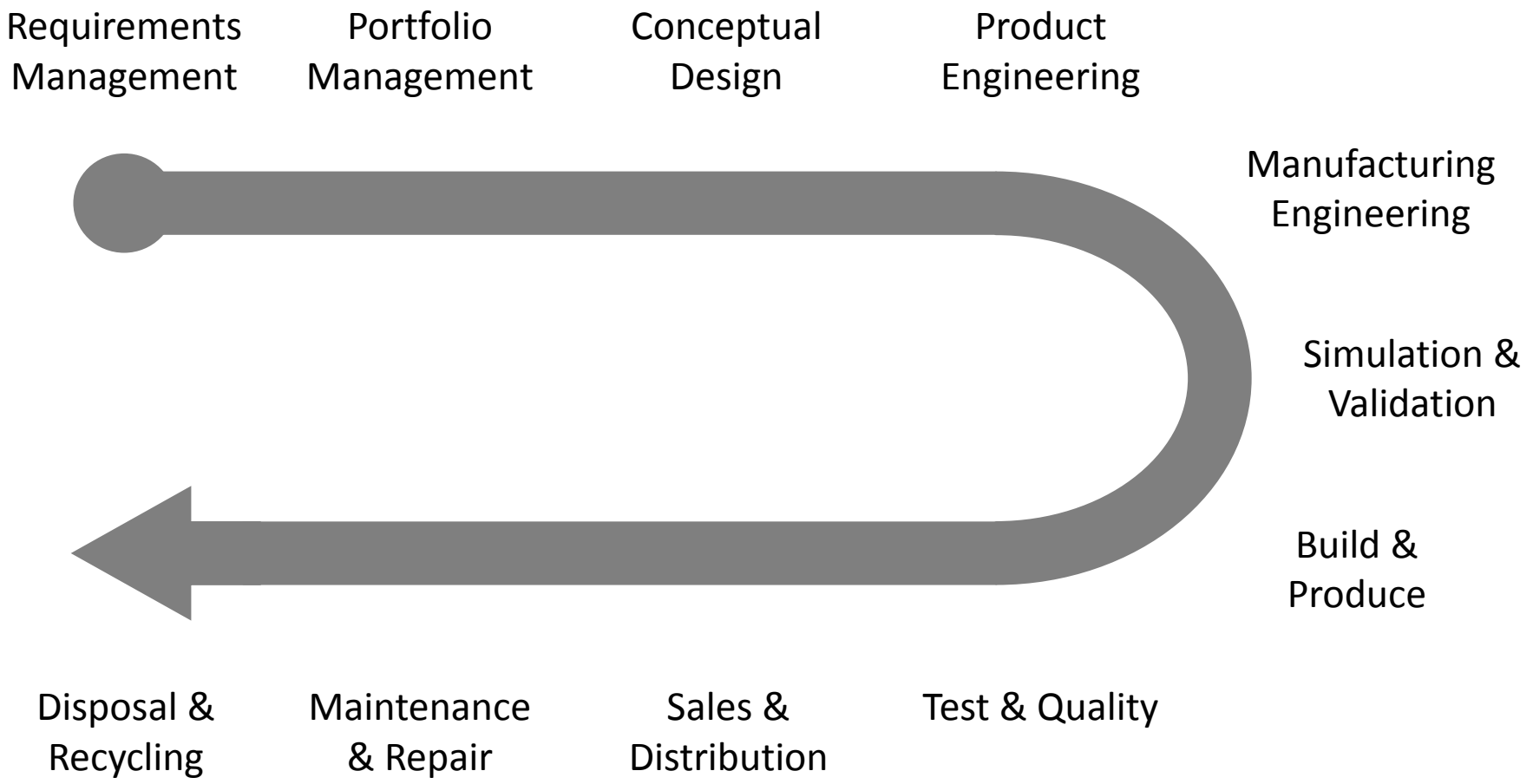
Carnegie Mellon University

Week 2 – Lecture
3D Part Design

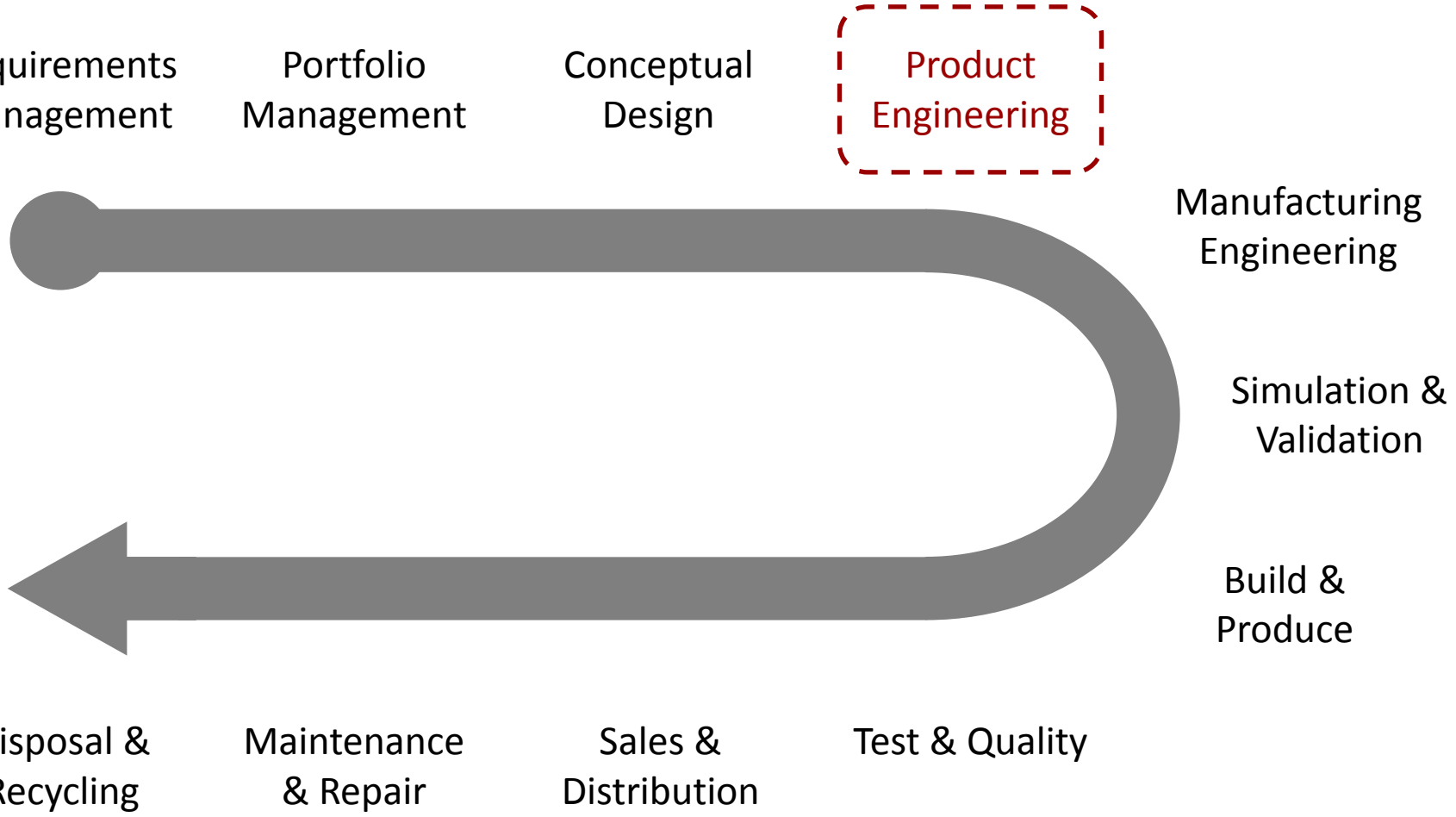
Lecture Topics

- Product Lifecycle Process Review
- Detailed Product Engineering
- Challenges and Purpose
- Evolution of CAD
- General 3D Design Concepts
- Case Study Examples

Product Lifecycle



Product Lifecycle – Week 2

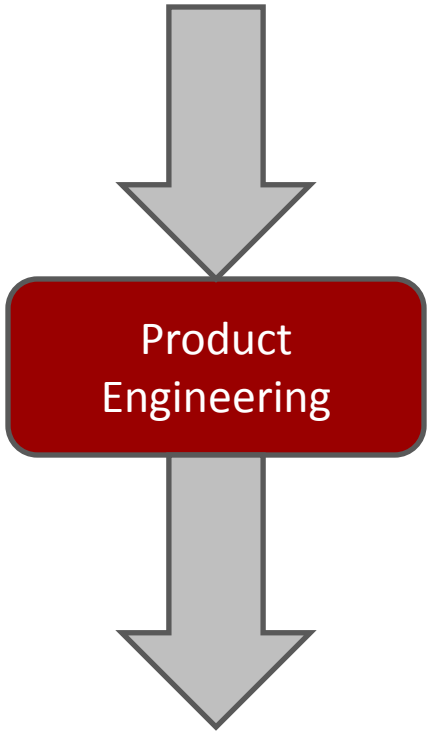


Product Engineering

- Product engineering following conceptual design is responsible for the continued development of the concept to a full technically complete design.

