

Modelagem 3D com **FreeCAD**

14 a 18 de junho

Semana da Indústria

Instituto Federal de São Paulo

Alexandre Aravecchia

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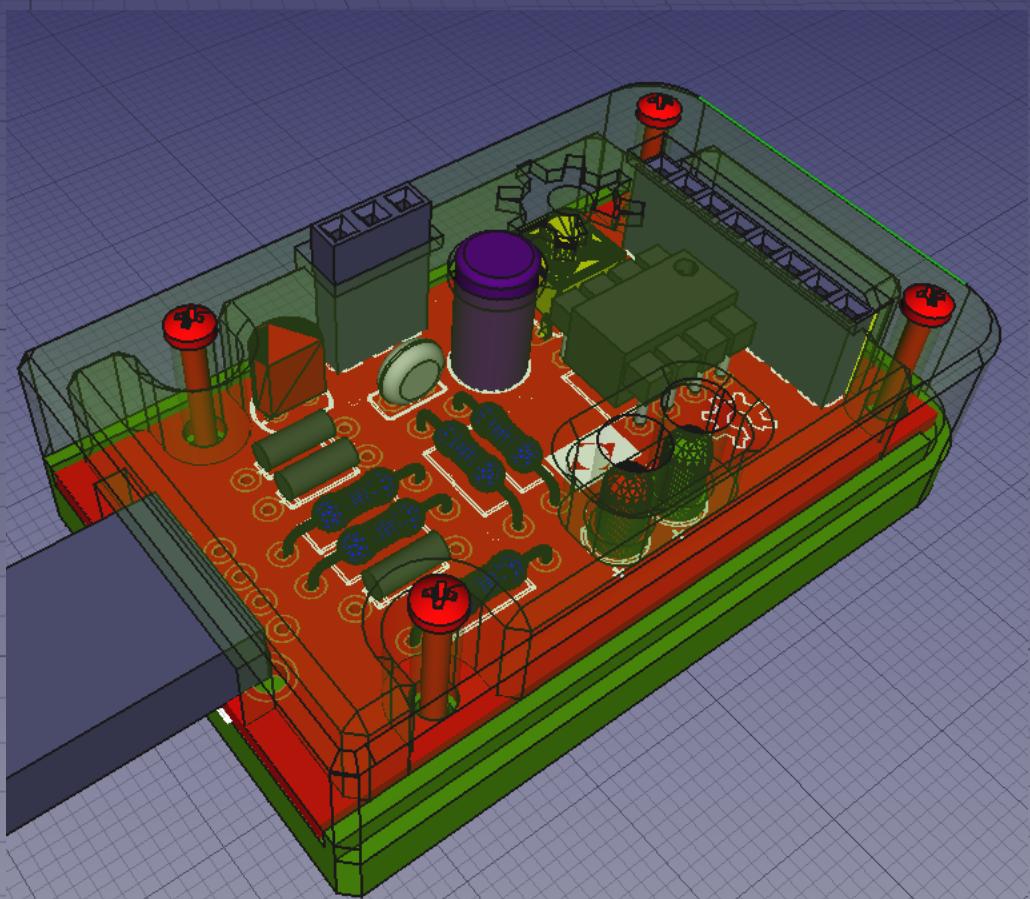
1 Convite

Eu tenho um convite pra você, que é aluno do IFSP.

Você ganhou um curso de modelagem 3D, totalmente online e gratuito, da Escola de Impressão 3D.

Será nos dias **14 a 18 de junho**, das 19 às 22h, durante a **Semana da Indústria** do IFSP.

Para participar, é se inscrever [neste link](#), com seu e-mail institucional do IFSP.



2 O Professor



Alexandre Aravecchia

projetista industrial

Um dos pioneiros da modelagem 3D no Brasil.

Professor da [Escola de Impressão 3D](#)

Palestrante [Latinoware](#).

Escreve na [Revista Espírito Livre](#) e no [Blog Filipe Flop](#).

Youtube: [Aravecchia3D](#).

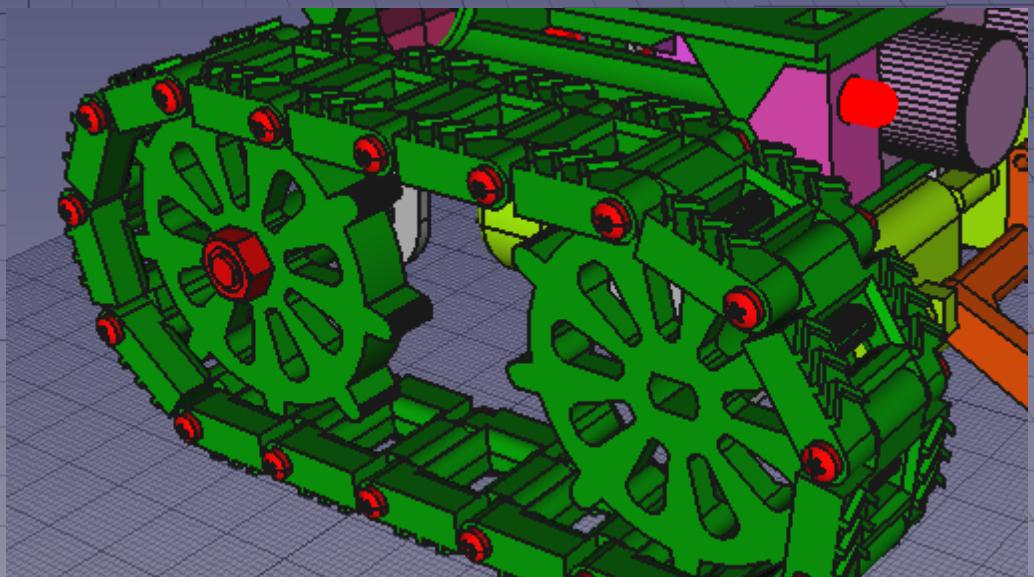
2.1 FreeCAD

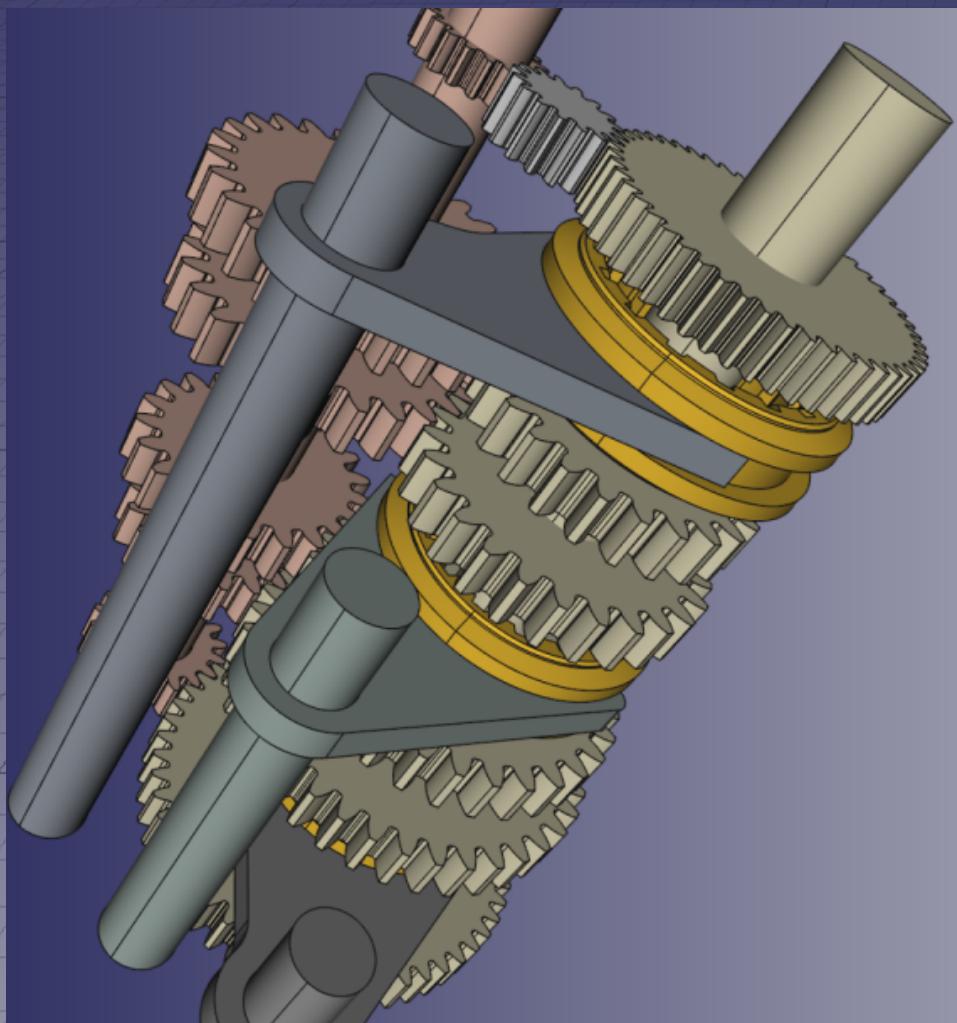
O **FreeCAD** é um *software* livre de modelagem 3D **paramétrica**.

Parametrização é a possibilidade de gerar e manipular formas geométricas em função de parâmetros matemáticos, de forma rápida e dinâmica.

Numa máquina, por exemplo, a alteração de um único componente muda todos os tamanhos e posições de outros componentes.

Com modelagem paramétrica, ao invés de ter que refazer todo o modelo, o FreeCAD remodela todos os componentes, em alguns segundos.



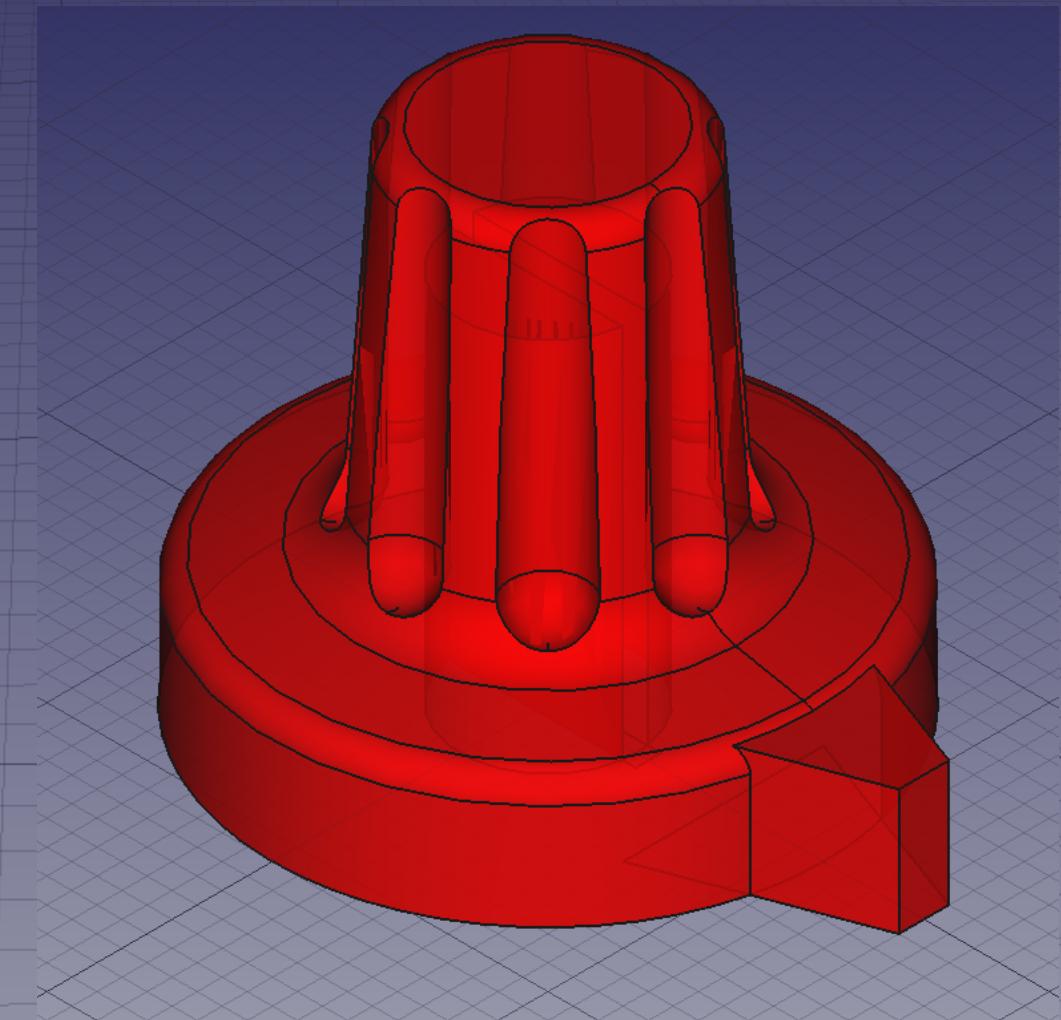
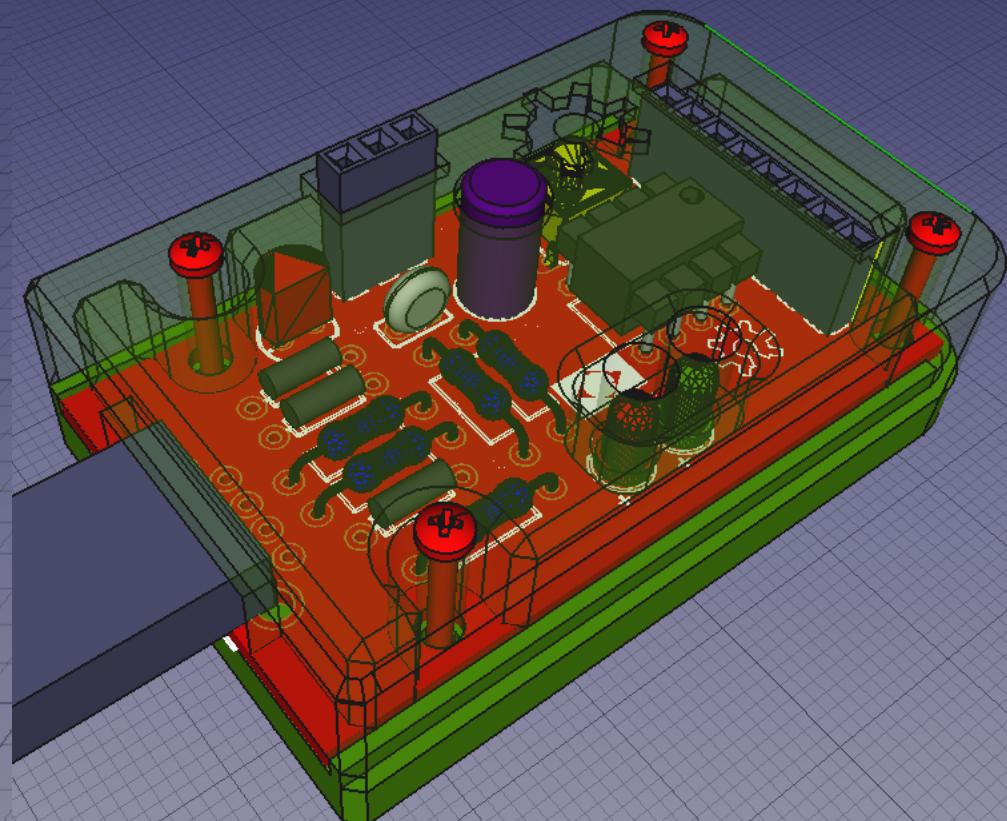


No FreeCAD, você pode modelar de uma forma rápida e automatizada, focando mais no projeto e menos nos uso das ferramentas.

O FreeCAD ainda possui recursos de simulação de movimentos físicos, banco de dados de componentes, cálculo de resistência pelo Método dos Elementos Finitos (FEM), e uma série de recursos que facilitam - e muito - a vida do projetista.

Você ganha tempo, qualidade e produtividade, e ainda valoriza seu trabalho.

Leia mais no [Blog Filipe Flop](#).



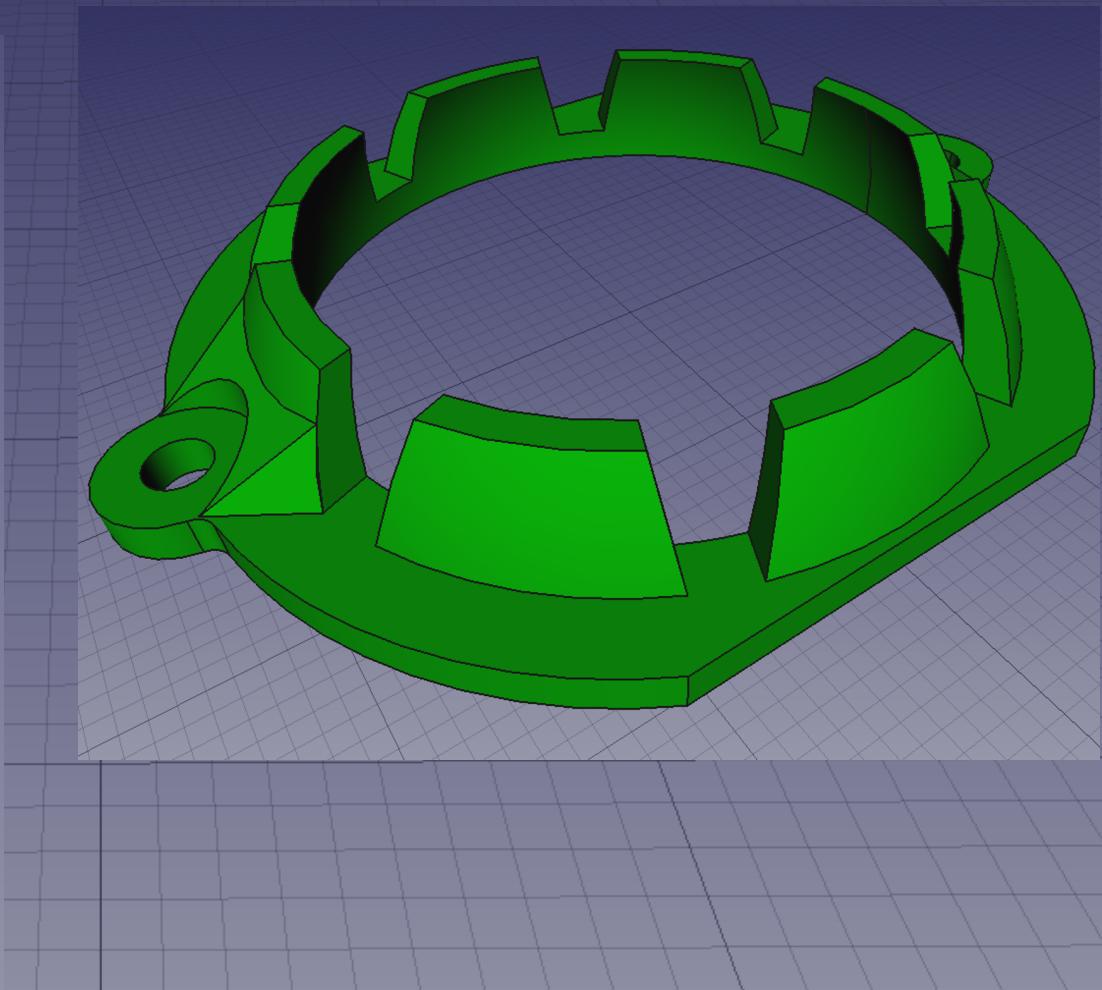
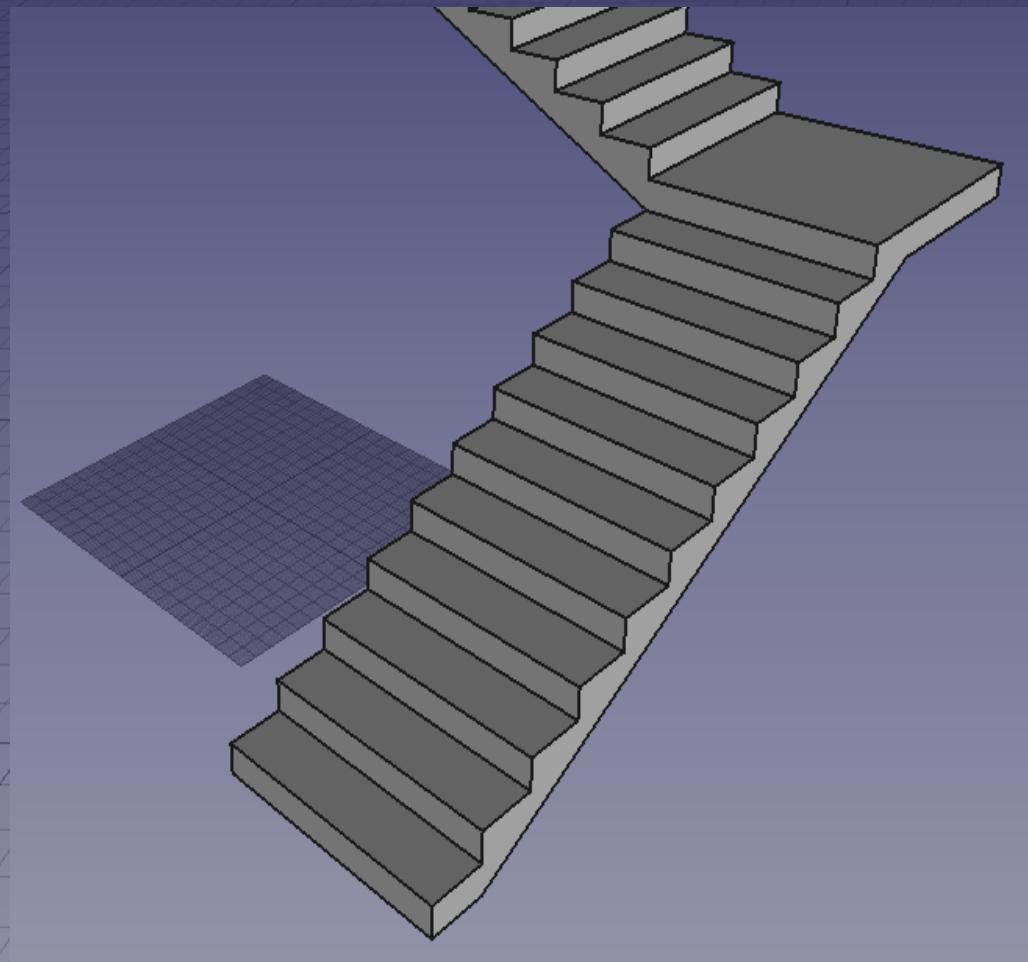
Spreadsheet*

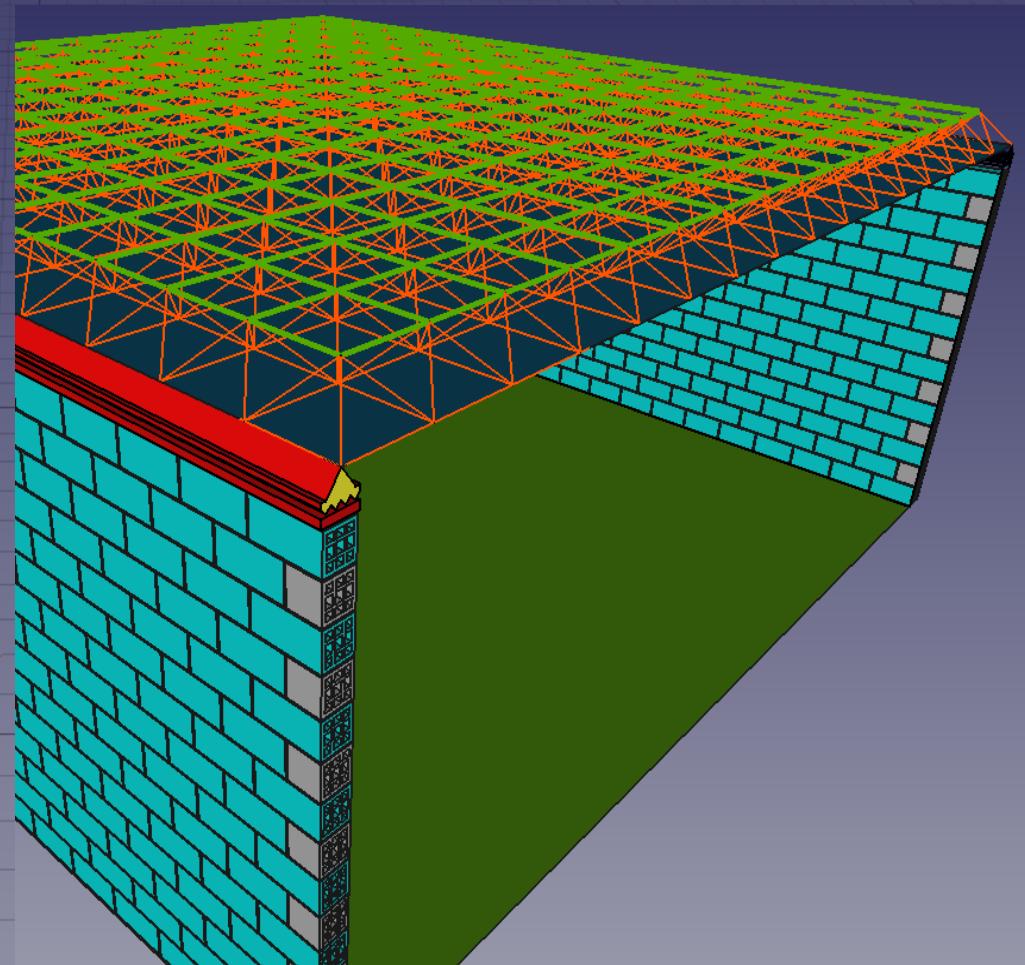
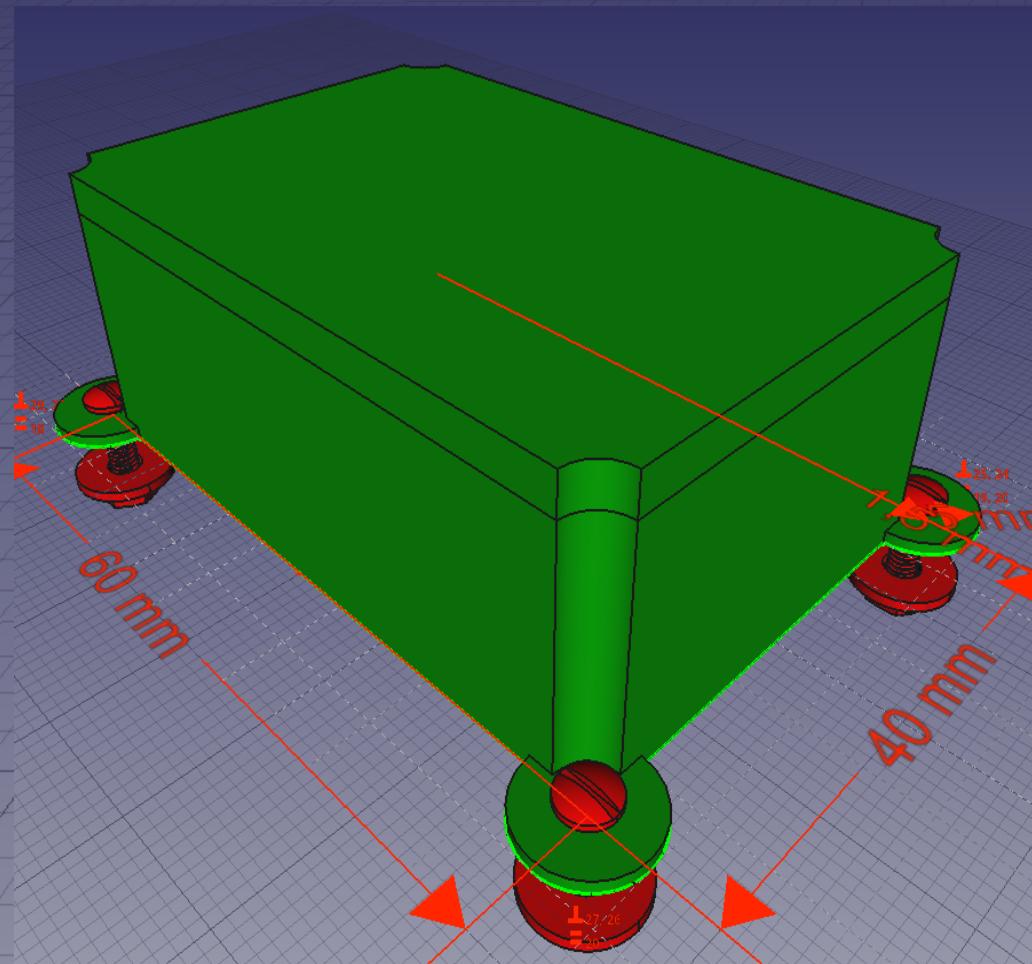
Content: 10 Alias: onnectorA

	A	B	C
1	Espessura	2,00	
2	Altura	17,00	
3	Furo	3,50	
4	Conector A	10,00	
5	Conector B	5,00	
6	Conector C	5,00	
7	Folga	1,00	
8	Nome	Aravecchia	
9			
10			
11			
12			
13			

CAIXA-ARDUINO_07 ; 1*

The image shows a FreeCAD interface. On the left is a spreadsheet window titled "Spreadsheet*" containing a table of parameters. The row for "Conector A" has a value of "10,00" highlighted with a red border. A red arrow points from this cell to a circular feature on the front-left corner of a 3D model of a green Arduino case. The 3D model also features a blue base plate. In the top right corner of the main window, there is a coordinate system cube labeled "TOP", "FRONT", and "RIGHT". The FreeCAD interface includes standard toolbars and a status bar at the bottom.





Modelagem 3D com **FreeCAD**

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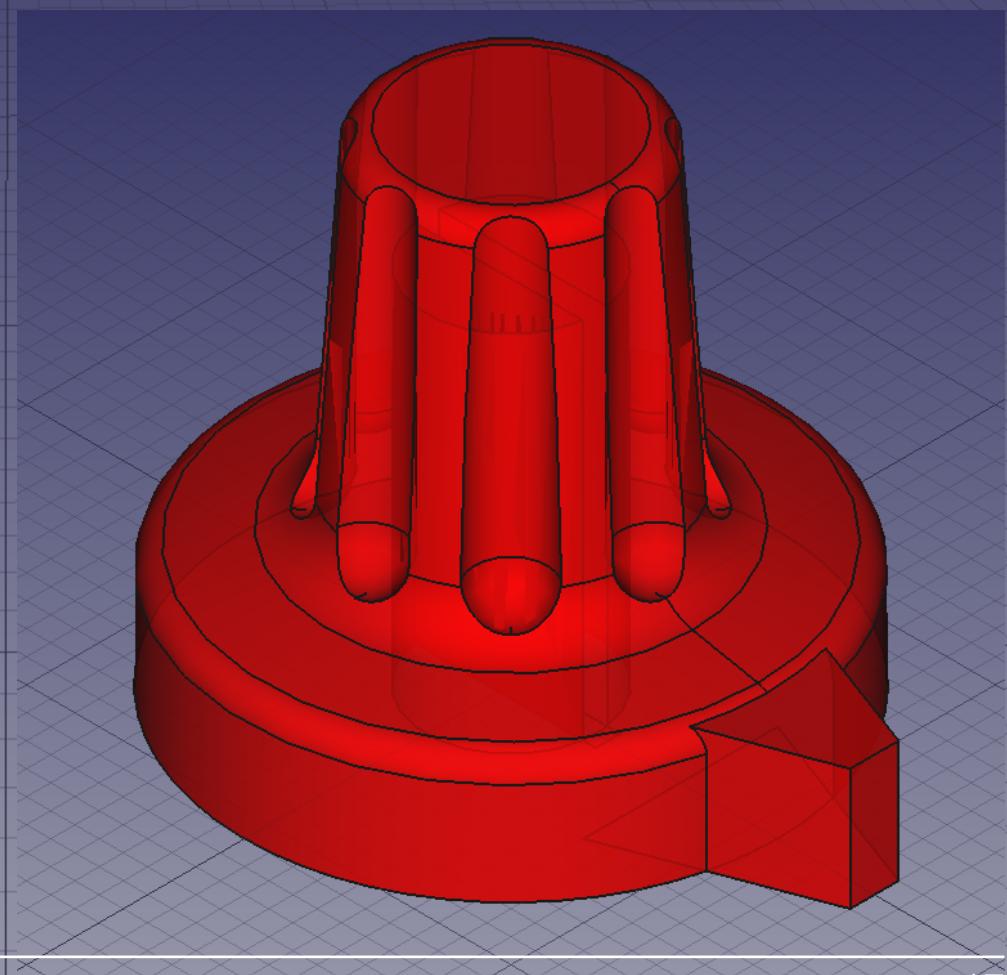
Instituto Federal de São Paulo

Inscrições:
[neste link](#)

2.2 Por quê FreeCAD

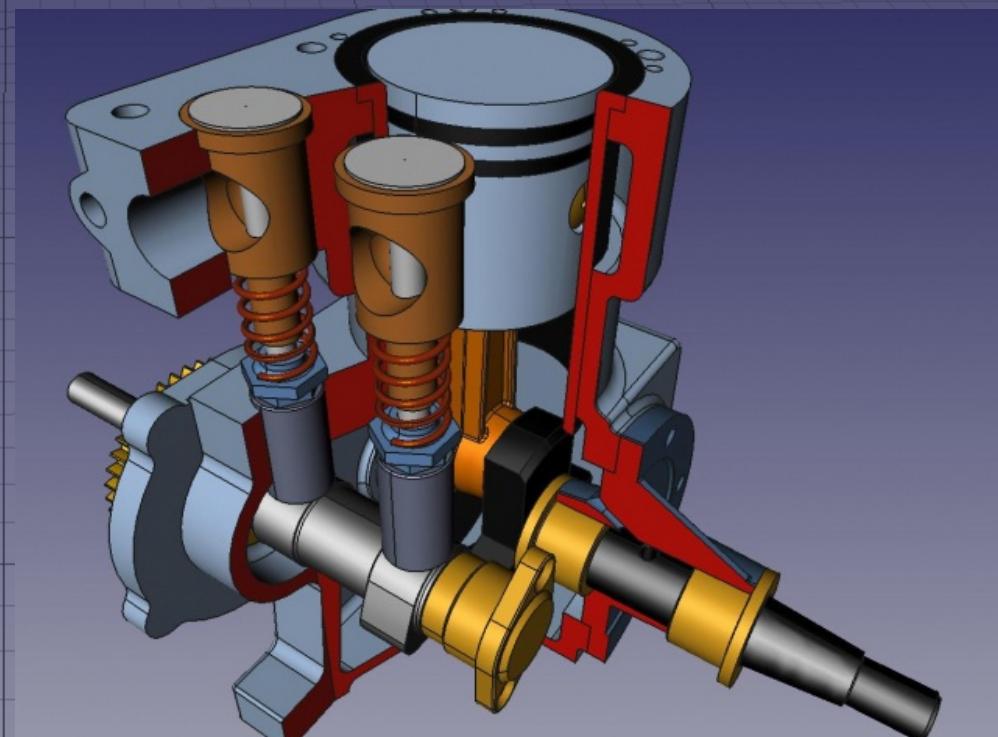
1. Liberdade

- ✓ **Liberdade 0:** executar o programa, para qualquer propósito.
- ✓ **Liberdade 1:** acessar o código-fonte e alterá-lo como quiser.
- ✓ **Liberdade 2:** redistribuir cópias.
- ✓ **Liberdade 3:** distribuir cópias de suas versões modificadas.



2. Vai funcionar?

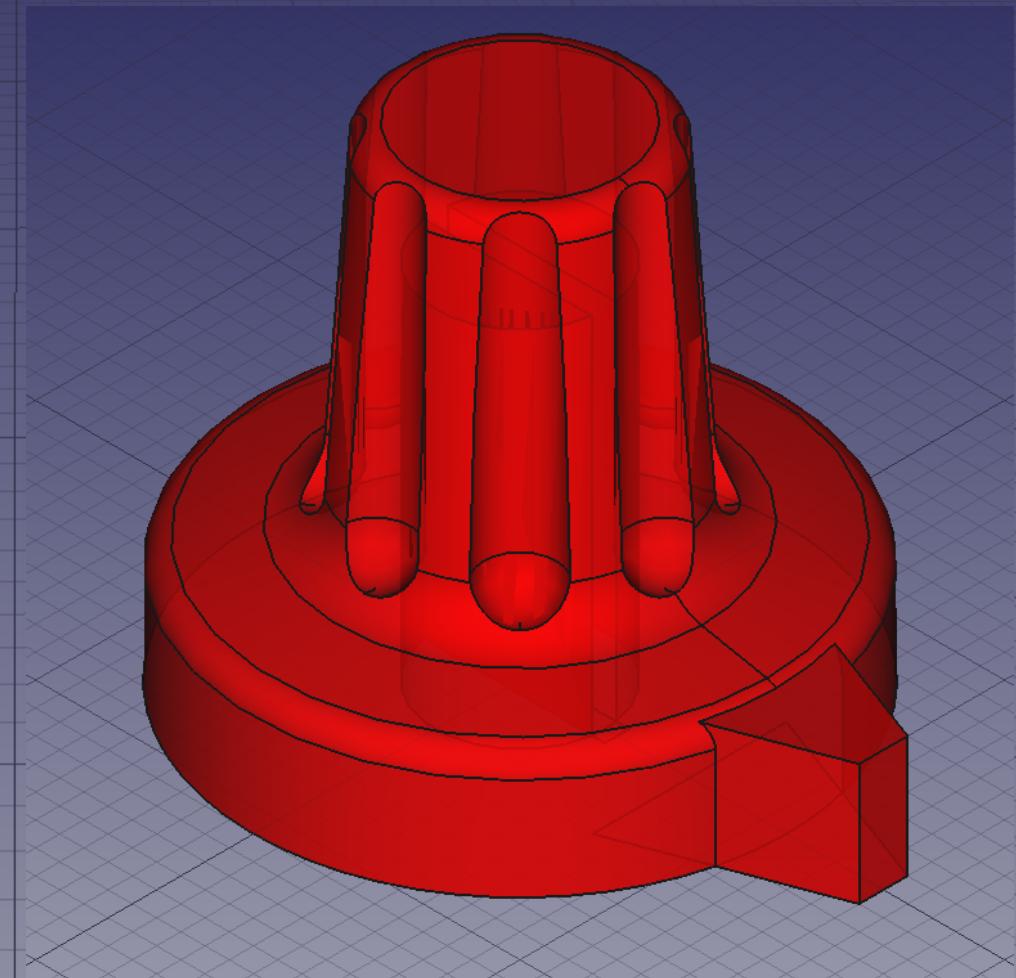
- ✓ Uso profissional
- ✓ Uso abrangente
- ✓ Desenvolvido por:
Técnicos e engenheiros da industria
- ✓ Para atender:
Técnicos e engenheiros da industria.



3. Quanto custa? ¹

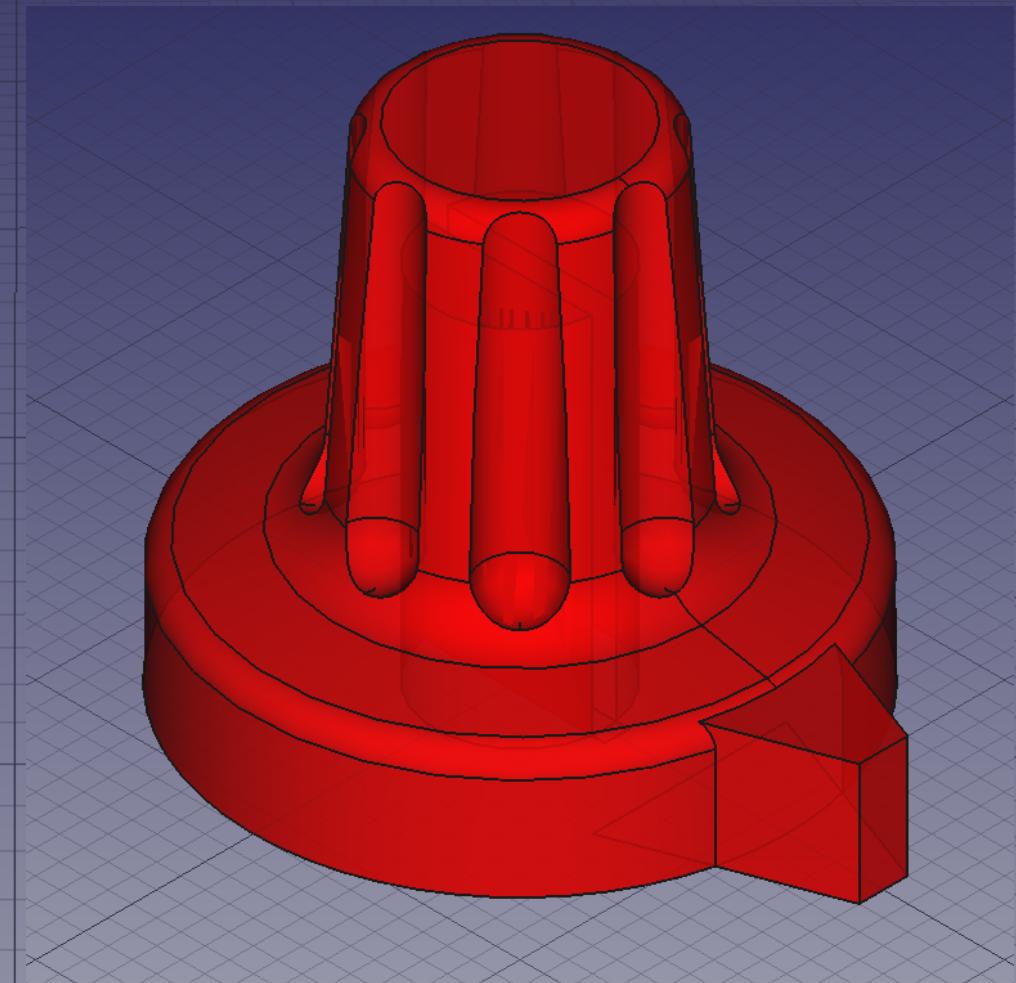
✓ **Promob:**

R\$ 908 + R\$ 1.366 / ano

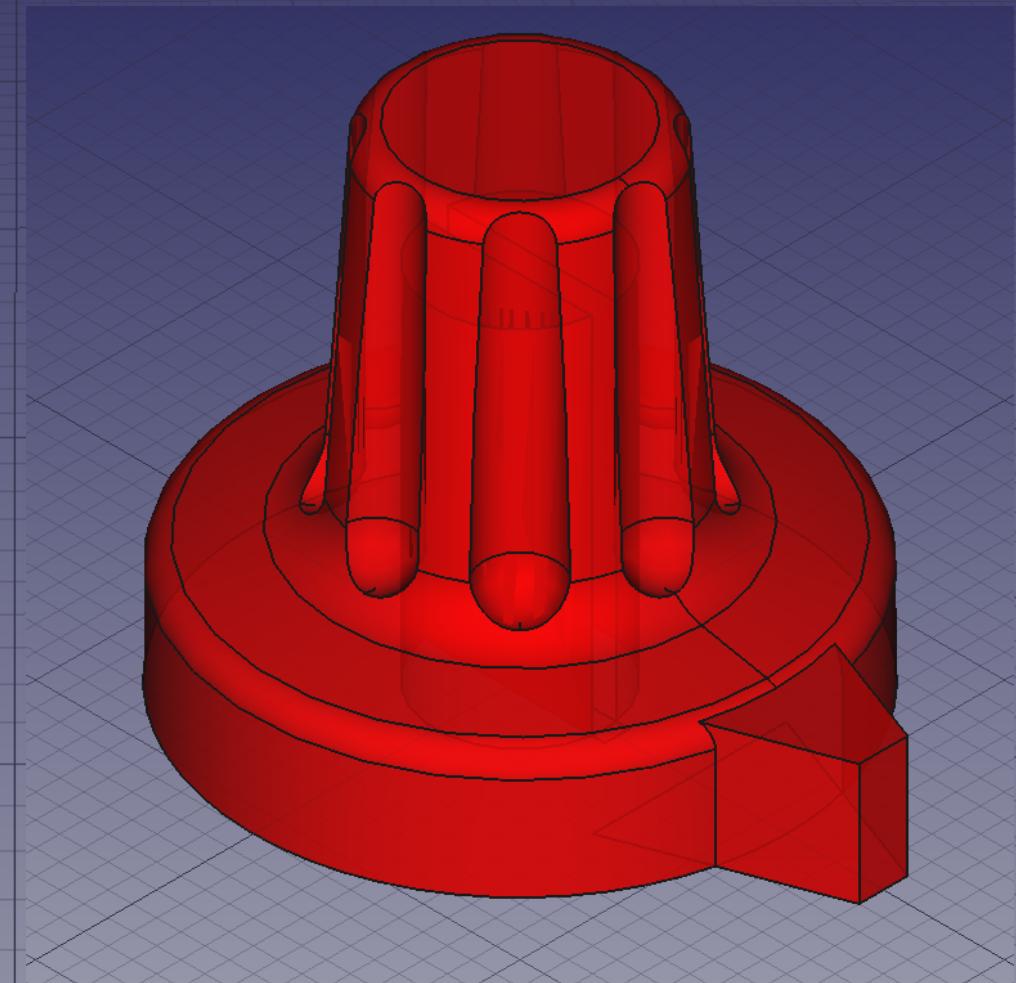


¹Valores de 21/05/2021, dolar a R\$ 5,37

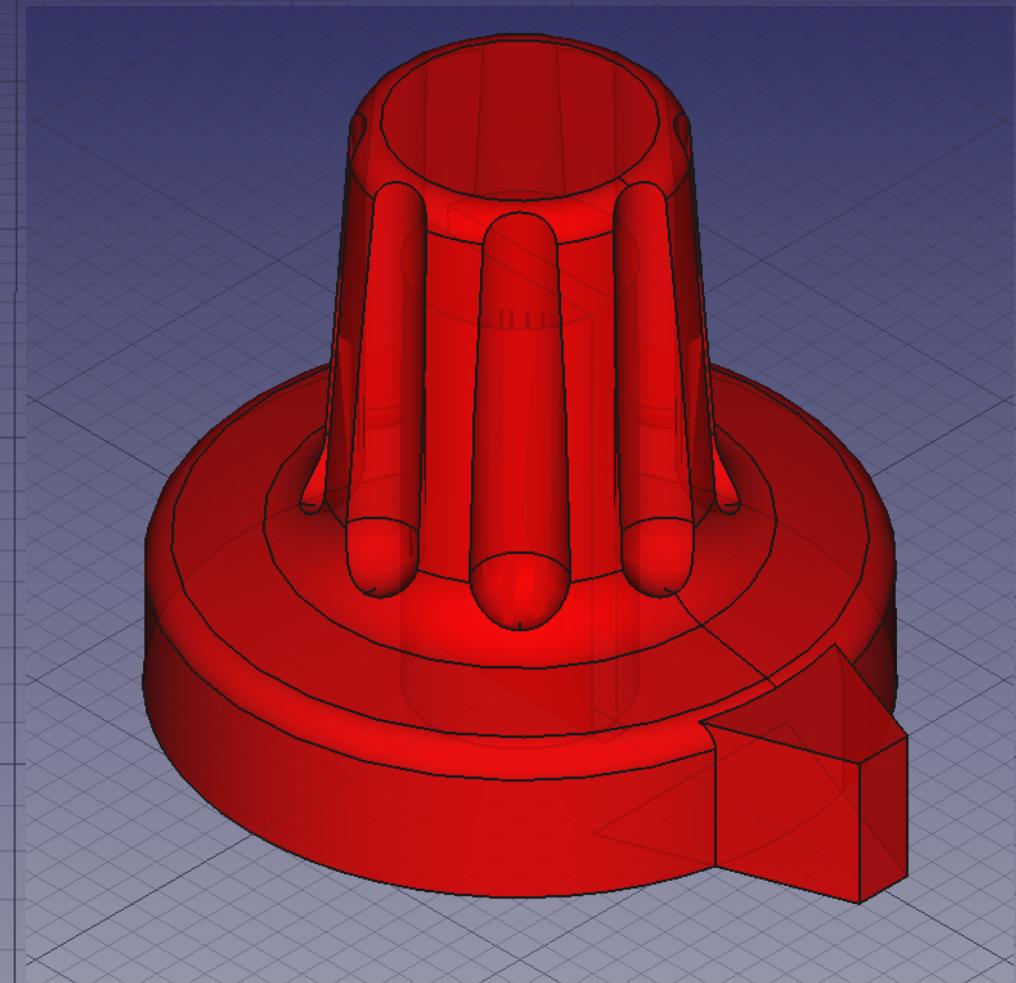
✓ **AutoCAD LT:**
R\$ 1.642 / ano



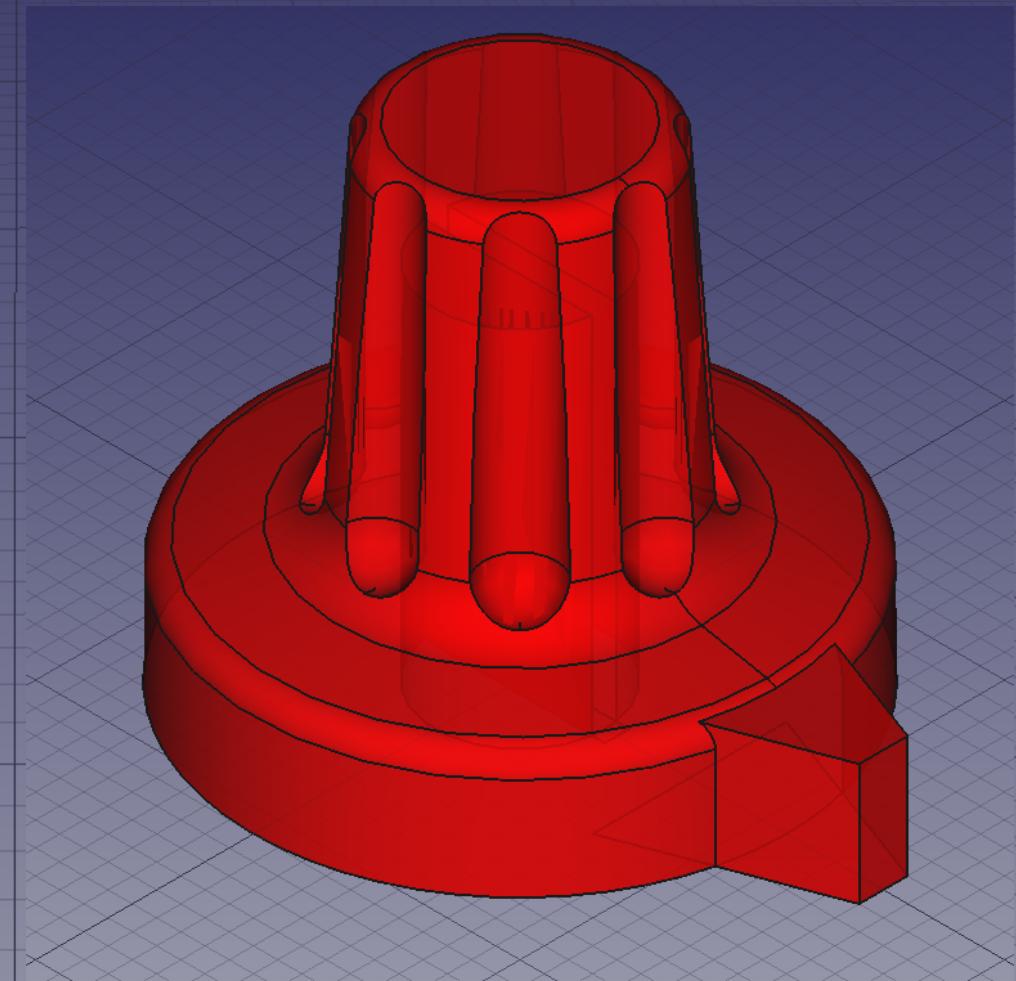
✓ **ZWCAD:**
R\$ 4.288 / ano



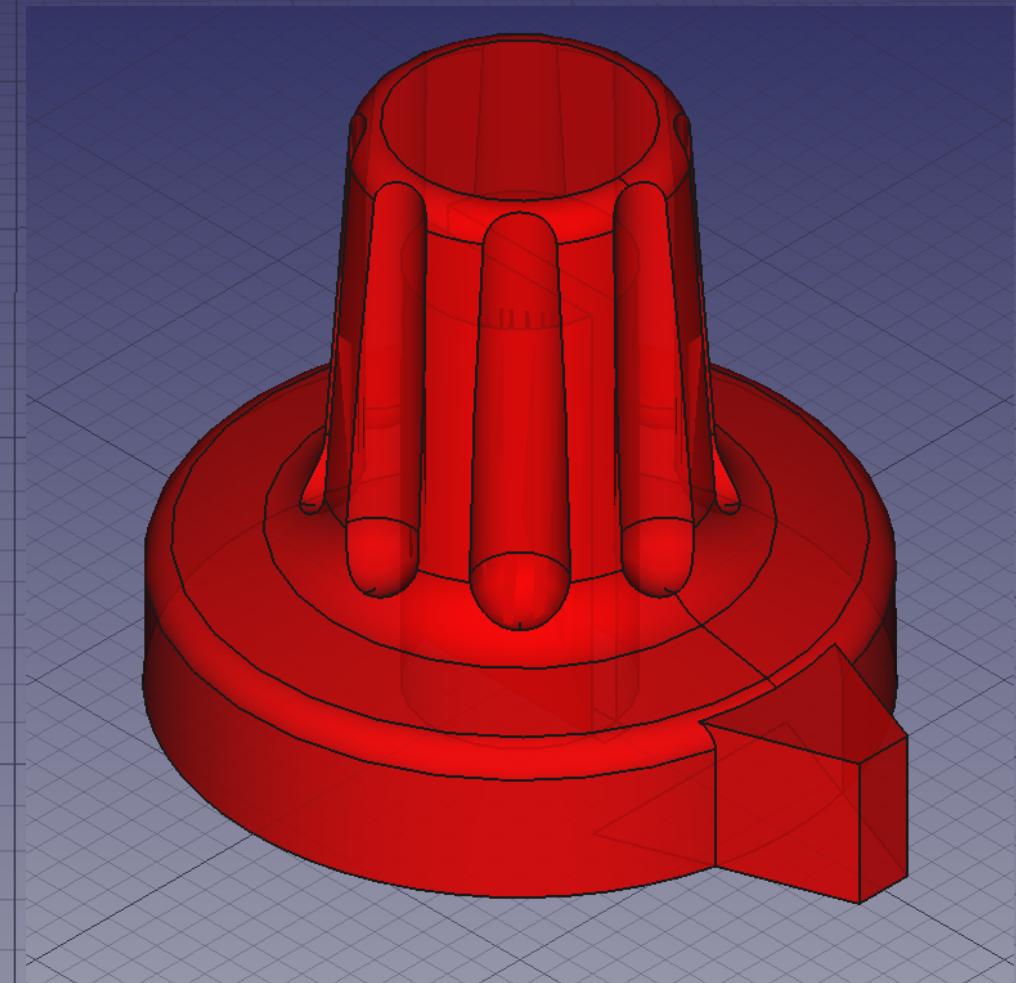
✓ **Solid Edges:**
R\$ 4.830 / ano



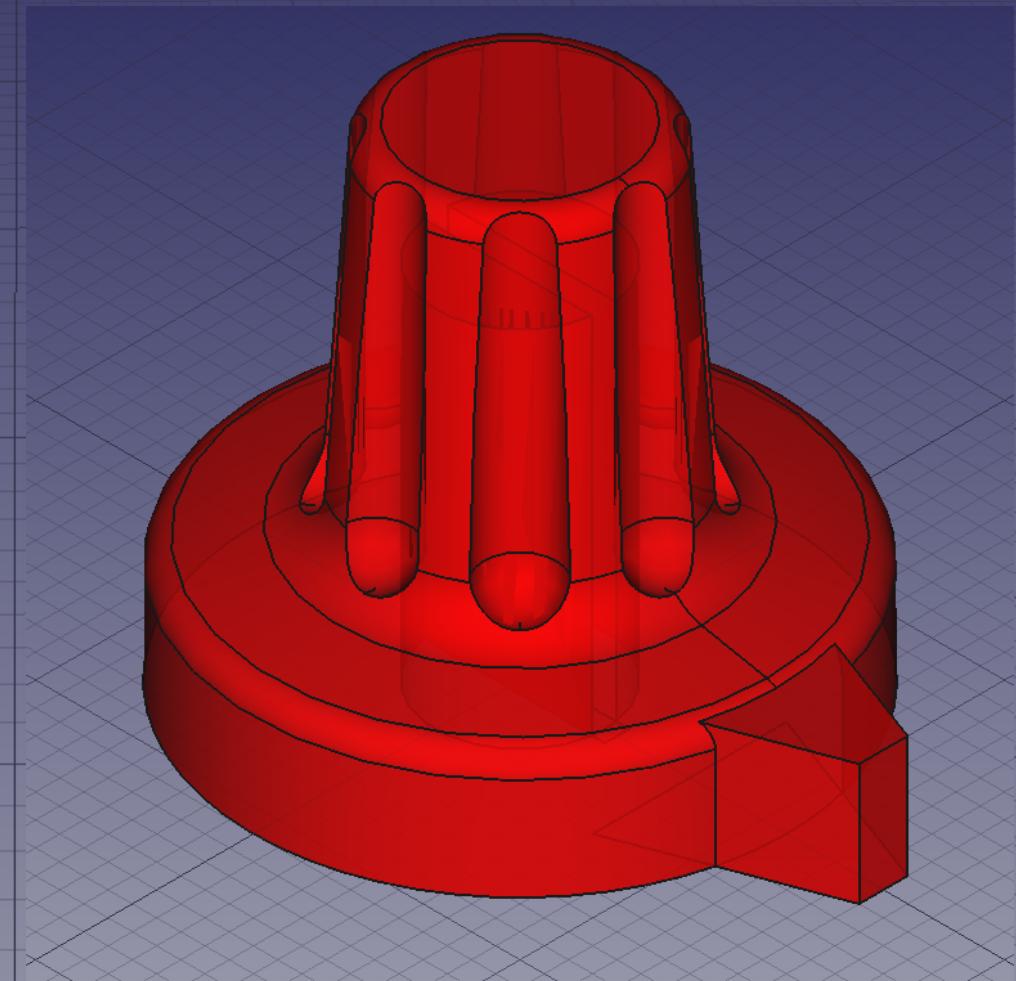
✓ Sketchup:
R\$ 6.104 / ano



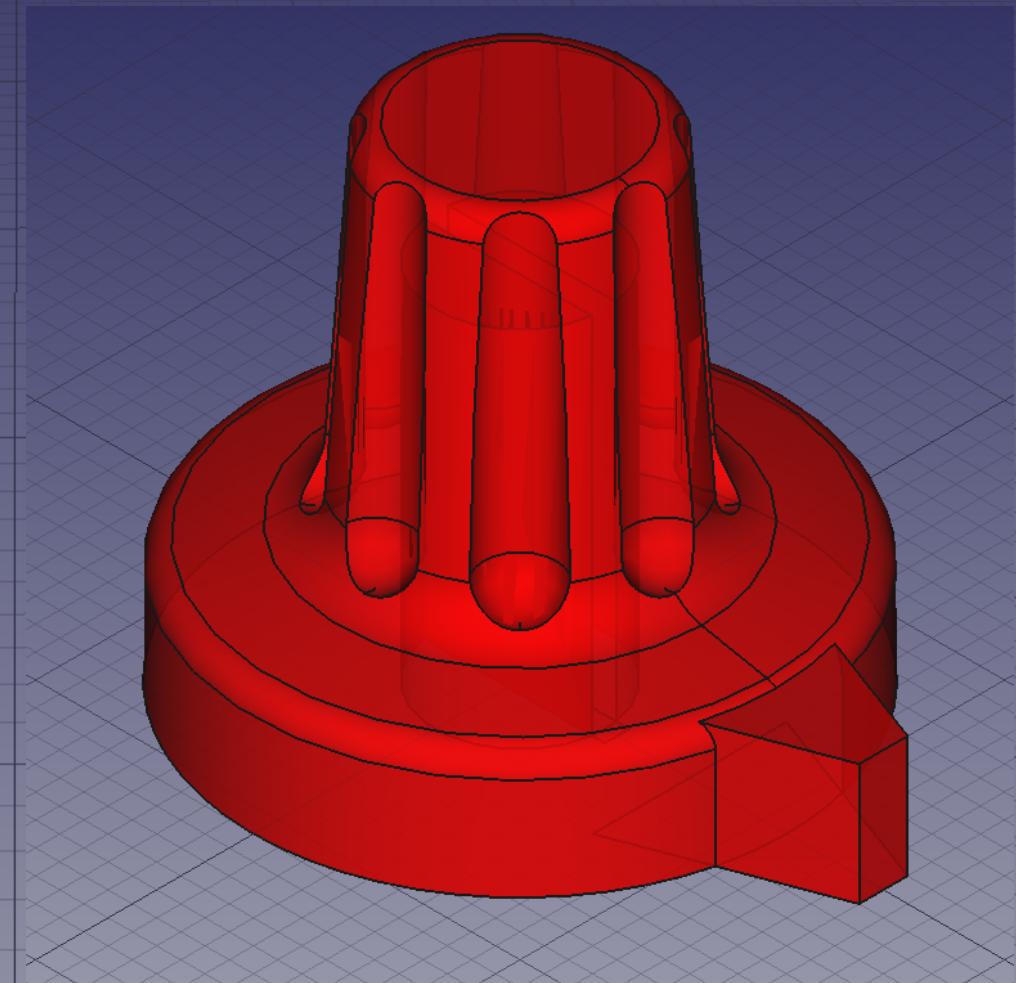
✓ **AutoCAD Full:**
R\$ 8.215 - 15.650 / ano



