Bridging Academia and Defense: Student-Driven Additive Manufacturing for Military Problem Solving

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Abstract

In modern combat environments, the failure of a powered optic can mean the difference between mission success and weapon inoperability. To address this critical vulnerability, undergraduate Manufacturing Engineering Technology students developed the Printed Reticle Iron Sight Emergency Module (P.R.I.S.E.M.), a 3D-printed backup sighting system for the M3 Multi-Role Anti-Armor Anti-Personnel Weapon System (Carl Gustav). This project emerged from a real-world operational problem identified by active-duty soldiers, aligning with prior research demonstrating that authentic, stakeholder-driven projects significantly enhance student engagement and learning in engineering education [1, 2]. It challenged students to apply engineering design, additive manufacturing, and materials science to produce a field-ready solution capable of being fabricated in forward-deployed environments using commercial 3D-printing technology already available to sustainment brigades of the 101st Airborne Division at Fort Campbell.

Using an agile, student-led design process, the team conducted extensive material testing of carbon-fiber-reinforced filaments and selected ASA-CF (Acrylonitrile Styrene Acrylate with Carbon Fiber) for its combination of high stiffness, thermal stability, and ultraviolet resistance. The material's matte, non-reflective finish further enhanced its suitability for tactical use. Through iterative prototyping, the students produced a lightweight, modular, and easily manufacturable sight assembly that can be replicated rapidly in austere or resource-limited conditions.

Pedagogically, the P.R.I.S.E.M. initiative demonstrates how mission-driven design transforms classroom learning into applied innovation. Students developed advanced competencies in additive manufacturing, CAD modeling, and material evaluation while gaining practical experience in communication, ethical decision-making, and collaboration with defense professionals. Learning outcomes were mapped to ABET Student Outcomes 1–5, reinforcing technical rigor and professional identity formation. This project illustrates how academic–military partnerships can transform Engineering Technology education, empowering students to become agile, purpose-driven technologists capable of innovating under real-world constraints.

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1. Introduction

Additive manufacturing (AM) is reshaping defense and industry by enabling rapid prototyping, customization, and field-ready part production. Austin Peay State University's collaboration with the Eaglewerx Applied Tactical Innovation Center (ATIC) bridges academic expertise with real-world defense challenges, allowing students to apply modern manufacturing principles to solve authentic operational problems. This paper uses the Printed Reticle Iron Sight Emergency Module (P.R.I.S.E.M.) as a case study to demonstrate how mission-oriented capstone projects can foster experiential learning, engineering identity, and real-world readiness.

2. Background and Motivation

The Printed Reticle Iron Sight Emergency Module (P.R.I.S.E.M.) project originated from a collaboration between Austin Peay State University (APSU), the Eaglewerx Applied Tactical Innovation Center (ATIC), and the U.S. Army 5th Special Forces Group (Airborne) at Fort Campbell, Kentucky. The Eaglewerx ATIC serves as the central point of connection for warfighters and partners to learn, research, innovate, build, and explore new ideas to solve tactical problems. As described by the organization, "The ATIC provides the resources and network to empower warfighter-centered innovation to increase readiness to win the future fight."

The collaboration emerged from the shared objective of advancing warfighter readiness while providing students with an authentic, high-impact learning experience. During initial planning discussions in the Spring 2025 semester, a Senior Weapons Logistics Support Analyst from the 5th Special Forces Group identified a critical operational vulnerability in the M3 Multi-Role Anti-Armor Anti-Personnel Weapon System (MAAWS), also known as the Carl Gustav recoilless rifle. Although the weapon's digital optic provides enhanced accuracy and target acquisition, it is dependent on powered components that can fail in austere or combat environments [3]. In its Additive Manufacturing Strategy, the **United States Department of Defense** emphasizes distributed, point-of-need production as a means to reduce logistical burden and increase operational resilience, an approach directly reflected in the design and documentation of the P.R.I.S.E.M. system [4].

For APSU Manufacturing Engineering Technology students, the project represented a rare opportunity to engage in mission-driven engineering. Working alongside active-duty soldiers and innovation specialists, students translated classroom learning in materials science, design for manufacturability, and additive manufacturing into a tangible, field-ready solution. The project demanded that they balance competing priorities, such as thermal and mechanical performance, operational safety, and manufacturability, while working within the ethical and procedural boundaries associated with a defense-focused application.

