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MECHANICAL ENGINEERING · CS MINOR · UNIVERSITY OF ILLINOIS URBANA-CHAMPAIGN · BS DEC 2027

Mechanical engineer working across structural FEA, machine design, and simulation. The sheets that follow give the assumptions, load cases, and numbers behind each result, not just the result.

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ABOUT

I am a mechanical engineering student at the University of Illinois, drawn to the point where analysis meets hardware: sizing a part from its worst-case load, proving a simulation result is real before I trust it, and carrying a design through to something that can actually be built. My work spans vehicle structures, production tooling, and applied machine learning for manufacturing.

I currently lead the suspension and brakes subsystem on Illini EV Concept, and I have designed production hardware at Volvo Construction Equipment and Schindler. My interests sit in mechanical systems, vehicle engineering, and manufacturing, and I like problems where the analysis and the hardware both have to be right.

SELECTED WORK

CAD & ANALYSIS

SOLIDWORKS & Simulation · Creo Parametric & Simulate · Fusion 360 · Static structural FEA · Modal analysis · Mesh convergence · GD&T

PROGRAMMING

Python · PyTorch · Salabim (discrete-event sim) · MATLAB / Simulink · C++ · Grad-CAM / transfer learning

MANUFACTURING & METHODS

Manual mill · lathe · waterjet · sheet-metal fabrication · FDM 3D printing · Design for manufacturability · Taguchi & Latin-hypercube DoE

FRONT SUSPENSION LOAD CASE STUDY

ILLINI EV CONCEPT · SUSPENSION & BRAKES LEAD · AUG 2024 TO PRESENT

I ran both the knuckle and the lower control arm in SOLIDWORKS Simulation under two load regimes each, to see which part and which case actually sets the design. The result surprised me: the combined braking case carries only half the vertical load of a pure bump, yet it produces almost twice the stress. What governs this corner is longitudinal load, not how hard the wheel hits a bump.

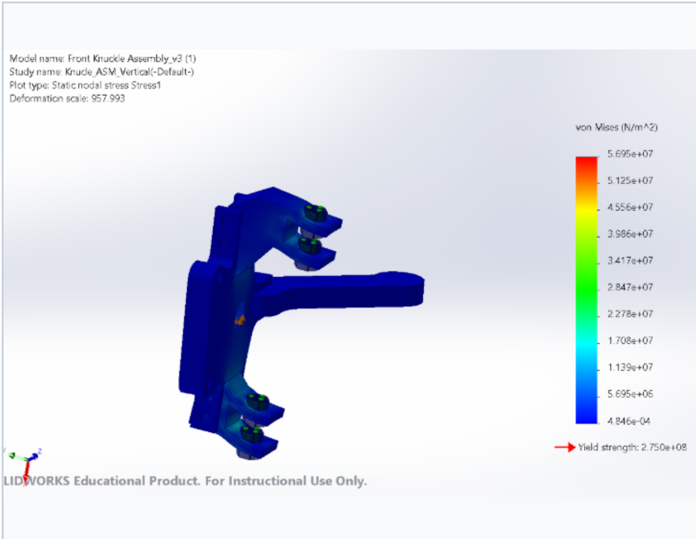


FIG 1 Knuckle, vertical bump. 56.2 MPa converged, FS 4.9.

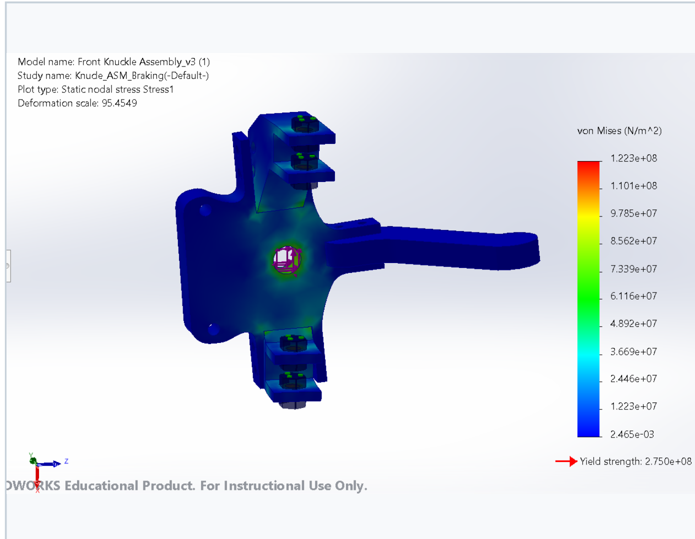


FIG 2 Knuckle, braking + bump. 122.3 MPa, FS 2.2. The peak jumps to the wheel bearing bore.

