

CAD and Technical Drawings

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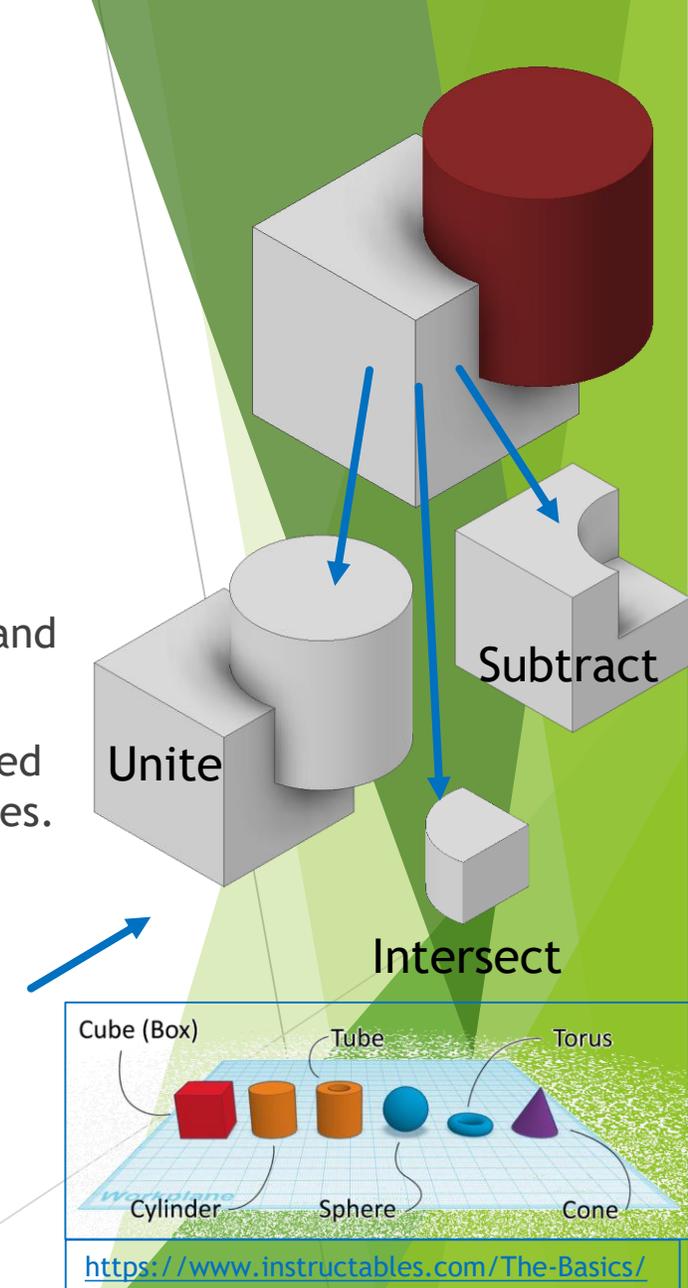
Lecture Content

- ▶ Brief introduction to how a CAD package “thinks”
- ▶ Brief overview of Mechanical CAD Software
- ▶ Common tools/plugin-ins
- ▶ Typical Design Engineering Workflow
- ▶ Introduction to Technical Drawings (AKA Technical Product Specification - ISO)
- ▶ Note on Configuration Management and Quality Control
- ▶ Working with CAD/CAM packages
 - ▶ Not all file formats are equal, or compatible.

- ▶ What I won't cover: Computer Aided Machining. This is a whole other beast, and is best left to the professionals in the manufacturing facilities!

How Does CAD Software “Think”?

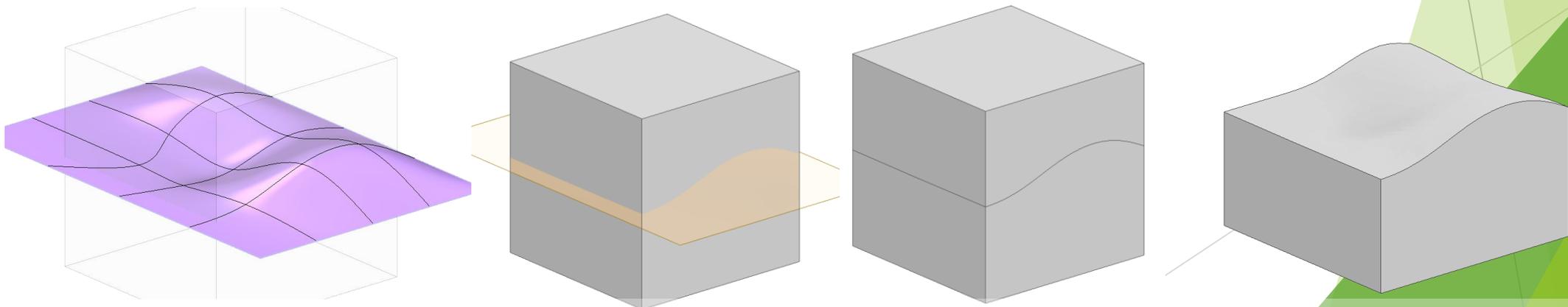
- ▶ Starting in 1957 with PRONTO, then SketchPad in 1963, through to today’s modern 3D CAD/CAM Software compatible with futuristic VR/AR systems, engineering productivity has improved drastically.
- ▶ Nowadays, 3D CAD/CAM typically works in two ways:
 - ▶ Parametric Modelling: Also referred to as “ordered” modelling, sketches are created and used to create features with parameters stored within each sketch and feature command.
 - ▶ Direct/Explicit Modelling: Sketches are used to create geometry and are consumed by the process. Modifications can be made by ‘pushing’ or ‘pulling’ on the surfaces.
- ▶ For “Constructive Solid Geometry” (CSG), primitive shapes and boolean commands form a majority of what is happening ‘behind the scenes’. These commands are typically called Unite, Subtract, and Intersect
 - ▶ Alternatively, Boundary Representation modelling forms a solid by defining the spatial boundaries (points, edges etc.), then joining these.



