Demonstration

-3D Printer

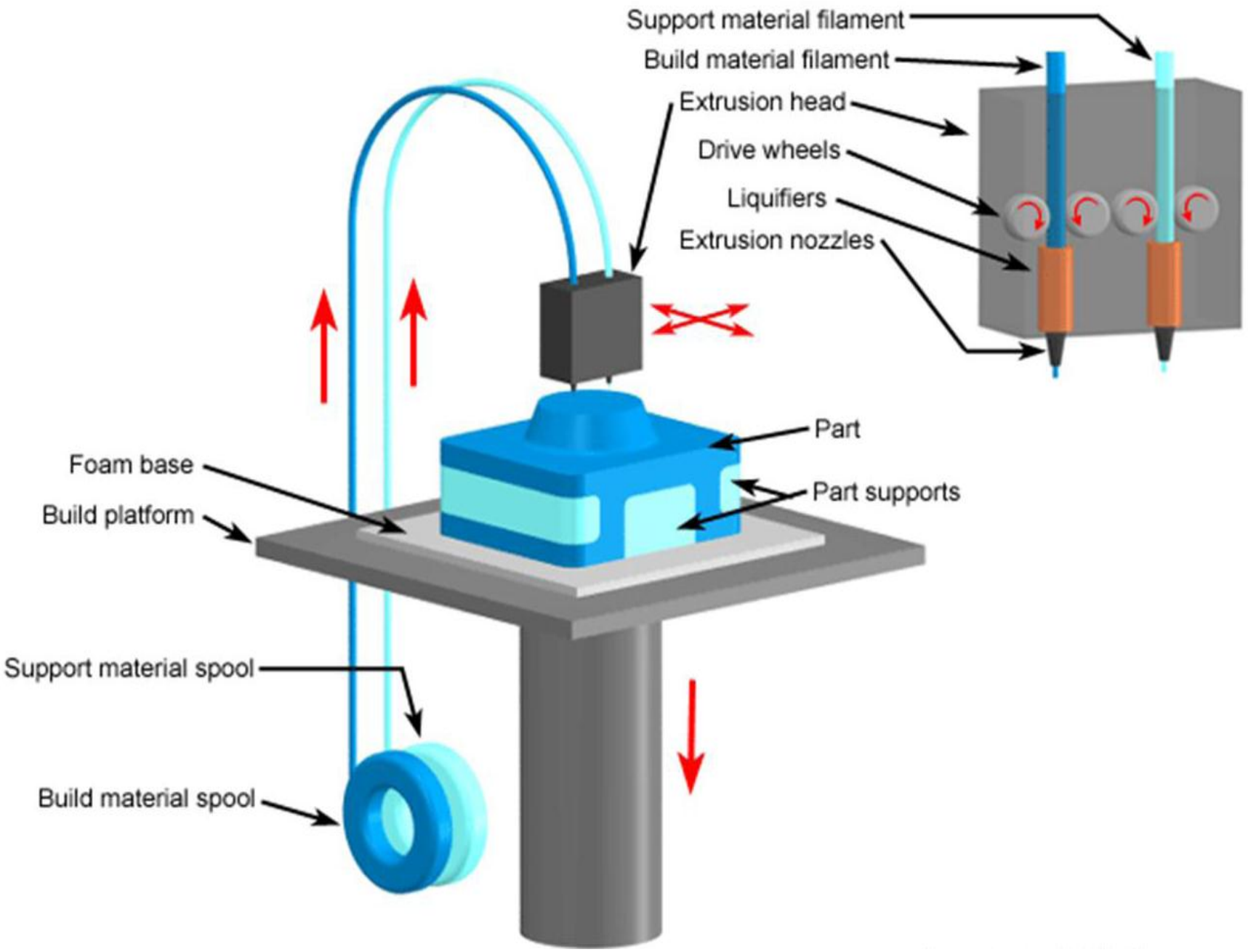
-CNC Milling Machine

ENGINEERING LABORATORY EE-100

Lahore University of Management Sciences
Electrical Engineering Department, SSE

Non-conventional Manufacturing – 3D Printing

- A process of making a three-dimensional solid object of virtually any shape from a digital model.
- A 3D printer is a limited type of industrial robot that is capable of carrying out an additive process under computer control.


Support material filament
Build material filament
Extrusion head
Drive wheels
Liquifiers
Extrusion nozzles
Part
Part supports
Foam base
Build platform
Support material spool
Build material spool

Creating .stl file from CAD

- Create your model in PTC Creo.
- Save your part file as .prt
- Then Proceed as:
  - File > Save As > File type stl, then Enter a file name.
  - A dialog box will appear for the information of Chord height and Angle Control.
  - Values for Chord Height and Angle Control determine the triangulation mesh. Small numbers make a fine mesh (larger file size), larger numbers yield a coarse mesh (smaller file size).

PRT0001 (Active) - Creo Parametric Student Edition

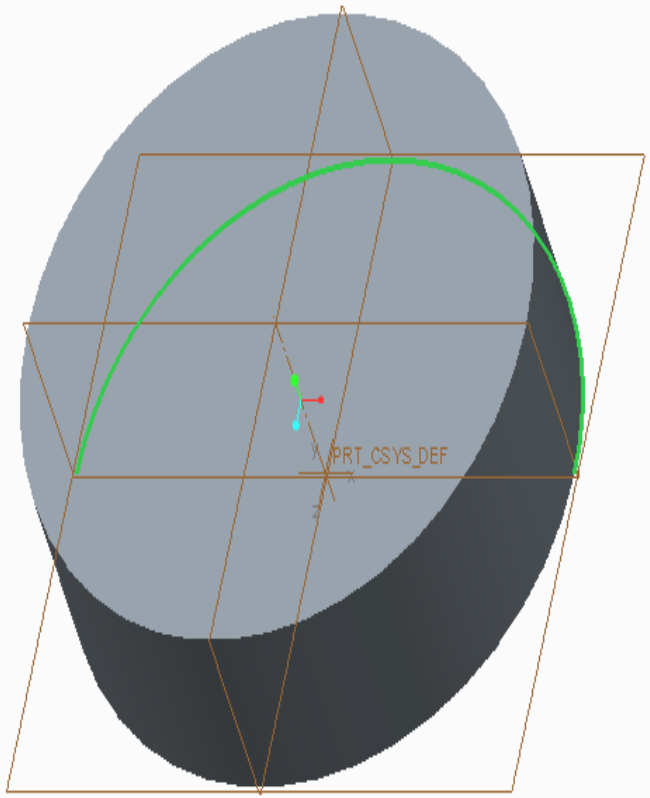
File | Model | Analysis | Annotate | Render | Tools | View | Flexible Modeling | Applications

