

Kareem Abu Salah

HARDWARE ENGINEERING PORTFOLIO

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B.S. Mechanical Engineering · A.B. Computer Science · Duke University, Pratt School of Engineering · Expected May 2028 · GPA 3.56

ABOUT

I reason from physics and cost, then validate the design against what I measure. I study mechanical engineering and computer science at Duke, and I build physical systems end to end: structures, enclosures, power, and the firmware that runs them. I also operate what I build, with 30+ flight tests on lab hexacopters and 26 FPV drones built and tuned. This portfolio collects six projects. Five carried from CAD to prototype to test and were revised against measured data; the solar sail is analyzed and specified, with its tests planned for the build phase.

TECHNICAL SKILLS

PRODUCT DESIGN & CAD

SolidWorks · Onshape · enclosure, snap-fit & wall-thickness design · production drawings · GD&T per ASME Y14.5 · functional dimensioning

MATERIALS & PROCESSES

thermoplastics (ABS, PLA, PETG) · CFRP composites · adhesive bonded joints · polyimide film · metals · materials selection

PROTOTYPING & TEST

FDM printing · CNC mill & lathe · G-code · CFRP wet layup · laser cutting · Pratt shop certified · static-load & water-ingress test, modal FEA correlation planning

DFM / DFA

injection-molding design · straight-pull tooling · worst-case tolerance stack-up · sink & warp control · BOM & per-unit cost ownership

ANALYSIS

FEA (Ansys, EasyFEA) static, modal, thermal · classical hand calculation · mass & margin optimization · trade studies

ELECTRONICS & SOFTWARE

Altium / KiCad PCB · Arduino, ESP32, STM32 · FreeRTOS · I²C / SPI / UART · Python · C++ · embedded C

SELECTED PROJECTS

01	Duke Solar Sail.	Materials selection, beam-element modal FEA, a verification test plan, and integration and test.	p.2
02	CubeSat.	1U enclosure packaging, internal layout, embedded sensing, and launch-load FEA.	p.3
03	Plantogachi.	ESP32-S3 sensor firmware, a \$32 snap-fit enclosure, and a shipped app MVP.	p.4
04	McRocket.	Injection-molding DFM, worst-case tolerance stack-up, and a snap-fit toy modeled at \$0.36/unit.	p.5
05	Sunflower Seed Shelling Machine.	Roller mechanism and gear drive, fastest across all four sections.	p.6
06	Tiger Enrichment Device.	Client product validated to 400 lb and a water soak, with scent electronics.	p.7

Not shown: FaunaLabs, Embedded & Mechanical Intern, Mar–Sep 2026. I qualified a whale-tag enclosure to 20 MPa, designed a timed-release link, and fixed a Cortex-M7 cache/DMA race that cut dropped sensor frames 90%, with 97% uptime across the deployed fleet. Publishing is restricted.

01 Duke Solar Sail CFRP Frame Structure

Structures and Integration & Test Lead · Duke Solar Sail Spacecraft, Earth Cup RACE 1 · Mar 2026 – Present

MATERIALS SELECTION · MODAL FEA · TEST PLANNING · INTEGRATION & TEST

27.6 Hz

first mode, Python FEA vs. the standard's 20 Hz floor

2.96 g

per beam, 25% under mass budget

+73%

EI margin ($6.56 \text{ N}\cdot\text{m}^2$)

1 of up to 50

teams advanced to STEP 2

I led the structural design, modal analysis, and verification test plan for a **hexagonal carbon-fiber frame**, 0.5 m per edge, that tensions a thin CP1 polyimide membrane, for Earth Cup RACE 1, an international student spacecraft competition. The design clears both MembraneSat Standard floors, flexural rigidity $EI \geq 3.8 \text{ N}\cdot\text{m}^2$ and launch first-mode $f_1 \geq 20 \text{ Hz}$, inside a tight mass budget. We advanced to **STEP 2, one of up to 50 teams**. The frame is **analyzed and specified, not yet built**, at technology-readiness level (TRL) 3 to 4; STEP 2 is the build-and-test phase toward TRL 6 and a very-low-Earth-orbit launch targeting summer 2027.