Product Engineering

- Inputs
  - Conceptual Design Data
  - Project / Design Requirements
  - Reference Data
- Outputs
  - Technical Complete Product Design
  - Design Data for Manufacturing
  - Bill of Materials (BOM)

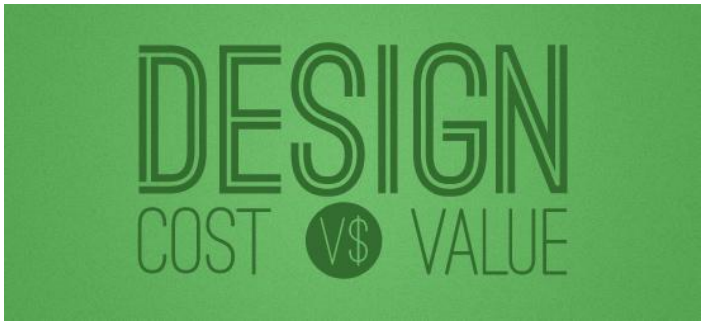


Product Engineering Challenges

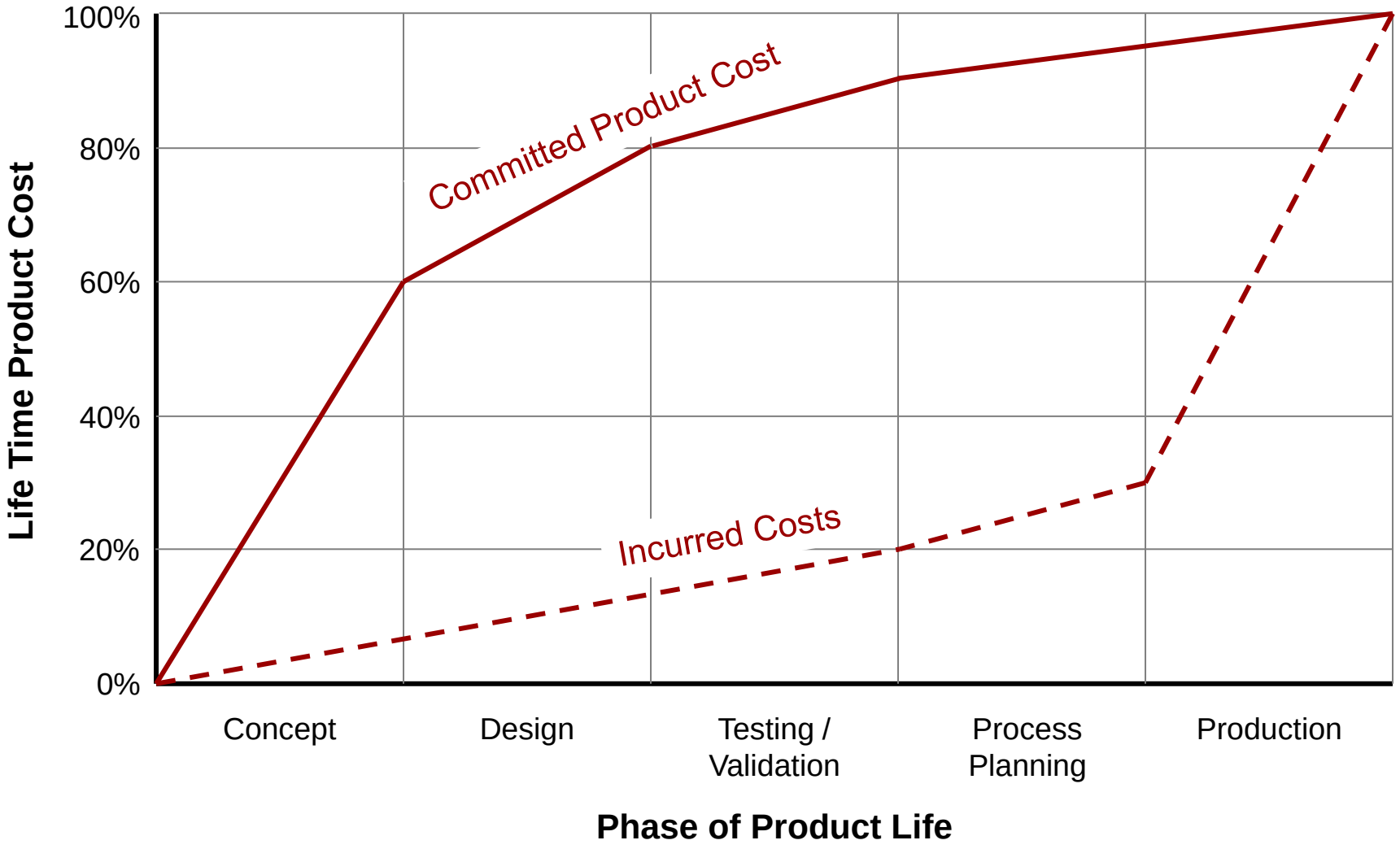
- Project Schedules
- Design Cost
- Product Quality
- Addressing Requirements
- Changes (All Types)

Consigli Construction
Project Schedule

Activity	Duration	2006	2007
Design	60	Jan - Apr	
Procurement/Mobilization	20	Apr - May	
Start Construction	0	May	
Dowden Hall Parking	60	May - Aug	
Sitework	50	May - July	
Foundations	40	July - Sept	
Erect Structure	30	Mar - Apr	
MEP's	70	Apr - Aug	
Elevator	50	May - Aug	
Garage Finishes	20	July - Aug	
Finish Construction	0	Aug	



Product Cost vs. Time



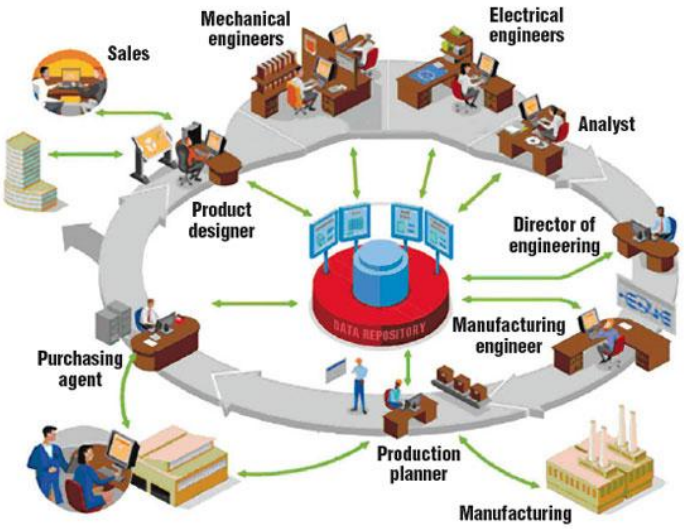
Rule of Ten

- The “Rule of Ten” specifies that it costs 10 times more for an engineering change at the next phase.

Time of Change	Cost of Change
During Design	X
During Design Testing	10 X
During Process Planning	100 X
During Test Production	1,000 X
During Final Production	10,000 X

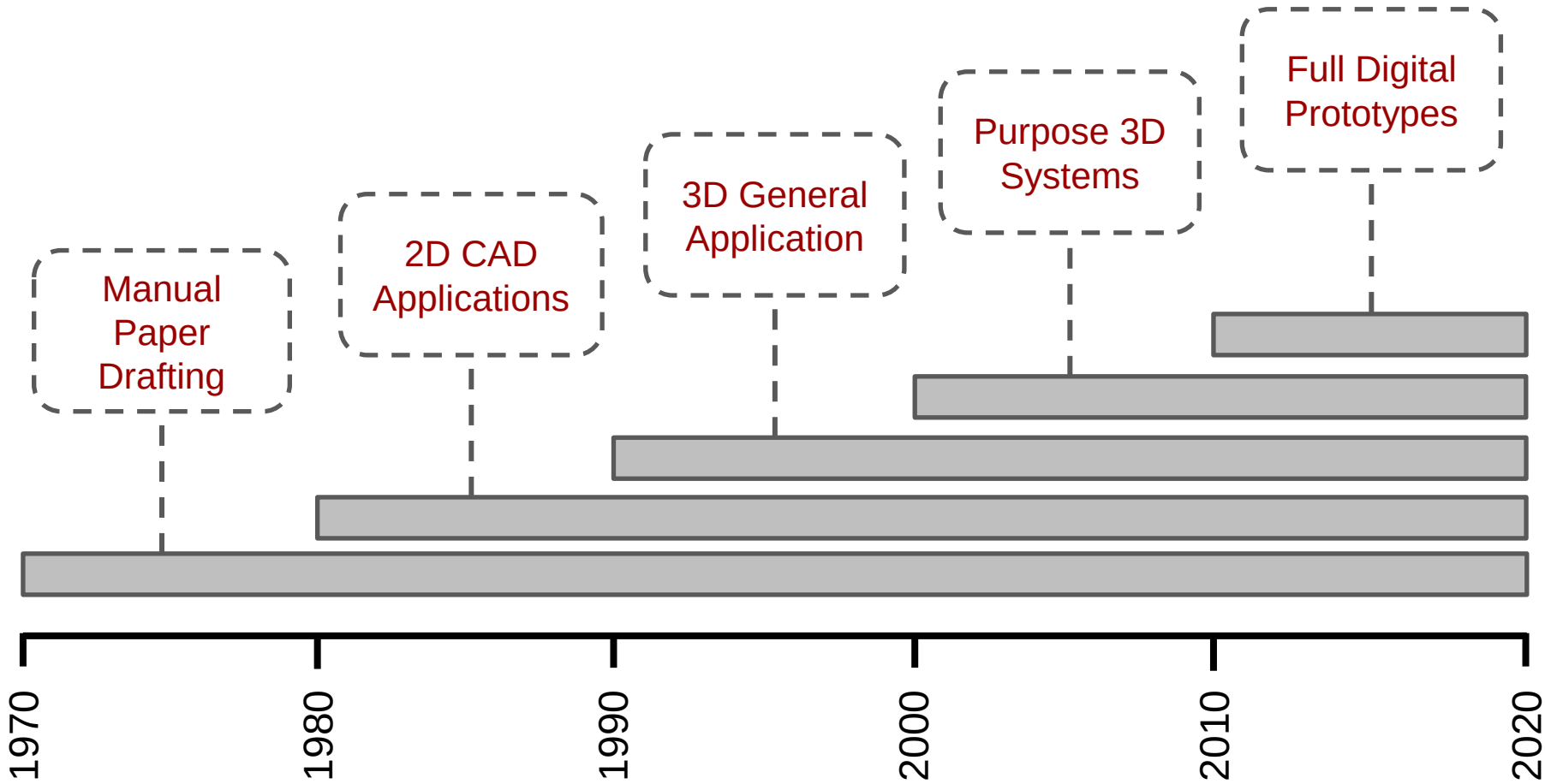
Software Tools Used

- CAx
  - Computer Aided Design (CAD)
  - Computer Aided Manufacturing (CAM)
  - Computer Aided Engineering (CAE)