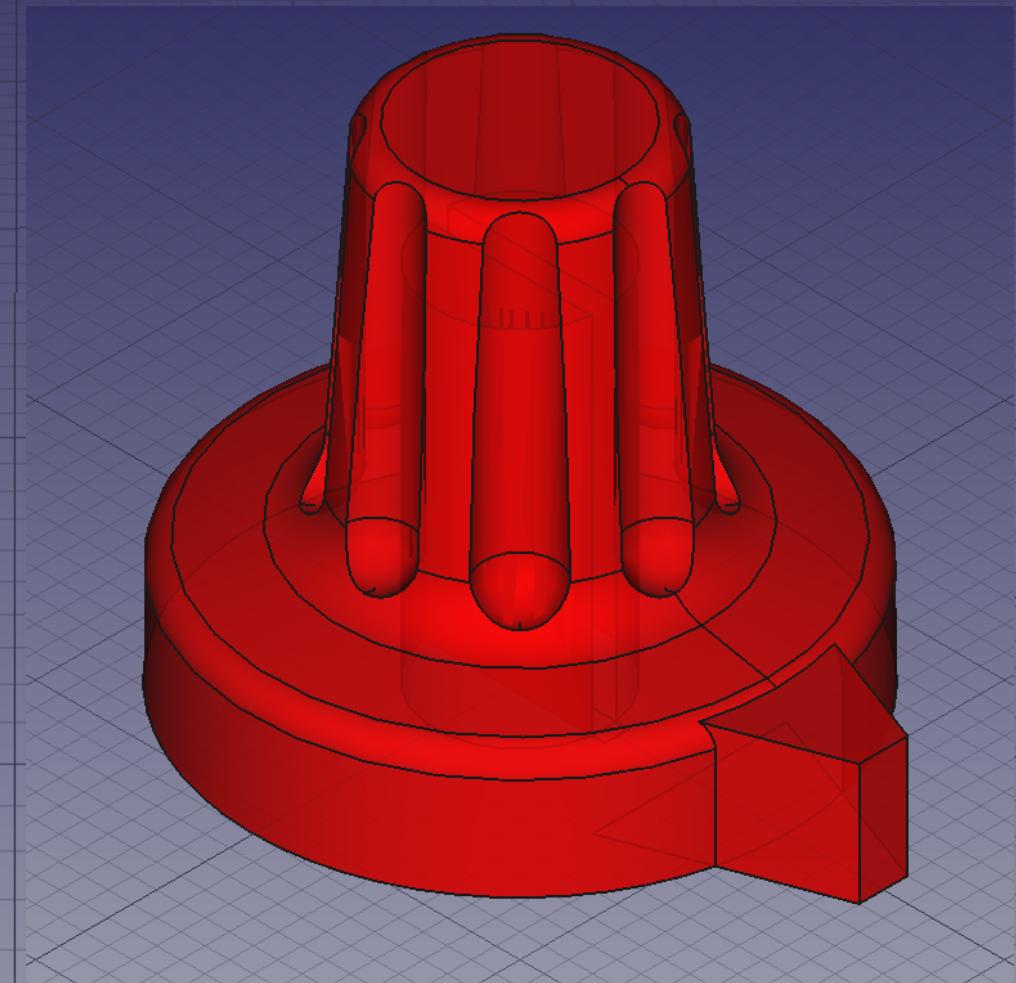
✓ Autodesk Fusion
R\$ 8.931 / ano



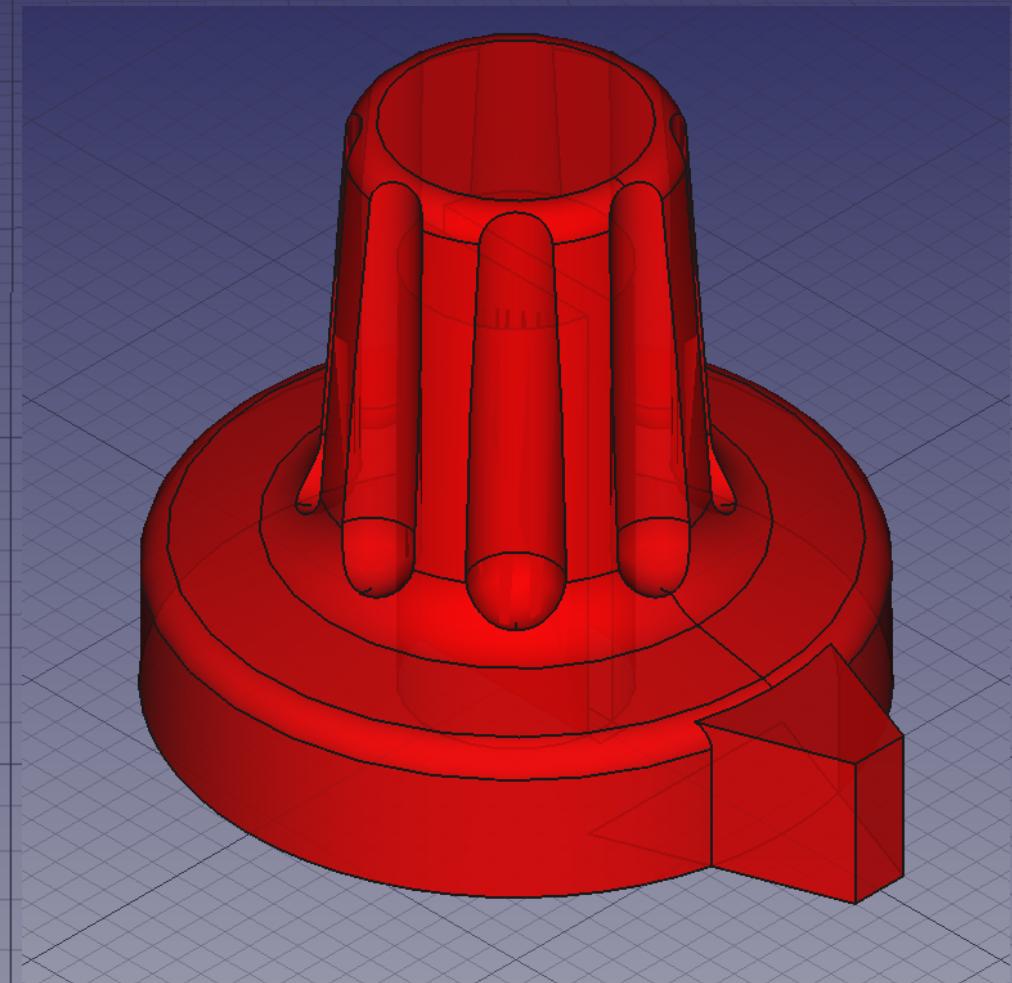
✓ Autodesk Inventors
R\$ 11.753 / ano



✓ Autodesk Revit
R\$ 13.658 / ano

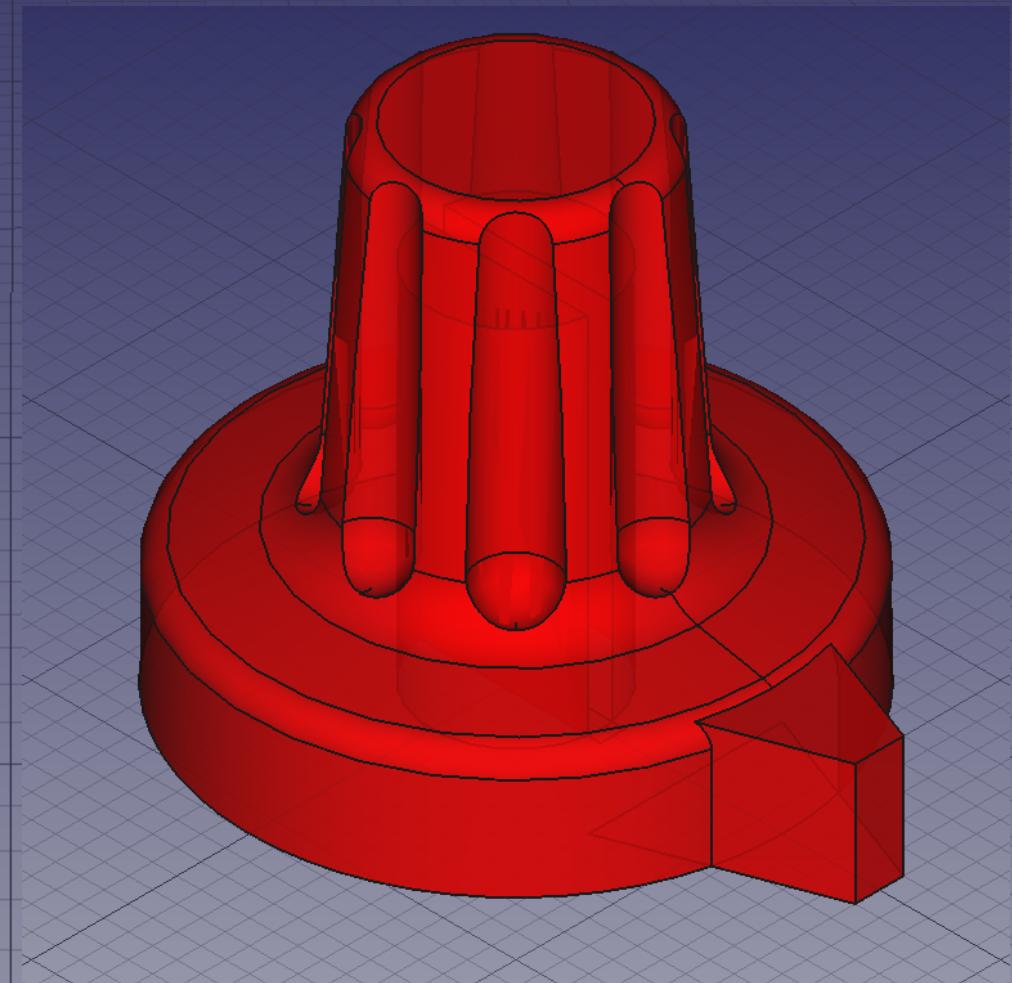


✓ **Solidworks:**
R\$ 21.440 + R\$ 6.950 / ano

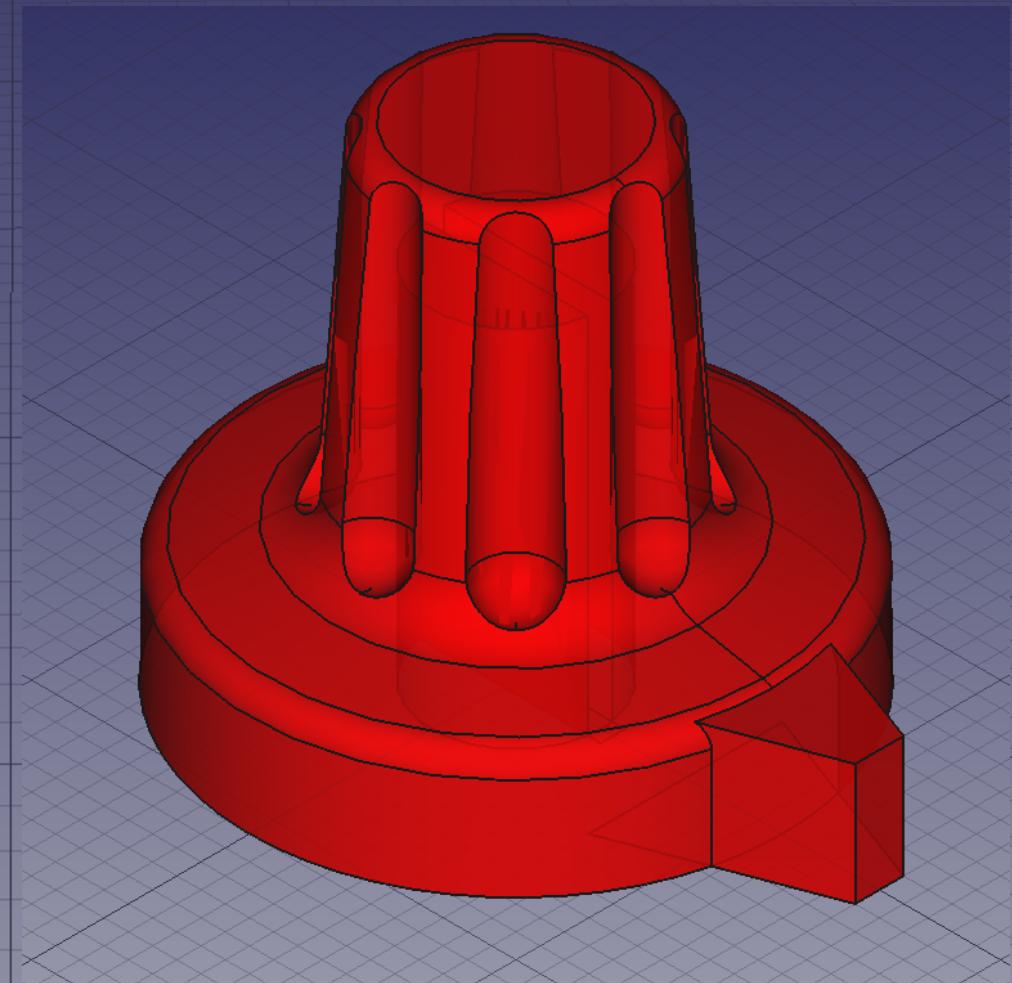


✓ **Catia:**

R\$ 60.107 + R\$ 10.733 / ano



✓ **FreeCAD:**
ZERO!



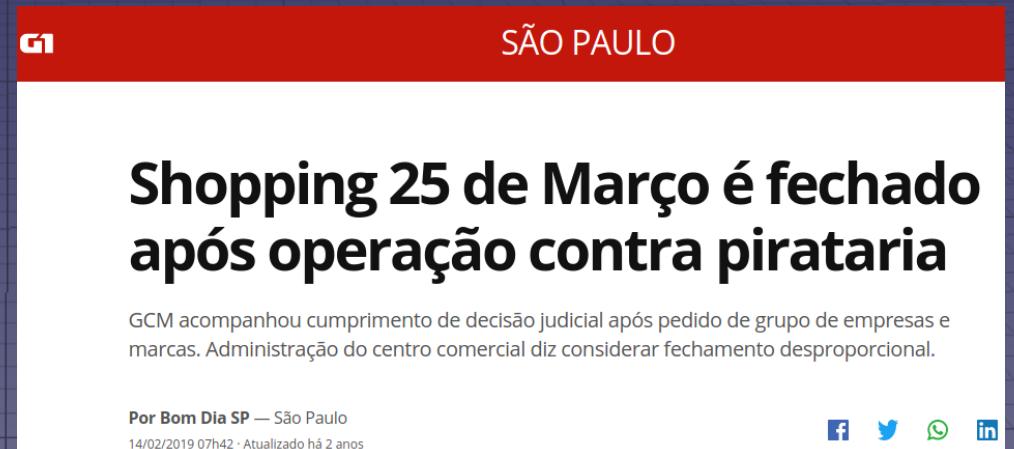
4. Mas não pode usar pirata mesmo?

✓ Poder, pode, mas...



The screenshot shows a news article from Tecmundo. The title is "Universidade do Rio tem prédio leiloadado por ter usado Windows pirata". Below the title is a photo of a hand holding a wooden gavel. On the left side of the article, there is a "SHARE" button with icons for Facebook, Twitter, LinkedIn, and WhatsApp.

Licença Windows + Office: R\$ 189 / ano



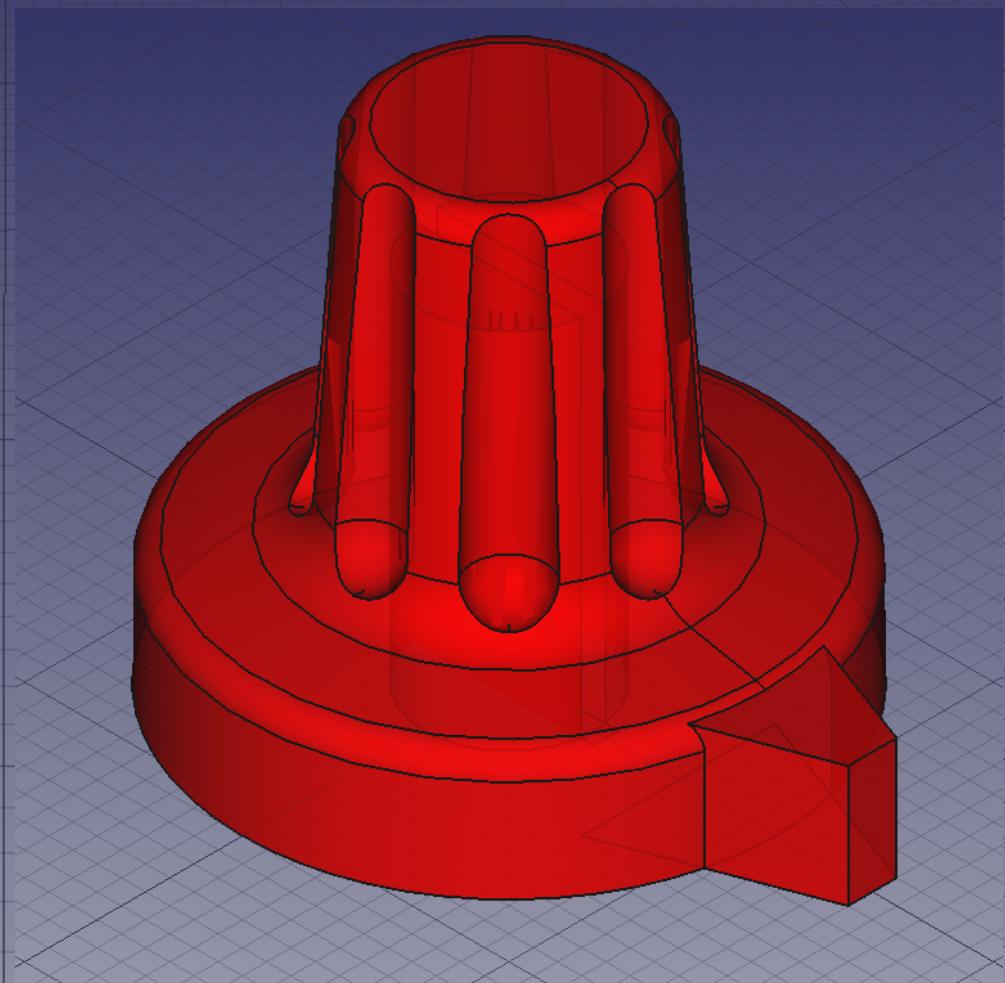
The screenshot shows a news article from G1 São Paulo. The title is "Shopping 25 de Março é fechado após operação contra pirataria". Below the title, it says "GCM acompanhou cumprimento de decisão judicial após pedido de grupo de empresas e marcas. Administração do centro comercial diz considerar fechamento desproporcional." The author is "Por Bom Dia SP — São Paulo" and the date is "14/02/2019 07h42 · Atualizado há 2 anos". There are social media sharing icons at the bottom right.



The screenshot shows a news article from Gizmodo Brasil. The title is "Mulher é condenada a seis meses de prisão na Espanha por piratear Windows e Office". Below the title, it says "por Caio Carvalho" and "publicado em 31 de maio de 2021 @ 17:05". The page includes a navigation bar with links like HOME, TECNOLOGIA, MICROSOFT, and a newsletter sign-up section.

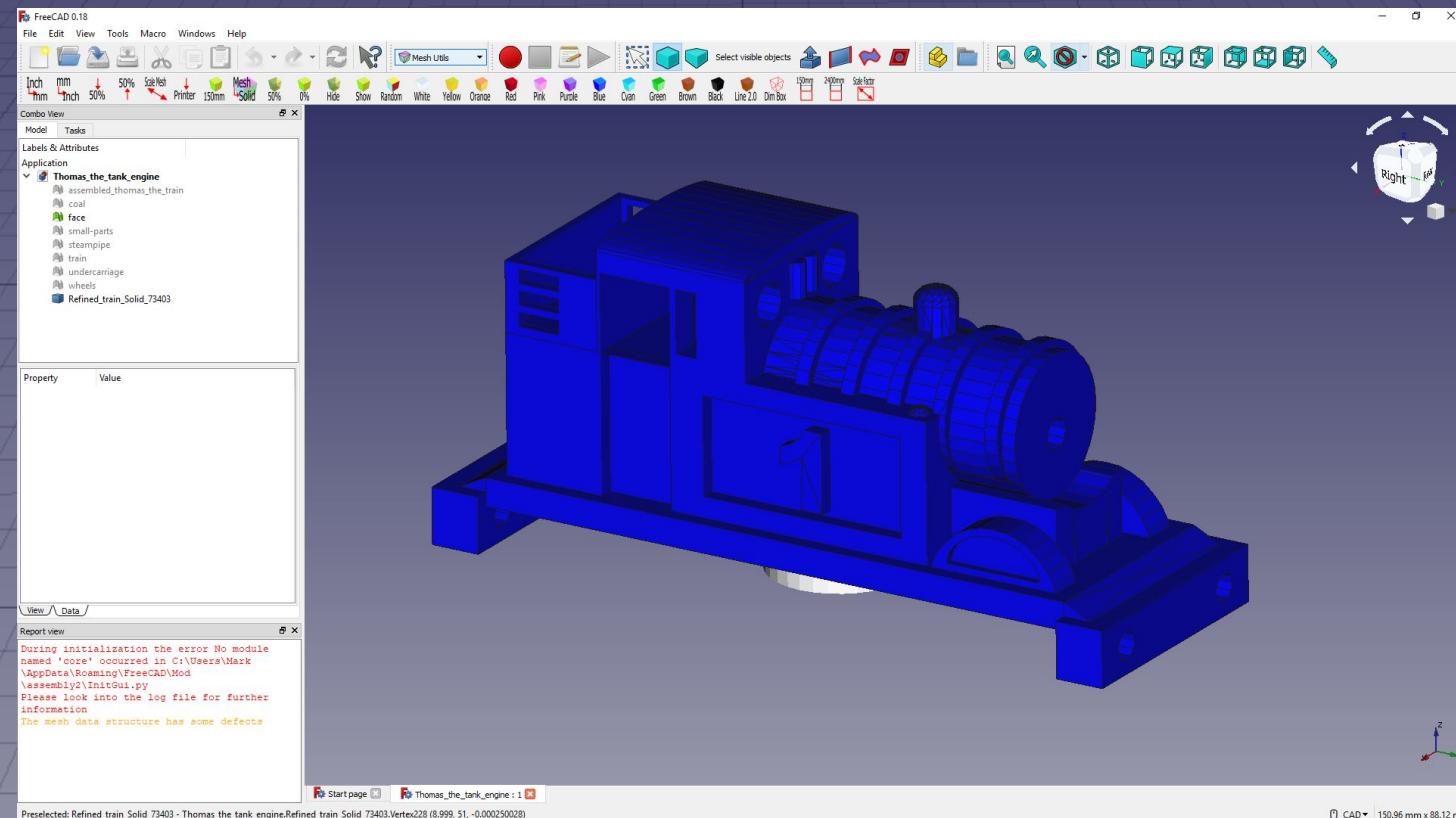
5. Mas tem a cópia educativa...

- ✓ Multa = $3000 * \text{licença} * \text{nº de máquinas}$.
- ✓ Multa para AutoCAD LT: **R\$ 4.926.000**
- ✓ Ou 1-4 anos de reclusão.
- ✓ O RH do seu cliente vai adorar saber!
 - ▷ Lei 9.609/98:
 - ▷ Responsabilidade solidária.
- ✓ O concorrente também!
- ✓ A Receita Federal mais ainda!

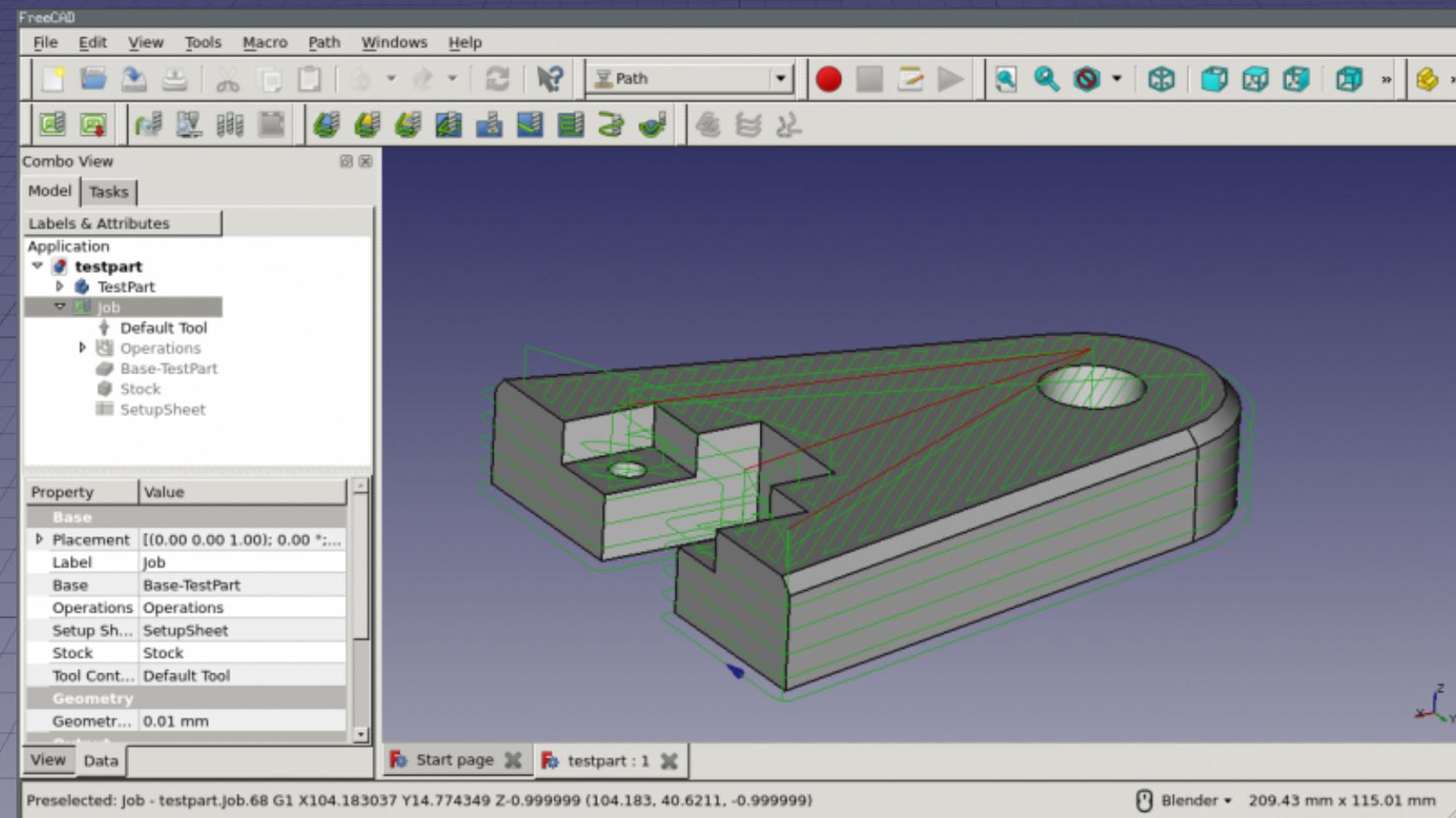


6. E tem as ferramentas que eu preciso?

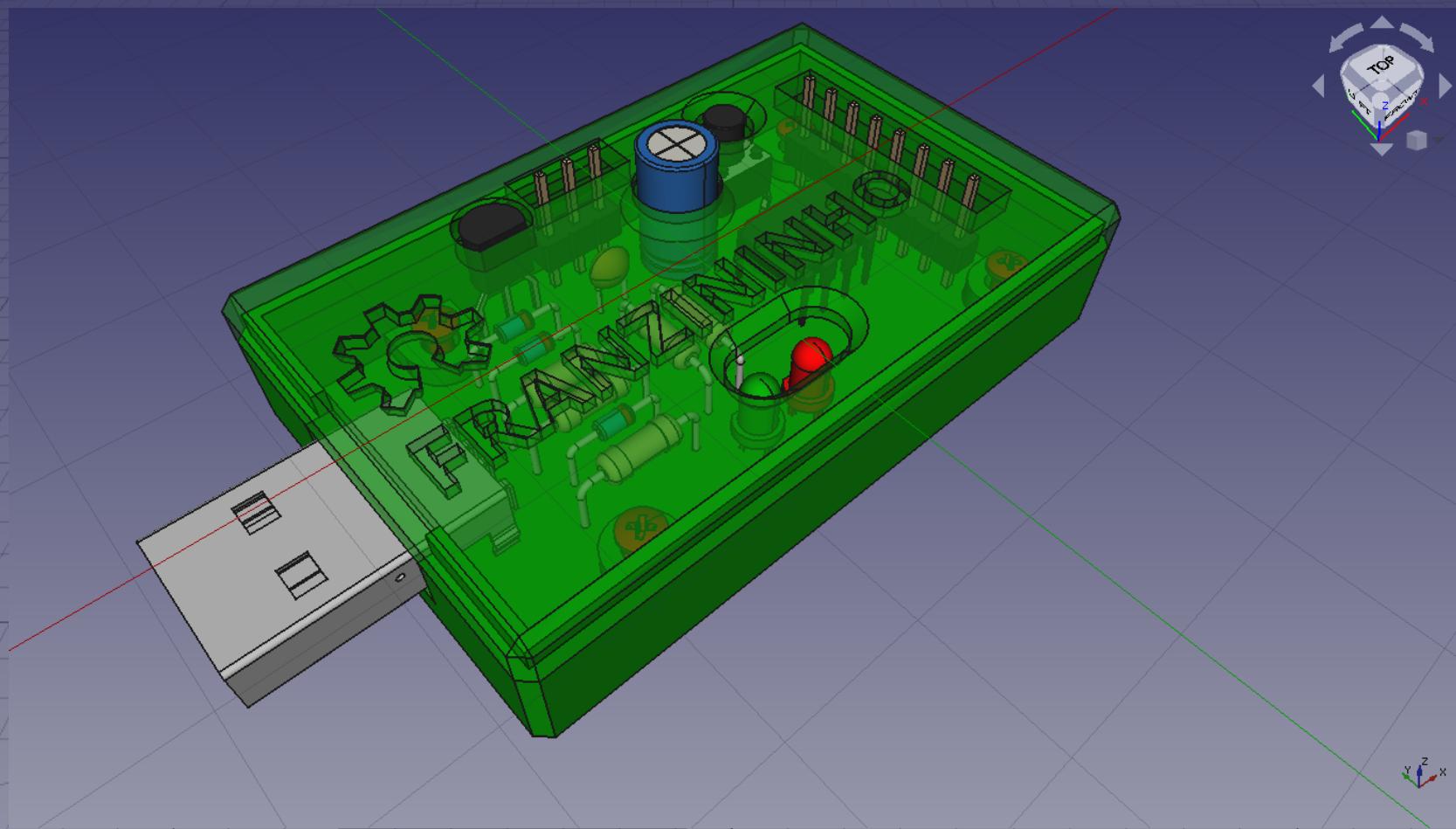
I. Impressão 3D



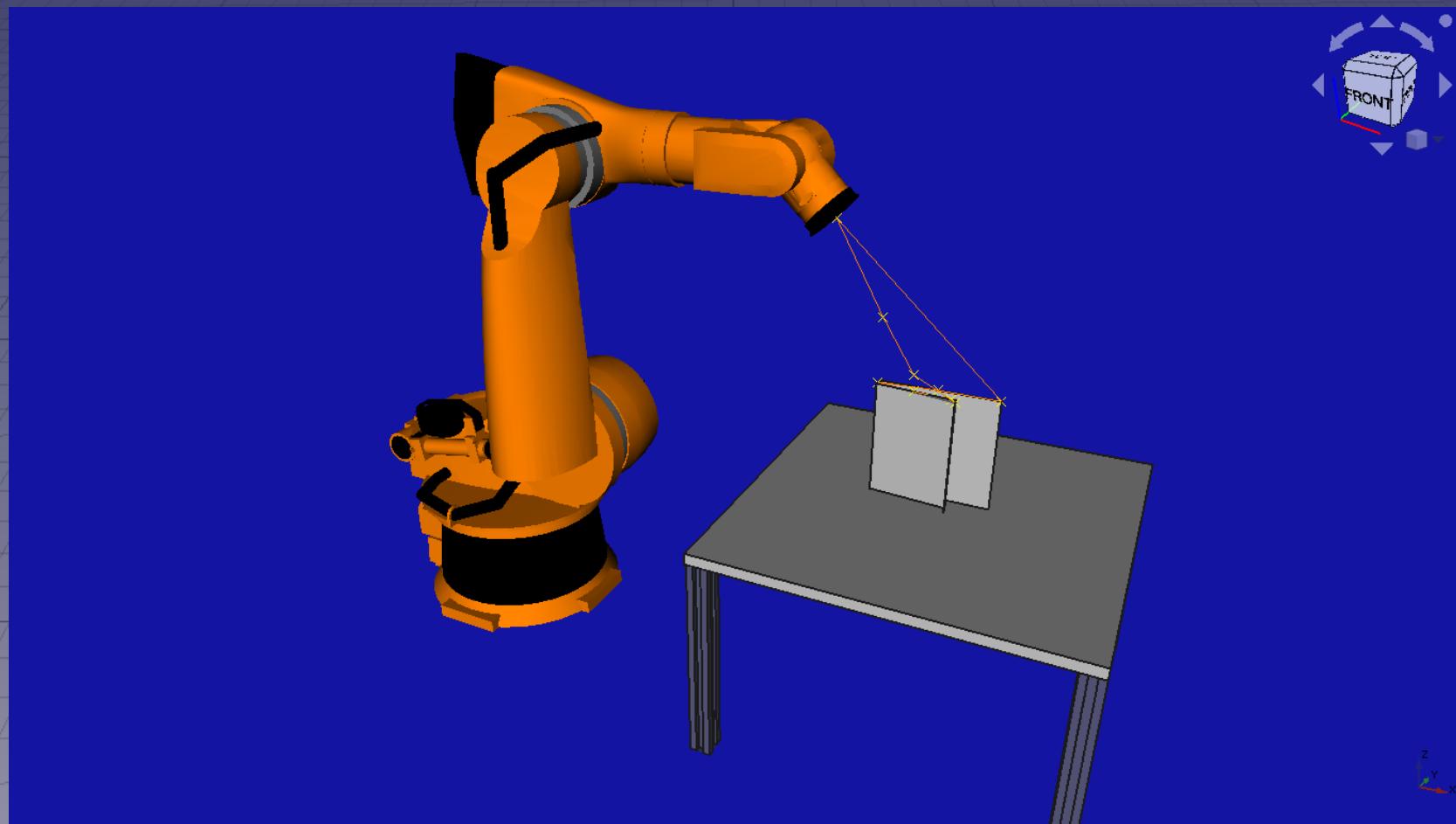
II. GCode para CNC



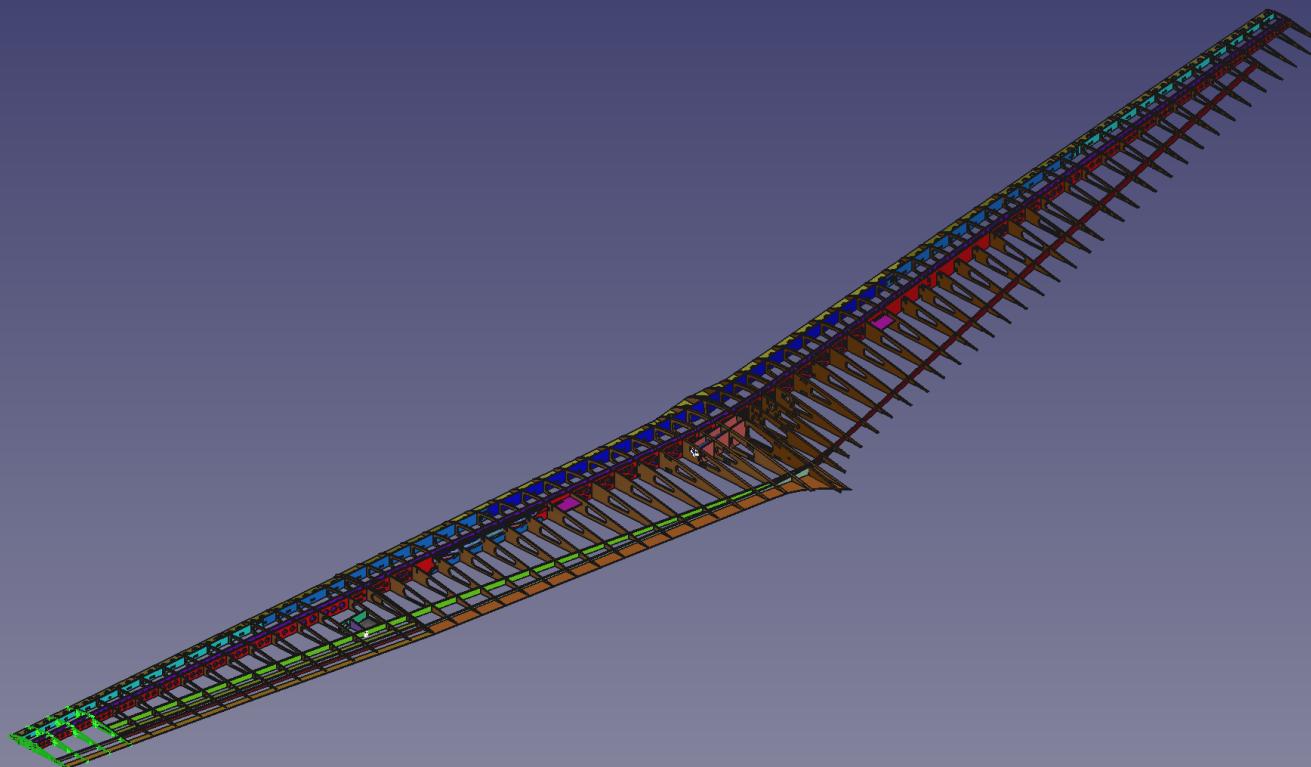
III. Integração com KiCAD para projetos de circuitos eletrônicos.



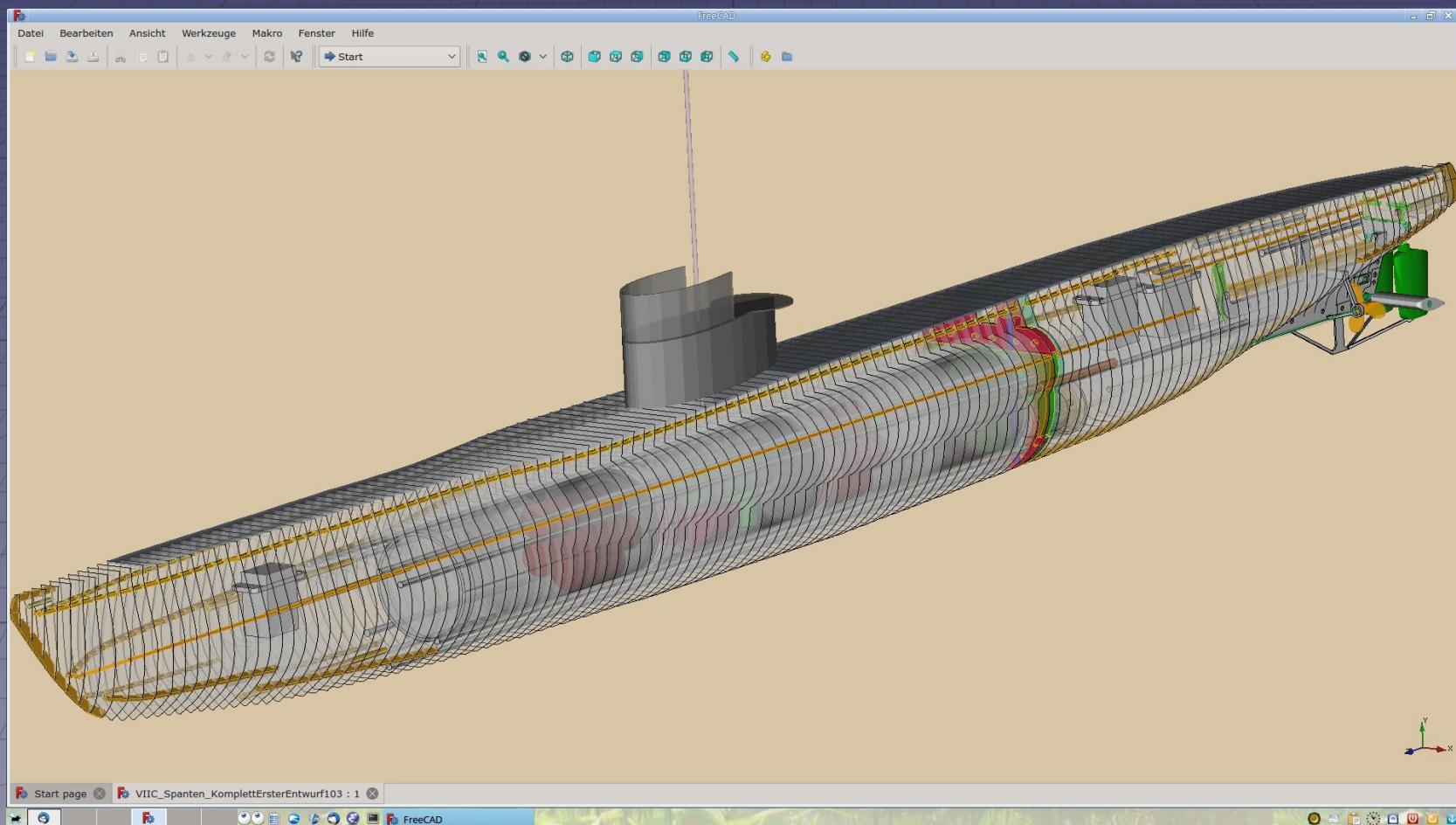
IV. Trajetórias de robôs



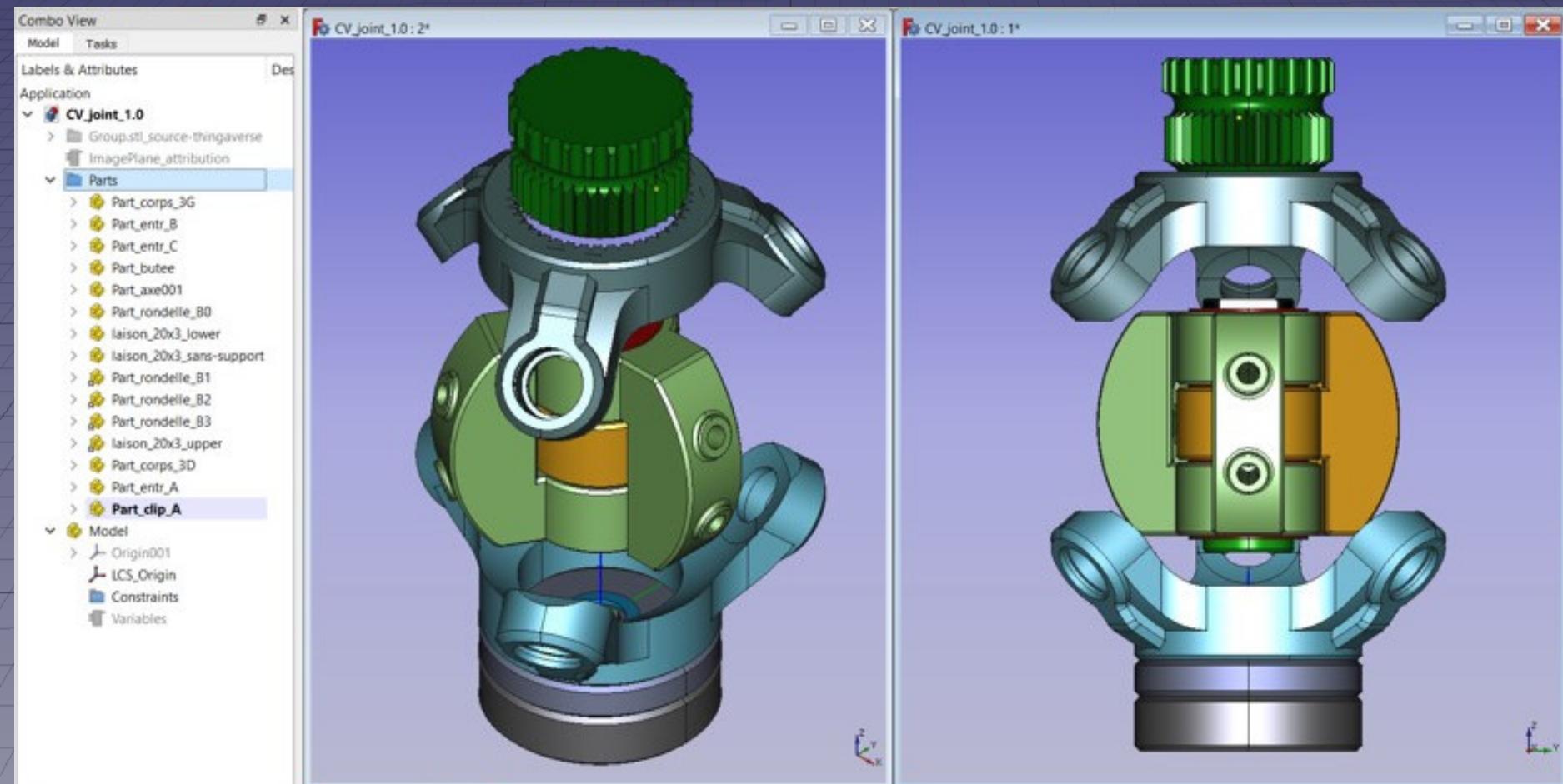
V. Design de aeronaves



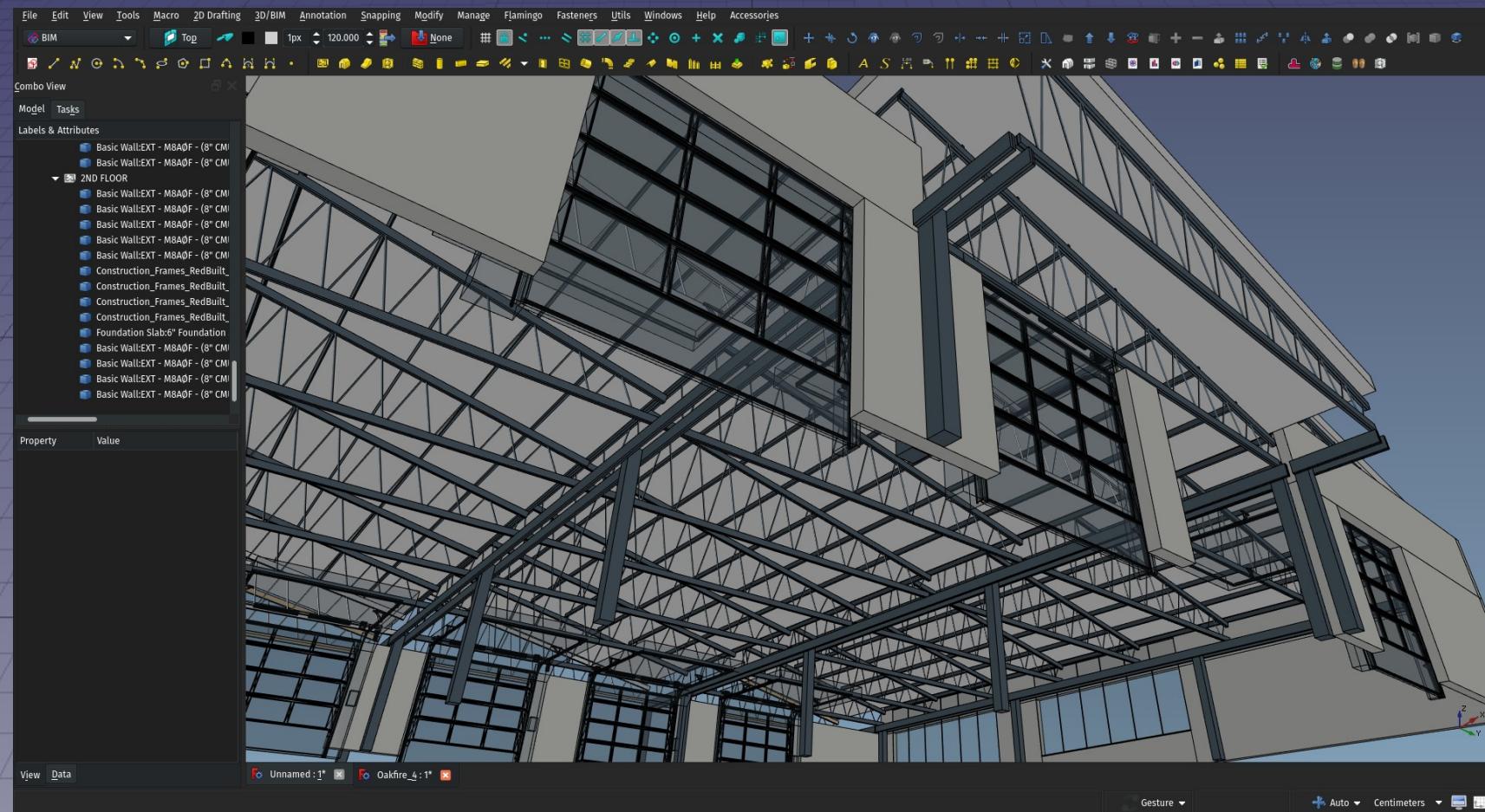
VI. Construção naval



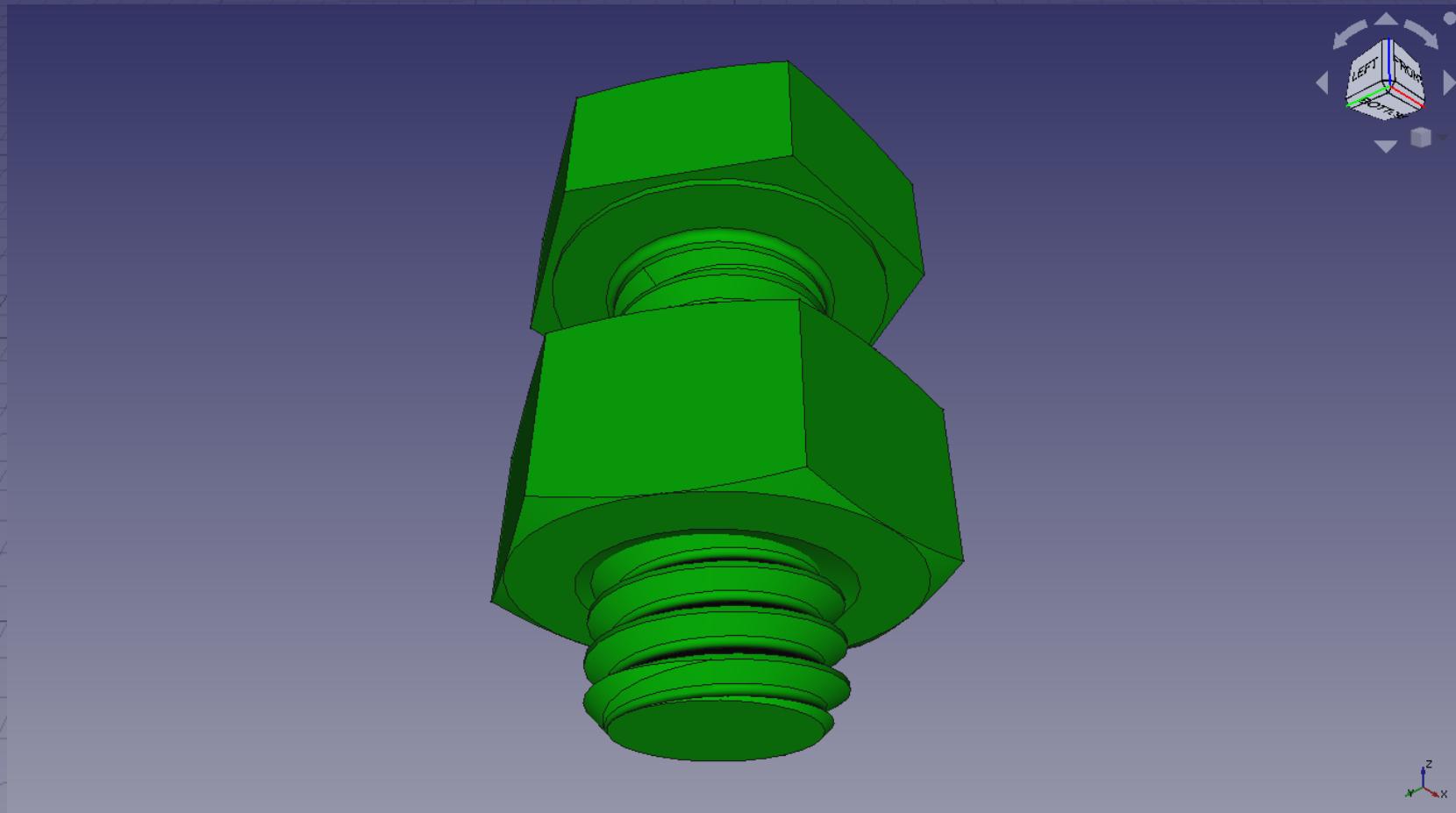
VII. Assembly: montagem e movimentação de peças.



