MAXWELL REBELLA

Mechanical Engineering & Computer Science · University of Wisconsin–Madison

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I combine strong technical skills with creative, abstract problem solving to translate ideas into real-world results. My engineering experience spans structural and composite design, fluid dynamics, injection molding, and medical device development, with hands-on experience designing for real-world manufacturing and assembly. This technical depth, paired with a strong work ethic, gives me the agency to take ownership, solve difficult problems, and create tangible value.

SELECTED WORK *Full research paper, drawing packages, and CAD available on request.*

	PROJECT	FOCUS	OUTCOME
01	WiscMed Rechargeable Otoscope Power Handle	Medical device · Li-ion power system · PCB & firmware	Entering production · Q1 2027 launch
02	WiscMed Nasal Foreign-Body Extraction Tool	Medical device · Mechanism · DFM	<15¢ molded cost · patent pending
03	Modular Injection Mold Base	Mechanism design · Tooling · Hydraulics	30–60 min → <5 min changeover · in use at UW
04	Gradient-Reinforced Composite Tooling	Materials R&D · DOE · Process development	~6× cheaper than aluminum tooling · patent pending
05	FSAE Monocoque Mounting Attachments	Structural design · FEA · Composites	38% mass reduction · ±7% FEA/test correlation
06	FSAE Aerodynamic Ready-to-Move Light	CFD · Packaging · Optics	47% drag reduction · 12.4 g assembly
07	Software & AI Projects	Full-stack · RAG · Computer vision	deventic.ai live · custom YOLO pipeline

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01 Rechargeable Power Handle for Digital Otoscope

Design for FDA & IEC regulation · Mechanical + Electrical + Industrial Design · Custom PCB & firmware design

THE PROBLEM

Optics advancements have led to the development of a digital otoscope that greatly improves diagnostic capabilities versus traditional analog otoscopes. Current battery handles, designed to power a small light source, are suboptimal for the needs of the digital otoscope. These issues include variable rheostat settings, limited battery capacity, proprietary charging docks, and no remaining charge indication.

OBJECTIVES

I was tasked with providing a design-for-manufacturing power handle with consistent output, improved capacity, USB-C charging, and battery strength indication with a production target cost below $125/unit.

ENGINEERING CHALLENGES, APPROACH & SOLUTIONS

The power handle needed to integrate a 3.7 V lithium-ion cell, two circular PCBs, USB-C charging, status indicators, power switching, and regulated output within a 3.0 cm-diameter housing—all while remaining practical to injection mold and assemble. Charging and status indication was deemed best positioned at the base while switching and power output at the top. The design necessitated a compact, repeatable connection between the two PCBs without compromising reliability or manufacturability. These constraints introduced challenges with ensuring robust internal connections and minimizing assembly complexity.

I designed the enclosure around injection-molding requirements, ultrasonic welding, PCB retention, battery access, and an efficient assembly sequence. The internal architecture uses two custom PCBs arranged around a high-capacity 18650 lithium-ion cell. I developed mounting bosses, component clearances, battery-retention features, and electrical conductor paths to support this layout (*Figures 1 & 2)*.

The base PCB manages USB-C charging, battery fuel gauging, MCU and I^2C communication, and LED control. The upper PCB manages boost conversion, circuit protection, power switching, and regulated output. Voltage-protection features are distributed across both PCBs to improve fault isolation and overall system reliability.

A MAX17048 fuel-gauge IC provides load-independent state-of-charge monitoring. I also incorporated a hard undervoltage shutdown to protect the battery and prevent the gradual decline in output performance that can occur as cell voltage falls.

Rigid metal-strip interconnects replace long internal wires, reducing wire-pinching risk, simplifying assembly, and improving unit-to-unit manufacturing consistency.

VALUE

I achieved a 16% reduction in components over an industry-leading power handle with greater capacity and reliability—while providing a stylish design matching the Wispr digital otoscope aesthetics (*Figure 5*).

DIGITAL OTOSCOPE BATTERY HANDLE

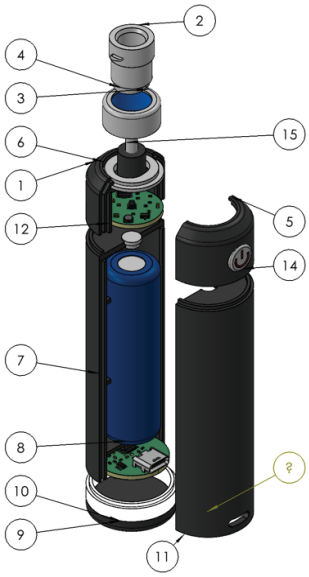


Figure 1 Exploded assembly of initial design.



Figure 2 SolidWorks design and FDM 3D print of housing.

