



**Wie man seine DIY 3D-Drucker, Fräsen,  
Folienschneider und LASER-Plotter  
mit OpenSource-Software,  
Firmware und sogar Hardware  
aufbauen kann**

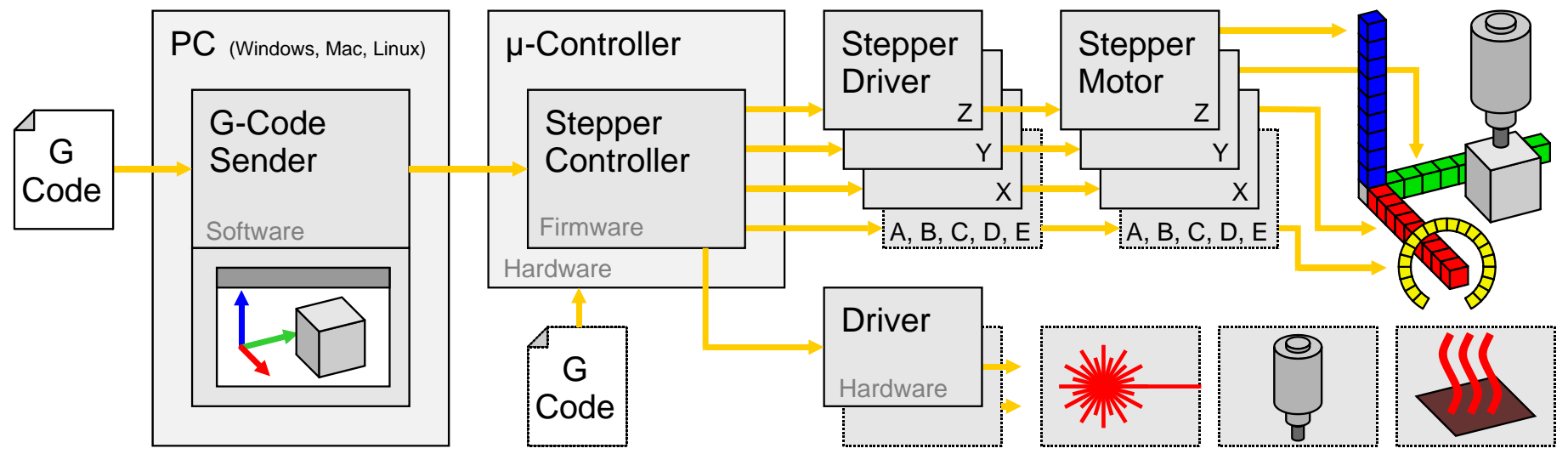
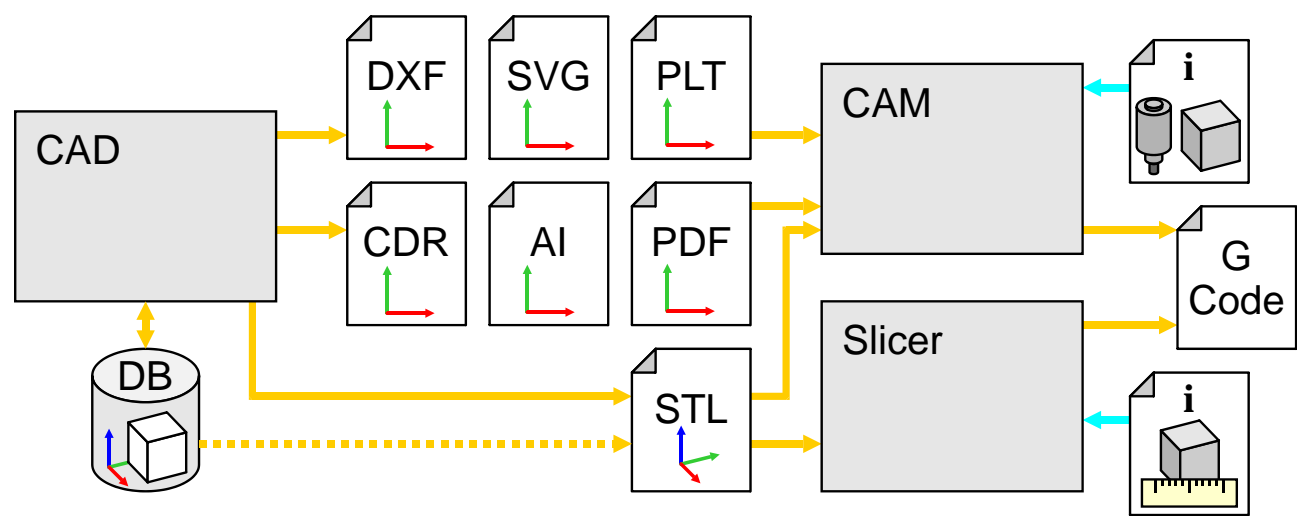
**Jochen Krapf**

**KNF-Kongress 2015**

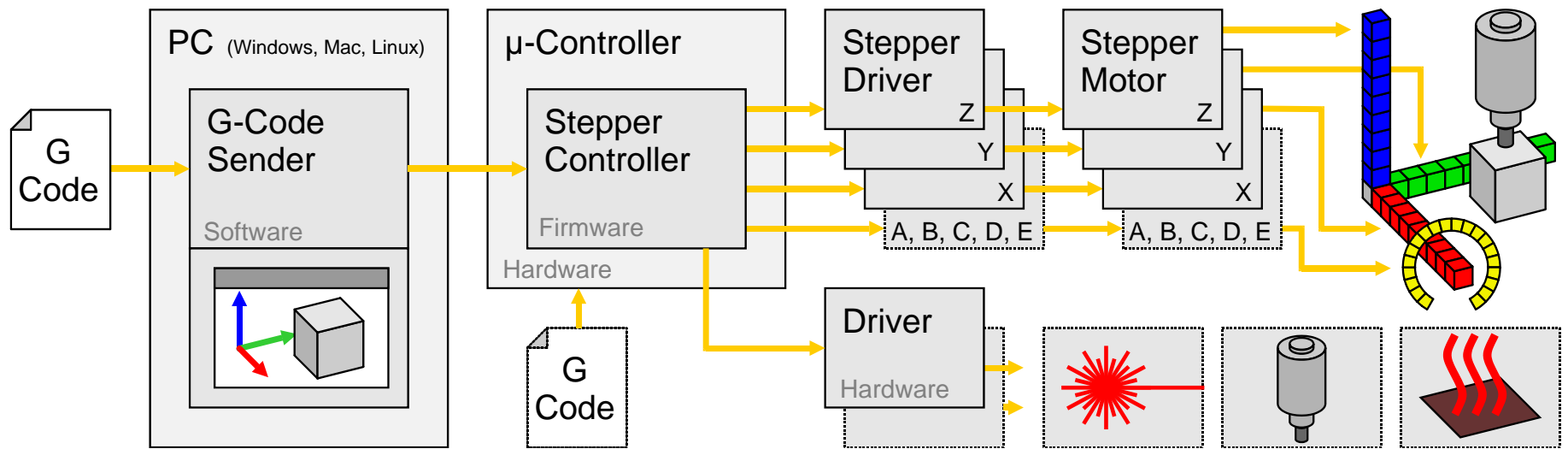
# Agenda

- **Die CNC-Maschine**
  - **Mechanik/Achsen**
  - **Stepper-Motor**
  - **Stepper-Driver**
  - **$\mu$ -Controller**
  - **Controller Firmware**
  - **G-Code-Sender**
- **Der CAD-CAM-Workflow**
  - **CAD**
  - **DB**
  - **CAM**
  - **Slicer**
- **Experten**
- **G-Code**