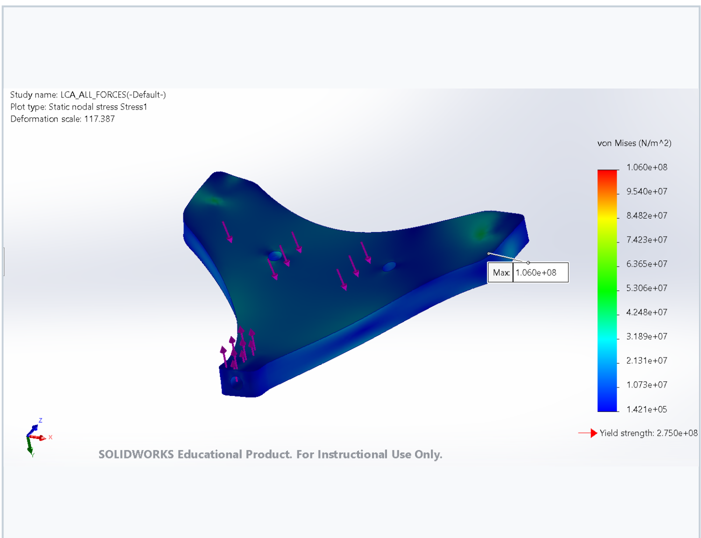


FIG 3 Control arm, vertical bump with shock reaction. 106.0 MPa, FS 2.6.

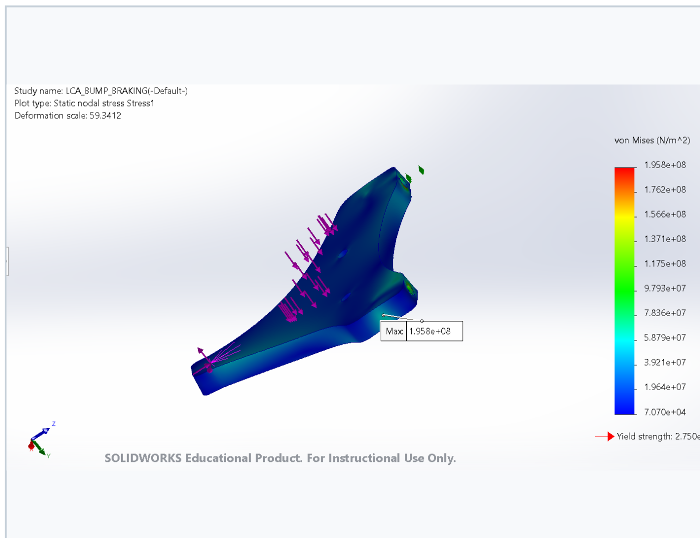


FIG 4 Control arm, braking + bump. 195.8 MPa, FS 1.4. This is the case, and the part, that governs.

SHEET 01 · STRUCTURAL ANALYSIS · CONT.

WHAT THE LOAD CASES SHOWED

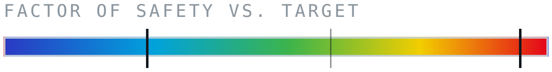
FRONT SUSPENSION · ILLINI EV CONCEPT

COMPONENT AND CASE	PEAK VON MISES	FACTOR OF SAFETY
Knuckle, vertical bump	56.2 MPa	4.9
Knuckle, braking + bump	122.3 MPa	2.2
Control arm, vertical + shock	106.0 MPa	2.6
Control arm, braking + bump	195.8 MPa	1.4

HOW THE LOADS WERE BUILT

STATIC BASIS	225 kg vehicle ÷ 4 corners × 9.81 = 552 N per corner
VERTICAL BUMP	3.0g, so 1,656 N
BRAKING + BUMP	607 N longitudinal (1.1g) with 828 N vertical (1.5g), applied together
CORNERING	773 N lateral (1.4g). Defined, not yet run.
MATERIAL	6061-T6 aluminum, yield 275 MPa
CONSTRAINTS	Bolt connectors at the UCA and LCA joints; bracket faces fixed
TARGET / TOOL	FS 3.0 · SOLIDWORKS Simulation

