB's Precision Machine Shop produced a highly rigid, specialized tooling package to mount and index cutting inserts at precise orientations.

1.2 Scope of Branch Support

The EFB Machine Shop was tasked with translating conceptual tooling designs from LMB into physical hardware under the Decisive Lethality mission program. The primary objective of this technical note is to capture and document the following direct fabrication and modification methods developed and applied by the branch:

- Sourcing materials;
- Interpreting design requirements and specifications to produce design for manufacturing documentation;
- Fabricating primary components of the custom 90° tool holder assembly;
- Performing precise, high-tolerance modifications to existing lathe tool posts, milling fixtures, and specialized cutting components; and

* GenAi (Gemini) was used to assist with report structure and reviewed by Marshal Childers.

- Documenting challenges encountered during initial manufacturing runs to establish standard operating procedures that alleviate slow turnaround times and improve overall efficiency.

2. Fabrication and Modification Procedures: 90° Tool Holder Project

2.1 Overview of Machine Shop Work Orders

Branch support was executed across multiple work centers through a series of four closely coordinated work orders submitted under Project Code “26_TE_LMB_1” (Table 1). These work packages established an incremental development path, moving from modifying legacy angled tools and fabricating a ground-up 7075 aluminum tool holder assembly to using EDM to enlarge legacy tool holders and slicing custom tungsten carbide plunge-cutter discs.

Table 1. Work orders.

Work order identifier	Submission date	Primary work center	Status	Key deliverables/ actions
26_TE_LMB_1_Angle tool modification	May 8, 2026	Precision Machine Shop 1	Work completed	Manual modification of angled tool
26_TE_LMB_1_90 degree tool holder	June 12, 2026	Precision Machine Shop 1	Work in-progress	Computer numerical control (CNC) machining (lathe, mill, EDM) of primary 7075 aluminum multicomponent assembly
26_TE_LMB_1_ID bore enlargement	July 10, 2026	Precision Machine Shop 1	Work completed	EDM bore expansion on legacy tool holder
26_TE_LMB_1_stock cutter discs	Aug 28, 2026	Precision Machine Shop 3	Work received	Tungsten carbide EDM slicing, keyway milling, shaft fitment, and nut fabrication

2.1.1 Work Order Naming Convention Breakdown

The project code identifier is structured systematically to enable tracking across fiscal-year cycles and administrative branches. The string “26_TE_LMB_1” is defined as follows:

- **FY (26):** Represents Fiscal Year 2026, the budget year under which the support is authorized
- **Division (TE):** Represents the Terminal Effects Division, the requesting organization

- **Branch (LMB):** Represents the Lethal Mechanisms Branch, the requesting customer group
- **Facility (1):** Identifies the EFB Machine Shop 1, the primary performing shop facility

2.1.2 Interpretation of Design Requirements

For each work package, the provided design requirements consisted of engineering drawings (see the Appendix) and/or CAD part/assembly files, written or spoken specifications, and existing parts for evaluation that were used to translate the requirements into design for manufacture instructions and code. When clarifications or discrepancies regarding manufacturability arose, EFB Machine Shop personnel consulted the project’s technical POC to communicate the issue and arrive at a solution. Having good engineering drawings that indicated critical dimensions and tolerances at the start of the project facilitated an efficient fabrication approach and minimized the need for rework.

2.2 Work Package 1: Angled Tool Modification

Submitted on May 8, 2026, this initial task involved rapid-turnaround modifications to an existing angled tool to support early-stage mock setups. The customer hand-delivered the legacy tool to Precision Machine Shop 1, where it was evaluated and processed by shop personnel.

- **Execution:** Mating surfaces of the legacy angled tool were milled and ground to adjust its centerline height and tool posture. This ensured compatibility with prototype test fixtures.