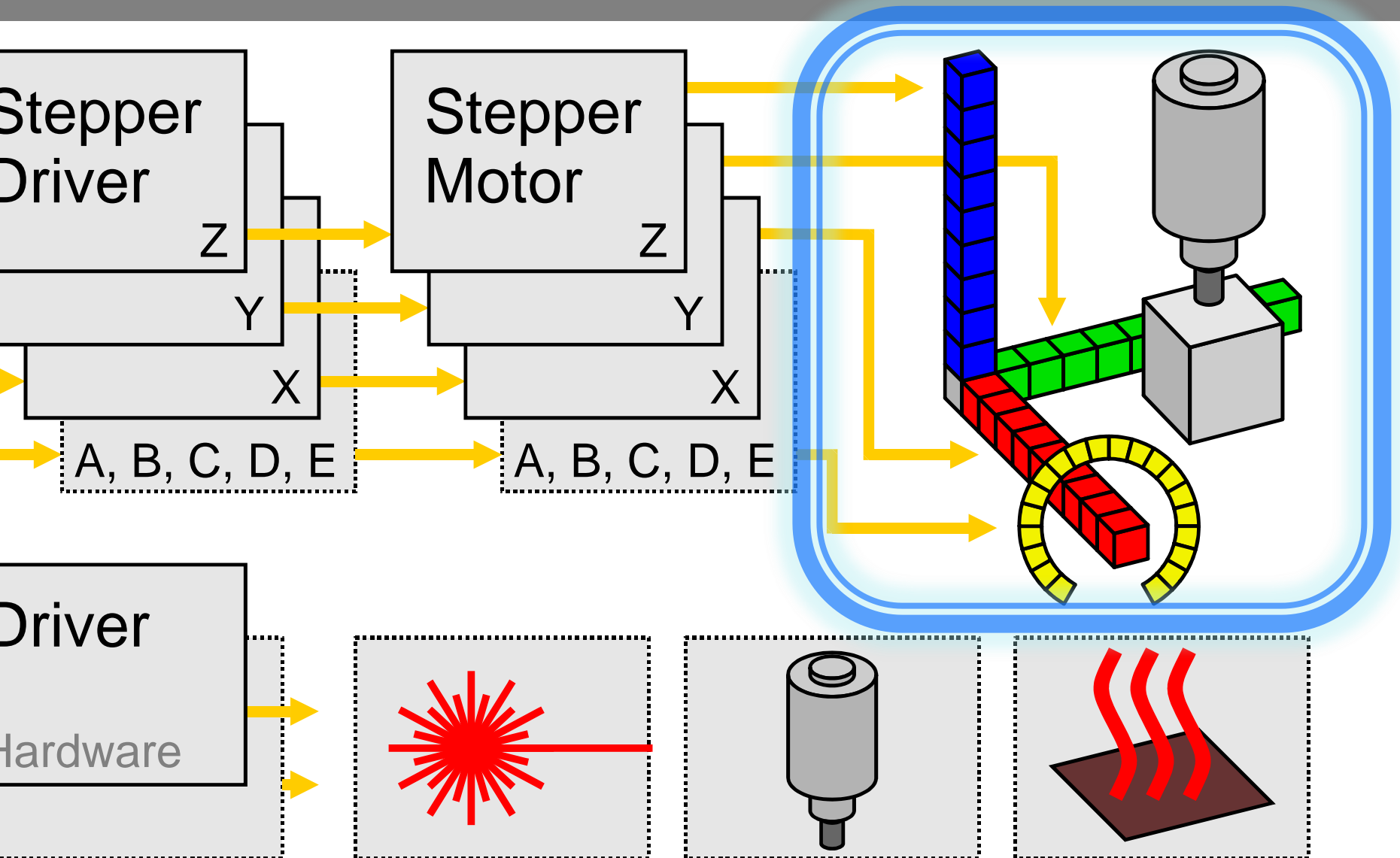
# Überblick Module



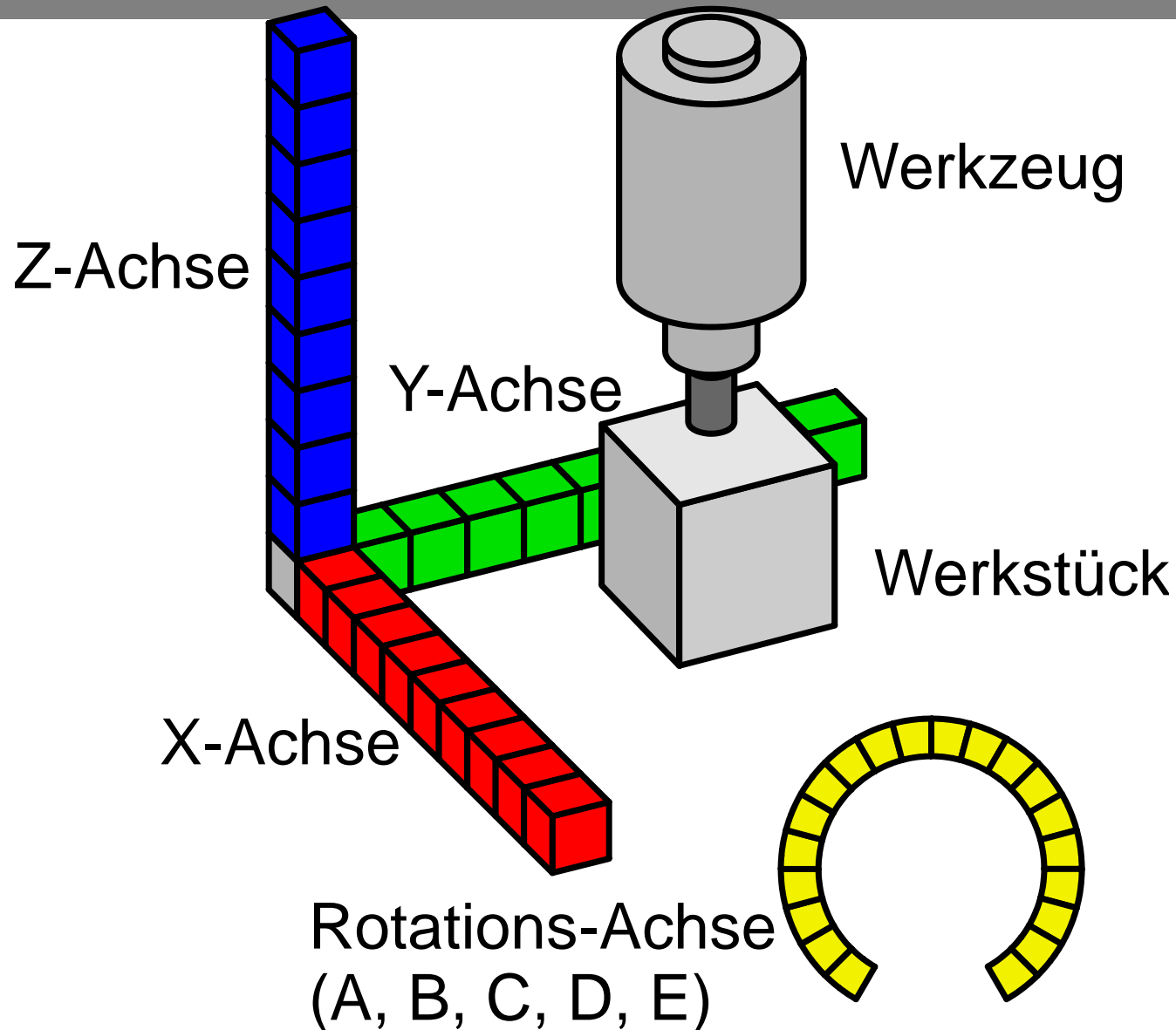
# Die CNC-Maschine...



# Mechanik/Achsen



# Mechanik: Achsen



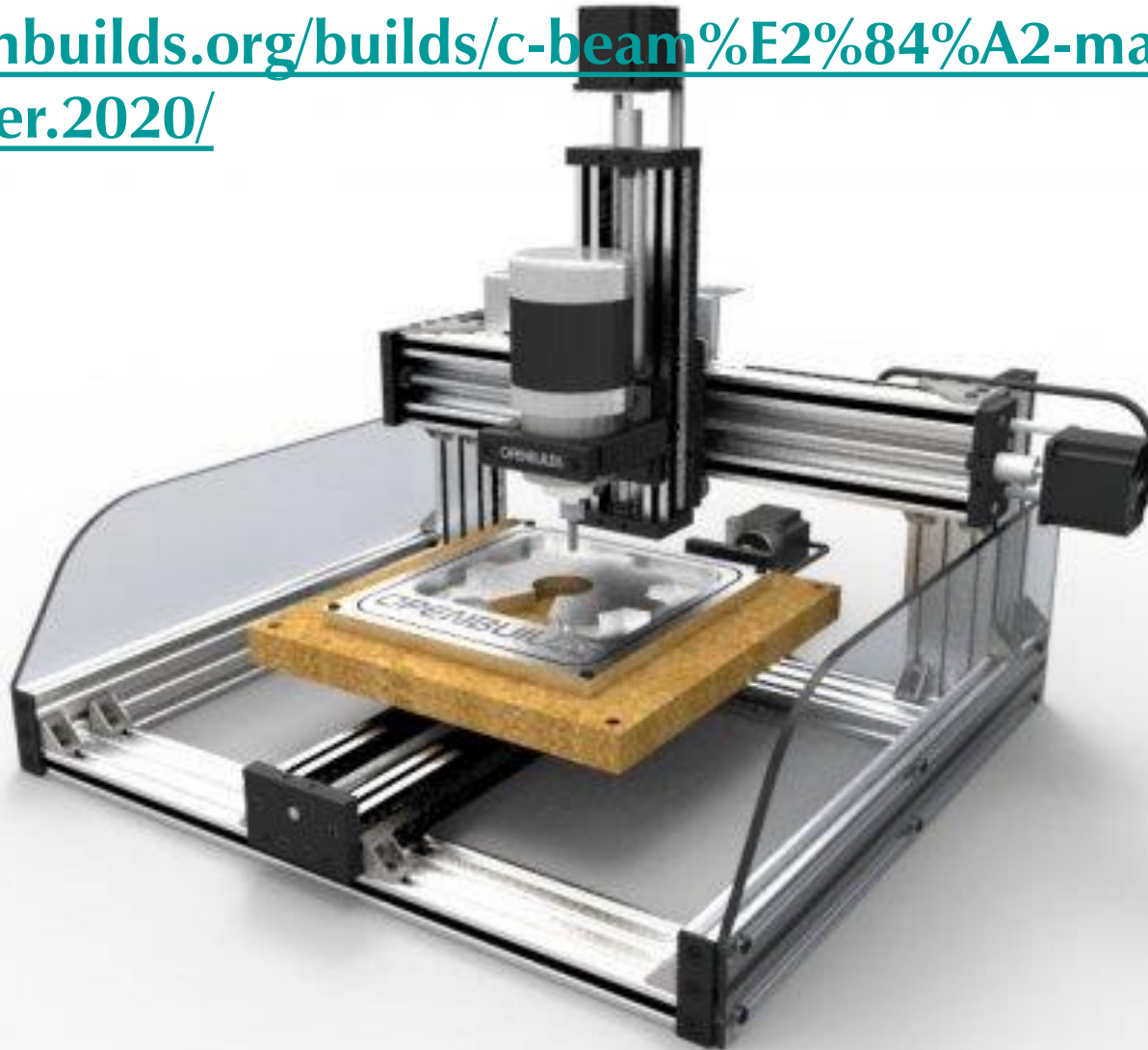
# Mechanik: Beispiel 1

<https://www.inventables.com/technologies/x-carve>



# Mechanik: Beispiel 2

<http://openbuilds.org/builds/c-beam%E2%84%A2-machine-plate-maker.2020/>





# Mechanik: Beispiel 3

[http://reprap.org/wiki/Prusa\\_i3](http://reprap.org/wiki/Prusa_i3)



# Mechanik: Beispiel 4

<http://reprap.org/wiki/Ormerod>



# Mechanik: Beispiel 5

<http://openbuilds.org/builds/designer-jeans-with-a-laser.2821/>



# Mechanik: Beispiel 6

<http://reprap.org/wiki/Kossel>

**Delta-Printer**

**X,Y,Z-Achsen durch  
Kinematik**

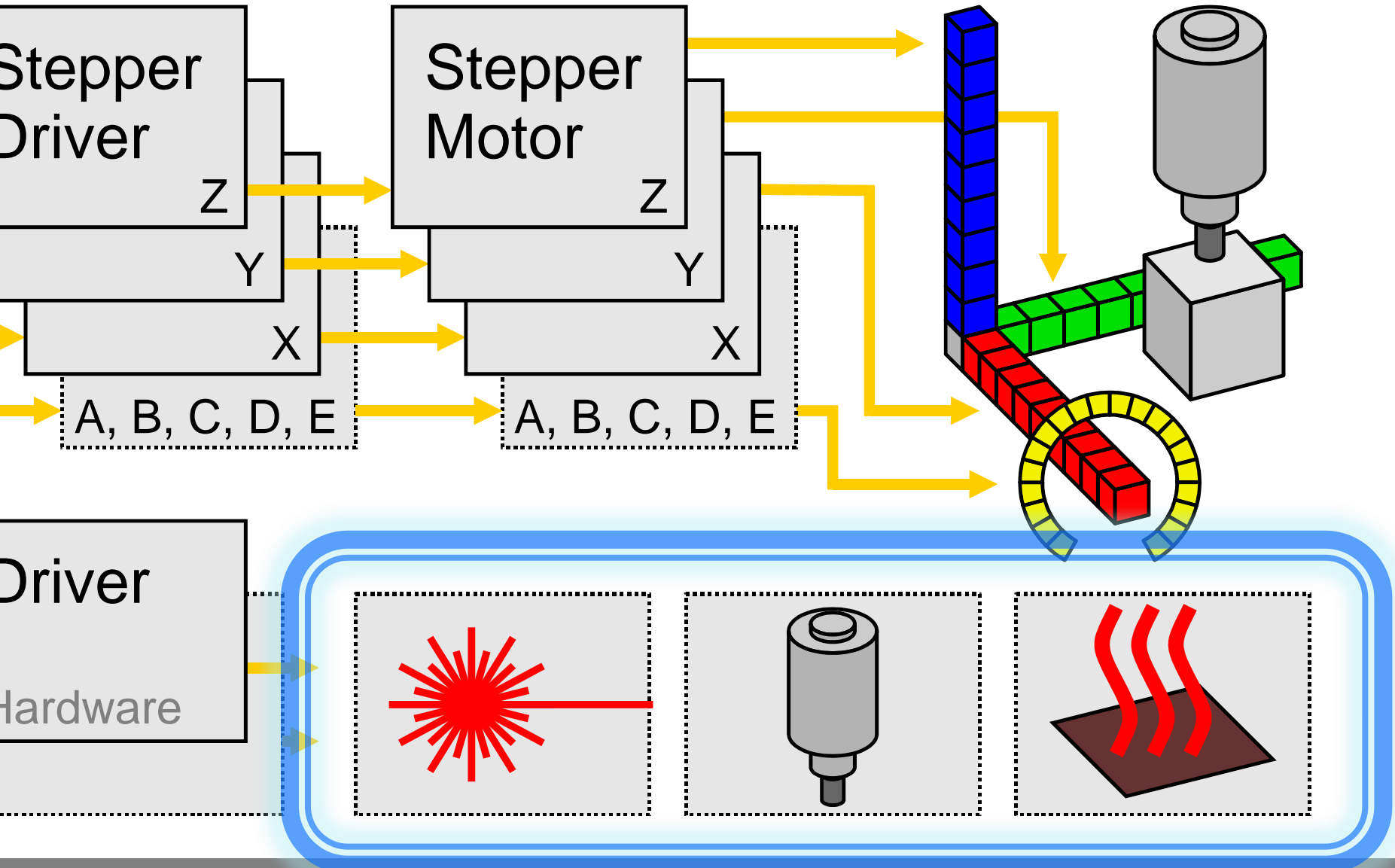


# Mechanik: Beispiel 7

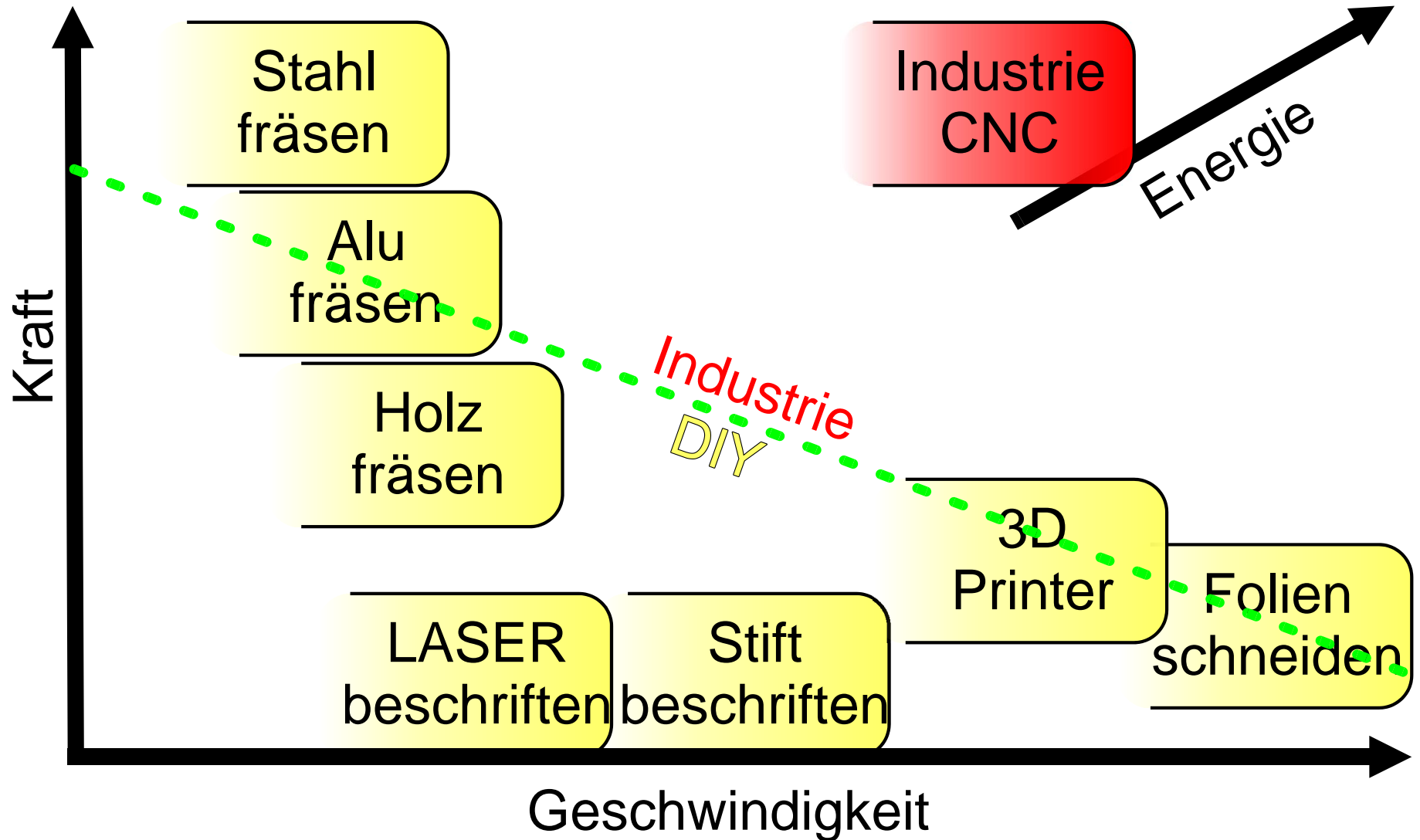
<http://openbuilds.org/builds/niko%E2%80%99s-egg-painter-robot-openbuilds.1953/>



