

Computer-Aided Design

Types of CAD • File Formats • Manufacturing Integration • Design Automation

for engineers beginning a career built on digital design tools

What This Manual Covers

01

Foundations of CAD

What CAD is, its evolution, and why it matters

02

Types of CAD Modeling

2D vs 3D, wireframe, surface, solid, parametric

03

CAD File Formats

Native formats and neutral exchange standards

04

CAD in Manufacturing

CAM, CNC machining, and additive manufacturing

05

Design Automation

Parametric tools, APIs, generative design, PLM

06

Career Guidance

Best practices, pitfalls, and a learning roadmap

Foundations of CAD

What Is Computer-Aided Design?

CAD is the use of software to create, modify, analyze, and document engineering designs. It replaced the drafting board with a digital model that carries geometry, dimensions, and engineering intent through the entire product lifecycle.



1960s–70s

2D Drafting

Digital replacement for pencil-and-paper drawings (e.g. early Sketchpad, CADAM)



1980s–90s

3D Wireframe & Solids

Solid modeling kernels emerge — ACIS, Parasolid; PC-based CAD grows



1995–2010

Parametric Modeling

Feature-based, history-driven modeling becomes the industry standard



2010–Today

Cloud & Automation

Cloud collaboration, generative design, and API-driven automation

CORE CAPABILITIES

- 3D solid & surface modeling
- Assembly design & motion study
- Automatic 2D drawing generation
- Tolerance & fit analysis (GD&T)
- Basic simulation (FEA/CFD hooks)
- Bill of Materials (BOM) generation
- Data exchange with CAM & PLM systems

Why CAD Matters in Modern Engineering



Faster Iteration

Design changes propagate automatically across models and drawings, cutting revision time from days to minutes.



Fewer Errors

Interference checks, tolerance stacks, and simulation catch problems before a part is ever machined.



Team Collaboration

Cloud-based CAD lets distributed teams co-design, review, and manage version history in real time.



Full Lifecycle Support

One digital model feeds analysis, manufacturing, documentation, and service — from concept to end of life.

Types of CAD

How designs move from 2D drawings to intelligent 3D models

2D Drafting vs. 3D Modeling



2D CAD

Flat, orthographic representations plans, elevations, and sections drawn with lines, arcs, and dimensions. Still essential for schematics and manufacturing drawings.

- Used for: circuit diagrams, floor plans, weld symbols
- Fast to produce, lightweight files
- Limited spatial/interference checking
- Tools: AutoCAD, DraftSight, LibreCAD etc

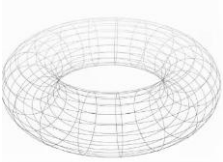


3D CAD

Volumetric digital models describing the full geometry of a part. Drawings, mass properties, and simulations are all derived automatically from the same model.

- Used for: parts, assemblies, mechanisms
- Enables simulation, CAM, and 3D printing
- Larger files, steeper learning curve
- Tools: SolidWorks, Fusion 360, CATIA, NX

3D Modeling Techniques

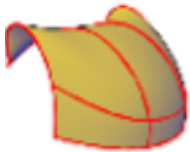


Wireframe

Geometry defined only by edges and vertices — no surfaces or volume.

TYPICAL USE

Quick concept layouts, reference geometry



Surface Modeling

Zero-thickness skins that define complex, free-form shapes with precision.

TYPICAL USE

Car bodies, consumer product housings, aerodynamic parts



Solid Modeling

Fully defined, watertight volumes with mass, material, and topology.

TYPICAL USE

Machined parts, structural components, most mechanical design

Parametric vs. Direct Modeling

The two dominant approaches to building and editing 3D geometry — most CAD careers begin with one and eventually touch both.

Aspect	Parametric Modeling	Direct Modeling
How it works	Features are built in a recorded history tree, driven by dimensions and relationships	Geometry is pushed, pulled, and edited directly — no history tree
Editing changes	Edit the originating feature or dimension; downstream features update	Select a face/edge and modify it on the spot
Best for	Repeatable, engineered products with defined rules (brackets, housings)	Quick concept changes, imported or “dumb” geometry
Learning curve	Steeper — requires planning the feature tree	Gentler — more intuitive for beginners
Examples	SolidWorks, Inventor, Creo, NX (Synchronous adds direct)	Fusion 360 (Direct mode), SpaceClaim, Onshape (Direct)

The CAD Software Landscape

SolidWorks

● *Parametric, feature-based*

Machine design, product development

Autodesk Fusion 360

● *Parametric + Direct, cloud-native*

Startups, integrated CAM & simulation

Autodesk Inventor

● *Parametric, feature-based*

Manufacturing, large assemblies

CATIA

● *Parametric, surface-heavy*

Aerospace, automotive, complex surfaces

Siemens NX

● *Parametric + Synchronous (direct)*

Aerospace, automotive, high-end mfg.