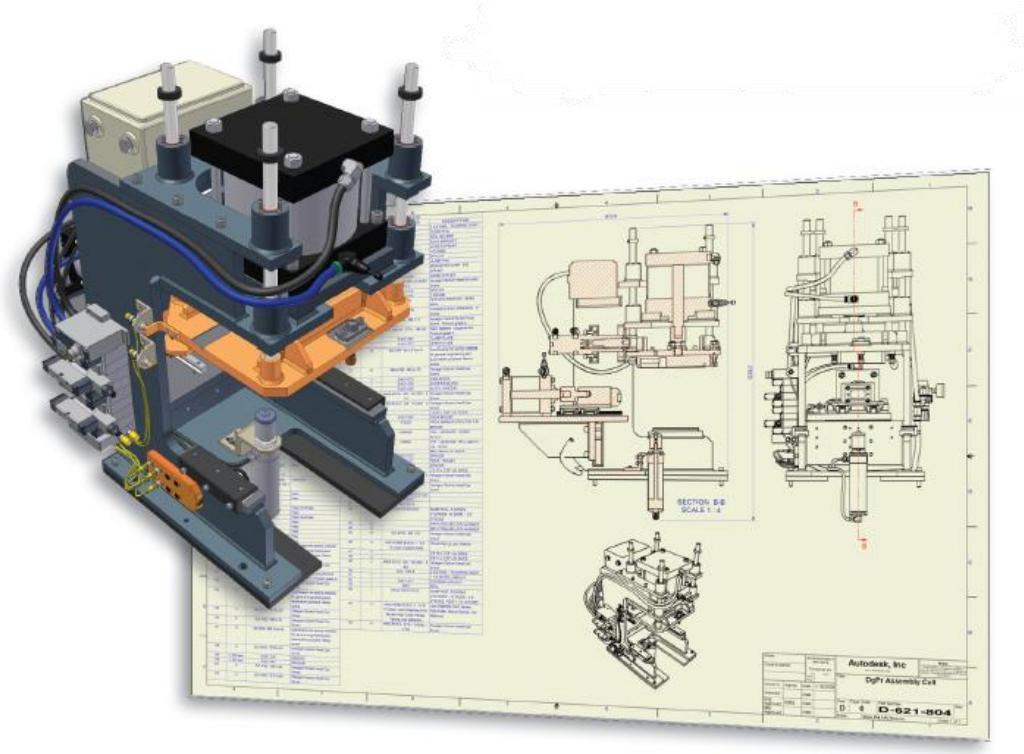
- PLM
  - Product Lifecycle Management (PLM)
  - Product Data Management (PDM)
  - Management of companies intellectual virtual product assets
- ERP
  - Enterprise Resource Planning (ERP)
  - Management of companies deliverable physical product assets

Evolution of Design Tools (CAD)

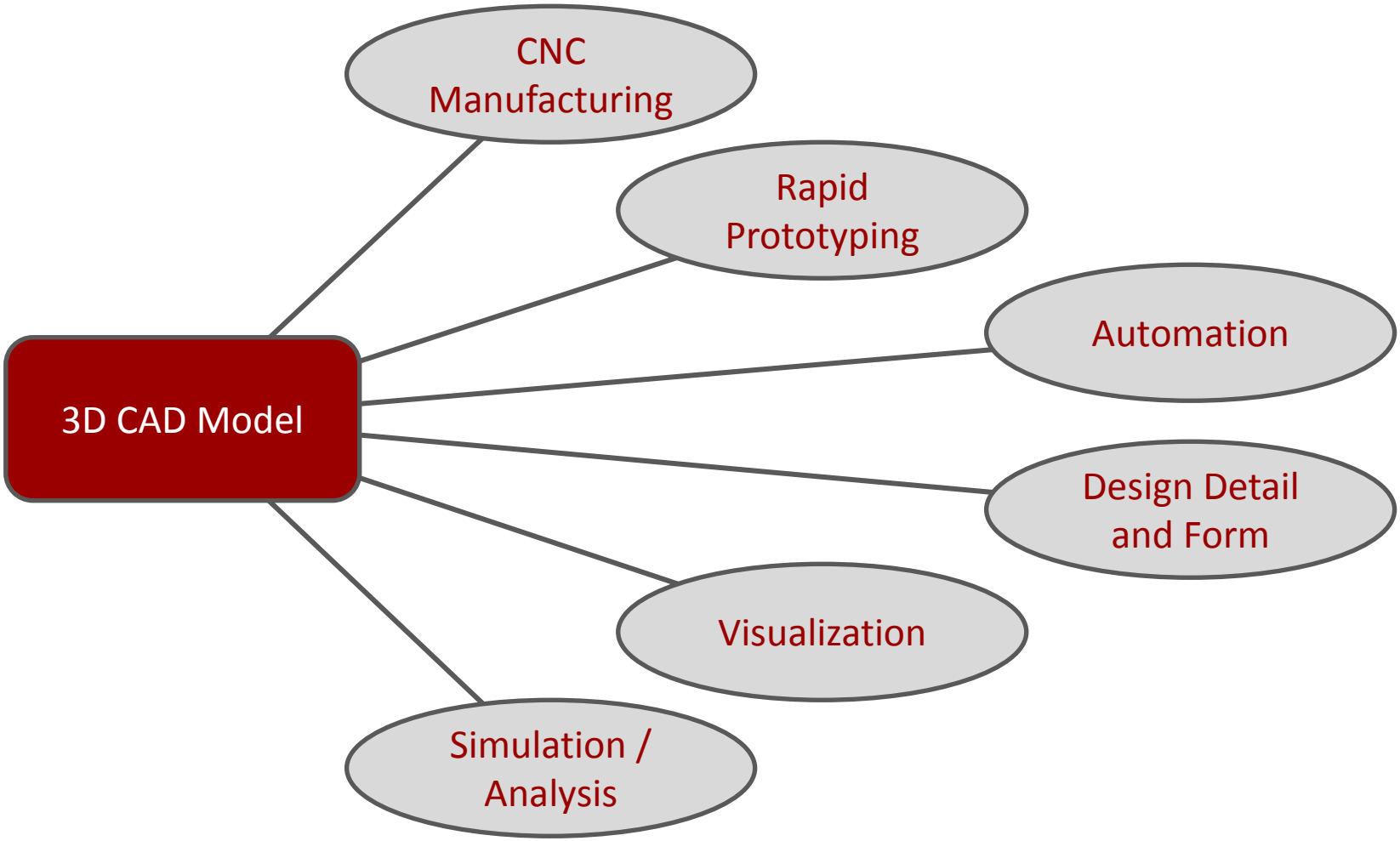


What is 3D Modeling

- Creation of a digital model of the real physical object.



3D Design Use



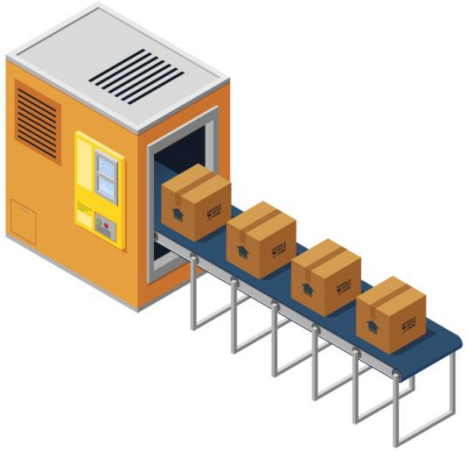
3D Downstream Benefits (1 of 3)

- CNC Manufacturing
  - Programming of Computer Numerical Control (CNC) manufacturing equipment from 3D model geometry to automate manufacturing of production components.

- Rapid Prototyping
  - 3D printing of physical prototype models from 3D model geometry.

3D Downstream Benefits (2 of 3)

- Automation
  - Fully automated process with low overhead for creating product configurations and design personalization's for clients.

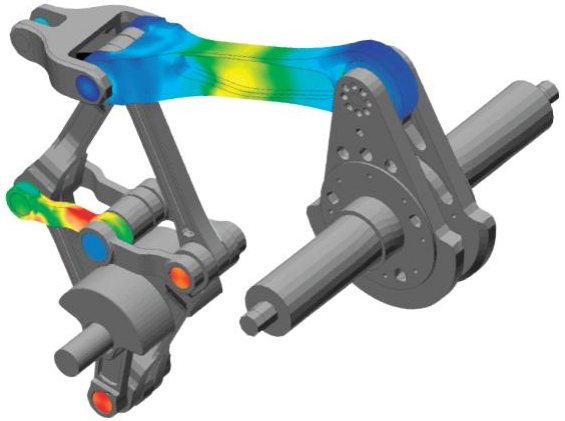


- Design Detail and Form
  - Ability to design and communicate complex objects that are almost impossible to do without 3D design.

3D Downstream Benefits (3 of 3)

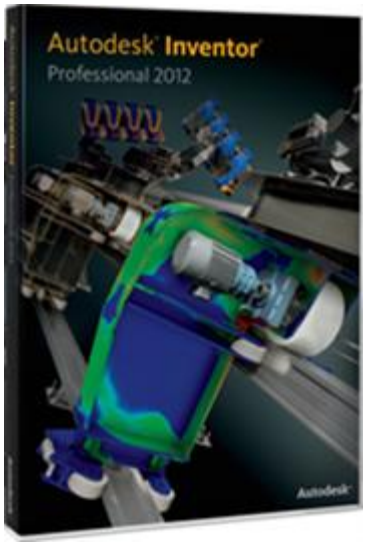
- Visualization
  - Leveraging of 3D design models for creating realistic visualizations for communicating designs.

- Simulation / Analysis
  - Ability to analysis 3D design models early and often in the design cycle to optimize the design and identify defects without physical components.



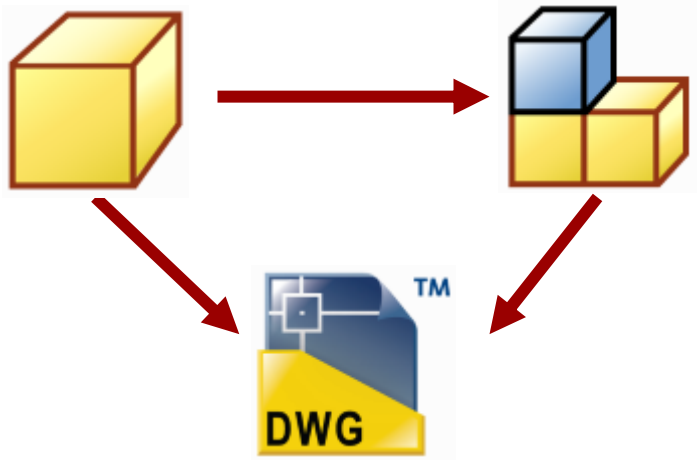
Autodesk Inventor

- Autodesk Inventor 3D mechanical design software includes CAD productivity and design communication tools. The Inventor model is a detail 3D digital prototype that can validate the form, fit, and function of a design.