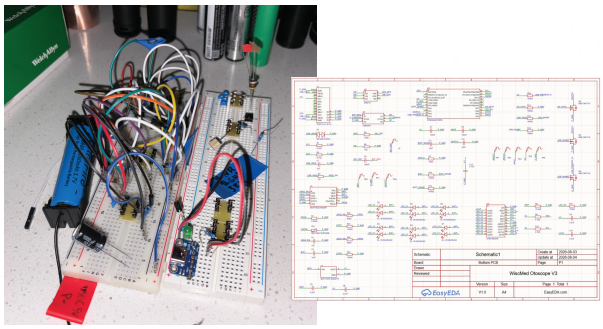


Figure 3 Schematic and early PCB design.



Figure 4 Early physical iterations to assess industrial design elements and branding.



Figure 5 Power handle with Wispr otoscope attached and rendering developed for presentation to WiscMed board.

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02 Nasal Foreign Body Extraction Tool

Medical device accessory · Iteration & Clinical Testing · DFM · Utility patent pending (WARF)

THE PROBLEM

Foreign body extraction from nasal passages often requires significant resources for removal, particularly in children. There is potential to expand the clinical usefulness and marketability of the Wispr digital otoscope by providing an accessory device that leverages its lighting and visualization capabilities.

OBJECTIVE

I was tasked with designing a low-cost foreign body retrieval device that attaches to the Wispr digital otoscope.

ENGINEERING CHALLENGES, APPROACH & SOLUTIONS

The tool needed to allow retrieval of a variety of shaped foreign bodies without injuring the sensitive tissue in the nasal passage. The device must be ergonomic, operate smoothly, and attach seamlessly with the otoscope without altering its base design. Material properties necessary for prototyping versus those used in manufacturing introduced challenges in developing economical functional prototypes.

I utilized a two-component retrieval system combining a commercially available balloon-catheter attached to a customized right-angled inflation tool (*Figure 6*). The final iteration utilizes a plunger & barrel with an internal right-angled channel capable of delivering 2ml of air to the balloon-catheter (*Figure 7*). Trials with materials for prototyping to match the polypropylene used in manufacturing were undertaken with PLA filament, PP filament, ABS-like resin, and PP resin. The most successful material was PLA filament that was then lubricated with silicone, facilitating an air seal and easy inflation pressure (*Figure 8)*.

VALUE

Final architecture packages the mechanism into three injection-moldable parts, 17 mm depth, and 4.8 g total mass, with a projected molded component cost below $0.15/unit excluding the catheter. The device provides WiscMed with an additional high ROI product offering as well as enhancing the value of the otoscope for their customers, increasing its marketability and improving sales by an estimated >10%. I am a co- inventor on **nonprovisional utility patent** filed through the Wisconsin Alumni Research Foundation (WARF) *(Figure 9)*.

FOREIGN BODY EXTRACTION TOOL



Figure 6 SolidWorks final design ⓐ and early assembly iteration ⓑ.



Figure 7 Rendering of complete assembly attached to Wispr otoscope.

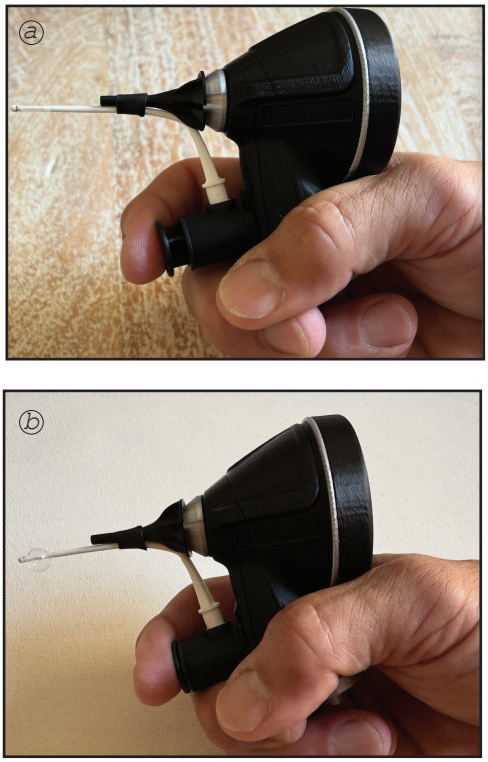
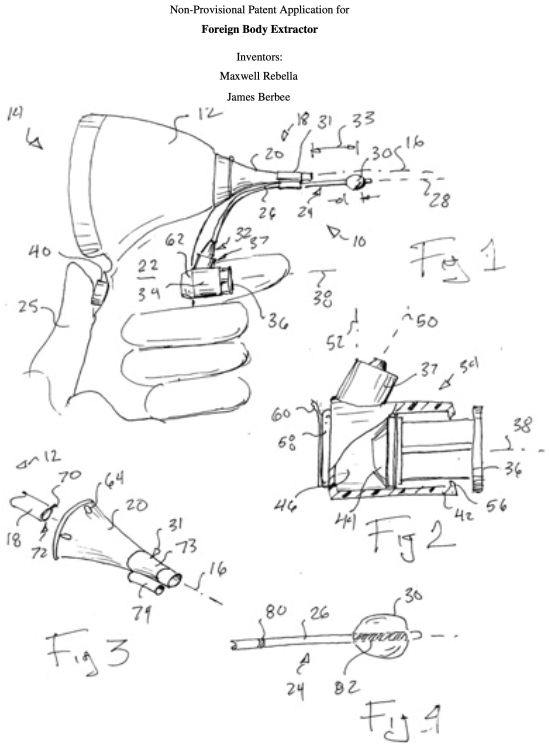


Figure 8 3D printed functional prototype. Deflated balloon ⓐ. Inflated state via pressure to the plunger ⓑ.