2.3 Work Package 2: 90° Tool Holder Assembly Fabrication (7075 Aluminum)

Submitted on June 12, 2026, this work package represents the core structural fabrication effort. Technical drawings titled, “*90 degree holder with clamps (Sheets 1–4)*” (Appendix), defined a high-rigidity multicomponent tooling package. To achieve an optimal balance of structural strength-to-weight ratio, rapid thermal dissipation, corrosion resistance, and high-strength 7075-T6 aluminum were selected for all components. Figure 1 shows a picture of the 90° tool holder assembly.



Figure 1. 90° tool holder assembly.

Fabrication required a sequential, multicenter routing plan using CNC lathe turning, CNC milling, and precision EDM. The tooling package consists of three main components, which are described in the following subsections.

2.3.1 Quill–Spindle–Tooling Profile: Item 1

This primary spindle-mating component acts as the main adapter core, featuring complex stepped cylindrical geometry and deep internal bores (Figure 2).



Figure 2. 90° tool holder spindle.

Turning operations for the 7075-T6 aluminum components were executed on a ProtoTRAK Lathe 1845RX using high-performance carbide tooling. Rough turning of the 4.50-inch round stock was performed at 800 sfm and 0.012 ipr, while finish turning of the stepped diameters used a finishing tool at 1,200 sfm and 0.004 ipr. Precision internal boring on the quill–spindle was completed using a 1.5-inch roughing bar at 500 sfm and a micro-boring bar at 450 sfm with a fine 0.002-ipr feed. Finally, bottom clamp step-turning was executed at 1,200 rpm and 0.006 ipr, followed by precision finishing boring with a 0.5-inch bar running at 1,800 rpm and 0.003 ipr. To maintain part tolerances, real-time speed and feed adjustments were implemented during the outside diameter cuts to eliminate machining chatter.

- **CNC lathe turning:** The raw 7075 aluminum round stock was turned on the lathe to machine the primary stepped outer diameters, establishing concentricity across the major flange down to the minor shaft steps (4.44, 1.74, 1.24, and 0.99 inches), within a tight tolerance of ± 0.002 inch.
- **CNC milling:** The component was transitioned to a three-axis CNC mill using soft jaws to machine the internal flat pockets, mill the counterbored clearance holes, and slot the horizontal features.
- **EDM machining:** To achieve the critical, high-precision concentric internal bores without introducing mechanical tool deflection, EDM was used to finish-bore the critical seating diameters, specifically the main relative to the central datum axis.

2.3.2 Top Clamp: Item 2

The top clamping collar (Figure 3) secures the upper flange of the quill–spindle tooling to the spindle assembly.

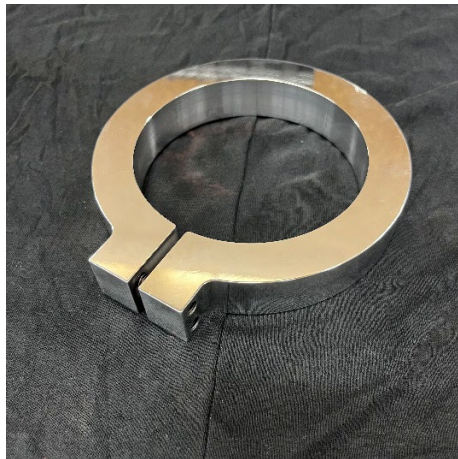


Figure 3. 90° tool holder top clamp.

Machining operations for the 7075-T6 aluminum clamps were executed on a ProtoTRAK Mill DPMRX5 using high-efficiency milling (HEM) techniques. Top clamp pocket roughing used a 0.5-inch, three-flute carbide endmill at 8,500 rpm and 90 ipm, while internal radius finishing employed a 0.375-inch tool at 10,000 rpm and 60 ipm. Thread milling for the 1/4–20 holes was completed with a 0.180-inch tool, and the bottom clamp was surfaced using a 2-inch indexable shell mill at 4,500 rpm and 35 ipm, with 8/32 holes created via peck drilling and thread milling.