MOTIVATION

Every gram of frame lowers the sail's area-to-mass ratio and its solar-pressure thrust, so the job is to hit the stiffness floor at minimum mass.

MY ROLE

I chose the material and cross-section, built the beam-element modal model, cross-checked it by hand, and wrote the verification test plan. As Integration & Test Lead I am now writing the magnetorquer acceptance procedure and reviewing how the membrane attaches to the frame.

TECHNICAL APPROACH

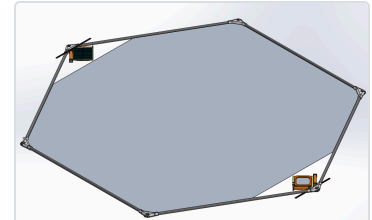
Material and cross-section. High-modulus M40J-class CFRP tubes joined at SLS-nylon nodes: specific stiffness about $5\times$ aluminum, near-zero axial CTE to hold preload across the $10\text{--}50^\circ\text{C}$ launch band. I took the round tube over a stiffer square (I/A 1.00 vs 1.34 at equal area) for roll-wrapped manufacturability and buckling margin. A seven-geometry OD/wall sweep landed on $8.0 \text{ mm} \times 0.15 \text{ mm}$, 2.96 g per beam, clearing the EI floor by 73%.

Modal FEA. A 402-DOF Python beam-element model (EasyFEA): six edges as Euler–Bernoulli beams, five nodes clamped. First mode out-of-plane at 27.6 Hz against the 20 Hz floor, mode-2 gap over $11\times$; a Rayleigh two-cantilever hand check lands within 4.3%. A lumped-mass sweep at the free node set the 15 g node mass budget. Ansys with rigid clamps gives 37.8 Hz; the gap is the rigid-clamp assumption against the real joint.

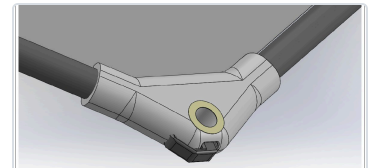
Verification plan (planned, not yet run). Every gate ties to a prediction: $k_{\perp} 345 \text{ N/m} \pm 15\%$, $f_1 \pm 10\%$, linearity $R^2 > 0.99$. A 0.8 g ICP accelerometer caps modal-test mass loading at 7%, so the plan corrects the f_1 gate from 27.6 to 26.7 Hz. An eight-cycle -40 to $+85^\circ\text{C}$ thermal-vacuum plan targets the riskiest joint, carbon bonded to nylon. I screened 3M Scotch-Weld 2216 for outgassing: CVCM 0.04%, TML 0.77% against ASTM E595.

Integration & test, in progress. I am writing the magnetorquer acceptance procedure: a water-float jig simulates 0 g and confirms each unit aligns with the field. Membrane attachment methods are under review against the literature; my review ruled out a rigid film mount on thermal growth and recommended constant-force springs at the nodes.

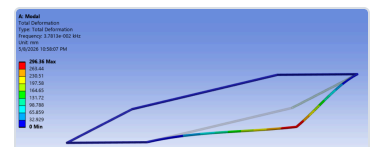
What I would do differently. I ran the Ansys cross-check after the Python model, so the rigid-clamp gap surfaced late; I would reconcile the two models before any hardware.



SolidWorks isometric of the sail assembly I designed: the hexagonal CFRP frame tensions the CP1 membrane, with magnetorquers and ChipSats on opposite edges for a balanced center of mass.



CAD node detail: a triangular SLS-nylon joint with rounded fillets carries load into the tube ends; the shear pad and screw hold the deployment preload.