Ultimately, the P.R.I.S.E.M. initiative demonstrates how academic–military partnerships can provide students with authentic learning experiences that extend beyond the classroom, developing not only technical competence but also a deeper sense of professional identity, service, and innovation.

3. Project Description and Methodology

The PRISEM project was conceived as a practical response to a real-world defense need identified by the U.S. Army 5th Special Forces Group (Airborne) and facilitated through the Eaglewerx ATIC at Fort Campbell, Kentucky. The operational problem centered on the vulnerability of digital optics used on the **M3 MAAWS**, commonly known as the *Carl Gustav recoilless rifle*, to damage, power loss, or environmental failure during field operations. The mission requirement was to design and fabricate a **low-cost, forward-deployable backup iron**

sight capable of being produced using additive manufacturing equipment already available to **sustainment brigades** deployed alongside the 101st Airborne Division.

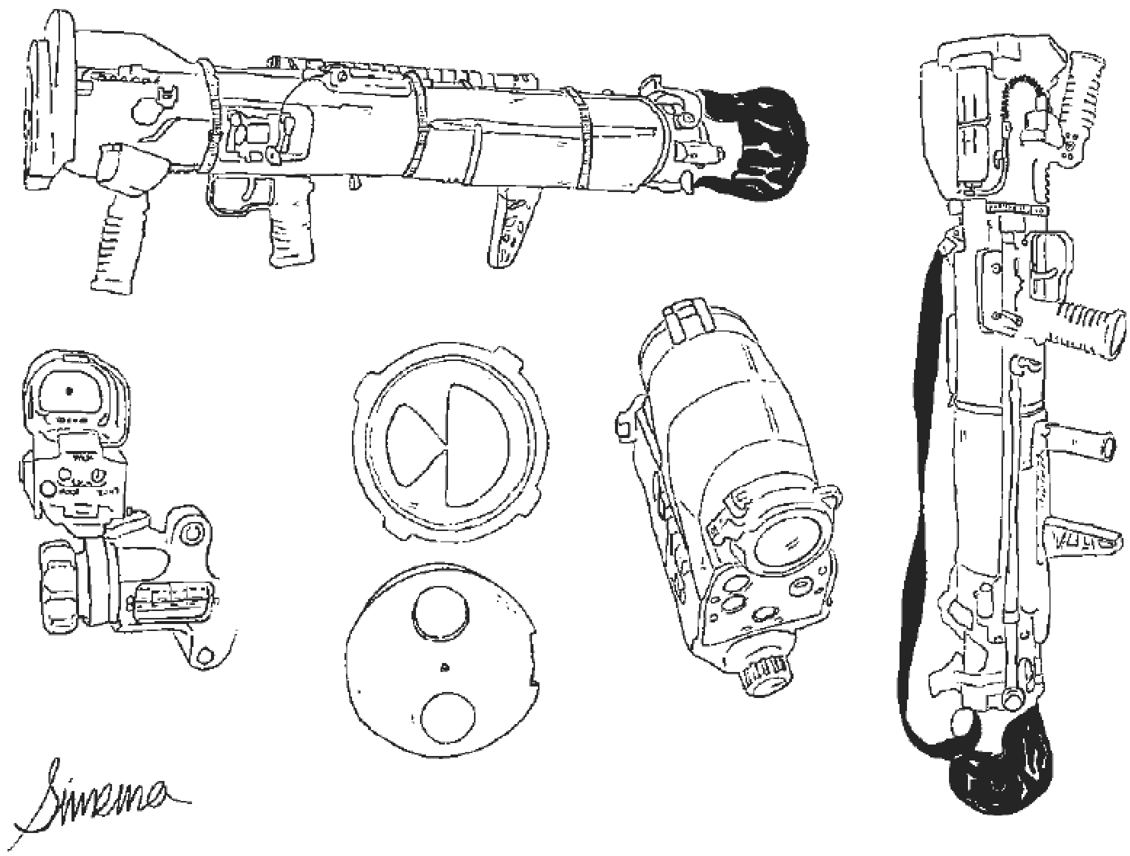

Figure 1- Illustration of the Carl Gustaf recoilless rifle by student author Simona Vest, created for the P.R.I.S.E.M. capstone project to support visual analysis and sight-system design.