- **CNC milling:** Machined from 7075 aluminum plate stock, the external profile (R2.97 inches) and the internal radius were contoured to ensure a seamless slip fit.
- **Drilling and tapping:** The split-collar ears were drilled and tapped for a 1/4–20 UNC clamping bolt, featuring a counterbored clearance pocket to keep the bolt head flush.

EMD was used to slice, slot, and bore ultra-hard and case-hardened components. For slitting the split joints on both the 7075-T6 aluminum Top and Bottom Clamps, the Makino EDM U6 H.E.A.T. wire EDM was configured with a standard 0.010-inch-diameter hard brass wire. The operation ran under Technology Code E1234 (i.e., the Makino database technology code selected specifically for 7075 aluminum, wire type, and workpiece thickness), which automatically dictated the optimal peak current, off-time, voltage, and flush pressure to achieve a highly stable, typical linear cutting feed rate without split-mating tapers or surface burrs.

- **Slitting:** The EDM slitting pass was executed to split the collar, establishing the necessary 0.20-inch clamping gap.

2.3.3 Bottom Clamp: Item 3

The bottom clamping assembly (Figure 4) provides lower alignment and support on the minor turned shaft.



Figure 4. 90° tool holder bottom clamp.

- **CNC lathe and mill:** The component was turned on a CNC lathe to establish the concentric outer sleeve high-tolerance inner diameter (+0.005, –0.000 inch) to slip-fit onto the lower shaft of Item 1.
- **Drilling and tapping:** A slotting pass established the split gap, and cross-holes were drilled and tapped with an 8/32-inch thread to accept a high-strength socket cap screw for clamping.

2.4 Work Package 3: Tool Holder Internal Diameter (ID) Bore Enlargement via EDM

Submitted on July 10, 2026, this critical modification task was routed to Precision Machine Shop 1 to bridge the gap between legacy milling components and the newly developed 90° tool. The customer supplied an existing, hardened CNC mill tool holder that required adaptation (Figure 5).



Figure 5. Modified CNC tool holder.

- **Challenge:** Standard off-the-shelf CNC tool holders are typically case-hardened to HRC 58–62. Traditional high-speed steel or standard carbide boring bars cannot easily machine this surface without significant tool deflection, rapid wear, or catastrophic fracturing.
- **EDM execution:** To open the ID bore safely and accurately, we used EDM. This thermal erosion process bypassed the material hardness entirely, allowing the shop to:
 - Precisely locate and align the existing centerline axis of the supplied tool holder.
 - Erode and enlarge the inner diameter bore to the exact clearance limits required to receive the newly fabricated 90° tool.
- **Outcome:** The EDM procedure successfully expanded the bore without inducing micro-cracking or thermal distortion in the hardened tool holder body.

2.5 Work Package 4: Cutter Discs and 90° Tool Modification

Submitted on August 28, 2026, this final work package was routed to Precision Machine Shop 3 to transition the tooling package into active cutting trials. This package required high-accuracy modifications and EDM of ultra-hard materials:

- 1) **Tungsten carbide slicing and EDM profiling:** Raw tungsten carbide stock, provided by the customer and stored in the tool crib, was sliced into thin stock cutter discs (Figure 6). Precision wire EDM was used to cut the ID profile of the carbide discs to meet tight clearance tolerances, saving the remaining stock for subsequent runs.
- 2) **Keyway modification:** The 90° drill tool shaft was modified to accept a drive keyway. Keyway stock sourced from the main tool crib was cut down and fitted precisely inside the shaft (Figure 7).
- 3) **Assembly and verification:** Machinists verified that the sabot groove plunge cutter stock disc fit securely on the drive shaft with the newly fabricated key.
- 4) **Retention nut fabrication:** A custom heavy-duty retention nut was fabricated and threaded to match the shaft, securing the cutter disc assembly against high axial forces during plunge cutting.



Figure 6. Sabot plunge cutter discs.



Figure 7. Shaft keyway.