PTC Creo

● *Parametric, feature-based*

Industrial equipment, mechanisms

Onshape

● *Parametric, fully cloud-based*

Remote teams, real-time collaboration

AutoCAD

● *2D drafting + basic 3D*

General drafting, civil/architectural

CAD File Types

Native formats, neutral exchange standards, and where each one belongs

Native Files vs. Neutral Exchange Files



Native Formats

Proprietary formats tied to one CAD system. They preserve the full feature history, parametric relationships, and design intent — but usually can't be opened by other software.

EXAMPLES

.SLDPRT / .SLDASM • .IPT / .IAM • .PRT / .ASM • .CATPART • .F3D

Best for: active editing within one CAD system, internal design work



Neutral Formats

Vendor-independent formats designed for interoperability between different CAD, CAM, and CAE systems — the common language of the supply chain.

EXAMPLES

.STEP (.stp) • .IGES (.igs) • .STL • .3MF • .OBJ • .DXF • .PDF

Best for: sharing with vendors, manufacturing, 3D printing, archival

Common Native File Extensions

Software	Part File	Assembly File	Drawing File
SolidWorks	.sldprt	.sldasm	.slddrw
Autodesk Inventor	.ipt	.iam	.idw / .dwg
Fusion 360	.f3d (cloud)	.f3d (cloud)	.f2d / exported .dwg
PTC Creo	.prt	.asm	.drw
Siemens NX	.prt	.prt	.prt (drawing part)
CATIA	.catpart	.catproduct	.catdrawing
AutoCAD	—	—	.dwg

Native files are usually version-locked — e.g. a part saved in SolidWorks 2026 may not open in SolidWorks 2023.

Neutral Formats: STEP & IGES

STEP

.stp / .step

Standard for the Exchange of Product Data. The modern default for sharing solid geometry between CAD systems preserves precise B-rep solids, assembly structure, and often colors/metadata.

- Accurate solid/surface geometry
- Preserves assembly hierarchy
- Widely supported — the safe default
- No feature history or parametrics

IGES

.igs / .iges

An older neutral format (1980s) still used in legacy workflows and for surface-heavy geometry. Largely superseded by STEP for solids but persists in aerospace and some CAM toolpaths.

- Strong for free-form surfaces
- Can lose solid/topology integrity
- Being phased out in favor of STEP
- Still requested by some legacy suppliers

Mesh Formats: STL, OBJ & 3MF

These formats approximate curved surfaces with flat triangles (a mesh) rather than exact mathematical geometry — the language of 3D printing.



STL

.stl

The de-facto standard for 3D printing. Stores only triangulated surface geometry no color, units, or scale metadata.



OBJ

.obj

Mesh format that also carries color and texture data. Common in visualization, rendering, and reverse engineering.



3MF

.3mf

Modern replacement for STL — adds units, color, materials, and print settings in one compact package.

2D Drafting & Documentation Formats

Format	Extension	Purpose	Editable?
DWG	.dwg	AutoCAD's native 2D/3D drawing format — the industry standard for drafting exchange	Yes
DXF	.dxf	Open, text-based drawing exchange format readable by nearly all CAD software	Yes
PDF	.pdf	Flattened, view-only drawing for review, approval, and the shop floor	No (view only)
Vector image (SVG/EPS)	.svg / .eps	2D profile export for laser cutting, engraving, or graphic use	Limited



Always confirm which file the recipient actually needs. A machinist may want a dimensioned PDF; a subcontractor doing further editing needs the native or STEP file.

Choosing the Right File Format

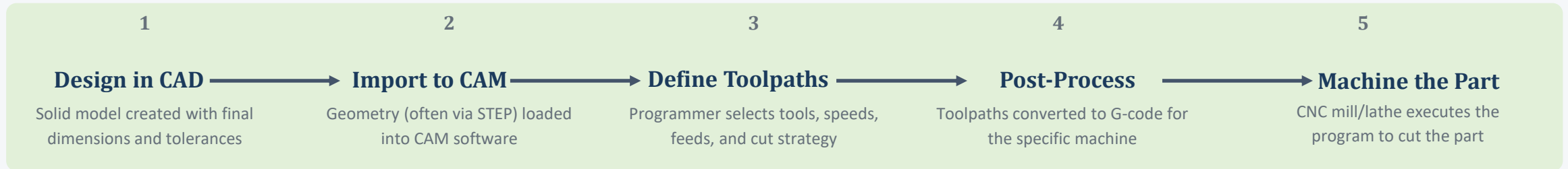
- | | |
|---|---|
| ✓ Editing in the same CAD system | Native format (.sldprt, .ipt, .prt ...) |
| ✓ Sharing a solid model with another CAD system | STEP (.stp) |
| ✓ Sending to a 3D printer / additive service | STL or 3MF |
| ✓ Issuing a manufacturing drawing for review | PDF |
| ✓ Exchanging 2D drawings with a drafter | DWG or DXF |
| ✓ Archiving a design for long-term storage | STEP + PDF (vendor-neutral) |

CAD in Manufacturing

From digital model to physical part: CAM, CNC, and additive manufacturing

CAD-to-CAM: Driving CNC Machines

The CAD model doesn't stop at design — it becomes the direct input for Computer-Aided Manufacturing (CAM) software, which generates toolpaths for CNC mills, lathes, and routers.



