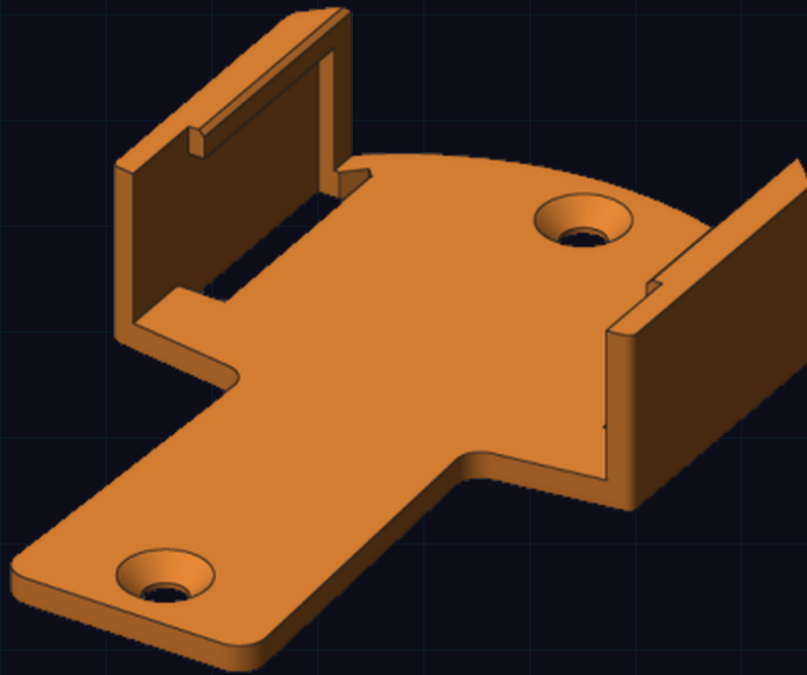




neuralDEEP.net



CASE STUDY · DESIGN FOR 3D PRINTING · MARINE

From phone photos to a part that fits.

How we reverse-engineered a windlass remote cradle in three iterations, and what it taught our CAD software.

CLIENT Malta Yachting www.maltayachting.com.mt

Neural Deep Network LTD · 23–30 September 2026 · Malta
neuraldeep.net · 3dj.app · 3d@neuraldeep.net

Designed with



3D

3DJ Studio

AT A GLANCE

A small part, a big lesson in measuring

Our client Malta Yachting needed a replacement for the plastic cradle that holds an AutoAnchor / Muir / Lewmar windlass remote. There was no drawing and no spare part in stock. All we had to start from was a set of phone photos. Seven days later a printed ASA part was on the real handset, and the verdict was the one that matters: "it fits, we tested."

This booklet tells the whole story, wrong turns included. We wrote it to teach. Each chapter says what we did, the real numbers we got, and the lesson that carries over to other parts. Every method in it is now built into **3DJ Studio**, our parametric CAD and photo-to-part platform, and each one is covered by automated checks that replay this job's real numbers.

3 design iterations, from a guess to a measured part	7.7 % photo-scale error caught by modelling the camera	3.4 → 1.9 % snap-fit strain, brought down to the material limit
0 mismatches between two independent descriptions of the part	38 / 38 automated checks in 3DJ replaying this job	< €0.50 filament cost of the final part

The timeline

Date	Step	What happened
23 Sep	v1	Modelled from shop photos with the proportions guessed. It looked plausible, but it was about 6 mm too wide.
24 Sep	v2 Rev B	Re-measured from ruler photos with a height-aware scale. Every number was tagged with its source, and we issued a drawing and a fit coupon.
24 Sep	v3 Rev C	The customer's annotated close-ups corrected the lip detail. The snap strain was checked, and the easy-snap variant was chosen.
30 Sep	Printed	v3 easy-snap printed in ASA on a Bambu Lab A1 for Malta Yachting, then fit-tested on the real handset: it fits .

Who this is for

This booklet is for makers and engineers who reverse-engineer parts from photos, for print farms that want fewer failed first prints, and for anyone building CAD tools, human or AI, who wants a part that fits instead of one that only looks right. The maths is kept to three short formulas, and each one is explained in plain words.