3. Manufacturing Bottlenecks and Optimization Guidance

3.1 Analysis of Production Lead Time Factors and Lessons Learned

While the initial phases of the 90° Tool Holder Project successfully delivered verified hardware, fabrication speed was slower than desired by project stakeholders. An internal review identified several critical bottlenecks:

- **Multicenter transition latency:** Routing the primary quill–spindle–tooling profile sequentially across three separate machine tools (CNC lathe turning, CNC milling, and EDM boring) incurred significant setup delays. Each transition required the fabrication of unique work-holding setups to prevent damaging the turned aluminum surfaces.
- **High-tolerance boring in 7075 aluminum:** Maintaining the tight clearance bore limits (+0.005, −0.000 inch) required slow feeds and extensive verification measurements. Aluminum’s high thermal expansion coefficient

required components to be fully normalized to room temperature before final measurement, slowing down checking procedures.

- **Thread integrity in small bores:** Tapping the fine 8/32-inch threads in the 7075 aluminum bottom clamp risked thread tearing or tap breakage, necessitating cautious manual or specialized rigid-tapping cycles.
- **Material preparation:** Face-milling oversized 7075 aluminum block stock to final thickness for the top clamp wasted significant machine time and generated excessive scrap material.

3.2 Recommendations for Process Acceleration

To streamline subsequent fabrication runs and reduce turnaround times, the following standardized manufacturing approaches are warranted:

1) Transition to Mill-Turn CNC Spindles:

- a) Action: Consolidate the turning and milling operations of the quill–spindle–tooling profile onto a single CNC mill-turn center equipped with live tooling.
- b) Impact: Eliminates the transition and alignment setups between separate lathes and mills, reducing machining cycle times by approximately 35%.

2) Sourcing Presized Decarb-Free Ground Flat/Round Stock:

- a) Action: Source preground 7075 aluminum flat stock closest to the final top clamp thickness (tolerance +0.015/–0.000 inch).
- b) Impact: Eliminates preliminary squaring and face-milling passes, reducing primary milling time by approximately 25%.

3) Standardize Reusable Soft-Jaw Fixturing:

- a) Action: Fabricate a set of dedicated aluminum soft jaws contoured to the turned major diameters of the quill–spindle profile.
- b) Impact: Prevents surface jaw-marking, ensures rapid part centering, and eliminates the need to manually re-indicate the part between operations.

4) Utilize Form-Tapping for Aluminum Threads:

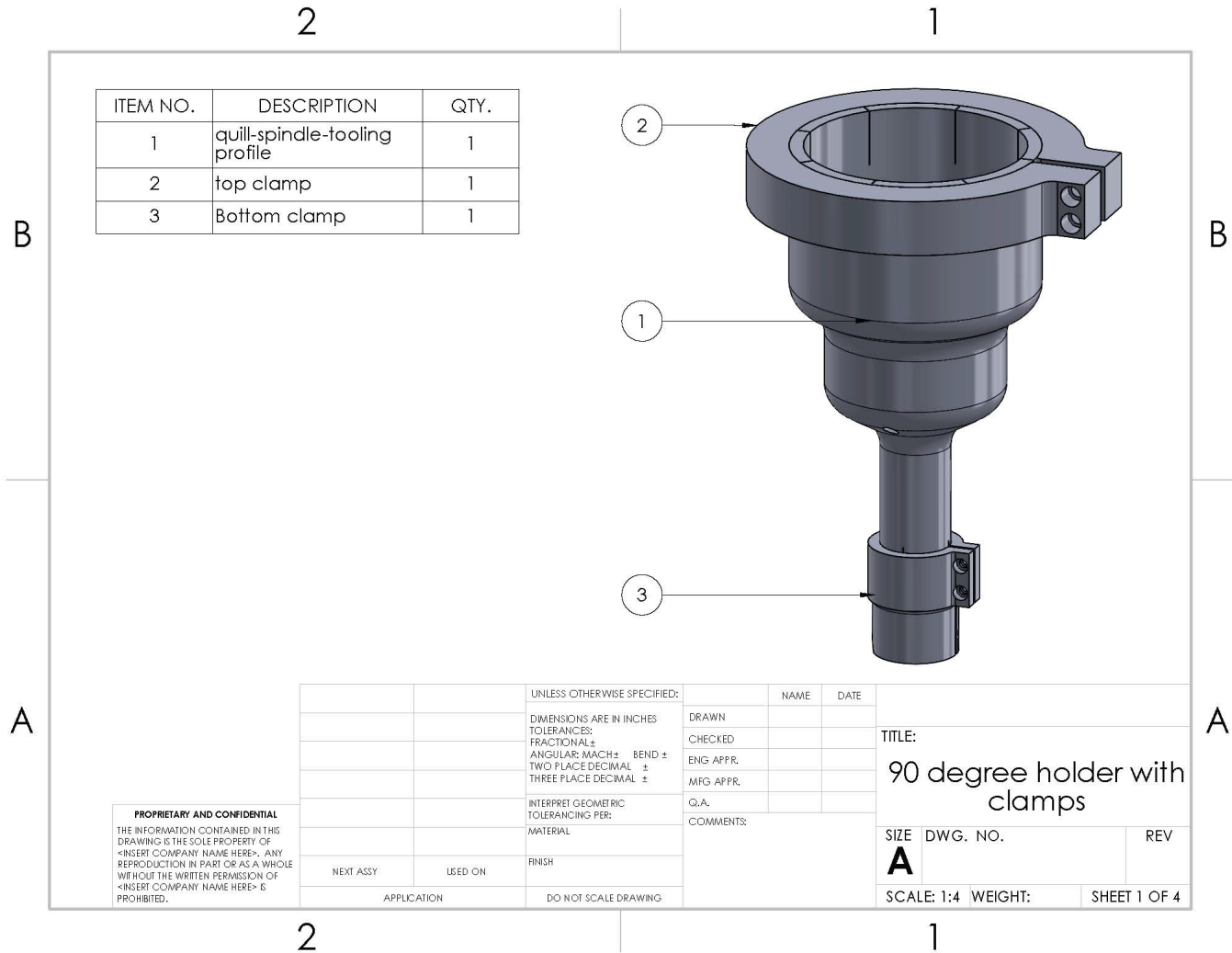
- a) Action: Replace standard cutting taps with thread-forming (roll) taps for the 1/4–20 UNC and 8/32-inch clamped threads in the 7075-T6 aluminum components.
- b) Impact: Form-tapping cold-works the aluminum thread profiles, increasing thread strip resistance by up to 20% while eliminating chip pack-up and tap breakage risks.

4. Conclusion

ARL EFB's Machine Shop successfully demonstrated its capability to support high-priority research initiatives by fabricating and modifying critical hardware for the LMB's sabot-grooving project. The technical modification of the multicomponent 7075 aluminum 90° tool holder assembly and the successful EDM modification of legacy CNC mill tool holders provided a robust, rigid platform that allows LMB to accurately test their new high-speed grooving methods.