FACTOR OF SAFETY VS. TARGET



Control arm **1.4** · Target **3.0** · Knuckle **4.9**

WHAT I TOOK AWAY

- [ ] **Longitudinal load governs, and it isn't close.** The combined case puts 828 N through the corner vertically, half of the 1,656 N bump, plus 607 N fore-and-aft, and still drives peak stress up by 2.2× on the knuckle and 1.85× on the control arm. A braking force acts through a much longer moment arm about the suspension pickups than a vertical force does, so a smaller load does more damage. If I had sized these parts on bump alone, both would have been under-built.
- [ ] **When the load path moves, the critical spot moves with it.** Under bump the knuckle is worst at its lower mounting boss; under braking the worst point shifts to the wheel bearing bore. There is no single "danger zone" to reinforce, which is exactly why every case has to be run rather than guessing at the ugliest one.
- [ ] **The control arm is what sets the corner.** At FS 1.4 under combined bump and braking it sits below the 3.0 target and below every knuckle result, so that is where the redesign effort went, not into the part the team had been reworking.
- [ ] **The knuckle has margin to give back.** Even in its worst case it holds FS 2.2, and peak deflection is only 0.018 mm, so it is both strong and stiff. That makes it a good candidate to shave mass from, which is worth more on an unsprung part than extra safety factor it doesn't need.
- [ ] **Where this stands.** Cornering is defined at 1.4g but not yet run. I have verified mesh convergence on the knuckle (Sheet 02); the control arm hasn't had that check yet, so I treat its FS 1.4 as a working number until it does.

MESH CONVERGENCE STUDY

FRONT KNUCKLE · VERTICAL BUMP CASE · SOLIDWORKS SIMULATION

The knuckle's peak stress lands at the lower control-arm mounting hole, a bolted and constrained feature, which is exactly where a fixed-constraint singularity would appear. A singular stress rises without bound as elements shrink, so the result is only reportable once the mesh has been shown not to be driving it.

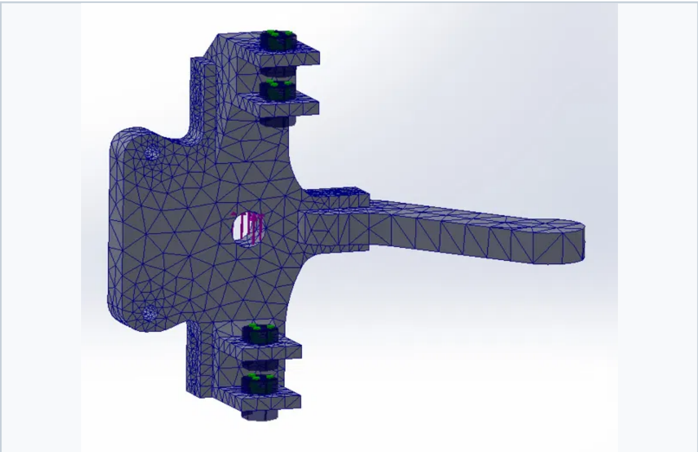


FIG 1 Baseline mesh. 11.3 mm global element size, 13,484 elements.

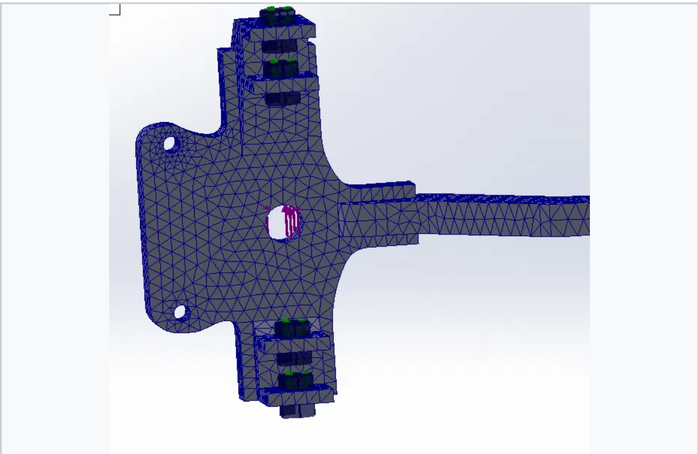


FIG 2 Refined mesh. 5.5 mm global with 1.5 mm local control at the peak region, 20,672 elements.