Non-Provisional Patent Application for

Foreign Body Extractor

Inventors:

Maxwell Rebella

James Berbee

Figure 9 Patent application artwork, assigned to Wisconsin Alumni Research Facility.

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03 Modular Injection Mold Base for Rapid Insert Swapping

Mechanism design · SolidWorks Mold Flow · Creative Thinking · Machining & Tooling · Hydraulics · Utility patent pending

THE PROBLEM

I wanted a low-cost way to injection mold my own product ideas without building a complete dedicated tool for every geometry. Conventional mold setups often tie each cavity/core set to its own mold base, ejector hardware, and press setup, making low-volume iteration expensive. Product changeovers can also require removing and reinstalling the full mold assembly, creating roughly 30–60 minutes of machine downtime and reducing the economics of short production runs.

OBJECTIVE

Design an injection mold insert to facilitate easier and more rapid mold changes and setup.

ENGINEERING CHALLENGES, APPROACH & SOLUTIONS

Rigid under load, fast to exchange. The insert had to resist 50,000+ lbs of clamp force without shifting but still release quickly during changeovers. I designed locking pins that pass through the mold base and into the insert, carrying the load mechanically during molding. Retracting the pins releases the insert so it can be swapped without removing the full mold from the press (*Figure 10)*.

Configurable ejection. Because each insert can require a different ejector pattern, a fixed ejector plate would defeat the modular design. I created custom ejector pins with locking grooves that fit into a sliding comb, allowing pins to be placed anywhere in a 6 × 6 in field with 760 possible locations. Sliding the comb into place locks the selected pins together; a hydraulic cylinder then drives them as one set. Retracting the comb releases the pins for rapid reconfiguration (*Figure 11*).

VALUE

My modular mold base system is now **in use at the UW–Madison Polymer Engineering Center**, where it reduced mold changeover from 30–60 minutes to under 5 minutes by allowing both cavity inserts and ejector layouts to be reconfigured without removing the full mold base from the press. Testing at molding temperature and full clamp load showed no observed insert shift or flashing, validating the locking and ejection architecture. **Patent pending USPTO No. 63/740,887**.

MODULAR INJECTION MOLDING BASE

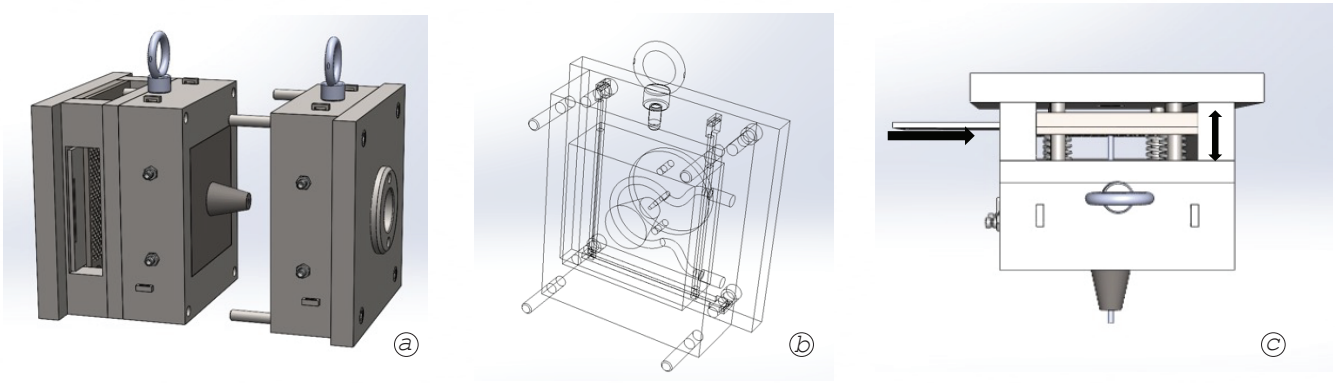


Figure 10 SolidWorks assembly of the modular mold base with representative interchangeable cavity insert ⓐ. X-ray view showing the internal locking pins engaging the removeable mold insert to resist molding loads ⓑ. Close-up of the custom sliding-comb mechanism used to lock and actuate ejector-pin layouts ⓒ.