Ansys modal cross-check of the first bending mode at 37.8 Hz with rigid clamps, an upper bound on the 27.6 Hz Python FEA result; both clear the 20 Hz floor.

02 CubeSat Atmospheric Sensing System

Structures & Flight-Computer Engineer · Duke SEDS · Sep 2025 – Present

ENCLOSURE PACKAGING · INTERNAL LAYOUT · LAUNCH-LOAD FEA

28 km

peak altitude logged in flight

2×

FEA margin at the 9 g launch spec

8 screws

the only fasteners in the assembly

9 parts

printed jigsaw-keyed chassis

I owned the chassis and internal layout for a **1U CubeSat prototype that records atmospheric data on a weather-balloon flight**. I designed the printed structure, wired and tested all electronics, wrote the Arduino firmware, and ran FEA confirming the structure survives a 9 g launch load at a 2× safety factor. I analyzed to the CubeSat launch spec rather than the balloon's actual loads, so the chassis carries over to a future orbital launch unchanged.

MOTIVATION

A flight-representative 1U prototype for the Duke Society for Exploration of Deep Space. It has to package sensing, logging, power, and recovery hardware into a printed chassis that survives launch and reads clean outside air at altitude.

MY ROLE

I designed all nine printed parts and the internal layout, wired and bench-tested the electronics, wrote the firmware, and ran the launch-load FEA.

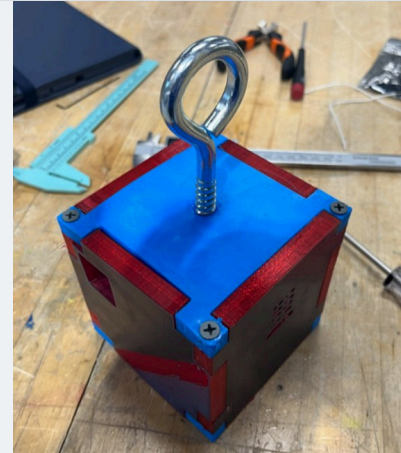
TECHNICAL APPROACH

Chassis. Nine 3D-printed parts, six jigsaw-style exterior panels and three internal mounts, clamp top-to-bottom under eight wood screws through channels. Each panel carries a laser-cut foam insert sized to its components for altitude insulation.

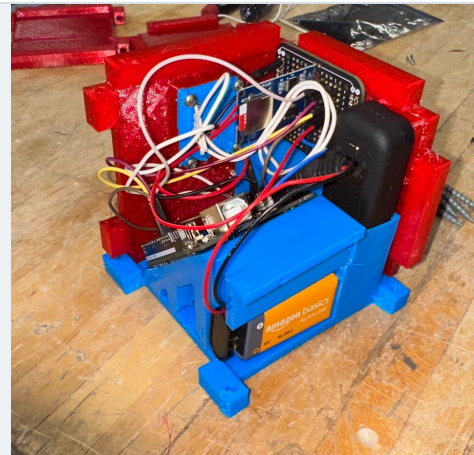
Layout decisions. I angled the Arduino on a 45° platform so the over-long battery cable tucks into the bay. I sealed the BMP390 in a ventilated front cavity so it reads outside air while the electronics bay stays isolated. The camera and the GPS/AirTag tracker each sit in a form-fitted cage for imaging and post-flight recovery.

Electronics. An Arduino Uno reads a BMP390 barometric and temperature sensor over I²C and logs to an SD-card module over SPI through the flight.

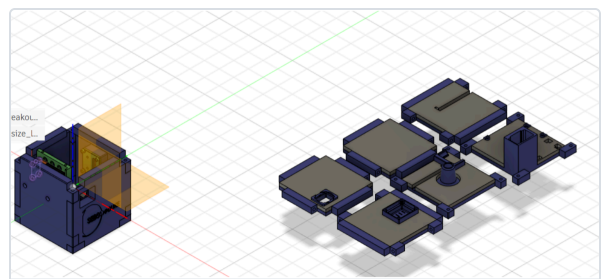
What I would do differently. I angled the Arduino on a 45° platform to swallow an over-long battery cable instead of specifying a shorter one, spending bay volume on a problem I could have deleted. I would drop the wood screws: they carry the 9 g load path into printed panels, and they are the joint I expect to loosen under a vibration the balloon flight never applies.



