

Camera Document Stand for **dvi3v** project
v3.9.2.208

Peter Felecan
with Claude (Anthropic AI), model Sonnet 5

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Design, manufacturing, and dvi3v-workflow integration for the parametric camera document stand test rig ([hardware/](#) directory). For slicer and print-configuration details specific to these parts, see [Manufacturing Configuration](#).

1 Overview

1.1 Purpose

Systematic data collection test rig for dvi3v project validation and improvement. Enables repeatable, high-quality photography with dimensional references.

1.2 Design Requirements

Functional Requirements:

- Camera height: 300-500mm adjustable (Z-axis only, first iteration)
- Working area: A4 paper (210×297mm)
- Device support: Smartphones (Pixel 9a, iPhone 15, ~155×75×10mm envelope)
- Load capacity: 200g maximum
- Vibration resistance: Minimal deflection under typical use

Manufacturing Constraints:

- Material: PETG (primary), PLA (support)
- Printer: Prusa Core One (250×220×270mm) or Prusa XL (360×360×360mm)
- Tolerance: 0.3mm (printer slop)
- Assembly: Tool-based (M5/M6 hex bolts), no glue
- Transport: Disassemblable for storage

Design Philosophy:

- Minimize filament via tessellation/struts
- Smooth angles (chamfer/fillet for printability)
- Modular construction (easy assembly/repair)
- Parametric design (OpenSCAD + BOSL2)

1.3 Architecture

Component Hierarchy:

Camera Document Stand

- ├─ Base Plate (350×250×8mm, tessellated)
 - | ─ Hexagonal lightening pattern
 - | ─ Column mount (central, reinforced)
 - | ─ Alignment pins (4×, registration)
 - | ─ Rubber feet recesses (4× corners)
- ├─ Column Segments (Ø25mm hollow, 50mm height each)
 - | ─ Internal ribs (4×, structural)
 - | ─ Height adjustment holes (M6, 50mm spacing)
 - | ─ Alignment pins (top/bottom, stacking)
- └─ Camera Holder Arm
 - ├─ Column clamp (split design, M6 bolts)
 - ├─ Horizontal cantilever (~160mm)
 - └─ Phone bracket (adjustable springs, foam-padded)

Material Distribution:

- Base: ~320g PETG (tessellation reduces from ~500g solid)
- Column: ~85g/segment × 4 = 340g
- Arm: ~165g
- **Total: ~825g** (vs ~1200g if solid)

1.4 Key Design Features

1. Hexagonal Tessellation

Purpose: Reduce filament while maintaining rigidity

Pattern: Regular hexagons, 20mm cells, 1.6mm walls

Savings: ~35-40% material reduction

Trade-off: +20% print time (complexity)

2. Modular Column System

Segments: 50mm height each, stackable

Adjustment: 300mm (6 seg) to 500mm (10 seg)

Precision: $\pm 0.5\text{mm}$ (limited by print tolerance)

Connection: Alignment pins + gravity (no bolts between segments)

3. Split-Clamp Arm Mount

Mechanism: Split cylinder + 2× M6 through-bolts
 Friction: PETG-on-PETG, dry (no lubricant)
 Torque: Hand-tight + 1/4 turn (~3 Nm)
 Security: 2-bolt system prevents rotation

4. Phone Holder Design

Grip: U-channel + flexible spring clips
 Padding: 2mm EVA foam (adhesive-backed)
 Access: Open top/sides for buttons/ports
 Camera: Ø30mm clearance hole (aligned to center)
 Compatibility: 70-80mm width, 10-15mm thickness

1.5 Design Calculations

Structural Analysis (Simplified):

Column as cantilever beam:

- Material: PETG ($E = 2100 \text{ MPa}$, hollow tube)
- Length: 400mm (typ), Overhang: 160mm (arm)
- Load: 200g phone + 165g arm = 365g = 3.6N
- Deflection: $\delta \approx (F \times L^3) / (3 \times E \times I)$
 Where $I = \pi/64 \times (D^4 - d^4)$ for hollow cylinder
 $I \approx 11,500 \text{ mm}^4$ ($D=25\text{mm}$, $d=19\text{mm}$)
 $\delta \approx 0.8\text{mm}$ (acceptable for photography)

Vibration damping:

- Natural frequency: $f \approx 3.5 \text{ Hz}$ (calculated)
- Damping: Inherent PETG (~0.02 damping ratio)
- Settling time: <2 seconds after disturbance

Weight Budget:

Component	Mass (g)	% Total
Base	320	39%
Column	340	41%
Arm	165	20%
Hardware	50	6%
Total	875g	100%

1.6 Parametric Design

OpenSCAD + BOSL2 Implementation:

- All dimensions parameterized (easy customization)

- Device envelope adjustable (future phones)
- Height range configurable (add/remove segments)
- Tessellation density tunable (performance vs strength)

Key Parameters:

```
// Adjustable heights
HEIGHT_MIN = 300; // mm
HEIGHT_MAX = 500; // mm
HEIGHT_ADJUSTMENT_STEP = 50; // mm

// Device envelope (accommodates Pixel 9a, iPhone 15)
DEVICE_LENGTH = 160; // mm
DEVICE_WIDTH = 80; // mm
DEVICE_THICKNESS = 12; // mm

// Tessellation (lightening)
TESSELLATION_SIZE = 20; // mm - hex cell size
TESSELLATION_WALL = 1.6; // mm - wall thickness
```

1.7 Manufacturing Specifications

Print Settings (PETG):