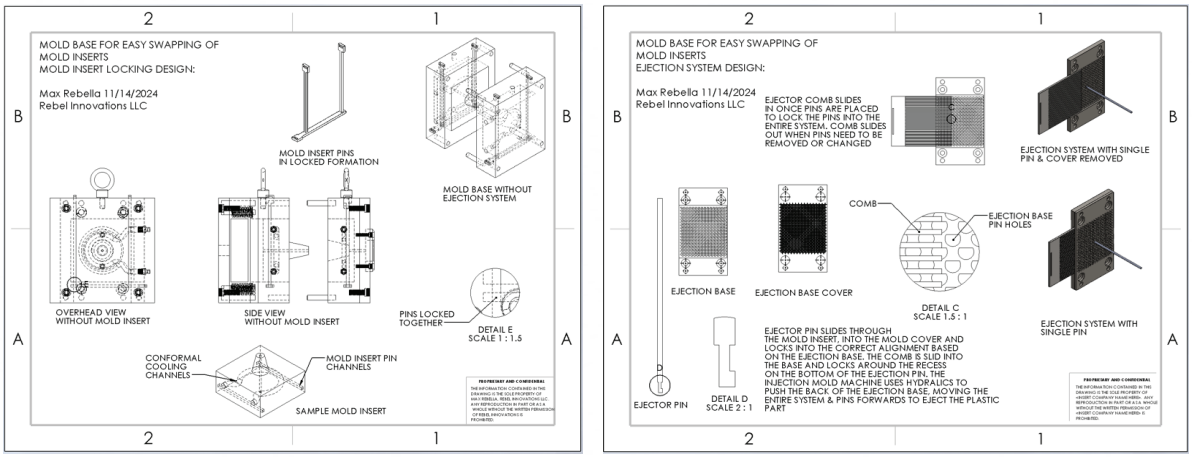


Figure 11 SolidWorks engineering drawings detailing the mold-insert locking interfaces and configurable ejector-pin and sliding-comb mechanism.

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04 Gradient-Reinforced Composite Injection Mold Insert Research

Materials R&D · Design of experiments · Process development · Utility patent pending

THE PROBLEM

There is a major gap between prototype molds and production tooling: metal molds are durable but expensive and slow to machine, while polymer/composite molds are faster and cheaper but limited by surface wear, thermal performance, and cycle life.

OBJECTIVE

I set out to develop a full two-plate mold that could maintain standard injection-molding tolerances, cost at least 5× less than metal tooling, and push beyond the typical ~10,000-cycle composite limit by concentrating reinforcement only where the mold needs it.

THE INSIGHT

Metal, ceramic, and carbon reinforcement can improve surface hardness, wear resistance, and thermal performance, but uniformly reinforcing an epoxy mold adds cost and is constrained by the matrix itself. More importantly, most of the mold does not experience the same thermal and mechanical demands as the cavity surface. I used centrifugal force to create a controlled reinforcement gradient, concentrating atomized stainless steel and zirconia near the cavity face while leaving the bulk of the mold epoxy dominant. This puts the highest-performance material where wear and heat are concentrated, without paying the cost or manufacturing penalty of reinforcing the entire mold.

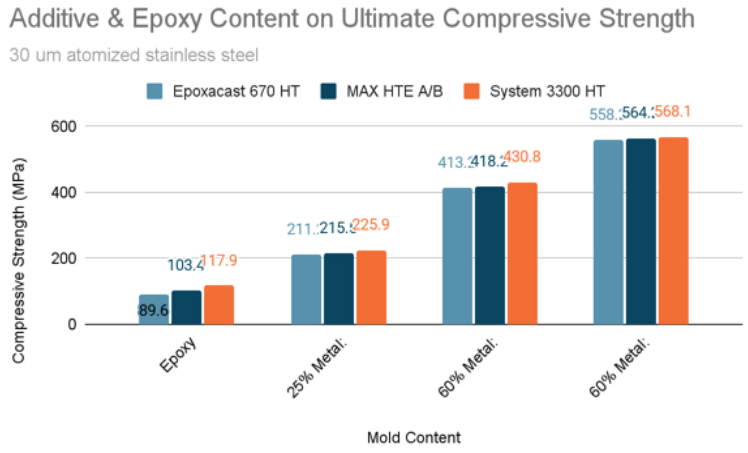
METHOD

Phase I (*Graph 1*) characterized the composition space — epoxy systems, 30–44 µm atomized stainless, powdered zirconia, chopped carbon fiber — against hardness, compressive strength, thermal resilience and castability. Phase II (*Graph 2*) turned those relationships into gradients in a custom high-torque centrifuge I designed, with angular velocity and duration as control variables: gradient strength scales non-linearly with RPM, from near-zero to over 70% metal change per inch between 1,000 and 7,000 RPM, which makes the gradient a tunable process parameter rather than a side effect. Cavity, gates, ejector channels and conformal cooling are formed by a 25–40 µm SLA shell, which removes CNC machining entirely and makes conformal cooling nearly free.