File Types and Relationships

- Part Files (IPT)
- Assembly Files (IAM)
- Drawing Files (DWG / IDW)

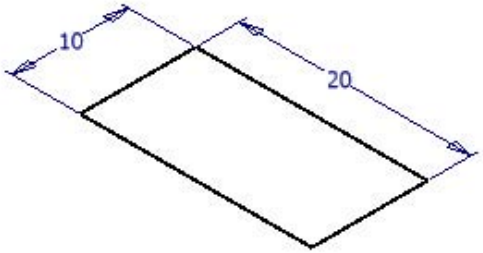


Parametric Modeling

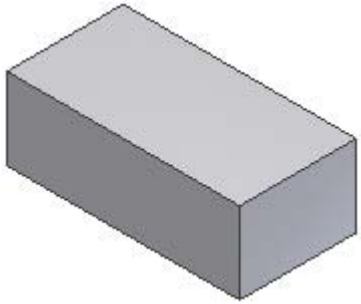
- A parametric model is a 3D model that is controlled and driven by geometric relationships and dimensional values.
- With a parametric model, you can change a value of a feature and the part model is adjusted according to that value and existing geometric constraints.

Progression of a Parametric Model

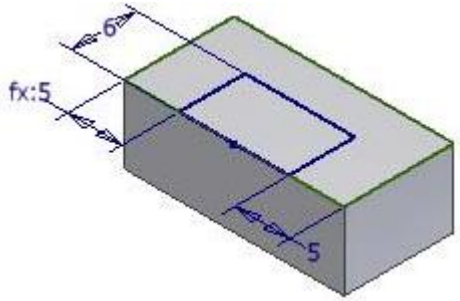
1. Initial Sketch



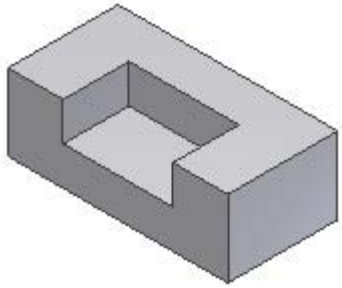
2. Base Sketch Feature



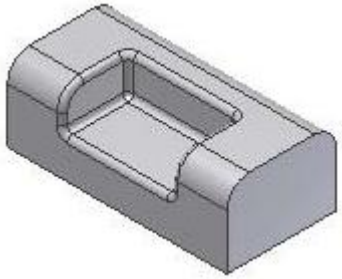
3. Secondary Sketches



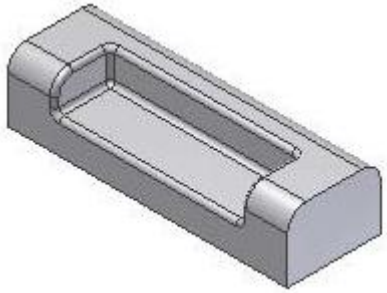
4. Secondary Feature from Sketch



5. Add Placed Features



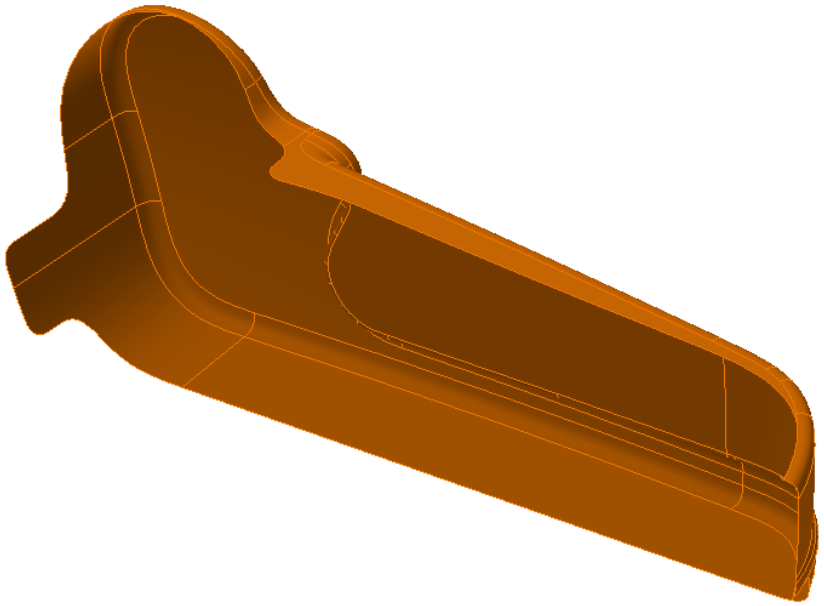
6. Parametric Change with Update



Solid Model vs. Surface Model

Solid Model

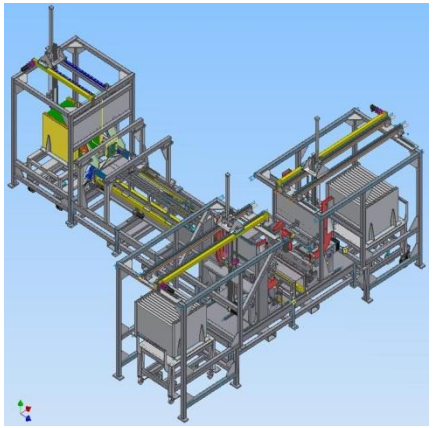
Surface Model

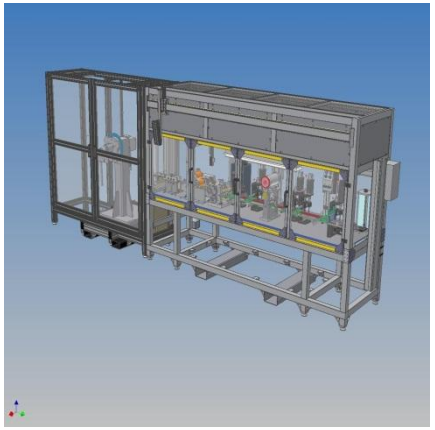


Guidelines

- Start your 3D model like you would if you where making it from real materials in most cases.
- Create the model to the perfect world conditions with no tolerances.
- Capture all elements of the model to create a digital version of the real component.

Gefit Livernois Engineering - Case Study





Challenge

Improve Livernois competitive strength in designing machines for the heat exchange equipment market while improving design accuracy and decreasing time to delivery.

Results

- 10% fewer errors overall
- Maintained productivity level despite 20% staff reduction
- 30% reduction in re-work time; 10% overall cost savings on new semi-automatic core builder
- Won contract in part by presenting customer designs in 3D with Inventor

"By showing Inventor presentations to our international customers we don't have to explain what we're doing—they can see it on the screen. Inventor presentations remove the language barrier. Over 50% of our customers reside outside the US."

Larry Schester
Mechanical Design Supervisor
Gefit Livernois Engineering, LLC
United States

Brokk AB - Case Study

Challenge

Build more innovation into products, improve product quality, and get to market faster than competition.

Results

- Reduced time to market by 30%.
- Reduced physical prototypes from 4 to 2.

"The number of design errors has decreased substantially since we started to design with Inventor."

Anders Norberg
Design Manager
Brokk AB
Sweden

Carnegie Mellon University

Computer-Cluster Projects (CP2)

Cluster Project 1

- Guided instructions for modeling clevis mount part.

Cluster Project 2

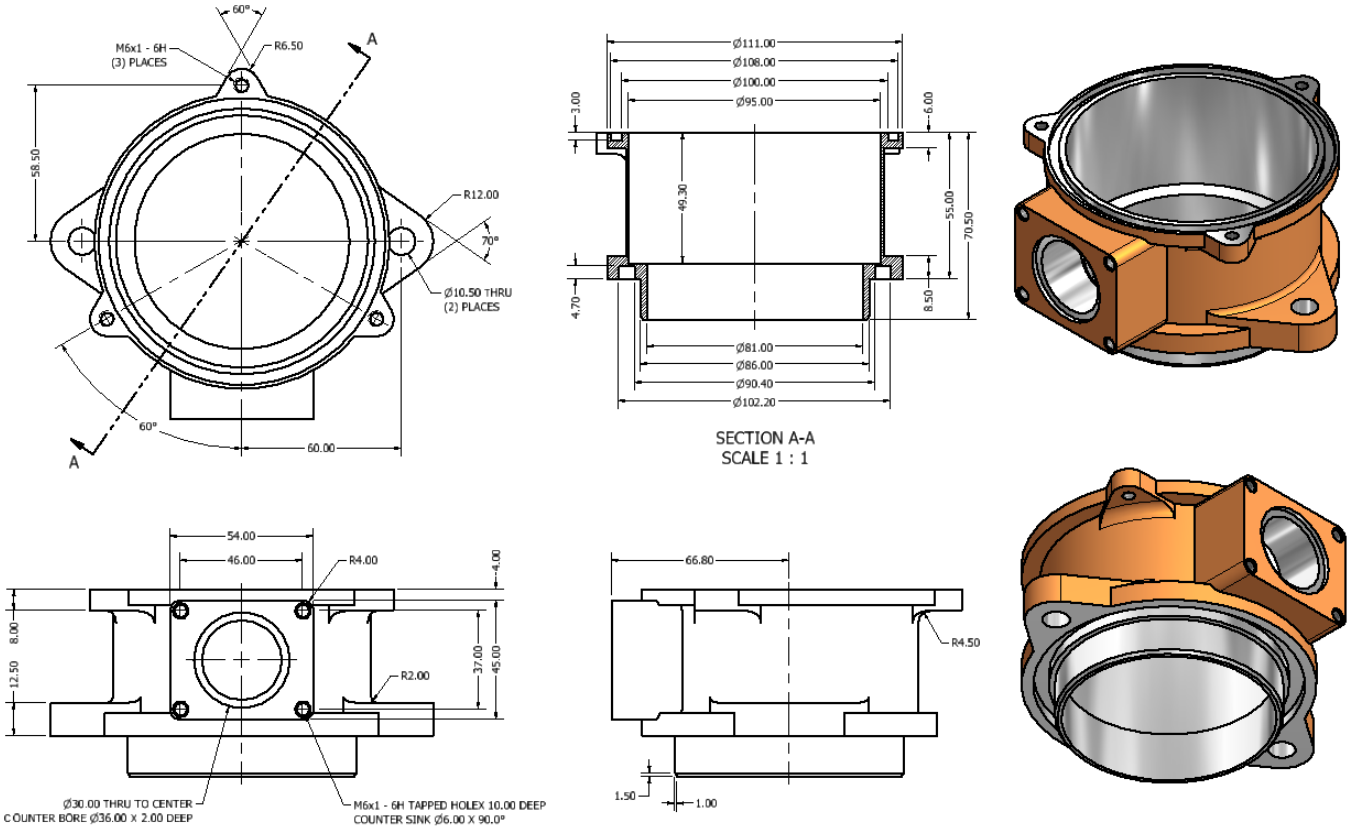
- Guided instructions for modeling flange manifold part.