CHAPTER 1

The job

One clip, one or two millimetres, and a boat that moves.

The part is the handset cradle for AutoAnchor AA300, AA320, AA710 and AA730 windlass remotes, sold as Imtra SPA-AA9404 and Lewmar B15351. It screws to a bulkhead. The handset clicks in between two springy side walls, each with a small lip at the top. The brief was simple: print a replacement.

CLIENT**Malta Yachting**www.maltayachting.com.mt

Part: AutoAnchor / Lewmar windlass remote cradle (Imtra SPA-AA9404, Lewmar B15351)

Delivered: v3 easy-snap in ASA, 30 September 2026

Result: fit-tested on the real handset: it fits



Left: the original cradle with a ruler, one of the customer's photos. Right: the handset kit the cradle belongs to (shop listing image).

What we had, and what we did not

We had phone photos of the original, some with a ruler and some without, plus two shop listings. We had no drawing, no CAD file and no calipers on the part at the start. That is the normal situation for spare parts on boats, where the original is discontinued, out of stock, or a week's shipping away.

Why it is harder than it looks

The fit that matters is the snap. If it is too tight, the arms crack or the handset will not go in. If it is too loose, the handset rattles out in a sea. That fit is set by one or two millimetres of lip, and you cannot see the underside of the lip in a top-down photo. Getting the overall size roughly right is easy. Getting those two millimetres right is the job.

LESSON

On a functional part, find the one interface that decides success, and spend your measuring effort there. Everything else only has to be close.

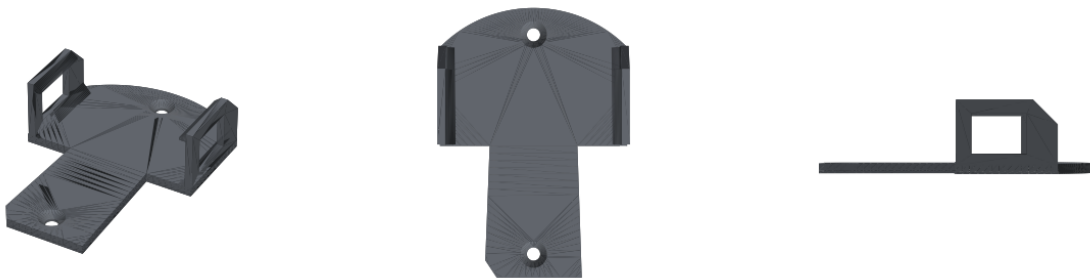
CHAPTER 2

Three iterations, with their real numbers

We kept the wrong turns in on purpose, because they teach the most.

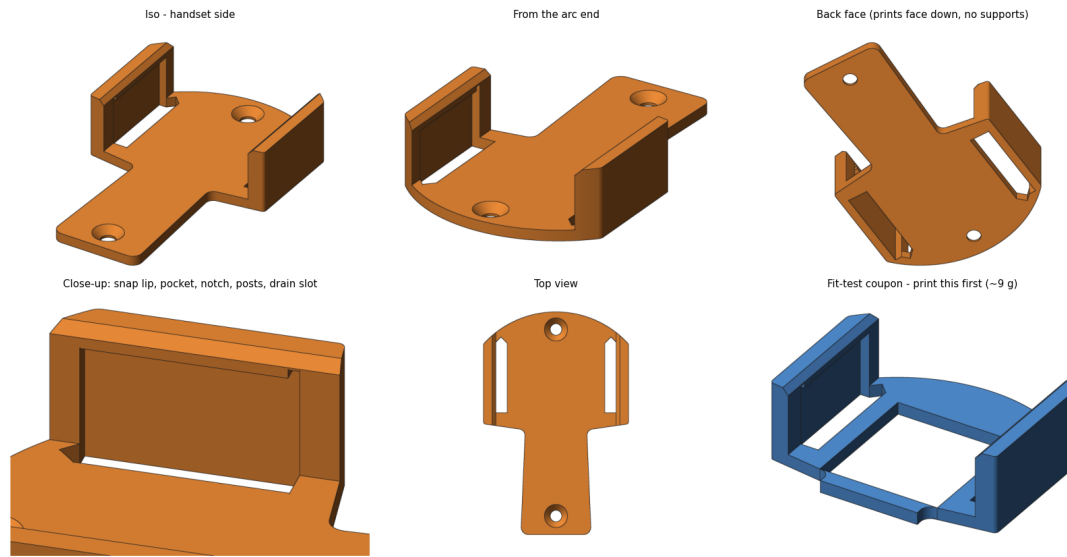
	v1 · 23 Sep	v2 Rev B · 24 Sep	v3 Rev C · 24 Sep	Printed · 30 Sep
Basis	shop photos, proportions guessed	ruler photos, height-aware scale	annotated close-ups of the lip	v3 easy-snap
Overall length	92	88.5 (ruler)	88.5	88.5
Width over arms	64	57.8 (ruler)	57.8	57.8
Arm height	24	19.5	19.5	19.5
Lip overhang	2.4	2.3 (easy 1.8)	1.7 (easy 1.3)	1.3
Root strain	≈ 2.1 %*	3.4 %	2.5 %	1.9 %
Result	would not have fitted (6 mm too wide)	geometry right, lip too aggressive	lip detail matched to the original	fits