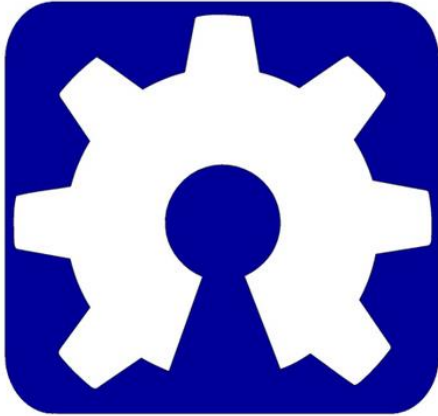
# Werkzeuge



# Werkzeug: Kraft vs Geschwindigkeit



# Mechanik: QUELLEN



**OPENBUILDS**

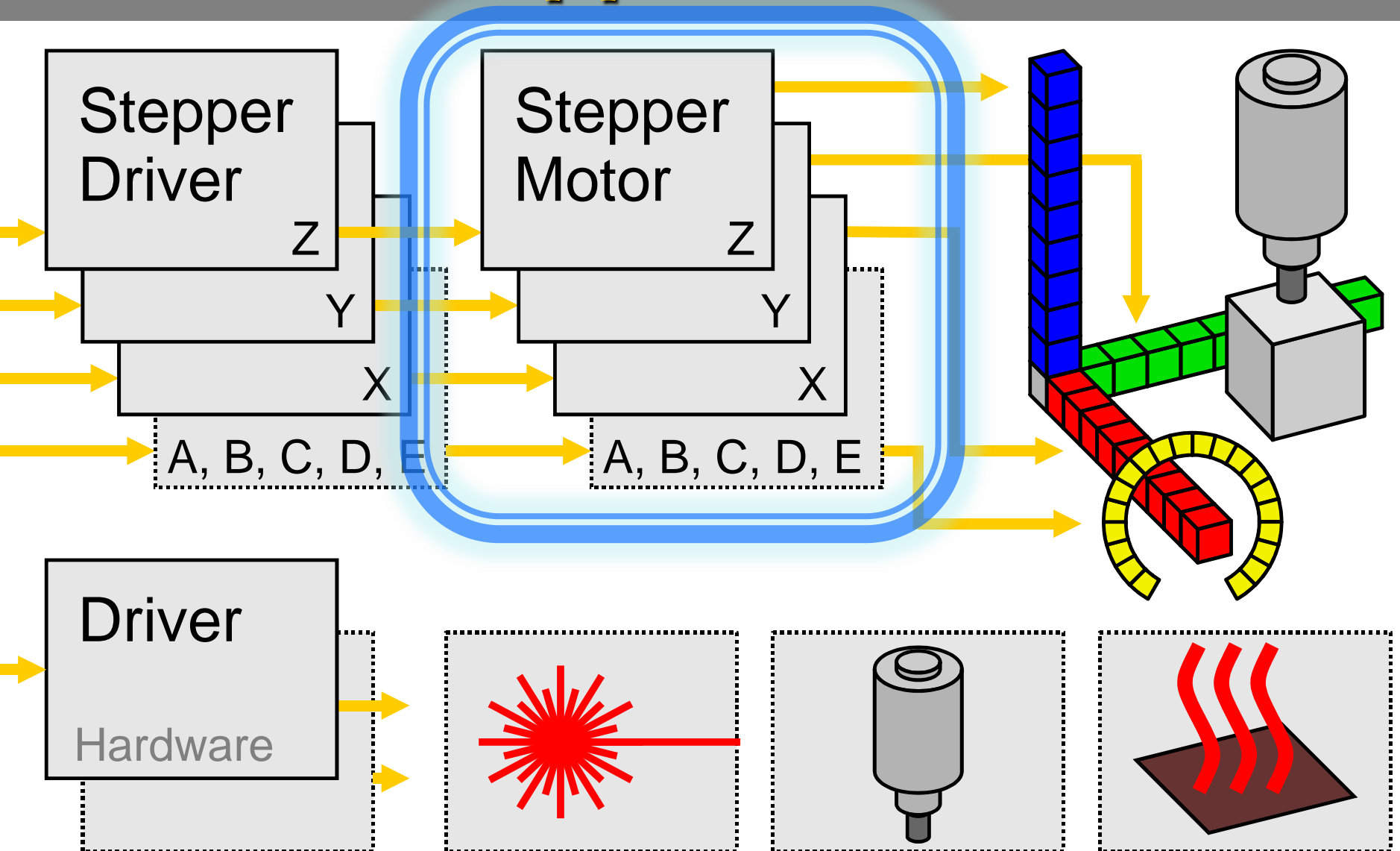
<http://openbuilds.org/>



<http://reprap.org/>



# Stepper Motor



# Stepper Motor (Schrittmotoren)



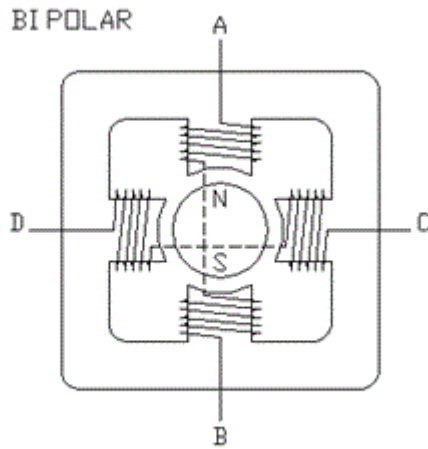
[www.pololu.com](http://www.pololu.com)

# Stepper Motor (Schrittmotoren)



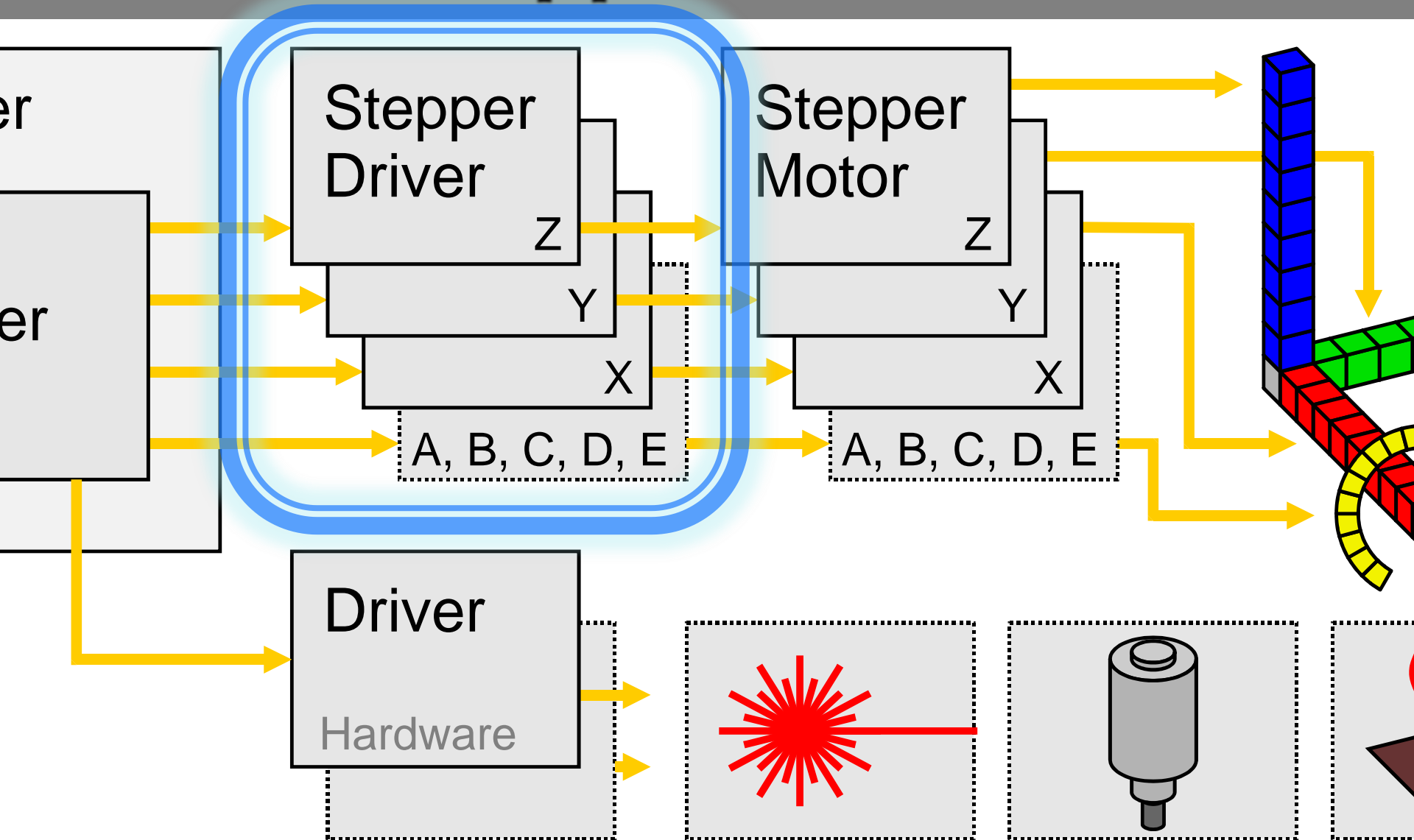
## Bipolare Schrittmotoren

- Einfache Handhabung (im Gegensatz zu Servos)
- Steuerung – keine Regelung
- Typ. 3200 Schritte je Umdr.
- Genormte Größen
- Viele Hersteller
- Begrenzte Geschwindigkeit ☹️
- Preis: 15 ... 200 €



Bipolar Stepper winding arrangement showing stator and rotor

# Stepper Driver



# Stepper Driver - Pololu



## Leistungstreiber für bipolare Schrittmotoren

- 3D-Printer, kleine CNCs
- Max. 35V 1A je Wicklung
- 1/16 Mikroschritte
- Original von Pololu.com
- Nachbauten aus China
- Preis: 5...15€