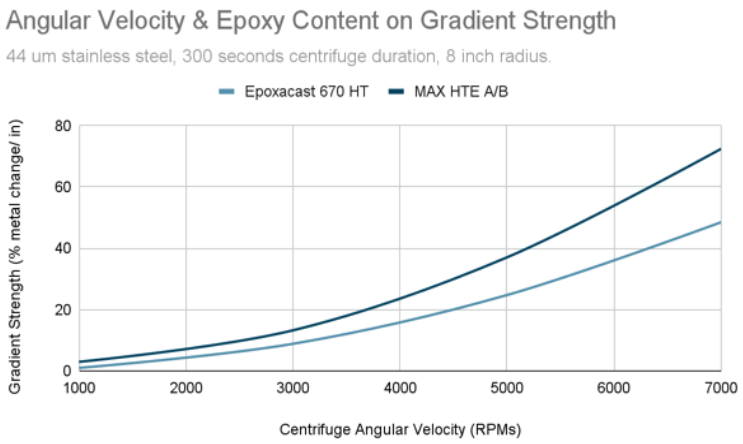
RESULTS & VALUE

For a 6 × 6 × 2.5 in two-plate mold, the graded composite achieved a <5% to >80% metal gradient, ≈44 HRC comparative cavity-face hardness, 572 MPa strength, and 25–40 µm SLA precision (*Table 1*). Tool cost was approximately $410 vs. ≈$2,500 for aluminum and production was roughly 70% faster. Metal-rich regions approached aluminum-like thermal behavior, while repeated molding of ABS, PP, and medical-grade materials showed no observed degradation. **Patent pending USPTO No. 63/740,887**

GRADIENT-REINFORCED COMPOSITE INJECTION MOLD RESEARCH



Graph 1 Phase I experiment with various epoxy systems, demonstrating increased compressive strength with increasing atomized steel fractions.



Graph 2 Phase II experiment process model showing the nonlinear relationship between centrifuge angular velocity and resultant through-thickness reinforcement-gradient strength.

PERFORMANCE METRIC	BEST BALANCE	HIGH-TEMP	LOW COST	AL 6061-T6	P20 STEEL
Stainless content	60% / 44 µm	45% / 44 µm	40% / 44 µm	—	—
Spin condition	5000 RPM / 240 s	4000 RPM / 300 s	5000 RPM / 400 s	—	—
Gradient strength	≈33.4 %/in	≈22.5 %/in	≈41.4 %/in	—	—
Hardness, cavity face (HRC)	≈44.3	≈36.8	≈35.0	≈17.0	≈32.5
Ultimate compressive (MPa)	572	528	295	≈310	≈1050
Max injection temp (°F)	475	575	425	≈800	≈1200
Dimensional precision (µm)	40	40	35	≈25	≈15
Est. cycle life	100,000	80,000	15,000	50–100,000	300,000+
Machine + material cost	**$410**	**$520**	**$180**	**≈$2,500**	**≈$5,000**

Table 1 Cost basis analysis for a 6x6x2.5in two-plate mold. Cycle life is estimated by comparing measured performance against published specifications for standard tooling. HRC on a metal-epoxy composite is comparable, not equivalent to bulk metal hardness.

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05 Formula SAE Monocoque Mounting Attachment Redesign

Structural design · FEA · Composites · Experimental validation · Technical Leadership & Communication

THE PROBLEM

Wisconsin Racing's carbon-fiber monocoque transfers suspension and powertrain loads through epoxy-bonded 7075-T6 aluminum inserts embedded in the composite structure. The original inserts were solid and structurally conservative, contributing 2.6lbs to a highly weight-sensitive vehicle.

OBJECTIVE

Our four-person team's objective was to remove maximum material while preserving interface geometry, stiffness, load capacity, and manufacturability.

ENGINEERING CHALLENGES, APPROACH & SOLUTIONS

Multiple load cases & failure modes. The attachments experience combinations of axial tension/compression, transverse shear, torsion, bearing, and pull-out loading. Material non-critical in one load case could become part of the primary load path in another, so each geometry was evaluated across separate Simcenter NASTRAN cases using historical vehicle-force data and strain-gauge measurements.

Model fidelity & validation. Early FEA diverged from physical testing. Rather than empirically tuning the model, we characterized the 7075-T6, composite layup, and structural epoxy, then incorporated measured Young's modulus and tensile, compressive, and torsional properties into the analysis.

Optimization vs. manufacturability. The lowest-mass geometries were not feasible on the team's 3-axis CNC equipment. I iterated pocket geometry, rib thickness, radii, and contours to preserve critical load paths while keeping all features machinable.

TEAMWORK & TECHNICAL LEADERSHIP

As a second-year member, I helped lead three new engineers, teaching the FEA and validation workflow, assigning CAD, analysis, and testing work, and reviewing results as a team. I especially enjoyed the late nights in the shop—running simulations, machining parts, testing, and working through failures together. The project reinforced how much I enjoy technical teams where engineers challenge one another, share ownership, and converge on a validated solution.