All dimensions in mm. * v1's taller arm (24 mm) made its beam longer and its strain lower. That did not matter, because the part was too wide to fit at all. Strain is explained in chapter 5.



v1: plausible, and wrong by 10 % in width. A part that looks right and does not fit is the most expensive kind of wrong.

AutoAnchor / Muir / Lewmar windlass remote cradle v2 | AA300 - AA320 - AA710 - AA730 | Neural Deep Network LTD

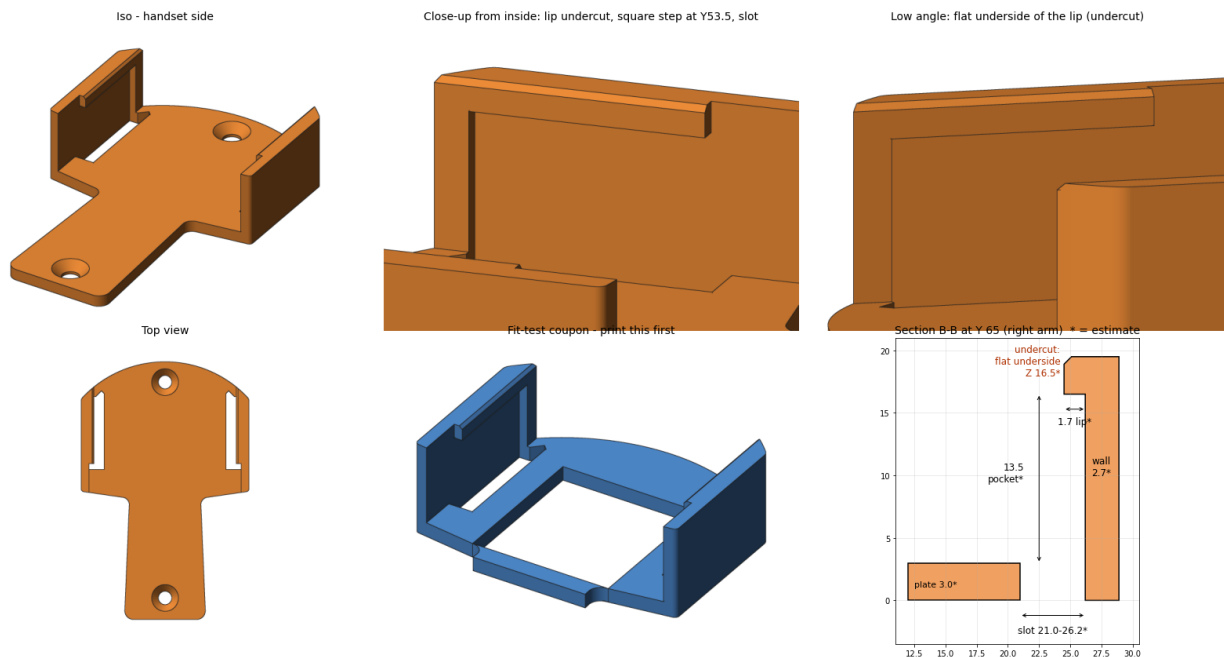


v2 Rev B: every dimension measured or labelled as an estimate, with a drawing and a fit coupon.