Quelle: pololu.com

# Stepper Driver - Module

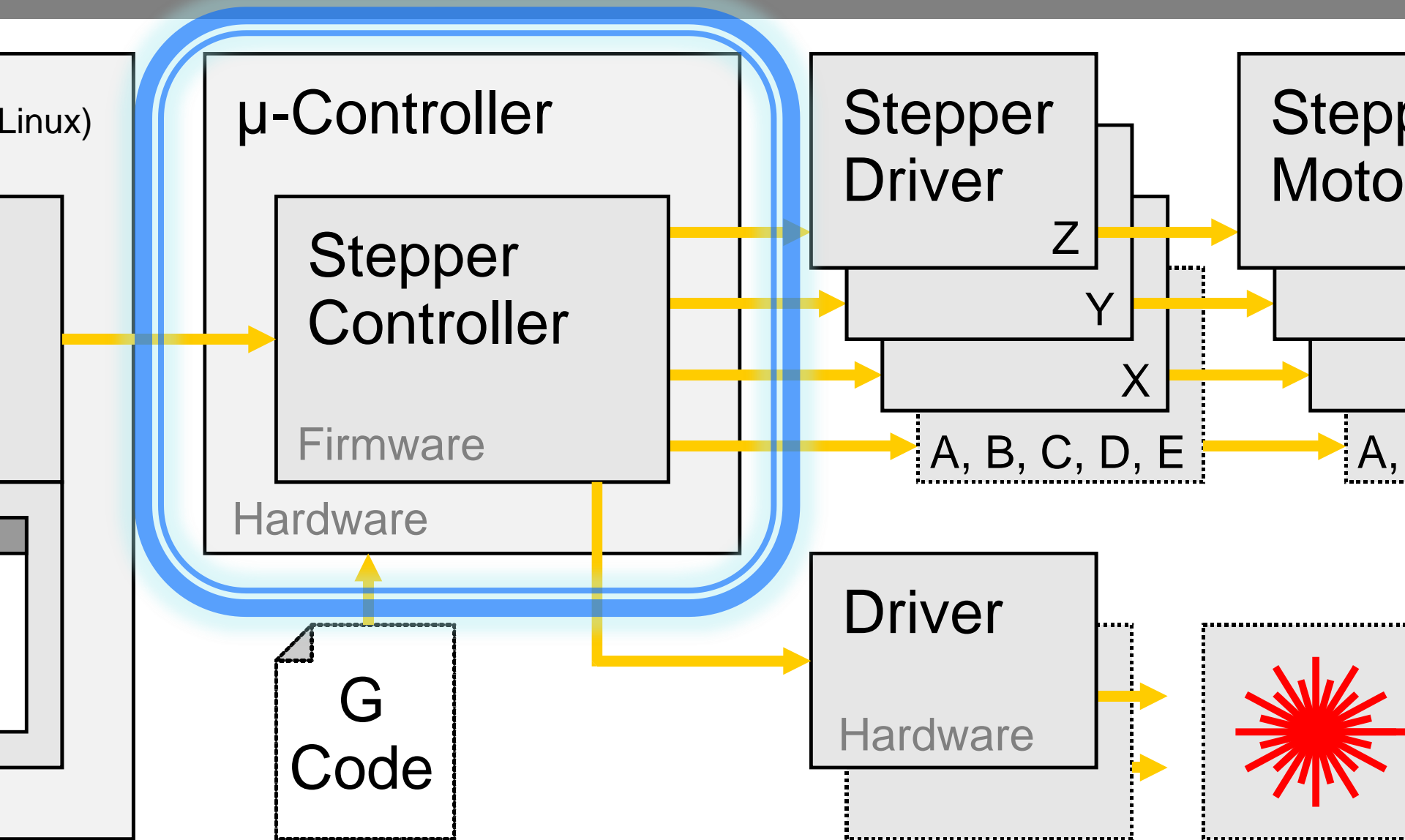


**Leistungstreiber für größere bipolare Schrittmotoren**

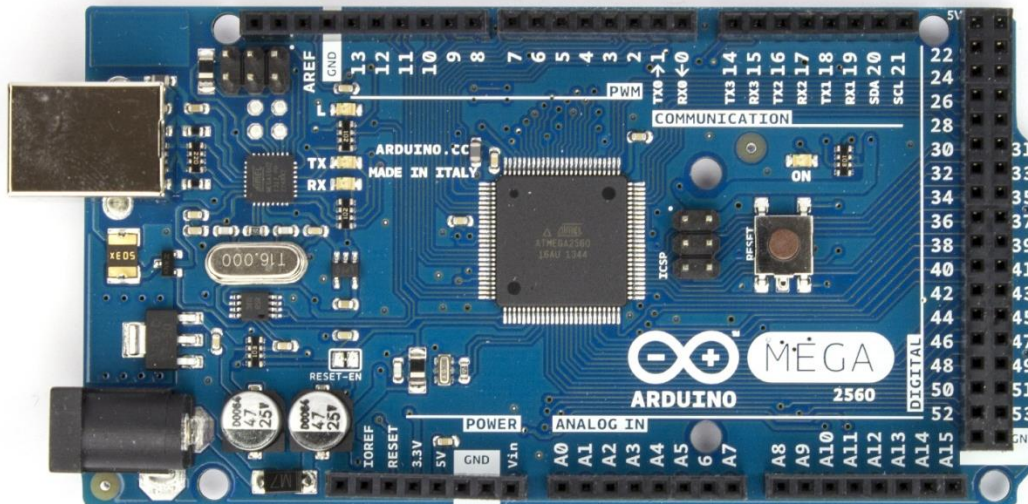
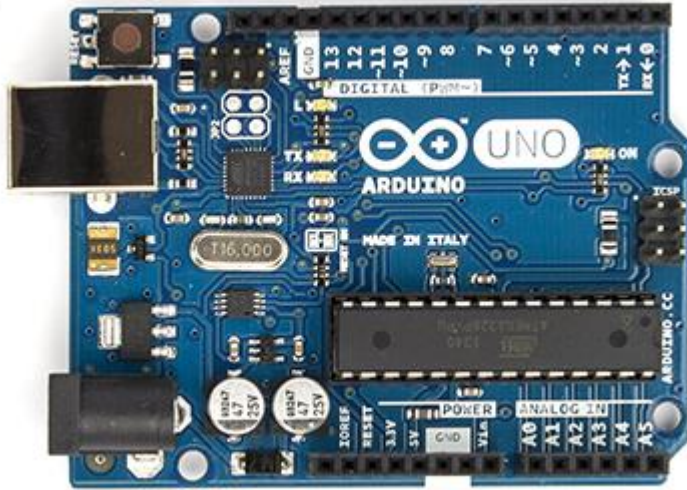
- **Fräse, Drehbank, Plasmaschneider, Laser...**
- **Max. 24...80V 1...8A je Wicklung**
- **Bis 1/128 Mikroschritte**
- **Viele Hersteller**
- **Preis: 30...80€**



# μ-Controller



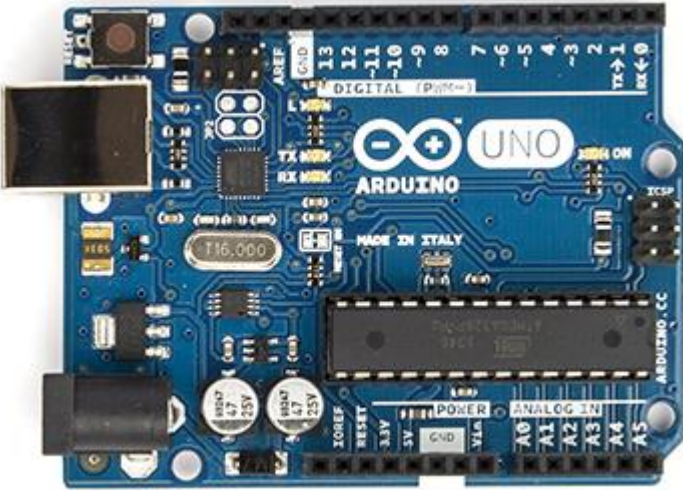
# $\mu$ -Controller - Arduino



Quelle: arduino.cc



# $\mu$ -Controller - Arduino

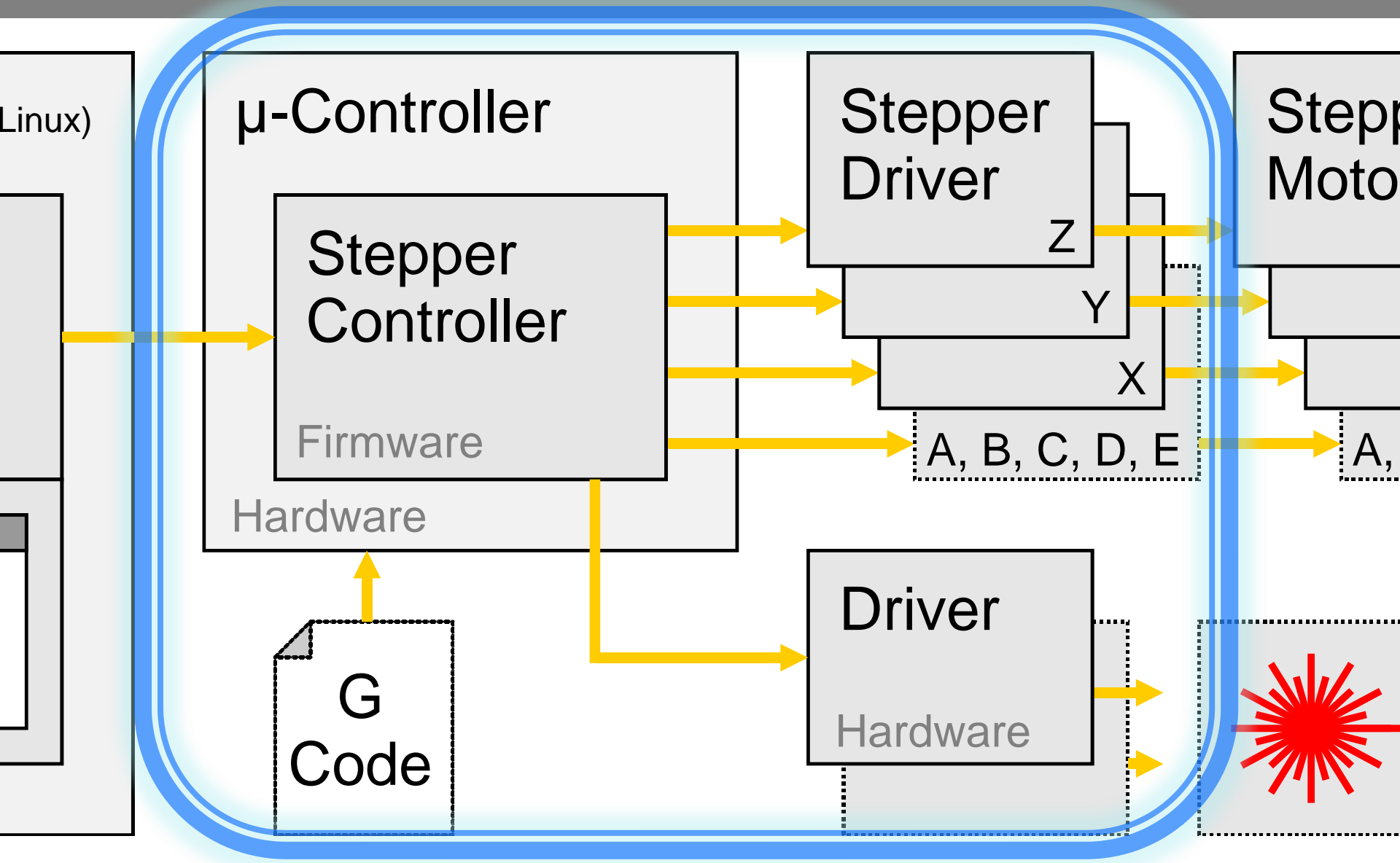


## 8-Bit-Prozessor-Board

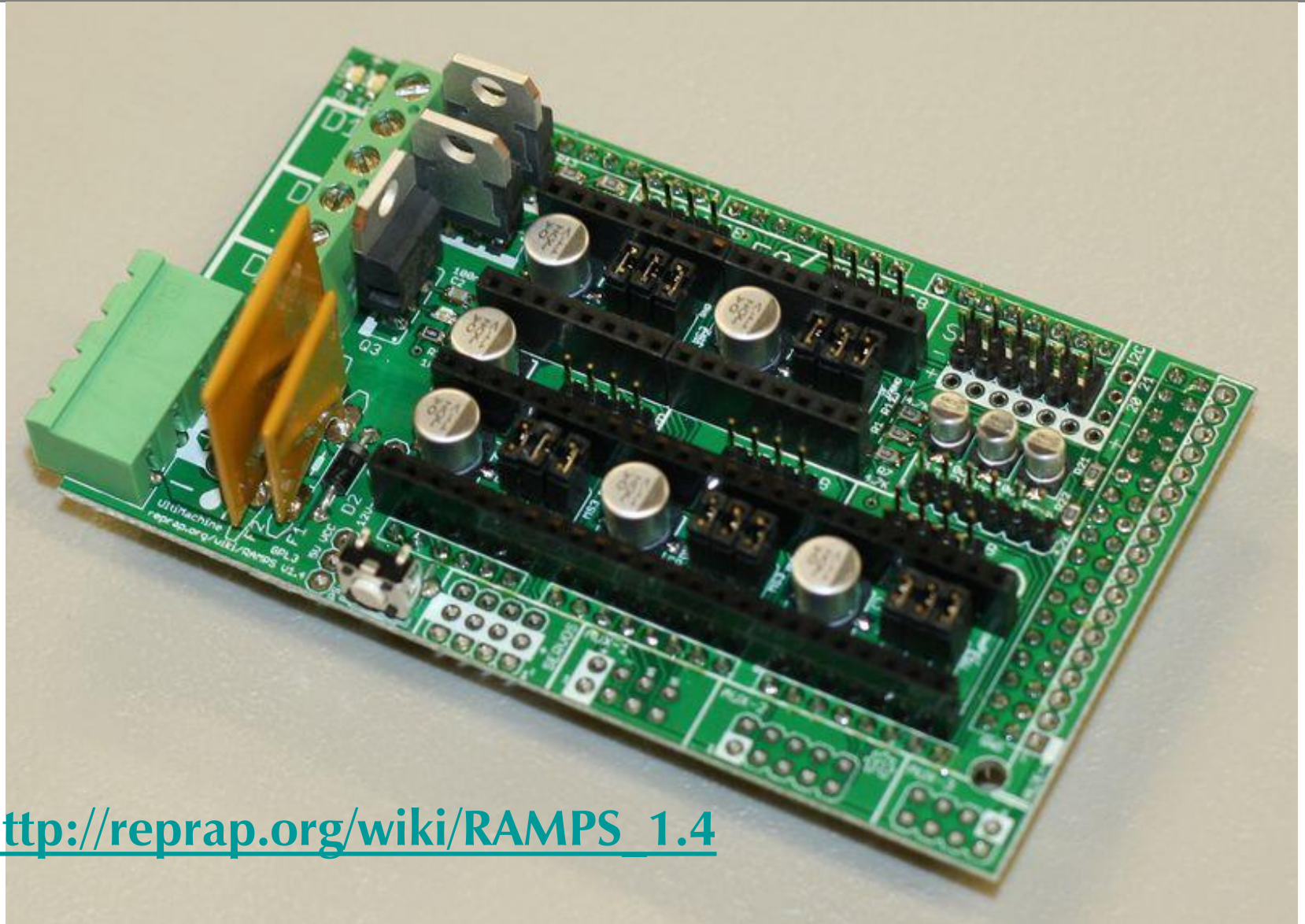
- **Basiert auf ATMEL AVR**
- **Viele Hersteller**
- **Freie IDE**
- **Preis: 3...25€**
- **License: CC BY-SA 3.0**