Regenerate | User-Defined Feature | Copy Geometry | Shrinkwrap | Plane | Axis | Point | Coordinate System | Sketch | Extrude | Revolve | Sweep | Swept Blend | Hole | Draft | Round | Shell | Chamfer | Rib | Pattern | Mirror | Extend | Project | Trim | Offset | Thicken | Merge | Intersect | Solidify | Boundary Blend | Component Interface

Operations | Get Data | Datum | Shapes | Engineering | Editing | Surfaces | Model Intent

Model Tree

- PRT0001.PRT
  - RIGHT
  - TOP
  - FRONT
  - PRT_CSYS_DEF
  - Sketch 1
  - Extrude 1
  - Insert Here



Export STL

Coordinate System
Default

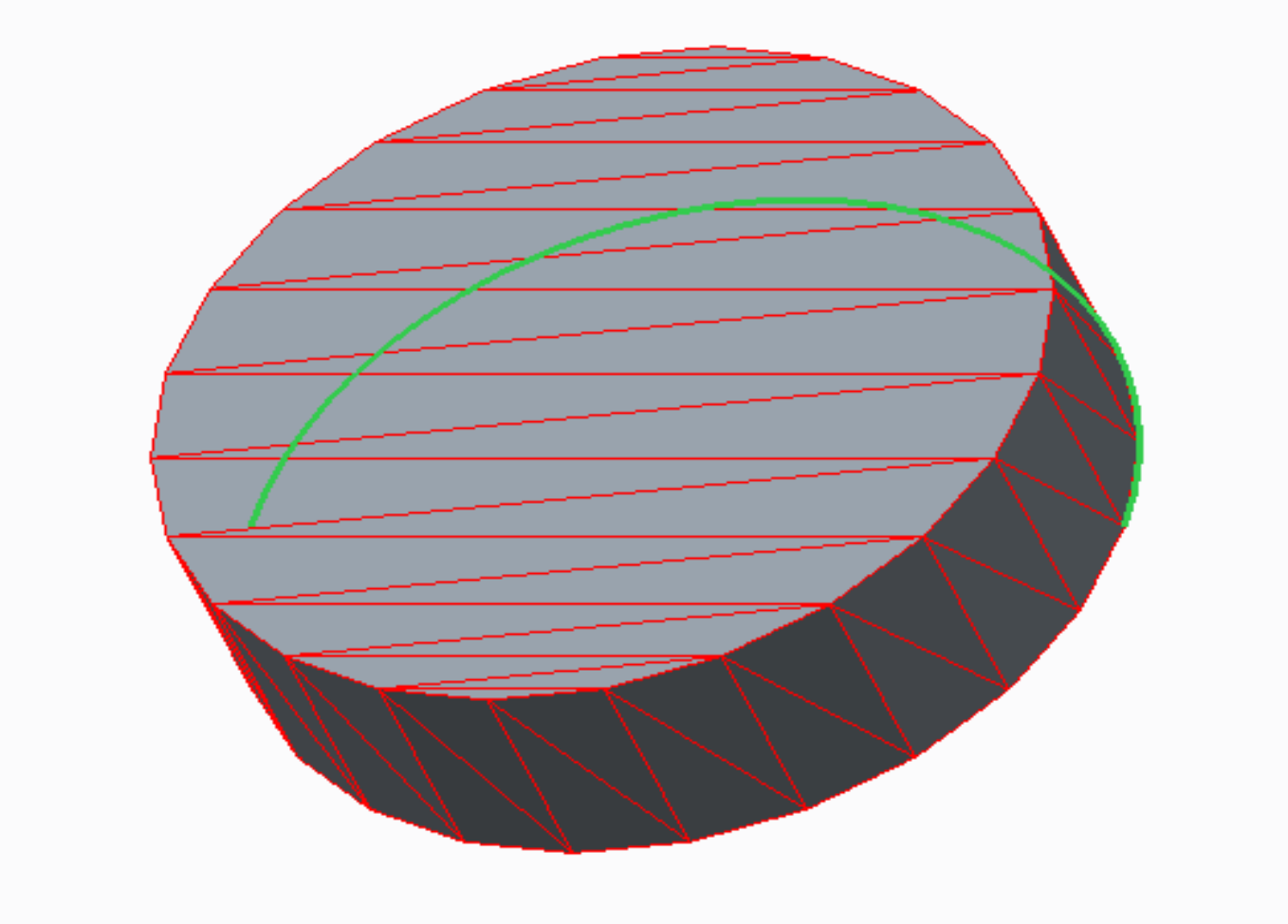
Format
Binary ASCII
Allow negative values

Deviation Control
Chord Height: 0.816586
Angle Control: 0.500000
Step Size: 8.165861

File name
prt0001

OK | Apply | Cancel

Triangular Mesh of the Model



Generating the Machine Specific File

- We will be creating the .cubex files for our CUBE 3D Printing Machine.
- Open your saved .stl file in the CUBEX environment.
- Adjust:
  - Material Cartridge
  - Part Placement
  - Printing Scales/ Dimensions
  - Layer Thickness (This would affect the printing resolution)
  - Part Density
  - Support Material