- ▶ Extra Reading: https://partsolutions.com/wp-content/uploads/2021/09/2021-History-of-CAD-Infographic_2000.png

How Does CAD Software “Think”?

- ▶ A parallel approach to modelling, which is seeing ever-increasing use as we move towards more efficient structures, is surface modelling.
- ▶ Surfaces are typically used in combination with 3D solids (CSG) and boolean commands to create the products that we use every day.
 - ▶ A modern ergonomic computer mouse won't have a constant radius of curvature, it is designed with a surface to better match the organic structures of our hands.
- ▶ Surfaces are typically represented by “NURBS”, Non-Uniform Rational B-Splines, applied to a set of points in 3D space.
- ▶ In solid modelling, we can generate and modify a surface which is then used as the second ‘body’ in a new Boolean command: Split.



- ▶ “Don't use Wikipedia”: https://en.wikipedia.org/wiki/Non-uniform_rational_B-spline

Brief Overview of Mechanical Design Software



creo®



AUTODESK®
AUTOCAD®

- ▶ These are the industry-leading CAD packages. License prices vary wildly, but so do the features included.
- ▶ Experience in many packages is essential due to the global research network that we are a part of.
- ▶ At Oxford TSG, we use a combination of Autodesk Inventor, SolidEdge, and CATIA.
- ▶ CAD packages are typically specified at the project level to ensure design compatibility at all stages, across all collaborating institutes.

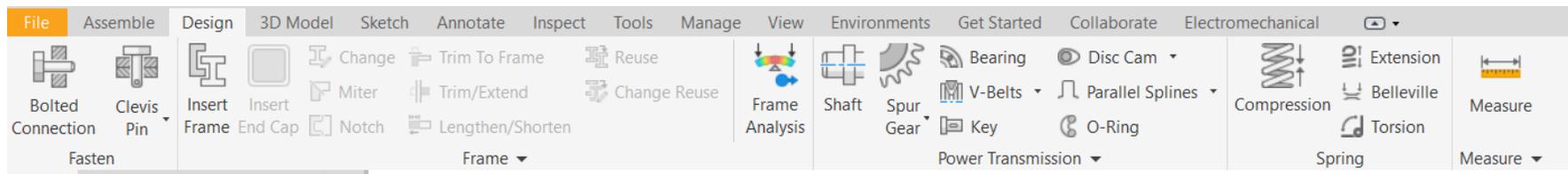
Common tools/plugin-ins

- ▶ *This list can never be complete, as new systems are added all the time.*
- ▶ *Typically, a CAD license will come with a selection of design-assisting tools, and compatability with other software.*

▶ Standard Parts Libraries

- ▶ Quick-generation of standard Fasteners, Bearings, Structural shapes, Seals, Bushings etc.

- ▶ Design Assistant Tools: Summarise textbook calculation methods and apply solutions directly into the design model. Example taskbar from Inventor shown below:



- ▶ Integrated Finite Element Analysis
- ▶ Additive Manufacturing Tools
- ▶ Cable and Harness Design
- ▶ Tube/Pipe Routing
- ▶ Mechanism Animation Tools
- ▶ Mechanism Interference/Contact Detection