<http://arduino.cc/>

# Combi-Boards



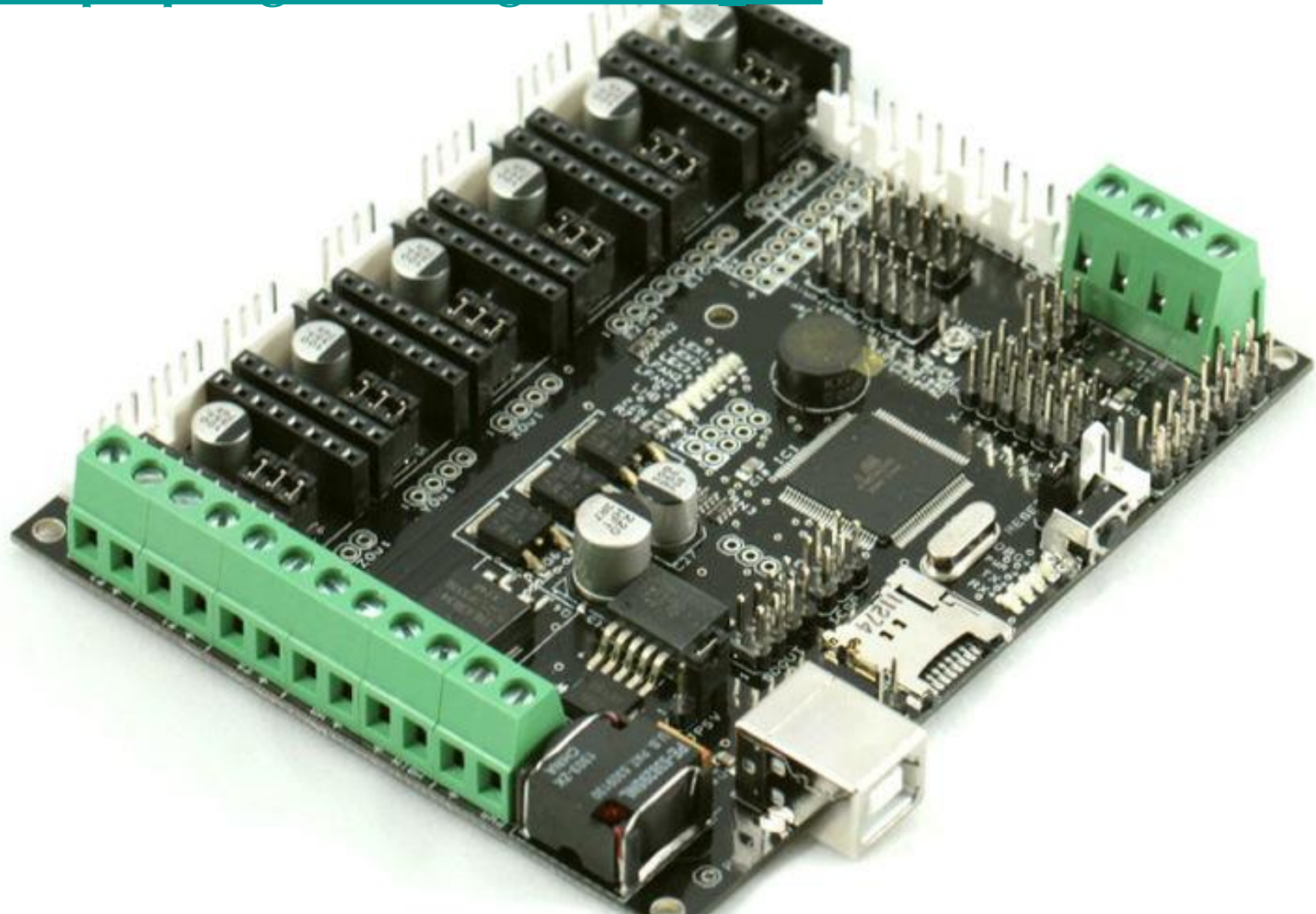
# Combi-Boards – RAMPS 1.4



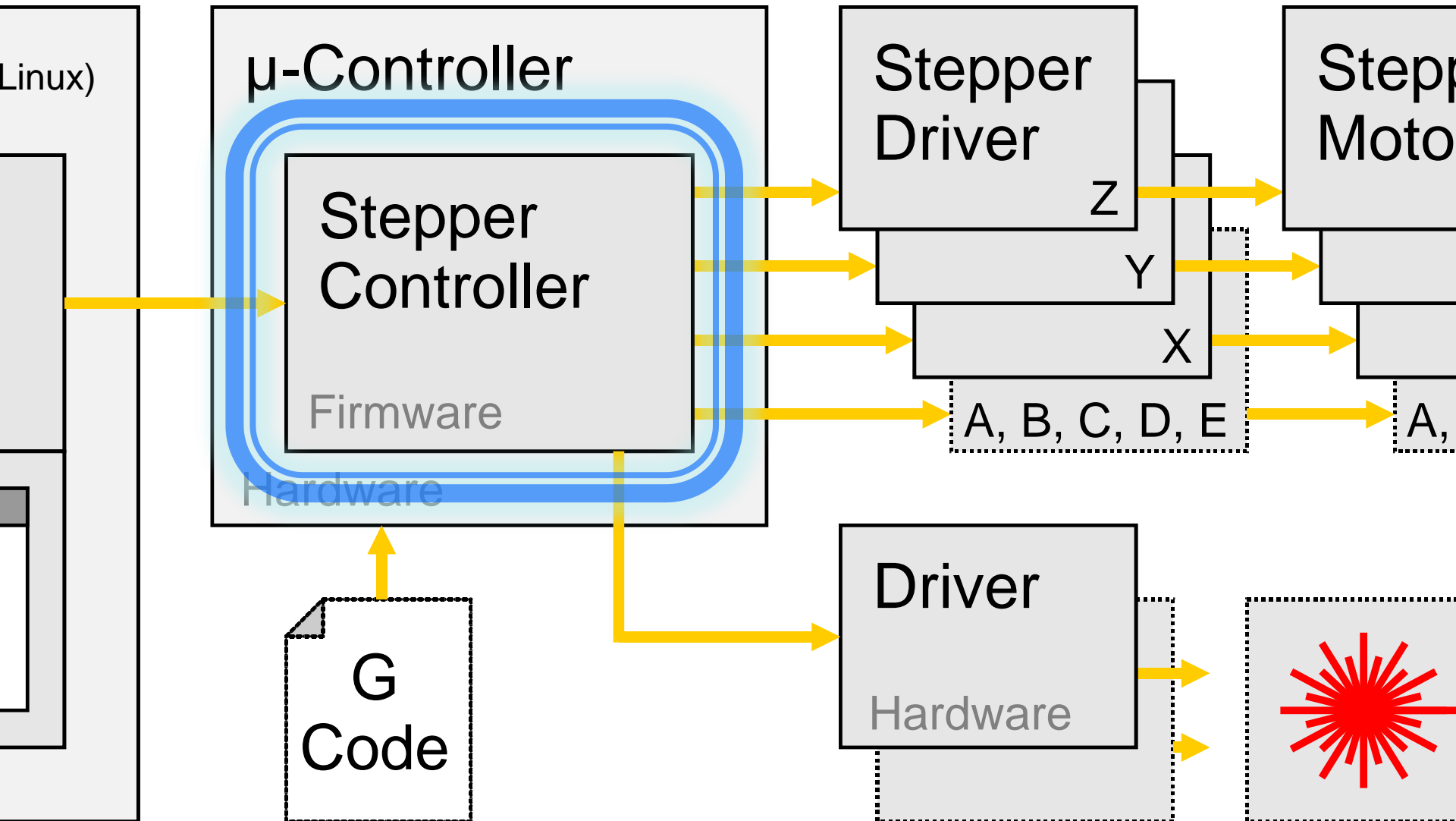
[http://reprap.org/wiki/RAMPS\\_1.4](http://reprap.org/wiki/RAMPS_1.4)

# Combi-Boards – RAMPS 1.4

[http://reprap.org/wiki/Megatronics\\_3.0](http://reprap.org/wiki/Megatronics_3.0)



# Stepper Controller



# Controller – Marlin-Firmware



**Platform: Arduino Mega – 3D Printer**

- **3 Achsen + 4 Extruder + Heizung**
- **Auto Bed Leveling**
- **LCD; SD**
- **Für viele Träger-Boards**
- **License: GPLv3**

**<https://github.com/MarlinFirmware/Marlin>**

# Controller – Repetier Firmware



**Repetier**

**Platform: Arduino Mega; DUE –  
3D Printer; Laser; CNC**

- **3 Achsen + 6 Extruder +  
Heizung/Laser/Spindle**
- **Web-Konfiguration**
- **LCD; SD; BlueTooth**
- **Für viele Träger-Boards**
- **License: GPLv3**

**<http://www.repetier.com/documentation/repetier-firmware/>**

# Controller – GRBL



grbl

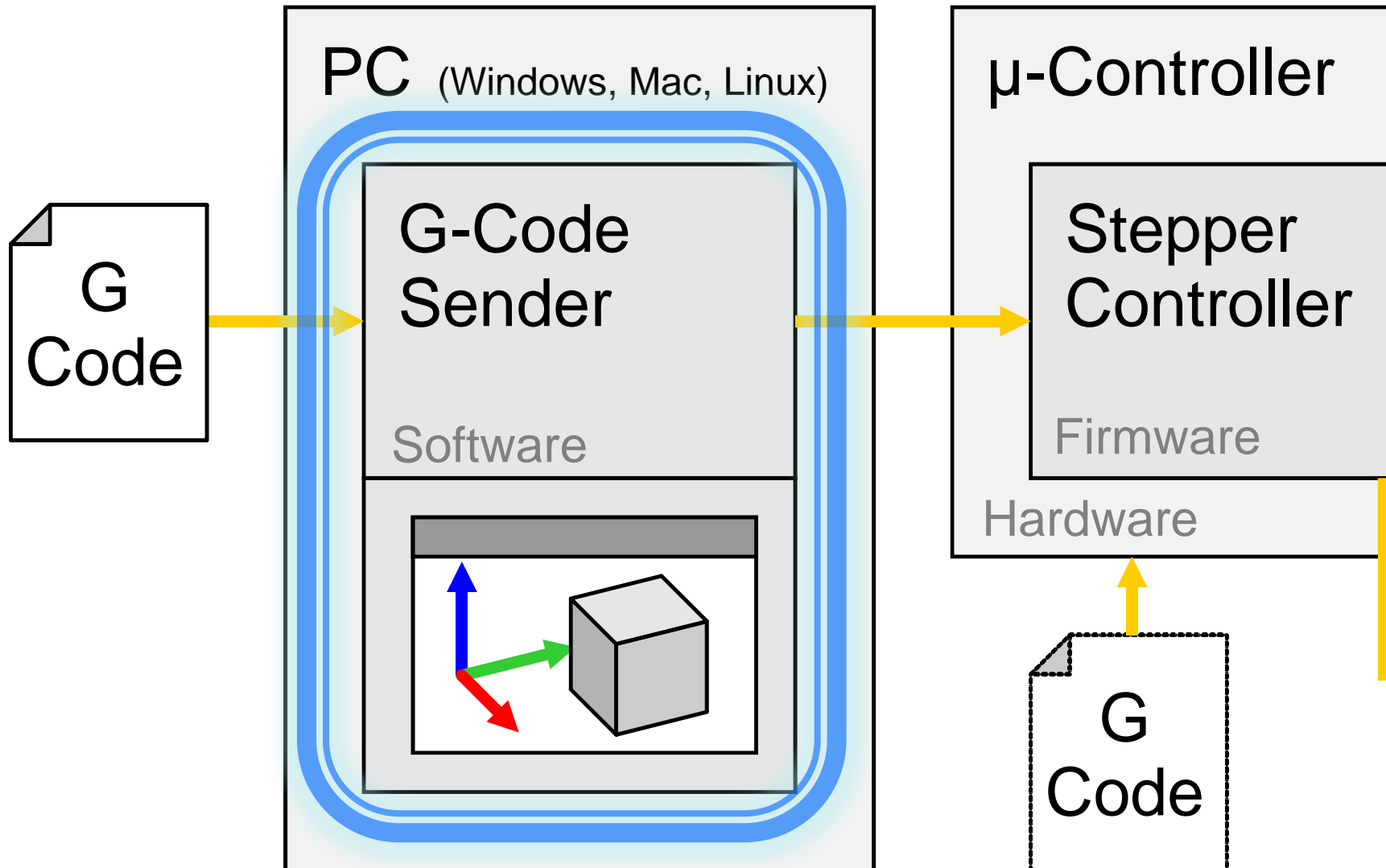
**Platform: Arduino Uno; Nano – Laser; CNC**