CubeX - 3D Systems

Home | View | Settings

Open Model | Open Model Assembly | Close | Close All | Save As | Single Color — CAD File

10 Move X | 10 Move Y | Auto Place | Move Model — Move Geometry

100 % | to mm — Scale Geometry

90 X° | 90 | 90 — Rotate Geometry

PLA | None | None — Pick Color

Open | Close | Save Print File — Print File

3D Model

Object Size

X: 169.51mm

Y: 169.51mm

Z: 50.00mm

Object Position

X: 0 mm

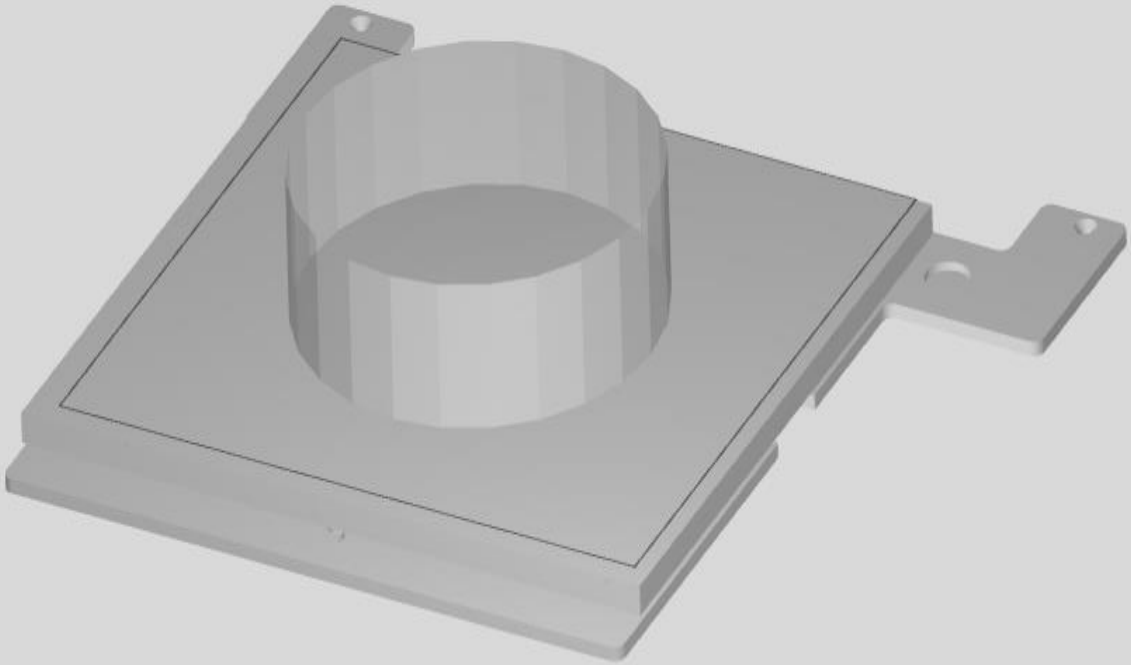
Y: 0 mm

Printer Configuration

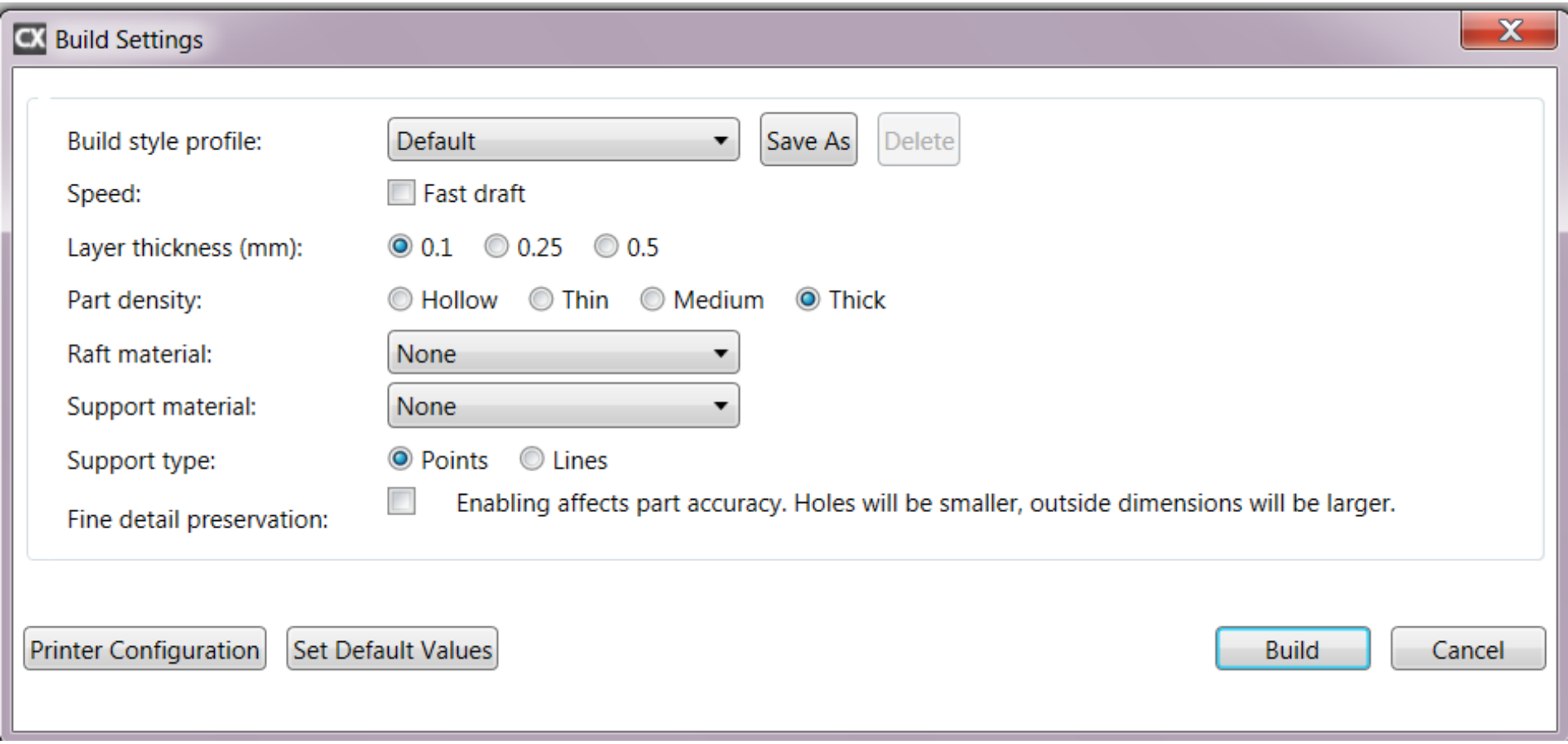