LESSON

v1 came from a "reasonable" guess and was 6 mm too wide. The error was only caught once a ruler was in the frame. Never ship a part in which every number is an estimate.

AutoAnchor / Muir / Lewmar windlass remote cradle v3 Rev C (improved top grip + undercut) | Neural Deep Network LTD



v3 Rev C: square step at Y 53.5, an undercut running the full lip length, a 0.6 mm lead-in, and a stem-side post removed because the original does not have it. Bottom right: section B-B through the arm. * marks an estimate.

CHAPTER 3

Measuring from photos properly

A ruler in the photo is a good start. It is not the end of the story.

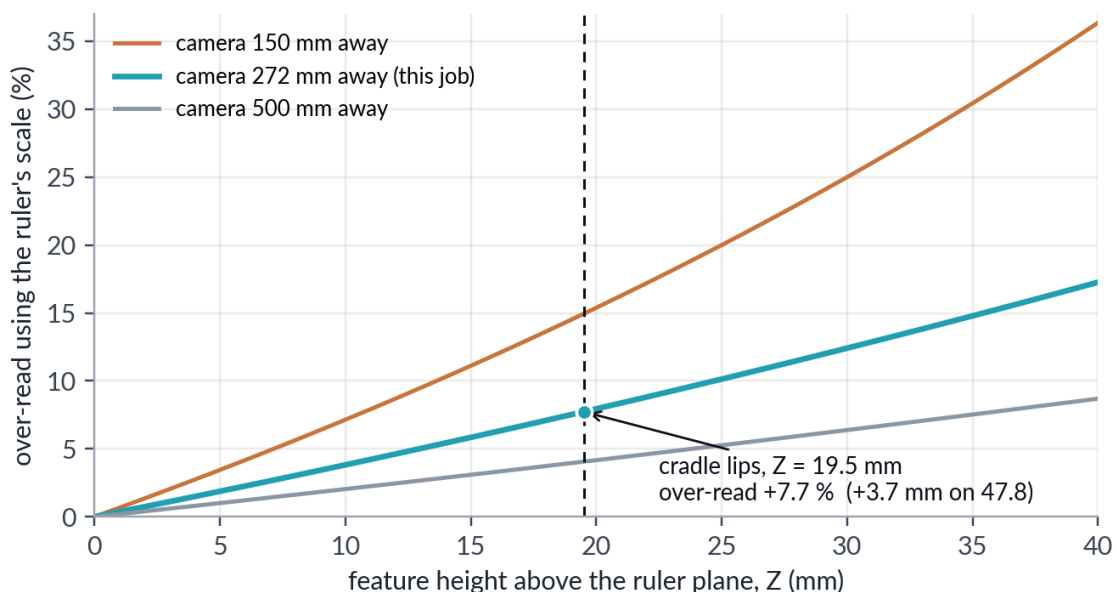
3a. The ruler only tells the truth in its own plane

The ruler lay on the bench, and the snap lips stood 19.5 mm above it. A phone camera behaves like a pinhole, so anything closer to the lens looks bigger. The scale in pixels per millimetre depends on the height Z of the feature you are measuring:

$$s(Z) = f / (D - Z)$$

f = focal length in pixels · D = lens-to-bench distance · Z = feature height above the bench

The ruler gave **14.10 px/mm** at $Z = 0$, and a known span at the arm tops gave **15.19 px/mm** at $Z = 19.5$. Those two numbers pin down the camera: $f \approx 3830$ px, and the lens was about 272 mm from the bench. Reading the lips with the bench scale would have made them **7.7 % too large**. On the 47.8 mm opening between the lips that is 3.7 mm, which is more than the whole lip.



How much a feature is over-read if you use the ruler's scale for it. The closer the camera, the worse it gets.

NOW IN 3DJ

`fitCamera(references)` takes two or more known lengths at different heights and returns the camera. With three or more it also reports a residual, so a height typed in wrong shows up as a misfit instead of silently skewing the part. `cameraFromRulerAndDistance` covers the case of one ruler plus a tape measure to the lens.