CONVERGENCE DATA

MESH	ELEMENTS	PEAK VON MISES
Baseline, 11.3 mm	13,484	57.0 MPa
Refined, 5.5 mm, 1.5 mm local control	20,672	56.2 MPa
Change	+53%	−1.4%

PEAK LOCATION	Lower control-arm mounting hole, unchanged under refinement
MAX DEFLECTION	0.018 mm at steering tie-arm tip
REPORTED VALUE	56.2 MPa · FS 4.9

ENGINEERING DECISIONS

- ☐ **Refinement targeted the peak, not the whole part.** Halving global element size doubles solve time for stress the analysis does not care about. Local control at 1.5 mm resolves the mounting-hole region while leaving the rest of the mesh coarse, a 53% element increase rather than several hundred percent.
- ☐ **The result moved 1.4% and its location did not move at all.** A singularity grows with refinement and often migrates. A resolved stress converges and stays put. Both tests pass.
- ☐ **This is what makes 56.2 MPa reportable.** Without it, the number is just a plot, not a result, and a peak sitting on a constrained face is exactly the case where an unverified number can fool you.
- ☐ **Same check is queued for the control arm.** That component governs the corner at FS 1.4, which makes verifying it more important than verifying the knuckle, not less.

MOTORIZED 180° ROTATION FIXTURE

VOLVO CONSTRUCTION EQUIPMENT · MECHANICAL ENGINEERING INTERN · MAY–JUL 2026

A 40 kg hydraulic turning joint was being rotated by hand during assembly. The fixture removes the manual handling and holds the part at any orientation through the build sequence, sized from the worst-case torque rather than the balanced condition.

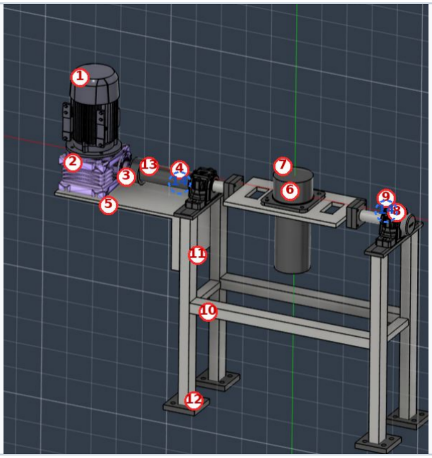


FIG 1 Fixture assembly, Fusion 360. Motor and worm gearbox at left, driven shaft through two plummer-block bearings, part mounted on the central tabletop plates.

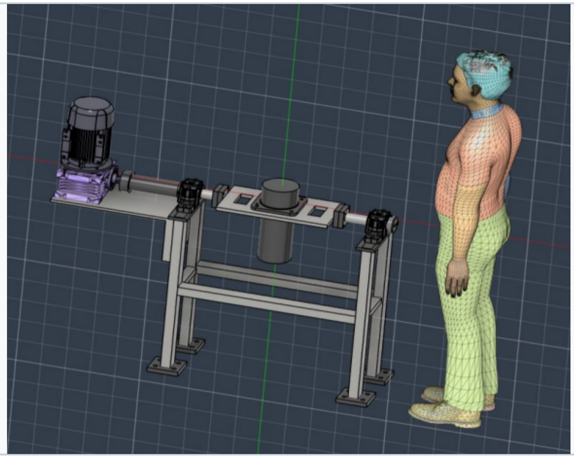


FIG 2 Working height and reach checked against a standing operator.

DESIGN DATA

PART	40 kg hydraulic turning joint
REQUIREMENT	141 N·m at rotation axis
DELIVERED	184 N·m, a 1.30× margin
DRIVE	Worm gearbox + electric motor, jaw coupling; self-locking under load
SUPPORTS	Spherical roller bearings in split plummer-block housings, ×2
INDEXING	Spring index plungers, ×4
BASE	Welded steel stand, 4 legs, cross-braced, floor-anchored
SOFTWARE	Fusion 360

ENGINEERING DECISIONS

- ☐ **Torque sized from worst case.** The 141 N·m requirement comes from the joint at maximum offset from the rotation axis, not the balanced position, since that offset is the condition the operator actually has to overcome.
- ☐ **Worm drive chosen for back-drive resistance.** The joint holds position with no brake and no power applied. The gear type was selected for that safety property, not only for the reduction ratio.
- ☐ **1.30× margin, stated as such.** Sufficient for the duty cycle and start-up inertia without oversizing the motor, shaft, bearings, and frame downstream.
- ☐ **Specified to purchasable parts.** Gearbox, motor, bearings, housings, plungers, and anchors selected from supplier catalogs so the design could be quoted and released to build.