Second prototype in blue and red PLA: jigsaw panel joints, top-to-bottom screws, and an eyelet for the balloon line.



Chassis with two panels off: the 45° Arduino platform, the enclosed 9 V battery bay beneath it, and the jigsaw tabs that key each panel to its neighbors.



CAD: the assembled cube beside all printed panels laid out flat, the jigsaw keys visible on each panel edge.

03 Plantogachi Sensor-Driven Plant-Care Device

Founder & Hardware/Firmware Lead · Plantogachi · May 2026 – Present

ESP32-S3 FIRMWARE · ENCLOSURE DFM · SENSOR TELEMETRY

\$32

prototype BOM (\$11 quoted at bulk)

3 weeks

battery on one charge, measured

86%

photo species ID

12+

customer-discovery interviews

I founded Plantogachi and lead its hardware and firmware. The product turns a houseplant into a Tamagotchi: **an ESP32-S3 sensor puck reads the plant, streams telemetry over TLS, and drives a pixel-art character in a phone app.** I shipped an end-to-end MVP and tested it across 12+ customer-discovery interviews. The hardware is still a work in progress, so this page shows the software proof of concept.

MOTIVATION

People kill houseplants because care gives no feedback until the plant already looks sick. I make the plant's state legible: the puck measures soil moisture, light, temperature, and humidity, and the app turns those readings into a character that reacts.

MY ROLE

A solo project: I designed the enclosure in SolidWorks, wrote the ESP32-S3 sensor drivers and TLS telemetry, set the bill of materials, and built the app.

TECHNICAL APPROACH

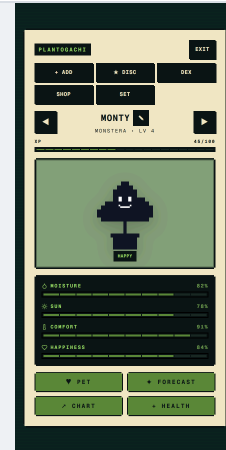
Firmware. An ESP32-S3 reads soil moisture, light, temperature, and humidity, then POSTs each reading over TLS to `/api/v1/telemetry`. I tuned the sample-and-sleep duty cycle for a 3-week battery.

Enclosure. A tool-free snap-fit puck in SolidWorks on 2 mm uniform walls held the device BOM to \$32 at prototype volume (\$11 at bulk); the radio transmits through the plastic, needing no antenna cutout.

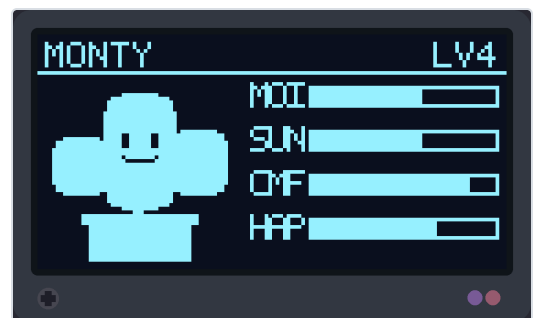
Software the puck feeds. The app IDs the plant from one photo through PlantNet at 86% accuracy, generates a pixel-art sprite, and runs a health check through Gemini Vision. A `GET /plants/{id}/forecast` endpoint also reasons over reading history and species care profile with Gemini, cached 12 hours. A demo slider stands in for the puck.

A second hardware node, single source of truth. Beyond the puck, I built a standalone ESP32 display device with a monochrome screen that renders the same pixel pet from a read-only endpoint, saving battery and CPU by never duplicating the backend's mood logic on-device.