LESSON

A scale belongs to a plane, not to a photo. Write down the height of every reference.

3b. Measure twin to twin, not along the image axis

The part sat about 0.9° off square in the photo. Reading a width straight across the image under-reads it slightly, and reading an offset from one edge picks up the full rotation. The fix is to measure between mirrored features (wall to wall, lip to lip, slot to slot) and average the pairs. The direction of each pair gives you the rotation for free, so you can check it against the others.

NOW IN 3DJ

`averageMirrorPairs(pairs)` returns rotation-free spans and the part's rotation. In the test suite it recovers a 0.9° rotation exactly.

LESSON

On a symmetric part, the symmetry is your best measuring instrument.

3c. Hidden features need other views

The undercut under the lip cannot be seen from above. We read it from several oblique photos, then from close-ups where the customer circled the details in blue. Anything we could not see was marked as an estimate (* on the drawing), and we asked the customer to measure it. We did not pretend.



Left: the customer's annotated close-up of the lip and undercut, which drove the v3 changes. Right: an oblique view with a ruler, used to read the arm and lip.

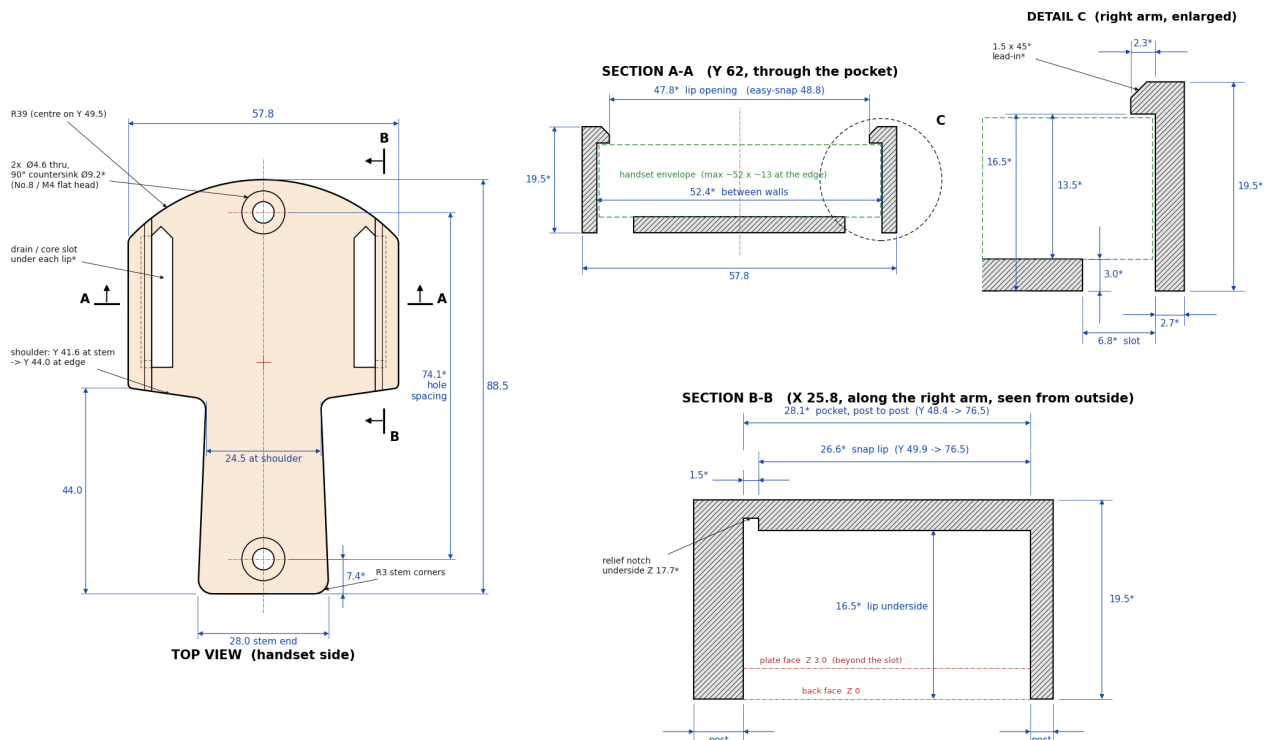
CHAPTER 4

Say where every number came from

Honesty about uncertainty is a feature, not a disclaimer.