CASTING DEFECT INSPECTION SYSTEM

INDEPENDENT PROJECT · PYTHON / PYTORCH · GITHUB.COM/RAGHAVSINGH1234

Visual inspection of cast parts is slow and inconsistent between operators. This system classifies a casting from a single image and returns a severity score and an accept/reject call, with a saliency overlay so an inspector can see what the model reacted to rather than taking the label on trust.

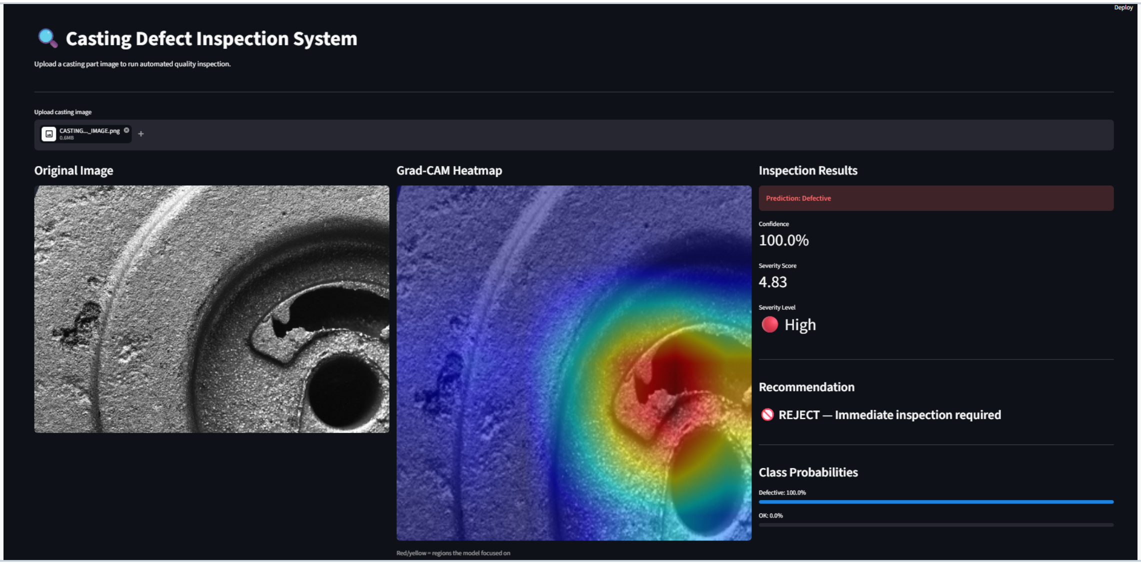


FIG 1 Inspection dashboard. Left: input casting. Centre: Grad-CAM activation, concentrated on the surface flaw rather than the background or part edges. Right: class, confidence, severity score, and disposition.

MODEL DATA

TASK	Binary classification, defective or acceptable
DATASET	7,000+ labeled cast-metal images (public)
BACKBONE	ResNet18, ImageNet pretrained
TRAINING	Two-stage: frozen backbone, then unfrozen final block
TEST ACCURACY	96%
OUTPUTS	Class, confidence, severity score, accept/reject
STACK	Python · PyTorch · Streamlit

ENGINEERING DECISIONS

- ☐ **Transfer learning over training from scratch.** 7,000 images is far too few to learn general edge and texture features; the pretrained backbone supplies them and only the task-specific layers are fitted.
- ☐ **Two-stage fine-tuning.** Training the head first with the backbone frozen prevents large early gradients from destroying the pretrained weights. Unfreezing the final block afterwards adapts the highest-level features to cast surfaces.
- ☐ **Grad-CAM as the acceptance check.** Accuracy alone does not show whether the model learned the defect or a lighting artifact. The heatmap confirms activation sits on the flaw.
- ☐ **Severity score, not just a label.** A binary pass/fail gives an inspector nowhere to triage. Grading the output lets borderline parts be routed for review rather than scrapped outright.