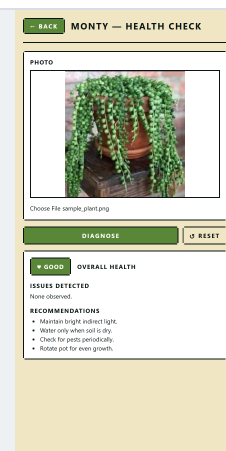
What I would do differently, next. I sequenced software first so the demo held even if hardware slipped, letting the enclosure lag the app instead of negotiating both together. Next: lock the duty cycle and battery target before freezing app scope; live-puck streaming and toy firmware are already built.



The shipped app's home screen: a live plant, its mood, level, and the four sensor-driven stat bars, all reading from the real telemetry pipeline.



The second hardware node: a standalone ESP32 display device (monochrome LCD) rendering the same pixel pet independent of the app. Shown as a to-spec design mockup, not a hardware capture.



An AI health check: a plant photo diagnosed by Gemini Vision, returned as a verdict and care recommendations.

04 McRocket Happy Meal Toy Designed for Injection Molding

Team Engineer, Nose Cone & Flame · EGR 121, Duke University · Spring 2026

DFM/DFA · TOLERANCE STACK-UP · SNAP-FIT · CONSUMER PRODUCT

< \$0.36

per unit in the DFM cost model

0.004"

snap-fit clearance on the FDM prototype

1.30" OD

beats the 1.25" choke test

6 parts

designed for straight-pull molds

A six-part ABS **Happy Meal toy designed for injection molding**: snap-fit, no batteries, under \$0.36 per unit against the course's \$0.50 material-plus-cycle-time cost cap, safe for ages 4 to 8. On a team of four over a 1.5-week sprint I owned the nose cone and the decorative flame, and I drove the design-for-manufacturing decisions that made the whole toy **moldable in a straight-pull tool**.

MOTIVATION

An EGR 121 DFM challenge with hard gates. Every part has to beat the 1.25" choke threshold, snap onto the cylinder body, mold without side-actions, and land under the course's per-unit cost model.

MY ROLE

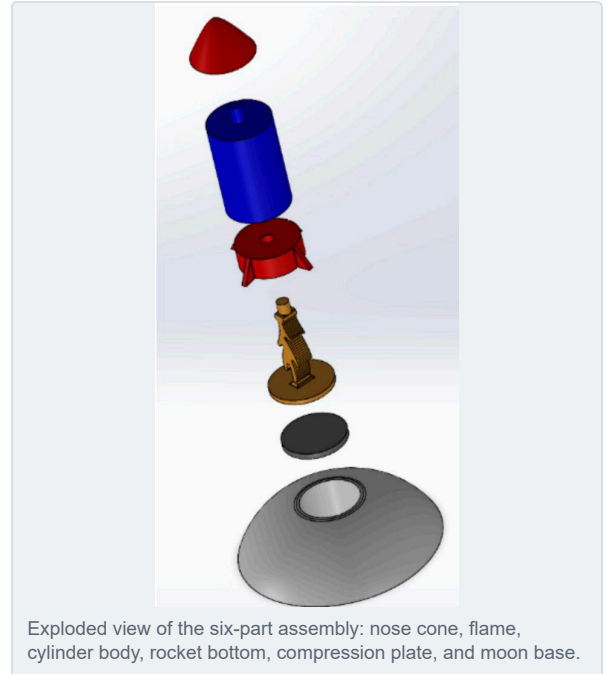
I owned the nose cone and the decorative flame through three-plus print iterations each, then led the DFM decisions across the assembly.