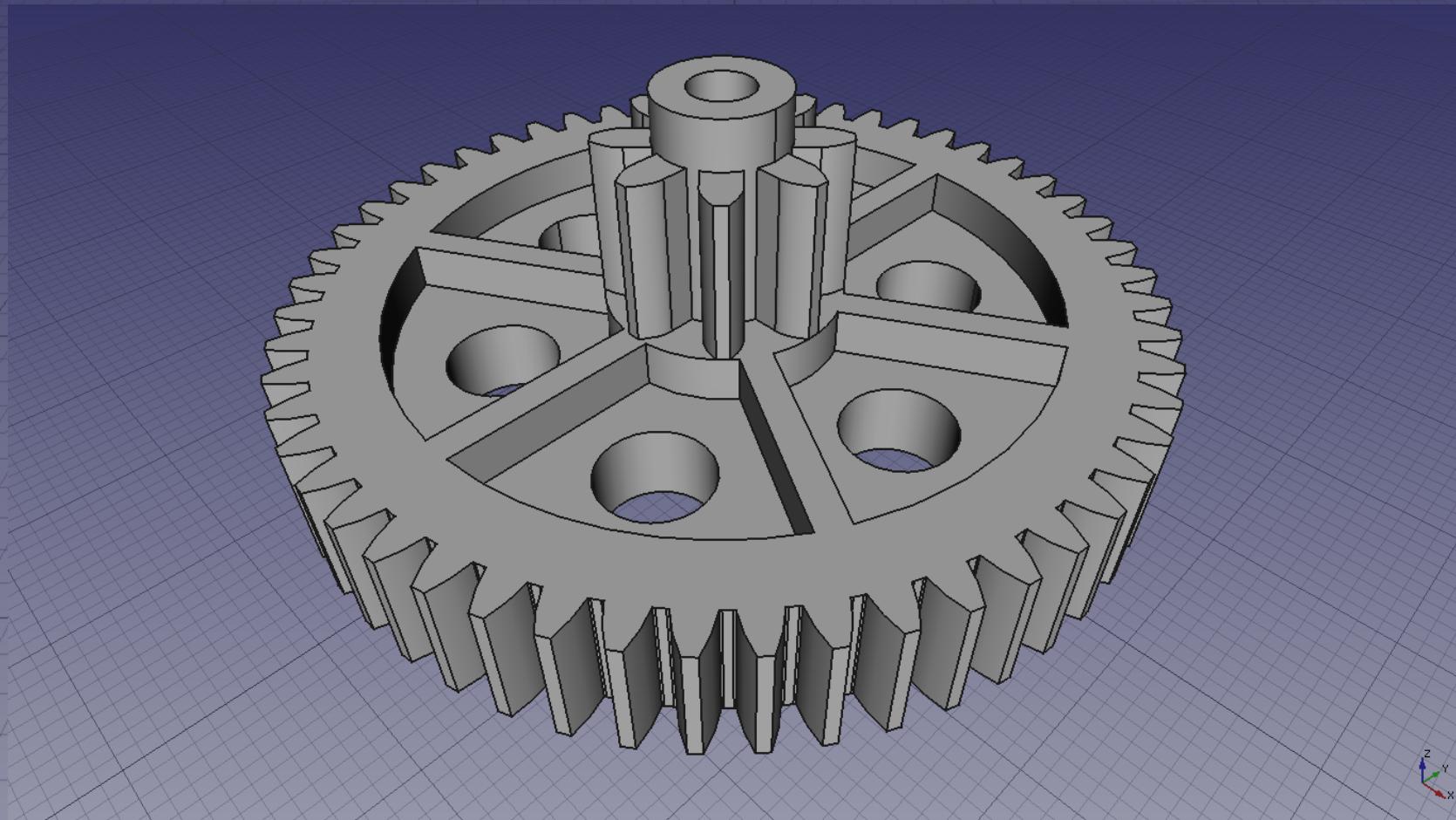
VIII. Metodologia BIM (Building Information Modeling)



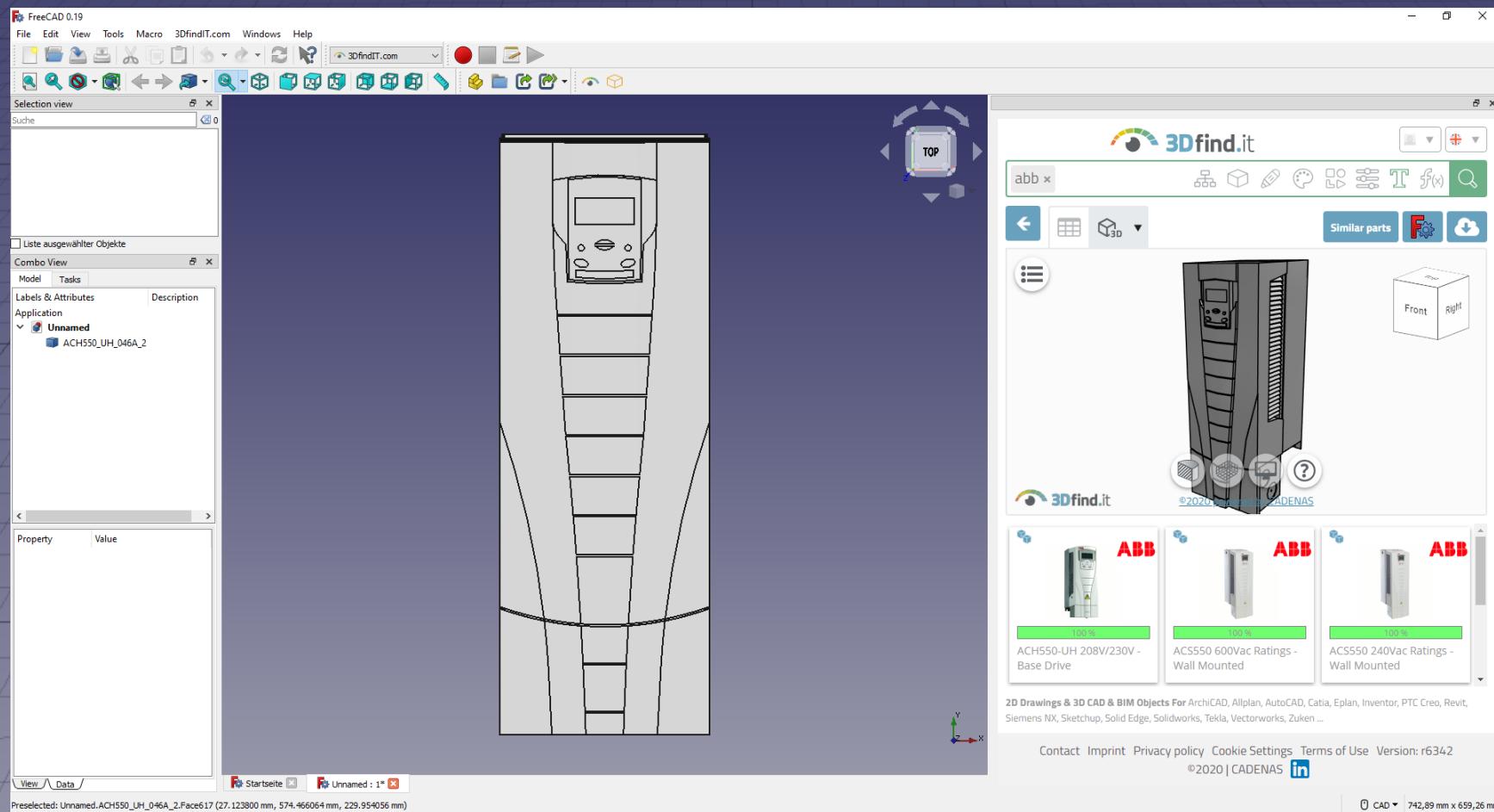
IX. Banco de dados de componentes



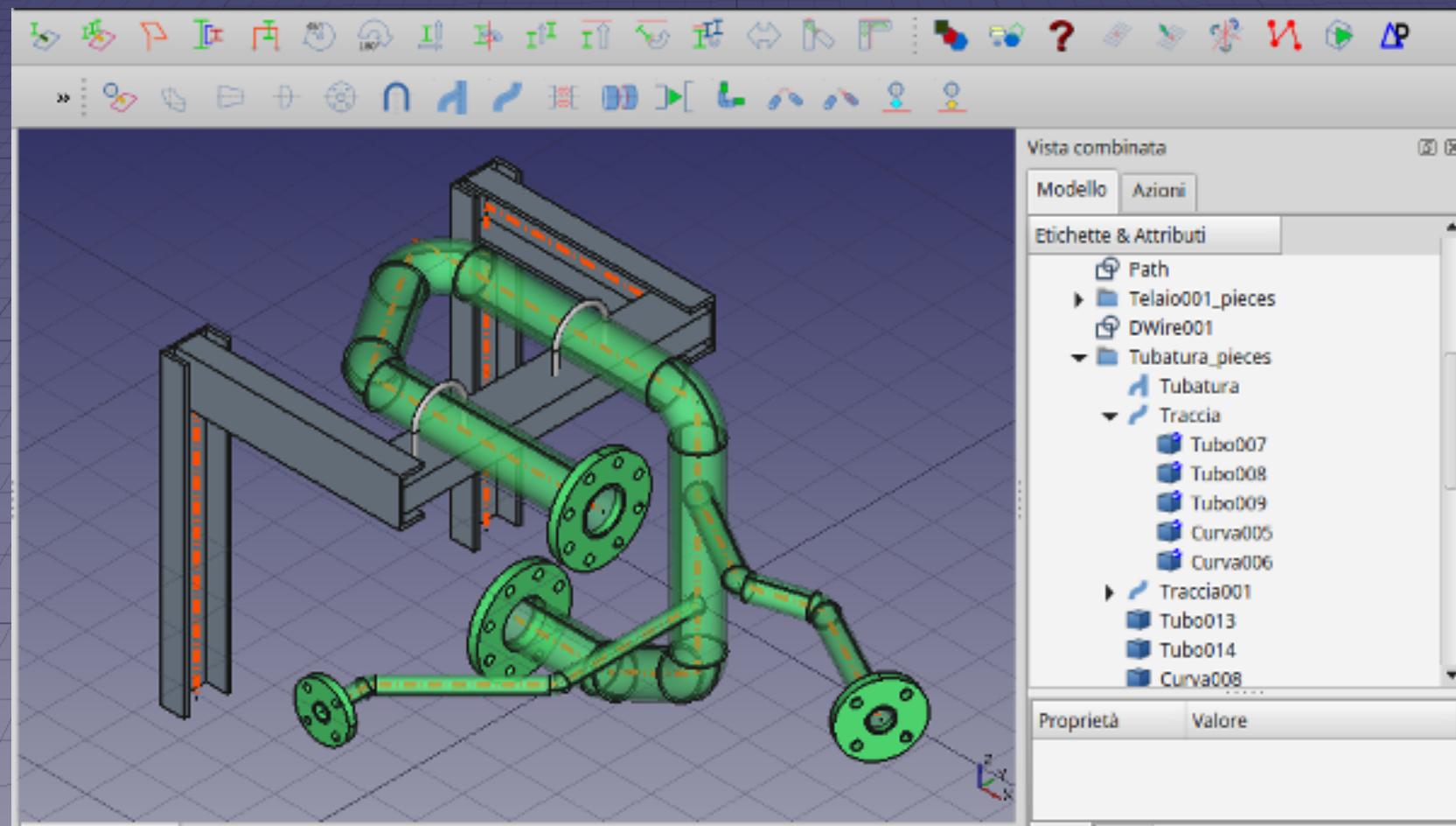
X. Desenho de engrenagens



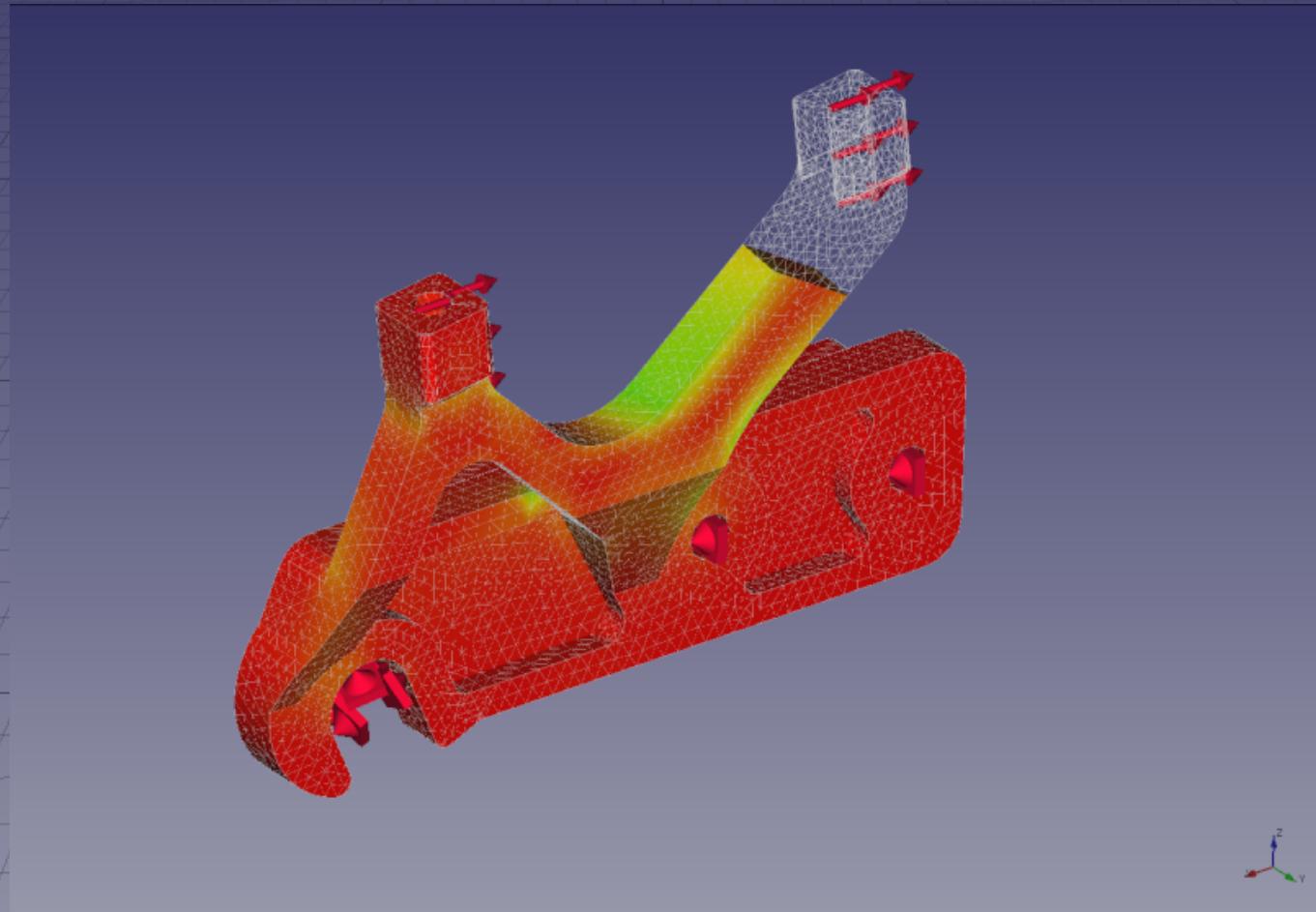
XI. Baixar modelos 3D diretamente da web



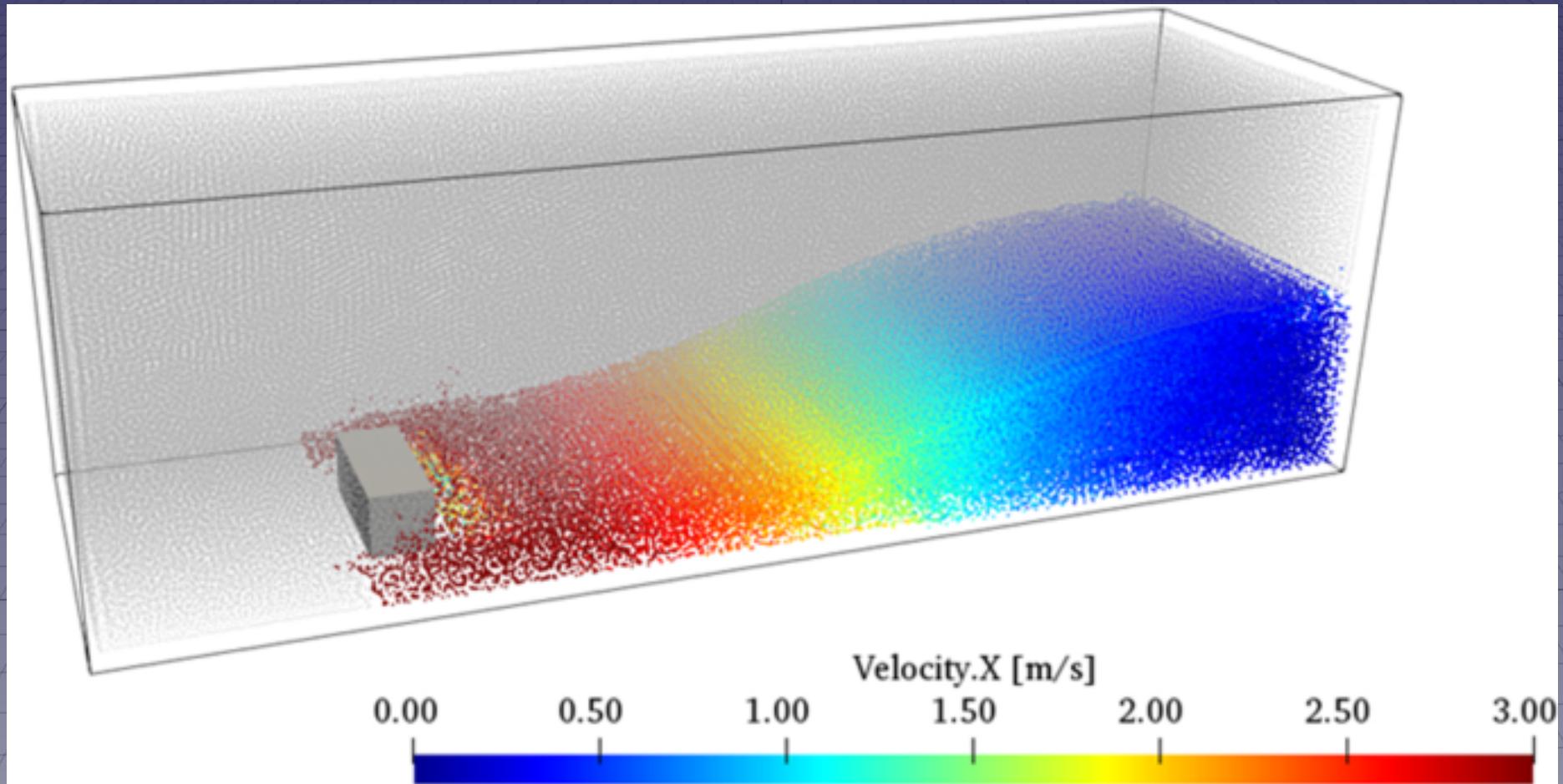
XII. Tubulações



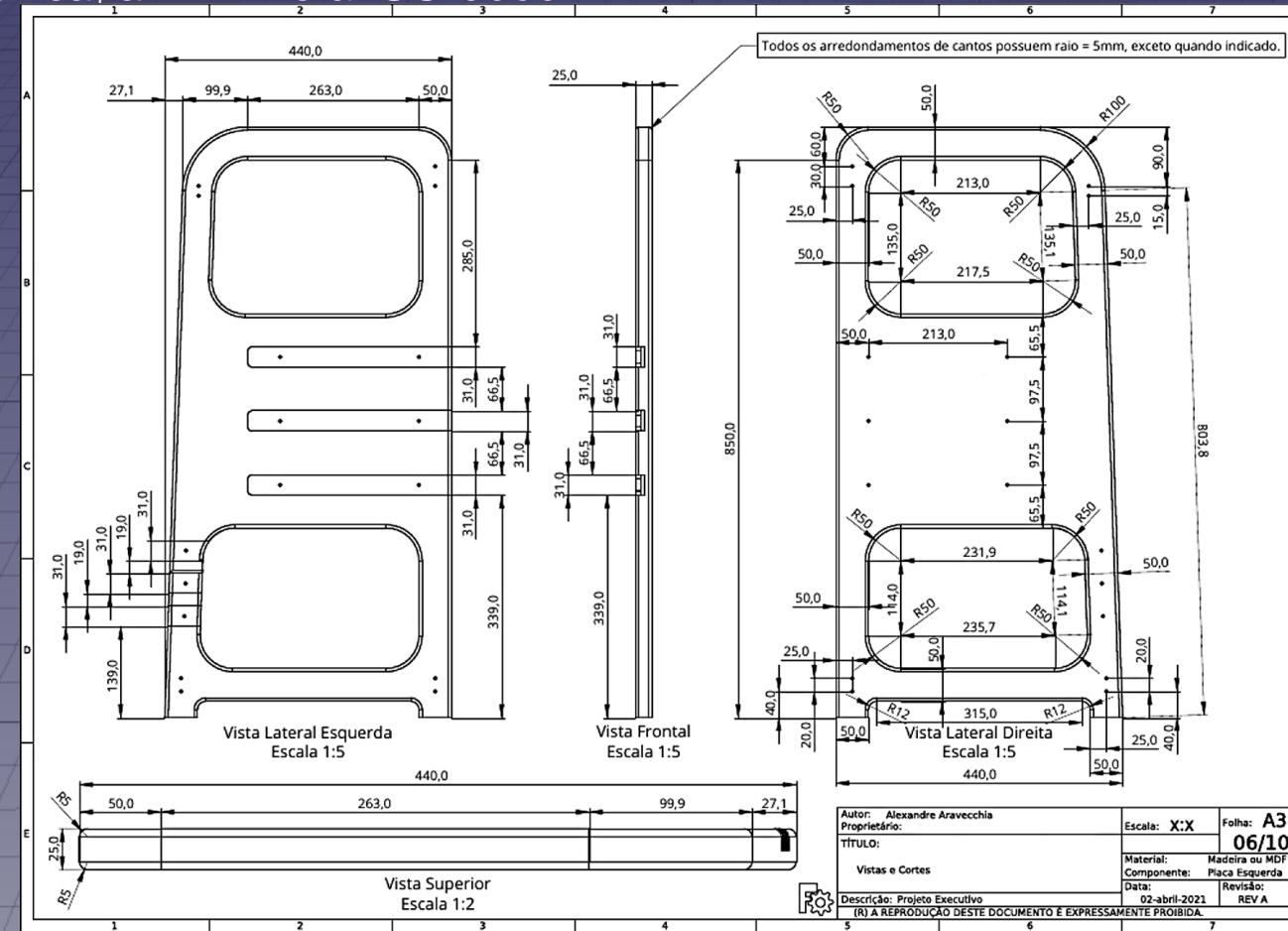
XIII. FEM: elementos finitos



XIV. Dinâmica de fluidos



7. Mas a Norma Técnica, a ABNT e a ISO-9000...



8. E o suporte?

- ✓ Comunidade!
- ✓ Atualizações diárias
- ✓ Acesso à documentação
- ✓ Alguém já teve este problema antes
 - ▷ E compartilhou a solução!
- ✓ Aprendizado constante e gratuito
- ✓ Contatos profissionais
- ✓ Parcerias
- ✓ Amigos!

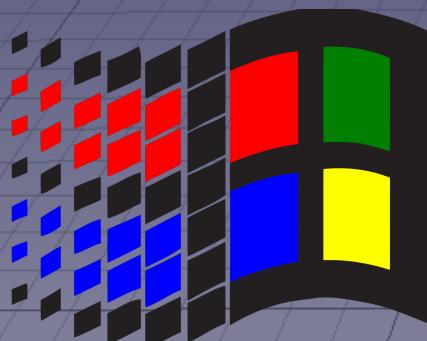






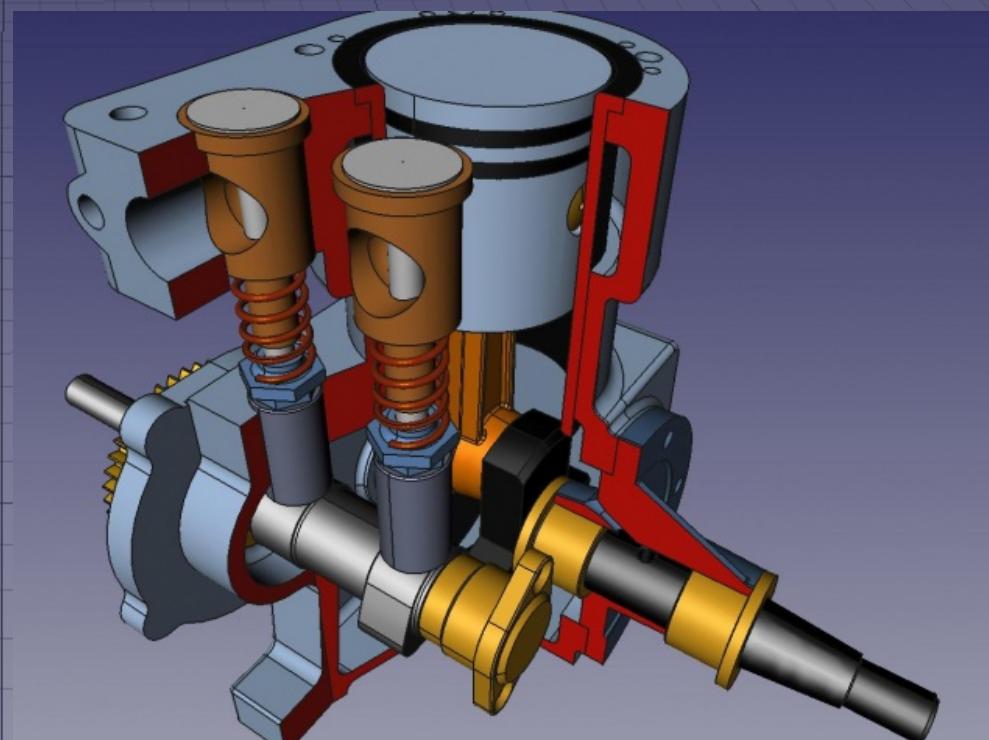
9. Mas roda em MAC?

- Multiplataforma



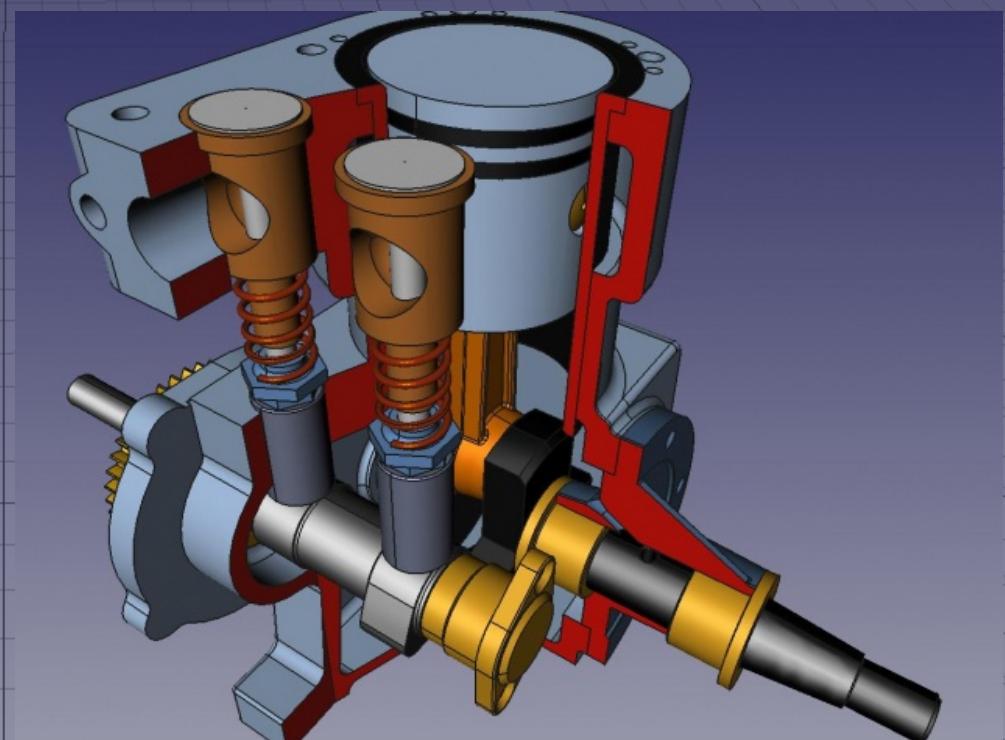
10. É seguro?

- ✓ Sim, baixando do site www.freecadweb.org.
- ✓ De preferência, use Linux.



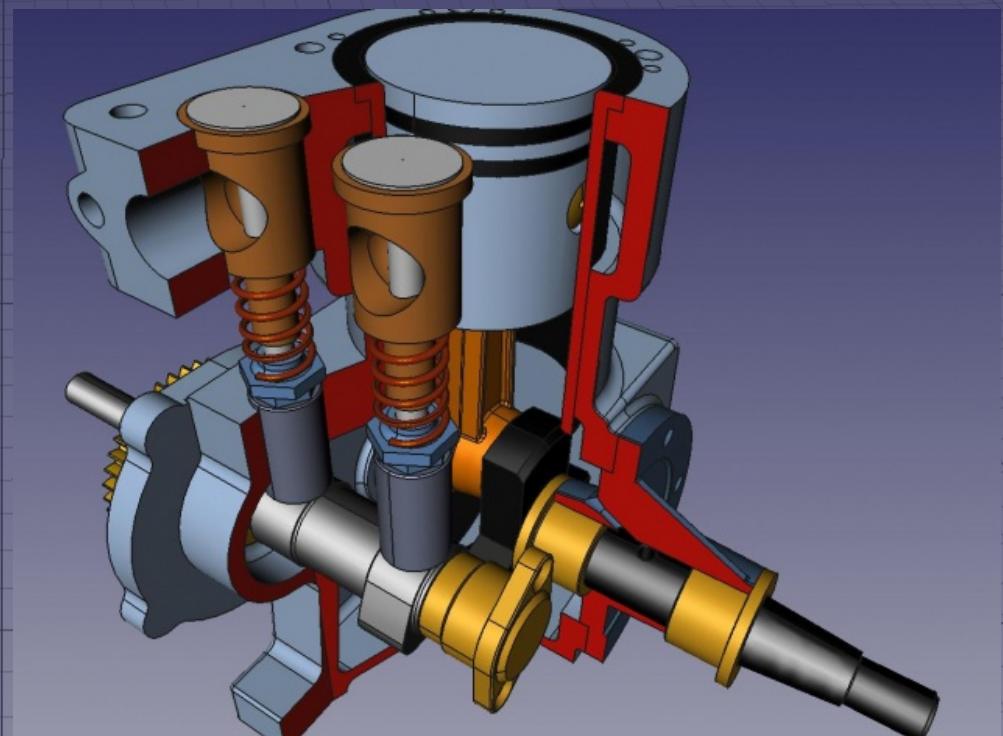
11. Não é pesado pro nosso computador?

- ✓ Leve
- ✓ Estável
- ✓ Dica: use Linux!



12. Parametrização:

- ✓ Precisão
- ✓ Rapidez
- ✓ Qualidade
- ✓ Produtividade.



3 Instalação do FreeCAD

www.freecadweb.org

3.1 Instalação Windows

Windows ⇒ Download ⇒ EXE ⇒ Click ⇒ Ok ⇒ Ok ⇒ Sim ⇒ Avançar ⇒ Ok ⇒ Ok...

3.2 Instalação Linux

- Versão estável:

- ✓ sudo add-apt-repository ppa:freecad-maintaine2rs/freecad-stable
- ✓ sudo apt-get update
- ✓ sudo apt-get install freecad -y

• Versão Daily:

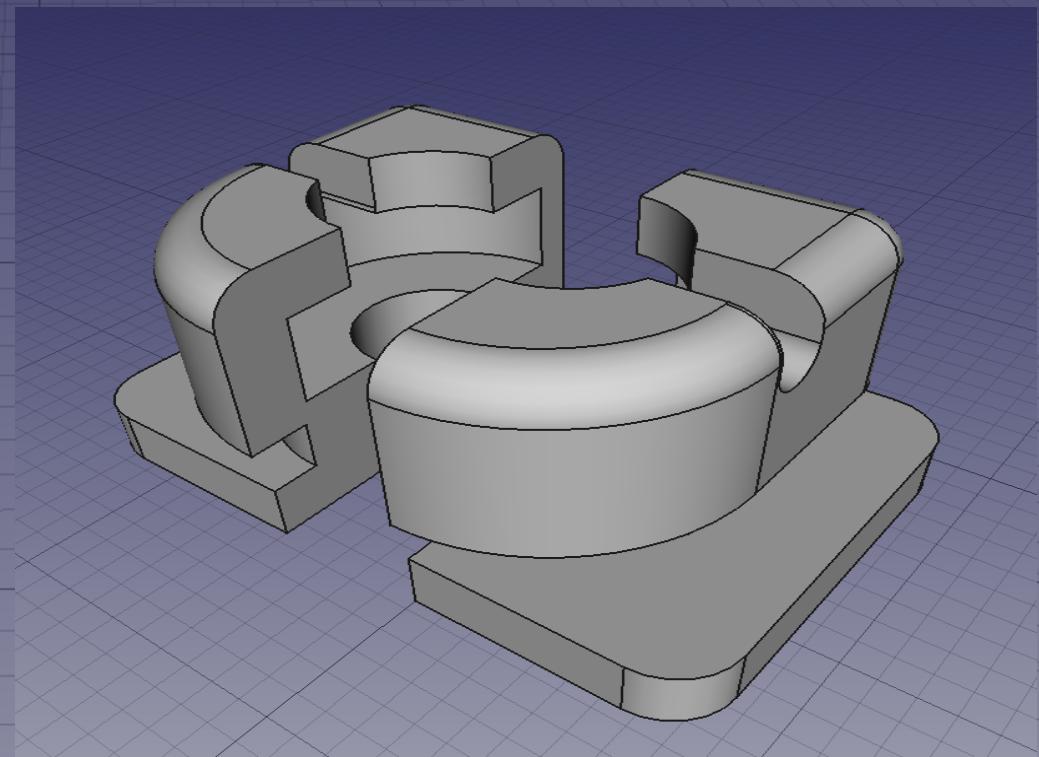
- ✓ sudo add-apt-repository ppa:freecad-maintainers/freecad-daily
- ✓ apt-get update
- ✓ apt-get install freecad-daily

• Versão Appliance:

- ✓ Baixar arquivo Appliance em www.freecadweb.org
- ✓ cd Downloads
- ✓ sudo chmod +x FreeCAD*.Appliance
- ✓ ./FreeCAD[TAB].Appliance (ou duplo clique no arquivo Appliance)

4 Modelagem 3D

- Computer Aided Design
- Projeto:
 - ✓ Criar
 - ✓ Modificar
 - ✓ Analisar
 - ✓ Otimizar
- Melhorar:
 - ✓ Qualidade
 - ✓ Comunicação
 - ✓ Documentação
- Banco de dados dos fabricantes



O problema era desenhar!

- Desenho técnico
- Precisão
- Altamente normatizado
- Totalmente artesanal
- Qualidade gráfica impecável
- Quantidade infinita de revisões
- Vidas em jogo

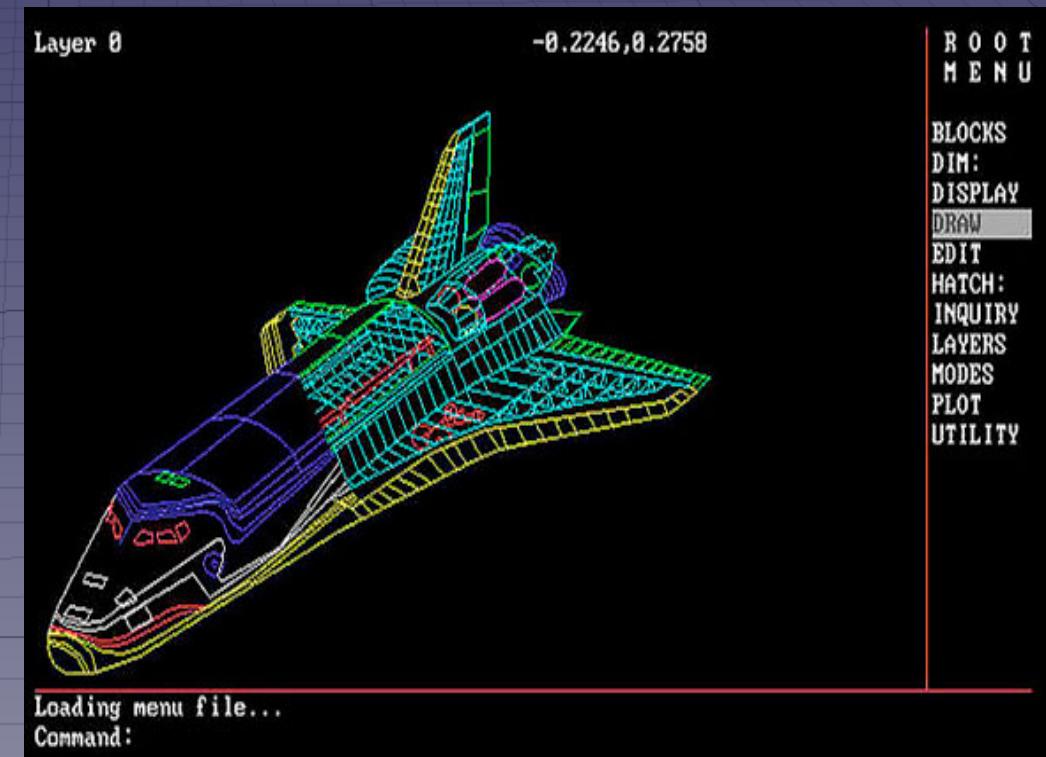
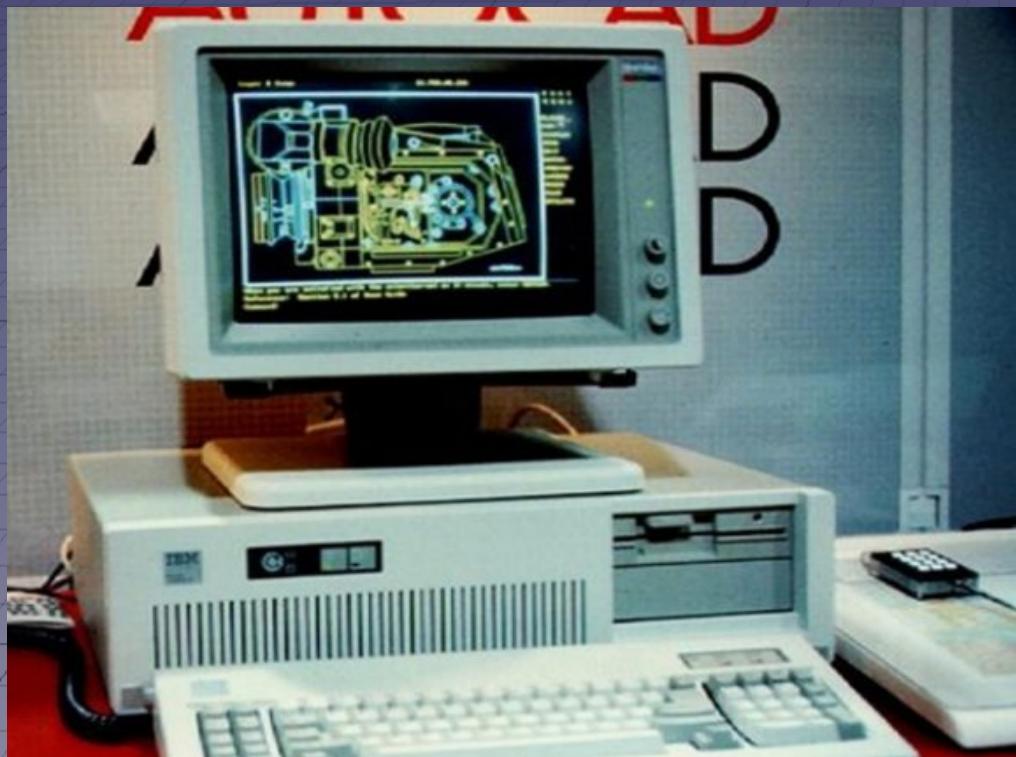


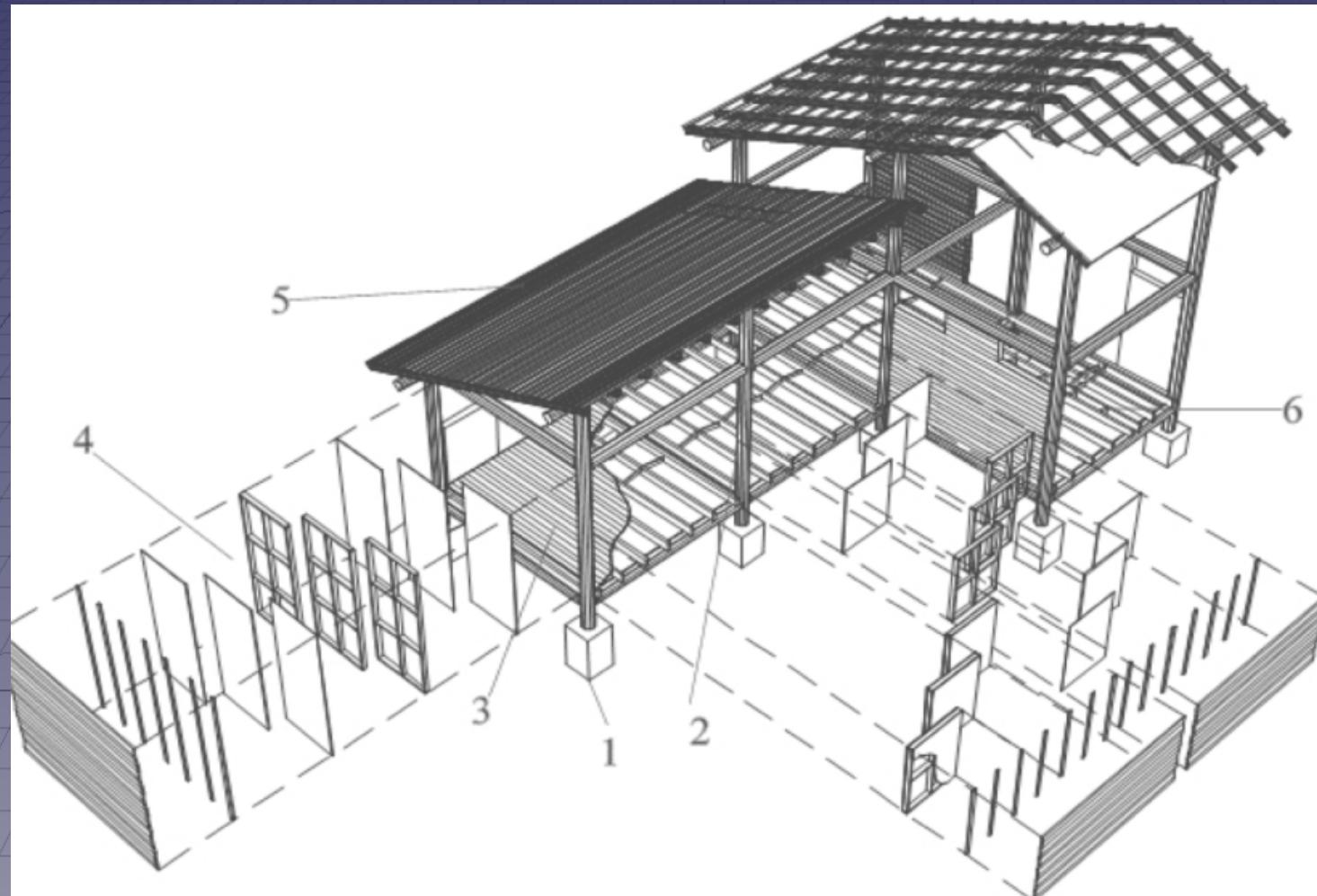
4.1 DAC-1

- Design Automated by Computer
- Mainframe IBM 7090
- 1959
- General Motors: 1964-69

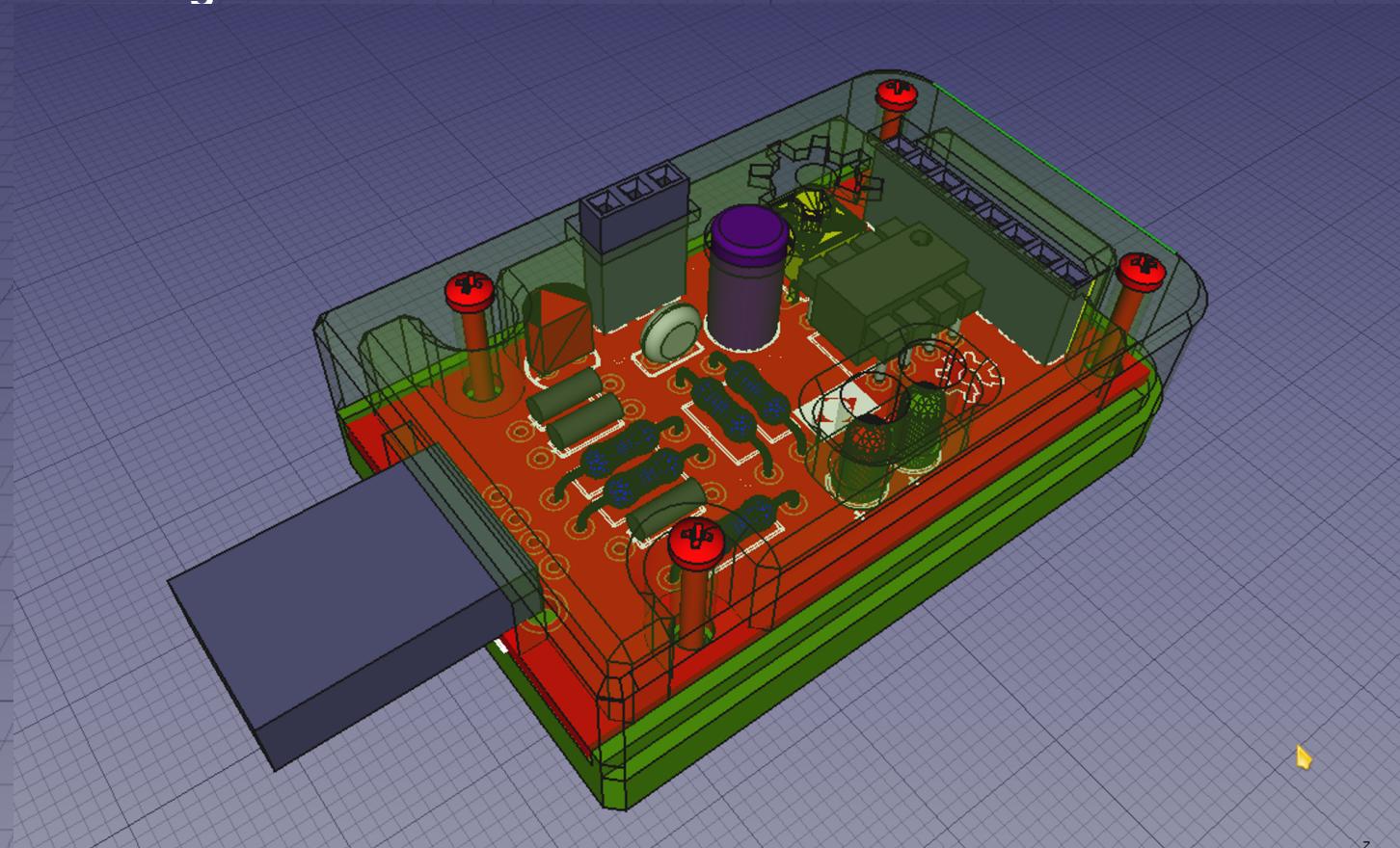


4.2 AutoCAD



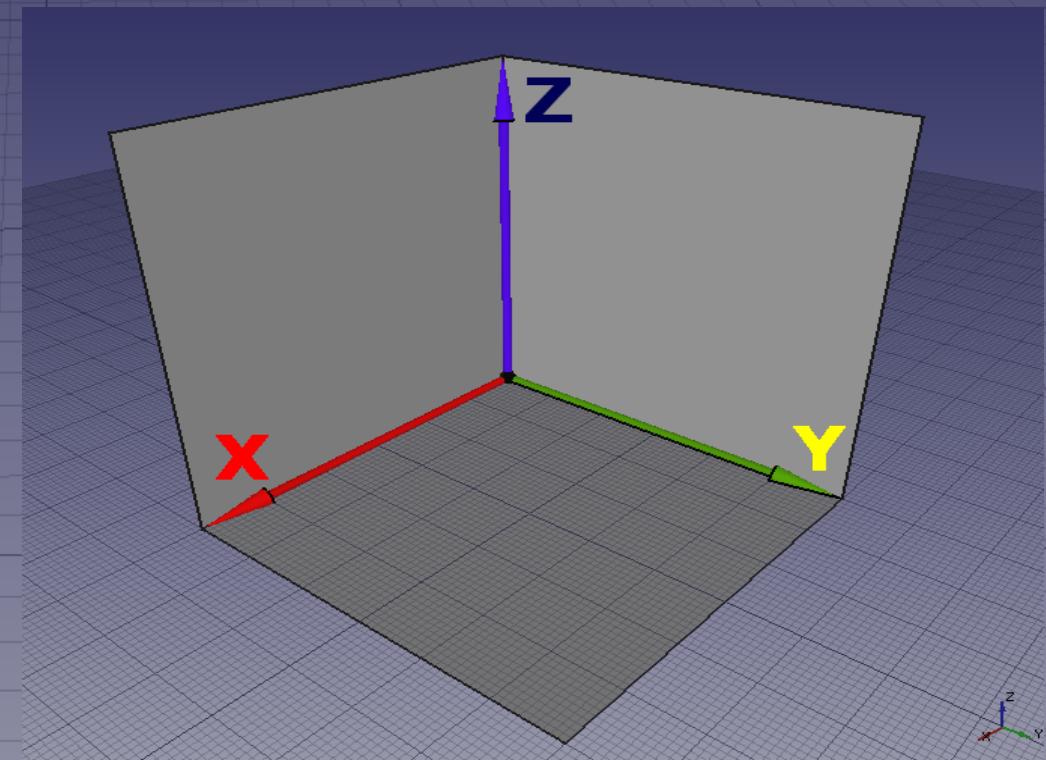
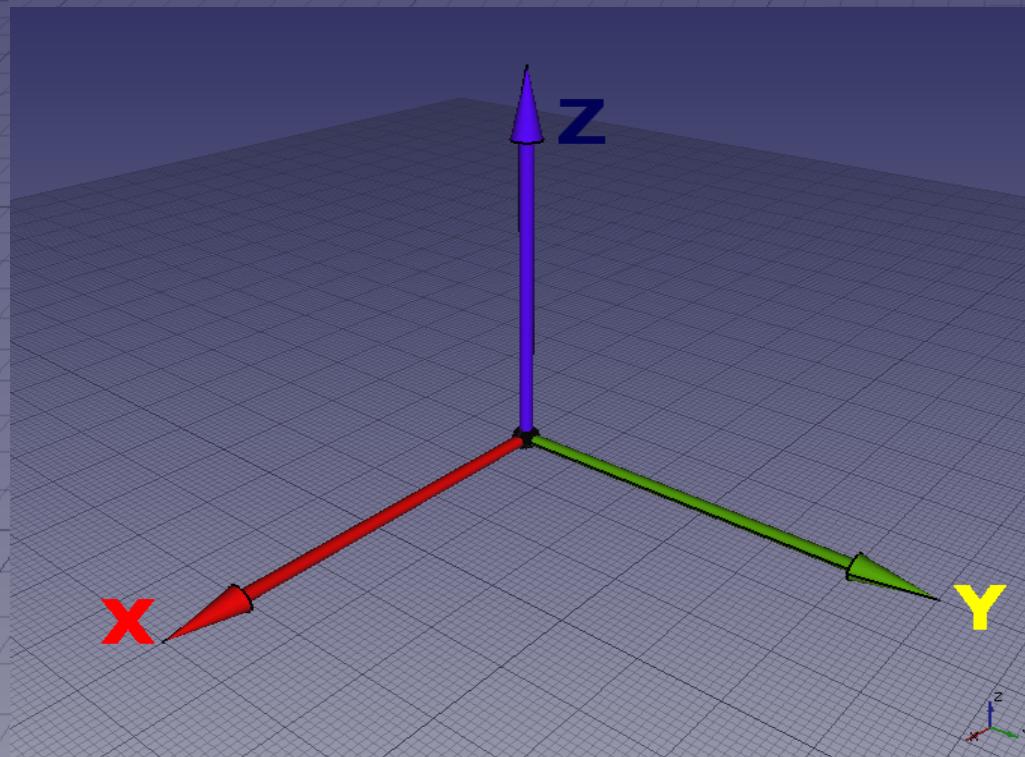


5 Princípios de Modelagem 3D



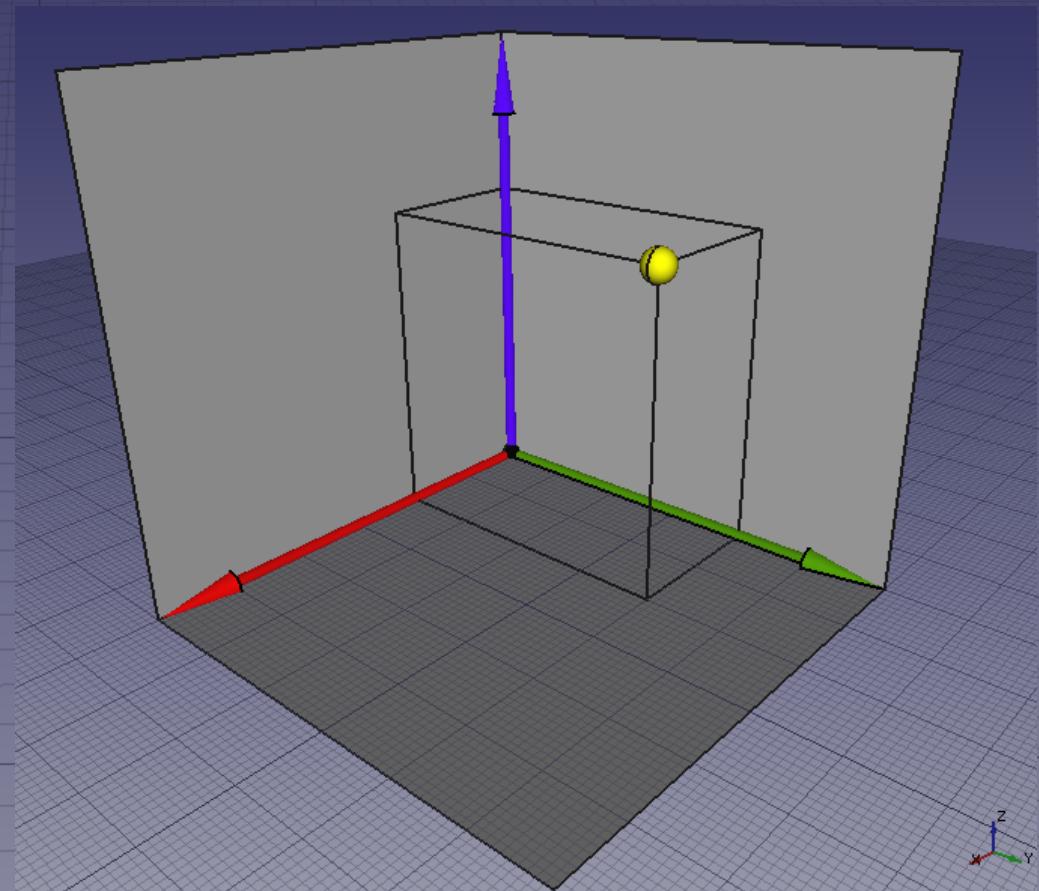
Espaço Cartesiano: eixos ortogonais de coordenadas cartesianas.