Each dimension in the v2 notes carried its source: **ruler**, **photo** (about ± 0.5 mm) or **estimate***. The drawing marked the estimates. The notes ended with a short list of the measurements that would firm them up, most important first. That list tells the customer exactly which three numbers to check before paying for a batch.

Source tag	Meaning	Typical confidence
measured / ruler	read against a scale in the same plane, or with calipers	± 0.2 – 0.3 mm
traced / photo	read from a photo with a height-corrected scale	about ± 0.5 mm
estimated *	not visible; inferred from function or other views	flagged for the customer
user	typed in by the customer or engineer	as stated



AutoAnchor / Muir / Lewmar windlass remote cradle - v2

Replacement for Imtra SPA-AA9404 / Lewmar B15351. Handsets AA300 / AA320 / AA710 / AA730

Neural Deep Network LTD | units mm | Rev B | 2026-09-24 | not to scale - use the STL / SCAD

L 88.5 and W 57.8 ruler-measured on the original. Other unmarked plan dims scaled from photos (about ± 0.5 mm, cosmetic).

* = estimated (hidden in photos / engineering judgement).

Confirm the fit with the coupon before a batch.

Print: PETG or ASA, back face down, no supports

0.2 mm layers, 6 walls / solid arms, 40 % infill

Mass about 16.6 g solid. Print the fit coupon first (about 9 g).

Easy-snap variant: lip 1.8 (opening 48.8)

The v2 Rev B drawing as issued to the customer. Estimated dimensions are marked *.

NOW IN 3DJ

Every number in a 3DJ part carries a NumSource: **measured** | **traced** | **estimated** | **user**. The repo's rules now include a "Measurement Honesty" invariant, so a part made only of estimates cannot be presented as measured.

CHAPTER 5

Design the snap with strain, not by eye

"More lip, more grip" is true right up until the arm cracks.

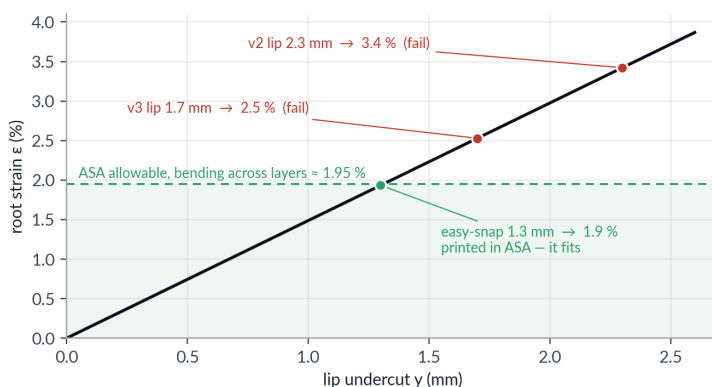
Each side wall is a springy beam, and the lip is its undercut. When the handset goes in, the wall bends outwards by the depth of the lip. The first-order cantilever model, in the form used by the classic Bayer/Covestro snap-fit guide, gives the strain at the root of the wall:

$$\epsilon = 1.5 \cdot t \cdot y / L^2$$

t = wall thickness 2.7 mm · L = free length $\approx$ 16.5 mm · y = lip undercut

Strain is the number that decides whether plastic survives. Because the walls print standing up, bending them pulls the layer lines apart, which is exactly where FDM parts crack. So the allowable strain for ASA (about 3 % for a single assembly) is derated to roughly 65 %, which gives $\approx$ **1.95 %**.

Variant	Lip y	Root strain ϵ	Against the $\approx$ 1.95 % allowable
v2 Rev B	2.3 mm	3.4 %	over the limit
v3 Rev C	1.7 mm	2.5 %	over the limit
v3 easy-snap (printed)	1.3 mm	1.9 %	at the limit, marginal pass



Strain rises in a straight line with the lip. Only the easy-snap lip sits inside the derated ASA limit. The largest safe undercut is 1.31 mm.

The part that was printed and tested was the **v3 easy-snap in ASA**. It was fit-tested on the real handset for Malta Yachting on 30 September 2026: it fits.