TECHNICAL APPROACH

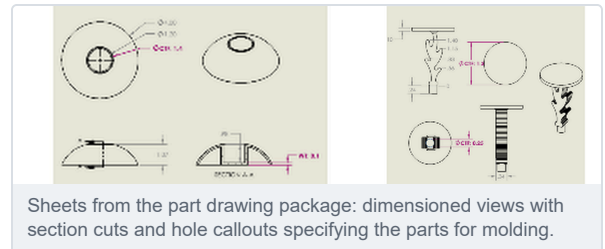
Tolerancing. The snap-fit is a 0.250" peg into a 0.254" hole. Worst-case stack-up on ± 0.002 " molding tolerances gives 0.000" minimum clearance (line-to-line) and 0.008" maximum. The FDM prototype measured 0.004" and confirmed the fit geometry, though printed tolerances do not stand in for molded ones.

DFM decisions. I scaled every part to 1.30" OD after early prints failed the choke test. I removed the cylinder window that needed mold side-actions and replaced it with a decorative sticker at zero tooling cost. I standardized wall thickness at 0.03–0.10" to prevent sink and warp, and enlarged the flame-joint fillet after the first version snapped.

What I would do differently. I abandoned a split-cylinder concept once printer tolerances made assembly impossible. The lesson I carry forward: run the DFM review before the first print.



Exploded view of the six-part assembly: nose cone, flame, cylinder body, rocket bottom, compression plate, and moon base.



Sheets from the part drawing package: dimensioned views with section cuts and hole callouts specifying the parts for molding.



The printed prototype as presented at the EGR 121 showcase.

05 Sunflower Seed Shelling Machine Hand-Powered Mechanism

Team Engineer · EGR 121, Duke University · Spring 2026

MECHANISM DESIGN · PROTOTYPE ITERATION · GEAR DRIVE

Fastest

of the 4 EGR 121 course sections

41 kernels

clean, in a 3-min run

13.7 /min

clean-kernel throughput

6 iters

printed roller versions

I led the crushing mechanism for a **hand-cranked machine that shells sunflower seeds**: roller geometry, the inter-roller gap, the funnel, and the drive train. My best three-minute run produced **41 clean kernels from 68 seeds fed (27 lost to shell damage) at 13.7 kernels per minute, the fastest machine across all four course sections**, after about six printed roller versions and four funnel geometries.

MOTIVATION

An EGR 121 build challenge: separate edible kernels from shells by hand, with a mechanism that survives repeated cranking and does not crush the kernels it frees.

MY ROLE

I led the crushing mechanism and drive system end to end, from roller geometry through the gear train and the kernel/shell separation stage.

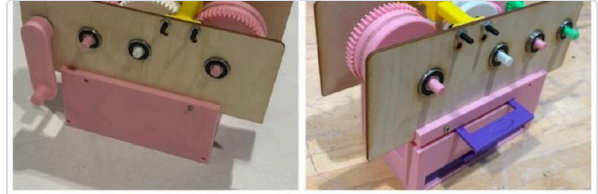
TECHNICAL APPROACH

Roller and feed. Vertical seed orientation forces the shell to fracture along its natural seam before the kernel compresses. Early horizontal feeds crushed most of the kernels. Ridged roller slots at a 0.253" gap concentrate stress on the brittle shell; smooth rollers damaged kernels and serrated rollers jammed.

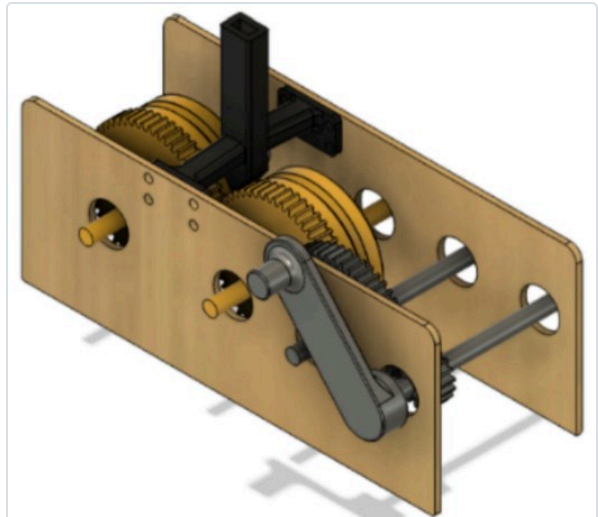
Drive train. A 9:1 gear reduction runs from crank to rollers, after the earlier 1:1 design snapped the printed shaft. An X-shaped key plus CA adhesive ties the crank to the shaft.