PJ1 **OUT OF BOUNDS**

PJ2 None

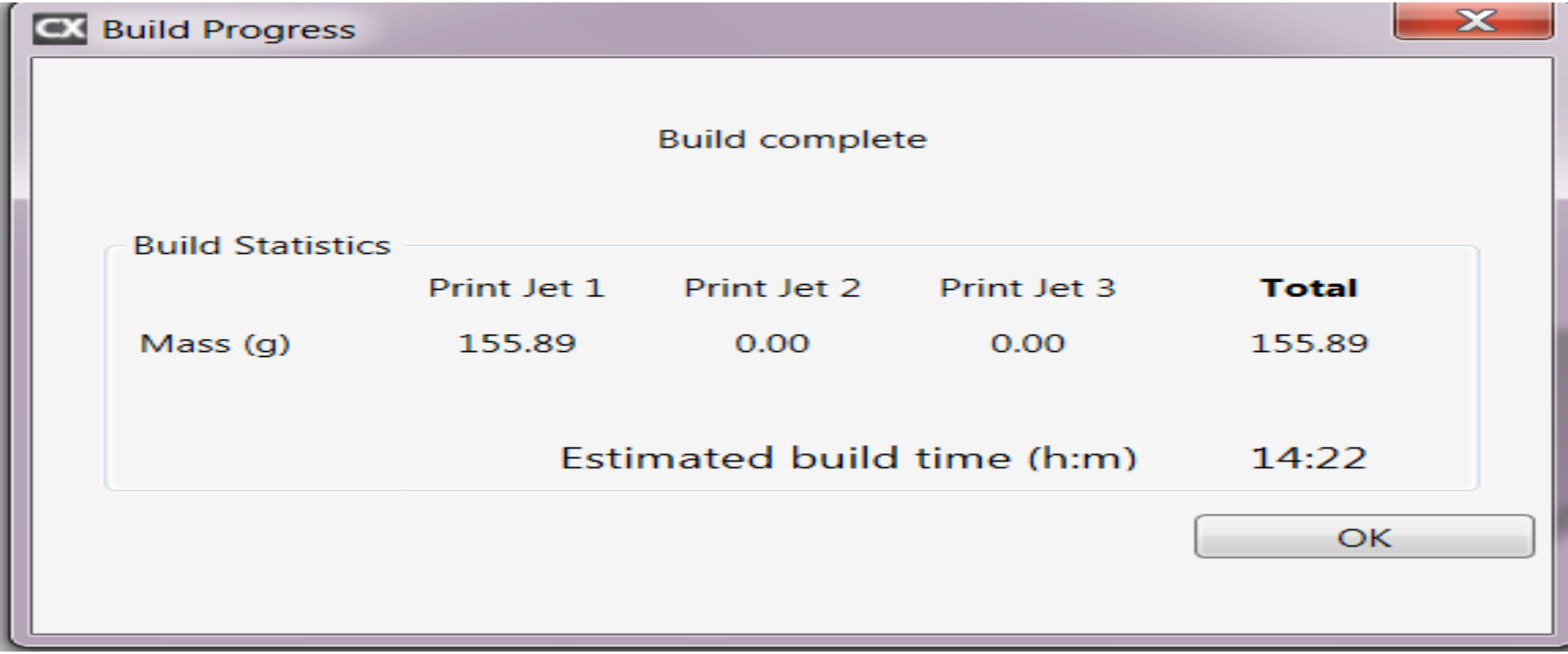
PJ3 None



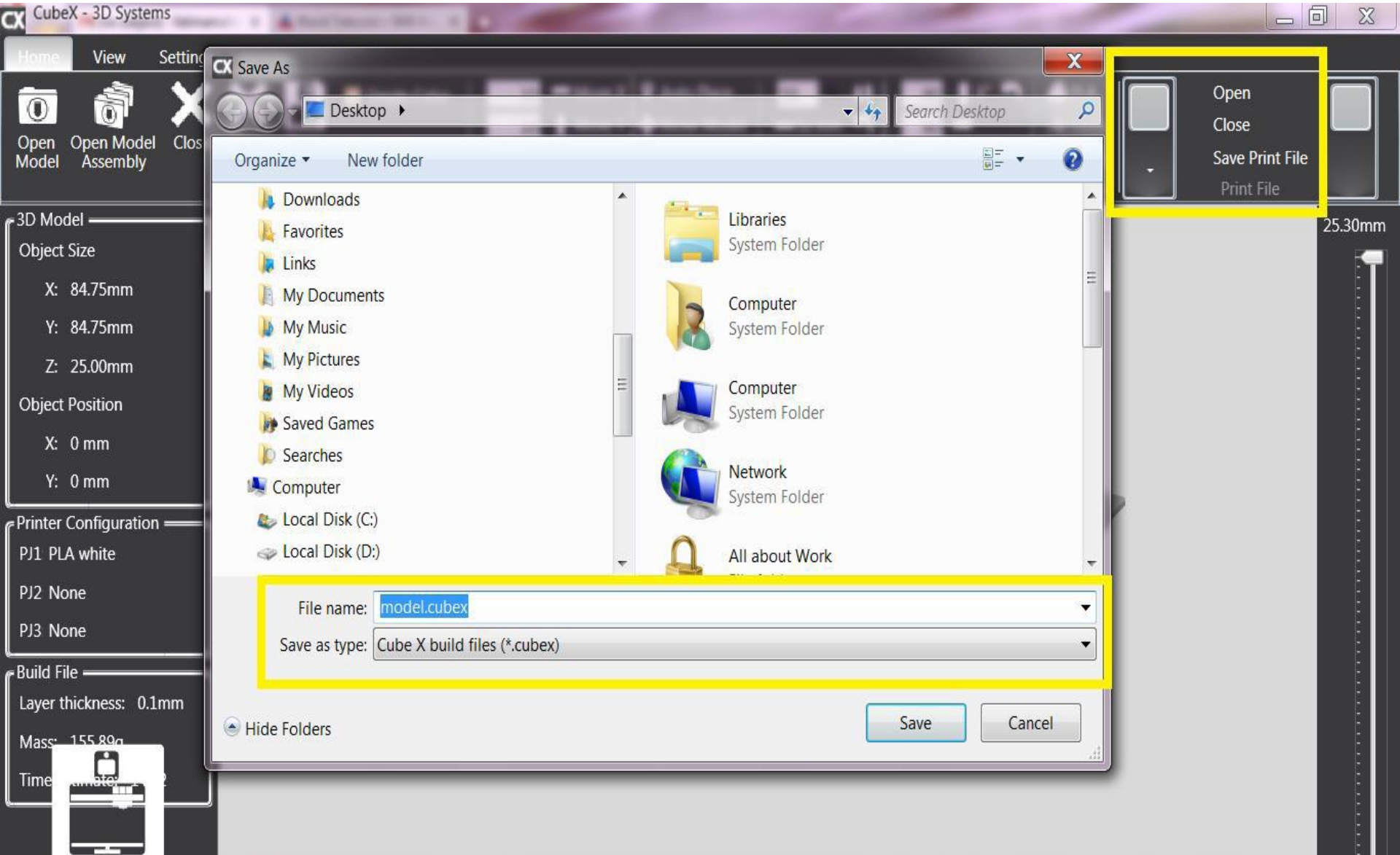
Build File


Build Settings
Build style profile:
Default
Save As
Delete
Speed:
Fast draft
Layer thickness (mm):
0.1
0.25
0.5
Part density:
Hollow
Thin
Medium
Thick
Raft material:
None
Support material:
None
Support type:
Points
Lines
Fine detail preservation:
Enabling affects part accuracy. Holes will be smaller, outside dimensions will be larger.
Printer Configuration
Set Default Values
Build
Cancel