- **3 Achsen + Laser/Spindle**
- **Hohe Verbreitung**
- **Viele G-Code-Sender**
- **Super Smooth Stepper Algorithm**
- **License: GPLv3**

**<https://github.com/grbl/grbl>**



# G-Code Sender



# G-Code-Sender – bCNC

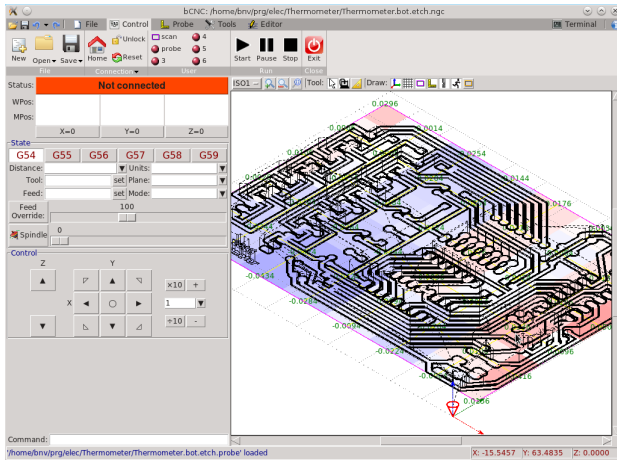
The screenshot displays the bCNC software interface. The title bar shows the file path: `bcNC: /home/bnv/prg/elec/Thermometer/Thermometer.bot.etch.ngc`. The interface is divided into several sections:

- Top Bar:** Contains menu items (File, Control, Probe, Tools, Editor) and a Terminal icon.
- Control Panel:** Includes buttons for 'New', 'Open', 'Save', 'Home', and 'Reset'. It also features a 'User' section with 'scan' (4), 'probe' (5), and '3' (6) indicators, and a 'Run' section with 'Start', 'Pause', 'Stop', and 'Exit' buttons.
- Status:** A red bar indicates 'Not connected'. Below it are fields for 'WPos:' and 'MPos:' with 'X=0', 'Y=0', and 'Z=0' values.
- State:** Shows G-code modes (G54, G55, G56, G57, G58, G59) and settings for 'Distance', 'Tool', 'Plane', 'Feed', 'Feed Override', and 'Spindle'.
- Control:** A grid of directional buttons for X, Y, and Z axes, along with 'x10 +', '1', and '+10 -' buttons.
- 3D View:** A central window showing a 3D model of a thermistor probe with various dimensions and a coordinate system. The model is rendered in black and white with green and red highlights. Dimensions are labeled with values like 0.0296, 0.0014, 0.0144, 0.0176, 0.0158, 0.0116, 0.0096, 0.0224, -0.0284, -0.0994, -0.0724, -0.0434, and 0.0356. A red arrow points to a specific feature on the probe.
- Command Line:** Shows the command `'/home/bnv/prg/elec/Thermometer/Thermometer.bot.etch.probe' loaded`.
- Coordinates:** A status bar at the bottom right displays 'X: -15.5457 Y: 63.4835 Z: 0.0000'.

# G-Code-Sender – bCNC

## Sender, Viewer, CAM

- Cross Platform (Windows, Linux, Mac)
- G-Code Editor und Evaluierung
- Einfache CAM-Funktionen
- License: GPLv2



<https://github.com/vlachoudis/bCNC>

# G-Code-Sender – ChiliPeppr

The screenshot displays the ChiliPeppr web interface in a browser window. The main area is a 3D viewer showing a blue and purple cone-shaped object. A context menu is open over the object, displaying the following options:

- Start X 0 Y 0 Z 3
- End X 0 Y 0 Z 3
- Send Gcode to Move to This Position
- Set as New Start Position

The G-code list on the left shows the following lines:

```
15 N15 G2 F800.0 X39.0
719 Y-3.7614 I-2.0806
J1.2144
16 N16 G2 X38.4511
Y-4.2692 I-1.5584
J1.2717
17 N17 G2 X37.6702 Y-4.
452 I-0.7659 J1.5128
18 N18 G2 X36.9056 Y-4.
2757 I-0.0154 J1.6797
```

The Serial Port Console at the bottom left shows the following table:

Lines	Showing	Sent	To Be Sent
585	1 - 50	0	585

The Serial Port Console also shows the following table:

Time Start	Est Time	Est Remain	Duration
-	00:01:56	-	-

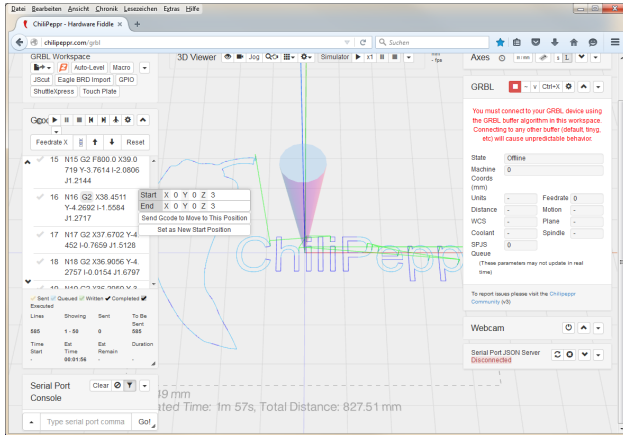
The right sidebar contains the GRBL control panel, which is currently Offline. It includes fields for Machine (0), Coords (mm), Units, Feedrate (0), Distance, Motion, WCS, Plane, Coolant, Spindle, and SPJS (0). A warning message states: "You must connect to your GRBL device using the GRBL buffer algorithm in this workspace. Connecting to any other buffer (default, tinyg, etc) will cause unpredictable behavior." The Serial Port JSON Server is also shown as Disconnected.

At the bottom of the 3D viewer, the following text is displayed: "Estimated Time: 1m 57s, Total Distance: 827.51 mm".

# G-Code-Sender – ChiliPeppr

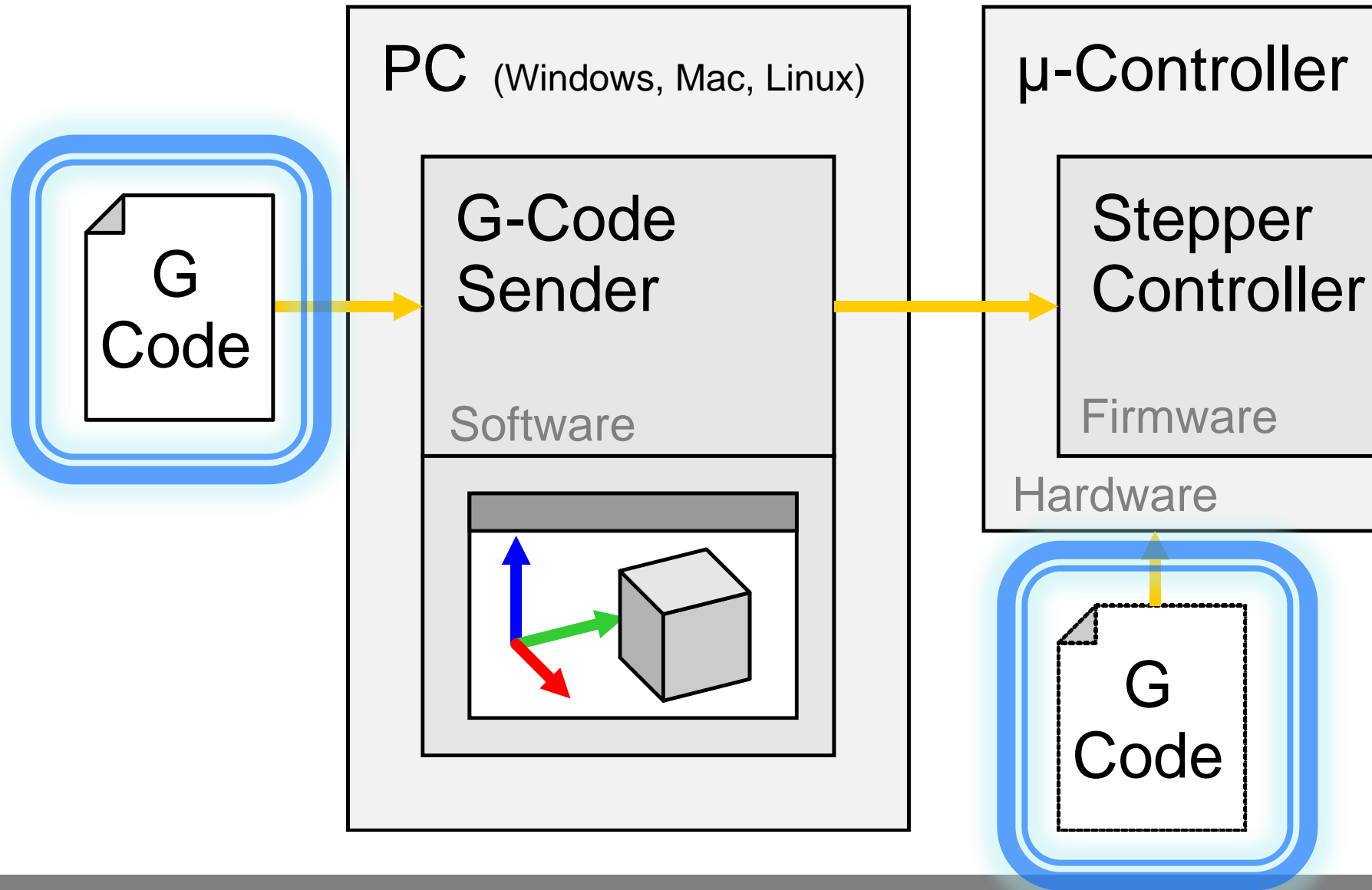
## Sender, Viewer, Analysator

- **Cross Platform (Web-Based, online)**
- **Auch als Offline-Projekt**
- **Getrennter Server über Netzwerk (z.B. RPi)**
- **License: MIT; GPLv2 (Server)**



<http://chilipeppr.com/>

# G-Code



# G-Code

## **Universelle Kommando-Sprache zum Steuern von Maschinen**

- **Einfache Positionierbefehle in ASCII**
- **Bewährt und unverändert seit 1960**
- **Erweitert um Temperaturregelung  
für 3D-Printer**
- **Viele Konverter, Viewer, Sender...**
- **Normen: NIST RS-274/NGC; DIN 66025;  
ISO 6983**

# G-Code

```
G0 X0 Y0 Z0 <CR>
```

```
G1 Z-10 <CR>
```

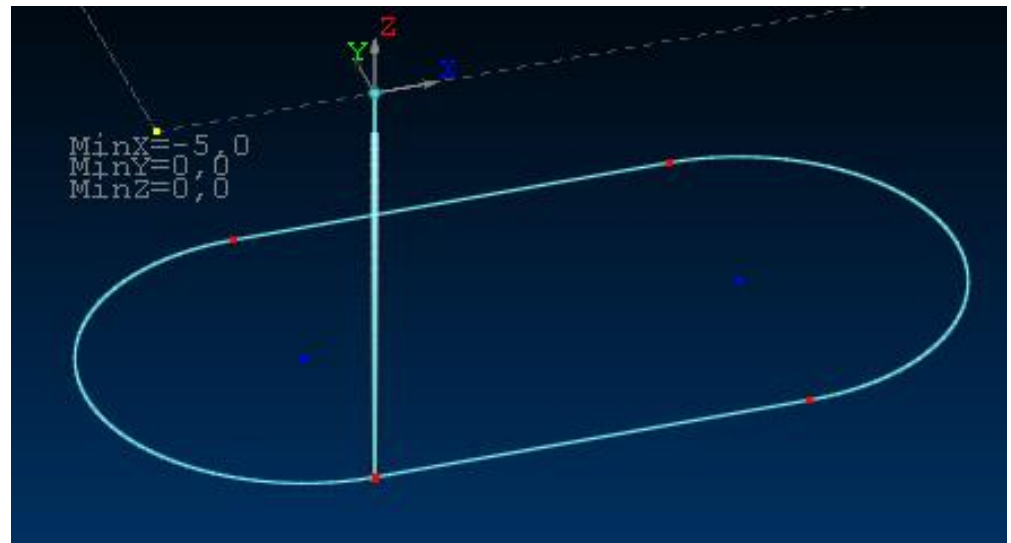
```
G2 X0 Y10 I0 J5 <CR>
```

```
G1 X10 Y10 <CR>
```

```
G2 X10 Y0 I0 J-5 <CR>
```

```
G1 X0 Y0 <CR>
```

```
G1 Z0 <CR>
```





