3D CAD & PARAMETRIC DESIGN WORKSHOP POSTER

Geometric Kernels · Decision Tree · Tolerances · Fastener Specs & Shortcuts (2026)

1. CAD GEOMETRIC KERNELS AND INDUSTRIAL DATA INTERCHANGE MATRIX

B-REP & NURBS STANDARDS

Geometric Kernel	Developer / License	B-Rep & Modeling Precision	Key CAD Software Using Kernel	Native File Format	Recommended Neutral Format	Critical Exchange Rule
Parasolid	Siemens (Commercial License)	Industry leader; zero surface failure, ultra-stable assembly solving	SOLIDWORKS, Onshape, Siemens NX, Solid Edge	`.x_t`, `.x_b`	`STEP AP242` / `Parasolid X_T`	Between Parasolid-based CADs, direct .x_t export is completely lossless.
Autodesk Shape Mgr (ASM)	Autodesk (ACIS fork)	High precision; seamless T-Splines freeform surface integration	Autodesk Fusion, Inventor, AutoCAD 3D	`.f3d`, `.ipt`	`STEP AP214` / `STEP AP242`	When exporting STEP from cloud, T-Splines convert to exact B-Rep solids.
OpenCASCADE (OCCT)	Open CASCADE SA (LGPL-2.1+)	Open source standard; v1.0 eliminates topological naming errors	FreeCAD, CAD Exchanger, SALOME	`.FCStd`, `.brep`	`STEP AP214`, `IGES`	STEP export from FreeCAD maintains full color hierarchy and assembly structures.
CGAL & OpenCSG	Open Source (GPL / LGPL)	Exact arithmetic precision; computational geometry & CSG Booleans	OpenSCAD	`.scad` (Text/Code)	`CSG`, `STL`, `3MF`, `DXF`	Does not output STEP; solids export to high-density 3MF for 3D slicing.
OpenNURBS	McNeel & Associates (Open)	NURBS freeform surface mathematics (G0 to G3 continuity)	Rhino 3D, Grasshopper	`.3dm`	`STEP AP214`, `IGES`	Must join and verify surfaces as a "Closed Solid Polysurface" before mechanical export.

2. PARAMETRIC MODELING DECISION TREE

- **Mechanical / Manufacturing / 3D Print:**
  → **FreeCAD 1.0** (100% Free & Open Source)
  → **Fusion** (Hobby / Integrated CAM & CNC)
  → **Onshape** (Zero-Install Cloud / Team)
- **Variable Code-Driven Functional Parts:**
  → **OpenSCAD** (Update all geometry by changing variables).
- **Ultra-Light Mechanism & Kinematic Solver:**
  → **SolveSpace** (3MB standalone, live DOF analysis).
- **NURBS Freeform Surfaces & Computational Form:**
  → **Rhino + Grasshopper** (Algorithmic industrial design).

3. PREVENTING BROKEN MODELS (5 RULES)

- **1. Reference Primary Datum Planes:**
  Attach sketches to base XY/XZ/YZ planes, never dynamic model faces.
- **2. Never Reference Fillet/Chamfer Edges:**
  Fillet edges regenerate on size change; always snap to core parent geometry.
- **3. Order Fillets Last in Feature Tree:**
  Complete all cuts, extrusions, and holes before adding edge radii.
- **4. Fully Constrain Every Sketch:**
  Sketches must turn green (0 degrees of freedom) before extruding.
- **5. Master Parameter Spreadsheet:**
  Drive global critical dimensions from a central variable table.

4. SHEET METAL BEND & K-FACTOR

- **Bend Allowance Formula (BA):**

```
BA = π × (R + K × T) × (A / 180)
```

  R: Inside Bend Radius | T: Material Thickness | A: Bend Angle.
- **Typical K-Factor Values (Air Bending):**
  - **Mild Steel (T < 2mm)** : K = **0.33 – 0.38**
  - **Aluminum (5052-H32)** : K = **0.40 – 0.45**
  - **Stainless Steel** : K = **0.45 – 0.50**
- **Minimum Bend Radius:**
  To prevent outer wall fracture: `R ≥ 1.0 × T`.

5. METRIC FASTENER CLEARANCE HOLE & COUNTERBORE STANDARDS (ISO 273 / ISO 4762)

Thread Size	Pitch	Close Clearance (H12)	Normal Clearance (H13)	Loose Clearance (H14)	Socket Head Cap Ø	Counterbore Ø	Counterbore Depth	3D Printing (FDM) Hole Rec.
M2	0.40 mm	2.2 mm	2.4 mm	2.6 mm	3.8 mm	4.4 mm	2.4 mm	**2.5 mm** (Loose fit)
M2.5	0.45 mm	2.7 mm	2.9 mm	3.1 mm	4.5 mm	5.2 mm	2.9 mm	**3.0 mm**
M3 (Standard)	0.50 mm	3.2 mm	3.4 mm	3.6 mm	5.5 mm	6.5 mm	3.4 mm	**3.5 – 3.6 mm**
M4	0.70 mm	4.3 mm	4.5 mm	4.8 mm	7.0 mm	8.2 mm	4.4 mm	**4.6 – 4.7 mm**
M5	0.80 mm	5.3 mm	5.5 mm	5.8 mm	8.5 mm	9.8 mm	5.4 mm	**5.6 – 5.7 mm**
M6	1.00 mm	6.4 mm	6.6 mm	7.0 mm	10.0 mm	11.5 mm	6.5 mm	**6.7 – 6.8 mm**

6. ASSEMBLY MATES & CONSTRAINTS

- **Coincident Mate:**
  Aligns two planar faces coplanar (removes 3 DOF).
- **Concentric Mate:**
  Locks circular axes together (Shaft to hole alignment).
- **Tangent Mate:**
  Maintains smooth contact between curved faces/cams.
- **Distance / Limit Angle:**
  Defines mechanical stroke boundaries.
- **Core Principle:**
  Always ground/fix the primary chassis base component first.

7. UNIVERSAL CAD SHORTCUTS

Action	FreeCAD	Fusion	SOLIDWORKS
Orbit	Shift + Right Click	Shift + Middle Click	Middle Click
Pan	Middle Click	Middle Click	Ctrl + Middle Click
New Sketch	Create Sketch	C / L	Start Sketch
Extrude Solid	Pad	E	`Extrude Boss`
Dimension	D (Constraint)	D	`Smart Dimension`

8. DFM: DESIGN FOR MANUFACTURING

- **Draft Angle for Mold Release:**
  Provide minimum **1.0° – 2.0°** draft on vertical walls.
- **Uniform Wall Thickness Rule:**
  Abrupt thickness variations create internal stress and sink marks.
- **Internal Corner Radii:**
  Sharp inside corners concentrate stress; apply `R ≥ 0.5 × T`.
- **Rib Sizing Proportion:**
  Keep reinforcing rib thickness below 60% of base wall (`t ≤ 0.6 × T`).