Results: Build Complete

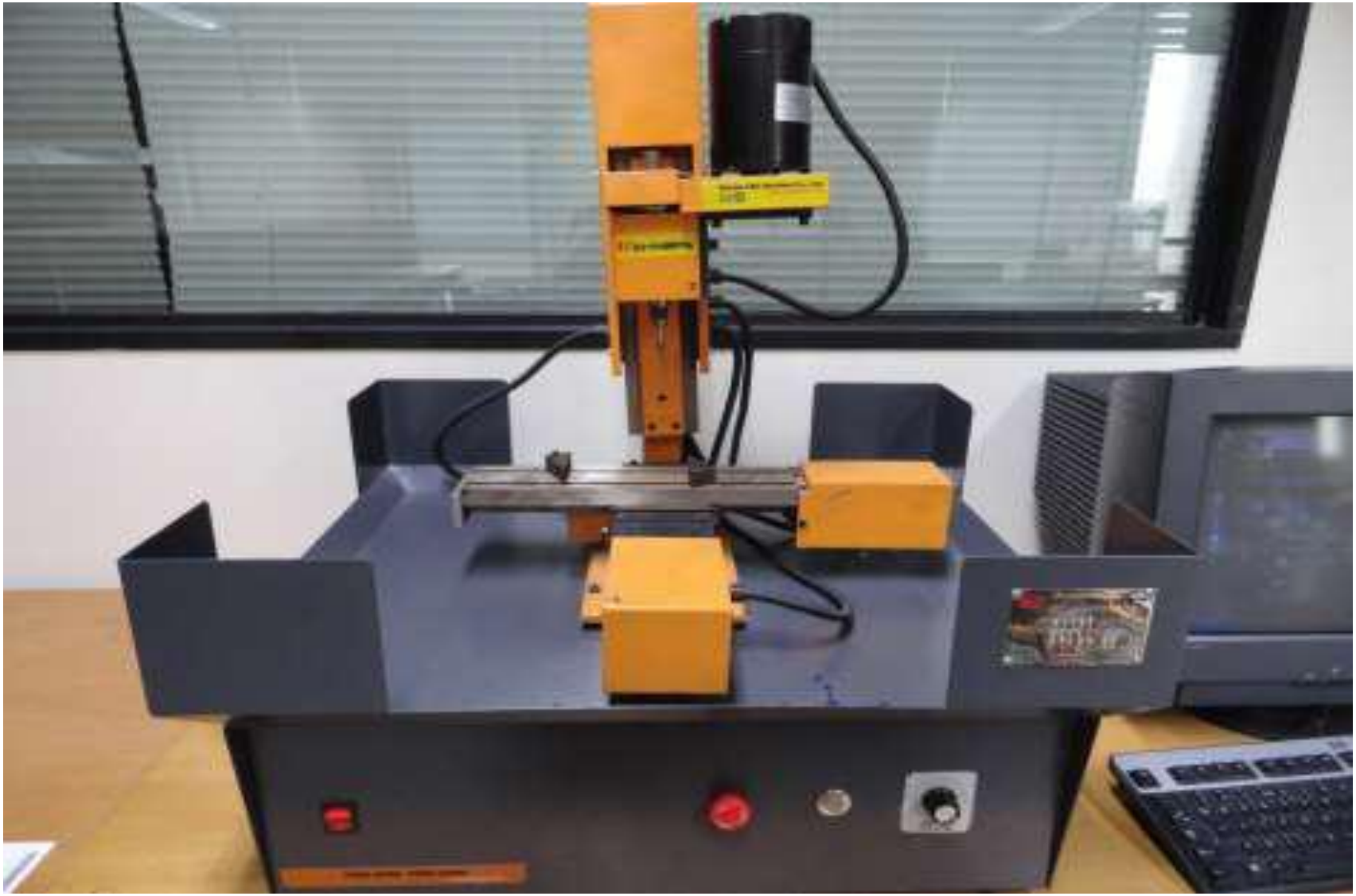


Save the Print file as .cubex



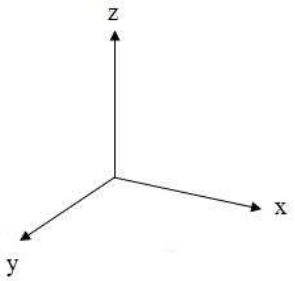
CNC Milling Machine

- **CNC Milling Machine**
  - CNC machine is a **Computerized Numerically Controlled** machining process of using rotary cutters to remove material.
- **Lab Apparatus of CNC Milling:**
  - SHARPE SXK01 is a desktop type, prototype making CNC machine. The machine is a multifunctional and cost effective apparatus with the following specifications:
    - Three-dimensional numerical control tool path to simulation experiment.
    - High-performance Mach3 control system.
    - Manual direction to prepare G code to complete the processing of desired part.



Machine Coordinate System

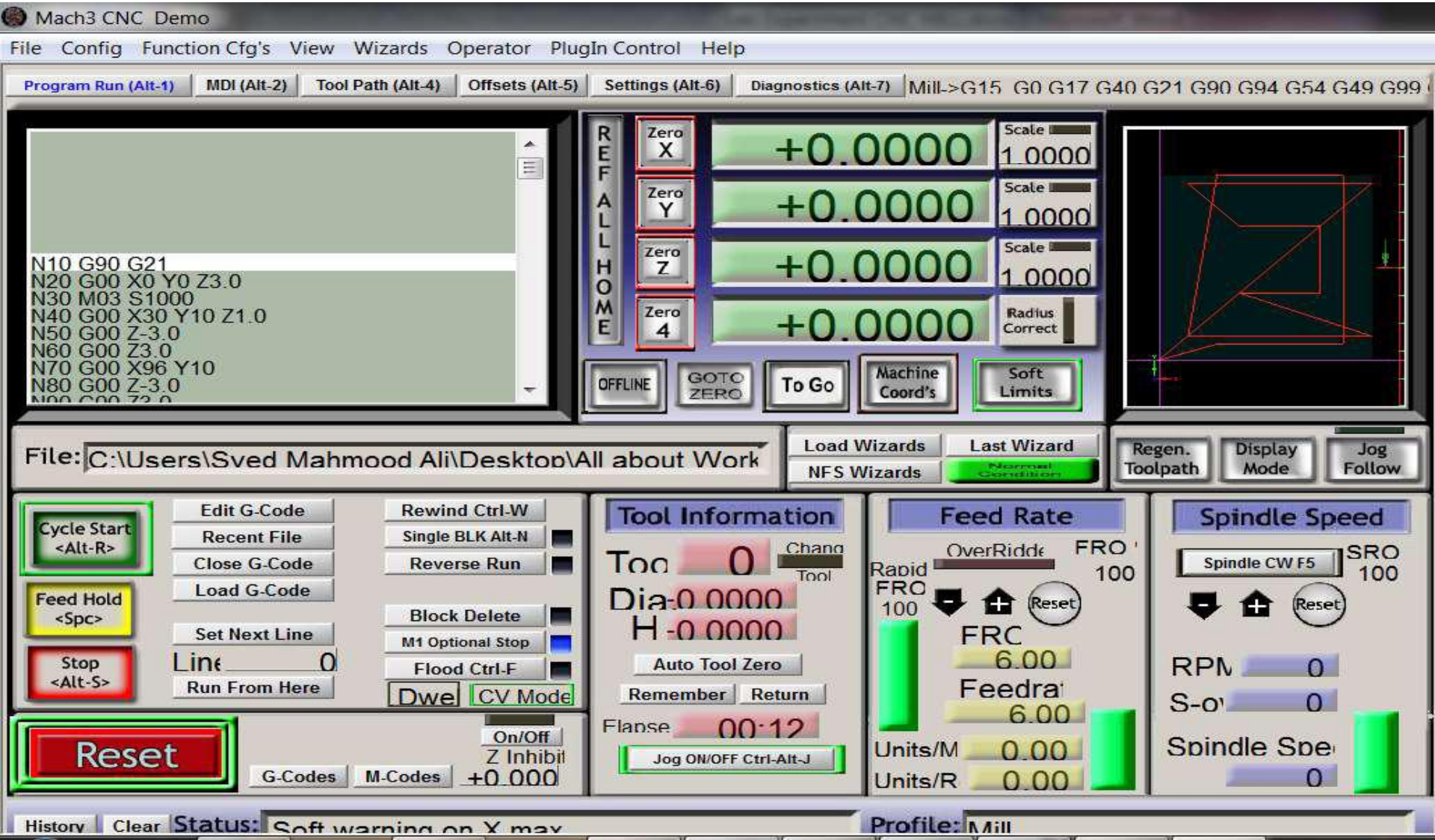
- The upward and downward movement of the machine has been marked as the Z- axis. Latitude on the horizontal plane has been specified as the X-axis and longitude has been marked as the Y-axis.