Cluster Project 3

- Guided instructions for modeling air cover part.

Problem Set Assignment

- Model and provide volume of following part.



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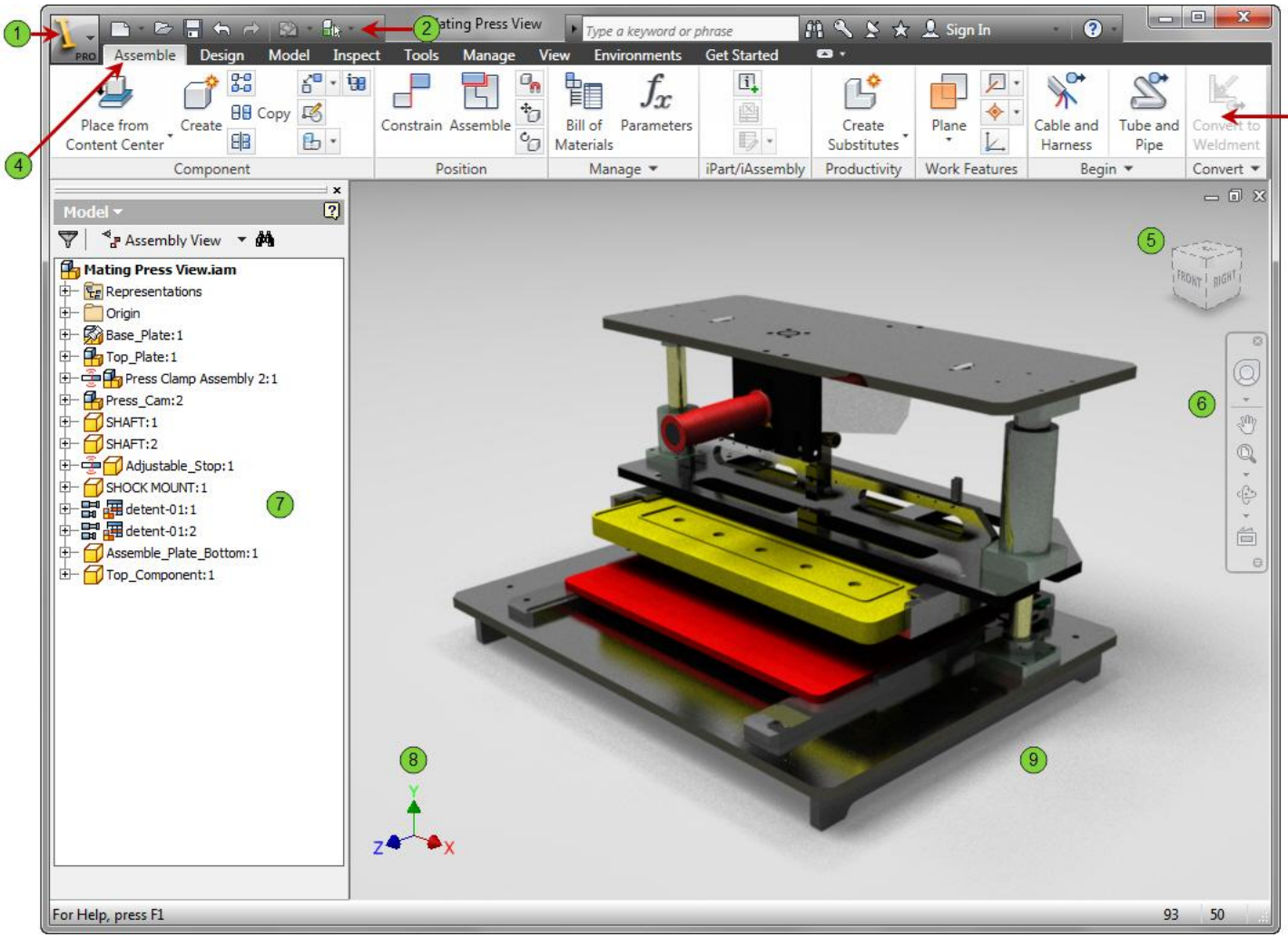
Demo Topics

File Types

1. **Assembly files:** **.iam* files reference part files and are referenced by drawing files.
2. **Part files:** **.ipt* files are referenced by assembly files and drawing files.
3. **Drawing files:** **.dwg* files reference assembly files and part files.
4. **Inventor Drawing files:** **.idw* files are interchangeable with **.dwg* files in Inventor and reference assembly and part files.

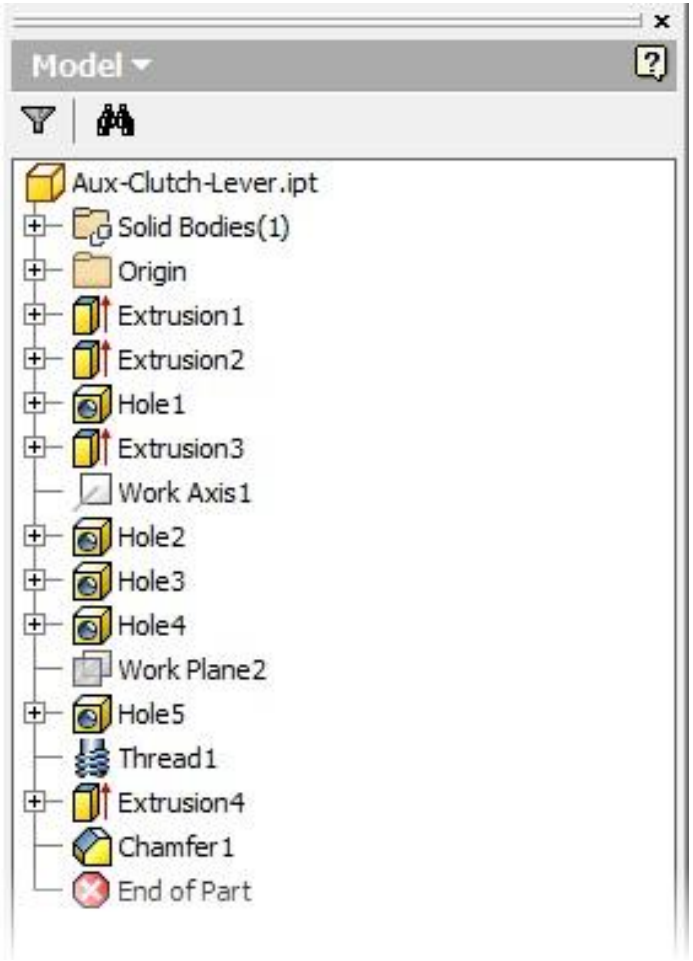
User Interface



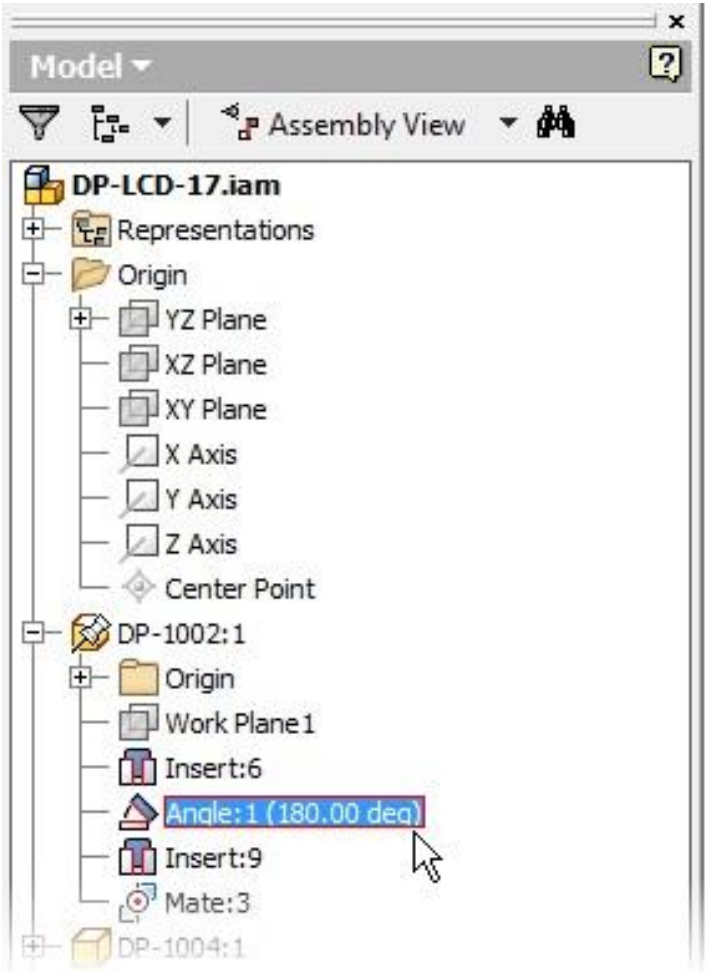
1. Application Menu
2. Quick Access Toolbar
3. Ribbon
4. Ribbon Tabs
5. ViewCube
6. Navigation Bar
7. Browser
8. 3D Indicator
9. Graphics Window