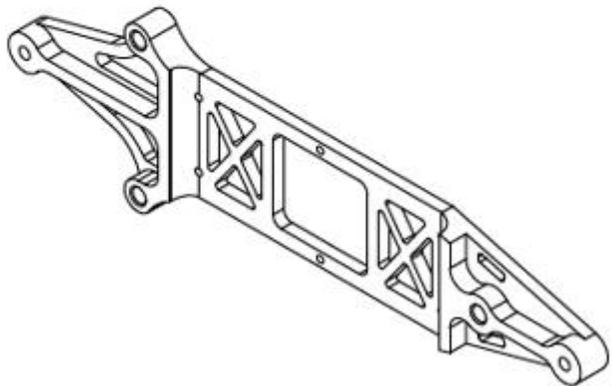
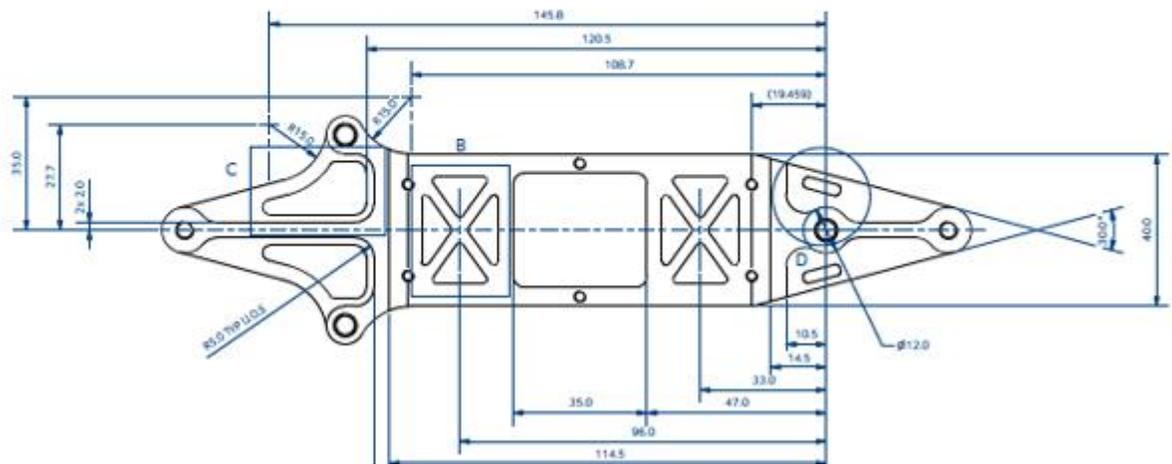
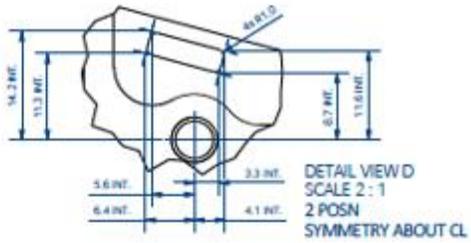
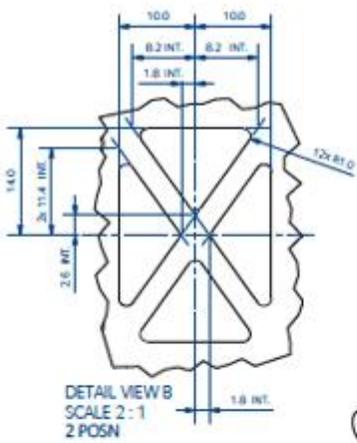
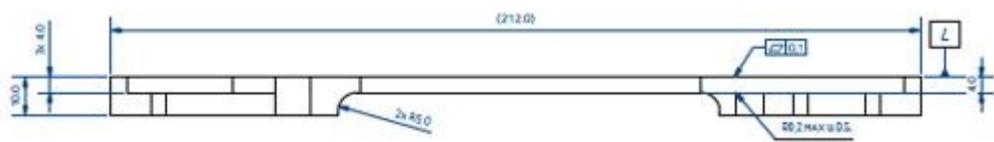
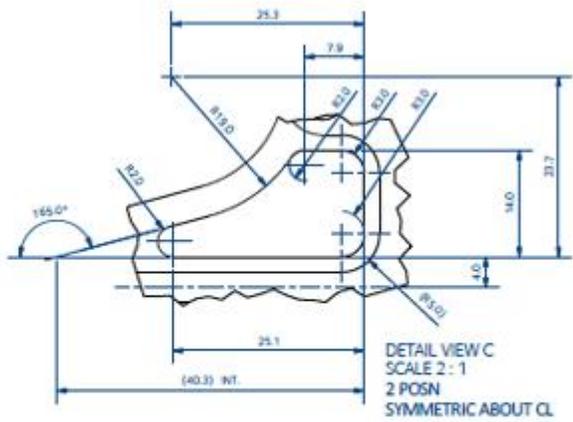
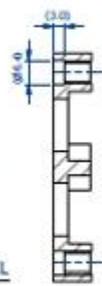
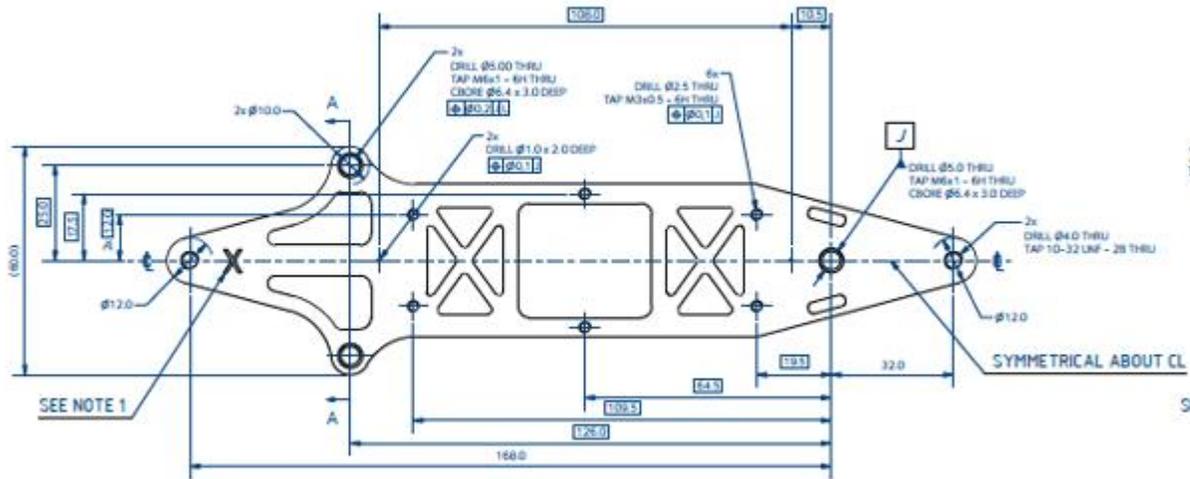
The background features abstract, overlapping geometric shapes in various shades of green, ranging from light lime to dark forest green. The shapes are primarily triangles and polygons, creating a dynamic, layered effect. The central area is white, providing a clear space for the text.