- The machine movements are scaled as per the machine units.
  - 1 cm = 1.4 units on X- axis of mill machine.
  - 1 cm = 2 units on Y- axis of mill machine.
- Machine has the total limitations on all the co-ordinates, i.e.
  - Total movement limitation on X-axis = 24.3 units
  - Total movement limitation on Y-axis = 17.3 units
  - Total movement limitation on Z -axis = 30 units
- Machine coordinates and zero position can be specified by manual adjustments.
  - Right and Left arrows on keyboard correspond to the X- axis of the machine.
  - Up and Down arrows on keyboard correspond to the Y- axis of the machine.
  - Page Up and Page Down arrows on keyboard correspond to the Z- axis of the machine.

Mach Mill 3 Simulator

Here are the basic Mach Mill simulators controls, described with their functions:



Here are the basic Mach Mill simulators controls, described with their functions:

- **Loading a file**
  - Pressing this button would open a file opening wizard.
- **Cycle Start**
  - Cycle Start button would execute the loaded G -code
- **Tool Information**
  - This button on Mach Mill displays the current tool info.
- **Spindle Speed**
  - Other than CNC machine control and G code instructions, spindle speed can be controlled through the simulator control.
- **Feed Rate**
  - Other than CNC machine control and G code instructions, feed rate can be controlled through the simulator control.
- **Display Area**
  - This area marks tool positions. A complete tool path, with step by step moving points is shown in this area.
- **Zero Reference Configuration of Milling Machine**
  - Student can adjust the specific reference point for individual work piece. By manually adjusting the X-Y-Z positions of machine tool on the work piece, press the button of REF ALL HOME on Mach Mill Simulator. The specific X-Y-Z positions would be saved as the zero point / reference of the machine.

Machine G/M Code for the Task

- G-Codes are prepared in TXT files. These codes can either be manually prepared, just like machine language computer program or can be directly simulated from CAD softwares like PTC CREO
- **Syntax and Explanation of most commonly used commands:**
- **Command: G01**
  - Explanation: Linear motion with feed rate
  - Syntax: G01 F10 X00 Y00 Z00 S00
  - F=Feed Rate
  - S= Spindle Speed
  - X00 Y00 Z00= Arguments for the command
- **Command: G00**
  - Explanation: Rapid Positioning
  - Syntax: G00 X00 Y00 Z00
  - X00 Y00 Z00= Arguments for the command
- **Command: G28**
  - Explanation: Go to the home position of the machine
  - Syntax: G28
- **Details of all G-codes are given below in the Appendix A, and M Codes in the Appendix B, below. You can also check their explanations from Mach Mill 3, while working on them.**