Material: PETG (Prusament recommended)
Nozzle: 0.4mm (standard), 240°C
Bed: 85°C, PEI sheet, brim for large parts
Layers: 0.2mm (0.3mm first layer)
Perimeters: 3 (2.4mm walls)
Infill: 30% gyroid
Supports: Tree supports where needed
Speed: 50mm/s (perimeters), 80mm/s (infill)
Cooling: 30% fan (PETG warping prevention)

Print Orientation:

- Base: Flat (tessellation up), tree supports
- Column: Vertical (standing), no supports
- Arm: On side (arm horizontal), supports for clamp

Post-Processing:

1. Remove supports carefully

2. Deburr with knife/sandpaper
3. Drill out bolt holes if tight (5.5mm, 6.5mm bits)
4. Test-fit before assembly

1.8 Assembly Hardware

Fasteners:

Type	Qty	Use	Notes
M5×16mm bolt	4	Base-to-column	DIN 912 socket head
M5 nut	4	Base-to-column	DIN 934 hex
M6×40mm bolt	2	Height adjustment	DIN 912, wing nuts
M6×20mm bolt	2	Arm clamp	DIN 912
M6 nut	2	Arm clamp	DIN 934 hex

Consumables:

- Rubber feet: Ø40mm × 5mm, self-adhesive (4×)
- EVA foam: 2mm thick, adhesive-backed (1 sheet)

1.9 Integration with dvi3v Workflow

Photography Setup:

1. Position stand on stable surface
2. Place A4 reference paper in work area (centered)
3. Install smartphone in holder (camera facing down)
4. Adjust height: 350-400mm typical for A4
5. Camera settings (if accessible):
 - Use timer (10s recommended for vibration settling)
 - Flash: OFF (use external diffuse lighting instead)
 - Grid: ON (helps with alignment)
 - Manual focus: Preferred but often unavailable in smartphones
 - Sharpening/Filters: OFF if accessible
6. External lighting: Diffuse, from sides (not overhead)
7. Capture image with timer to minimize vibration

Note on Smartphone Limitations: Modern smartphones (e.g., Google Pixel 9a) often don't expose full manual controls. The "Pro mode" may still be limited. This is acceptable - use what's available:

- ✓ Timer (essential for vibration damping)

- ✓ Flash control (turn OFF)
- ~ Manual focus (use if available, otherwise auto is acceptable)
- ~ ISO/Exposure (use auto if manual unavailable)

The key is consistent methodology, not perfect camera control.

Quality Criteria (from dvi3v requirements):

- ✓ Object in center of frame
- ✓ Sufficient contrast with background
- ✓ A4 paper visible for scale reference
- ✓ Uniform lighting (no harsh shadows)
- ✓ Minimal perspective distortion (parallel camera)
- ✓ No motion blur (vibration-free capture)

Data Collection Workflow:

FOR each test object:

1. Place object on A4 paper
2. Verify camera alignment (grid view)
3. Check focus (tap screen if needed)
4. Capture image
5. Review on phone (zoom to check sharpness)
6. Transfer to dvi3v processing pipeline
7. Record metadata (height, lighting, threshold used)

1.10 Future Enhancements

Identified Improvements:

1. **XY positioning:** Fine adjust camera position ($\pm 20\text{mm}$)
2. **Lighting integration:** LED ring light with diffuser
3. **Quick-release mount:** Bayonet-style phone attachment
4. **Electronic trigger:** Bluetooth remote or timer
5. **Reference scale:** Built-in ruler markings on base
6. **Leveling:** Adjustable feet with integrated bubble level
7. **Portability:** Foldable legs (tripod-style)

Material Research:

- PETG+CF: $3\times$ stiffness, test for vibration reduction
- TPU inserts: Dampen vibration at critical joints
- Steel plate: Adhesive base weight (500g) for stability

1.11 Design Rationale**Why Modular?**

- **Printability:** Fits Prusa Core One (250mm max)
- **Repairability:** Replace damaged segment, not entire column
- **Scalability:** Add segments for taller setups ($>500\text{mm}$)
- **Transportability:** Disassemble to $350\times 250\times 120\text{mm}$ package

Why PETG over PLA?

- **Temperature:** PETG stable to 60°C (PLA softens at 50°C)
- **Impact resistance:** PETG tougher (less brittle)
- **Longevity:** PETG doesn't degrade as fast
- **Trade-off:** PETG requires heated bed, more warping risk

Why Hexagonal Tessellation?

- **Strength-to-weight:** Honeycomb structure = optimal
- **Material savings:** $\sim 40\%$ reduction vs solid
- **Aesthetics:** Professional appearance
- **Trade-off:** Longer print time, more support material

Why Split Clamp vs Threaded Adjustment?

- **Simplicity:** No complex threading, easier to print
- **Speed:** Quick height changes (loosen, slide, tighten)
- **Reliability:** Fewer moving parts, less wear
- **Trade-off:** Less precise than leadscrew mechanism

1.12 Validation Metrics

To Be Measured During Data Collection:

1. Vibration decay time (target: <2 sec)
2. Deflection under load (target: <1mm)
3. Image quality: Sharpness vs hand-held (expect +30%)
4. Setup time per photo (target: <30 sec)
5. Repeatability: Position variance across 10 photos (target: <0.5mm)

Success Criteria:

- ✓ Enables consistent A4 detection in dvi3v
- ✓ Reduces failed detections by >50% vs hand-held
- ✓ Supports 100+ photo session without adjustment
- ✓ Survives disassembly/reassembly 20× cycles