VALUE

The final 7075-T6 attachments were CNC-machined and bonded into the monocoque with Hysol EA 9396. The redesign removed 422 g / 36% of attachment mass while maintaining torsional stiffness within 2%. Static torsion and deflection testing matched predicted strains within ±7%.

FORMULA SAE MONOCOQUE MOUNTING ATTACHMENT

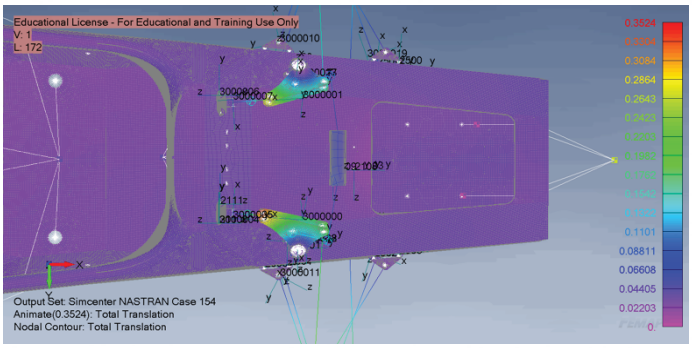


Figure 12 Simcenter NASTRAN total-displacement contour for baseline suspension/powertrain load case prior to material removal; used to establish structural load-transfer behavior.

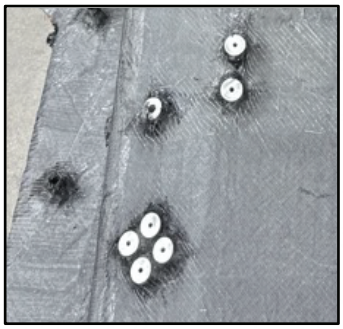


Figure 13 Close-up of early 7075-T6 mounting inserts embedded within the carbon-fiber monocoque structure.

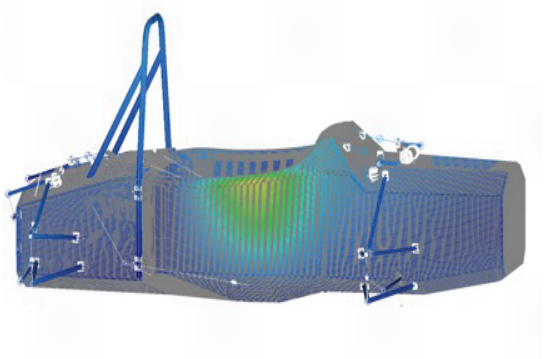


Figure 14 Full Simcenter NASTRAN model incorporating the monocoque, suspension mounting attachments, chassis beams, and head-mount beam for system-level structural FEA.



Figure 15 Carbon-fiber monocoque mold after epoxy cure; mounting attachments are embeddd during the subsequent layup process prior to sanding and surface finishing.

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06 Formula SAE Aerodynamic Ready-to-Move Light

CFD · Packaging · Optical isolation · Additive manufacturing · Wisconsin Racing

THE PROBLEM

FSAE rules require an illuminated Ready-to-Move Light (RTML) indicating when the vehicle is energized and capable of motion. Wisconsin Racing's existing rectangular housing met the requirement but produced unnecessary aerodynamic drag, added mass, and poorly integrated with the vehicle's aero package.

OBJECTIVE

I set out to redesign the assembly around the 2026 FSAE luminous-area, placement, and electrical-isolation requirements while improving aerodynamic performance.

ENGINEERING CHALLENGES, APPROACH & SOLUTIONS

Aerodynamics vs. electronics packaging. CFD favored a compact airfoil profile, but the PCB, LEDs, wiring, and required optical separation needed more internal volume. Increasing the section to fit the electronics would sacrifice much of the aerodynamic gain. I developed a two-chamber enclosure, isolating the amber/green status LEDs from the primary indicator to eliminate color bleed while keeping the PCB within the existing airfoil envelope. PCB dimensions and enclosure geometry were iterated directly with the electrical team.

Optical performance. Transparent FDM materials produced haze and surface artifacts that scattered light and reduced indicator clarity. I moved the transparent components to SLA printing, achieving substantially cleaner light transmission without additional post-processing.

I iterated symmetric airfoil geometries in ANSYS Fluent, comparing drag, downforce, flow separation, packaging volume, and manufacturability. The aerodynamic surface, PCB layout, optical chambers, mounting interface, and hood-bar integration were developed together rather than as separate systems.

VALUE

The final 12.4 g symmetric-airfoil housing reduced drag from 12.0 N to 6.4 N (47%), increased maximum downforce from 14.5 N to 15.8 N, and removed 8.6 g from the previous assembly. At approximately 88 mph, the aerodynamic improvement is equivalent to roughly 1.43 lb of effective mass reduction, while maintaining the required FSAE visibility, electrical isolation, and packaging constraints.