Honest limits

The real wall is also held by posts at both ends, so it is stiffer than a free cantilever. The material limits are conservative FDM guidance, not datasheet values. Use the check to rank options and catch the obviously wrong ones, then print a coupon (chapter 6) to confirm.

NOW IN 3DJ

`checkSnapFit({ thicknessMm, lengthMm, undercutMm, material })` returns the strain, the allowable, a verdict, the largest safe undercut, and the push-on force through the lead-in. It knows PLA, PETG, ABS, ASA, nylon and TPU, with a derating for bending across layers.

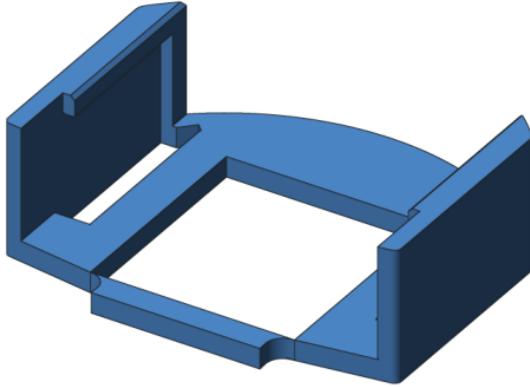
LESSON

Compute the strain and let it choose the lip.

CHAPTER 6

Print the interface first: the fit coupon

The cheapest test print is the one that contains only the question you are asking.



The coupon is just the arm end of the cradle (Y 38 → 88.5), with a window cut out of its plate. It is meant to be printed before the full part. It comes to **7.25 cm³** against **12.92 cm³** for the whole cradle, and it tests the one interface that can go wrong.

With it, we gave the customer a tuning table that says which parameter to change for each symptom: won't go in, rattles, jams, or loose sideways.

The v3 fit coupon: both arms and the lips, on a windowed plate.

Symptom on the coupon	What to change
Handset will not go in	reduce the lip overhang (or use the easy-snap file)
Handset rattles	increase the lip slightly, or reduce the pocket width
Jams half-way	increase the lead-in chamfer
Loose side to side	reduce the width between the arms

A coupon only pays off if it is much smaller than the part. On this cradle, the slab alone keeps 78 % of the volume, because the arms sit on the widest part of the plate. Cutting the window is what made the coupon worthwhile, and our planner says so honestly instead of promising savings that are not there.

NOW IN 3DJ

`planFitCoupon(mesh, { axis, from, to, base })` plans the slab around a critical interface and estimates the material it saves, including when the answer is "not much".

CHAPTER 7

Verify with two independent descriptions

Two descriptions that agree point by point are evidence. One that looks right is a hope.

In v2 the part existed twice: as a Python mesh generator, and as an OpenSCAD source for the customer. "The renders look the same" is not a check. So we turned the SCAD into a point-membership function, sampled a 3D grid **offset by an irrational fraction** of the step (so no sample sits exactly on a face), asked both descriptions "inside or outside?" at every point, and got **0 mismatches**. Every STL was also checked as a single watertight shell with no open or non-manifold edges.

Check	Result
SCAD vs mesh, point by point (v2)	0 mismatches
Watertight, single shell, manifold (all STLs)	pass
Grid volume vs exact volume (v3)	13.29 cm ³ vs 12.92 cm ³ (grid bias on 2.7 mm walls)
Point test on the 13,212-triangle v3 STL	≈ 0.35 s with YZ binning (116 s brute force)

NOW IN 3DJ

`crossCheckMembership(mesh, insidePredicate)`, backed by `createMembershipTester`, a binned ray-parity test. Use the CAD kernel for the exact volume, and the grid for agreement.

CHAPTER 8

The loop that got it right

Seven days, three iterations, one part that fits.

1

Guess → measure

v1 was a guess. The ruler photos corrected it by 10 %.

2

Measure → model with provenance

v2 was measured, height-corrected, symmetric by construction, and every number was tagged with its source.

3

Model → detail from the customer's eyes

The annotated close-ups fixed the step, the undercut and the post in v3.

4

Check → coupon → part

Strain check, independent cross-check and watertight check, then the coupon, then the part.