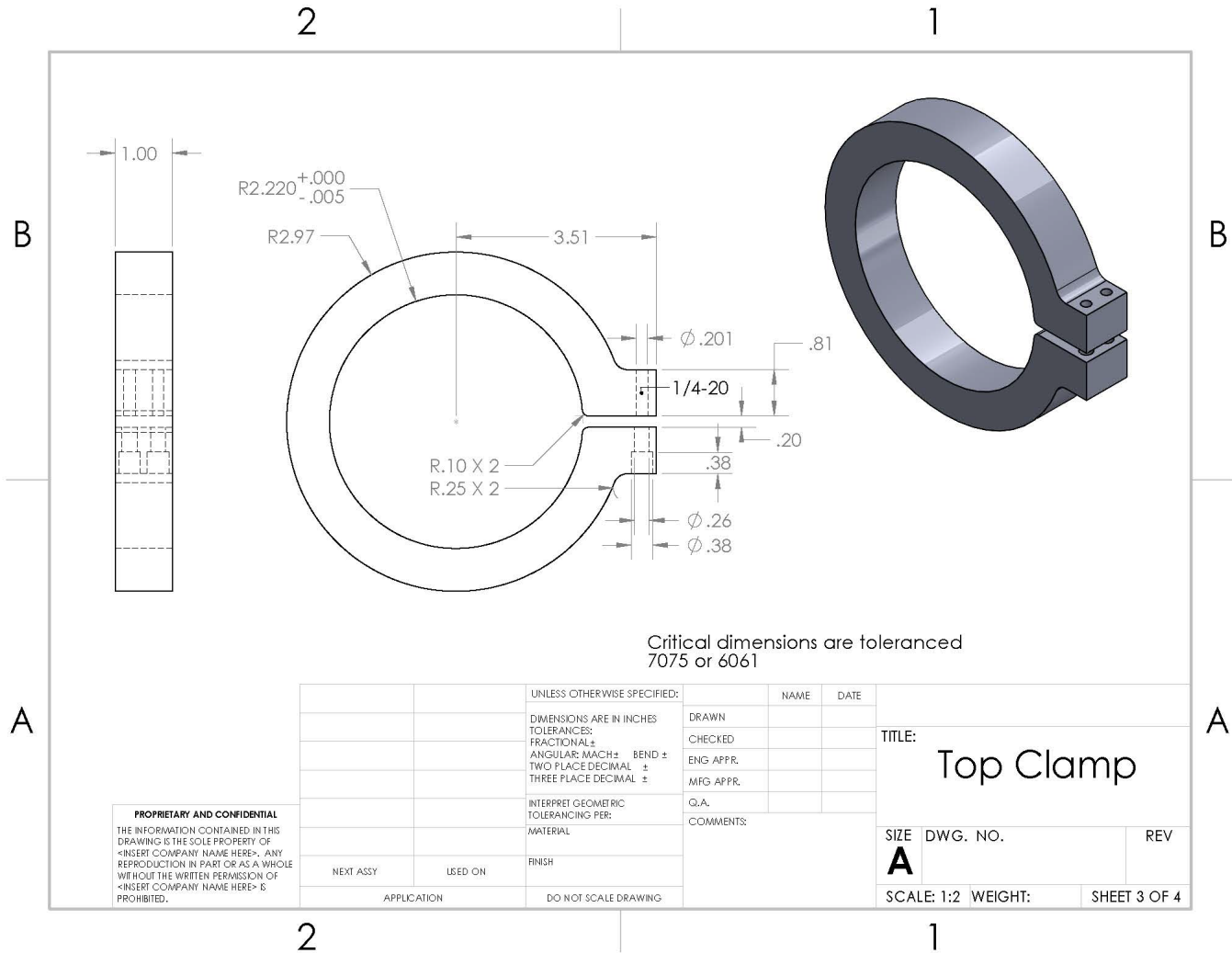
By transitioning to the optimized manufacturing guidance outlined in Section 3—namely, mill-turn CNC consolidation, presized stock, modular soft-jaw fixturing, and thread-forming parameters—the shop can dramatically reduce future fabrication cycle times. This support establishes a highly efficient manufacturing pipeline, directly accelerating ARL's technical progress and project delivery.