FORMULA SAE READY-TO-MOVE LIGHT

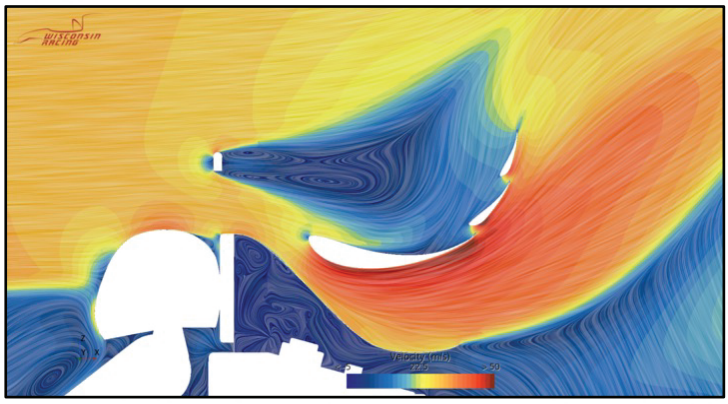


Figure 16 ANSYS Fluent flow-field analysis used to evaluate wake formation, flow separation, drag, and aerodynamic interaction around Ready-to-Move Light

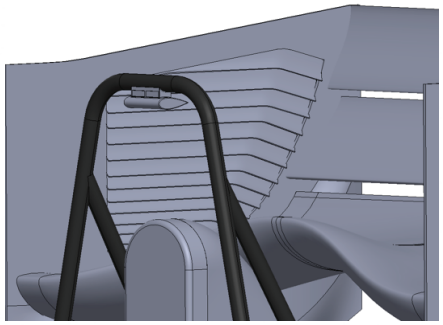


Figure 17 SolidWorks assembly showing integration of the redesigned aerodynamic RTML into the complete Formula SAE car.



Figure 18 Previous RTML assembly with bulky geometry and mass negatively impacting aerodynamics.

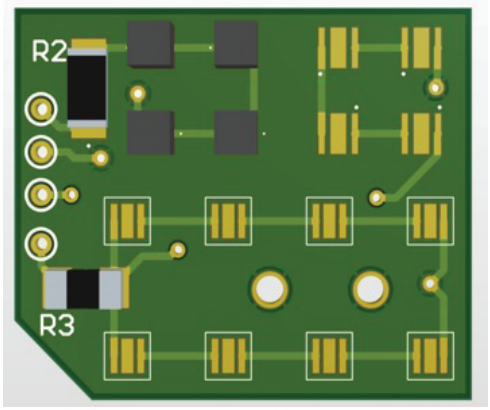


Figure 19 Custom RTML PCB with component layout and dimensions constrained to the minimum aerodynamic housing cross-section.

07 Software & AI - ENTITLEMENT & PRE-CONSTRUCTION REGULATORY AUTOMATION

Two projects outside mechanical design, included for systems and data work

THE PROBLEM

Real-estate development is driven by thousands of interconnected constraints—zoning, permits, engineering requirements, utilities, environmental conditions, financing, market assumptions, and agency approvals—but the underlying information is fragmented across municipal websites, PDFs, scanned ordinances, GIS databases, assessor records, and project documents. I built Deventic to organize that information into a single computational model, then determine the most viable path from site acquisition to shovel-ready construction.

CHALLENGES, APPROACH & SOLUTIONS

Turning fragmented data into a query-able system. Municipalities publish the same types of information in completely different formats and structures. I built an ETL pipeline using custom web scrapers, API ingestion, OCR fallback, document classification, hierarchical chunking, structured extraction, and geospatial joins to normalize these sources into a common schema. PostgreSQL/PostGIS stores parcel and spatial data, while embeddings and vector search allow AI to retrieve relevant regulations and project evidence without losing the original jurisdiction, document, or source.

Searching thousands of possible development strategies. Changing density, parking, land use, entitlement path, construction type, phasing, financing, or schedule creates a rapidly expanding state-space of possible projects. I built a scenario-search system that generates candidate paths and uses constraint-based pruning to reject impossible branches early—for example, exceeding zoning capacity, utility limits, lender constraints, or site-control deadlines—before running more computationally expensive analyses. Surviving scenarios are evaluated across financial, architecture, entitlement, utility, civil, traffic, environmental, and legal models, then compared on return, capital need, schedule, risk, and uncertainty.

Computing and continuously updating. I modeled permits, hearings, agency decisions, and project tasks as a directed acyclic graph (DAG) rather than a fixed checklist. Kahn's topological-sort algorithm determines which tasks can execute next, cycle detection prevents impossible dependency chains, and longest-path analysis identifies the critical path to approval. An event-driven state machine processes events such as permit approvals, denials, deadlines, conditions, and agency responses; when something changes, dependency traversal identifies the affected downstream nodes and recalculates only the impacted portion of the project plan.

VALUE

The result is not simply an AI wrapper over development documents. Deventic combines **data pipelines, spatial databases, graph algorithms, search optimization, deterministic engineering/business models, and AI reasoning** into one system that can answer: *What can be built here? What paths are possible? Which constraints eliminate them? Which path is best? What must happen next to reach approval?* When new information arrives, affected calculations and scenario rankings are automatically invalidated and recomputed, keeping the project model synchronized with the real-world development process.