Design-for-manufacturability (DFM) matters here: sharp internal corners, thin walls, or inaccessible features designed in CAD can make a part difficult or impossible to machine.

CAD for Additive Manufacturing (3D Printing)

Additive manufacturing builds parts layer by layer, opening design freedom that traditional CNC machining can't match — but it requires its own CAD discipline.

Design Freedom

- Internal lattices for weight reduction
- Organic, topology-optimized shapes
- Consolidated multi-part assemblies
- Conformal cooling channels

CAD-to-Print Workflow

- Export solid model as STL or 3MF
- Repair mesh (fill holes, fix normals)
- Orient part & generate supports
- Slice into layers and print

Design Considerations

- Minimum wall thickness per material
- Overhang angles that need supports
- Escape holes for trapped powder/resin
- Shrinkage & tolerance allowances

Design Automation in CAD

Letting the software do repetitive design work so engineers can focus on judgment

Why Design Automation Matters

Design automation uses rules, parameters, and code to generate or modify CAD geometry with minimal manual input — turning repetitive modeling into a configurable, reusable system.

70%+

of engineering time in some firms is spent on repetitive, non-novel design tasks

10×

faster quoting is achievable when configurators auto-generate models & drawings

Zero

manual re-drawing needed when a parametric change updates every dependent file

KEY BENEFITS

- Reduces human error in repetitive tasks
- Frees engineers for higher-value problem solving
- Speeds up quoting and configuration
- Ensures consistency across product families

Techniques & Tools for Automation

Design Tables & Configurations

Spreadsheet-driven variants of a single model generate a family of fastener sizes or enclosure options from one parametric file.

Macros, APIs & Scripting

Record or write code (VBA, Python, C#) to automate repetitive tasks, batch-exporting files, updating title blocks, or building custom features.

Generative & Topology Optimization

Software explores thousands of geometric variants against load cases and constraints, proposing optimized, often organic shapes.

PLM / PDM Integration

Product Lifecycle & Data Management systems automate revision control, approvals, and links between CAD files and the BOM.

Best Practices for New CAD Engineers

01

Plan before modeling

Sketch the feature sequence on paper first. A well-planned tree is easier to edit later.

02

Use clear naming conventions

Name parts, features, and files consistently so teammates (and future you) can navigate them.

03

Model design intent, not just shape

Use relations, equations, and symmetry so the model behaves correctly when dimensions change.

04

Learn GD&T fundamentals

Geometric Dimensioning & Tolerancing communicates fit and function not just size.

05

Keep files organized & backed up

Use consistent folder structures and a PDM/version-control system from day one.

06

Always verify before releasing

Check interferences, mass properties, and drawing views before a design goes to manufacturing.

Common Mistakes New Users Should Avoid



Over-constraining sketches

Fighting the sketch solver with redundant dimensions instead of using symmetry and relations.



Ignoring tolerances

Modeling nominal geometry only, without considering how parts will actually fit together.



Fragile feature trees

Referencing faces or edges that disappear when an earlier feature changes.



Wrong file format for the job

Sending a native file to a vendor who can't open it, or an STL when a STEP was needed.



Skipping design reviews

Releasing a model to manufacturing without a second set of eyes checking for errors.

A Learning Roadmap for New CAD Engineers



Certifications worth pursuing: CSWA/CSWP (SolidWorks), Autodesk Certified User/Professional, ASME Y14.5 GD&T training

KEY TAKEAWAYS

What to Remember

- ✓ CAD spans 2D drafting through parametric 3D solid modeling, know which tool fits which task.
- ✓ File format is a decision, not an afterthought: native for editing, STEP for CAD exchange, STL/3MF for printing, DWG/PDF for documentation.
- ✓ CAD is the starting point of manufacturing, not the end, it feeds CAM/CNC and additive workflows directly.
- ✓ Design automation — tables, scripting, generative tools, PLM turns repetitive modeling into leverage.
- ✓ Strong fundamentals (clean sketches, design intent, GD&T) matter more long-term than any single software package.

Keep Designing.

Every expert CAD engineer started with a first sketch. Build strong fundamentals, stay curious about new tools, and let the model do the repetitive work for you.