With all these tools at our disposal, how do we start?

Typical Design Engineering Workflow

There are too many valid ways to approach a design. This is my most common path.

- 1. Project Specification.**
Requirements. Deliverables. Constraints.
- 2. Research.**
Find relevant information. Check for existing solutions.
- 3. Concept**
Sketches and concept models. Critical calculations for the “known unknowns”
- 4. Evaluation**
Checking solutions against project specification.
- 5. Concept Design Review**
Selecting a design to run with. Getting feedback from key stakeholders. “everyone who cares”
↓
- 6. Detailed Design**
Building up the design starting with all known features. Allow for design flexibility wherever possible. An experienced CAD user can easily set up models with named parameters which link to each other, allowing quick “excel-style” modification of 3D solids. Example shown at the end of this talk. 
- 7. Design Analysis**
Investigating all critical parts for safety and agreement to operational limits/requirements.
- 8. Create Engineering Drawings, Discuss with Manufacturers.**
Getting feedback to optimise for manufacturability; Cost vs Quality vs Time.
- 9. Critical Design Review**
AKA Production Readiness Review. Have we met all of the requirements?



Introduction to Technical Drawings

- ▶ CAD Software makes technical drawing significantly quicker compared to the manual drawing-board techniques of old.
- ▶ We can now immediately generate views of a part in any perspective, at any scale, on any size paper and to any standard we require.
- ▶ We can create incredibly detailed exploded views of assemblies in a few clicks.
- ▶ We can generate a bill of materials to help track all of the parts.
- ▶ We can easily label every part with automatic updates so future additions can easily be captured.
- ▶ We can create standard note tables and apply them to several drawings at once
- ▶ We can automatically stamp and release drawings after they've gone through all the required checks.