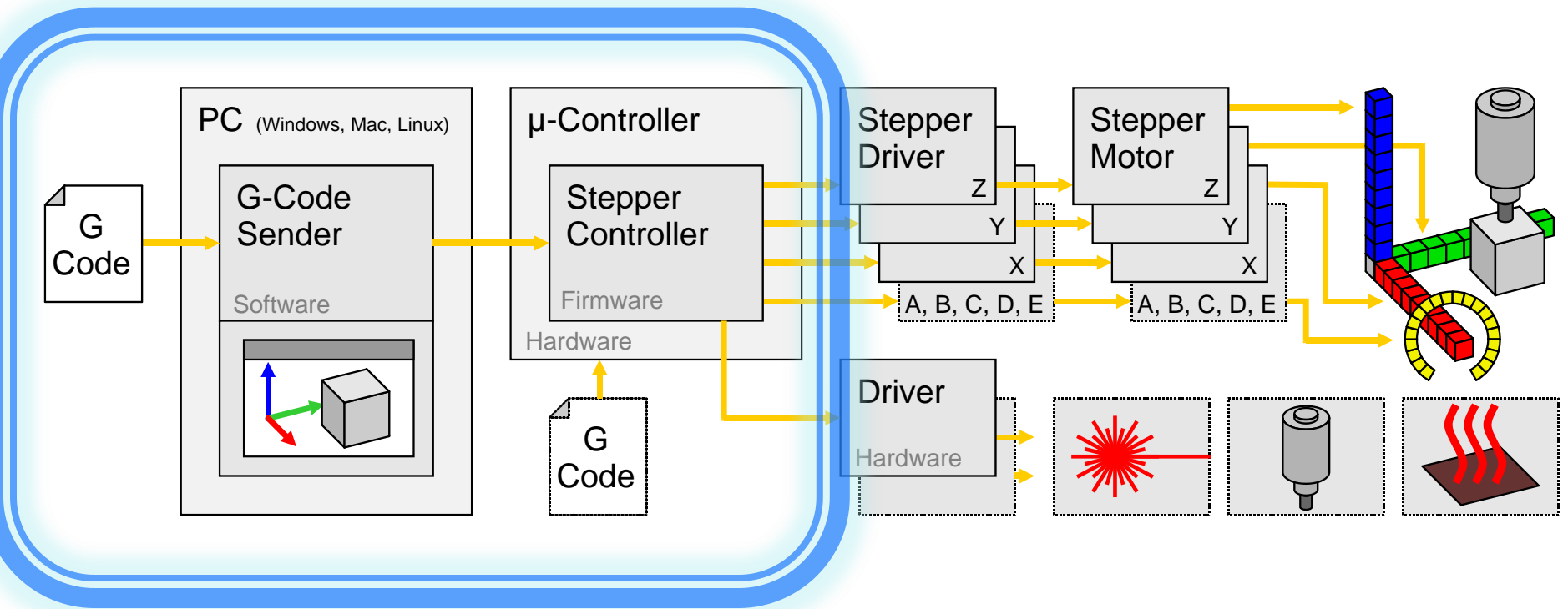
# G-Code

## Links:

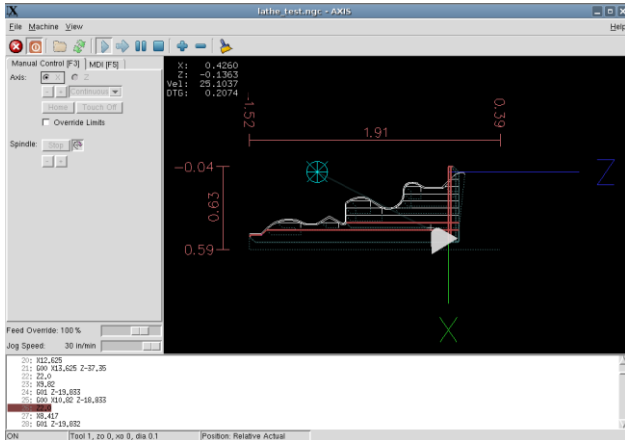
<https://en.wikipedia.org/wiki/G-code>

<http://gnipsel.com/linuxcnc/g-code/index.html>

# LinuxCNC



# LinuxCNC

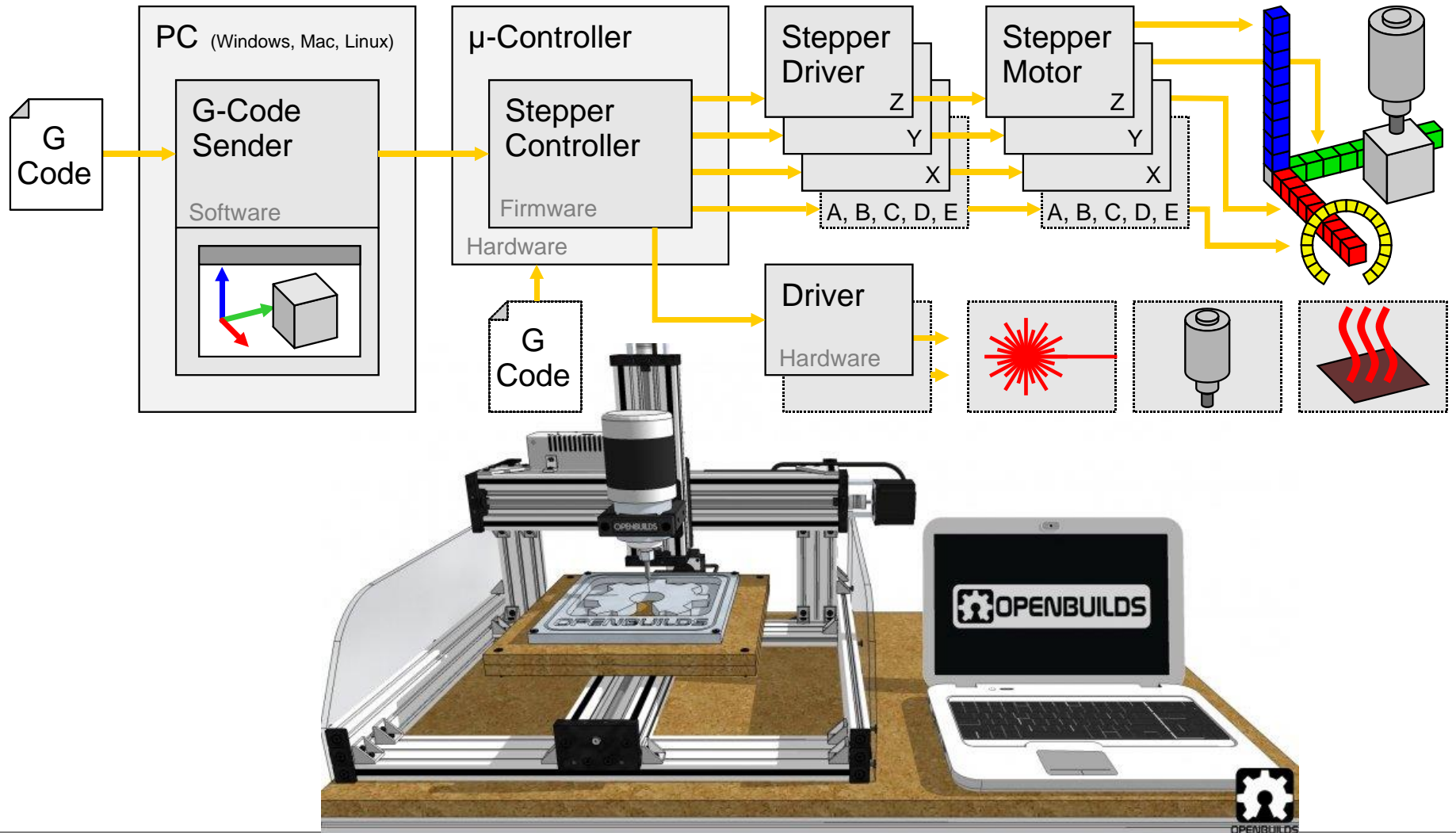


## Viewer, Sender, Controller...

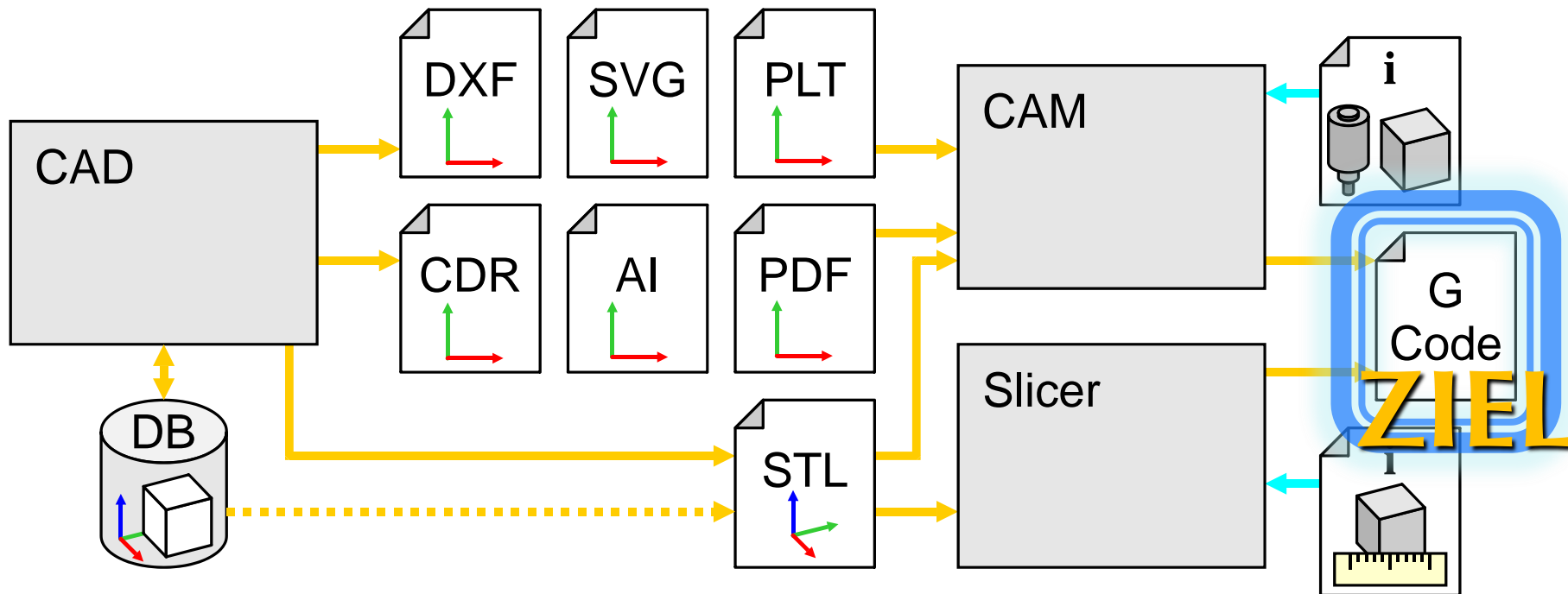
- PC-Linux (Debian, Ubuntu, Live-DVD)
- Unterstützt Fräsen, Drehen, Roboter...
- Umfassender G-Code
- PC: Parallele Schnittstelle
- BeagleBone: PRU-GPIO