Browser

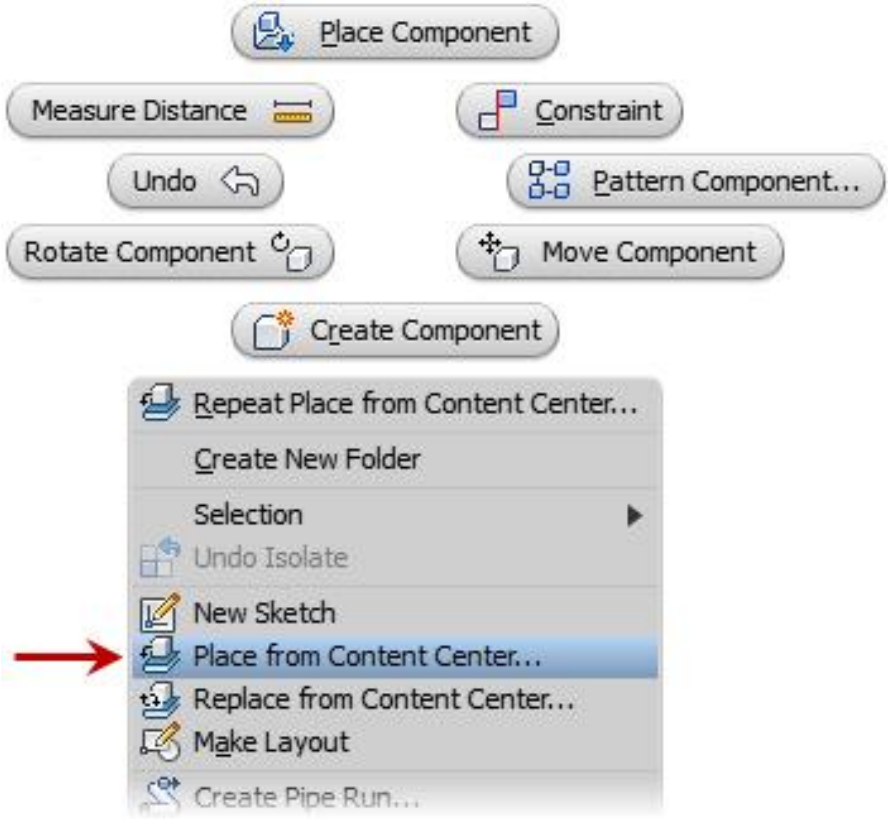
Model Browser



Assembly Browser

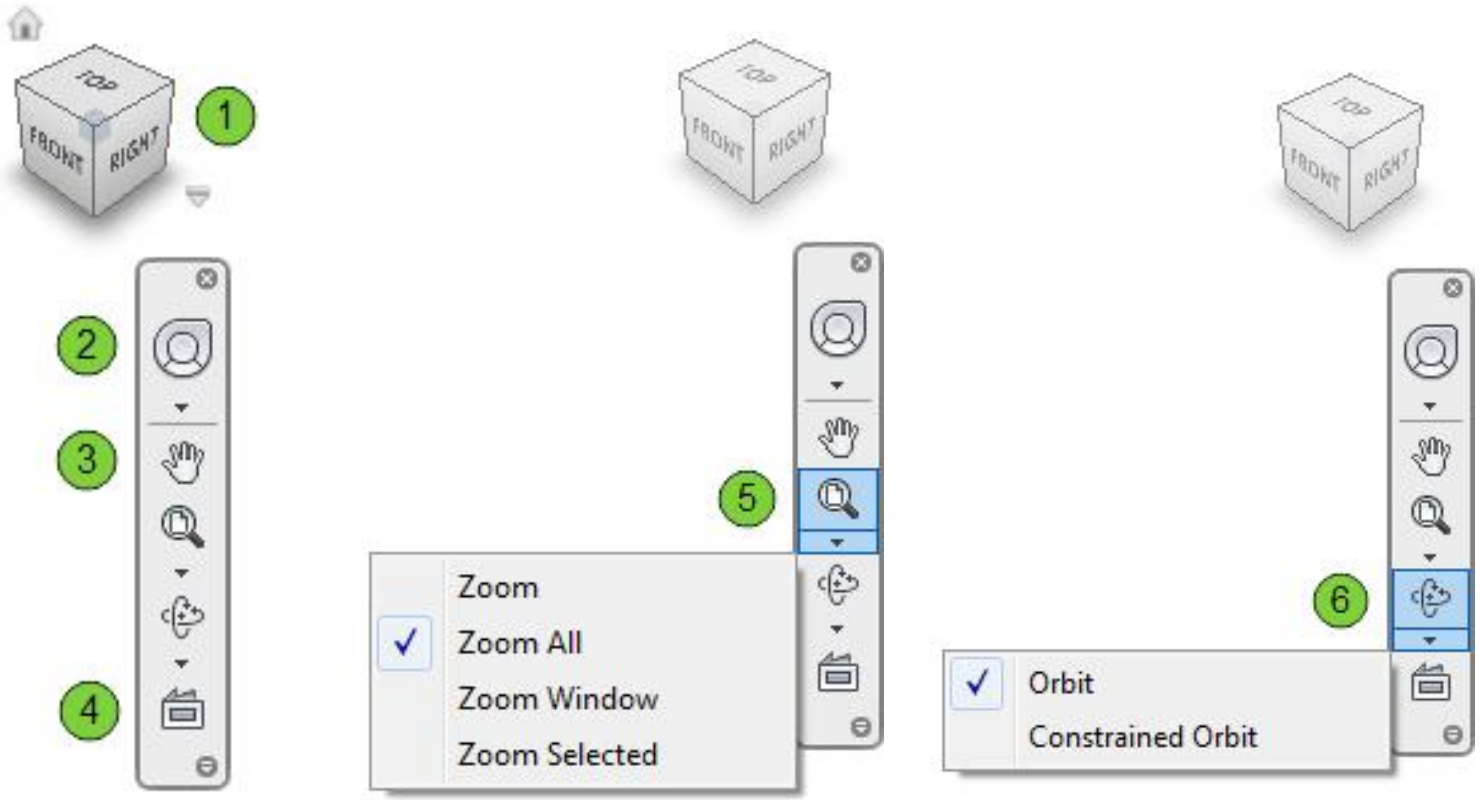


Marking Menu and Overflow Menu



Navigation Bar

1. ViewCube
2. SteeringWheel
3. Pan
4. View Face
5. Zoom All
6. Free Orbit



Function Key Shortcut Keys

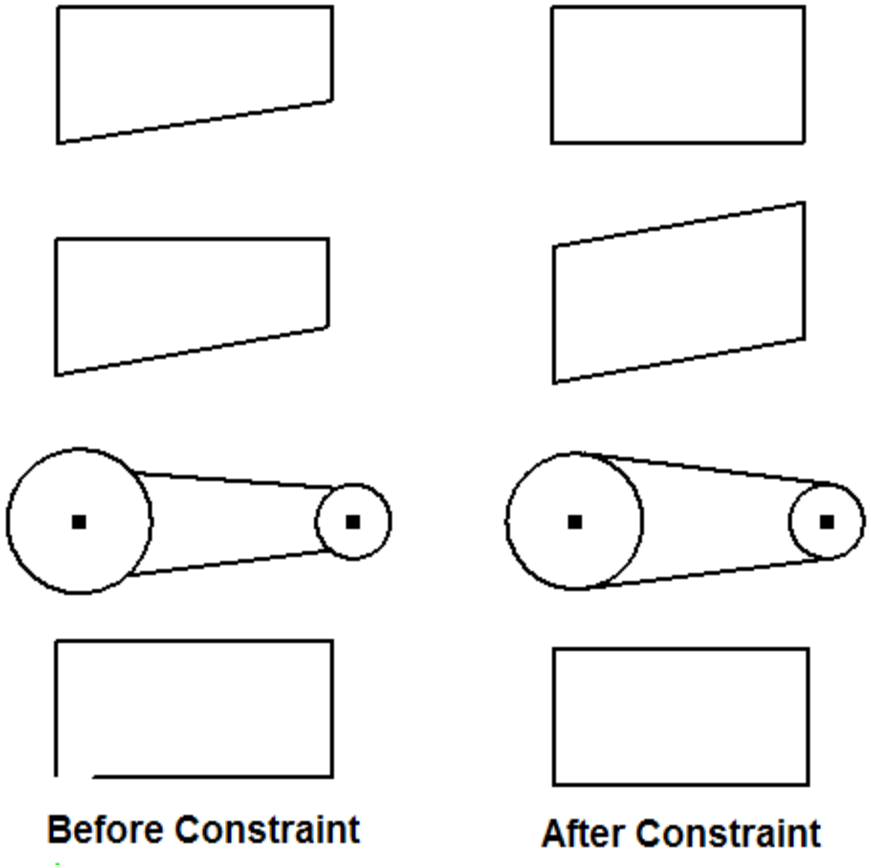
KEY	NAME	FUNCTION
F2	Pan	Pans the graphics window.
F3	Zoom	Zooms in or out in the graphics window.
F4	Rotate	Rotates objects in the graphics window.
F5	Previous View	Returns to the previous view.
F6	Isometric View	Display the isometric view of the model

Mouse Viewing Tools

MOUSE FUNCTION	NAME
Click and Drag Mouse Wheel Button	Pan
Roll Mouse Wheel	Zoom
Shift + Click and Drag Mouse Wheel Button	Free Orbit
Double-Click Mouse Wheel Button	Zoom All

Basic Sketching Techniques

- Constraint Types
  -  – Perpendicular
  -  – Parallel
  -  – Tangent
  -  – Coincident