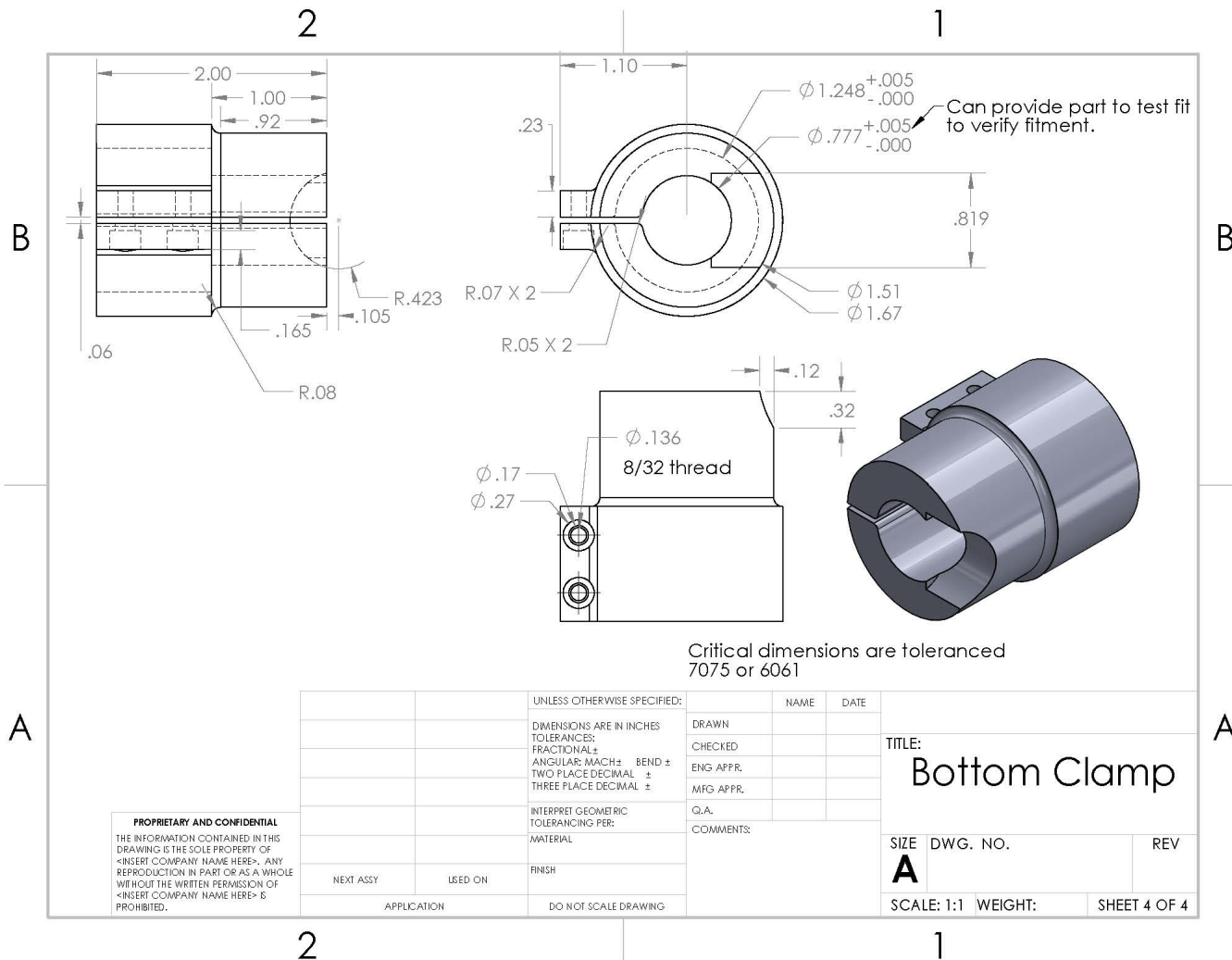
Appendix. Supplied Engineering Drawings



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List of Symbols, Abbreviations, and Acronyms

ARL	Army Research Laboratory
CAD	Computer-Aided Design
CNC	Computer Numerical Control
DEVCOM	U.S. Army Combat Capabilities Development Command
EDM	Electrical Discharge Machining
EFB	Experimental Fabrication Branch
FY	Fiscal Year
HEM	High-Efficiency Milling
ID	Internal Diameter
ipm	Inches per Minute
ipr	Inches per Revolution
LMB	Lethal Mechanisms Branch
POC	Point of Contact
rpm	Revolutions per Minute
sfm	Surface Feet per Minute
TE	Terminal Effects
UNC	Unified National Coarse

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