Design Approach

The student team, composed of two senior Manufacturing Engineering Technology majors, employed **agile and iterative design methods** using *PTC Creo Parametric* for 3D modeling and *Bambu Labs X1C* systems for additive fabrication. Early iterations focused on developing a sight module that could maintain alignment and structural integrity under recoil while providing accurate point-of-aim at ranges up to **500 meters**. The design emphasized **modularity**, **field repairability**, and **compatibility** with existing mounting locations on the M3 MAAWS.

Dimensional data were collected during an on-site visit to the 5th Special Forces Armory, where the team received guidance from a Senior Weapons Logistics Support Analyst. This engagement provided critical reference measurements and allowed students to verify tolerances directly against the weapon system, ensuring realistic integration.

Material Evaluation and Testing

Given the extreme environmental and operational demands of combat conditions, the team conducted a comprehensive **materials evaluation** to determine which thermoplastic composite would provide the best balance of **thermal resistance, mechanical strength, manufacturability, and infrared (IR) neutrality.** Three carbon-fiber-reinforced polymers were selected for experimental comparison:

1. **PLA-CF (Polylactic Acid with Carbon Fiber)** – inexpensive and beginner-friendly, but limited by a low Vicat softening point (≈69 °C) and poor UV resistance.
2. **PAHT-CF (High-Temperature Polyamide with Carbon Fiber)** – mechanically superior but difficult to process, highly hygroscopic, and costly.
3. **ASA-CF (Acrylonitrile Styrene Acrylate with Carbon Fiber)** – strong UV stability, moderate impact resistance, and a favorable Vicat temperature (≈108 °C).

The team printed standardized **8 × 8 cm test plates** and assessed **infrared reflectivity** using a white phosphor night-vision system in a controlled dark environment. None of the carbon-fiber composites exhibited measurable IR reflectivity, confirming their suitability for tactical use.

Mechanical evaluation was based on **manufacturer-provided data sheets** corroborated by practical manufacturability metrics such as post-processing time, ease of support removal, dimensional consistency, and failure rate per print. A weighted decision matrix was developed to compare materials across strength, thermal tolerance, UV resistance, cost, and production efficiency. ASA-CF emerged as the optimal choice, balancing **operational performance** with **production feasibility** for forward-deployed additive manufacturing units.

Prototyping and Assembly

Successive design iterations were printed in PLA for rapid prototyping and dimensional validation before transitioning to ASA-CF for the final functional build. The final module featured **folding front and rear posts**, an integrated **tension bar system**, and **locator markings** for fast sight acquisition. Post-processing steps included removal of support material, insertion of heat-set M3 nuts, and final assembly using standard fasteners and Loctite adhesive to simulate deployable field conditions.

Particular emphasis was placed on simplifying the assembly sequence for use in austere and resource-constrained environments. The final assembly process was intentionally designed to require only basic, commonly available hand tools and minimal technical training. To validate the usability of the assembly process, an operational soldier with no prior exposure to the system assembled the P.R.I.S.E.M. module using only the provided field manual. Feedback from this exercise informed revisions to the work instructions, reflecting established human-centered design and design-for-assembly principles that emphasize usability, clarity, and error reduction in constrained environments [5].

Testing and Validation

Although a live-fire range validation with Special Forces personnel was postponed due to operational scheduling conflicts, preliminary evaluations confirmed proper **fitment, alignment, and mechanical rigidity** under simulated loading conditions. The team also designed a **field questionnaire** (included in the report) for future operational testing to capture user feedback on usability, durability, and installation time under austere conditions.

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4. Educational Outcomes and Reflection

The P.R.I.S.E.M. capstone provided a unique opportunity for students to **translate theoretical knowledge into tangible results** under authentic defense-related constraints. Unlike traditional classroom projects, this initiative required students to engage directly with operational stakeholders, integrate user requirements from active-duty personnel, and manage iterative design cycles that mirrored professional engineering practice.

Students demonstrated measurable proficiency across the **core domains of Manufacturing Engineering Technology**:

- **Additive Manufacturing and Process Optimization** – mastering advanced print parameters for composite filaments, managing thermal distortion, and applying design-for-additive-manufacturing (DfAM) principles. Students demonstrated an understanding of design-for-assembly by deliberately simplifying component interfaces and validating assembly procedures through end-user feedback, reinforcing the importance of usability and clarity in field-deployable systems.
- **CAD Modeling and Tolerancing** – using *PTC Creo Parametric* to create precision assemblies with functional fits, mechanical retention systems, and field-serviceable features.
- **Material Selection and Validation** – analyzing performance tradeoffs among multiple carbon-fiber-reinforced polymers using both quantitative and qualitative decision criteria.
- **Technical Documentation and Communication** – producing a complete field-manufacturing manual (FM-4X P.R.I.S.E.M.) written to Department of the Army formatting standards, accompanied by graphical CAD drawings, process sheets, and a deployable manufacturing *kit* that included a reference standard for fit and finish, validated assembly guidance, and pre-sliced G-code files to enable rapid, repeatable production in field environments.