Triedro: Planos de coordenadas cartesianas.



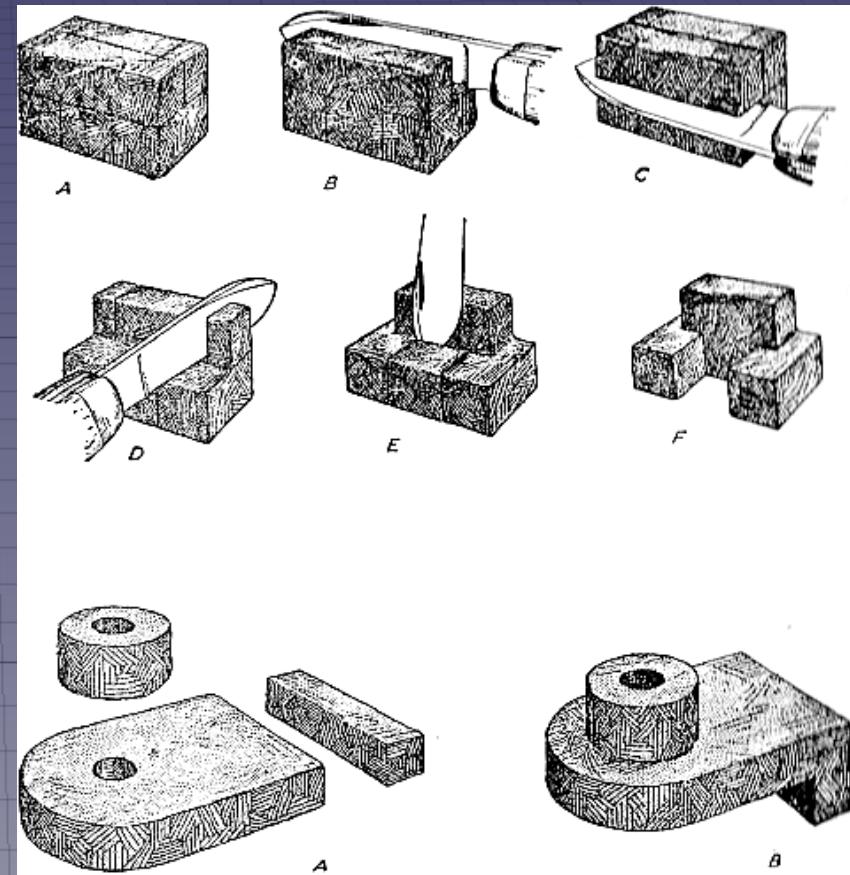
Todo e qualquer ponto no espaço tem uma coordenada:

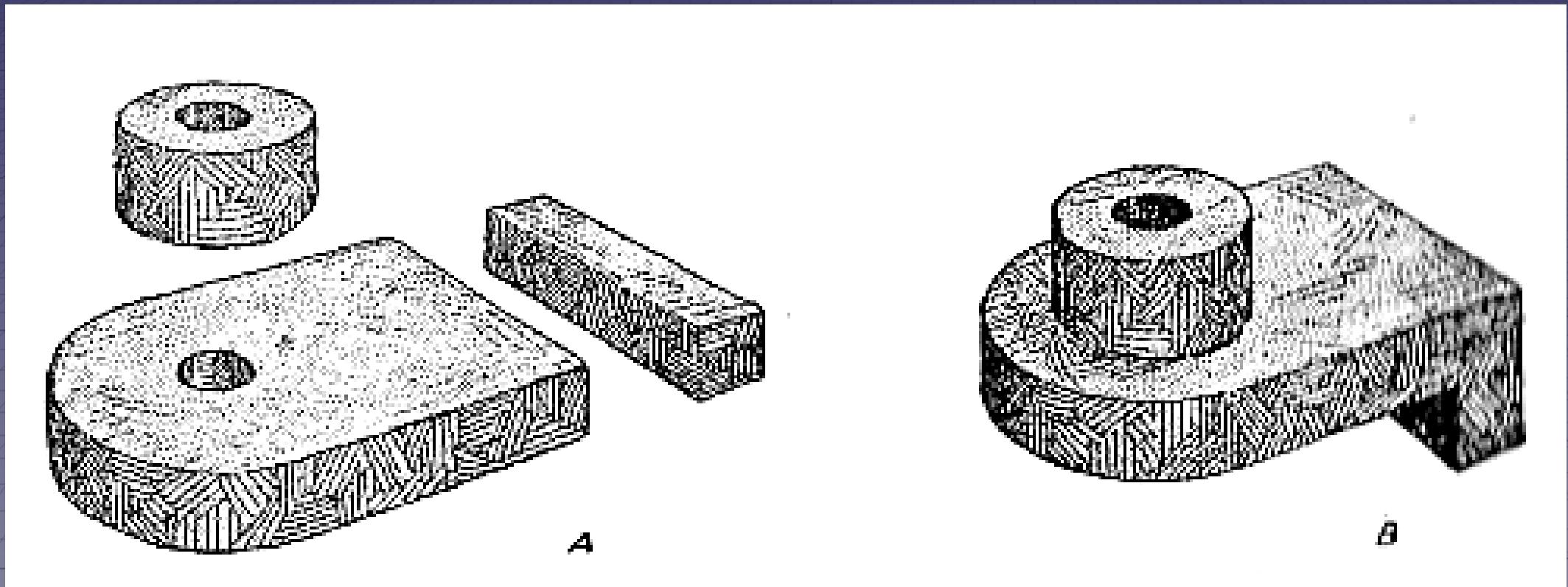
X, Y, Z

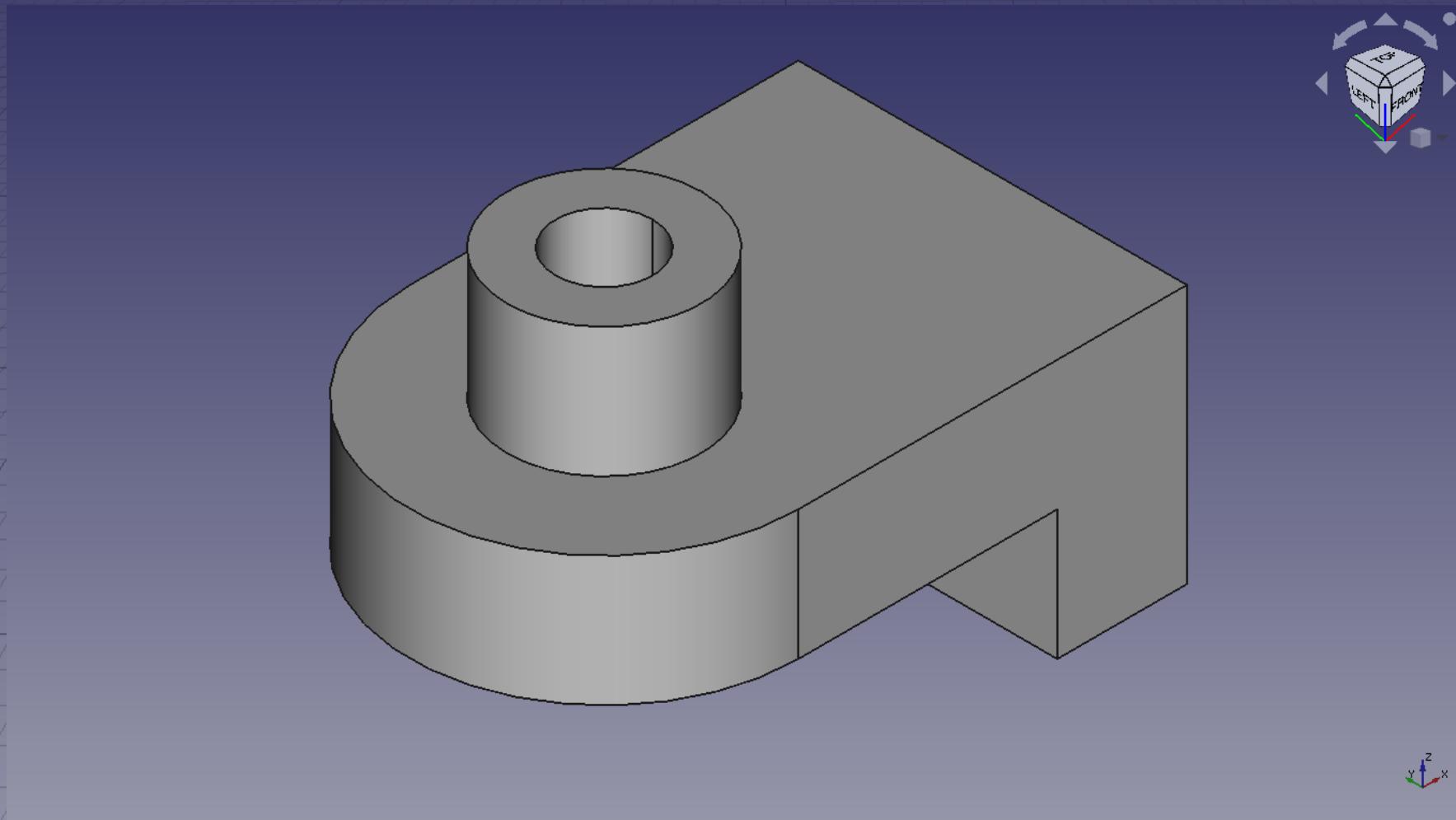


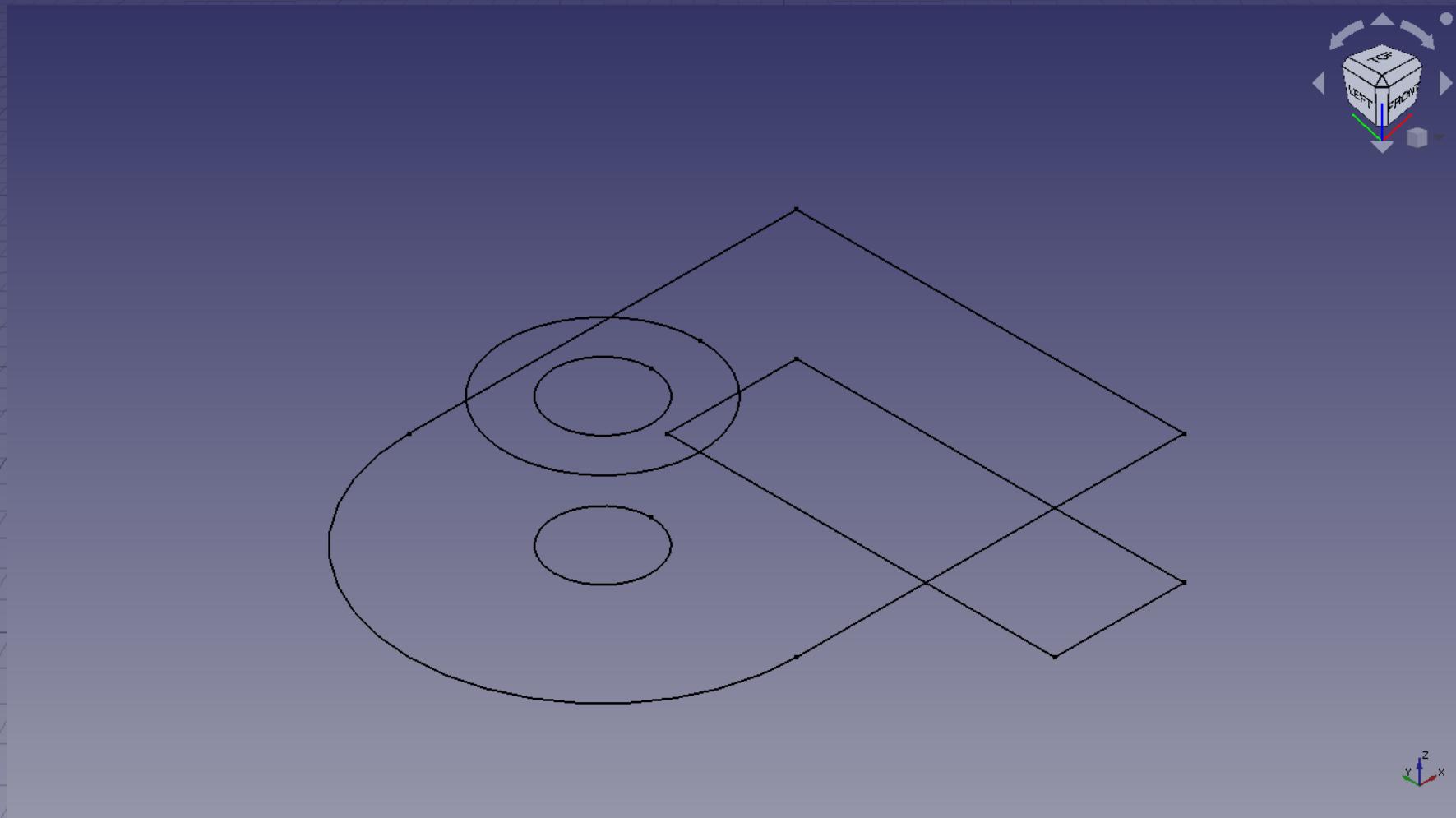
5.1 Planejamento

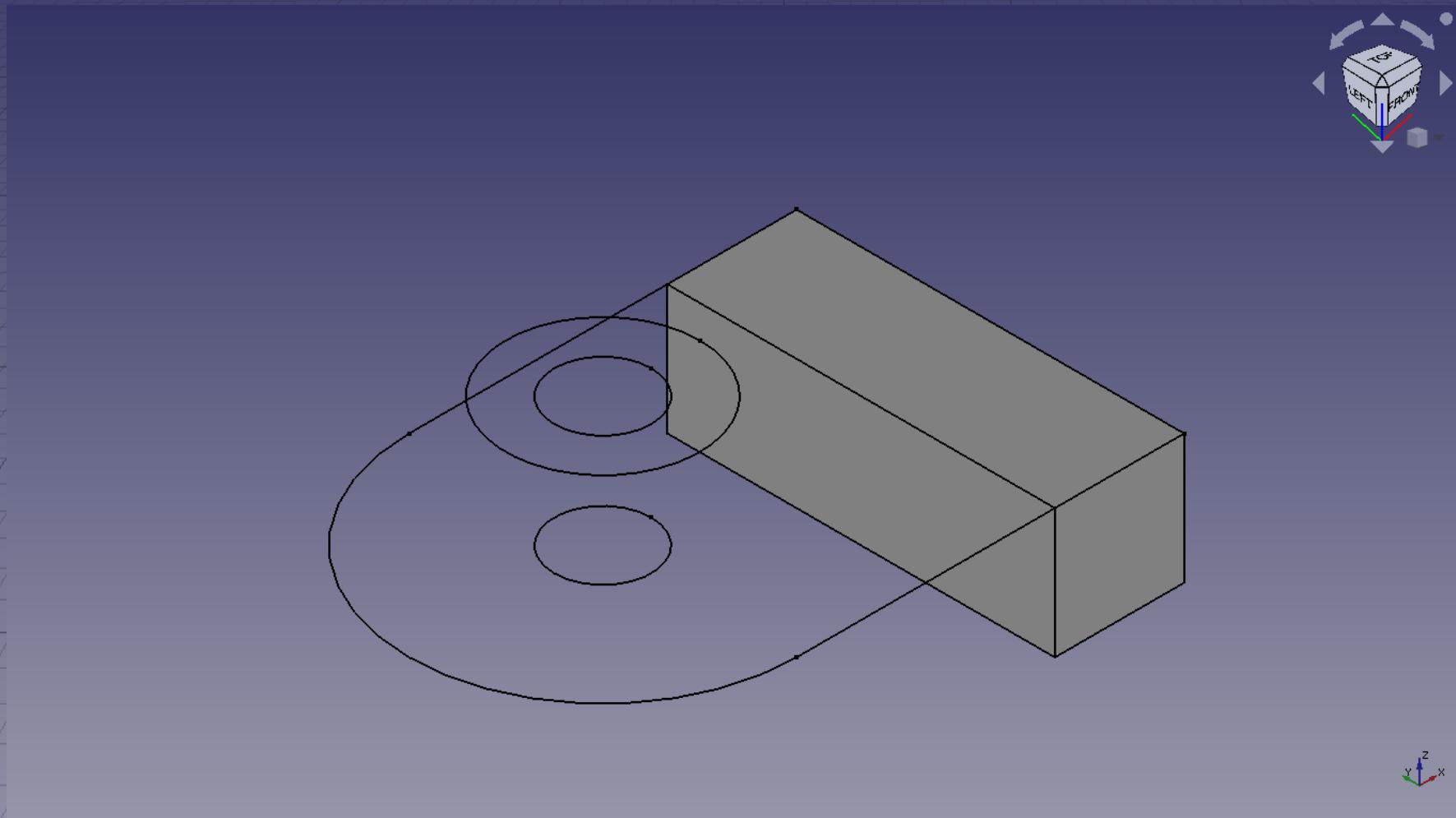
A lógica é a mesma da modelagem em marcenaria!

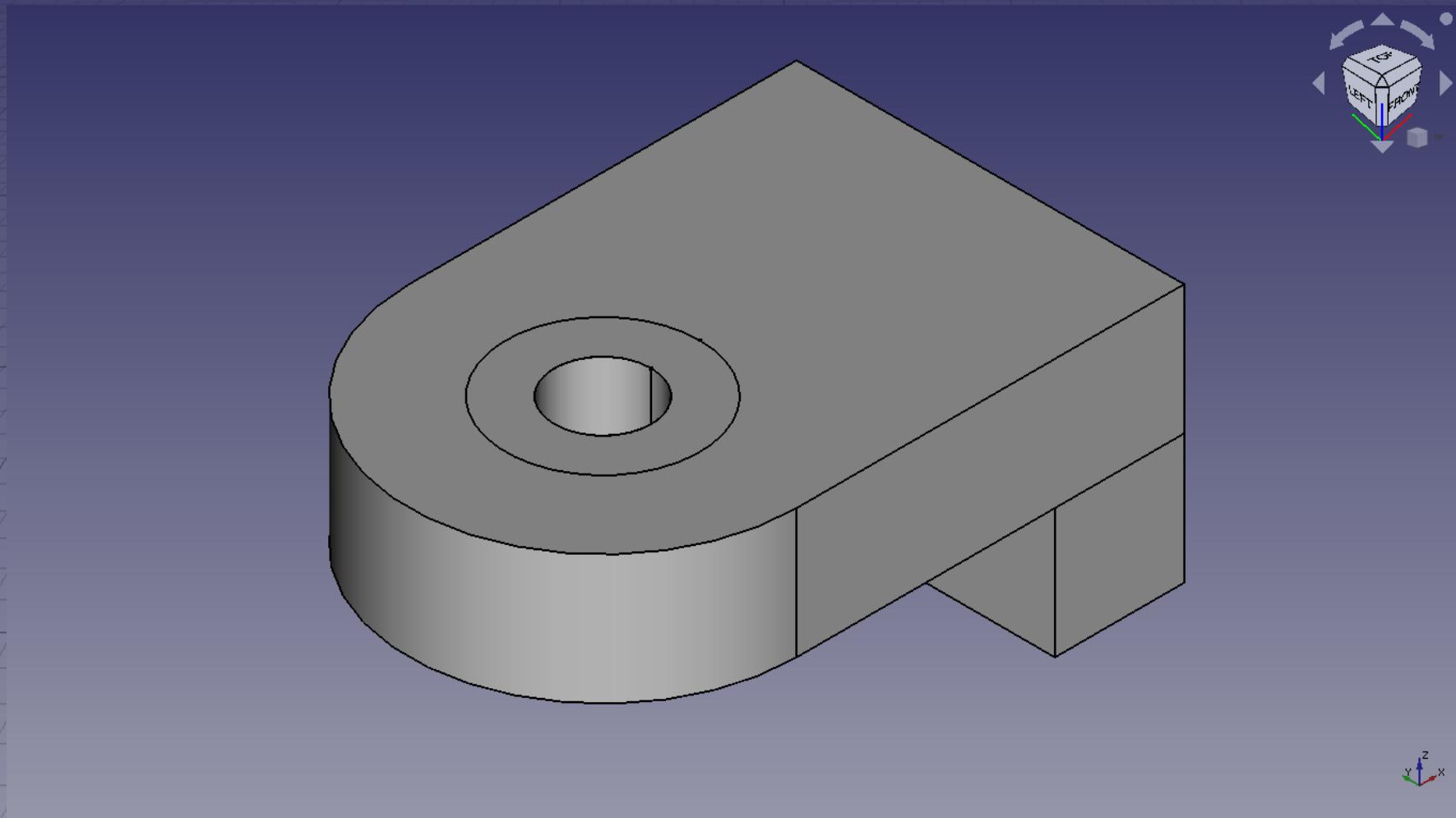


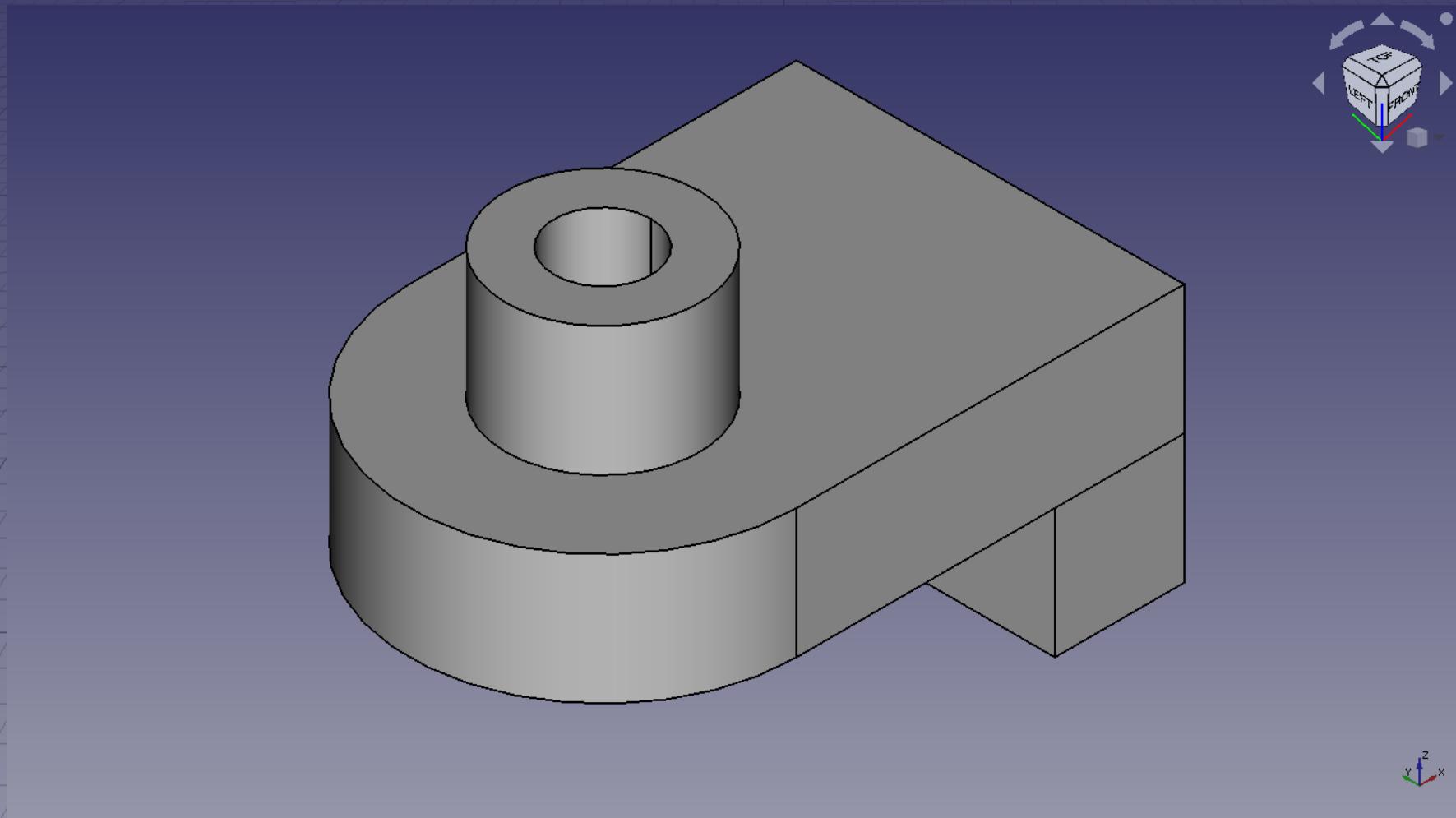


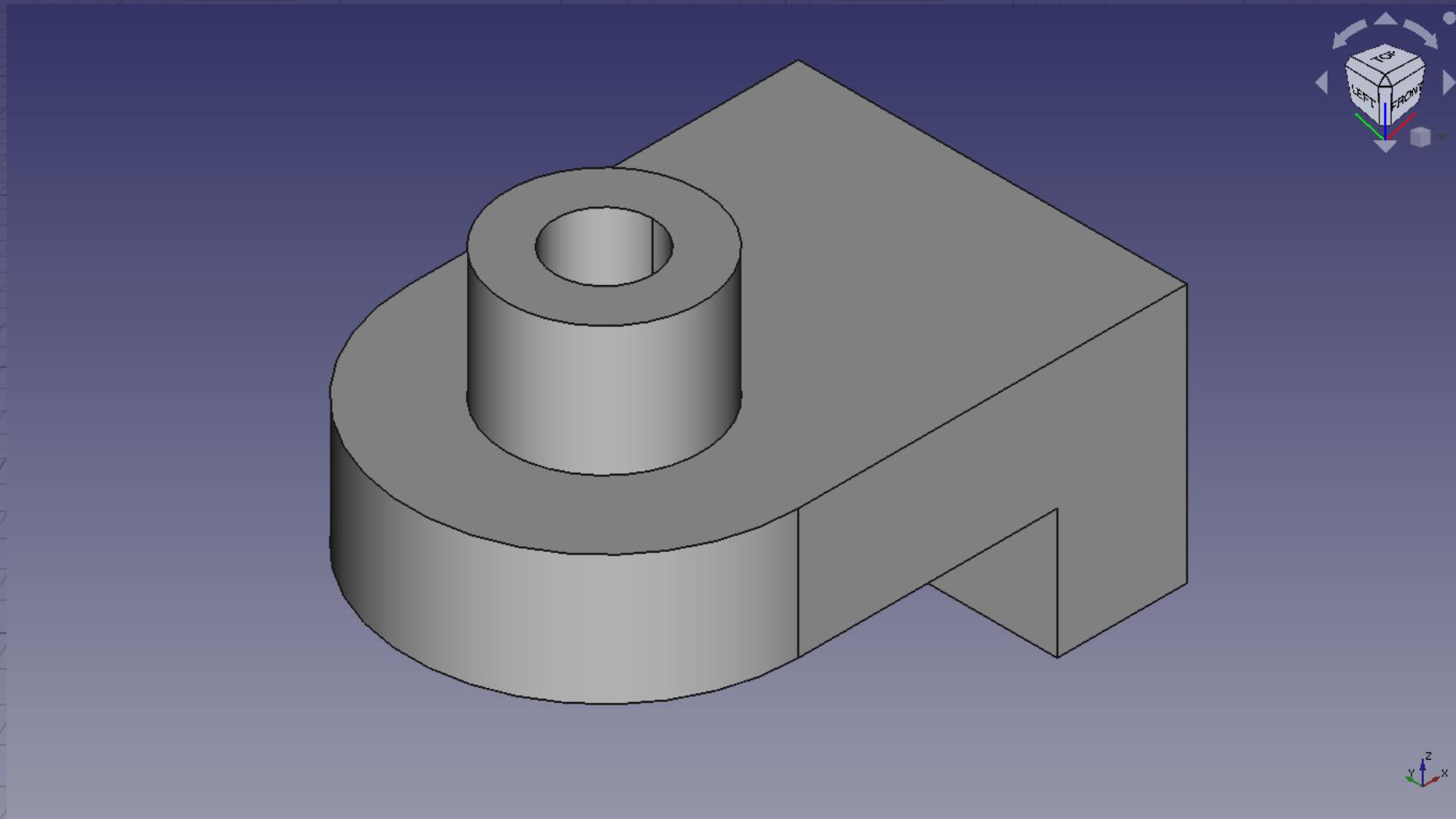




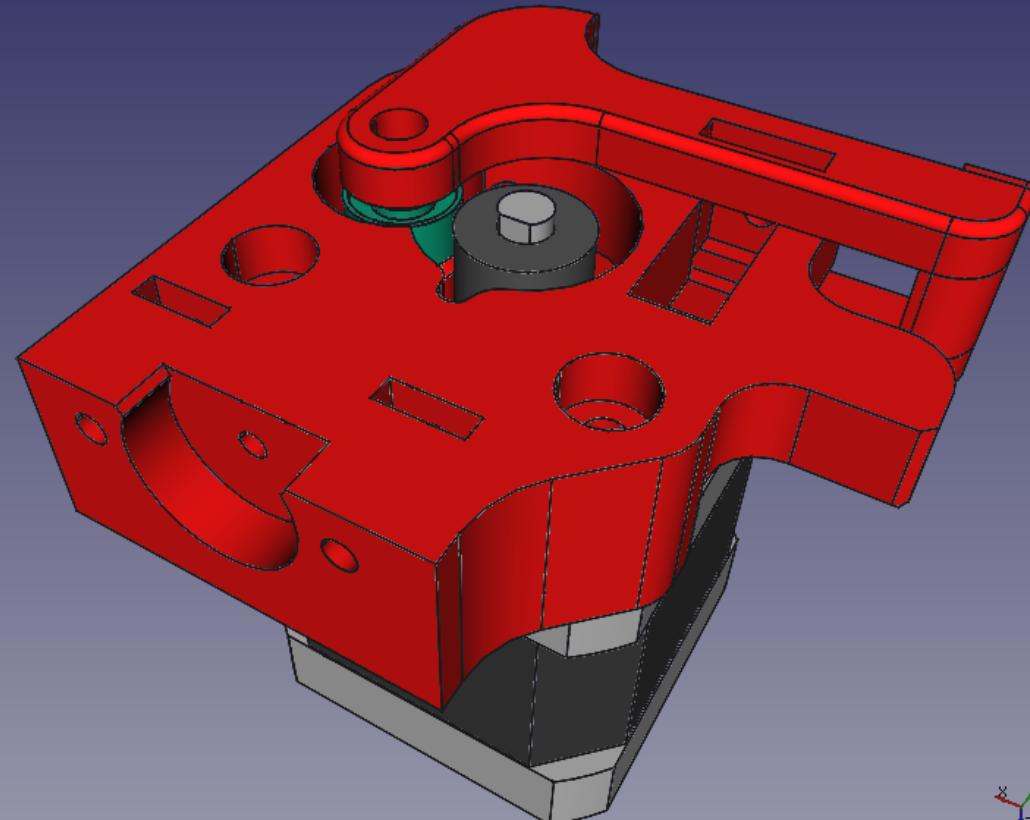




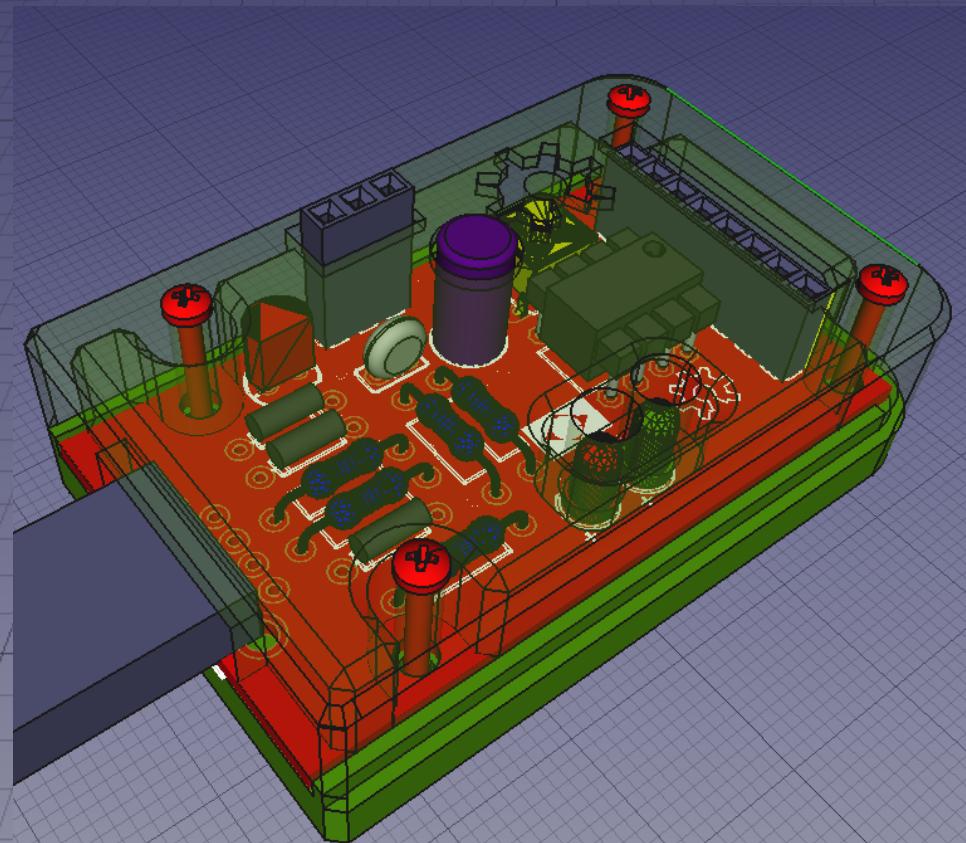


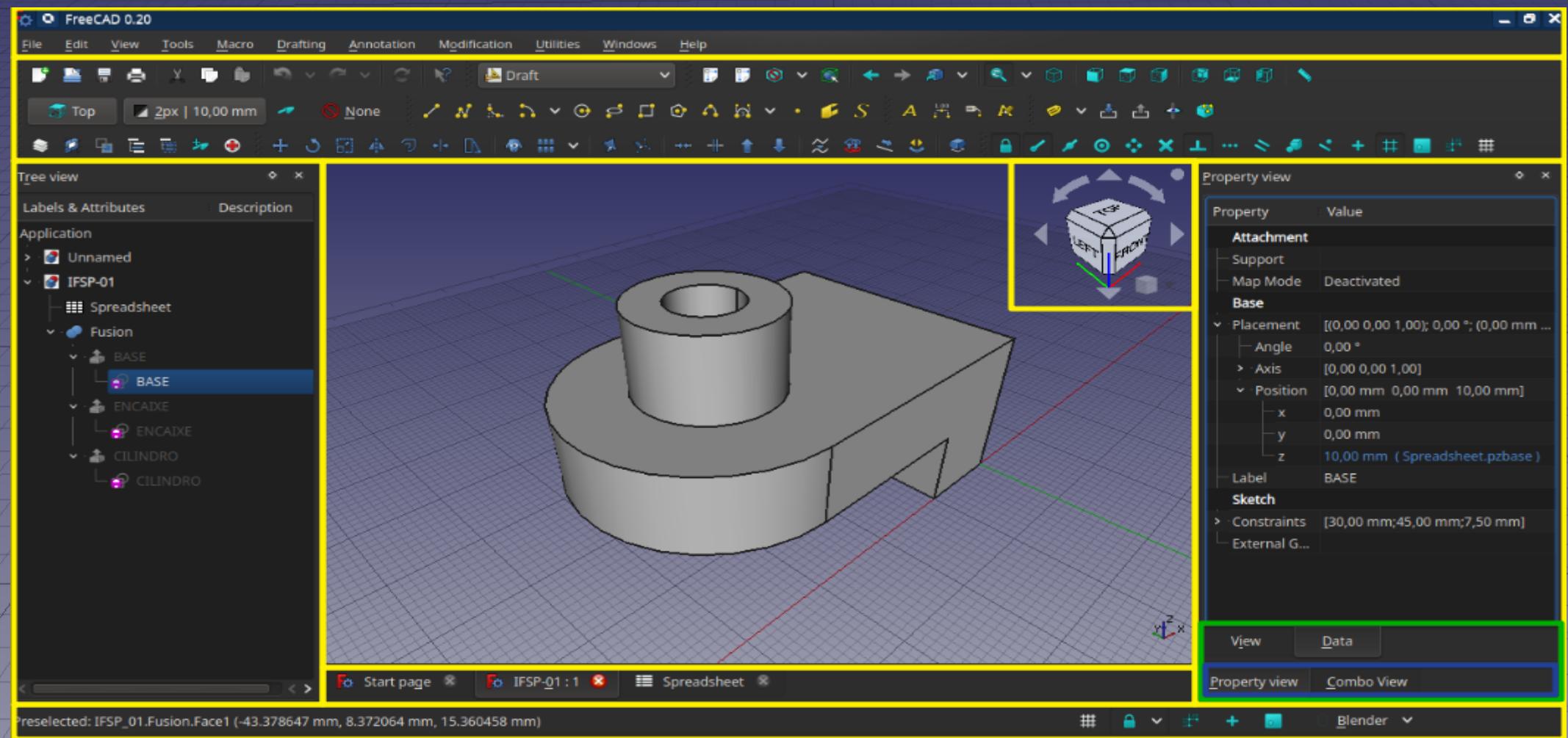


FreeCAD é GEOMETRIA!