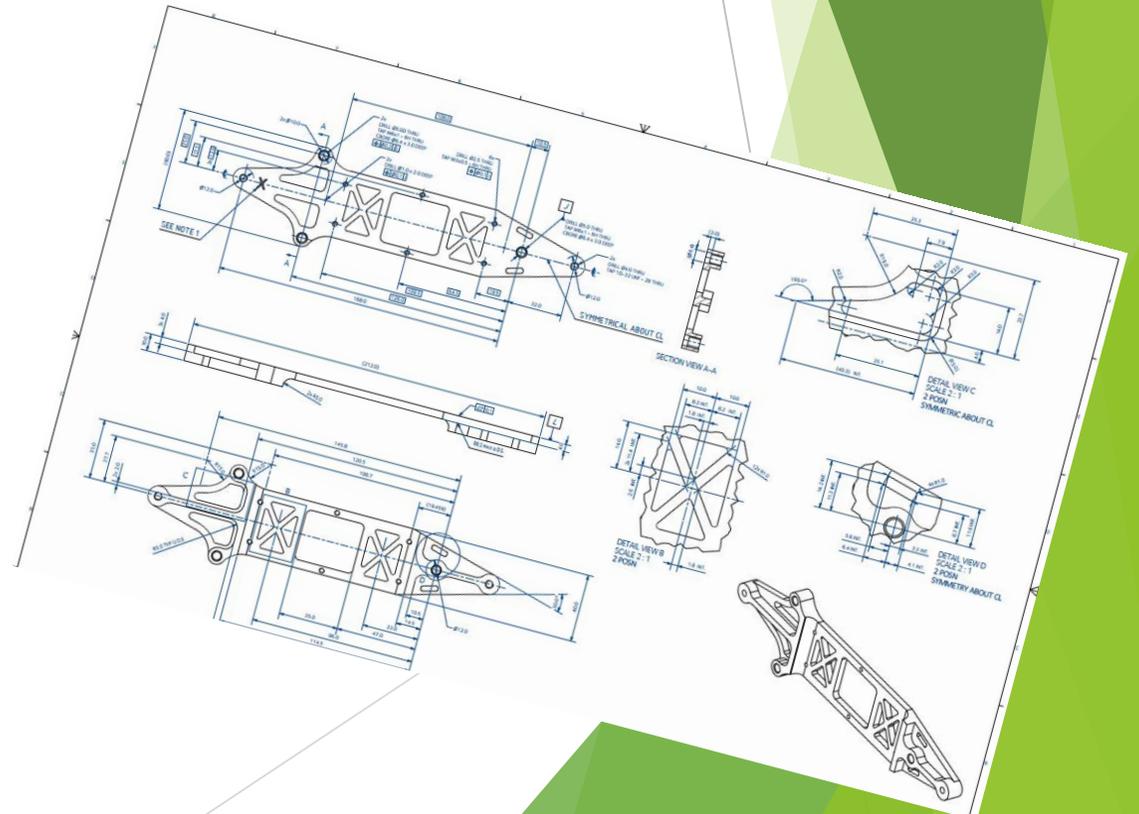
- ▶ With all of this convenience, there are a lot of traps you can fall into.

- ▶ Modern technical drawings are easy to generate.
- ▶ Getting the part you want/need, at a reasonable cost, is another story.

Introduction to Technical Drawings

- ▶ Many drawing standards exist across the globe. The International Standards Organisation (ISO) draws from all of these and attempts to unify global standards.
- ▶ Technical drawings are said to be a legal contract. With such importance and as the first avenue of interrogation for non-conformance, they must be carefully controlled.
- ▶ The intent of a technical drawing should be to remove all ambiguity in a product specification.
- ▶ It should contain all information relating to the manufacturing, and if applicable, inspection of a component or assembly.
- ▶ Where possible, use of words should be replaced by standardised symbols. A few are given below.

□ SQUARE	∇ DEPTH
└┘ COUNTERBORE	⊥ CENTRELINE
∨ COUNTERSINK	∠ ANGLE



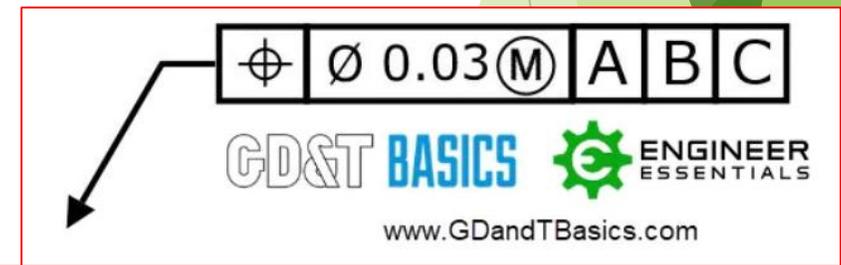
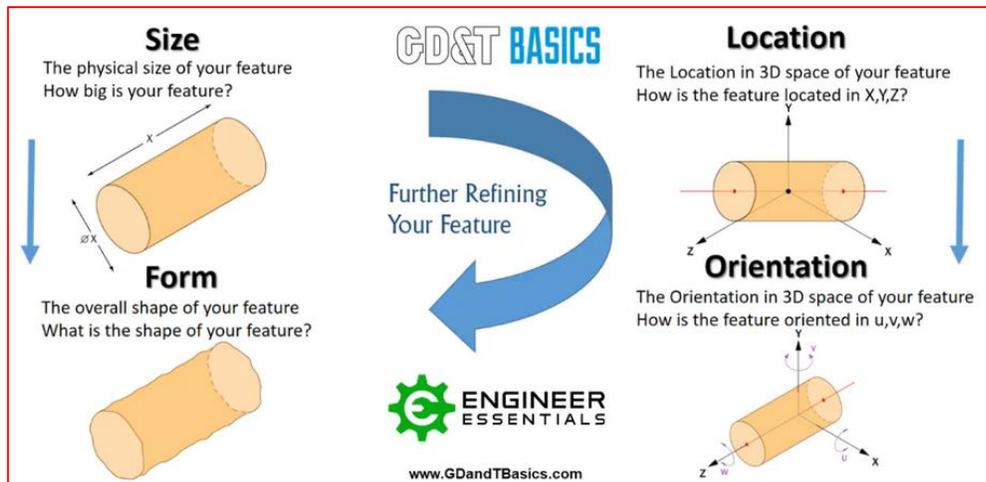
Introduction to Technical Drawings