Alignment to ETAC of ABET Student Outcomes

The learning outcomes demonstrated through the P.R.I.S.E.M. project were intentionally aligned with the Engineering Technology Accreditation Commission (ETAC) of **ABET** Student Outcomes framework, which emphasizes applied problem solving, communication, professional responsibility, and teamwork in engineering technology education [6].

- **SO1 – Apply knowledge, techniques, skills, and modern tools of the discipline to broadly defined engineering technology activities.**
  Students utilized advanced CAD and additive manufacturing tools to model, print, and validate a functional prototype consistent with real-world defense requirements. Their iterative design cycles demonstrated tool proficiency and process adaptability.
- **SO2 – Apply knowledge of mathematics, science, engineering, and technology to engineering technology problems that require the application of principles and applied procedures or methodologies.**
  The team applied physics-based reasoning (thermal stress, Vicat softening, and mechanical stiffness relationships) to evaluate filament performance under simulated field conditions. Calculations of target scaling and sight radius geometry translated abstract mathematics into practical design outcomes.
- **SO3 – Conduct standard tests and measurements; analyze and interpret experiments; and apply experimental results to improve processes.**
  Students conducted IR reflectivity and material-performance tests, analyzed results, and iteratively refined designs and process parameters. The data-driven material-selection matrix exemplified this outcome.
- **SO4 – Design systems, components, or processes for broadly defined engineering technology problems appropriate to program educational objectives.**
  The final P.R.I.S.E.M. design, an additively manufactured, field-deployable backup sight, met a specified operational need within practical manufacturing and logistical constraints. The project illustrated the design process from concept to prototype to production documentation.
- **SO5 – Function effectively as a member or leader on a technical team.**
  Working in a two-person design team with distributed responsibilities for design, testing, and documentation, students exhibited strong collaboration and professional communication. Engagements with Eaglewerx mentors and military partners further reinforced team-based project management and stakeholder communication skills.

Faculty Reflection

Faculty mentors observed substantial growth in student motivation, ownership, and professional identity over the semester, consistent with prior studies showing that participation in authentic engineering practice accelerates engineering identity formation [7, 8]. Students approached the project with the seriousness of a professional engineering task, often extending lab hours to refine prints and validate dimensions. The mission-driven context fostered an increased sense of responsibility, linking classroom learning to national defense readiness. The open collaboration between academia and the military environment provided a powerful experiential platform that enhanced both **technical competence** and **ethical awareness**, aligning well with ABET's emphasis on *lifelong learning, societal impact, and professional responsibility*.

Figure 2- Iterative design progression of the P.R.I.S.E.M. flip-up iron sight components, illustrating multiple prototype variations developed through rapid additive manufacturing to refine geometry, fit, and functional performance.

5. Discussion: University–Defense Collaborative Design Framework

The partnership between **Austin Peay State University (APSU)** and the **Eaglewerx Applied Tactical Innovation Center (ATIC)** illustrates a scalable **University-Defense Collaborative Design Framework** that links student innovation with real operational needs. Rather than serving as a rigid structure, Eaglewerx functioned as a **conduit**, translating tactical challenges identified by U.S. Army personnel into feasible, educationally sound projects suitable for student engagement under faculty supervision.

In this model, **Eaglewerx acts as the innovation intermediary**, bridging defense requirements with academic expertise, while **APSU faculty** provide the pedagogical structure and technical oversight that ensure alignment with ETAC of ABET educational outcomes. This arrangement allows military partners to surface authentic, unclassified problem statements, such as the need for a field-deployable sighting solution for the M3 MAAWS, and empowers students to develop, prototype, and validate solutions through modern engineering technology tools and methods.