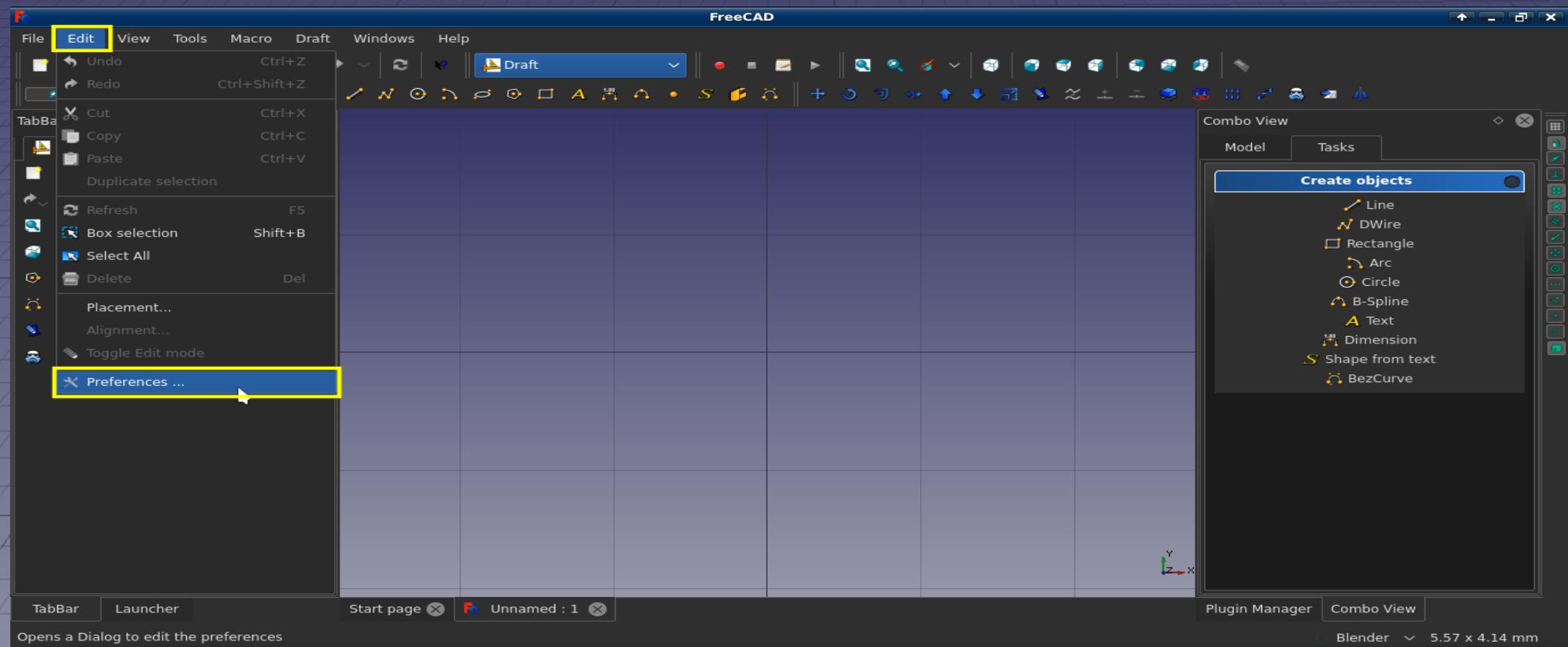


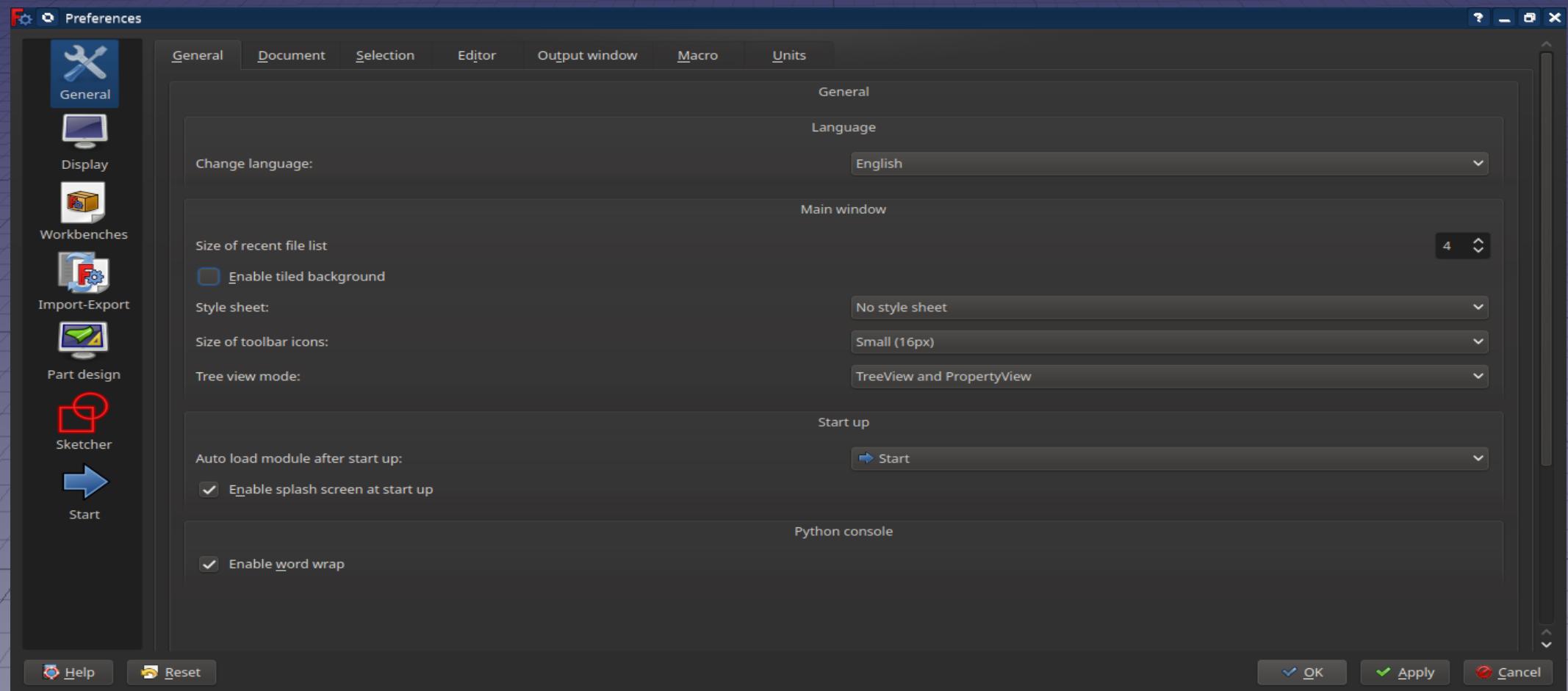
6 Área de Trabalho

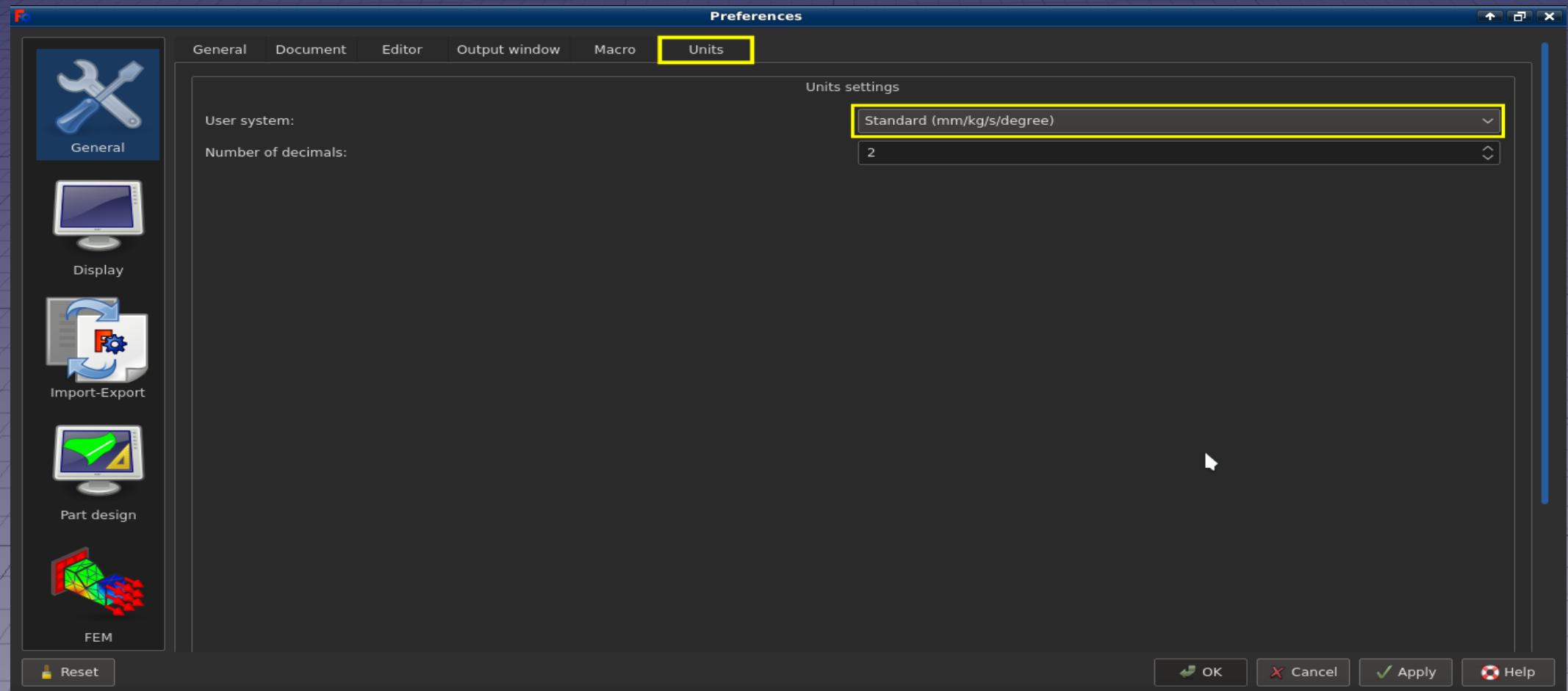


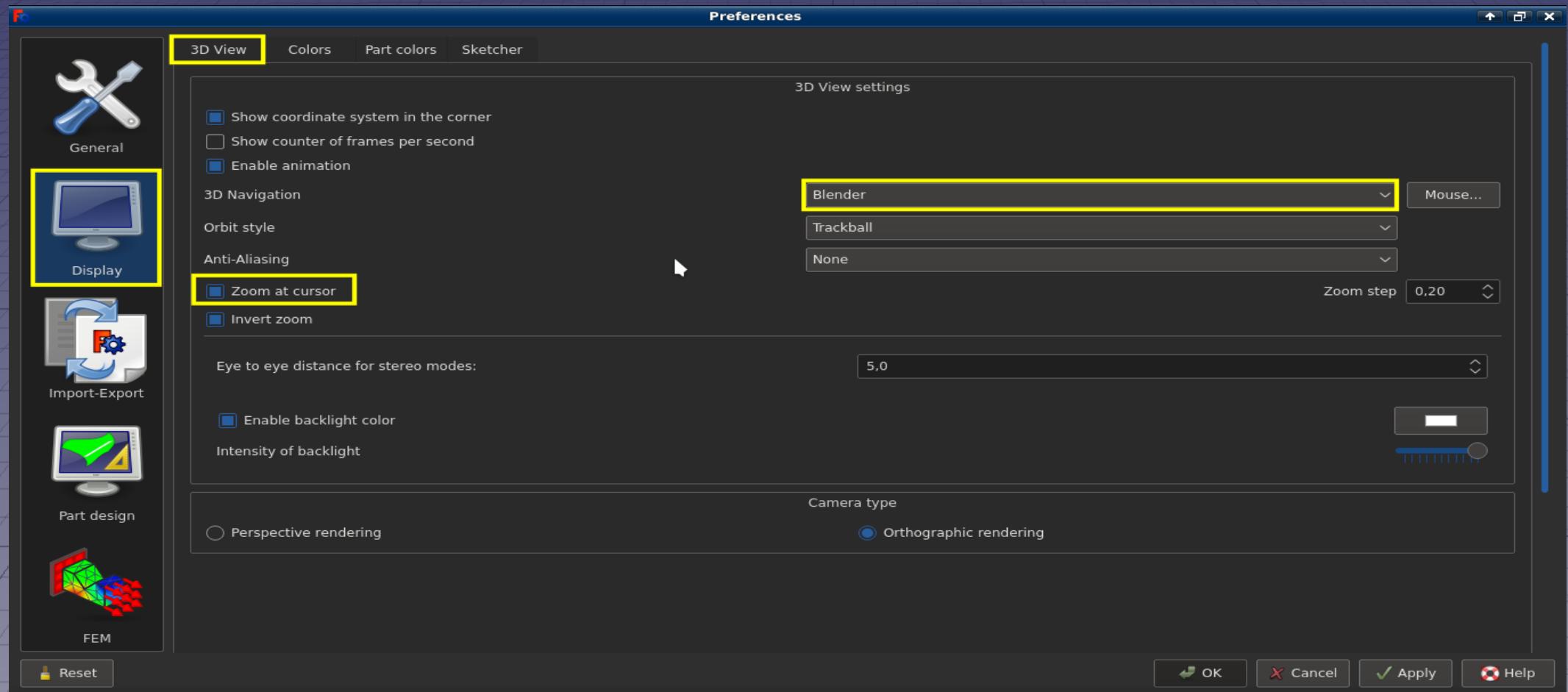


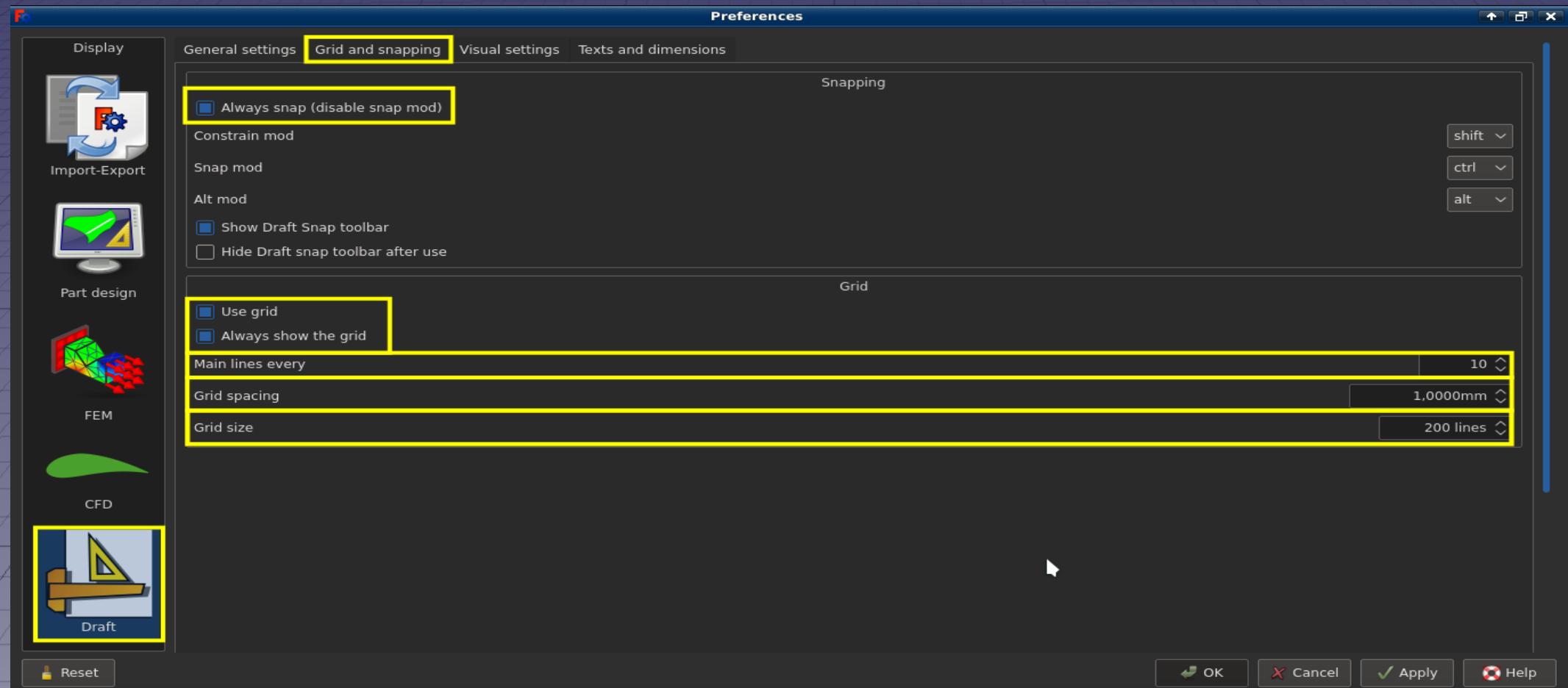
6.1 Preferências

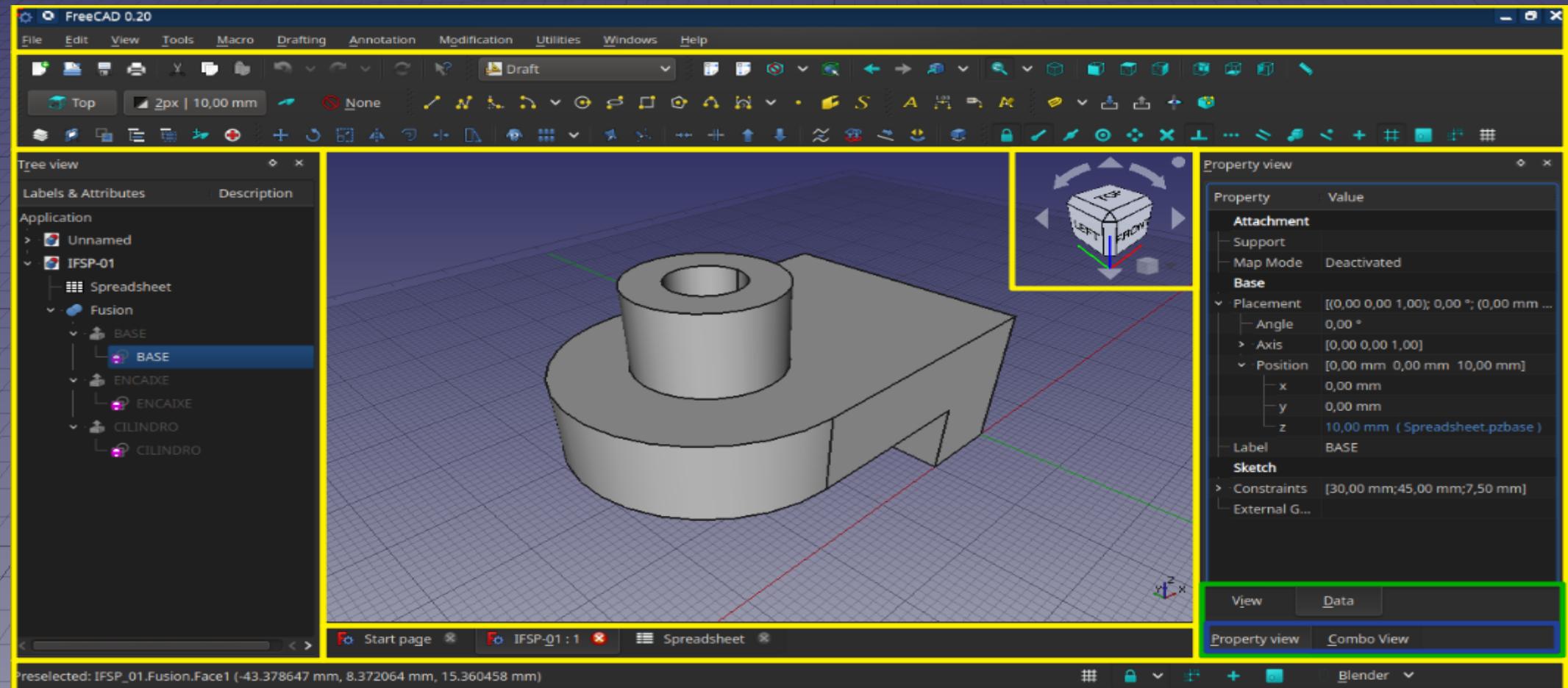






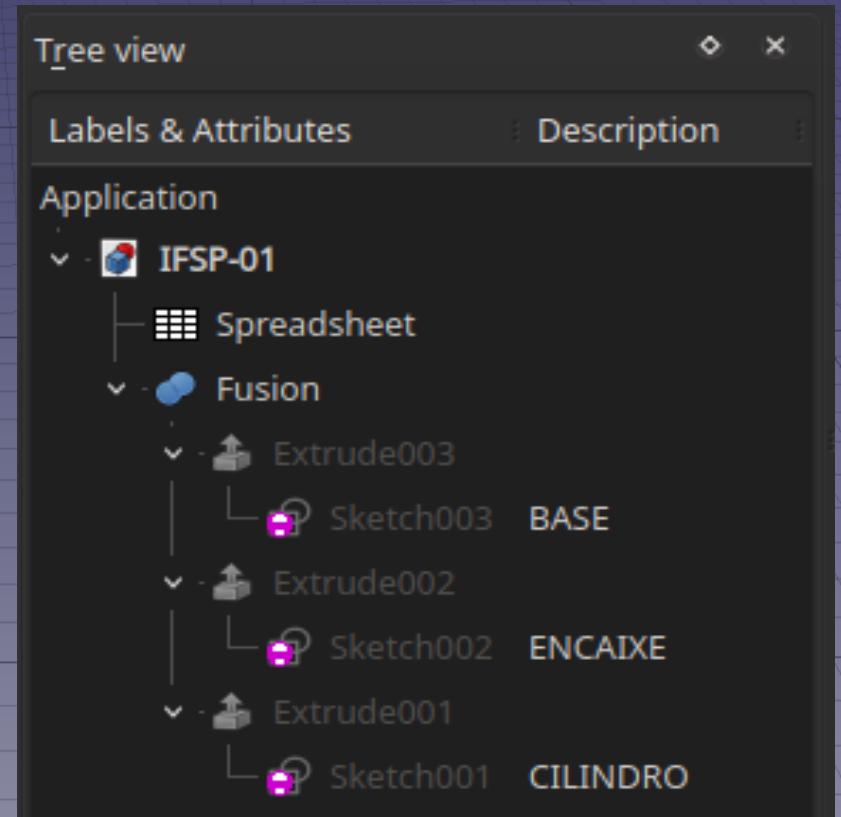




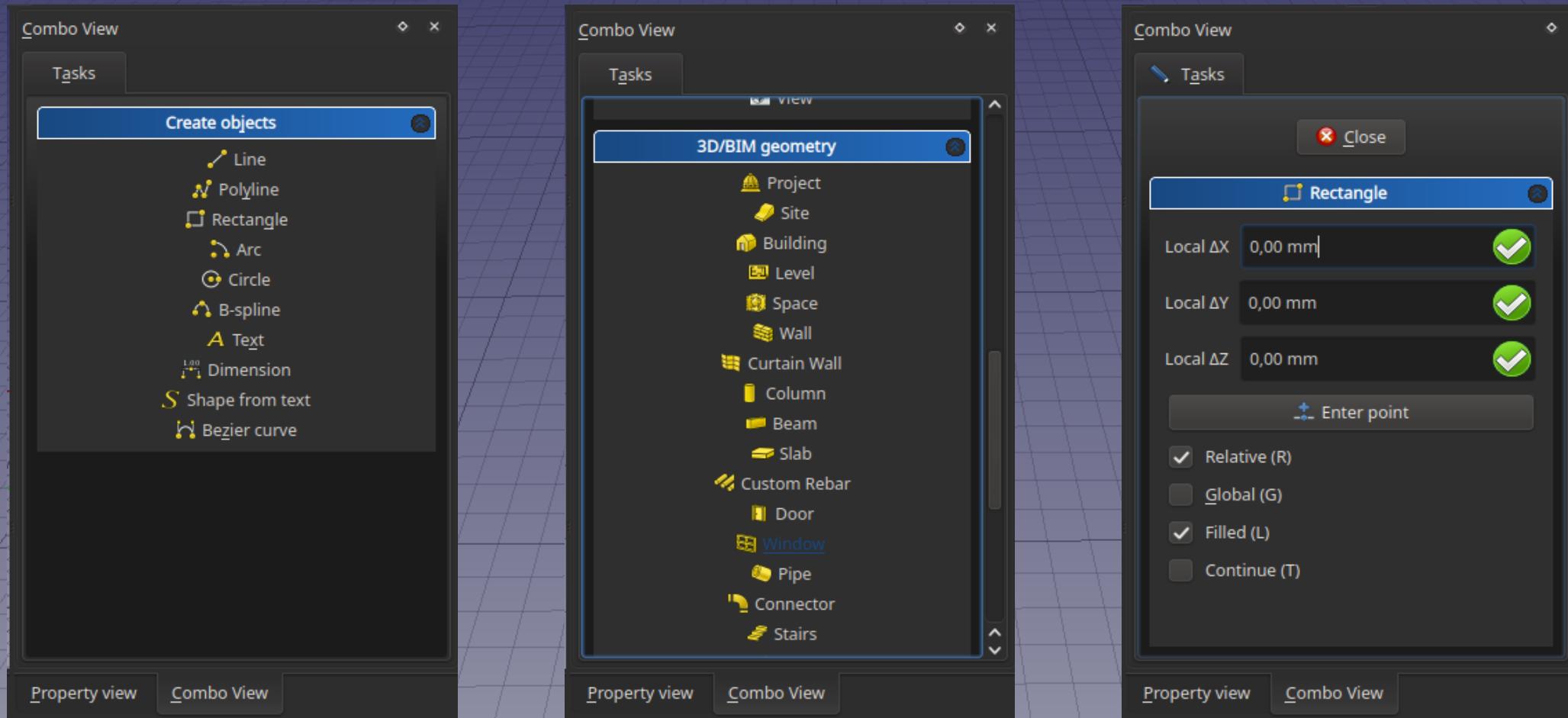


6.2 Tree View

- Spreadsheet
- Sketcher1 ⇒ Extrude1
- Sketcher2 ⇒ Extrude2
- Sketcher3 ⇒ Extrude3
- Extrude1 + Extrude2 + Extrude3 ⇒ Fusion

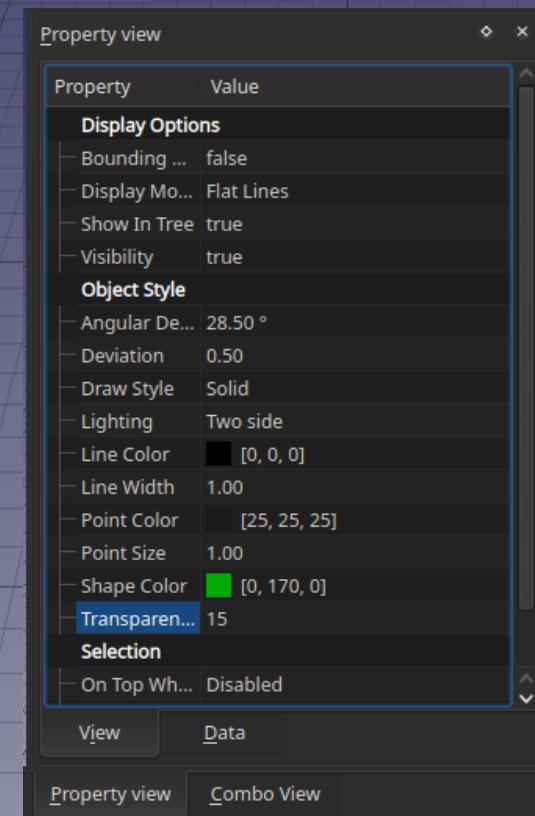


6.3 Combo View

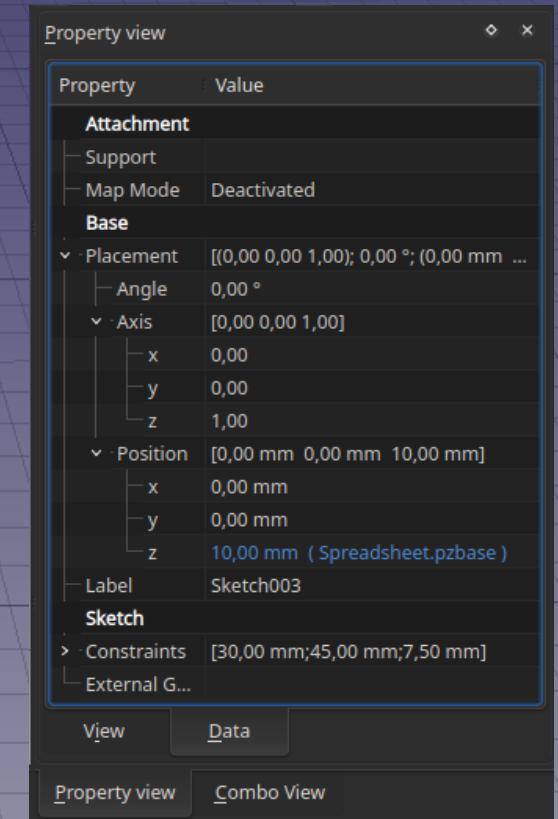


6.4 Property View

6.4.1 View

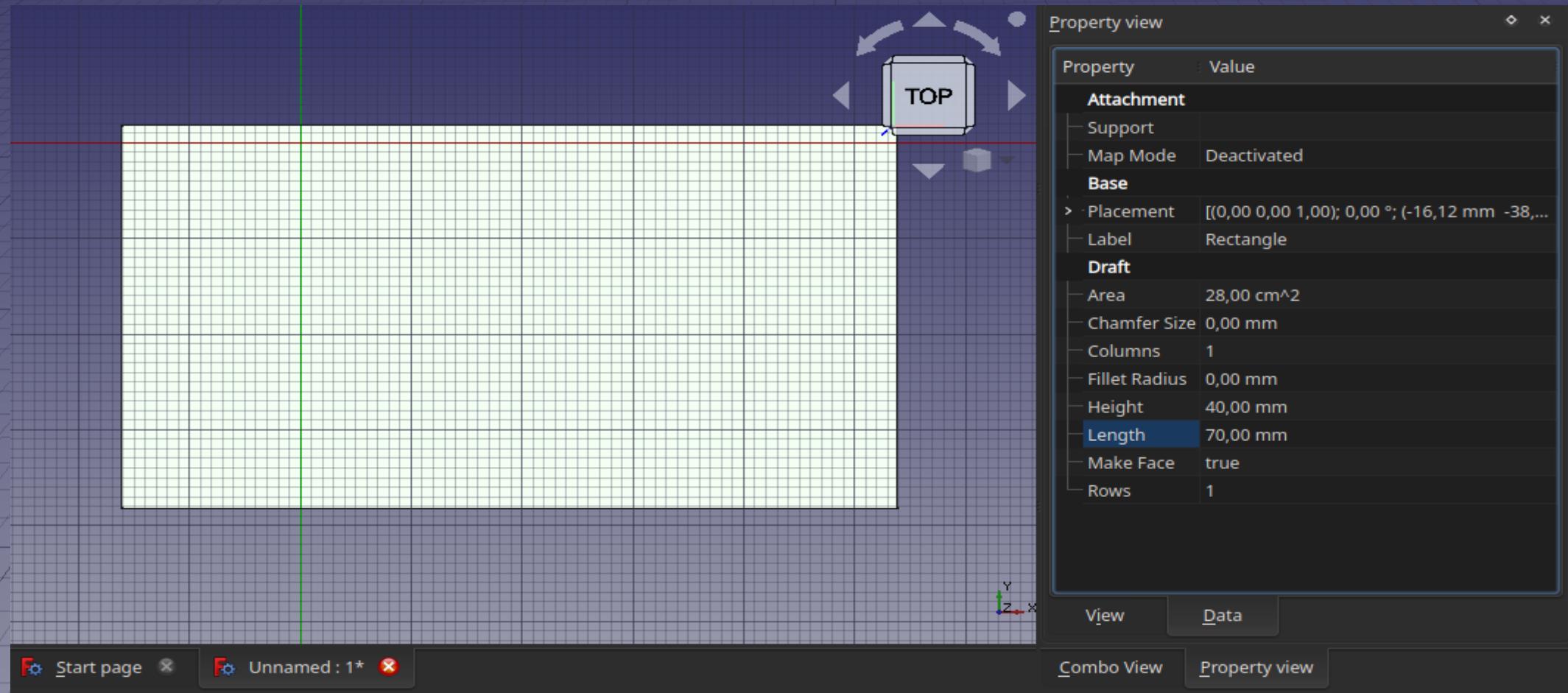


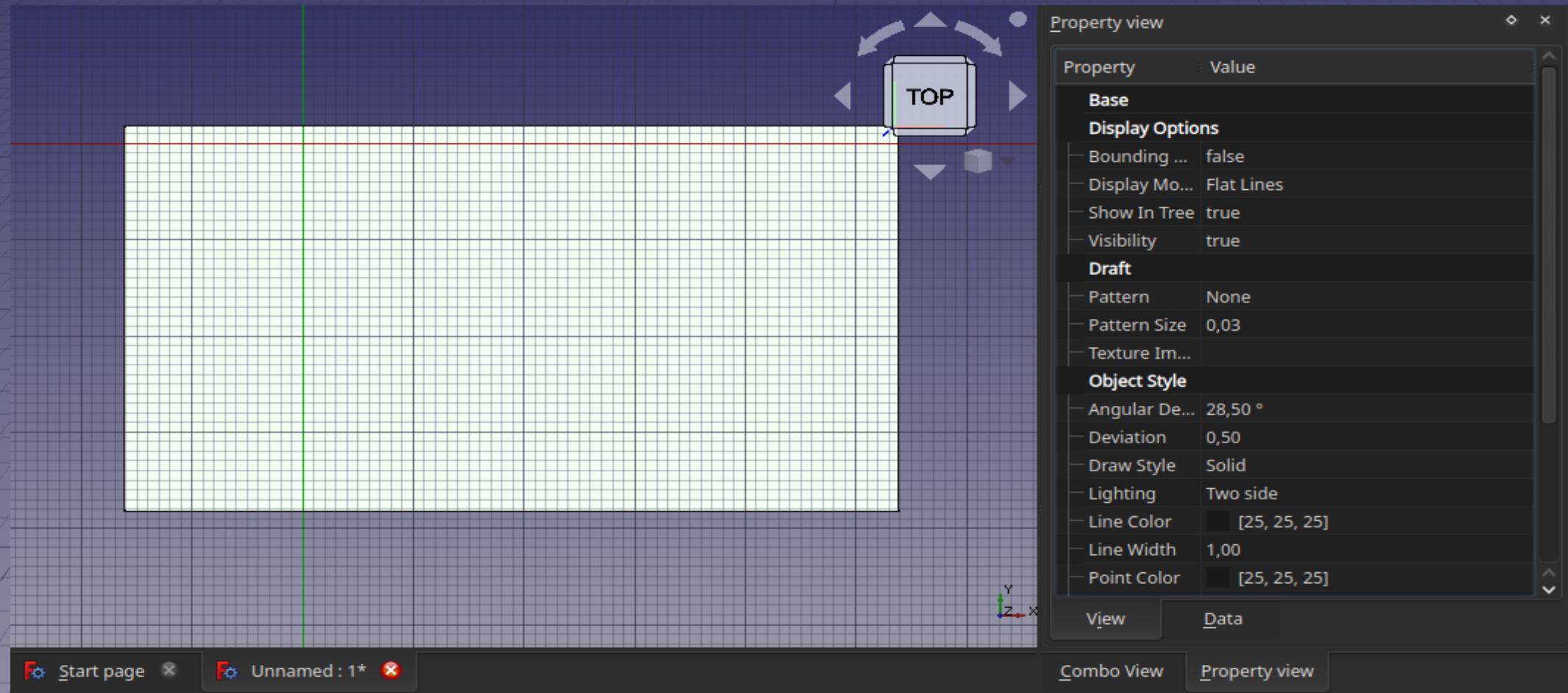
6.4.2 Data



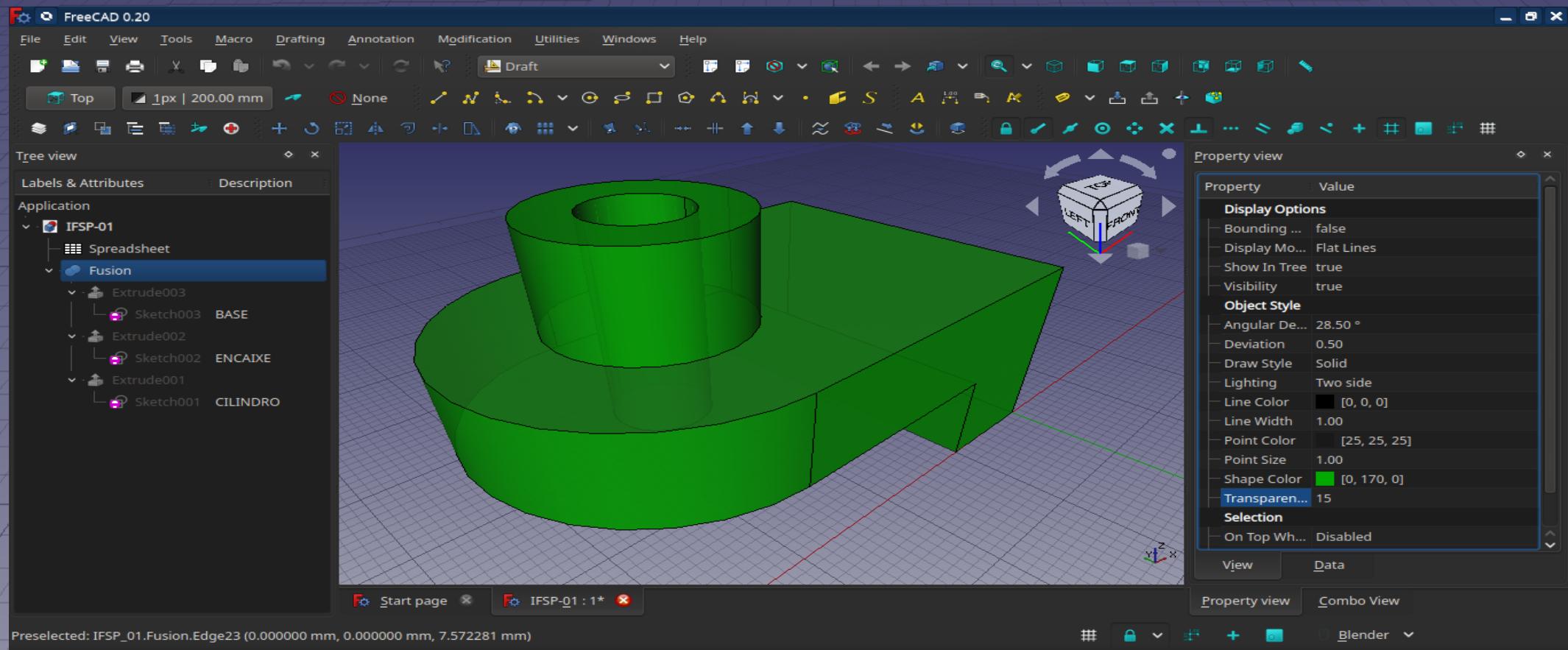
É aqui onde definimos os parâmetros!

- Gráficos (View)
- Algébricos (Data)