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08 Pole Vault Biomechanics Computer Vision Project

Computer Vision · YOLO · PyTorch · D1 Athletics

THE PROBLEM

As a Big Ten collegiate pole vaulter, I wanted a more objective way to analyze a movement that occurs too quickly and with too many coupled degrees of freedom to assess reliably by eye. Small deviations in takeoff geometry, joint sequencing, segment angular velocity, pole rotation, and body–pole interaction can materially change the outcome of the vault.

OBJECTIVES

I built this project to combine my experience in pole vaulting with my interest in learning new computer-science techniques to become a stronger software engineer.

ENGINEERING CHALLENGES, APPROACH & SOLUTIONS

Training videos vary in camera angle, scale, frame rate, lighting, and occlusion, making raw pixel coordinates unreliable across attempts. Pole bending also continuously changes its geometry, while body overlap and dropped detections break naïve frame-by-frame tracking. I addressed this using temporal association, interpolation, smoothing, coordinate normalization, and body-segment scaling to maintain stable athlete and pole trajectories across inconsistent video.

Feature engineering & modeling. A custom YOLO-based model detects athlete keypoints and the pole. Tracked coordinates are converted into joint angles, linear/angular velocities, pole angle, and athlete–pole geometry, then segmented into plant, takeoff, swing, and extension and time-normalized for phase-to-phase comparison. The resulting multivariate sequences feed a PyTorch temporal neural network trained on curated elite footage, allowing technique comparison in normalized biomechanical feature space rather than raw pixels.

VALUE

The project gave me hands-on experience with computer vision, neural networks, object tracking, feature engineering, data normalization, and time-series modeling while applying them to a technical problem in a sport I enjoy.

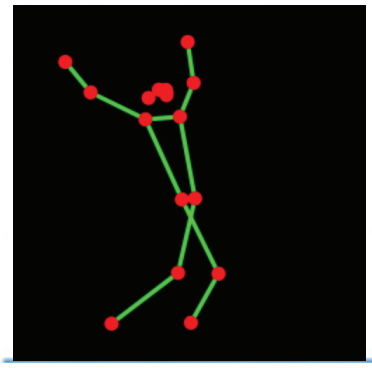
POLE VAULT BIOMECHANICS COMPUTER VISION PROJECT

Graph 3 Body angles versus time of a sample pole vault; converting frames to time.



Time 1.00-1.60: Planting of pole. Body in extended position. Still on ground.
Time 1.60-1.80 seconds: Initial Jump. Throwing shoulders, increasing angle.
Time 1.80-2.10: Swing. Long movement extended movements.
Time 2.10-2.35. Curled Position. Body position tight and hard angles.
Time 2.35-3.3: Extension up the pole. Body back in extended position.
Time 3.30+: Curl over the pole, vault finished. Start of erratic movement.)

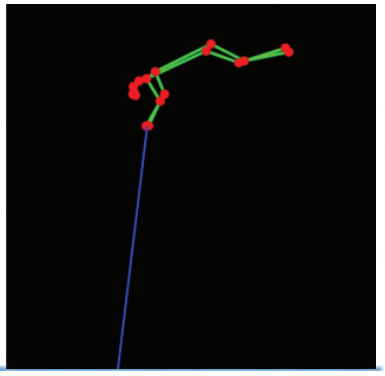
Figure 20 Computer modeling and illustrated images of selected phases and timing.



Plant & Take off
(1.00-1.60)



Initial Jump & Swing initiation
(1.60-1.80)



Clearance
(3.30+)

Max Rebella

Mechanical engineering | University of Wisconsin-Madison

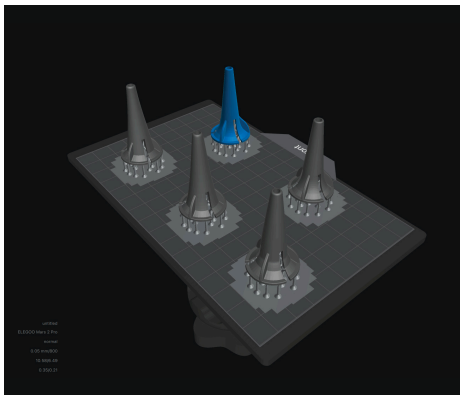
Additional Projects

Industrial design, CAD, and injection molding



Wall mount collar

Designed to secure the otoscope in a commercial wall mount.



Speculum redesign

Refined geometry for patient comfort and device fit.



Wispr protective cover

A fitted cover designed to protect the Wispr otoscope.





Wisconsin Racing

Formula SAE Electric

Team results

6th overall

1st in design

1st in acceleration



Athletics & academics

UW Student-Athlete Academic Award
2023 & 2024

All-Big Ten Academic Team
2023

National Merit Scholar