Separation. A narrow straight funnel enforces vertical orientation on its own, replacing a hopper-and-stopper that kept jamming. A perforated hand-shaken sifter plate separates kernels from shells, after a powered-fan prototype failed even at full drill speed.

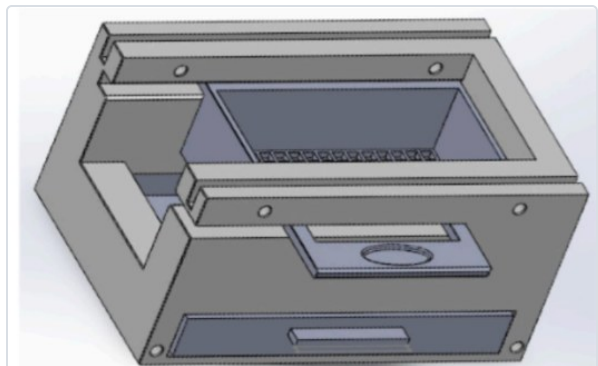
What I would do differently. I found the 0.253" gap by printing six roller versions and feeding seeds through each, when a bench measurement of shell fracture force and kernel crush strength would have set the gap before the first print. The machine still wastes 27 of every 68 seeds, and I never instrumented the crushing zone, so I cannot attribute that loss to gap variation, feed angle, or seed size spread. My next build measures the force, grades the seeds by size, and sets the gap from data. I would also size the drive shaft from a torque calculation instead of learning the 1:1 limit when it snapped.



The built machine, two views: printed rollers, gear set, crank, and the hand-shaken sifter tray.



Final assembly: ridged rollers, a 9:1 gear drive, a hand crank, and laser-cut wood side panels.



Crushing-zone detail: the roller pair, the seed chute, and the gap the shell is forced through.

06 Tiger Enrichment Device North Carolina Zoo, Client Project

Team Engineer · EGR 121 Design POD (Duke's engineering project studio) · Fall 2025 · Client: Cathy Mingee, North Carolina Zoo
CLIENT PRODUCT · RELIABILITY TESTING · ELECTROMECHANICAL

400 lb

static load, no damage

5 min

water-soak, full function held

6 mL

scent dosed every 5 h

Zero

damage or function loss, full test campaign

For the North Carolina Zoo's new tiger exhibit, my team of four built a **rope-wrapped enrichment device that gives the animal physical and olfactory stimulation**. A ball rolls on a track inside the frame, and a scent ball draws the tiger in. I handled the structural frame and the electronics. The device **passed a 400 lb static load test and a five-minute water-soak with no loss of function**.

MOTIVATION

A client deliverable for a zoo keeper. The device has to survive a tiger, weather the outdoors, release scent on a schedule, and let keepers swap the ball without tools.

MY ROLE

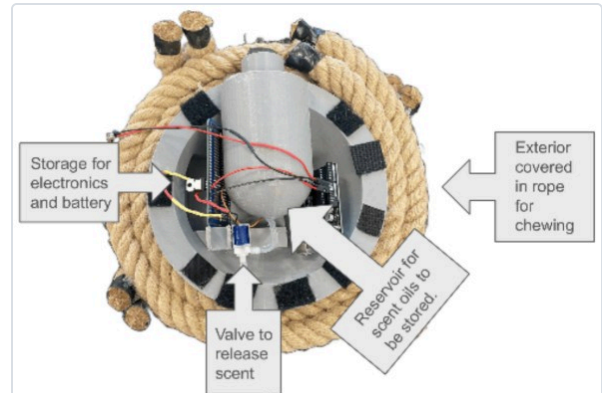
I designed the PVC spine, the track system, and the ball-change mechanism, and I built the actuating Arduino scent system.