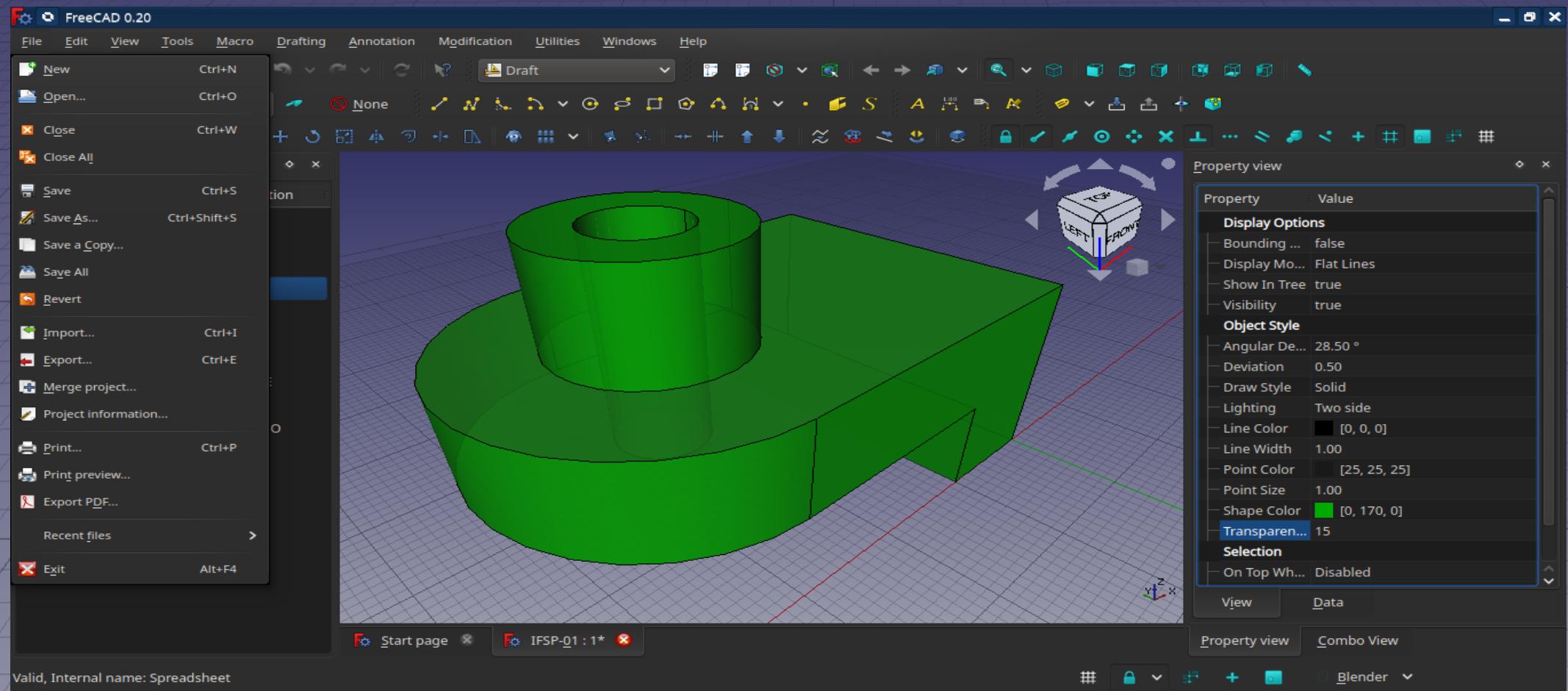




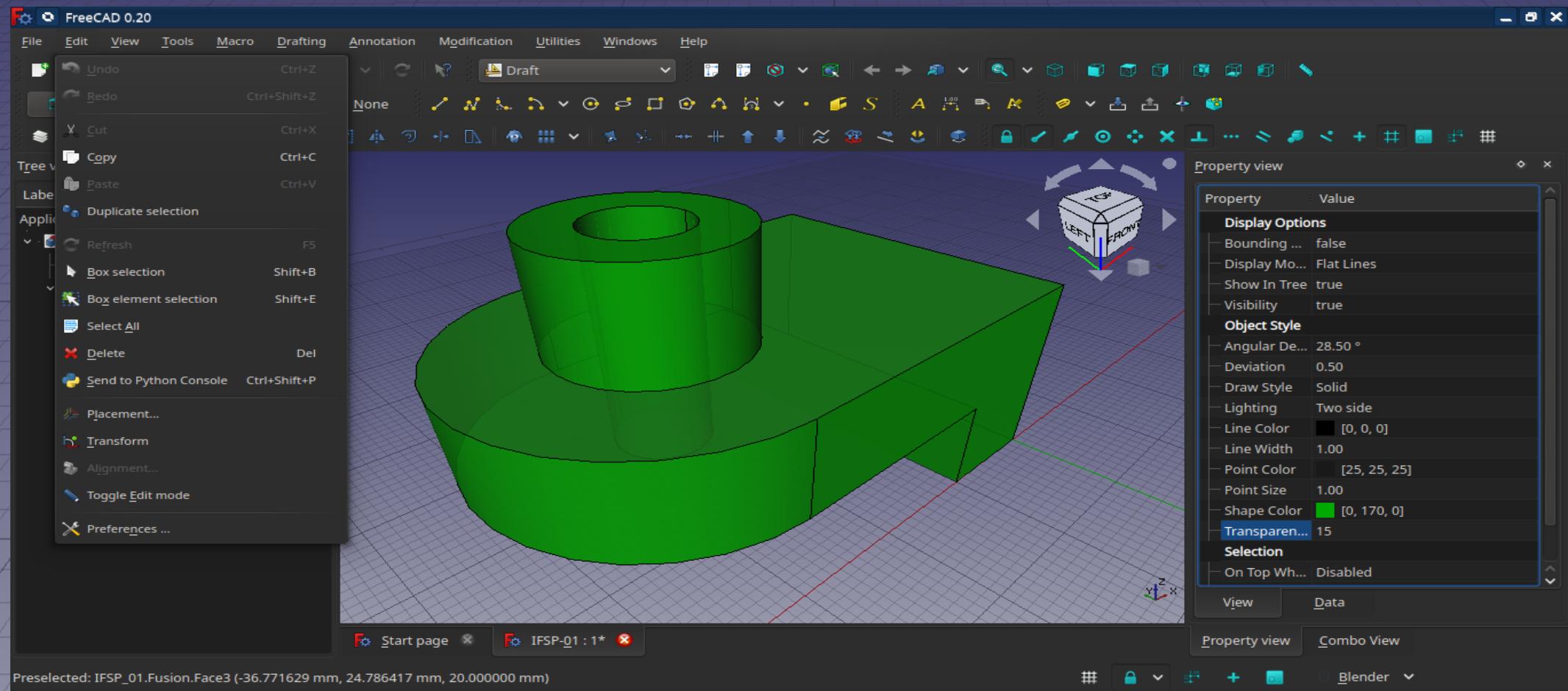
6.5 Menus



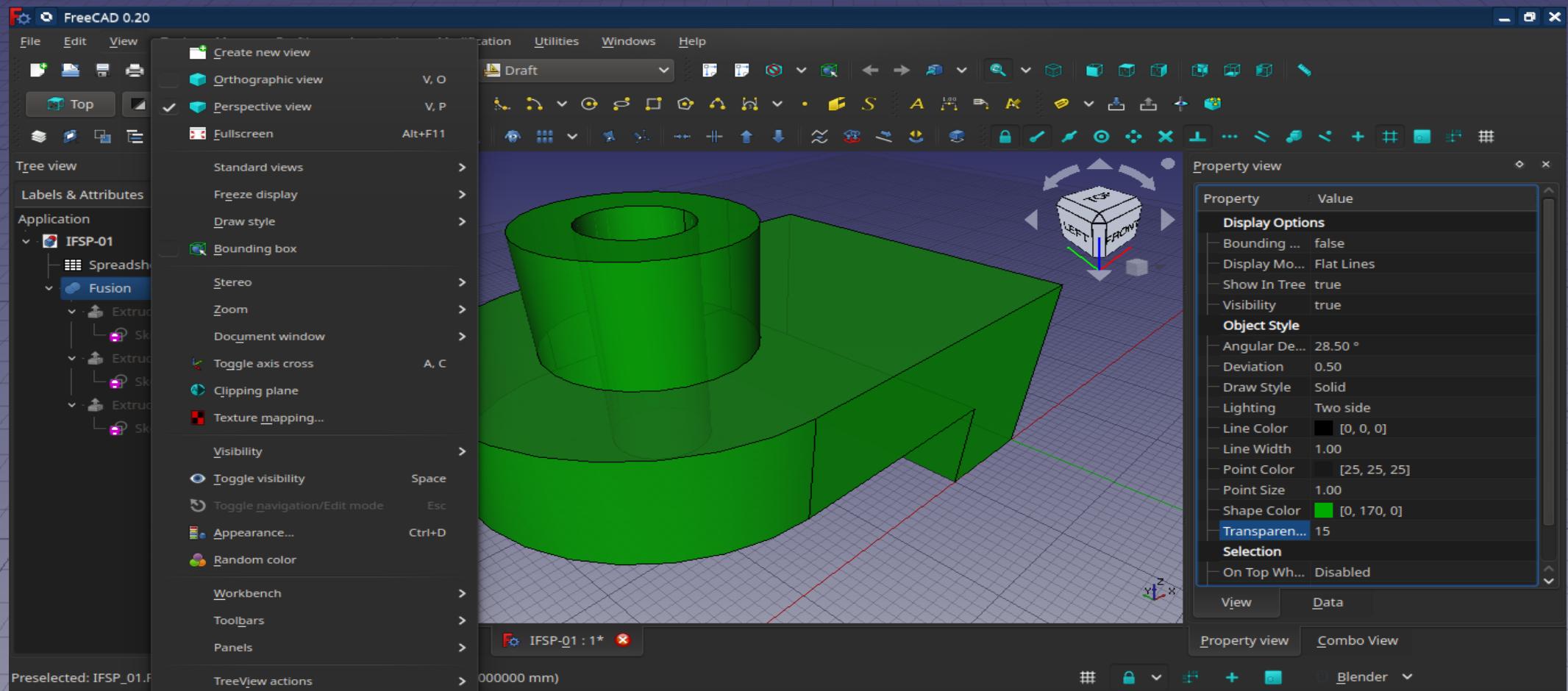
File



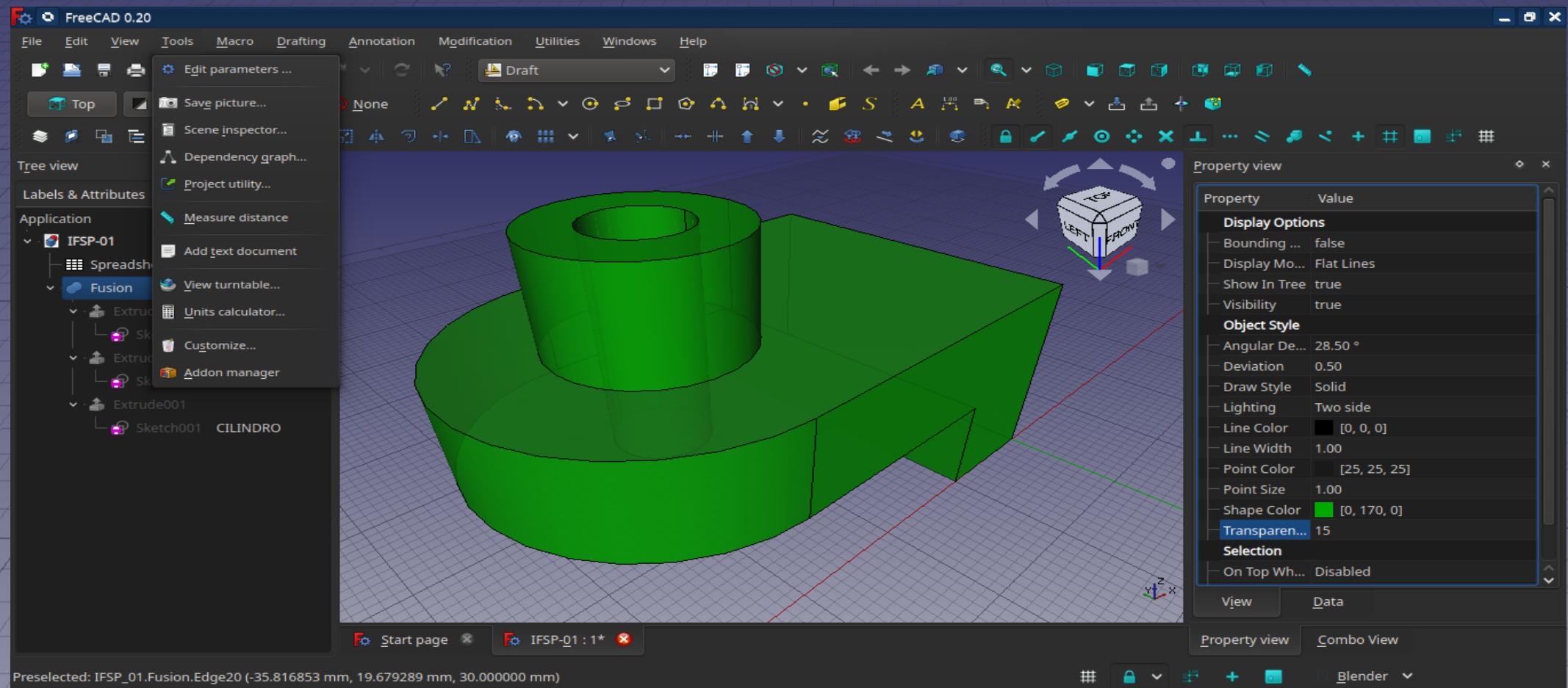
Edit



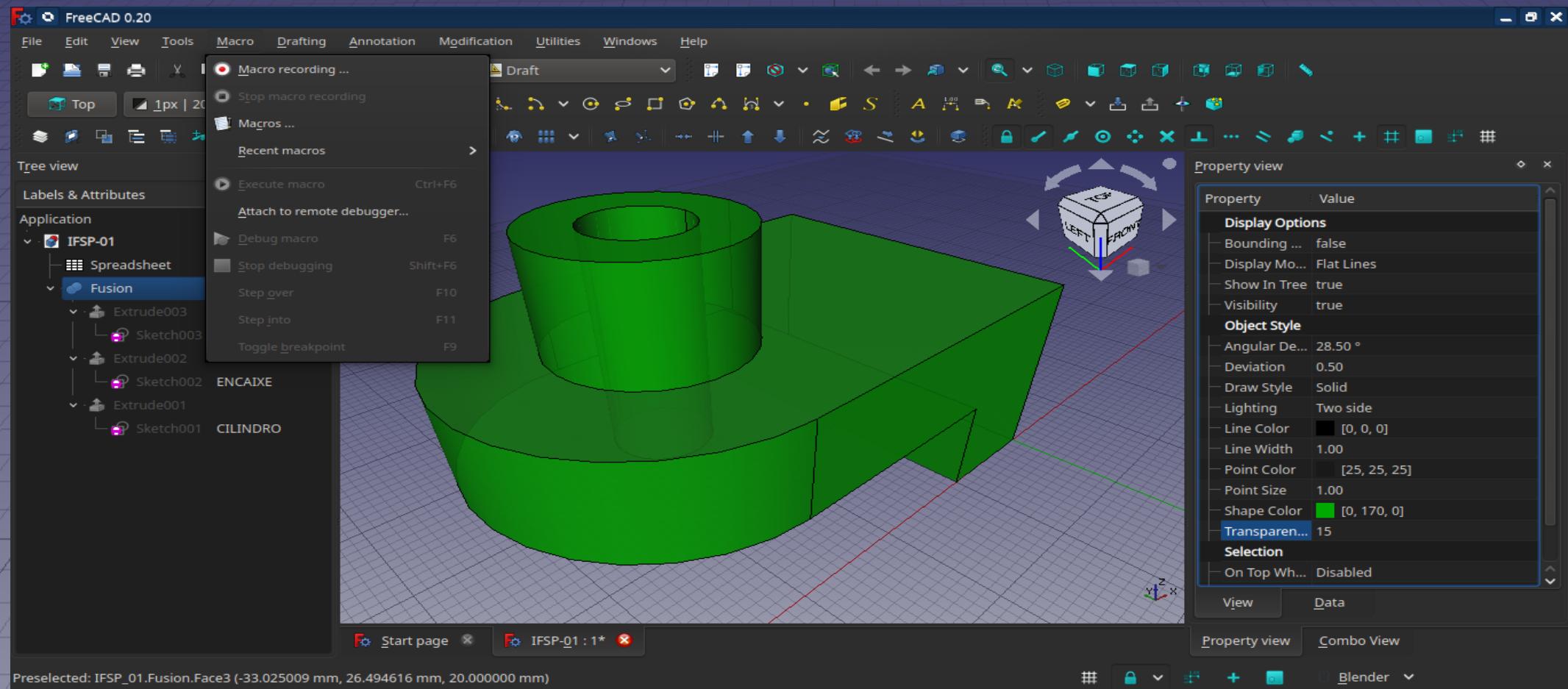
View



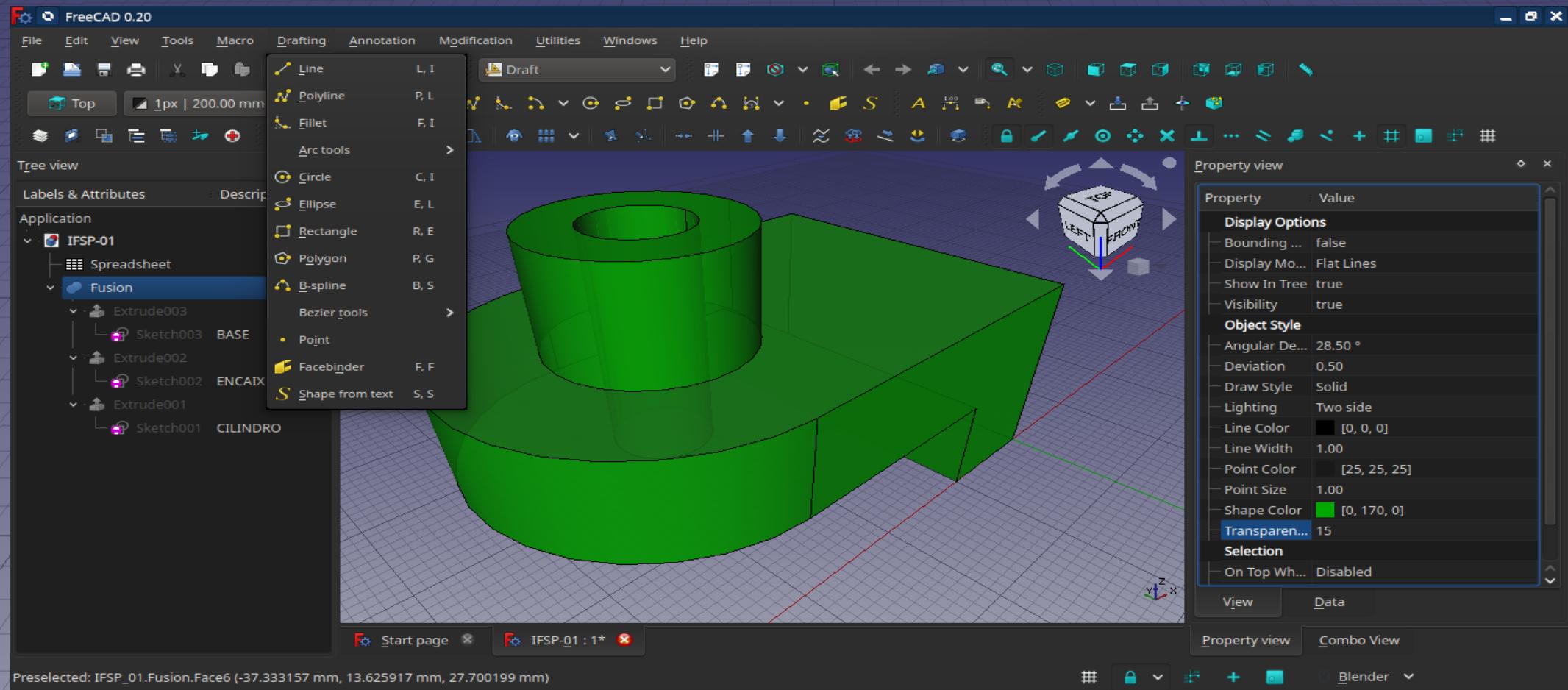
Tools



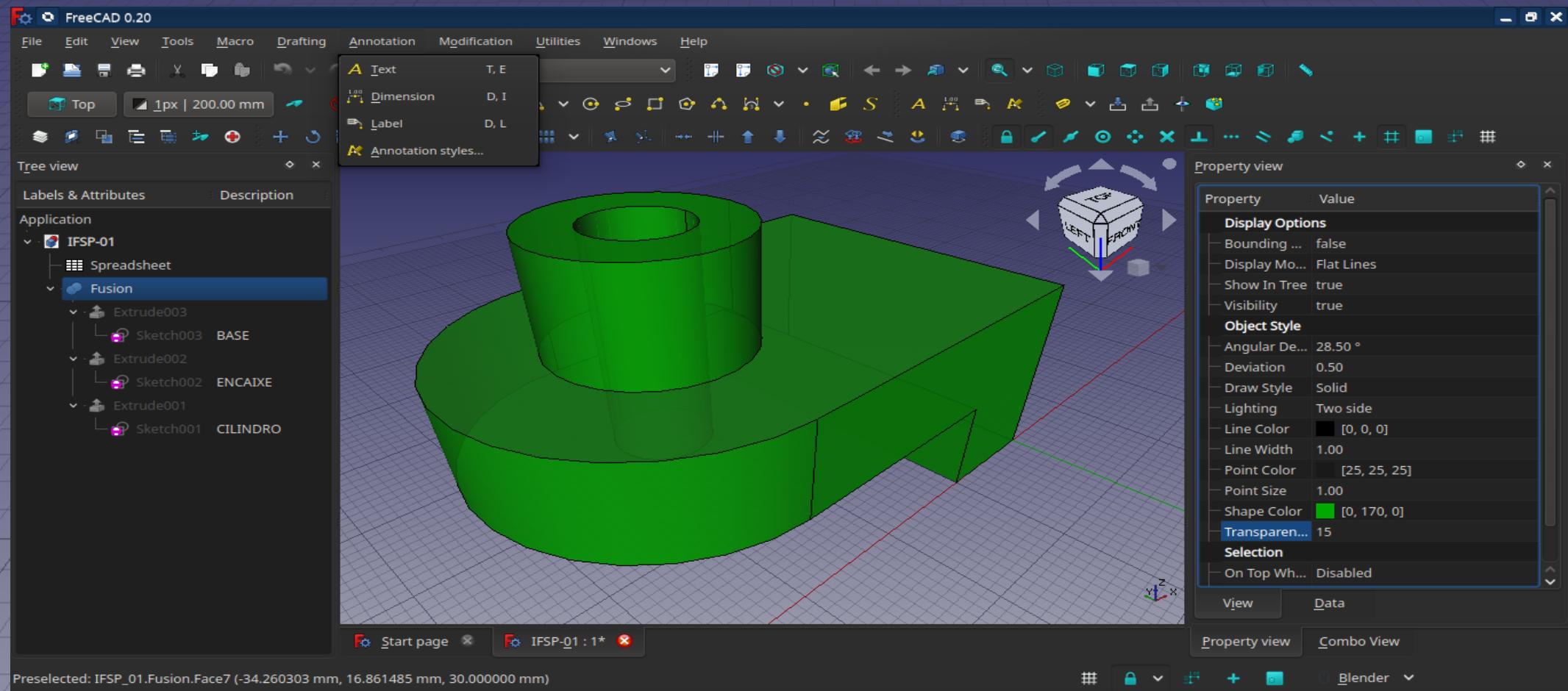
Macro



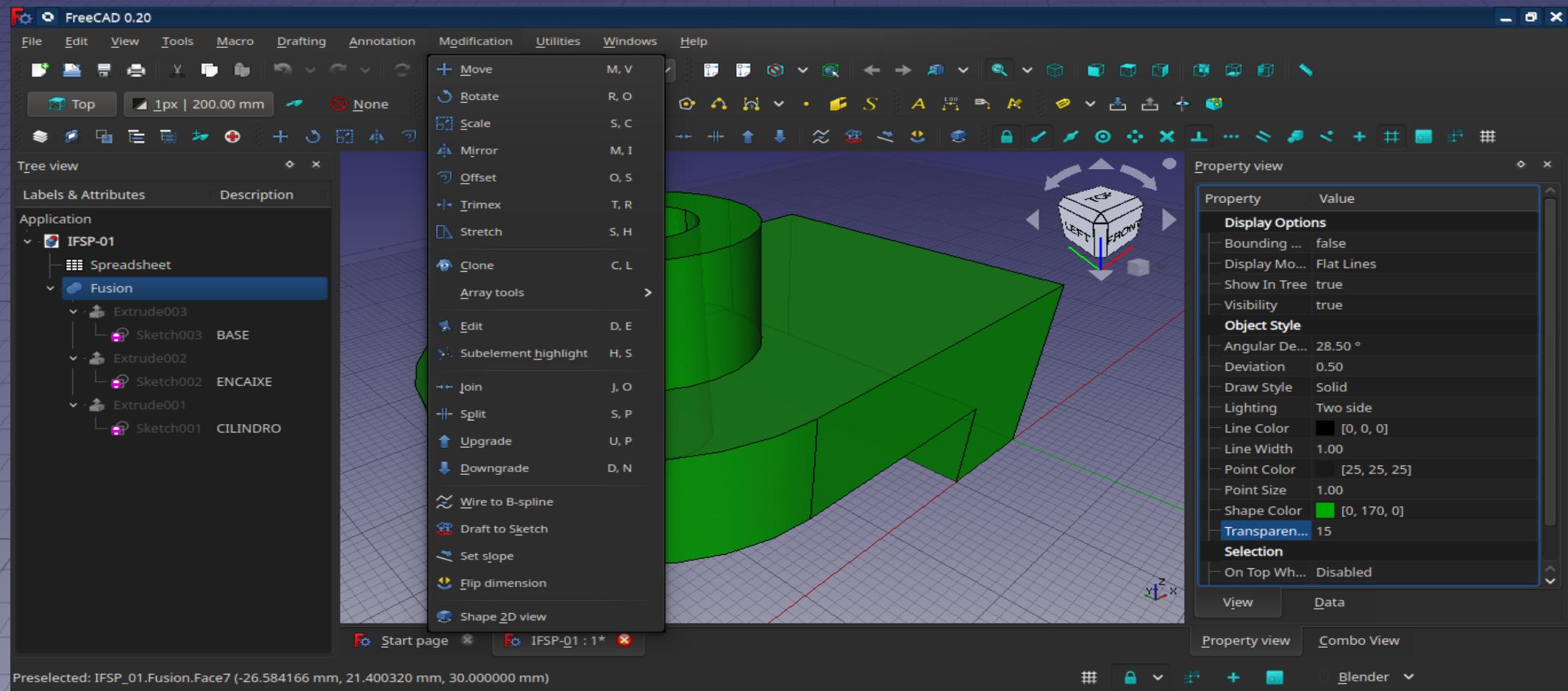
Drafting



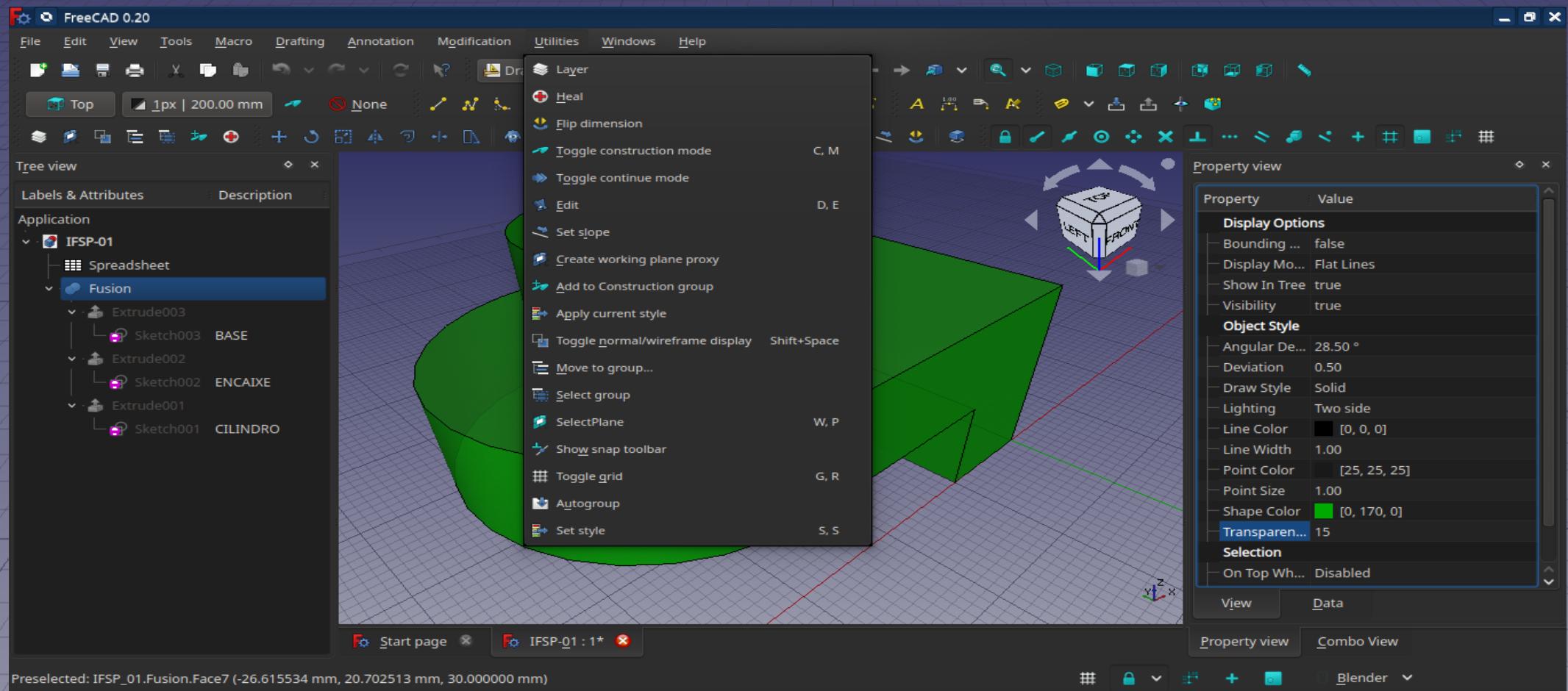
Annotation



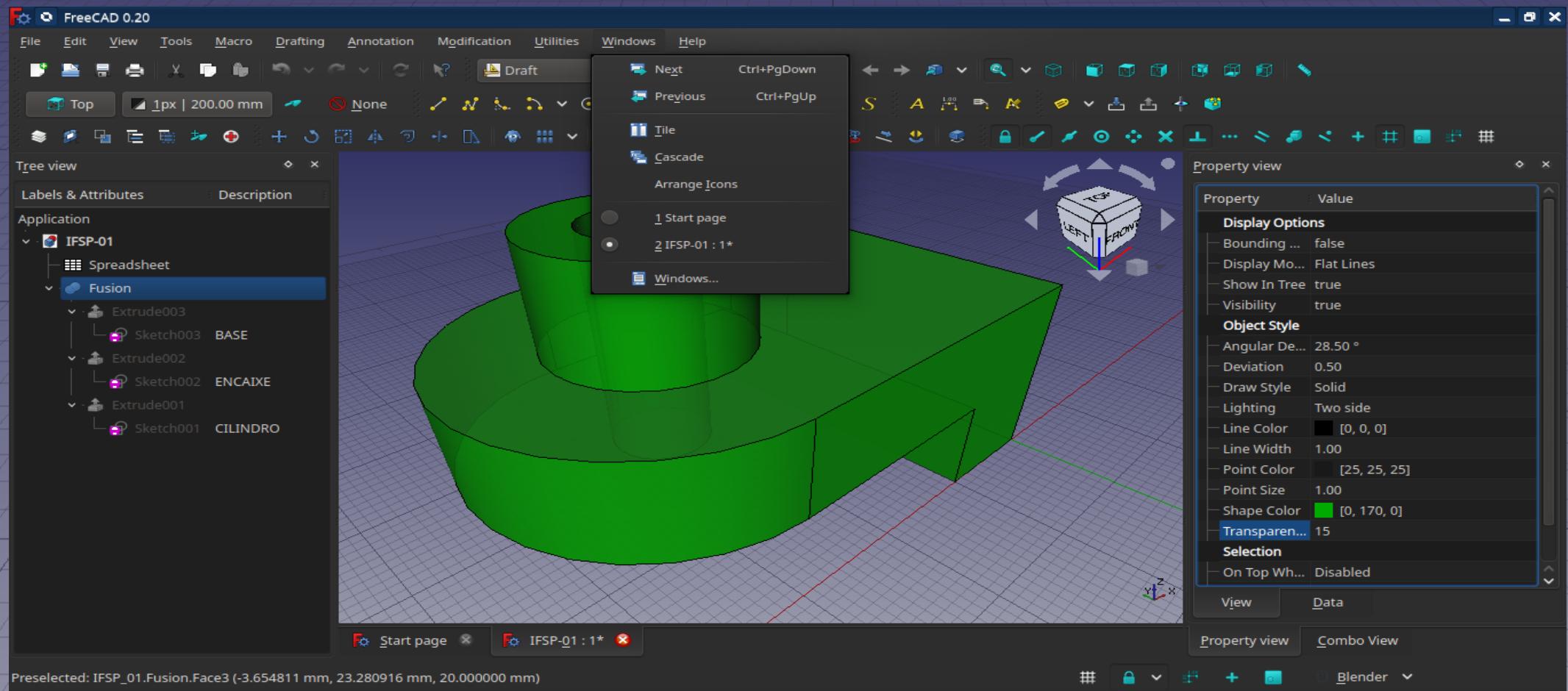
Modification



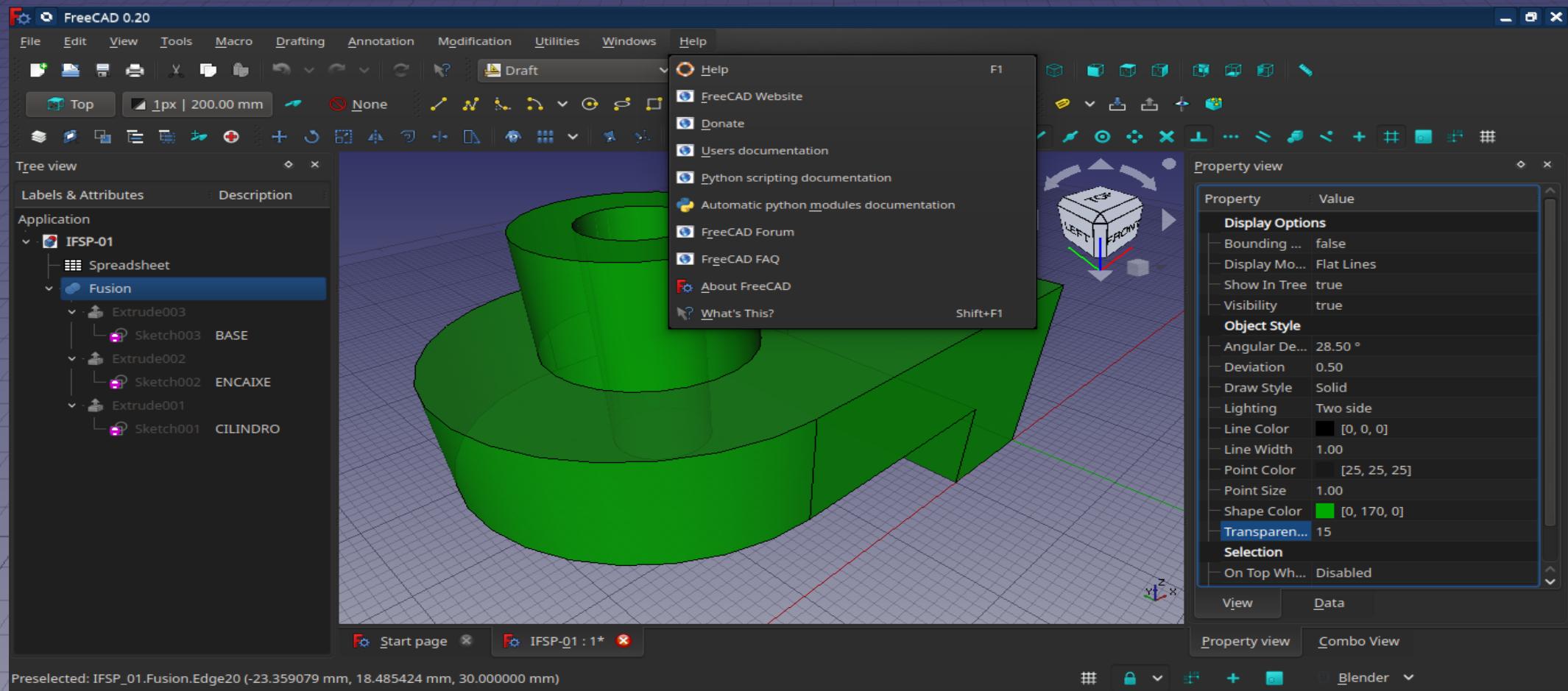
Utilities



Windows

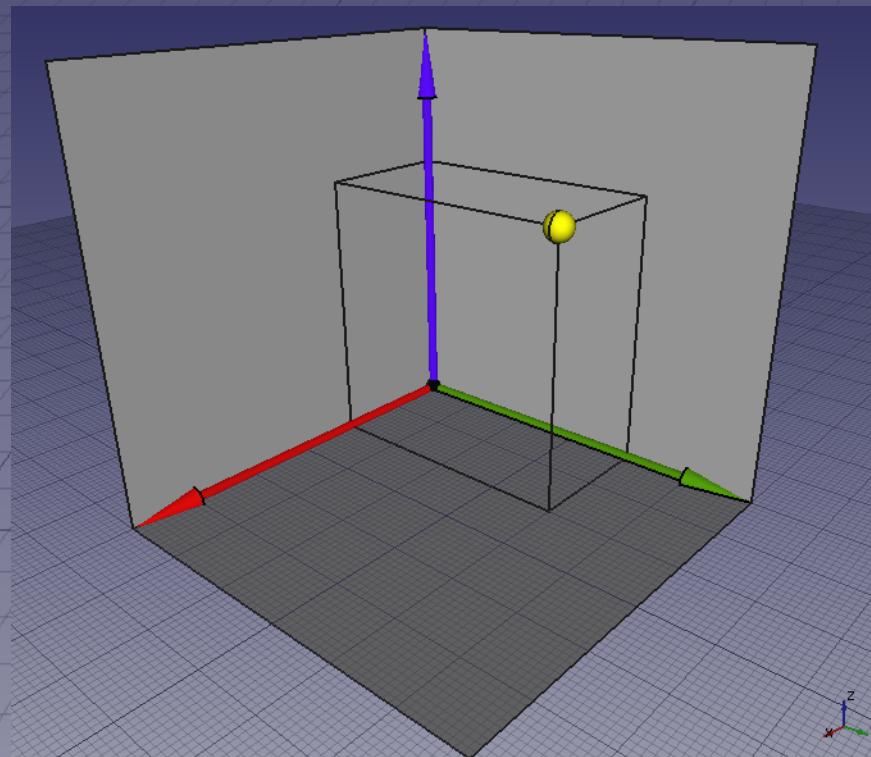


Help



7 A Matemática do FreeCAD

7.1 Ponto



Todo e qualquer ponto é definido por 3 **variáveis**.

$$P : (X, Y, Z)$$

Cada variável pode ser definida por **parâmetros** ou funções matemáticas, por exemplo:

$$P : \left[(X); (2 * X); \left(\frac{X}{2}\right) \right]$$

Parâmetro é uma variável, que pode ser definida uma **função**.

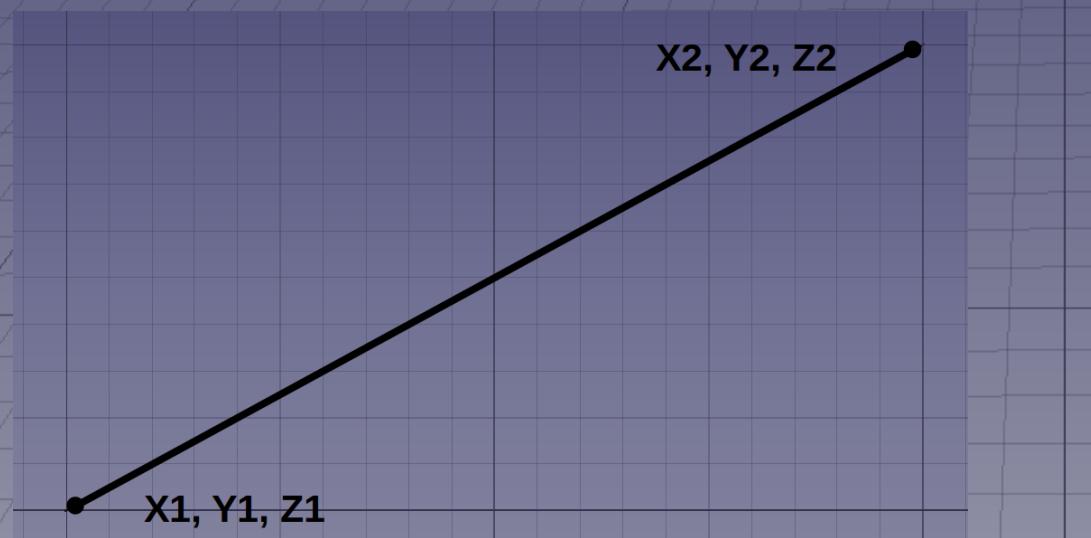
7.2 Linha

- Coordenadas Cartesinanas:

- ✓ Absolutas
 - Ponto inicial
 - Ponto final

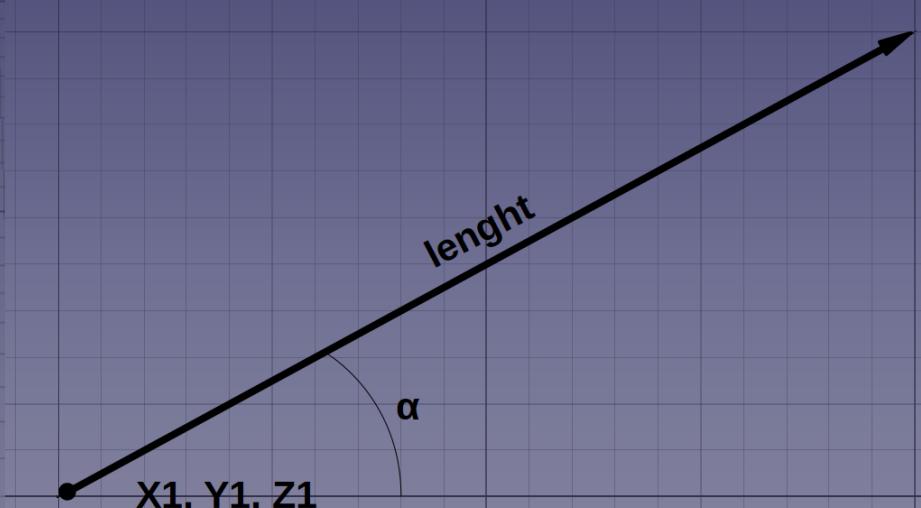
- ✓ Relativas

- Ponto inicial
- Distância em X
- Distância em Y



- Coordenadas Polares

- ✓ Ponto inicial
- ✓ Distância
- ✓ Ângulo



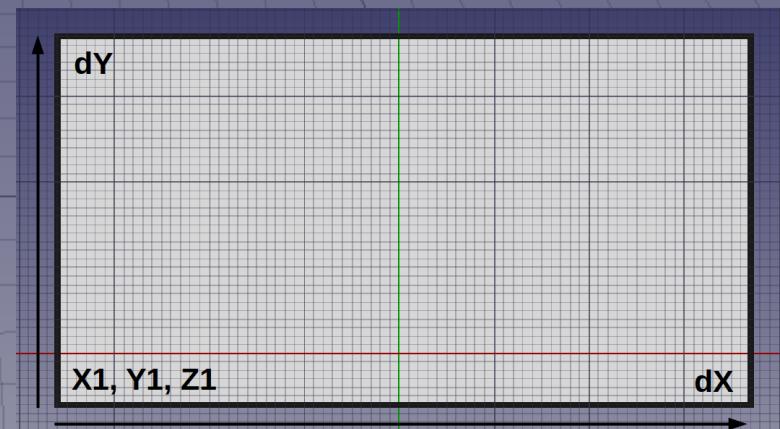
7.3 Formas planas

7.3.1 Retangulo

- Coordenadas:

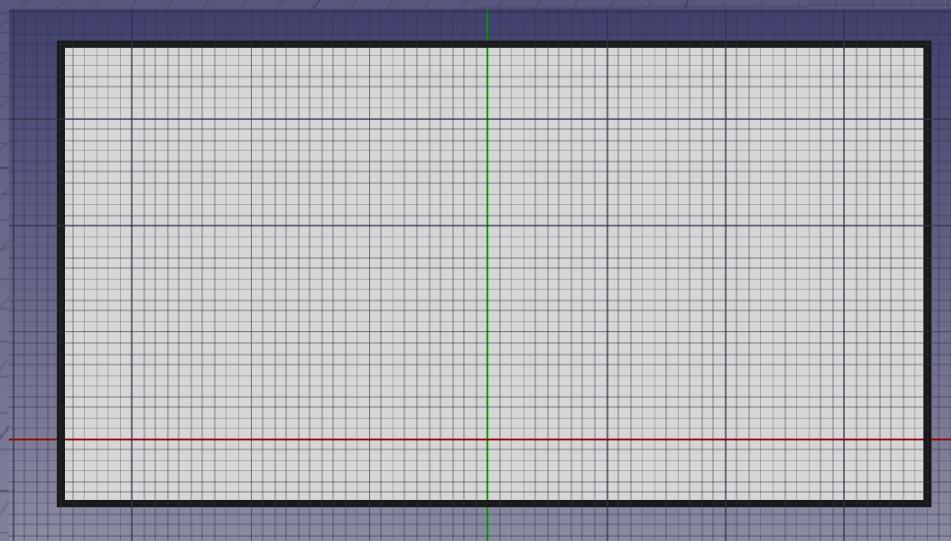
- ✓ Absolutas
 - Ponto inicial
 - Ponto final

- ✓ Relativas
 - Ponto inicial
 - Comprimento Dx
 - Largura Dy



- Preenchimento:

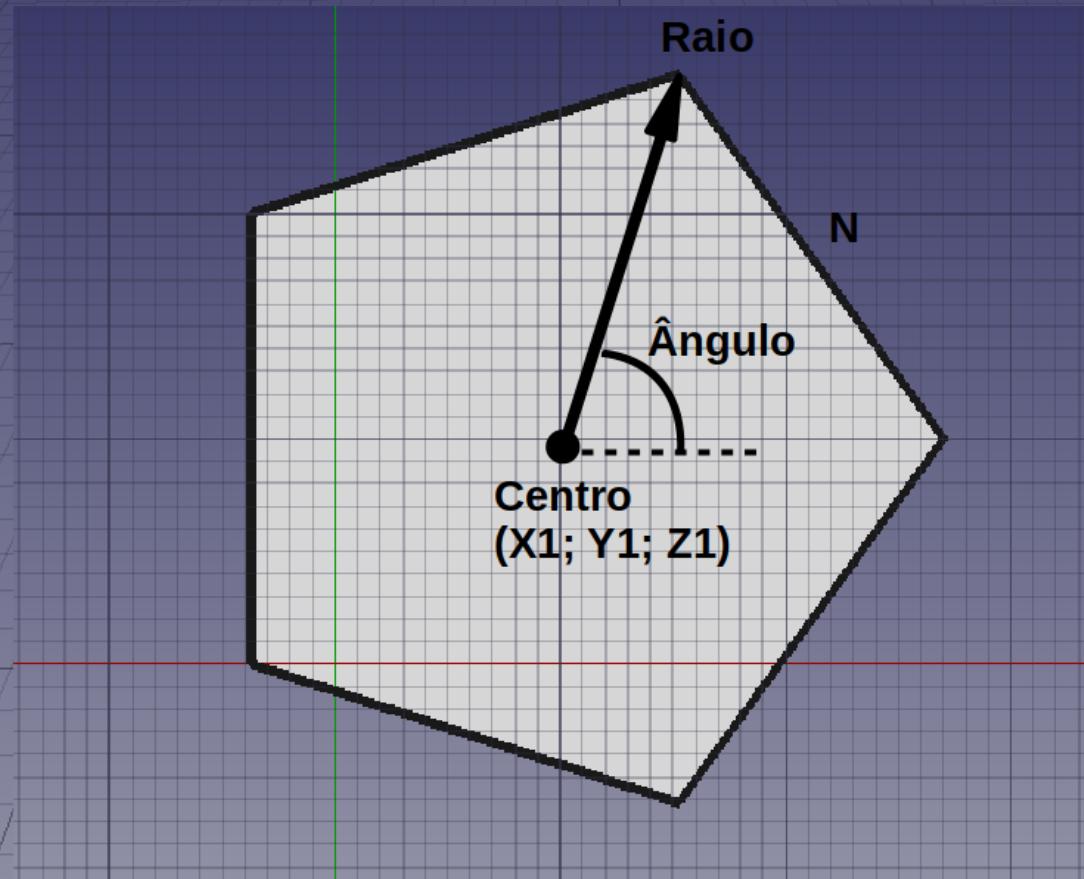
✓ Cheio



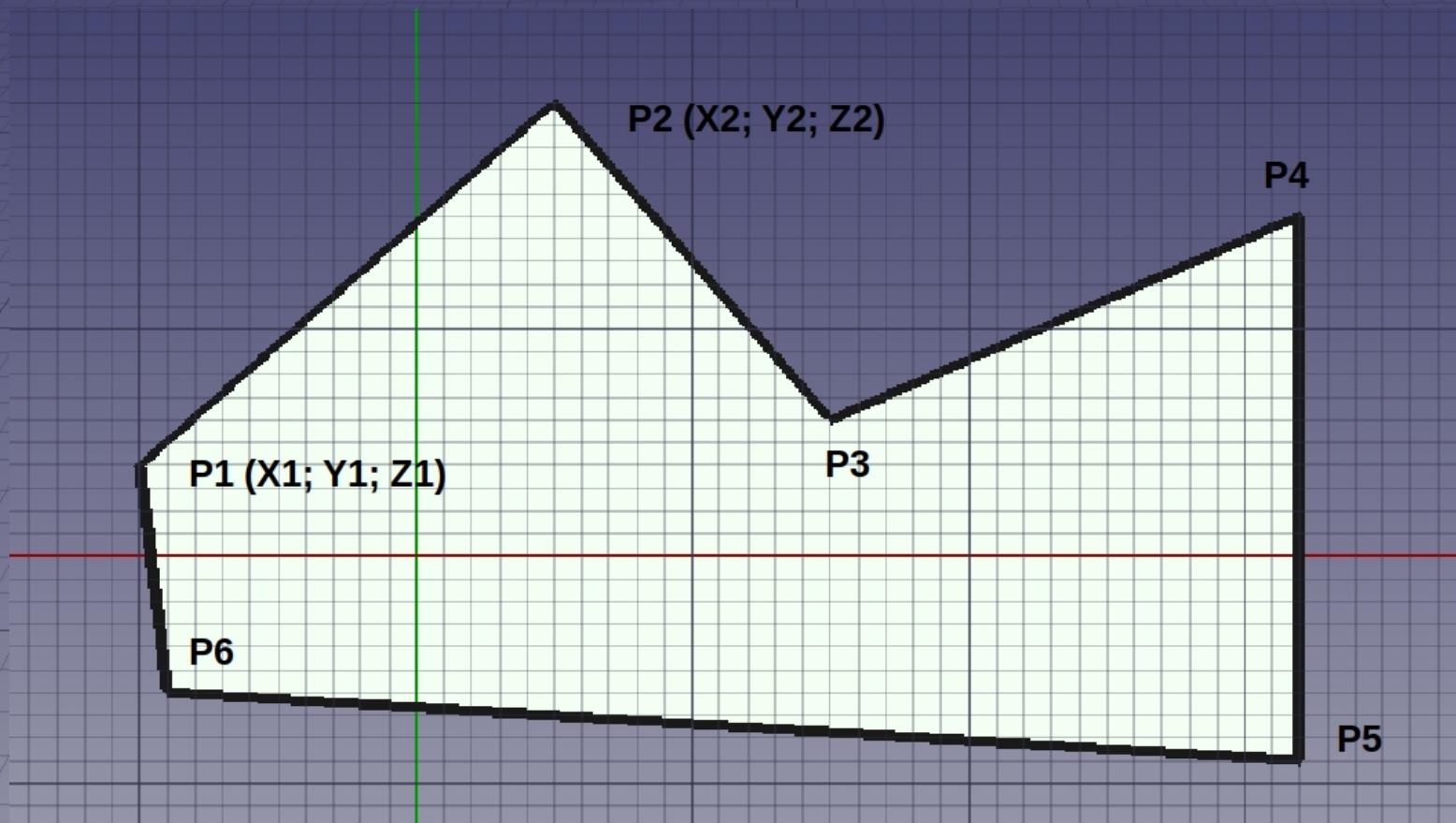
✓ Vazio



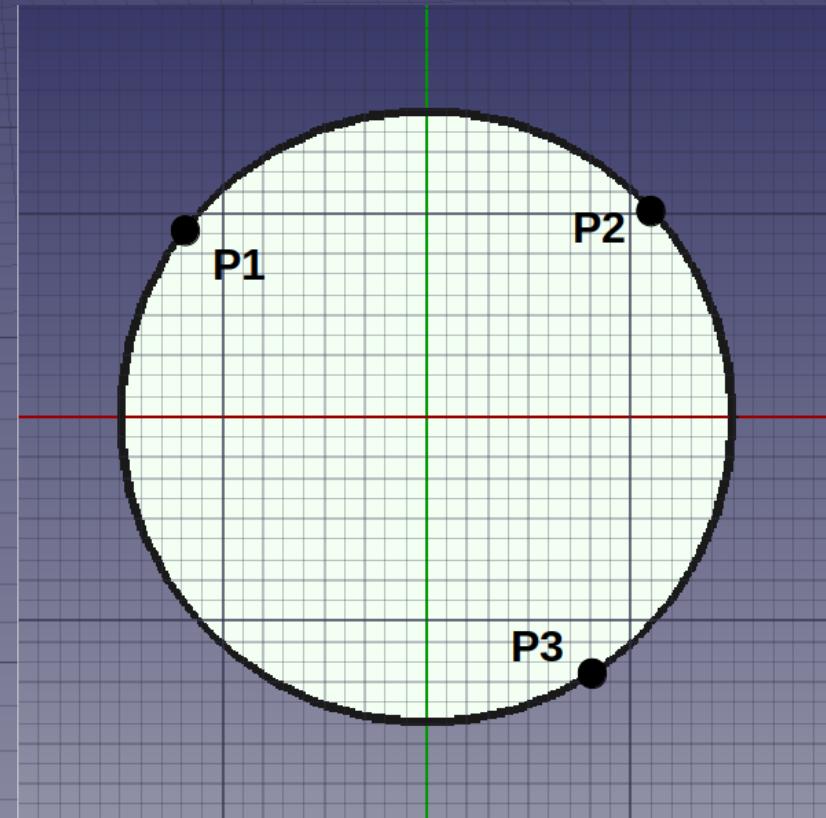
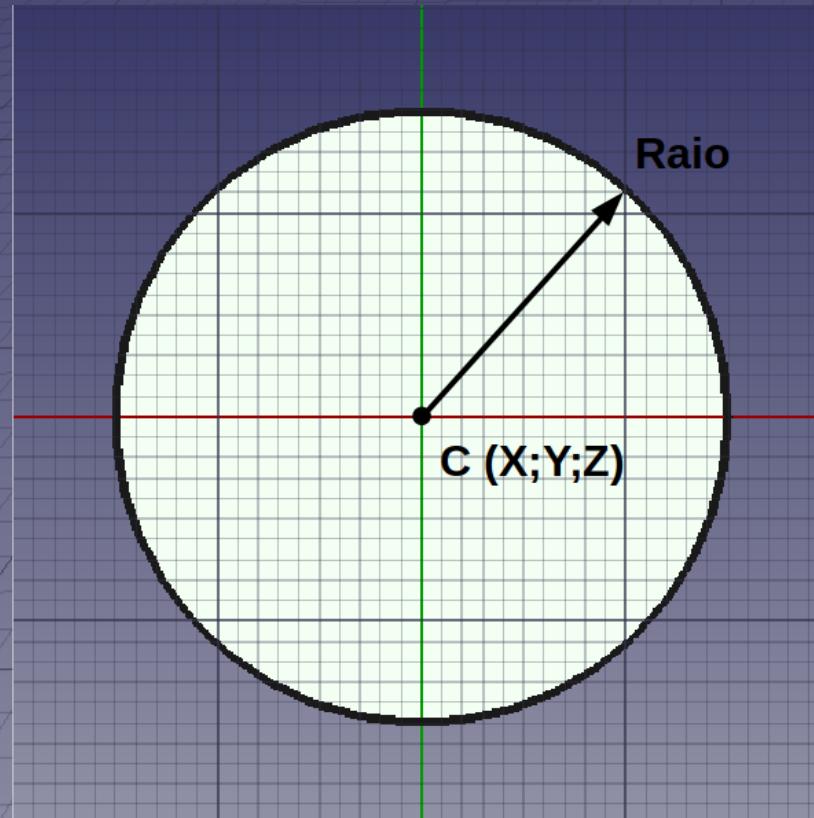
7.3.2 Polígono Regular



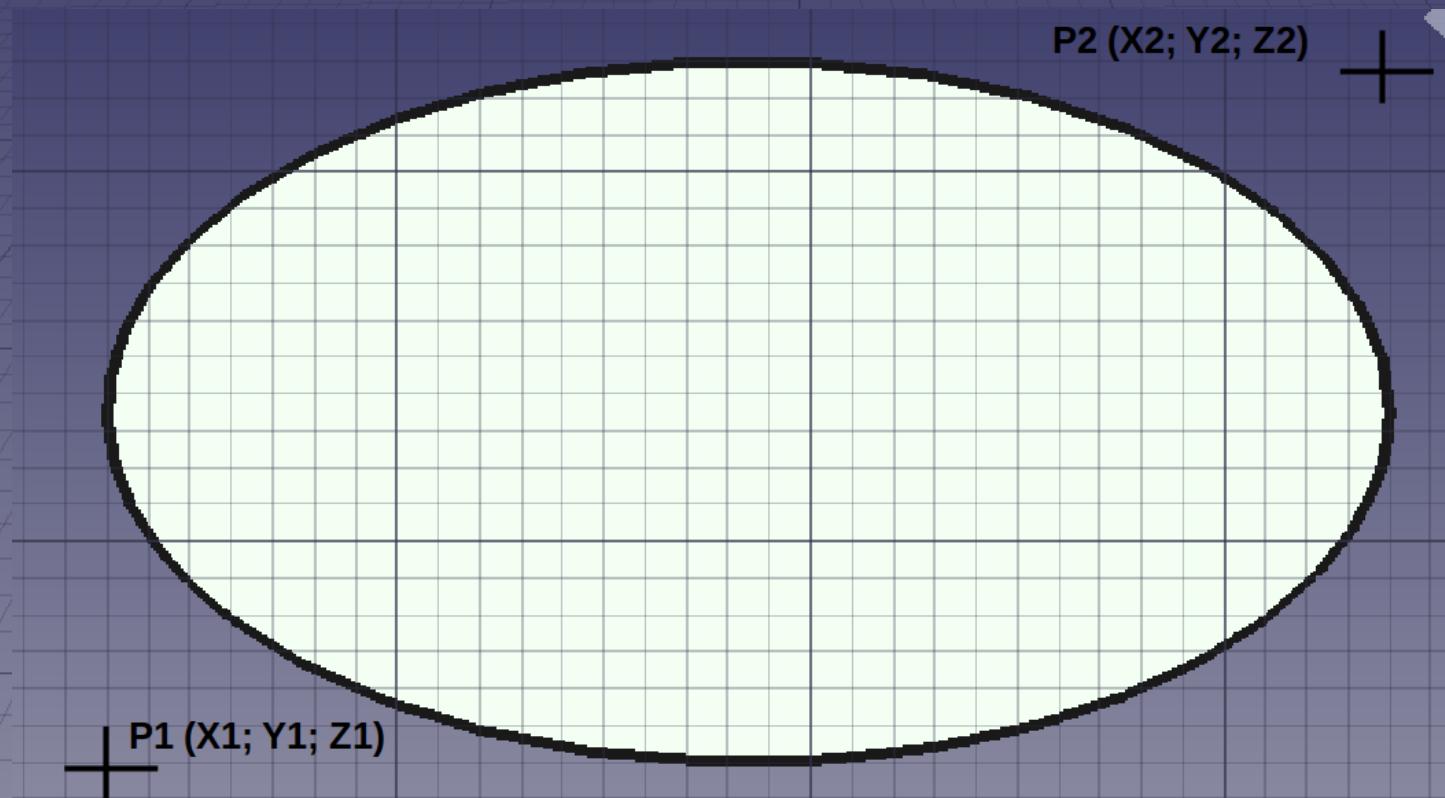
7.3.3 Polígono Irregular



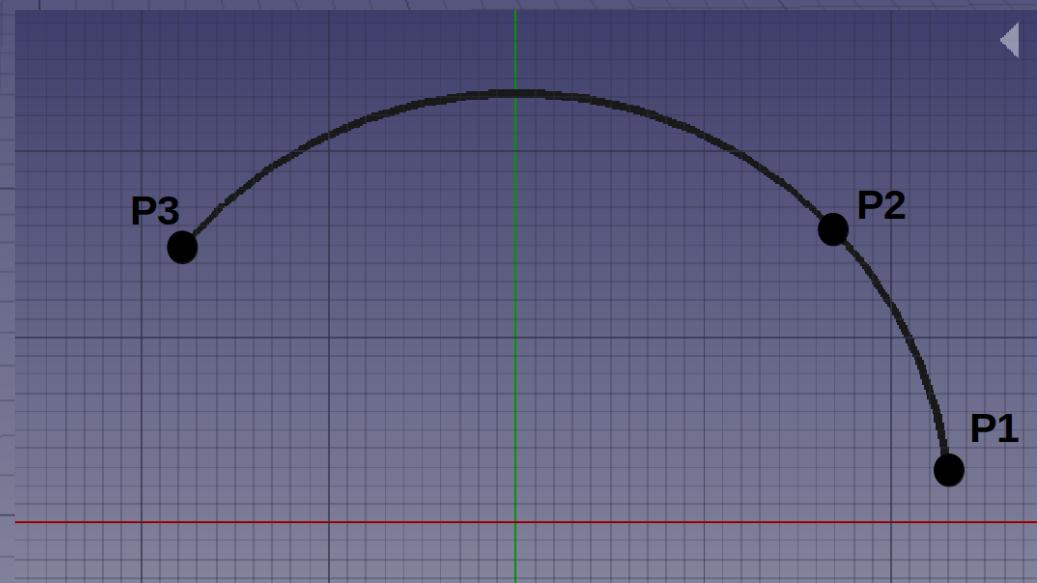
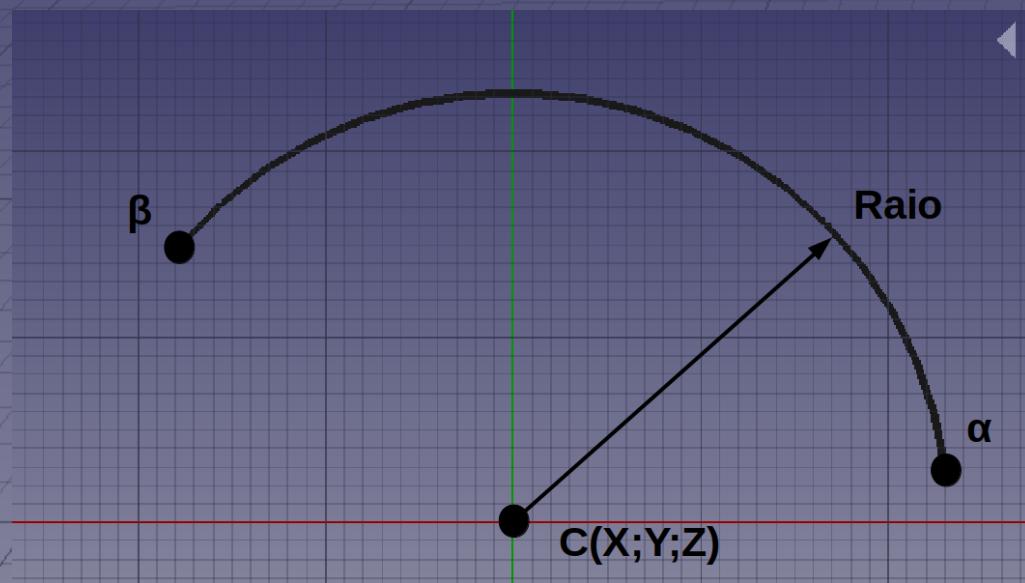
7.3.4 Círculo



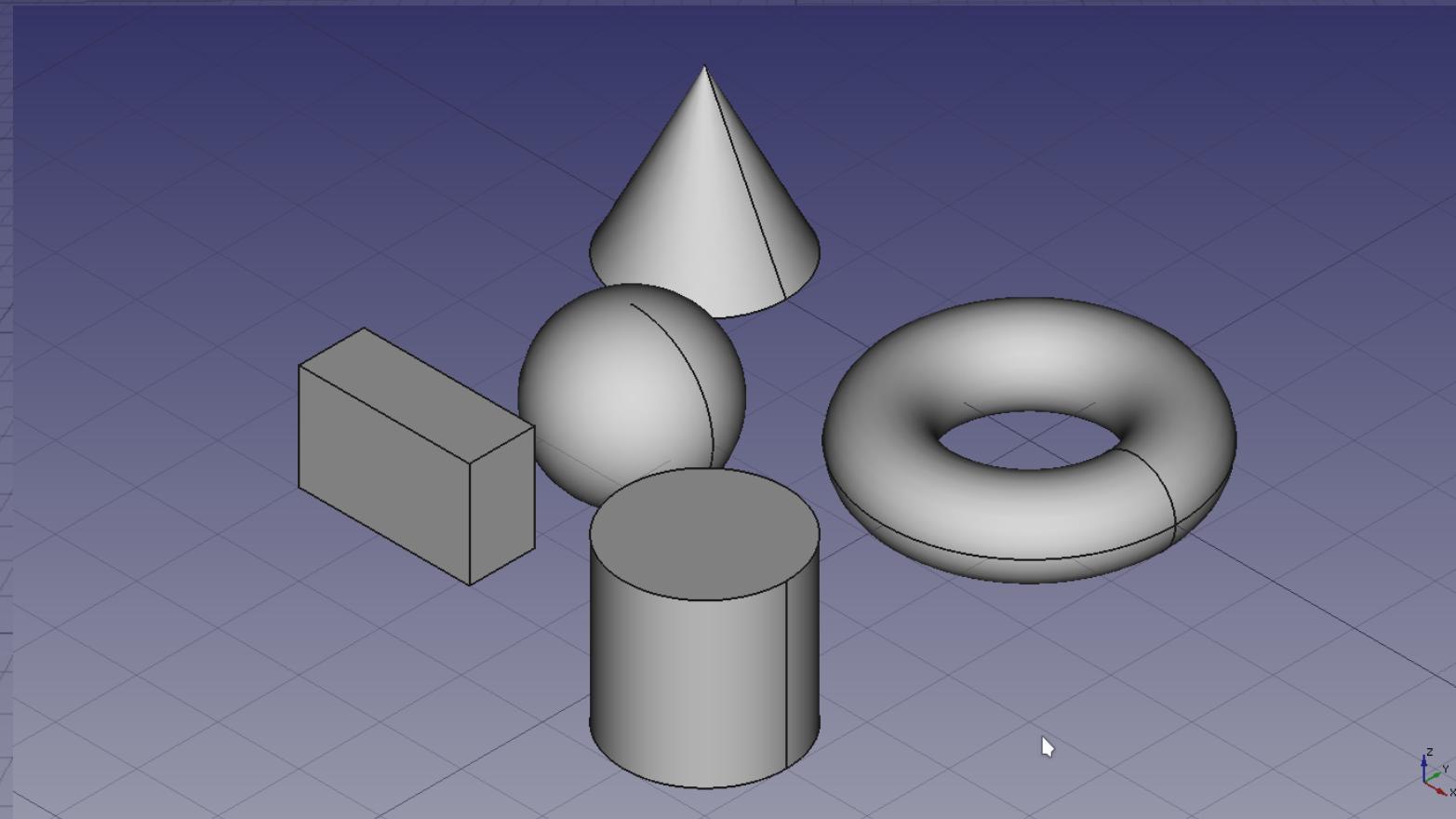
7.3.5 Elipse



7.3.6 Arco

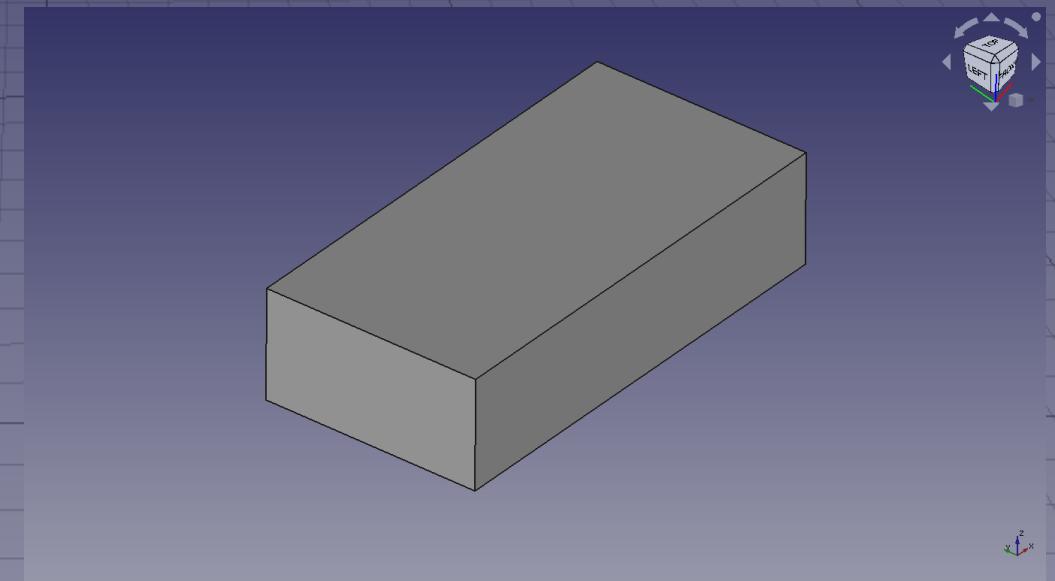


7.4 Primitivas



7.4.1 Paralelepípedo

- Posição
 - ✓ X
 - ✓ Y
 - ✓ Z
- Comprimento X
- Largura Y
- Altura Z



7.4.2 Esfera

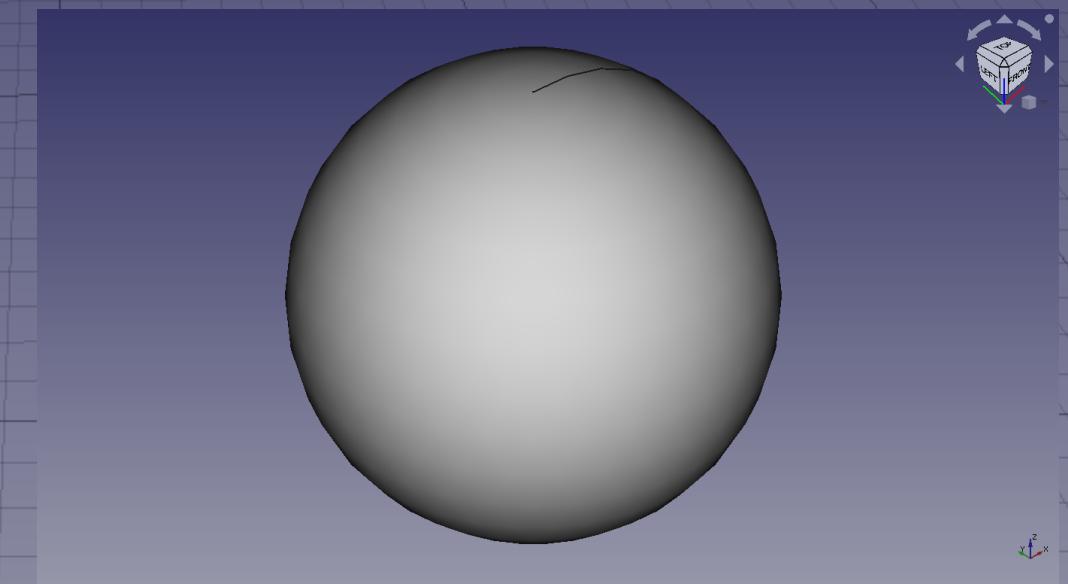
- Centro

- X

- Y

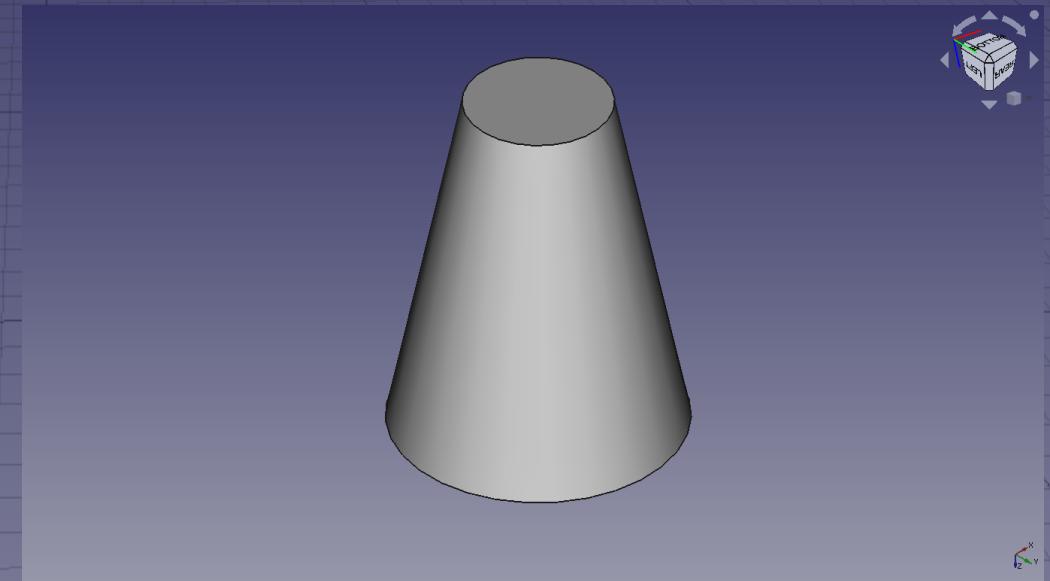
- Z

- Raio



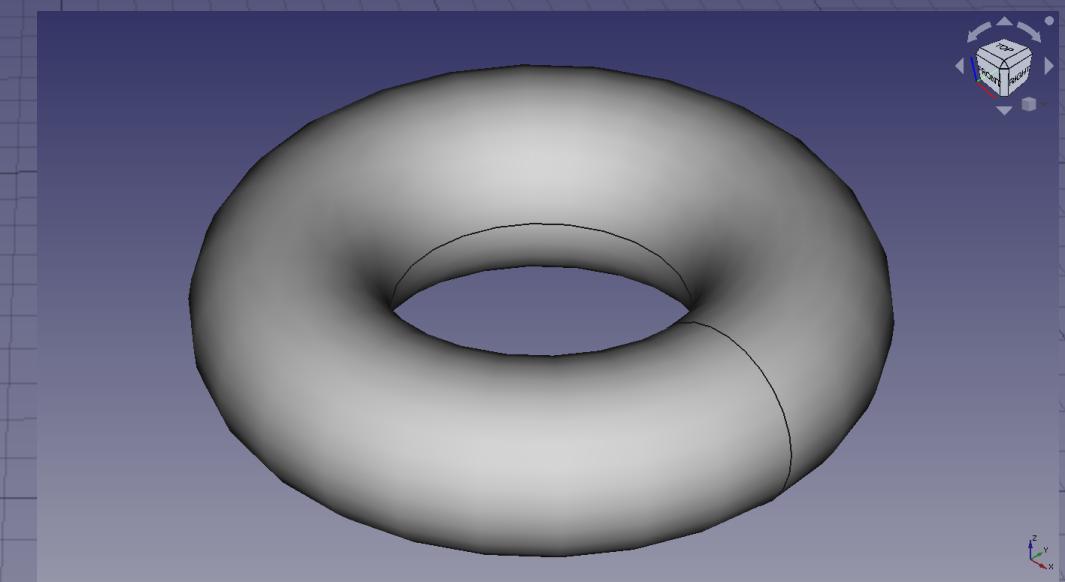
7.4.3 Cone

- Posição (Centro inferior)
 - ✓ X
 - ✓ Y
 - ✓ Z
- Altura
- Raio inferior
- Raio superior



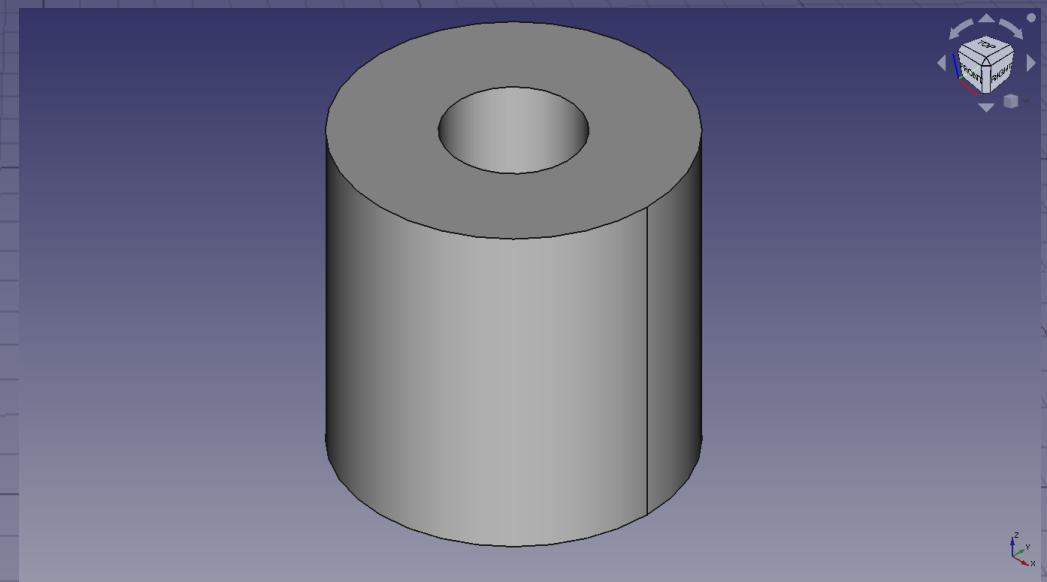
7.4.4 Torus

- Posição (Centro)
- Raio do toróide
- Raio do tubo



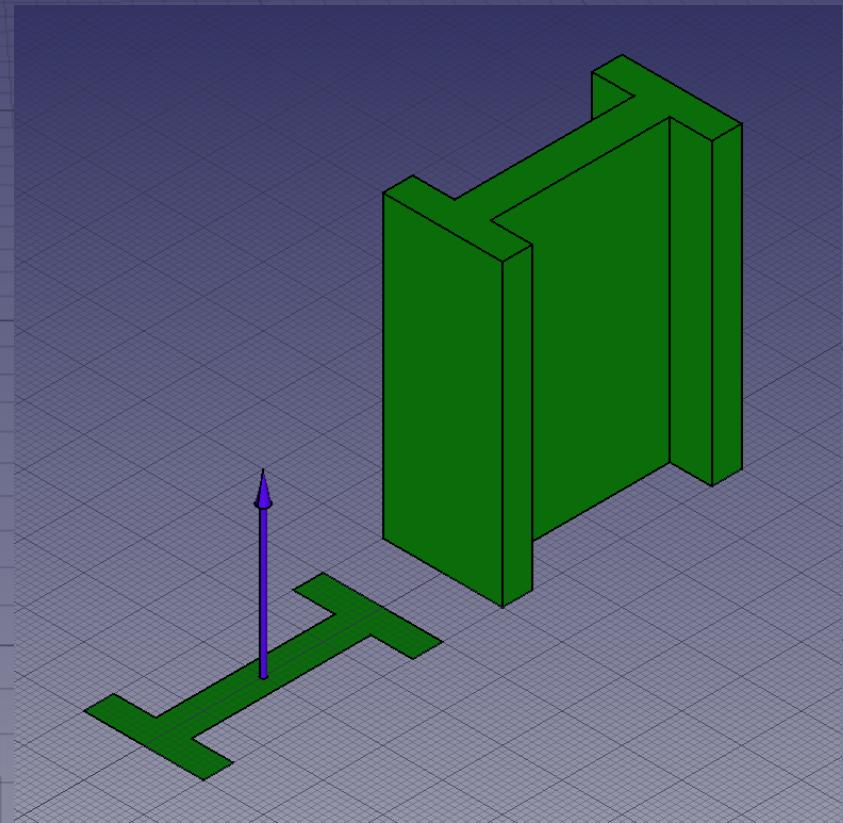
7.4.5 Tubo

- Posição (Centro inferior)
- Raio interno
- Raio externo
- Altura



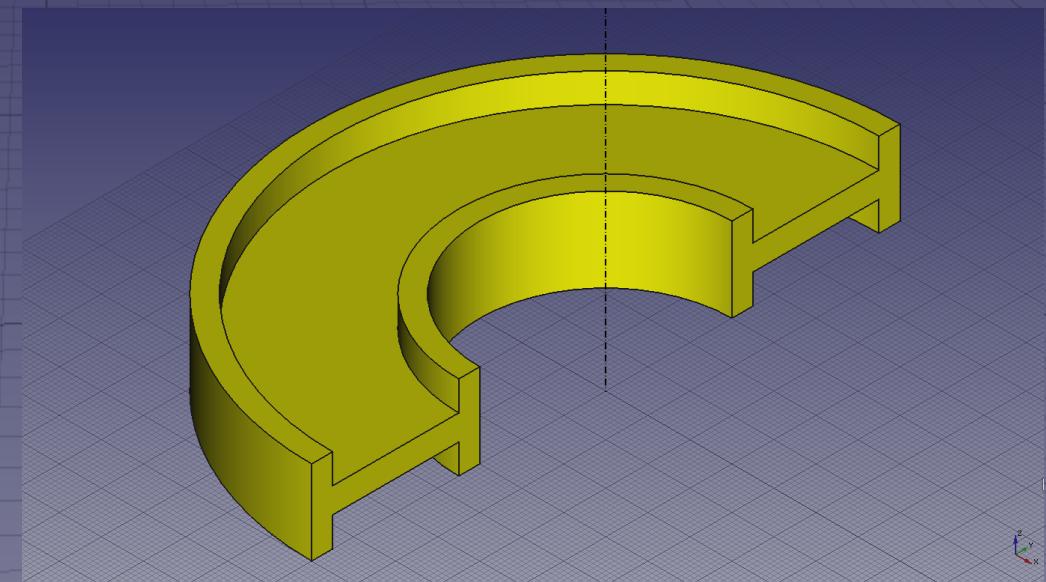
7.5 Extrusão

- Perfil
- Altura
- Ângulo de extrusão



7.6 Revolução

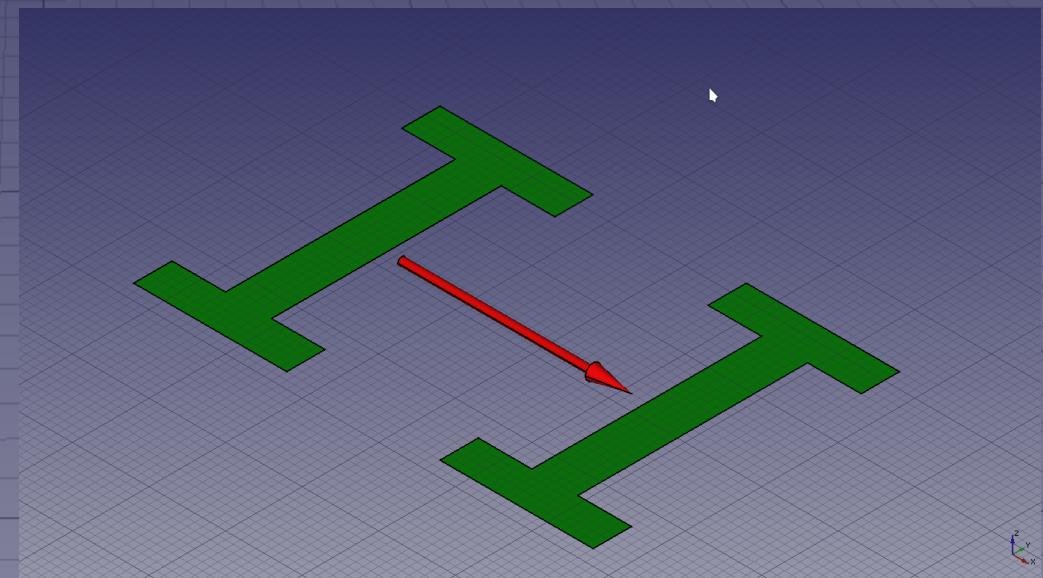
- Perfil
- Eixo de revolução
- Ângulo de revolução



7.7 Operações geométricas

7.7.1 Mover

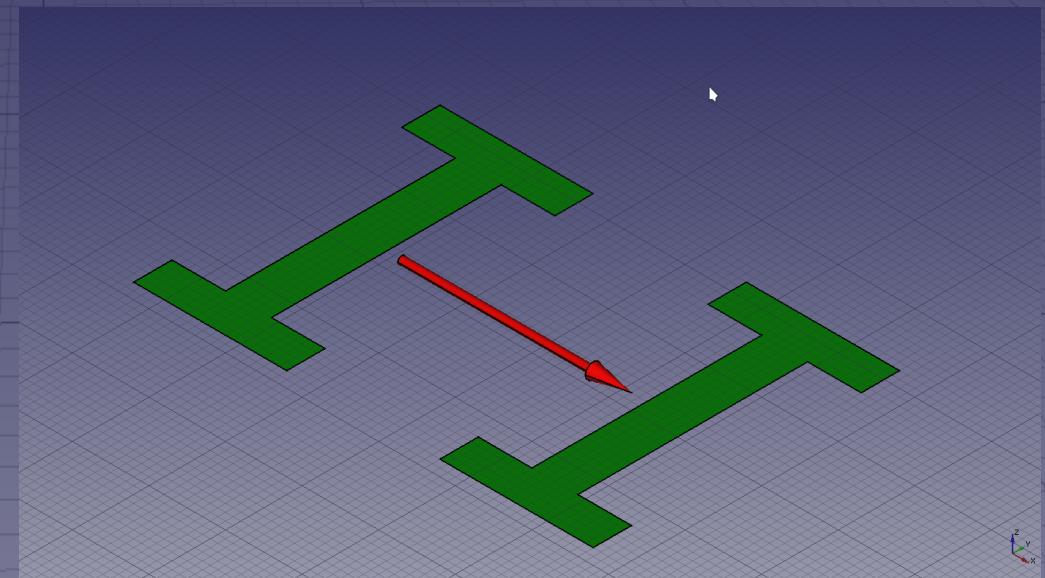
- Ponto de origem
- Ponto de destino



7.7.2 Copiar

Copiar é uma opção da função **Mover**.