Basic Sketching Techniques

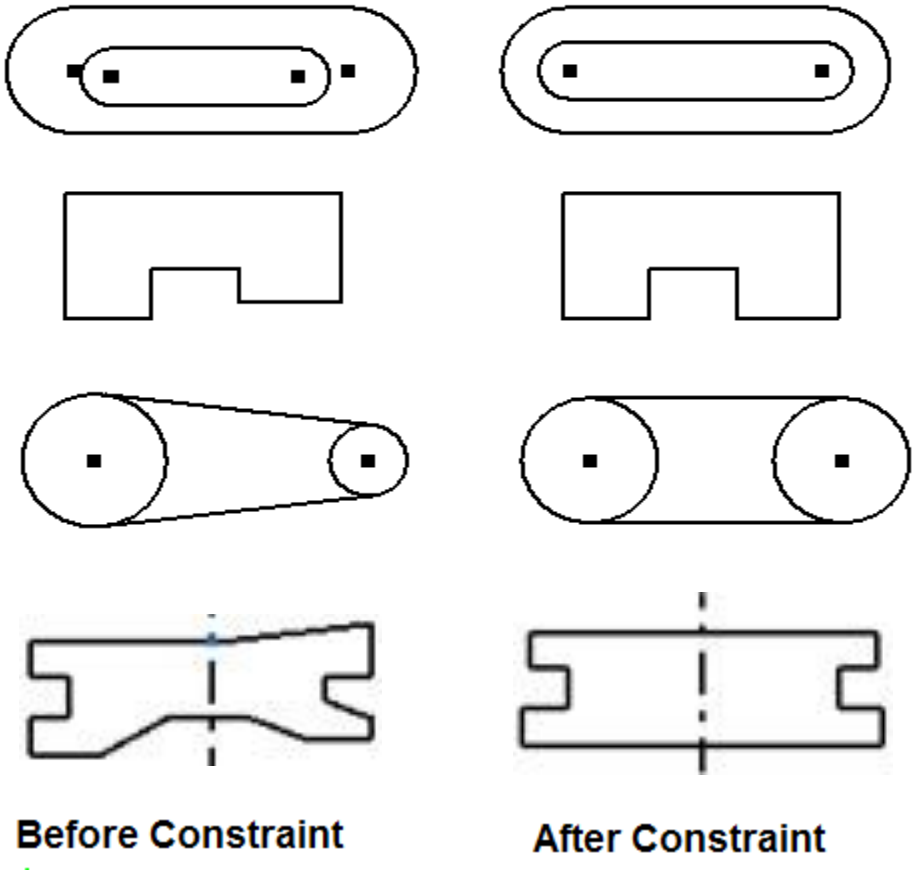
- Constraint Types Continued…


– **Concentric**


– **Collinear**


– **Equal**


– **Symmetric**

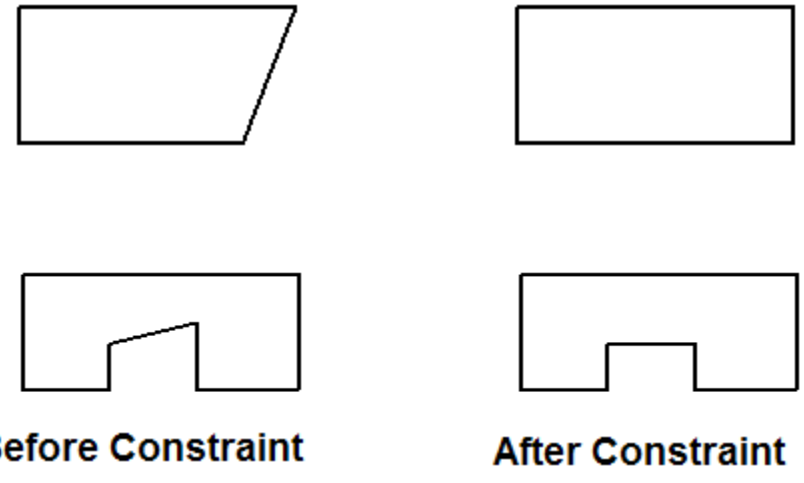


Basic Sketching Techniques

- Constraint Types Continued…

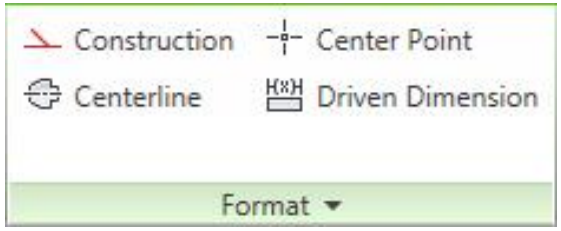
 – **Vertical**

 – **Horizontal**



Creating and Using Construction Geometry

- Ribbon: **Sketch tab | Format panel**



– **Construction Geometry**

– **Centerline Geometry**

Creating Extruded Features

- **Extrude**

  Ribbon: **Model tab | Create panel | Extrude**

  Keyboard Shortcut: **E**

- **Extrude Mini-Toolbar Options**

  – **OK**

  – **Cancel**

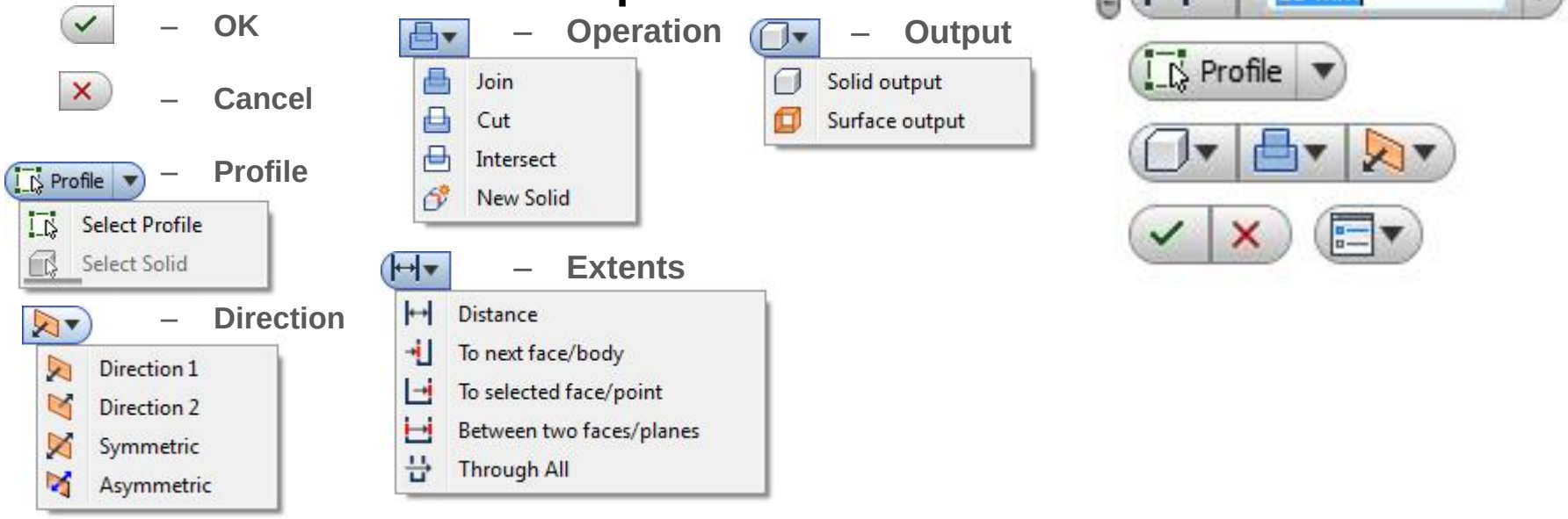
  – **Profile**

  – **Direction**

  – **Operation**

  – **Output**

  – **Extents**



Creating Revolved Features

- **Revolve**

  Ribbon: **Model tab | Create panel | Revolve**

  Keyboard Shortcut: **R**

- **Extrude Mini-Toolbar Options**

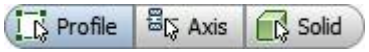
  – **OK**

  – **Cancel**

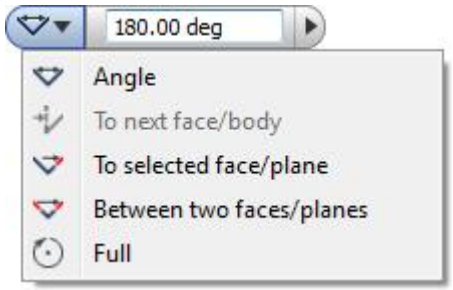
  – **Profile**

  – **Axis**

  – **Solid**

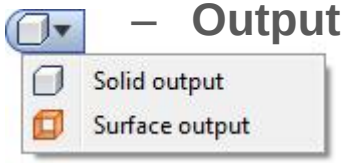


  – **Extents**



  – **Direction**

  – **Output**



Creating Chamfers

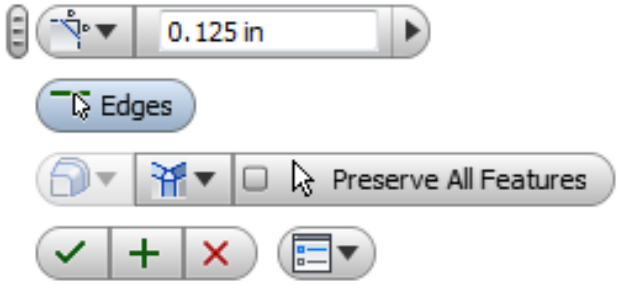
- **Chamfer**

  Ribbon: **Model tab | Create panel | Chamfer**

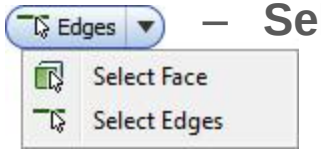
  Keyboard Shortcut: **CTRL+SHIFT+K**

- Mini-Toolbar: Click edge in active part, Select **Chamfer**

- **Chamfer Mini-Toolbar Options**
  - **Chamfer Style**



  - **OK**
  - **Apply**
  - **Cancel**



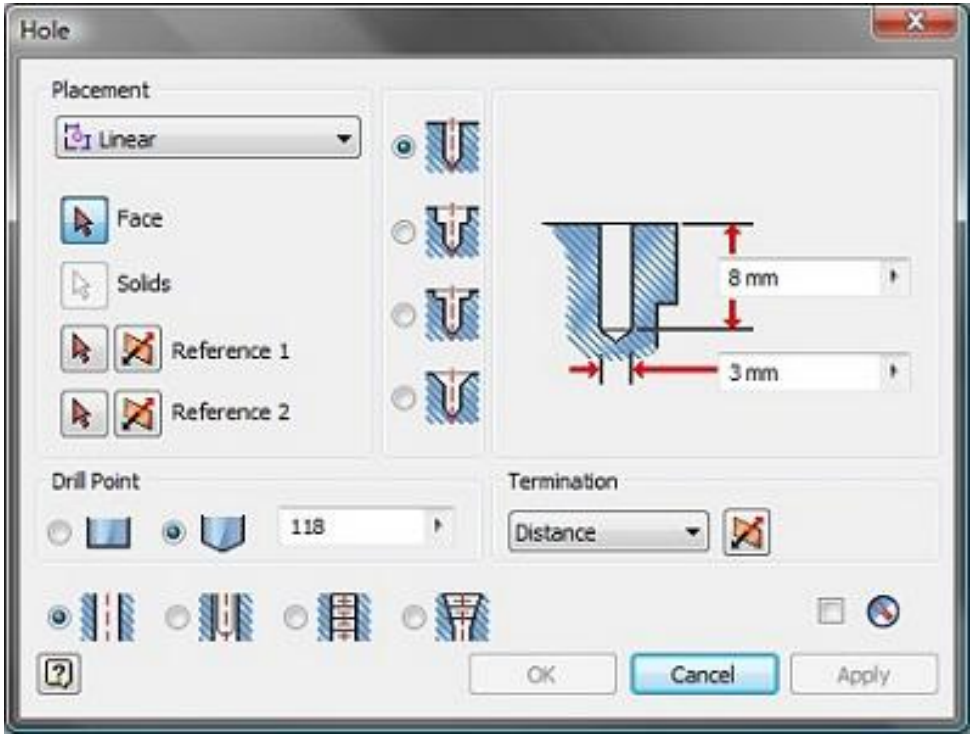
  - **Selection**

Creating Holes

- **Hole**

  Ribbon: **Model tab | Create panel | Hole**

  Keyboard Shortcut: **E**