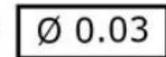
- ▶ So, we've drawn a part, will it work and meet all of our requirements?
- ▶ This depends on Engineering Tolerance.
- ▶ 3D models are geometrically perfect. In a virtual space, a dimension of 383.586 mm is exactly where it "should" be. In reality, we can't achieve such precision.
- ▶ Machining accuracy can be affected by:
 - ▶ Tool wear
 - ▶ Machine vibration
 - ▶ Clamping arrangement
 - ▶ Material properties
 - ▶ Hardness
 - ▶ Residual Stress
 - ▶ Coolant use
 - ▶ Thermal expansion of part and machine
 - ▶ Post-machining operations
 - ▶ Travel accuracy
 - ▶ Kinematic Errors (inaccuracy/clearance in machine components)
 - ▶ Machine calibration schedule
 - ▶ Ambient environment conditions
 - ▶ Static/Dynamic loads
 - ▶ Software Errors
 - ▶

It never hurts to arrange a meeting with the manufacturing facility and asking for a quick drawing review.

Introduction to Technical Drawings

- ▶ Drawings form part of a legal contract. Tolerances cannot be “as good as you can get”. This invites ambiguity.
- ▶ It’s possible to hit single digit precision. It’s also very expensive.
- ▶ A large part of good design practice is in knowing what you need.
- ▶ The majority of dimensions in our line of work can be controlled by simple limits. These may be displayed on the drawing border as a “general tolerance” scheme.
- ▶ For more critical features, most drawing standards include some variation of GD&T: Geometrical Dimensioning and Tolerancing.



This Feature has  of  In Reference to  with 
 True Position 30 Micron Diameter tolerance Datum A, B and C Max Material Condition

A great resource to learn more is www.gdantbasics.com

Configuration Management and Quality Control

- ▶ A huge topic that can't be covered in 1 minute.
- ▶ A well-specified drawing border contains critical information for quality control, and has a large impact on configuration management.

Example Drawing Border
(Removed for sensitive data)

- ▶ Naming, Numbering, and Version Control is CRITICAL.
- ▶ Lots of effort and lots of money has been wasted on poorly controlled documentation.
- ▶ Names should be clear and consistent with an agreed structure, e.g. “WHAT-WHERE-WHERE”
- ▶ Numbers should be grouped with agreed identifiers, e.g. Project, Subsection/Work Package
- ▶ Version/Issue should be updated on ANY change. A drawing must always be signed off and RELEASED at the given version prior to manufacture.

A Final Note on Data Transfer

- ▶ You'll typically see files shared between institutes and working groups as "STEP" files. STEP refers to the Standard for the Exchange of Product Data.
- ▶ Effectively, a STEP file converts your 3D geometry into a text format that is readable by most good CAD software.
- ▶ You may be asked by machine shops to provide an IGES file. The precursor to a STEP file and may be compatible with older CNC machines.
- ▶ Where possible, transferring working-data as an STL (Stereolithography) file should be avoided. There are exceptions (e.g. for 3D printing), but the conversion to STL turns all objects into a set of triangles, which is then very difficult to modify on the other end.
- ▶ Here's an example STL of our freeform surface from earlier

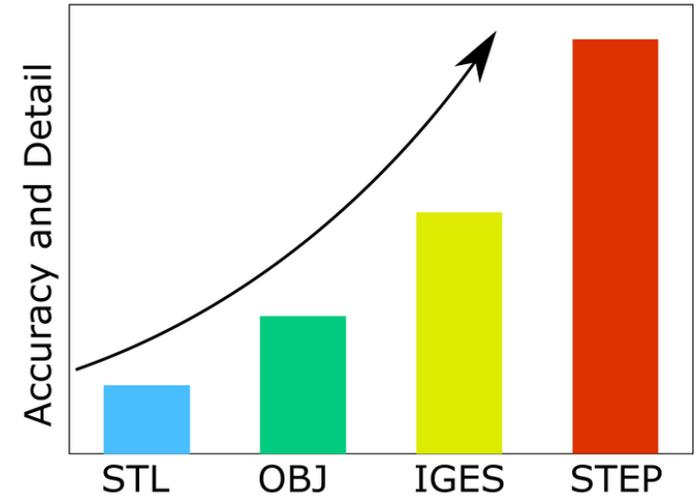
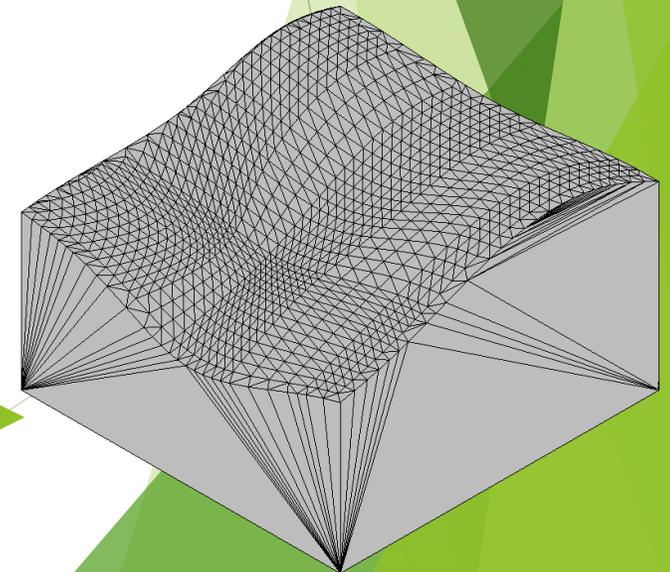