TECHNICAL APPROACH

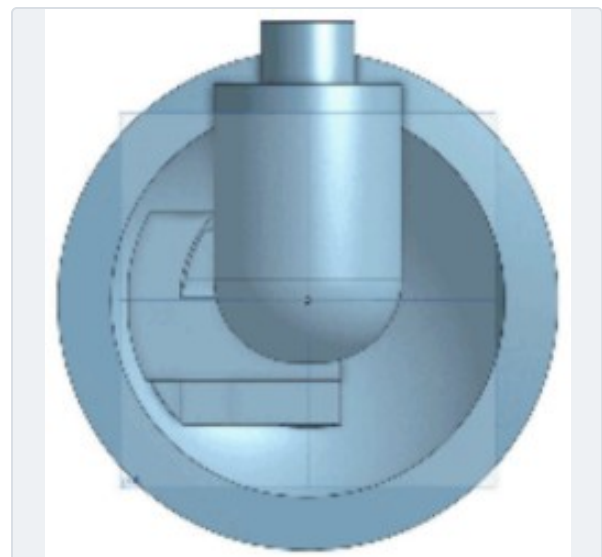
Structure & testing. I stacked 40 lb bags to 400 lb total on the frame with no joint or structural damage, then hosed the device for over five minutes with full function retained.

Scent electronics. A 3D-printed housing carries an Arduino Nano and a solenoid valve that doses 6 mL of essential oil every five hours. The battery compartment sits enclosed and shielded from impact.

What I would do differently. The tool-free quick-release pin missed its 2-minute target and ran inconsistently. My next revision machines the pin to a repeatable geometry, measures extraction force, and adds internal foam damping to the ball housing.



The rope-wrapped PVC frame. The side panel releases for ball changes; the scent valve and enclosed electronics bay are labeled.



The 3D-printed scent ball housing the Arduino Nano and solenoid valve, shown in section.

→ Roles I'm targeting

WHERE I'VE BEEN: TEST AND V&V

Most of my paid engineering has been test and validation. I integrated and checked out 15 fixed-wing UAVs and root-caused 30+ Li-ion test failures into QA fixes at Jordan Int'l Air Cargo & Defense, wrote the modal-correlation and 8-cycle thermal-vacuum plans for the solar sail, ran 30+ test flights on three Aurelia X-600 hexacopters and recalibrated their IMU and motion capture from flight logs in QGroundControl, and built and tuned 26 FPV drones. That work taught me what breaks and why: which weak spot-weld raises a battery pack's resistance, which wall sinks in the mold, which cached read goes stale under DMA.

WHERE I'M GOING: DESIGN, MANUFACTURING, EMBEDDED HW/SW

I want to move that failure judgment upstream into the design itself. I have already done it on my own work. **Design:** the CFRP solar-sail frame, analyzed and specified in SolidWorks and FEA, the Plantogachi enclosure, and the McRocket toy with its drawing package. **Manufacturing:** injection-molding DFM, worst-case tolerance stack-up, seal and part-count consolidation, and BOM-and-cost ownership down to \$0.36 a unit. **Embedded hardware and software:** ESP32-S3 and STM32 firmware, TLS telemetry, a drone power-distribution board in Altium, and radar, lidar, and depth cameras time-synced over ROS 2 in the Cyber-Physical Systems Lab. I'm looking for an internship where I own a device from CAD and firmware through the test that proves it. I stay open to any role, though: a product works as one interconnected system, and I learn fastest by seeing how each part, mechanical, electrical, and software, operates against the others.

NOW

Independent Project, Supersonic Flow Visualization (Sep 2026 – Present): researching computational models of supersonic flow ahead of schlieren imaging in NC State's supersonic wind tunnel.

GET IN TOUCH

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