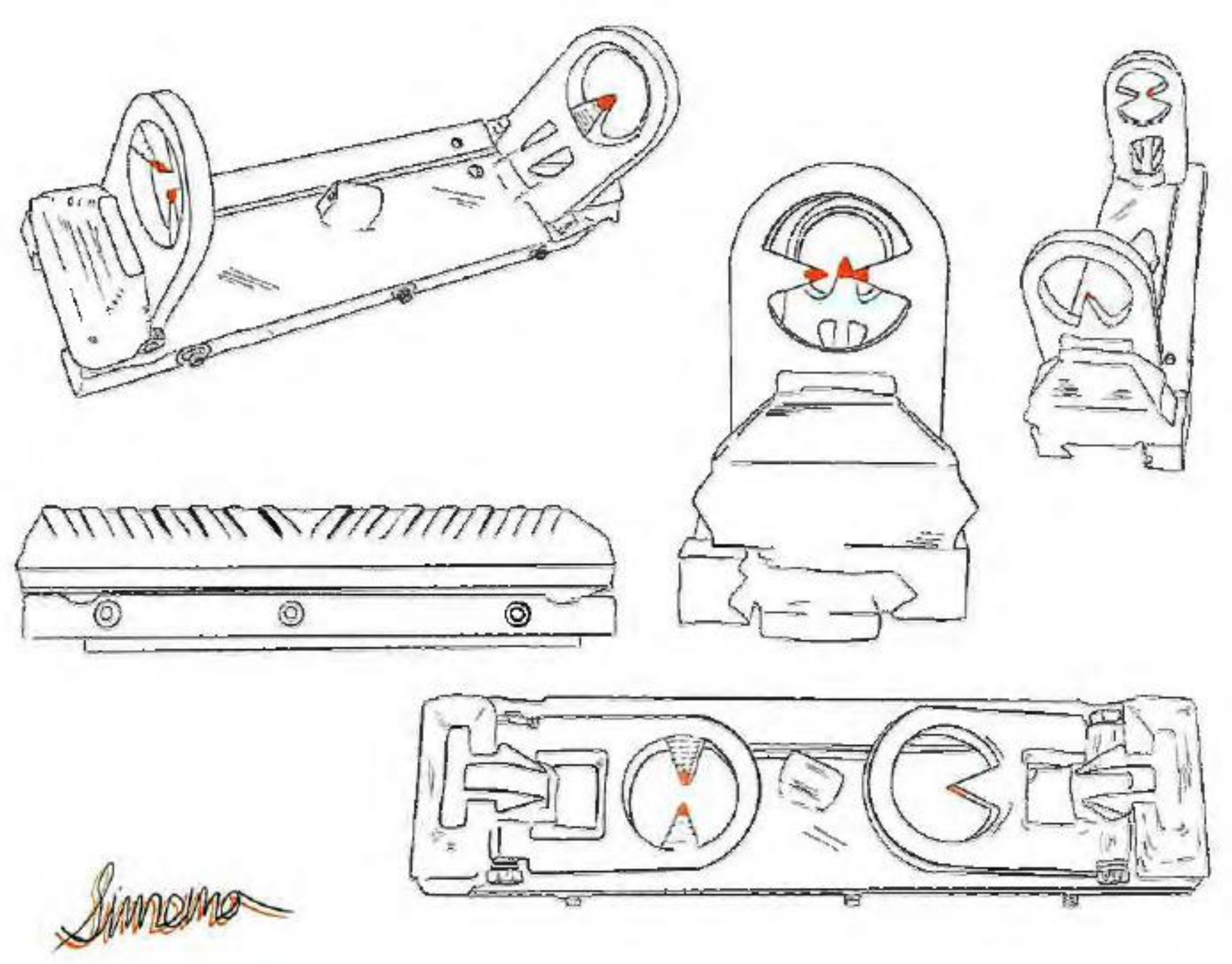

Figure 3- Concept sketches of the P.R.I.S.E.M. backup iron sight, illustrating multiple viewing angles and sight alignment features, by student author Simona Vest.

The **collaboration framework** that emerged through the P.R.I.S.E.M. project integrates three critical components:

1. **Proposal Solicitation from Military Stakeholders** – Problems are sourced directly from operational units through Eaglewerx, filtered for feasibility, and scoped into manageable capstone-scale projects.
2. **Student-Led Design Under Faculty Mentorship** – Students take ownership of concept development, material testing, and prototyping while faculty mentors provide guidance in design methodology, safety, and ethics.
3. **Controlled Research Environment** – Projects operate within a structured academic setting where deliverables are transparent, data is managed responsibly, and collaboration remains within non-sensitive, export-compliant boundaries.