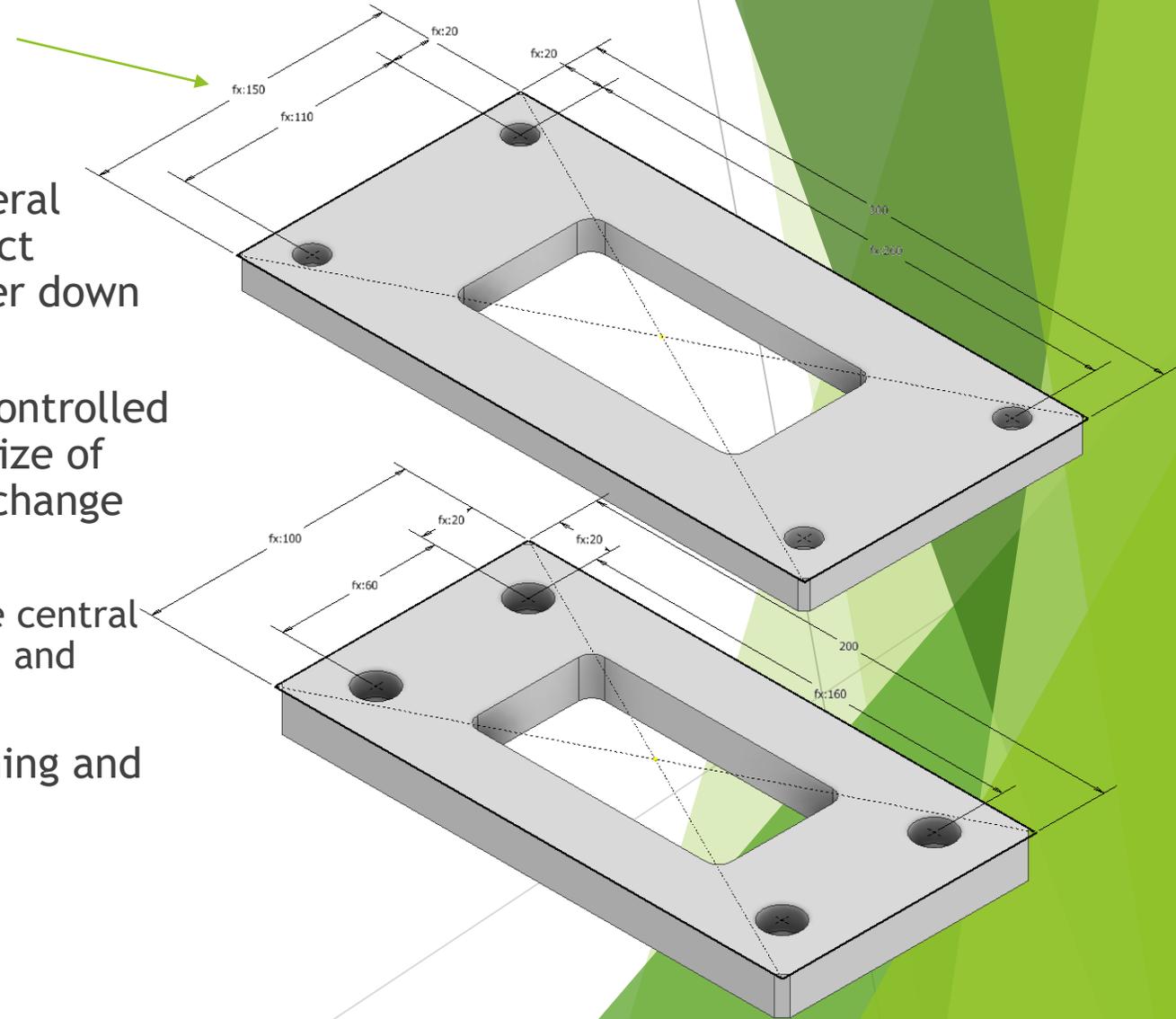
Image credit: <https://jayconsystems.com/>