- Ponto de origem
- Ponto de destino



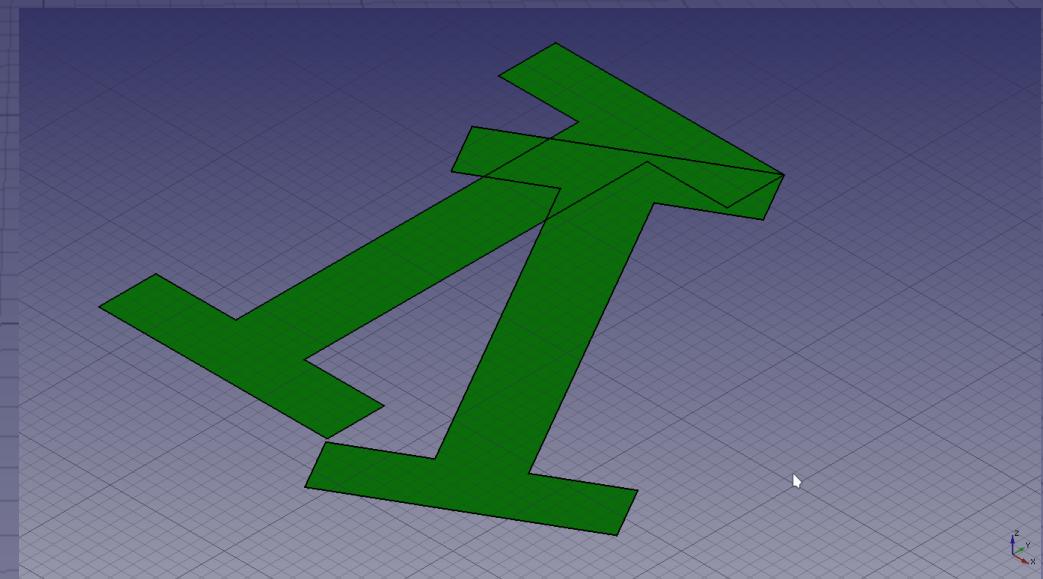
7.7.3 Clonar

- Um clone é uma cópia sincronizada.
- Dimensões do clone acompanham as dimensões do objeto.
- Posição e rotação independentes.



7.7.4 Rotacionar

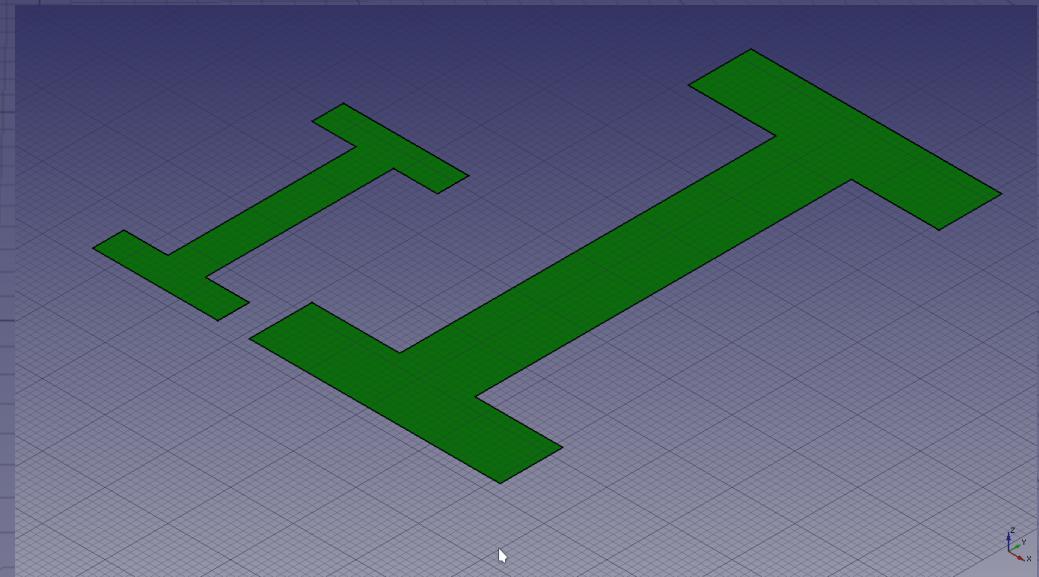
- Centro de rotação.
- Ponto ou ângulo de origem.
- Ponto ou ângulo de destino.



7.7.5 Escalonar

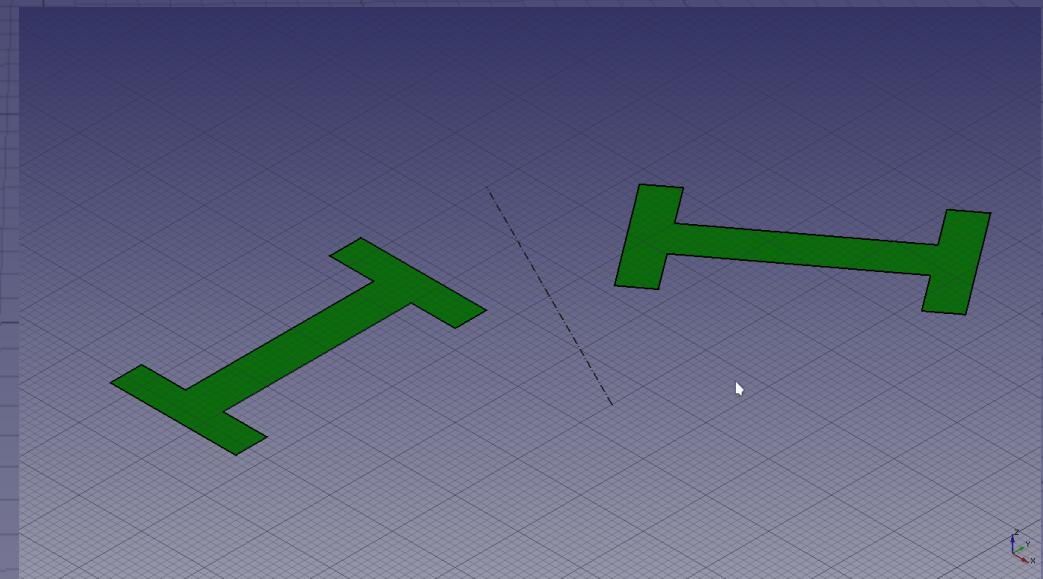
- Ponto de referência.
- Fator de escala.

- ✓ X
- ✓ Y
- ✓ Z



7.7.6 Espelhar

- Eixo de referência.
- Direção de referência.



7.8 Arrays

Cópias em sequências.

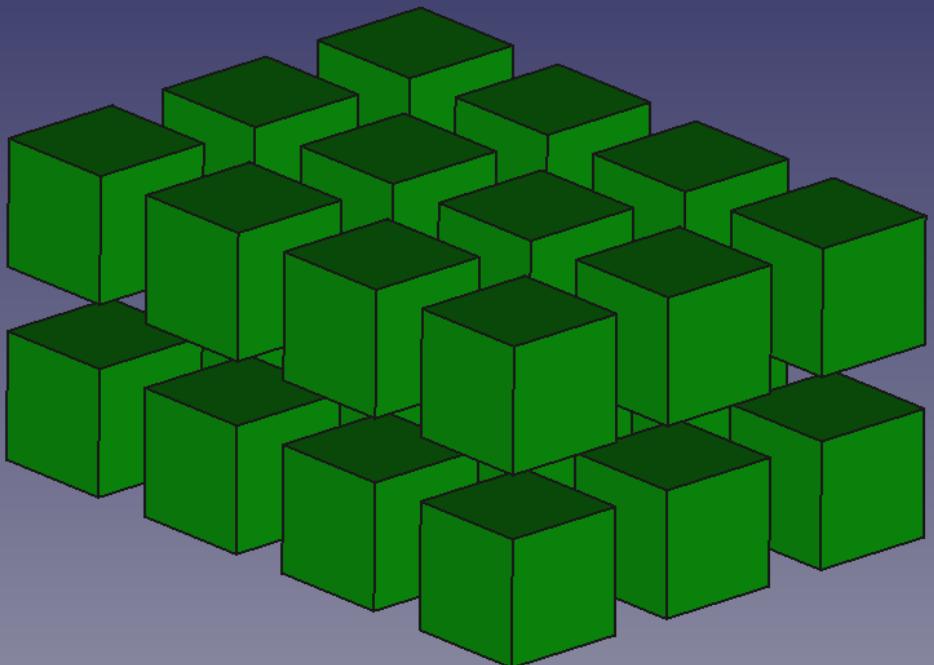
7.8.1 Array

- Quantidade

- ✓ nX
- ✓ nY
- ✓ nZ

- Intervalo

- ✓ dX
- ✓ dY
- ✓ dZ

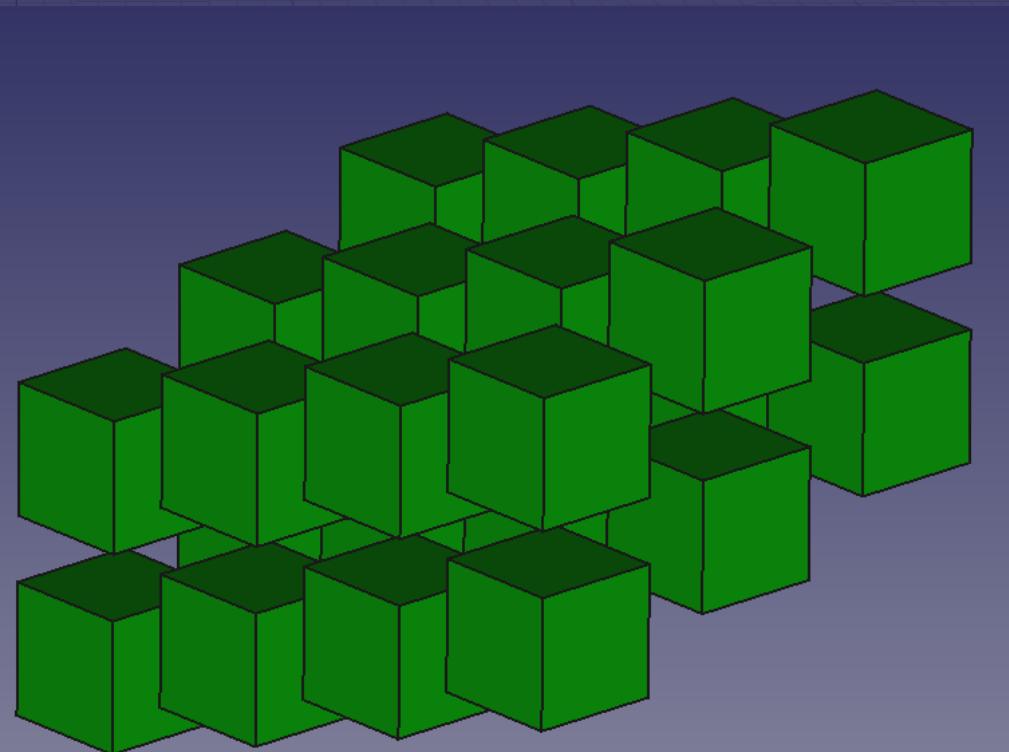


- Quantidade

- ✓ nX
- ✓ nY
- ✓ nZ

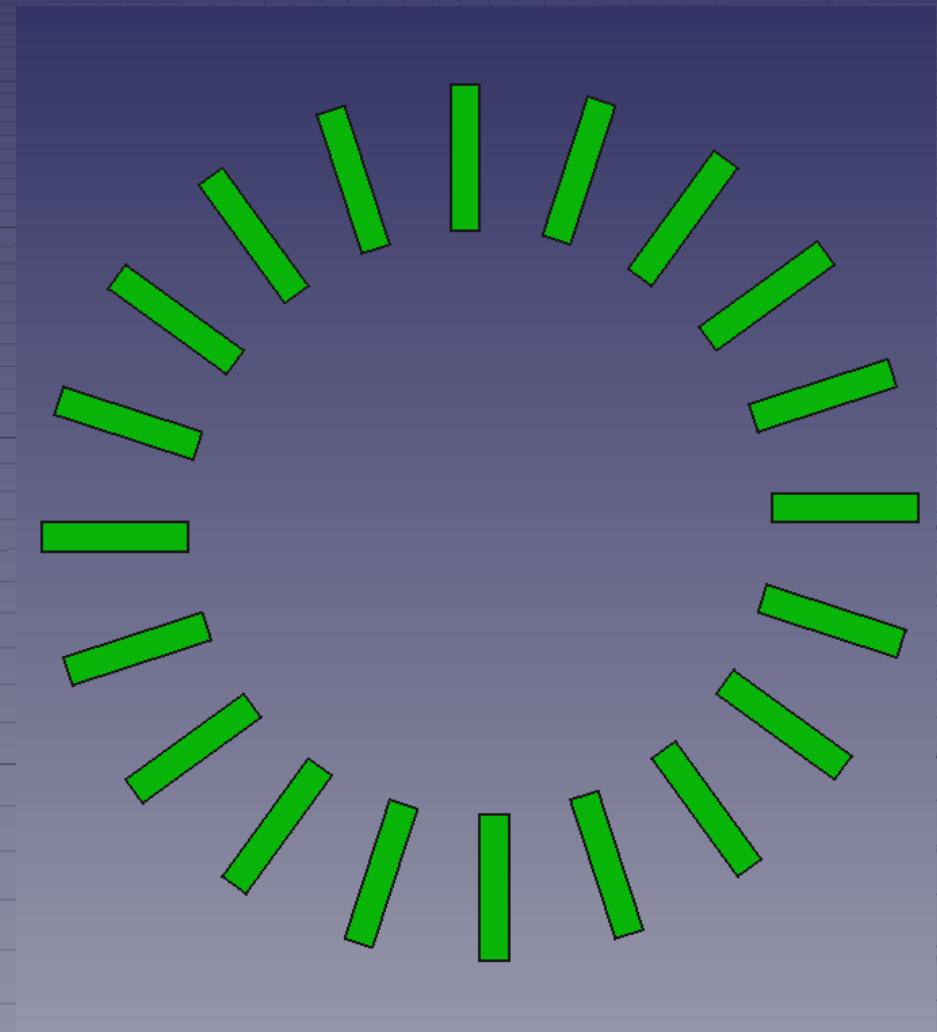
- Intervalo

- ✓ X-X
- ✓ X-Y
- ✓ X-Z
- ✓ Y-X
- ✓ Y-Y
- ✓ Y-Z
- ✓ Z-X
- ✓ Z-Y
- ✓ Z-Z

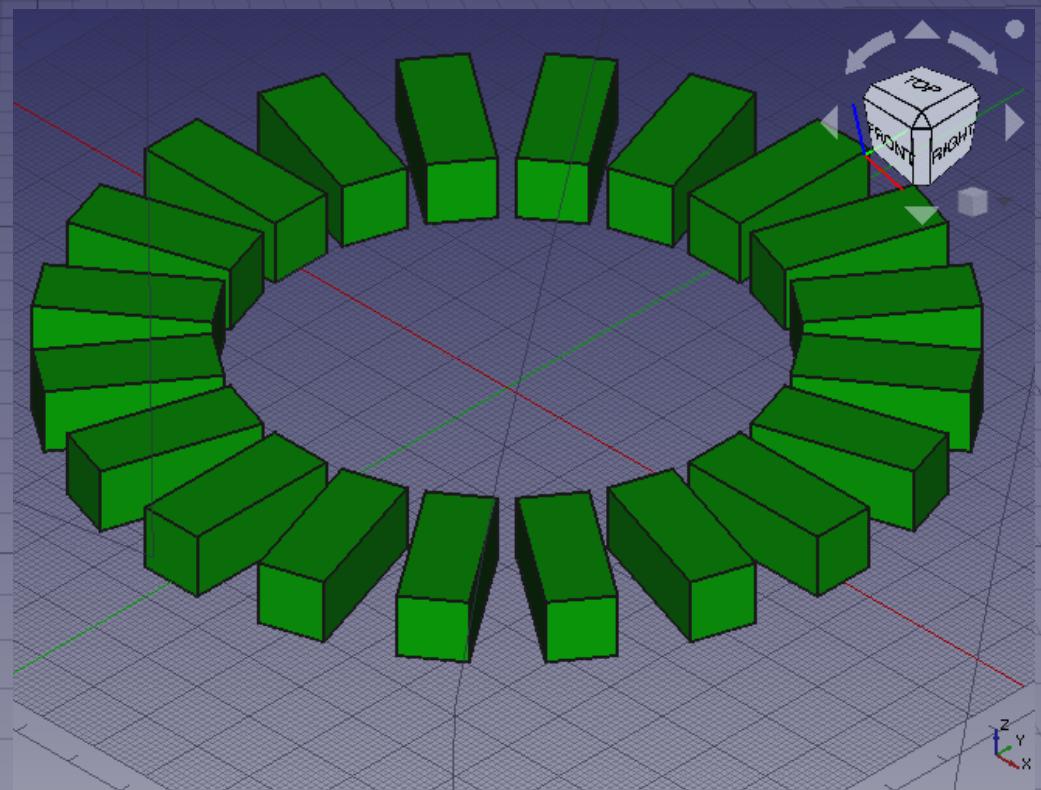


7.8.2 Polar Array

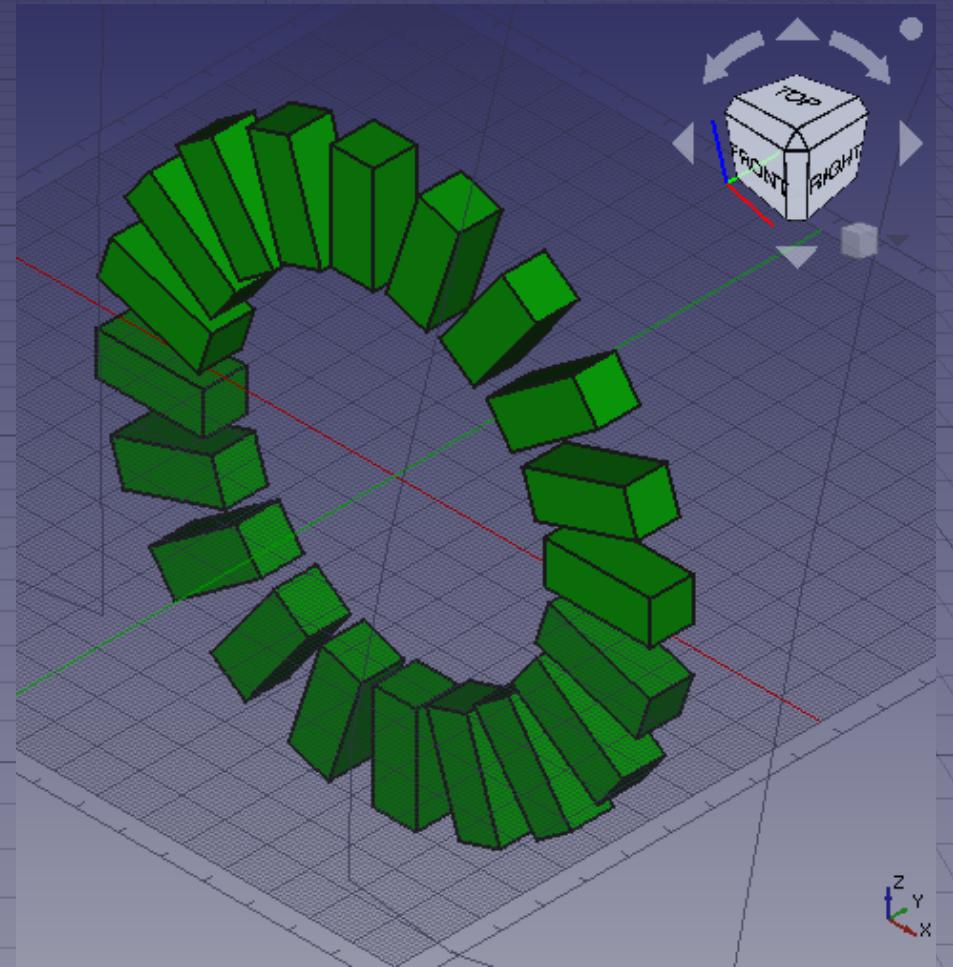
- Centro (X; Y; Z)
- Quantidade
- Ângulo
- Eixo de rotação



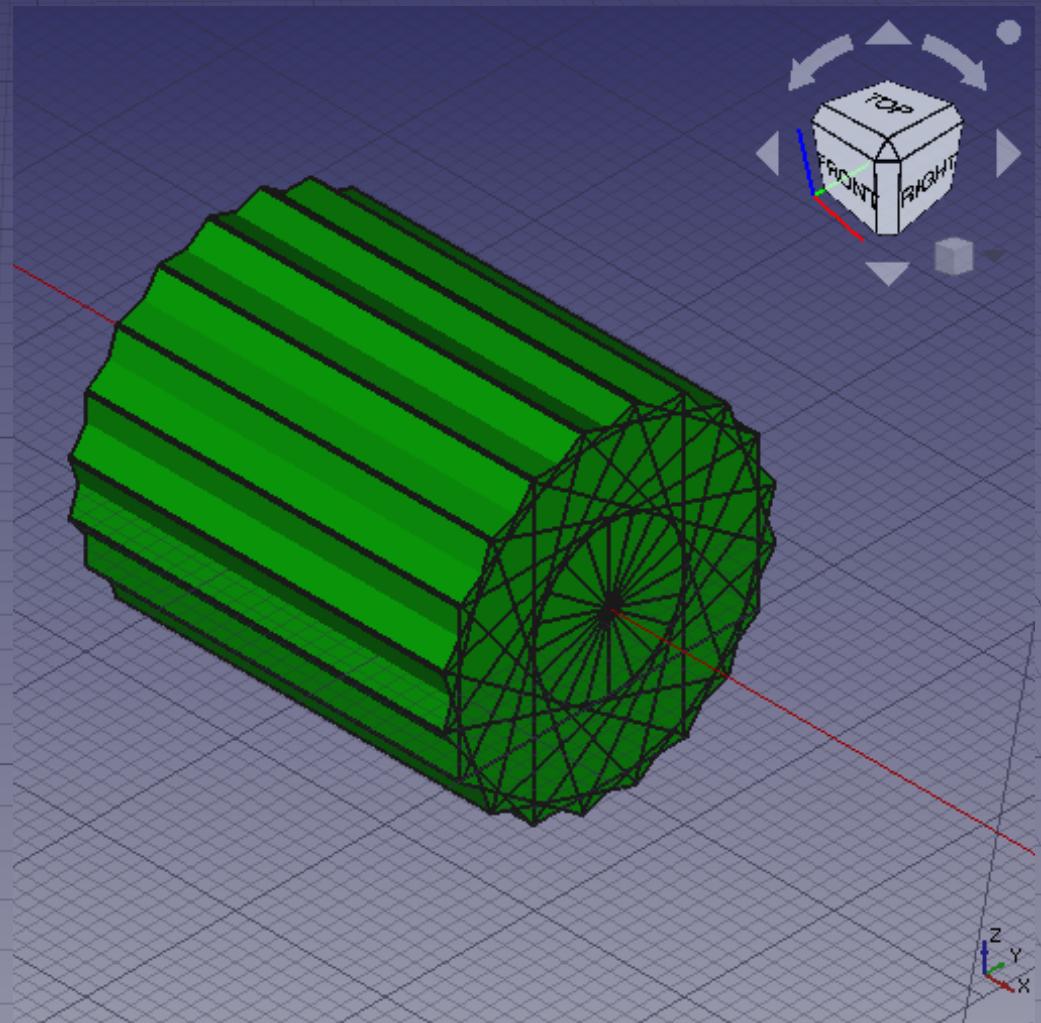
- Centro (X; Y; Z)
- Quantidade
- Ângulo
- Eixo de rotação
 - ✓ eX
 - ✓ eY
 - ▷ eZ



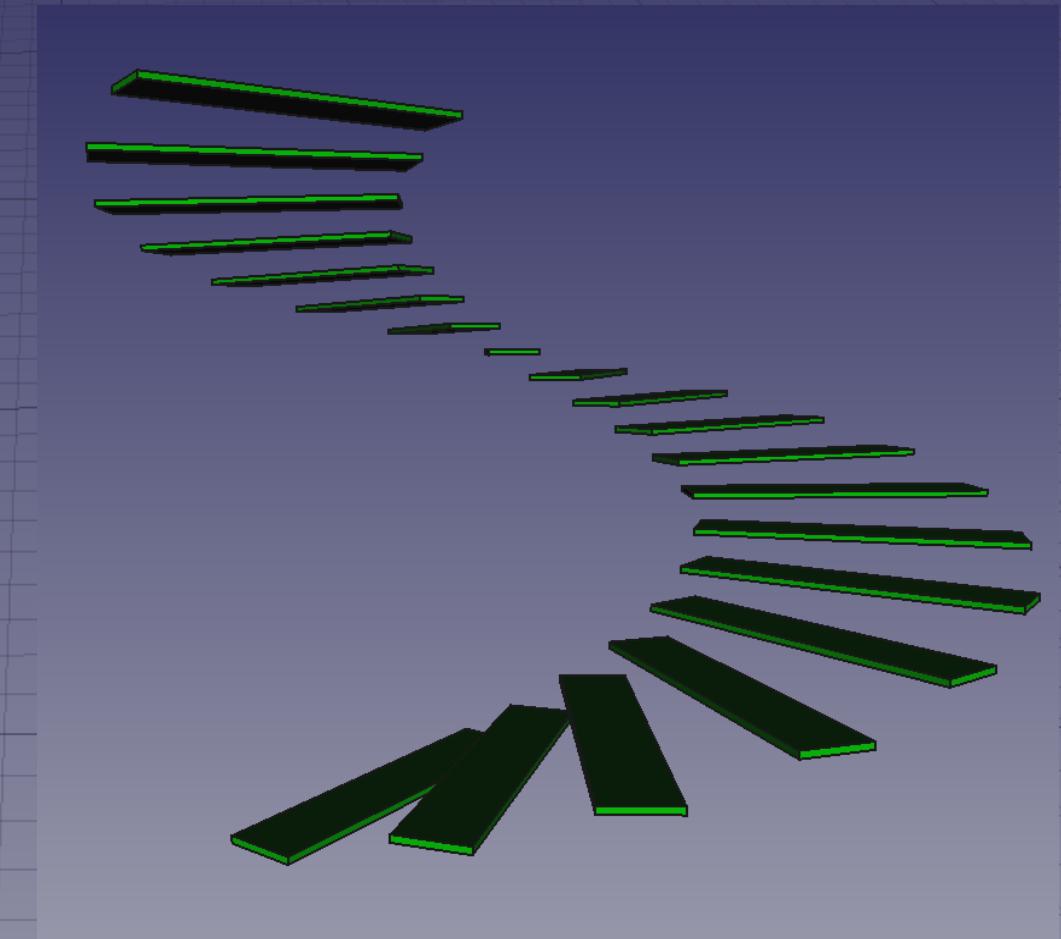
- Centro (X; Y; Z)
- Quantidade
- Ângulo
- Eixo de rotação
 - ✓ eX
 - ▷ eY
 - ✓ eZ



- Centro (X; Y; Z)
- Quantidade
- Ângulo
- Eixo de rotação
 - ▷ eX
 - ✓ eY
 - ✓ eZ

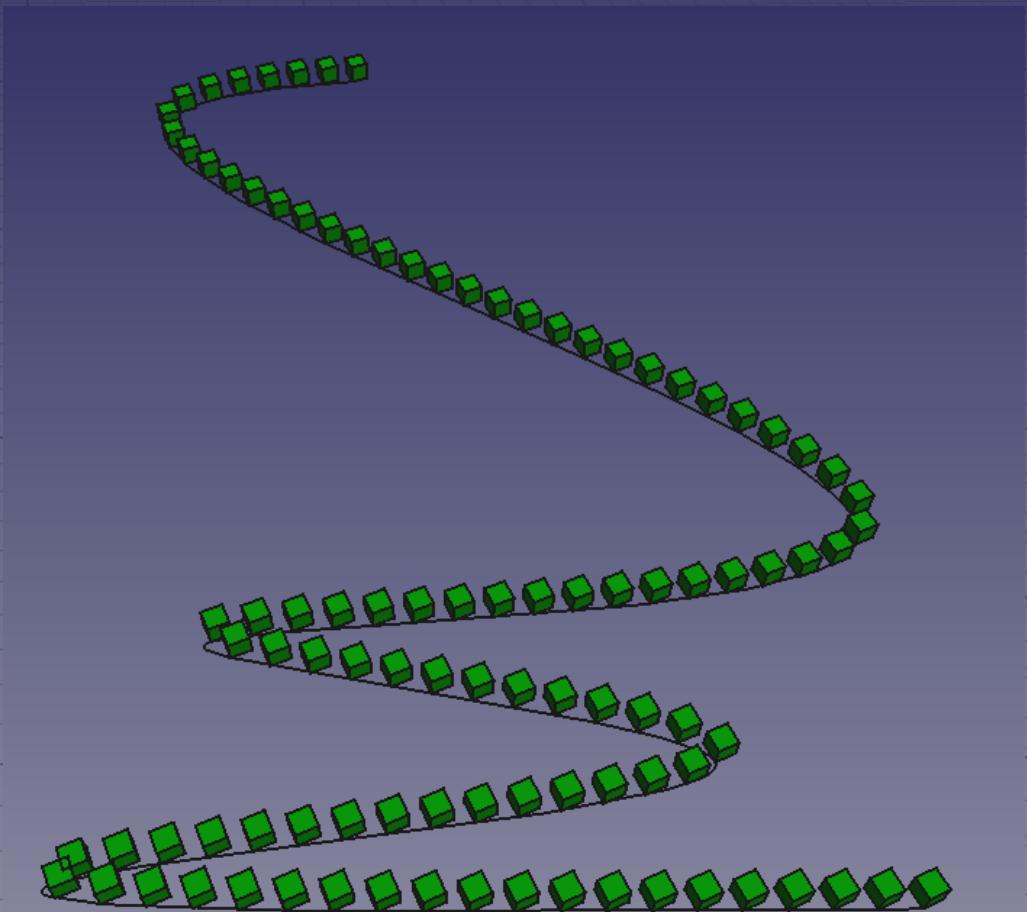


- Centro (X; Y; Z)
- Quantidade
- Ângulo
- Eixo de rotação
 - ✓ eX
 - ✓ eY
 - ✓ eZ
- Intervalo
 - ✓ dX
 - ✓ dY
 - ✓ dZ



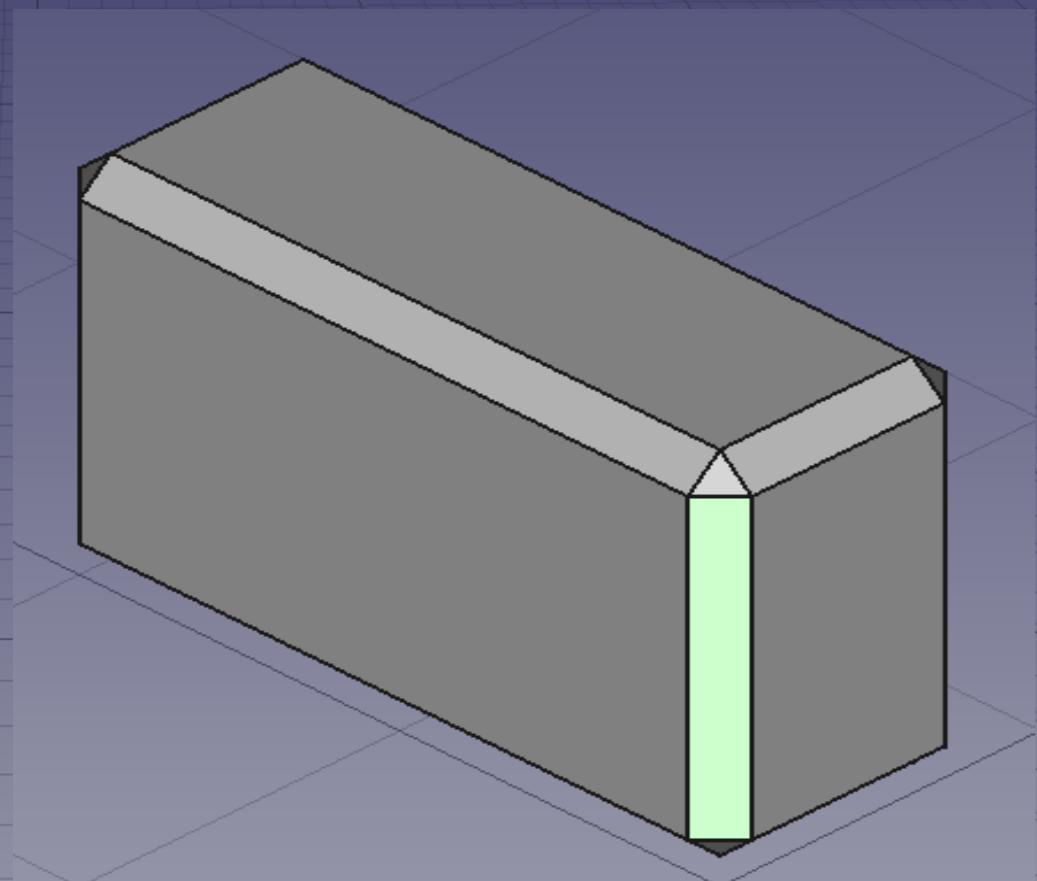
7.8.3 Path Array

- Caminho (linha, polilinha, bezier ou spline)
- Quantidade



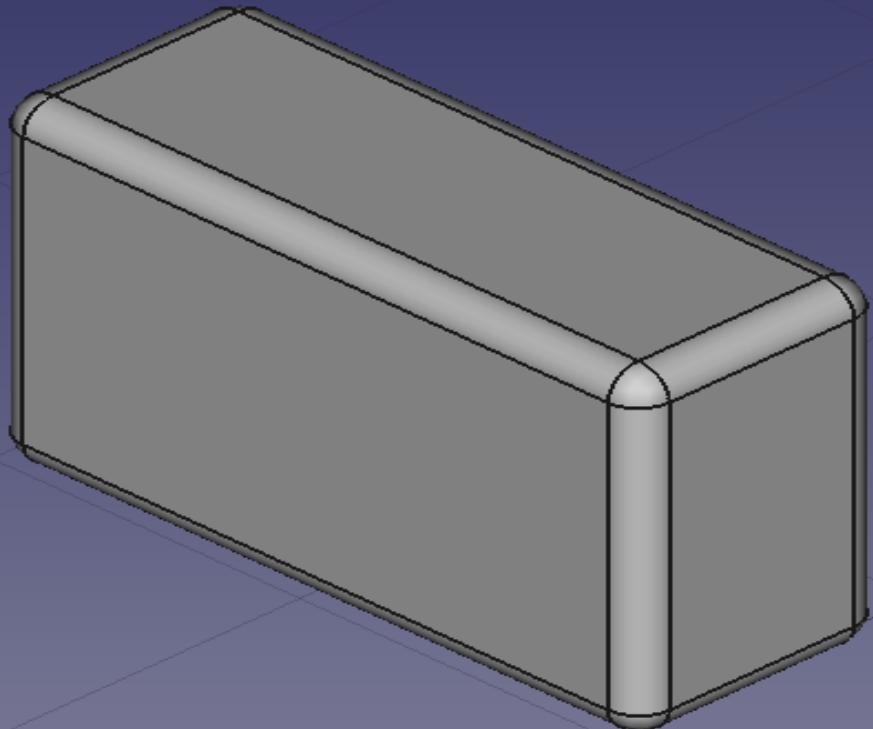
7.9 Chanfrar

- Areias a chanfrar
- Distância 1
- Distância 2



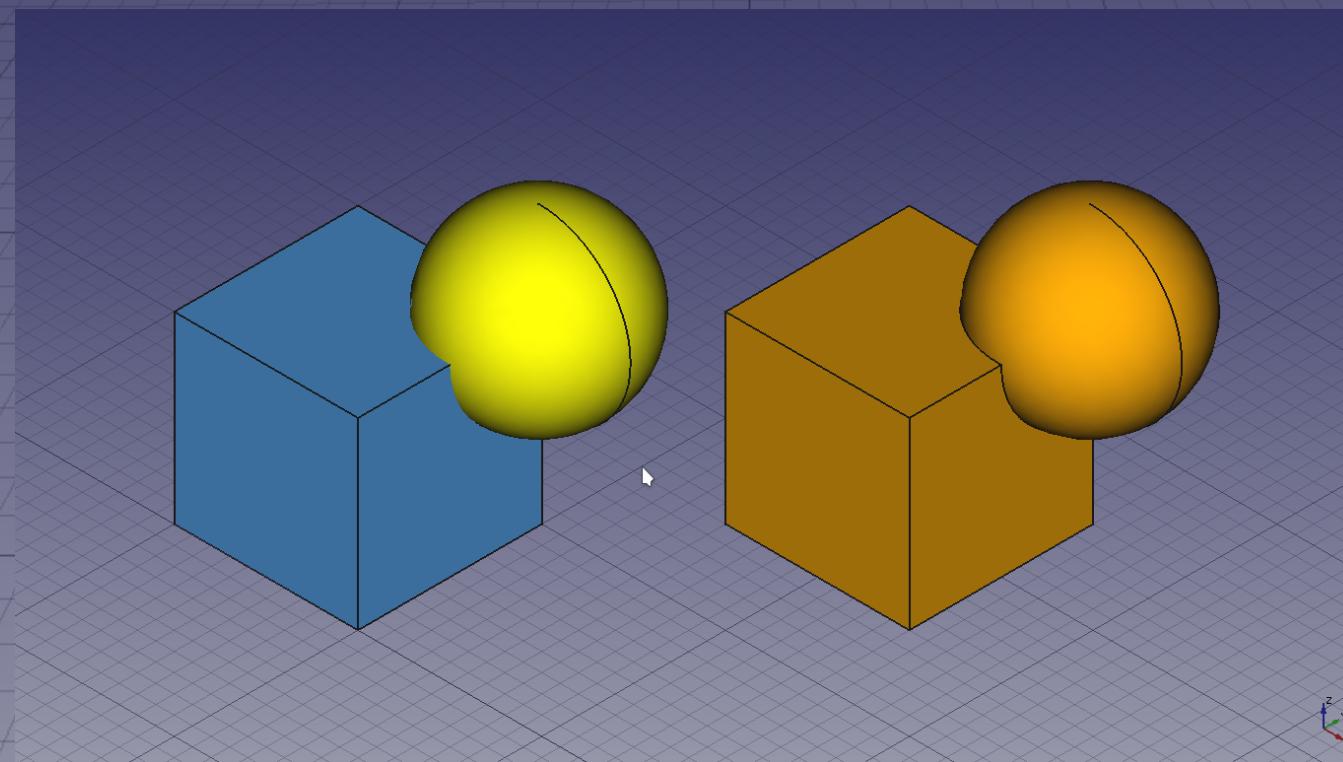
7.10 Arredondar

- Areias a arredondar
- Raio

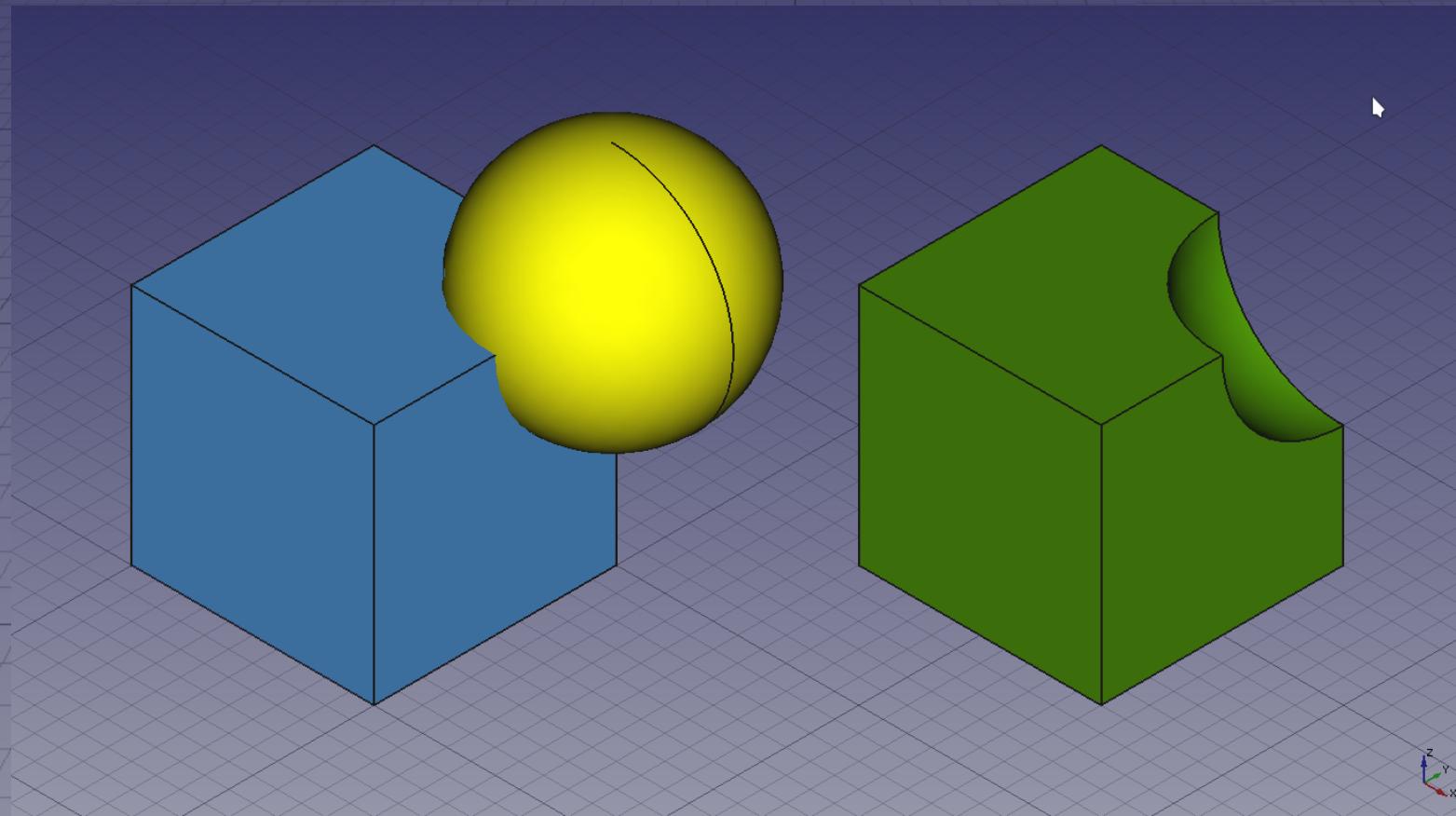


7.11 Operações Booleanas

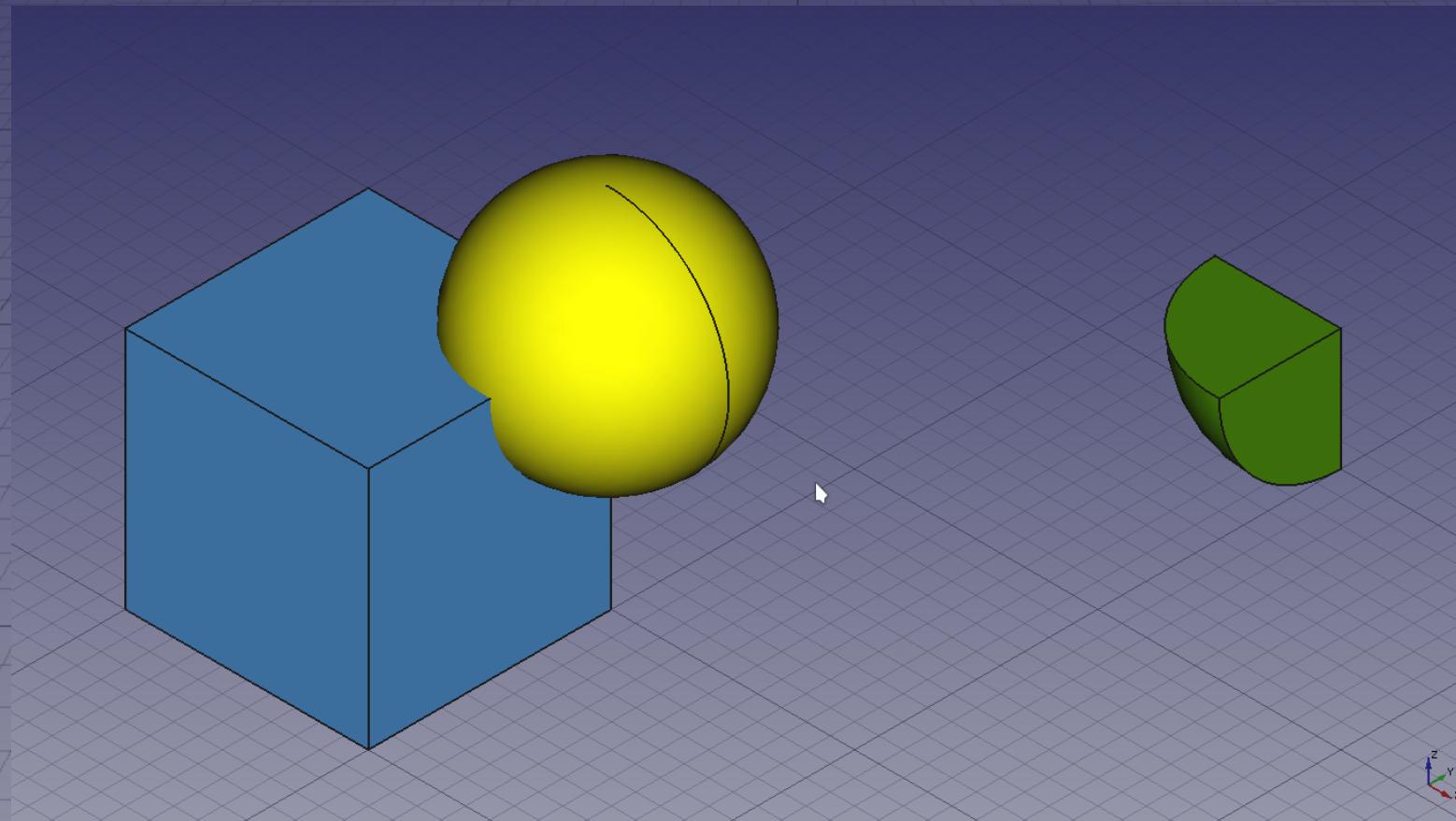
7.11.1 União



7.11.2 Subtração



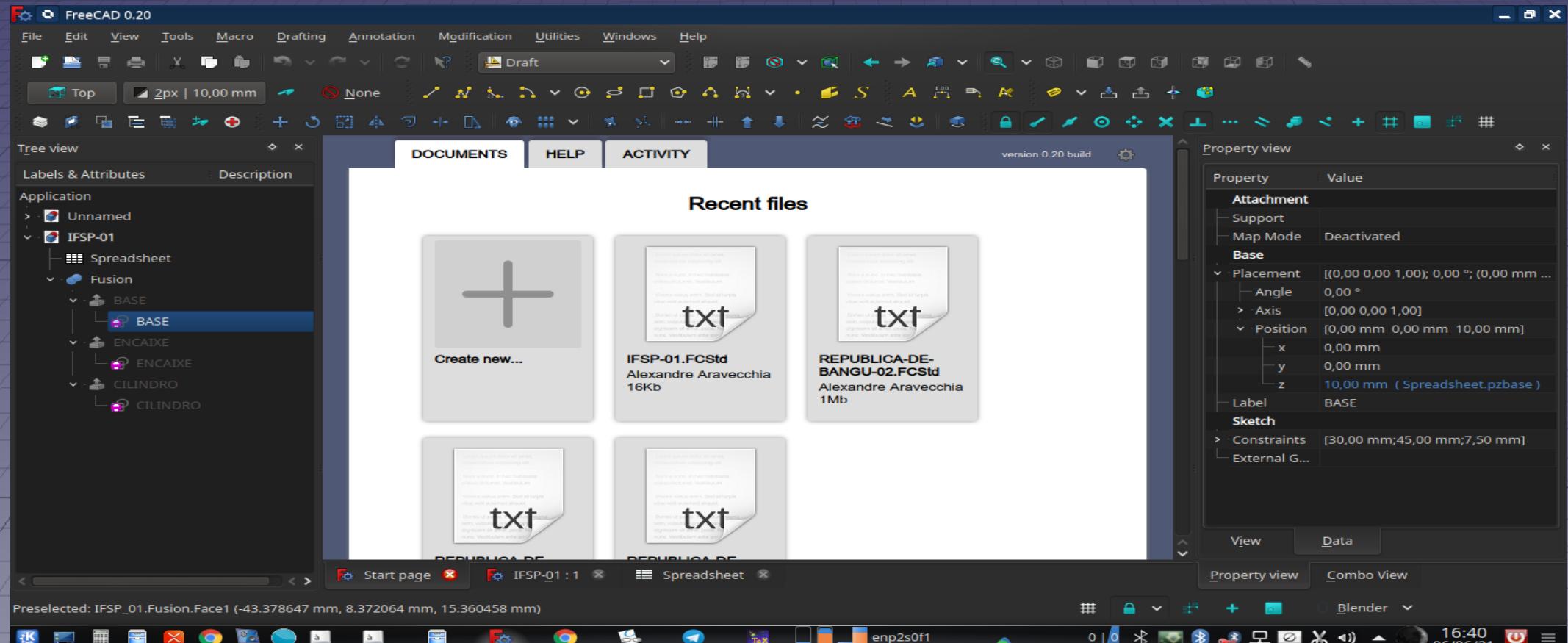
7.11.3 Intersecção

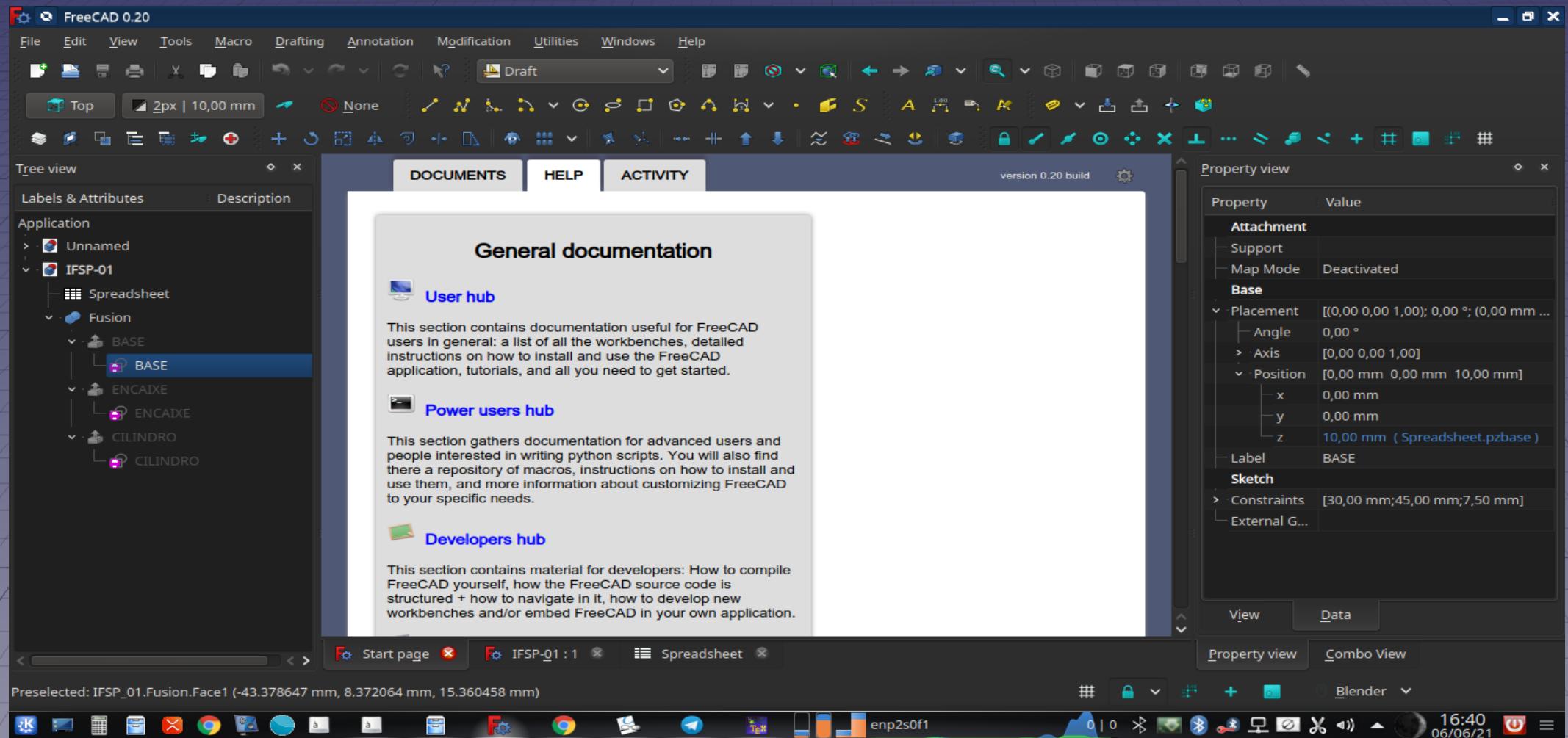


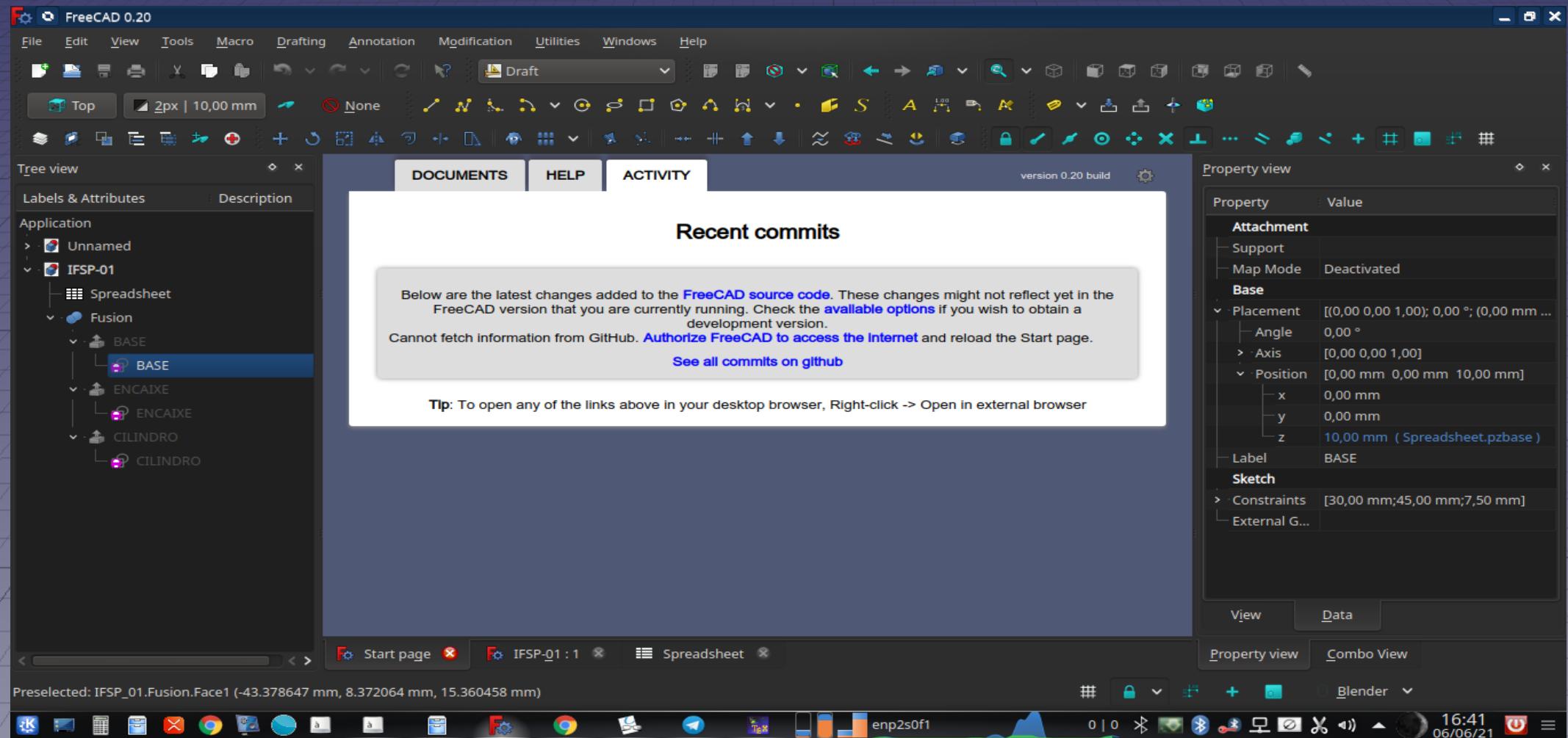
8 Workbenches

- Bancadas de trabalho
- Conceito de linha de produção
 - ✓ Ferramentas específicas em bancadas específicas
- Workflow
 - ✓ Fluxo de trabalho
 - ✓ Etapas do processo
 - ✓ Como se fabrica uma mesa?
 - ▷ Qual material?
 - ▷ Que ferramentas?
 - ▷ Quais técnicas?
 - ▷ Qual finalidade?