FAN-MOUNT BRACKET & MODAL ANALYSIS

SCHINDLER · MECHANICAL ENGINEERING INTERN · SUMMER 2025

A ceiling-mounted fan was raised out of an elevator car roof to cut cabin noise, which meant designing the sheet-metal bracket that carries it. Because the bracket holds a running fan, the design question was not only whether it is strong enough but whether the fan can shake it, so I checked it against the fan's own excitation frequency.

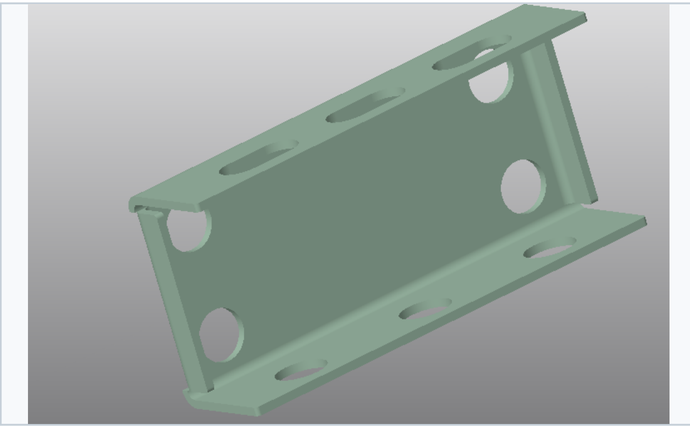


FIG 1 50 mm lift bracket, Creo. C-section with flange walls added for out-of-plane stiffness; four rear holes tie in the side brackets.

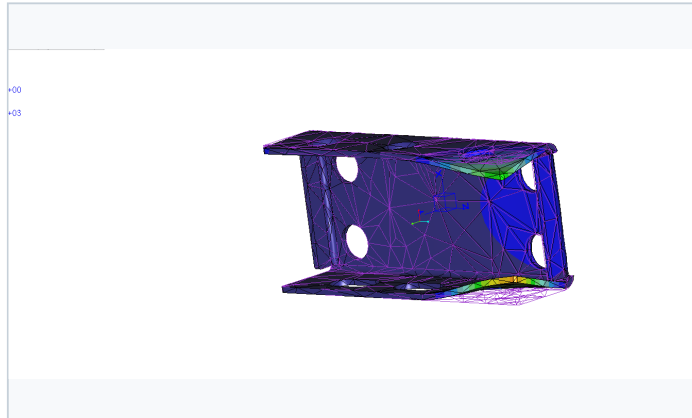


FIG 2 First mode in Creo Simulate, constrained at three mounting holes. First natural frequency 2,310 Hz.

DESIGN & ANALYSIS DATA

PART	Sheet-metal fan-lift bracket, 50 mm and 100 mm variants
EXCITATION	Fan at 2,050 RPM → ~35 Hz
1ST MODE	2,310 Hz (50 mm) · 1,230 Hz (100 mm)
SEPARATION	>35× above excitation, no resonance risk
ANALYSIS	Modal, 4 modes, 3-hole constraint · Creo Simulate
DOE	Taguchi orthogonal arrays + improved Latin-hypercube sampling; ~70% fewer test runs
OUTPUT	Production drawings + flat-pattern DXF for fabrication

ENGINEERING DECISIONS

- ☐ **The real risk was resonance, not static strength.** A bracket carrying a running fan can be shaken apart at a fraction of its yield load if a natural frequency sits near the drive frequency. That made modal analysis the governing check, not a stress plot.
- ☐ **The result is a frequency margin.** First mode at 2,310 Hz against ~35 Hz excitation is more than 35× of separation, so the fan cannot drive the bracket into resonance. The 100 mm variant, longer and more flexible, still clears it at 1,230 Hz.
- ☐ **Stiffness added where it counts.** Flange walls along the bends raise out-of-plane stiffness, the direction that sets the first mode, without adding a heavier gauge across the whole part.
- ☐ **Designed to be built.** Every bracket left as a production drawing and a flat-pattern DXF, ready for sheet-metal cutting and bending, with a DoE that cut the validation test matrix by roughly 70%.