5

Test on the real object

30 September 2026: "it fits, we tested."

"AI plans, math builds." The photos, the customer and the AI propose. Deterministic geometry, real measurements and simple physics decide.

The final print

Setting	Value
File	AutoAnchor_Cradle_v3_easy-snap (Final, Malta Yachting), 30 Sep 2026
Material	ASA (UV- and heat-resistant, suited to deck and cockpit use)
Printer / profile	Bambu Lab A1 · 0.4 mm nozzle · "0.20 mm Strength @BBL A1"
Walls / shells	6 walls · 5 top layers · 3 bottom layers
Infill	85 % 3D honeycomb
Supports	enabled
Filament cost	under €0.50 per part
Client	Malta Yachting · maltayachting.com.mt
Outcome	fit-tested on the real handset: it fits

What we are not claiming: this booklet reports a fit test on the real handset. Long-term service on the boat, UV ageing and cycle life have not been tested yet, and we will report them separately if and when we have the data.

CHAPTER 9

What changed in 3DJ because of this job

One customer's part became four reusable, tested methods.

Each method from this job was rewritten as a pure, dependency-free module in 3DJ Studio and covered by a test harness that replays the cradle's real numbers, so the story in this booklet and the code cannot drift apart.

Method	Module	Checked by
Height-aware photo scale; camera fit with residual	<code>src/lib/trace/height-scale.ts</code>	12 checks, incl. the real 14.10 / 15.19 px/mm
Mirrored-pair averaging (rotation-free spans)	<code>src/lib/trace/height-scale.ts</code>	5 checks, 0.9° rotation recovered exactly
Snap-fit strain, allowable, forces	<code>src/lib/snap-fit.ts</code>	10 checks, incl. the v2 / v3 / easy-snap numbers
Point-in-solid, independent cross-check, fit coupon	<code>src/lib/mesh-membership.ts</code>	11 checks, incl. binned tester = brute force

```
npx tsx scripts/verify-cad-methods.ts → 38 passed, 0 failed
```

Material allowables used by the snap-fit check

Material	Single assembly	Repeated	E (MPa)	Across-layer factor
PLA	2.0 %	1.0 %	3000	0.60
PETG	3.5 %	2.0 %	2000	0.70
ABS	3.0 %	1.8 %	2100	0.65
ASA	3.0 %	1.8 %	2000	0.65
Nylon (PA)	5.0 %	3.0 %	1400	0.75
TPU	30 %	20 %	30	0.80

Conservative FDM guidance used to rank designs, not datasheet values. Always confirm with a coupon.

What is next

Next step	Why it matters
Photo tab: a height for every caliper line, with fitCamera and the residual shown	brings the 7.7 % correction to every user, automatically
A snap feature in the part IR that runs the strain check and proposes the max safe undercut	stops cracked clips before they are printed
A "Print fit coupon" button	one click from a part to its cheapest useful test print
This case study: a v3 SCAD, a Rev C drawing, and the 45° band at the arc end	closes the loose ends of this job

These modules are in the 3DJ codebase today. Wiring them into the Photo tab and the checks table is the next step, so we describe it here as planned work, not shipped features.



neuralDEEP.net × 3DJ Studio

Neural Deep Network LTD

We build AI systems that do real work, and we hold them to engineering standards. This cradle is a small example of how we work: AI where it helps, measurement and maths where they decide, and an honest account of what is known and what is estimated.

neuraldeep.net

3DJ Studio

A browser-first parametric CAD and 3D studio for people and AI agents. Photos and caliper readings become watertight, print-ready STEP and STL parts, with print checks built in. Script CAD is free and runs offline in the browser.

3dj.app

CLIENT FEATURED Malta Yachting · www.maltayachting.com.mt

Have a part that is broken, discontinued or a week away?

Send us clear photos with a ruler in the frame and tell us how it is used. We will tell you honestly what we can measure, what we would have to estimate, and what a fit coupon would cost before you commit to a part.

3d@neuraldeep.net

© 2026 Neural Deep Network LTD · Registered in the EU · All product names are the property of their owners. AutoAnchor, Muir, Lewmar and Imtra are referenced only to identify the original part; this is an independent replacement design, not an OEM part. 3DJ and neuralDEEP.net are brands of Neural Deep Network LTD.