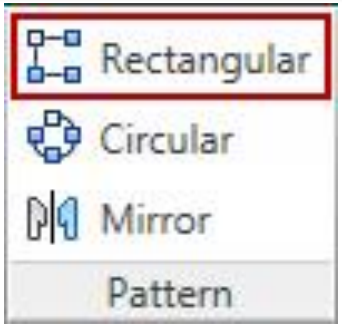


Creating Rectangular Patterns

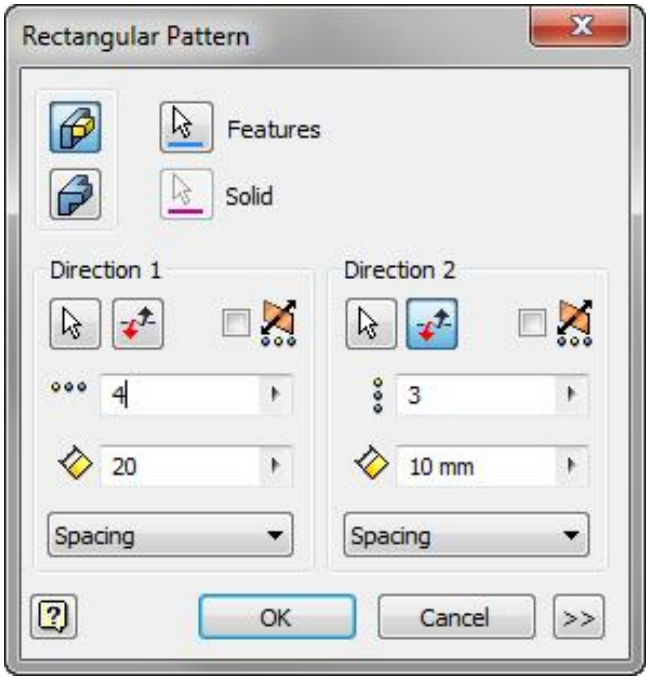
- **Rectangular Pattern**

  Ribbon: Model tab | Pattern panel | Rectangular

  Keyboard Shortcut: **CTRL+SHIFT+R**



- **Rectangular Pattern Dialog Box**



Pattern Feature

- Individual Feature
- Features
- Solid

Pattern Solid

- Entire Solid
- Solid
- Include Work/Surface Feature
- Join
- Create new bodies

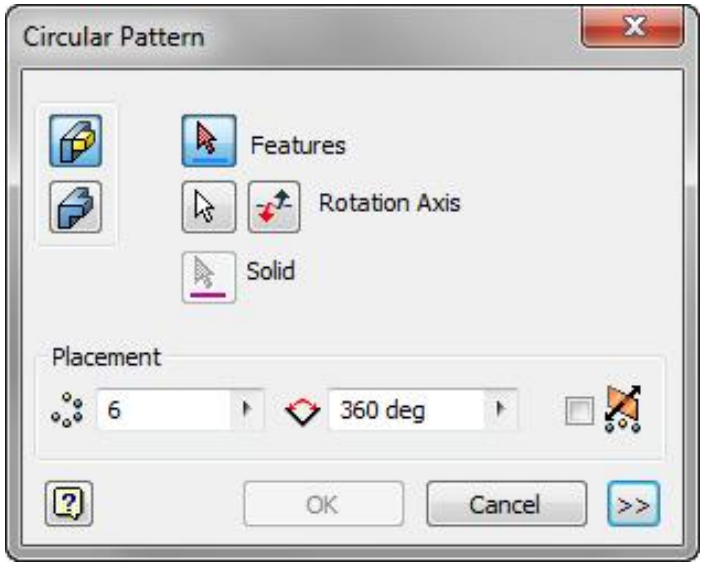
Creating Circular Patterns

- **Rectangular Pattern**

  Ribbon: Model tab | Pattern panel | Circular

  Keyboard Shortcut: **CTRL+SHIFT+O**

- **Circular Pattern Dialog Box**



Pattern Feature

- Individual Feature
- Features
- Rotation Axis
- Solid

Pattern Solid

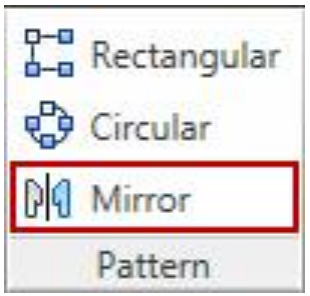
- Entire Solid
- Solid
- Include Work/Surface Feature
- Rotation Axis
- Join
- Create new bodies

Mirroring Features

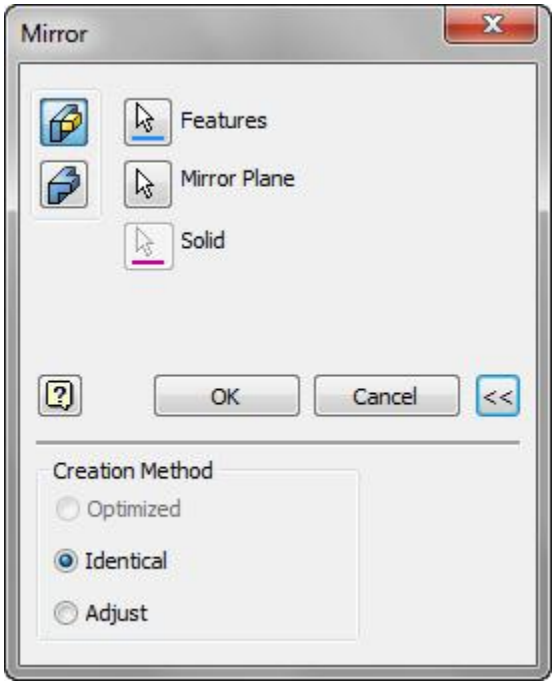
- **Rectangular Pattern**

  Ribbon: Model tab | Pattern panel | Mirror

  Keyboard Shortcut: **CTRL+SHIFT+M**



- **Mirror Dialog Box**



Mirror Feature

- Individual Feature
- Features
- Mirror Plane
- Solid

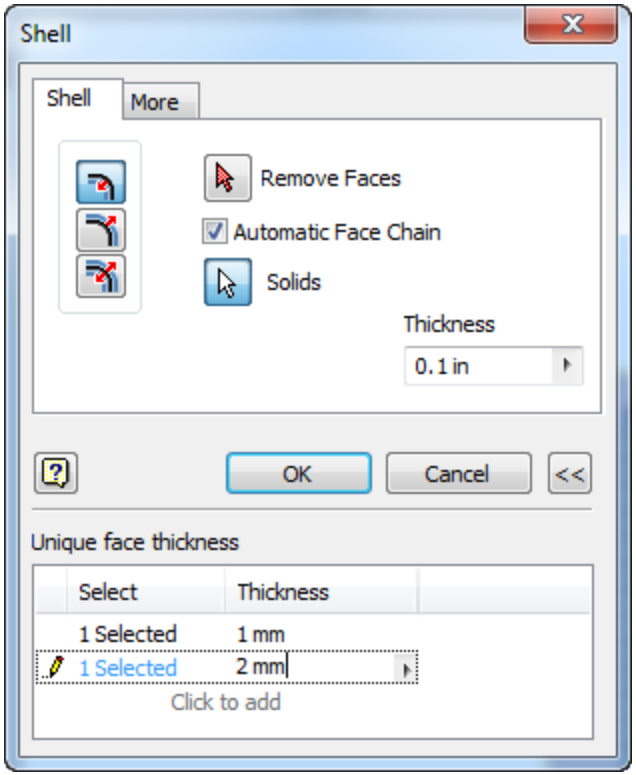
Pattern Solid

- Entire Solid
- Solid
- Include Work/Surface Feature
- Mirror Plane
- Join
- Create new bodies
- Remove Original

Creating Shell Features

- **Shell**
  Ribbon: **Model tab | Modify panel | Shell**

- **Shell Dialog Box**



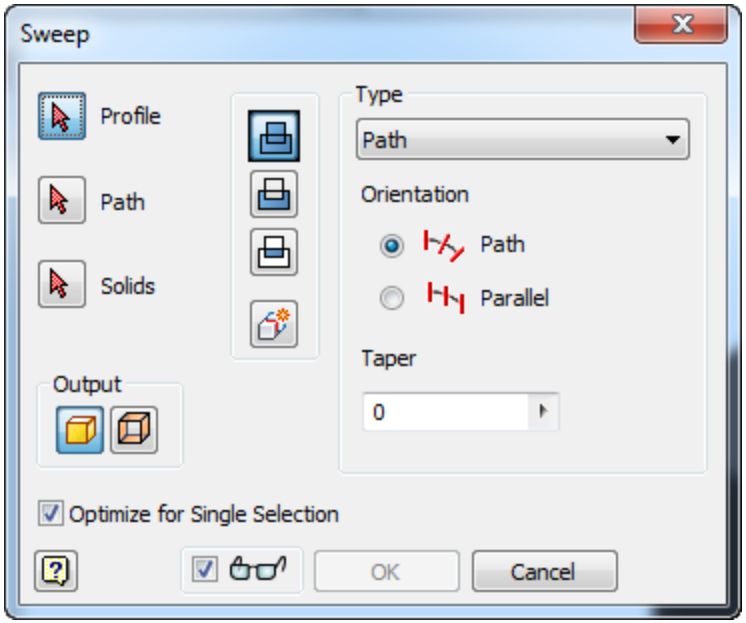
Shell Dialog Box

- Inside
- Outside
- Both: Half
- Remove Faces
- Automatic Face Chain
- Solids

Creating Sweep Features

- **Sweep**
  Ribbon: **Model tab | Create panel | Sweep**

- **Sweep Dialog Box**



Sweep Dialog Box

- Profile
- Path
- Solid
- Remove Faces
- Automatic Face Chain
- Solids