Examples of Parametric Modelling

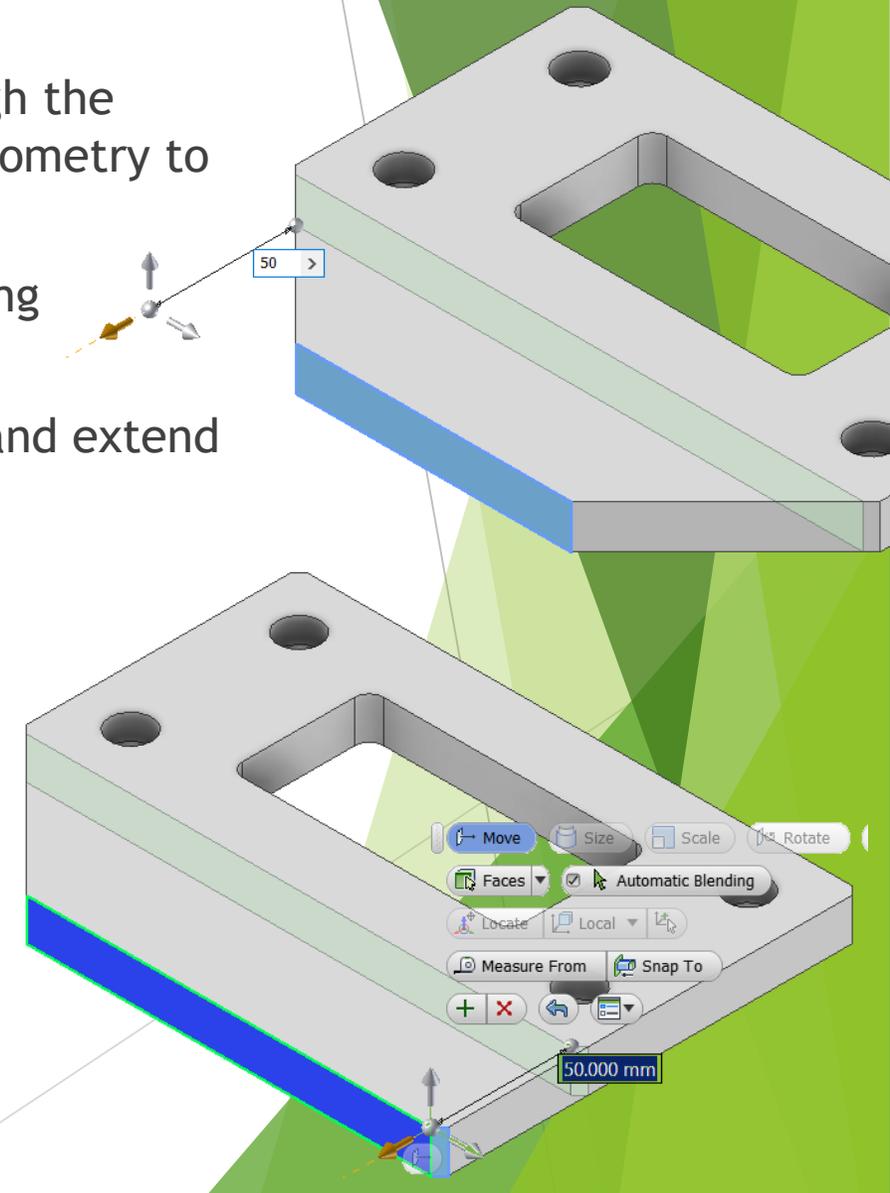
“fx” here implies that the dimension is a function of another.

- ▶ Parametric modelling lets us quickly build several models for multiple designs in the same product “family”, or to allow rapid design changes later down the line.
- ▶ Here, we have a plate whose entire design is controlled by the longest dimension, thickness, and the size of the holes. Changing “Length” propagates the change down the model tree.
 - ▶ For example, Width is equal to $0.5 * \text{Length}$. The central cutout is equal to “ $0.5 * \text{Length}$ ” in one direction and “ $0.5 * \text{Width}$ ” in the other.
- ▶ It’s a powerful tool, but requires careful planning and thought to get the most advantage.



Example of Synchronous Modelling

- ▶ Unlike previously, where we have a change that propagates through the model tree, synchronous/direct modelling manipulates existing geometry to add features or change dimensions.
- ▶ On the example, we pull one face, which extends the corresponding chamfers.
- ▶ Alternatively we can pull 3 faces (as above, including chamfers), and extend the whole plate in this direction.
- ▶ This is a quick way to make changes, but care must be taken as it can be very easy to trip up.



Extra Slides?
Let's just dive into some CAD.