8.1 Start







8.2 Draft



- Formas planas
- Operações geométricas
- Transformações geométricas
- Organização de objetos
- Planos de trabalho
- Texto
- Anotações

8.2.1 Desenho



8.2.2 Modificação



8.2.3 Anotações



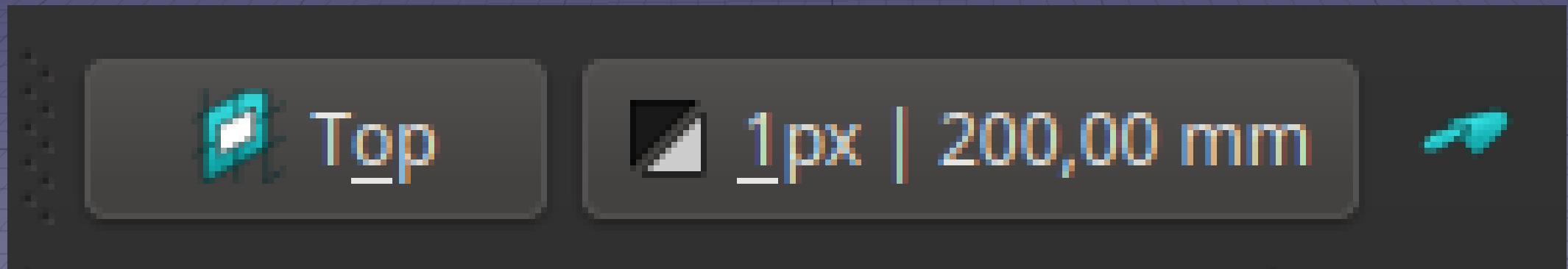
8.2.4 Visualização



8.2.5 Draft Snap



8.2.6 Planos de Trabalho



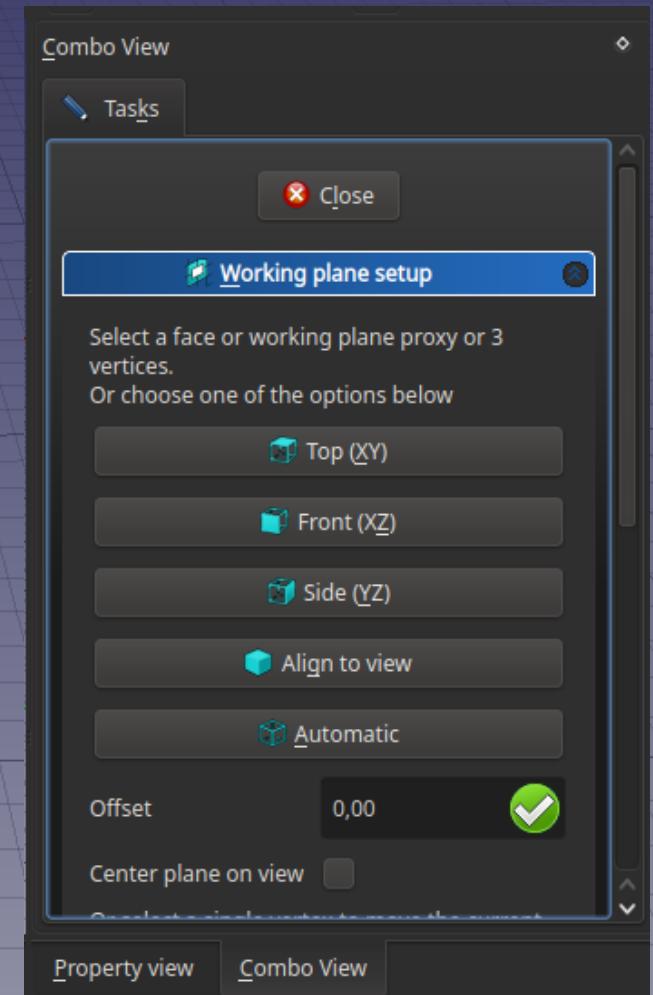
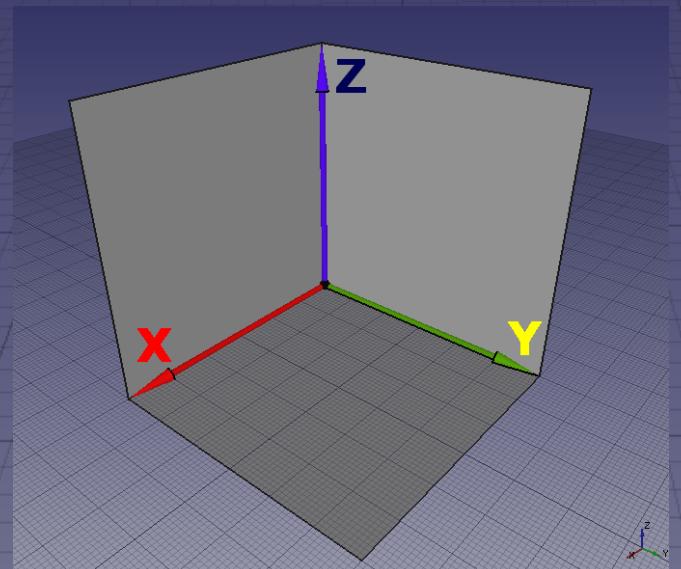
XY

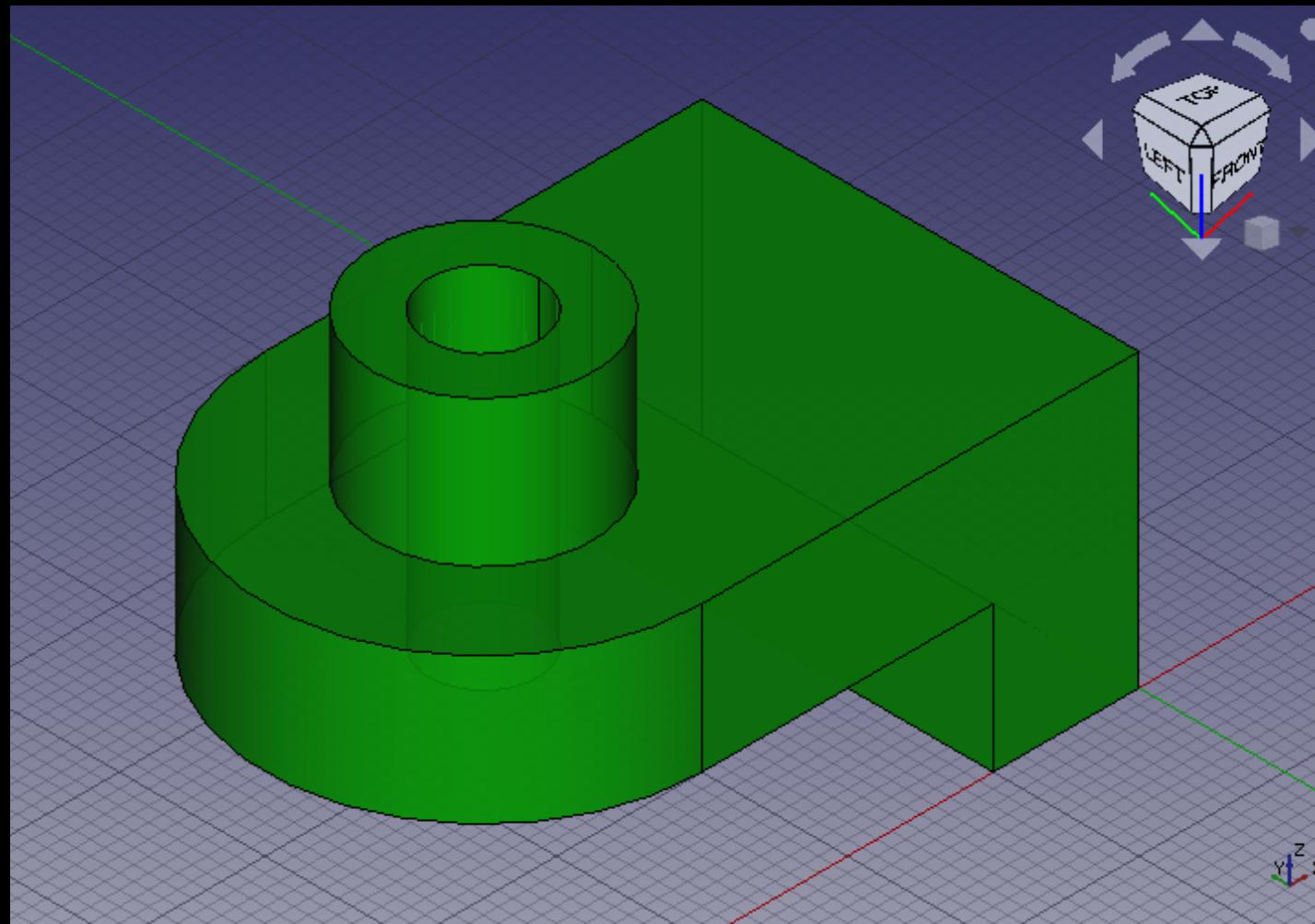
XZ

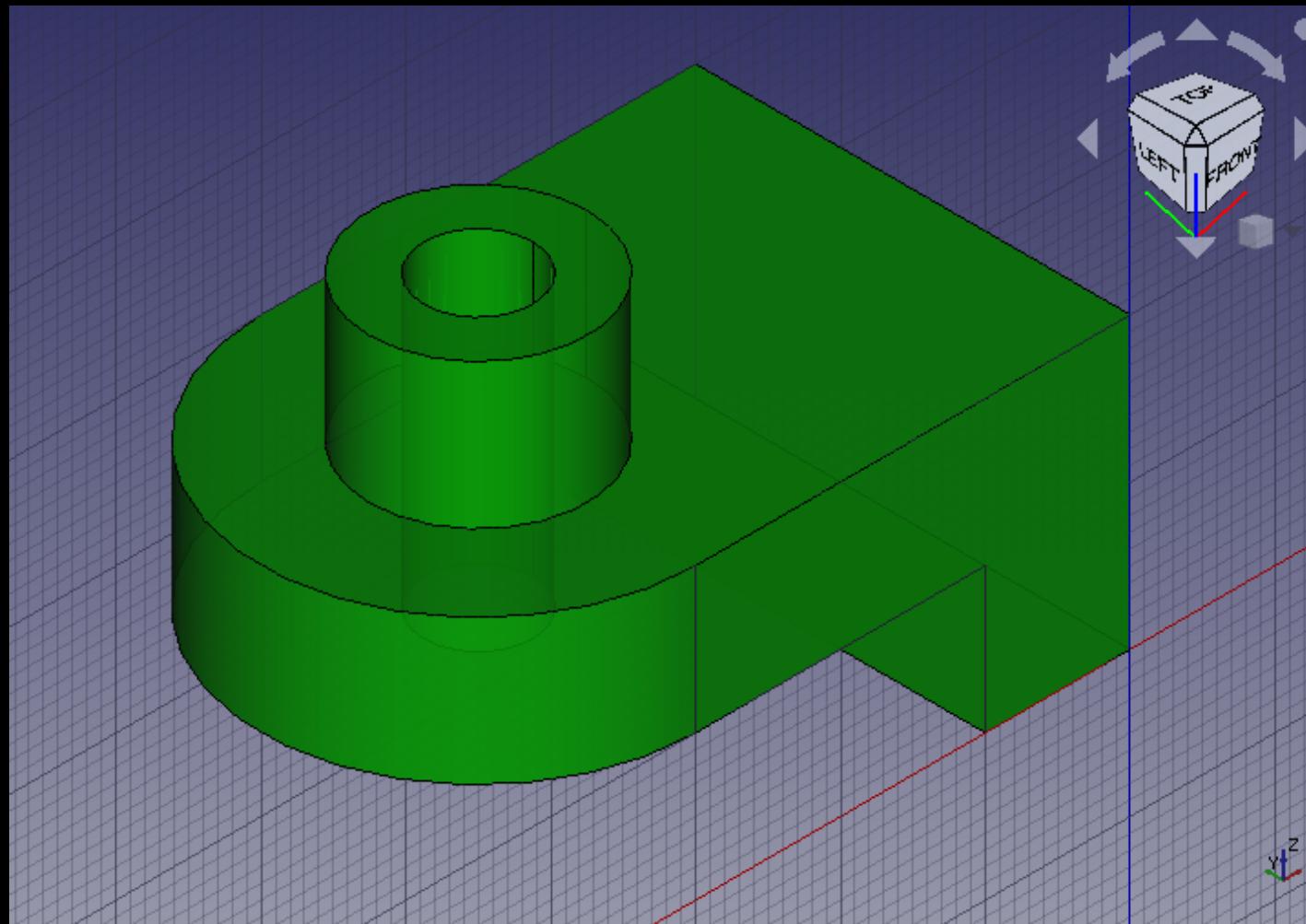
YZ

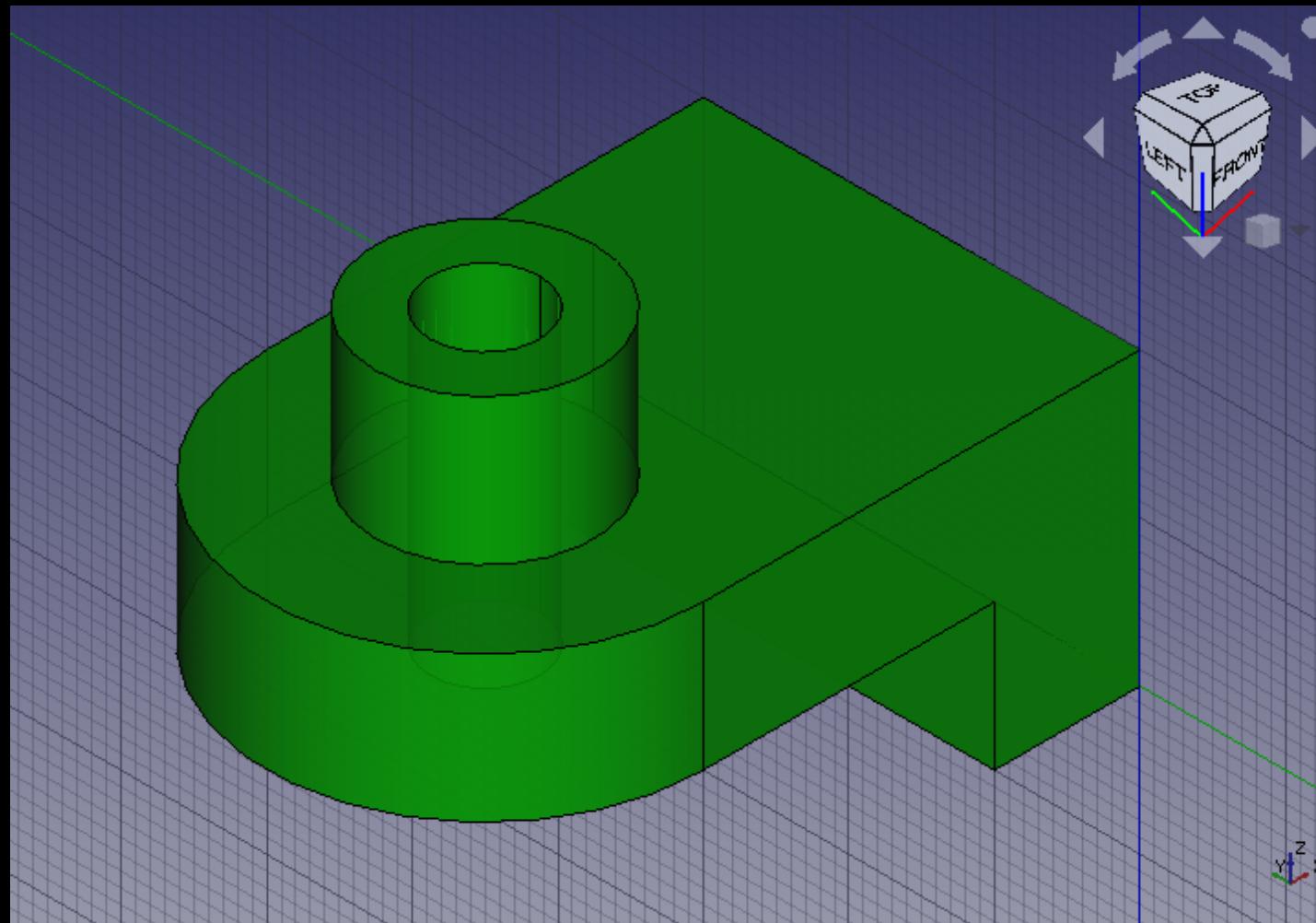
Offset:

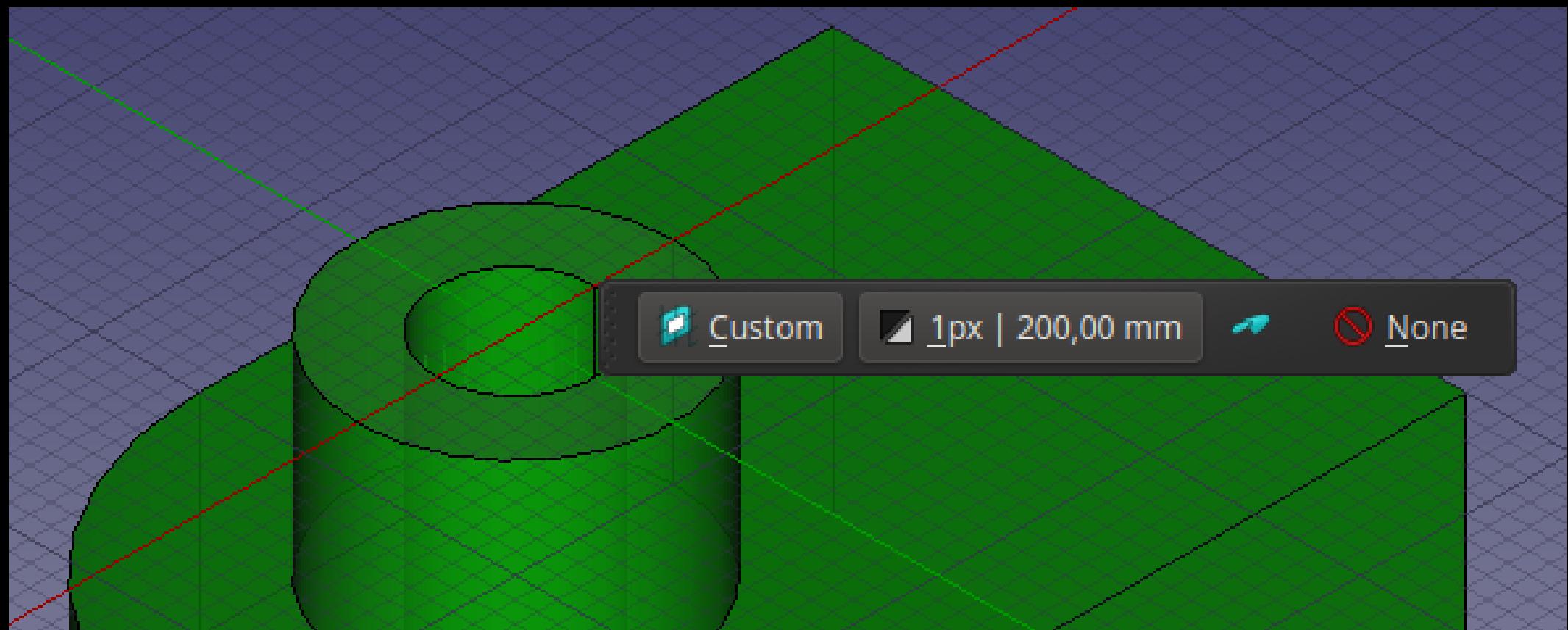
distância do plano original.











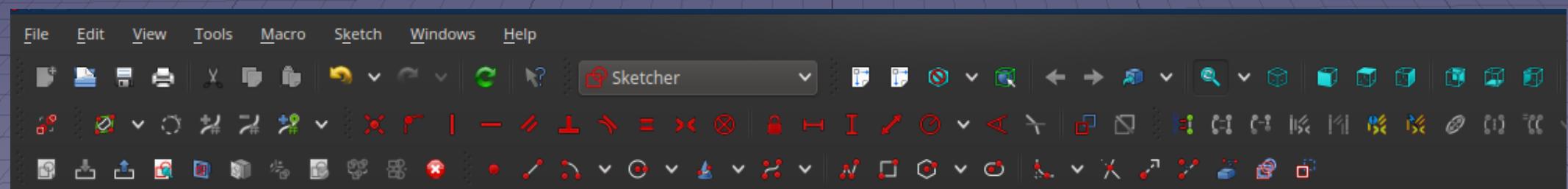
8.3 Part

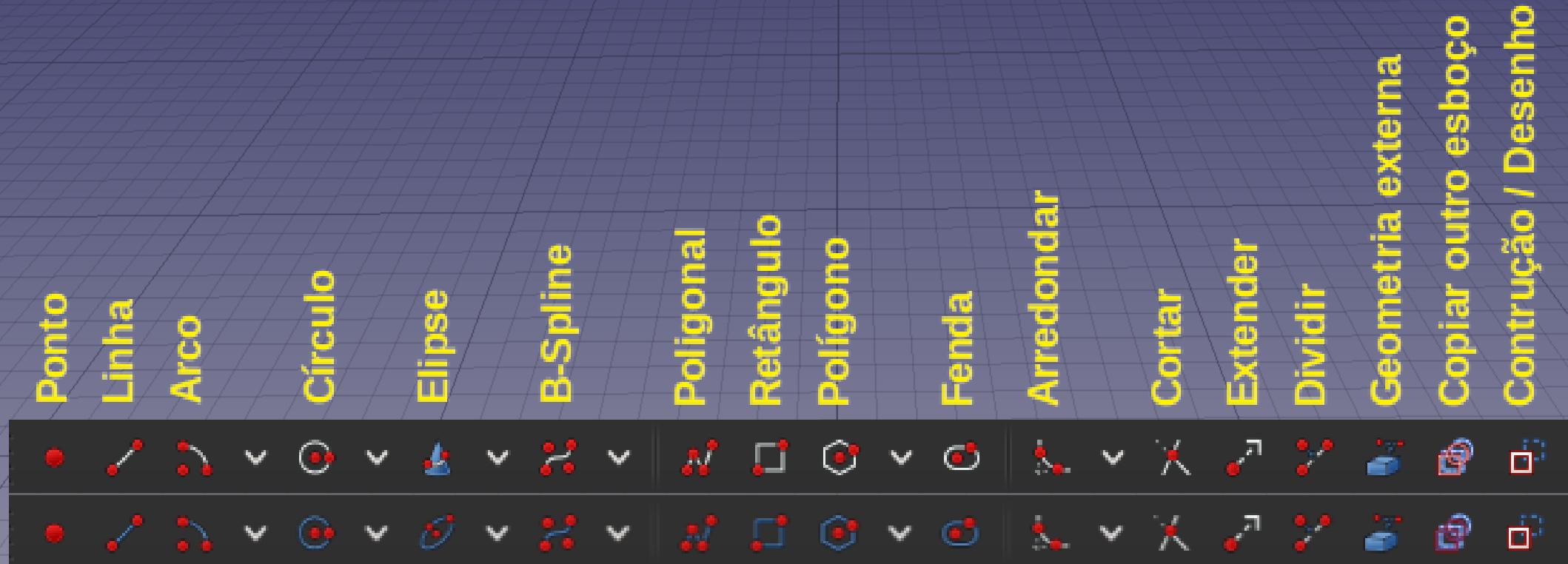
Formas tridimensionais.



8.4 Sketcher

Esboços.



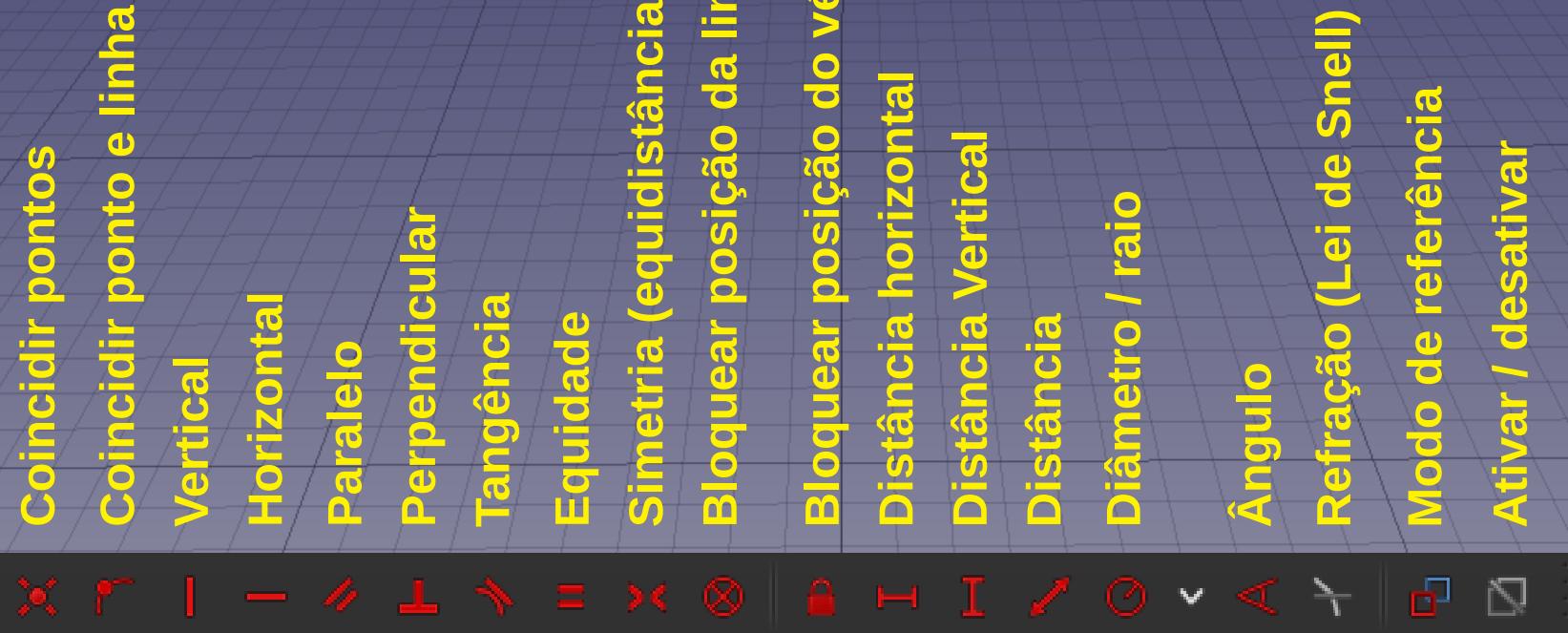


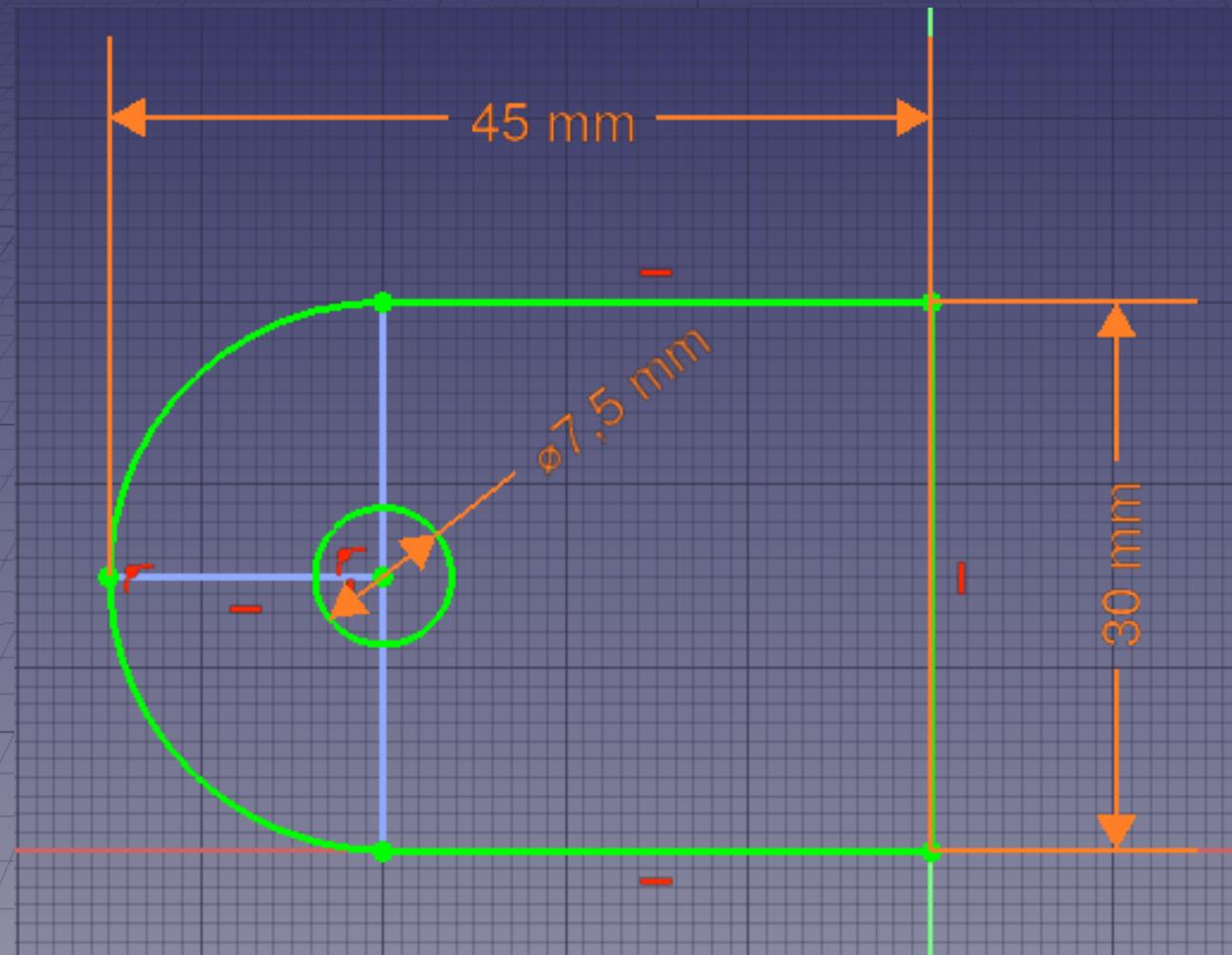
8.4.1 Constraints

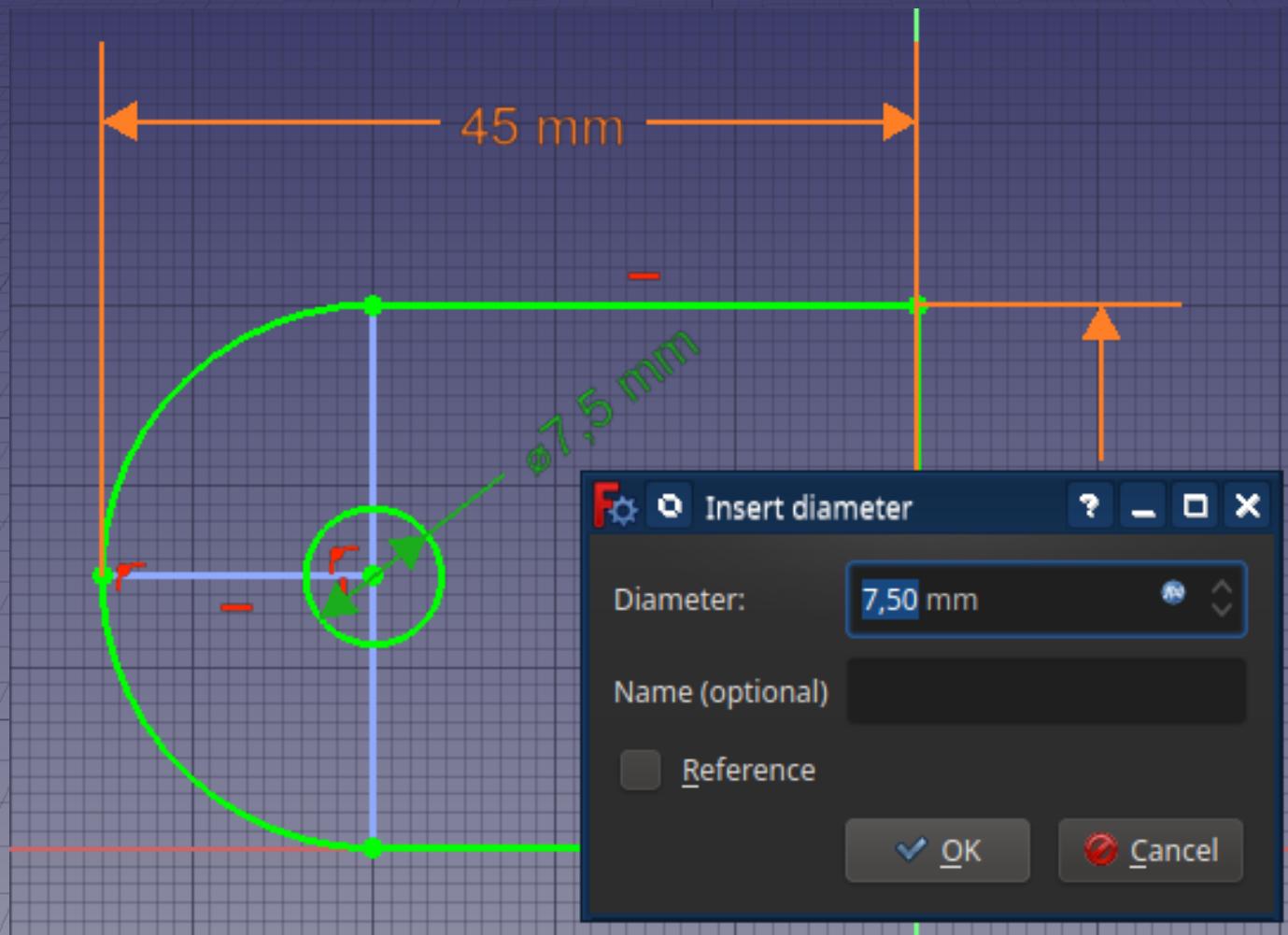
Restrições:

- Geométricas
 - ✓ Coincidências
 - ✓ Verticalidade
 - ✓ Horizontalidade
 - ✓ Paralelismo
 - ✓ etc...
- Algébricas
 - ✓ Dimensões
 - ▷ Planilha
 - ▷ Bancada Spreadsheet
 - ▷ Cálculos!

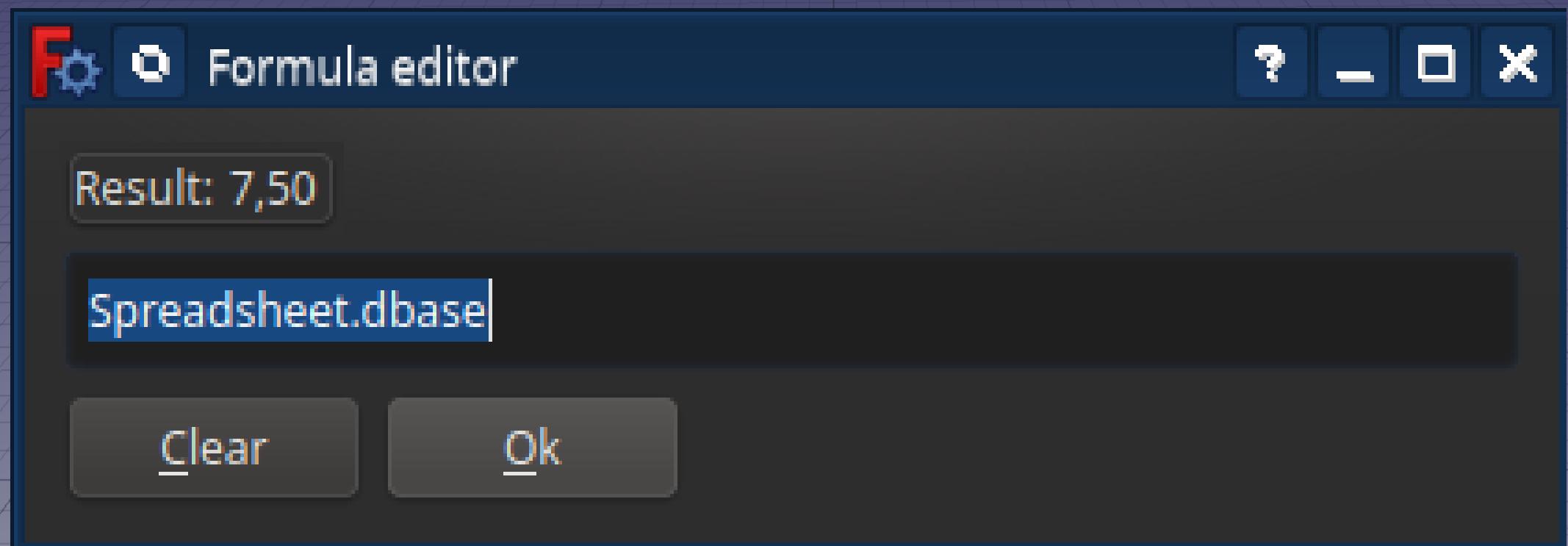
Lembre-se: restrições também são parâmetros!





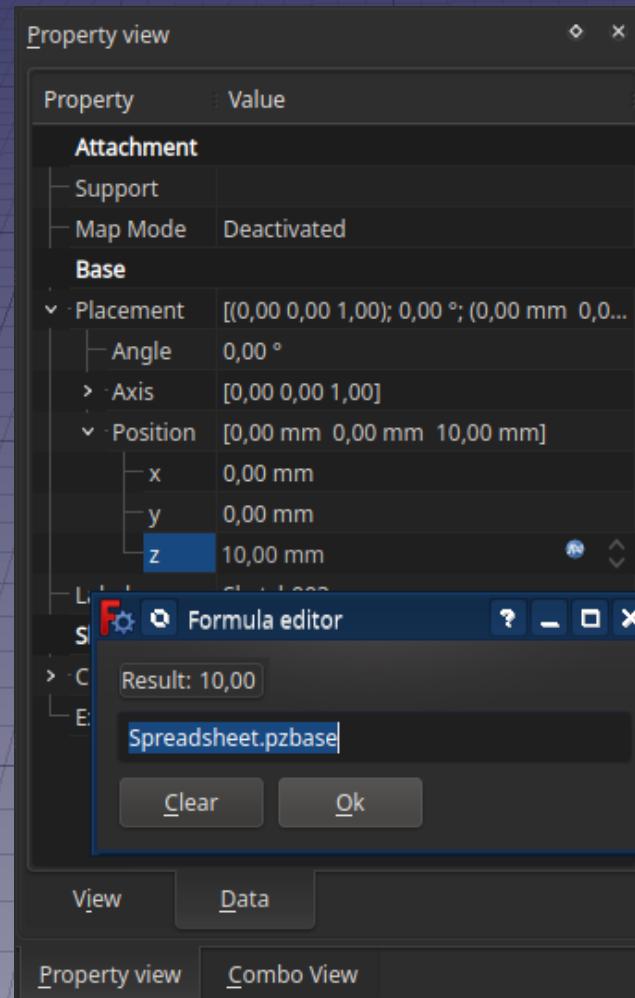


É aqui onde inserimos as variáveis (valores)!



Da mesma forma que fazemos na Caixa de Propriedades:

- alturas
- posicionamentos
- ângulos
- nomes
- textos
- etc...

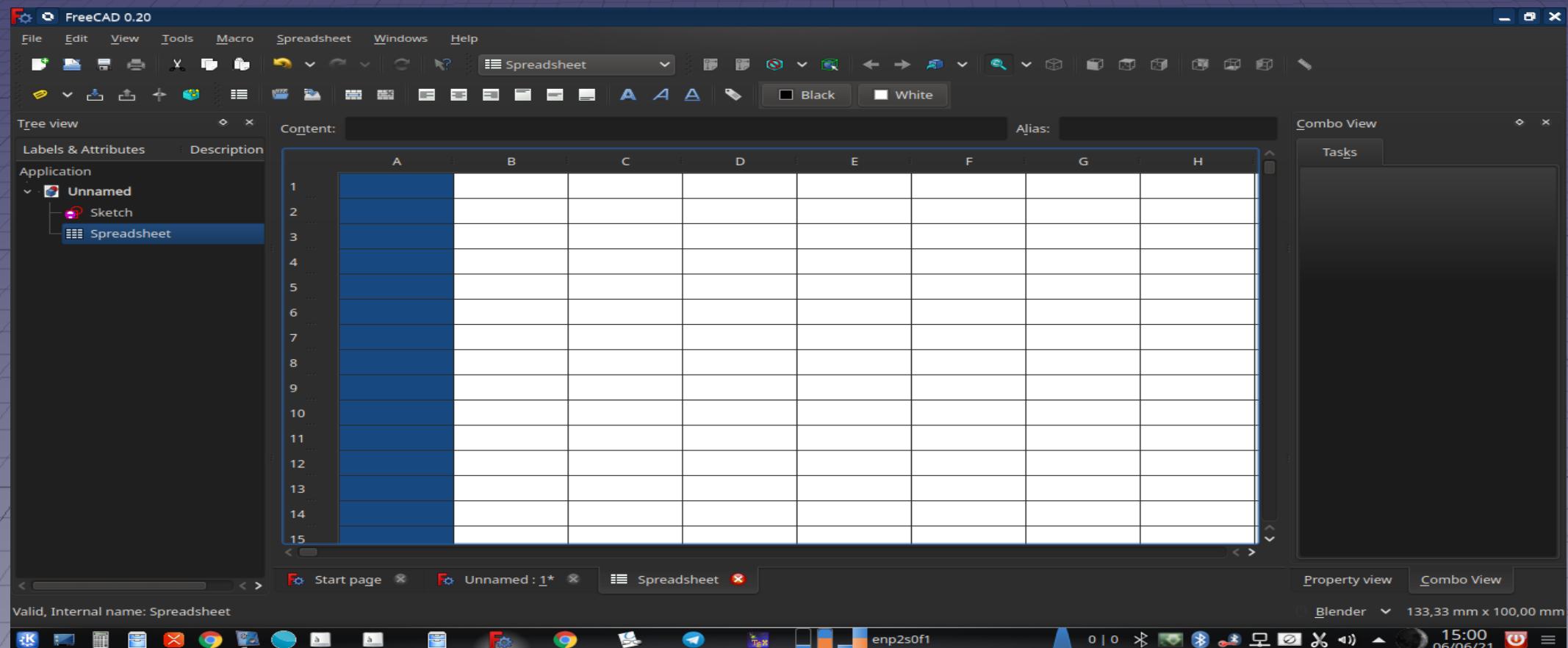


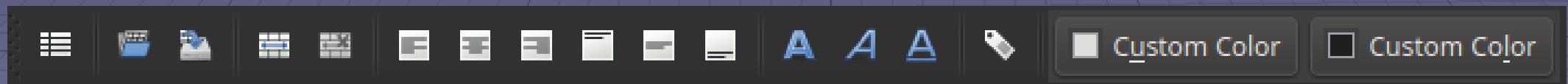
Variável → Parâmetro

Planilha → Modelo

Parâmetros geométricos:
constantes!

8.5 Spreadsheet





Tree view

Content: =zbase

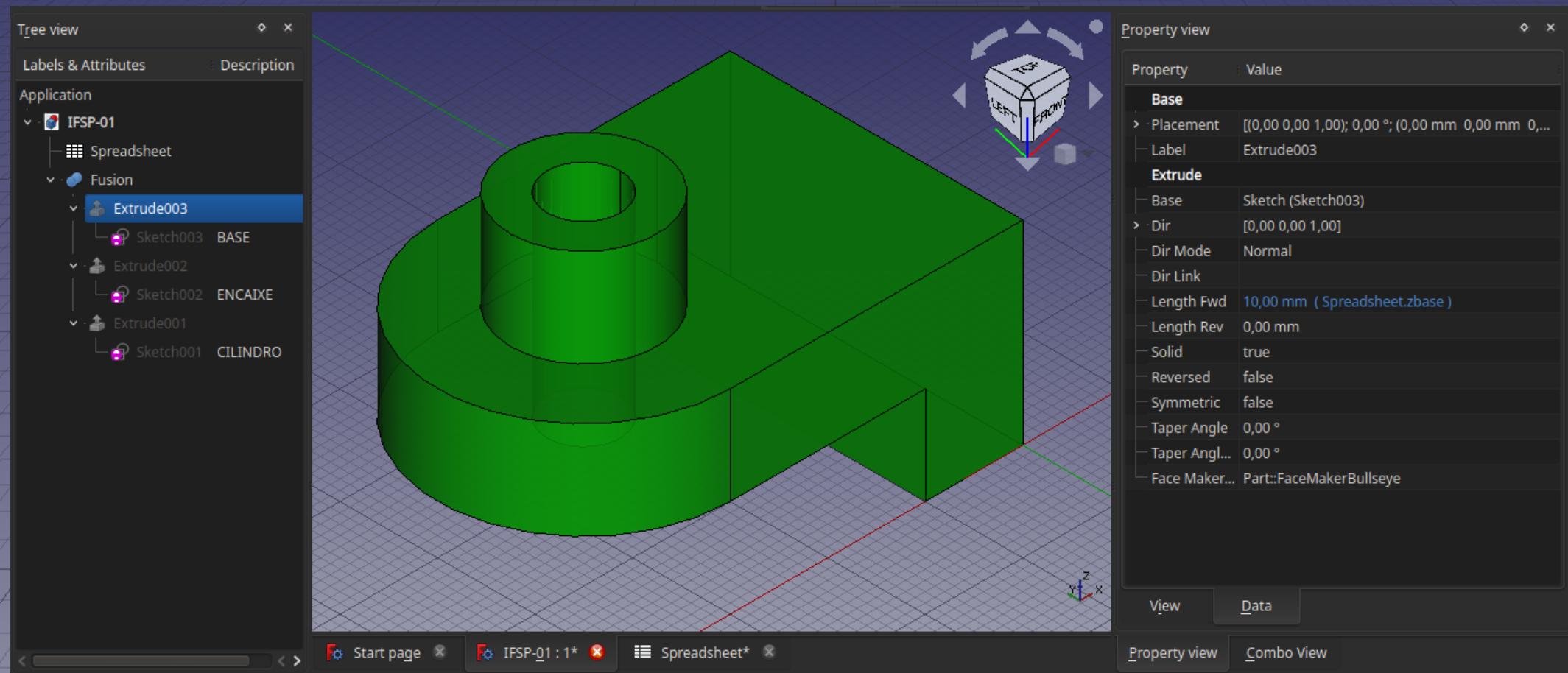
Alias: pzbase

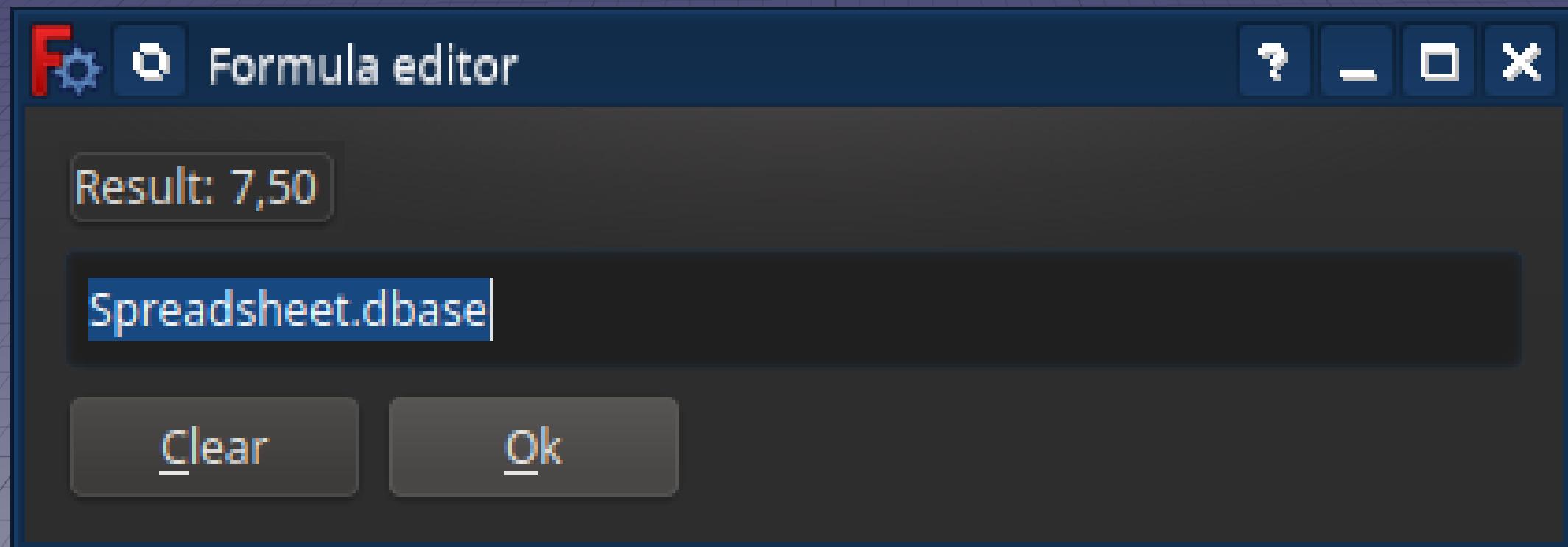
	A	B	C	D	E	F	G	H	I	J
1	COMPONENTE:	PX	PY	PZ	X	Y	Z	D	d	N
2	BASE			10,00	45,00	30,00	10,00	30,00	7,50	
3	ENCAIXE				10,00	30,00	10,00			
4	CILINDRO			20,00			10,00	15,00		
5										
6										
7										
8										

Labels & Attributes Description

Application

- IFSP-01
- Spreadsheet
- Fusion
 - Extrude003
 - Sketch003 BASE
 - Extrude002
 - Sketch002 ENCAIXE
 - Extrude001
 - Sketch001 CILINDRO





9 Prática



Muito
Obrigado!