This framework enables a unique intersection of **academic rigor, experiential learning, and national service**, giving students hands-on exposure to defense-sector problem solving while maintaining compliance with educational and legal standards. The **P.R.I.S.E.M. initiative** highlighted this balance by allowing student engineers to interact directly with end users, collect field data, and iterate designs, all within a safe, supervised, and mission-relevant environment.

Several strengths of the **APSU-Eaglewerx collaboration** became evident:

- **Authenticity:** Projects are grounded in real defense challenges, reinforcing student motivation and professional identity.
- **Mutual Value:** The military receives rapid, low-cost prototyping capability; the university gains experiential learning opportunities that align with ABET outcomes.
- **Mentorship and Oversight:** Joint supervision by faculty and defense liaisons ensures academic integrity and operational relevance.
- **Replicability:** The process can be adapted to other universities and defense innovation hubs, emphasizing local partnerships and additive manufacturing as a common technological bridge.

Challenges included managing **security boundaries**, maintaining **export control awareness (ITAR/EAR)**, and synchronizing **academic schedules** with military availability. These hurdles underscored the importance of formalizing communication channels and establishing clear expectations at the project's outset.

Moving forward, this **University–Defense Collaborative Design Framework** will expand to include **quantitative assessment of learning outcomes**, longitudinal tracking of student professional identity development, and structured mechanisms for **cross-disciplinary participation** from fields such as mechatronics, materials science, and cybersecurity.

In essence, the APSU–Eaglewerx partnership demonstrates how **applied, mission-driven collaboration** can create a sustainable pipeline of engineers and technologists capable of serving both national and societal needs. By transforming defense challenges into student learning laboratories, the framework unites two historically distinct domains, education and defense, around a shared goal of **innovation through purposeful design.**

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6. Conclusions and Future Work

The **PRISEM** project demonstrates the powerful intersection of **student innovation, additive manufacturing, and defense collaboration**. Through hands-on engagement with real-world military partners, students transformed classroom learning into a tangible product designed to enhance operational readiness while deepening their own engineering competencies and professional identities. This approach aligns with the United States Department of Defense Additive Manufacturing Strategy, which emphasizes distributed, point-of-need production as a means of increasing sustainment resilience in austere and forward-deployed environments [4].

The project validated that **mission-oriented capstone experiences** can serve as authentic laboratories for developing ABET-aligned skills in design, analysis, teamwork, and ethics.

From a technical standpoint, the successful design and fabrication of a **field-deployable sighting system** using **carbon-fiber-reinforced thermoplastics** underscores the maturing capabilities of additive manufacturing within military sustainment contexts. The use of **ASA-CF filament** and **forward-compatible 3D printing platforms** (e.g., Bambu X1C systems already available to sustainment brigades) illustrates how low-cost, distributed production can complement traditional logistics chains in contested or austere environments.

Educationally, the P.R.I.S.E.M. project reaffirmed the value of **experiential learning through partnership**. Students not only mastered technical tools but also navigated interdisciplinary challenges, ethical considerations, and communication across civilian and military boundaries, skills directly aligned with ETAC of ABET outcomes and lifelong professional growth.

Future Work

Future directions for the P.R.I.S.E.M. project and the broader **University–Defense Collaborative Design Framework** include:

- **Field Validation:** Conducting live-fire testing and operational feedback sessions with Special Forces personnel to assess sight durability, accuracy, and usability under combat-relevant conditions.
- **Framework Expansion:** Scaling the APSU–Eaglewerx collaboration to include additional military partners and cross-disciplinary student teams spanning mechatronics, cybersecurity, and materials engineering.
- **AI-Driven Design Integration:** Incorporating artificial intelligence and generative design tools into the additive manufacturing curriculum to accelerate optimization of mechanical performance and print efficiency.
- **Quantitative Assessment:** Developing rubrics and survey instruments to measure student learning outcomes, technical competency, and professional identity growth within mission-driven project environments.
- **Dissemination and Replication:** Sharing curricular models, design documentation, and field data to encourage replication of this approach across other Engineering Technology programs and defense innovation networks.

Ultimately, the P.R.I.S.E.M. project illustrates how **purpose-driven engineering education** can align seamlessly with **national innovation priorities**. By linking student creativity with defense needs through structured collaboration, Austin Peay State University and Eaglewerx have established a model for **transformative, real-world learning**, one that prepares future technologists not just to design solutions, but to serve with impact.

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