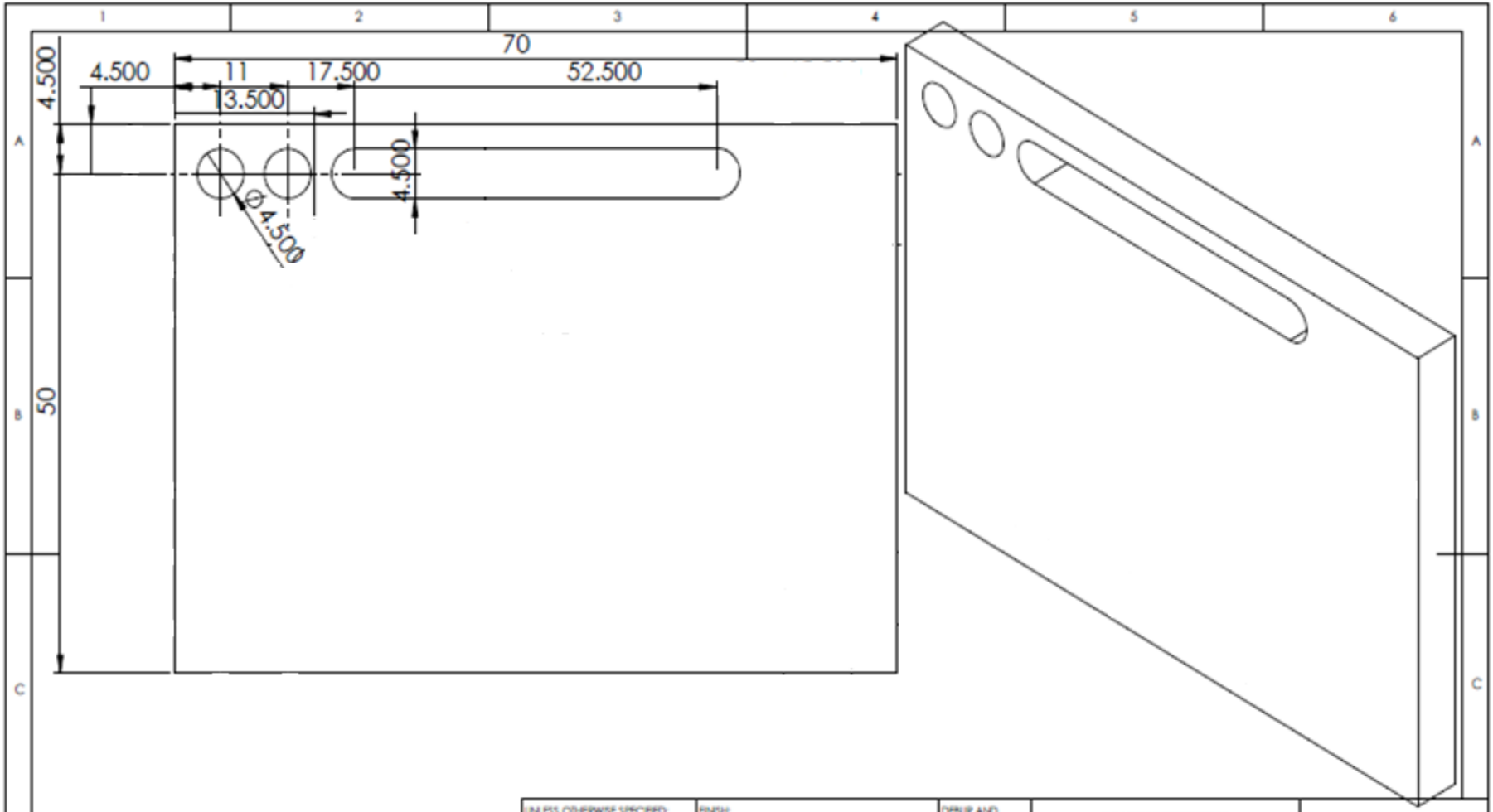
GCodes Example

- Below given figure shows, isometric view of a plate having 1 slot and 2 holes to be drilled in the plate.
- Dimensions are presented in standard position coordinates.
- The diameter of milling tool is 4.5.
- The depth of machining is 5.

GCodes:

G00 - Positioning

G01 - Straight interpolation



UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MILLIMETERS SURFACE FINISH: TOLERANCES: LINEAR: ANGULAR:	FINISH:			DEBUR AND BREAK SHARP EDGES	DO NOT SCALE DRAWING	REVISION
	NAME	SIGNATURE	DATE			TITLE:
DRAWN						
CHK'D						
APPV'D						
MFG						
Q.A				MATERIAL:	DWG NO.	A4
					Base Plate	
				WEIGHT:	SCALE:2:1	SHEET 1 OF 1

```
(Length=70 Width=50 Thickness=5)
(Material=Aluminium FeedRate=10 ToolDia=4.5)

G28 (Go to home)
M03 S1000 (Clockwise spindle at 1000)

(Drill Hole, 1)
G00 X04.50 Y04.50 Z00.00
G01 Z-05.00 F10.00
G00 Z00.00

(Drill Hole, 2)
G00 X11.00 Y04.50 Z00.00
G01 Z-05.00 F10.00
G00 Z00.00

(Straight Slot, 3)
G00 X17.50 Y04.50 Z00.00
G01 Z-05.00 F10.00
G01 X52.50 Y04.50

G28 (Go to home)
M05 (Stop Spindle)
M30 (Program End)
```

Demonstration

Lab Task

Appendix A: G- Code

- All the G codes are explained with their description

G0 Rapid positioning
G1 Linear interpolation
G2 Clockwise circular/helical interpolation
G3 Counterclockwise circular/Helical interpolation
G4 Dwell
G10 Coordinate system origin setting
G12 Clockwise circular pocket
G13 Counterclockwise circular pocket
G15/G16 Polar Coordinate moves in G0 and G1
G17 XY Plane select
G18 XZ plane select
G19 YZ plane select
G20/G21 Inch/Millimetre unit
G28 Return home
G28.1 Reference axes
G30 Return home
G31 Straight probe
G40 Cancel cutter radius compensation
G41/G42 Start cutter radius compensation left/right
G43 Apply tool length offset (plus)
G49 Cancel tool length offset
G50 Reset all scale factors to 1.0
G51 Set axis data input scale factors
G52 Temporary coordinate system offsets
G53 Move in absolute machine coordinate system

G54 Use fixture offset 1
G55 Use fixture offset 2
G56 Use fixture offset 3
G57 Use fixture offset 4
G58 Use fixture offset 5
G59 Use fixture offset 6 / use general fixture number
G61/G64 Exact stop/Constant Velocity mode
G68/G69 Rotate program coordinate system
G70/G71 Inch/Millimetre unit
G73 Canned cycle - peck drilling
G80 Cancel motion mode
G81 Canned cycle - drilling
G82 Canned cycle - drilling with dwell
G83 Canned cycle - peck drilling
G85/G86/G88/G89 Canned cycle - boring
G90 Absolute distance mode
G90.1 Absolute IJK mode
G91 Incremental distance mode
G91.1 Incremental IJK mode
G92 Offset coordinates and set parameters
G92.x Cancel G92 etc.
G93 Inverse time feed mode
G94 Units Per Min.
G98 Rapid Height By Z Height
G99 Rapid Height By R Height

Appendix B: M- Code

- All the M codes are explained with their description

M-code	*Functions*
M0	Program stop
M1	Optional program stop
M2	Program end
M3 / M4	Rotate spindle clockwise/counterclockwise
M5	Stop spindle rotation
M6	Tool Change (by two macros)
M7	Mist coolant on
M8	Flood coolant on
M9	All coolant off
M30	Program end and rewind
M47	Repeat program from first line
M48	Enable speed and feed override
M49	Disable speed and feed override
M98	Call subroutine
M99	Return from subroutine/repeat

A	A axis of machine
B	B axis of machine
C	C axis of machine
D	Tool radius compensation number
F	Feedrate
G	See G-codes table
H	Tool lenght offset index
I	X axis offset for arcs
	X offset in G87 canned cycle
J	Y axis offset for arcs
	Y offset in G87 canned cycle
K	Z axis offset for arcs
	Z offset in G87 canned cycle
L	Number of repetitions in canned cycles/subroutines
	L1 / L2 : tool offset settings / fixture offset (with G10)
M	See M-codes table
N	line number
O	Subroutine label number
P	Dwell time in a canned cycle
	Dwell time with G4
	Tool / Fixture number (with G10)
	Tool radius (with G41 / G42)
Q	Feed increment in G83 canned cycle
	Repetitions of subroutine call
R	Arc radius
	Canned cycle retract level
S	Spindle speed
T	Tool selection
X	X axis of machine
Y	Y axis of machine
Z	Z axis of machine