<http://www.linuxcnc.org/>

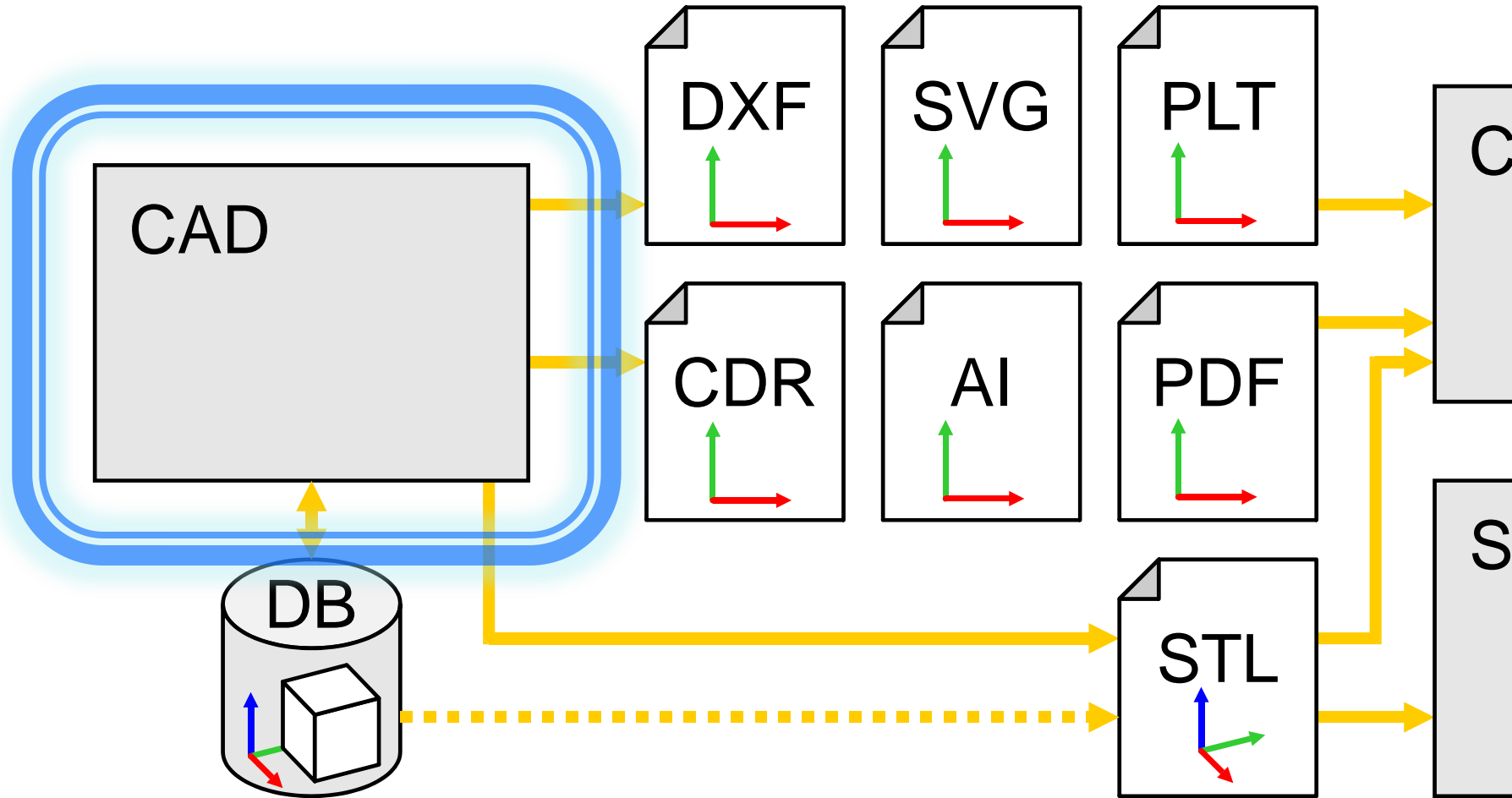
# ...fertige CNC...



# Der CAD-CAM-Workflow...



# CAD (Computer Aided Design)



# CAD-Programme

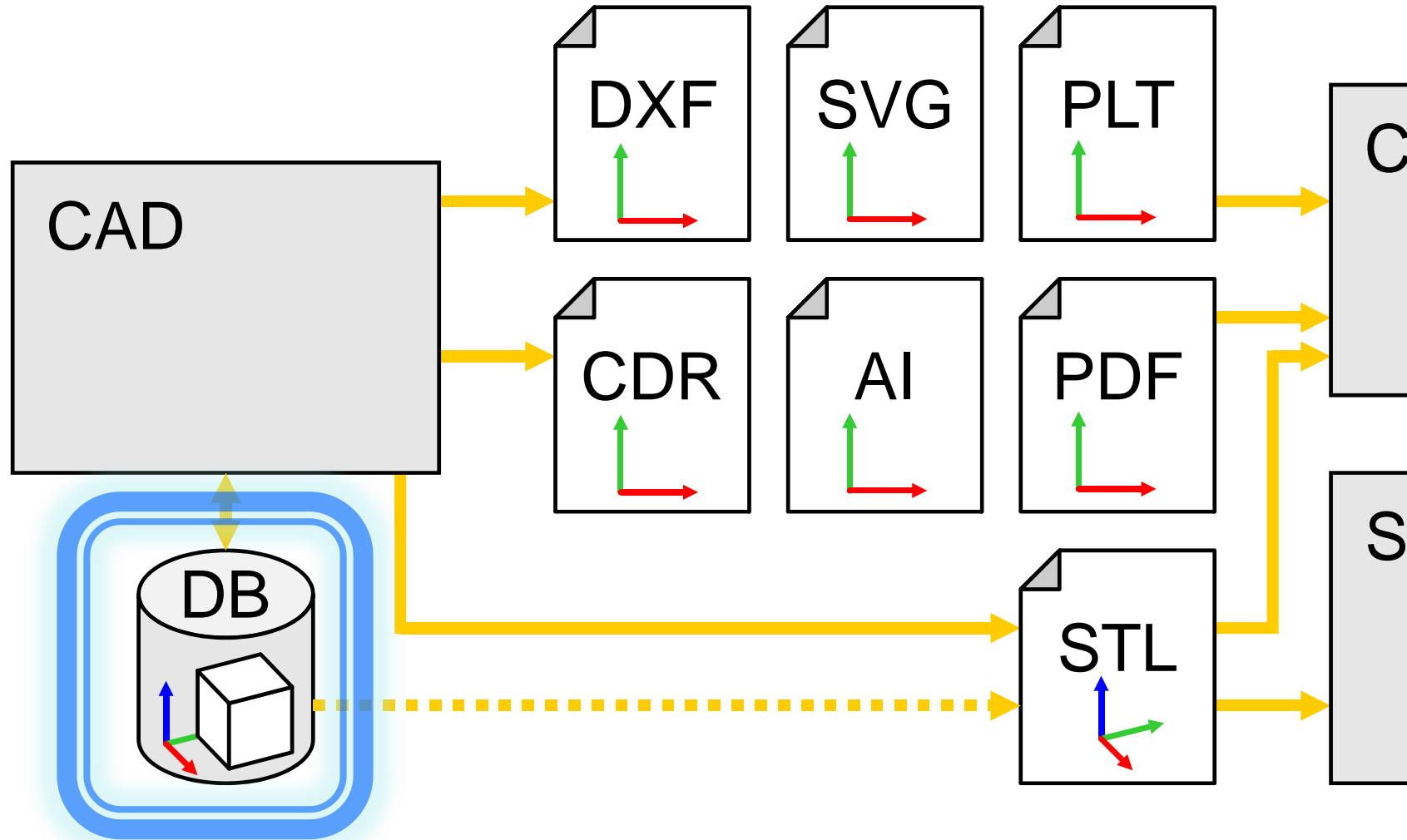
## 3D-Programme → STL

- **Blender**
- **FreeCAD**
- **OpenSCAD**
- **Google SketchUp**
- **Autodesk 123D**

## 2D-Programme → DXF

- **Inkscape**

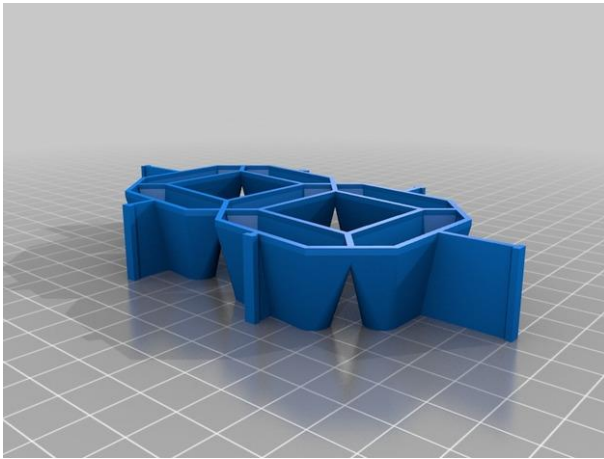
# Datenbanken mit Dingen





# DB - Thingiverse

MakerBot Thingiverse

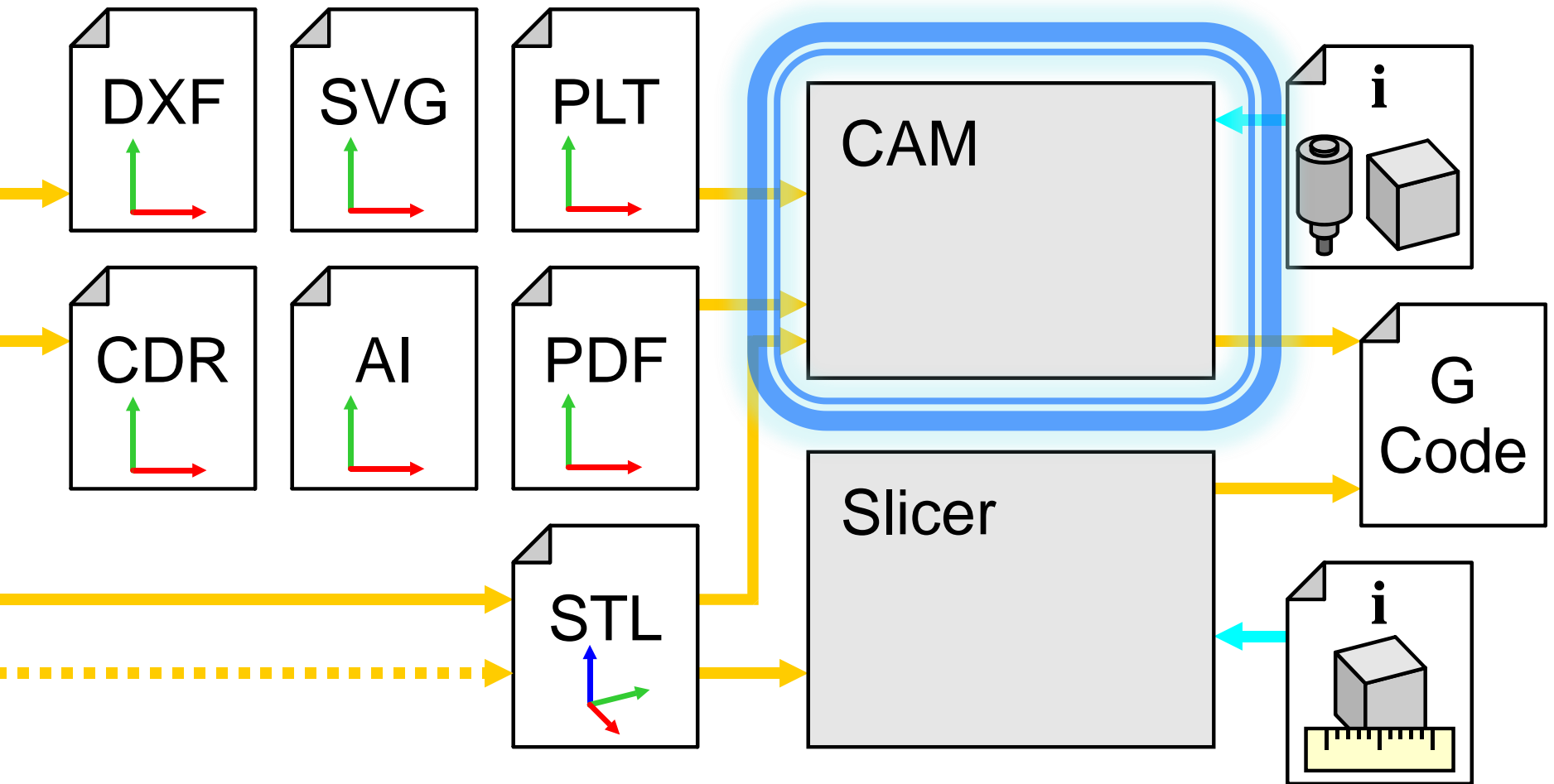


## Freie Objekt-Datenbank

- Alle Genres
- STL und OpenSCAD
- Parametrische Objekte
- License: CC (typisch)

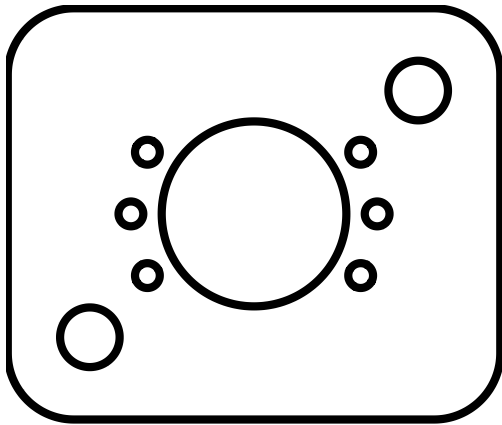
<http://www.thingiverse.com/>

# CAM (Computer Aided Manufacturing)

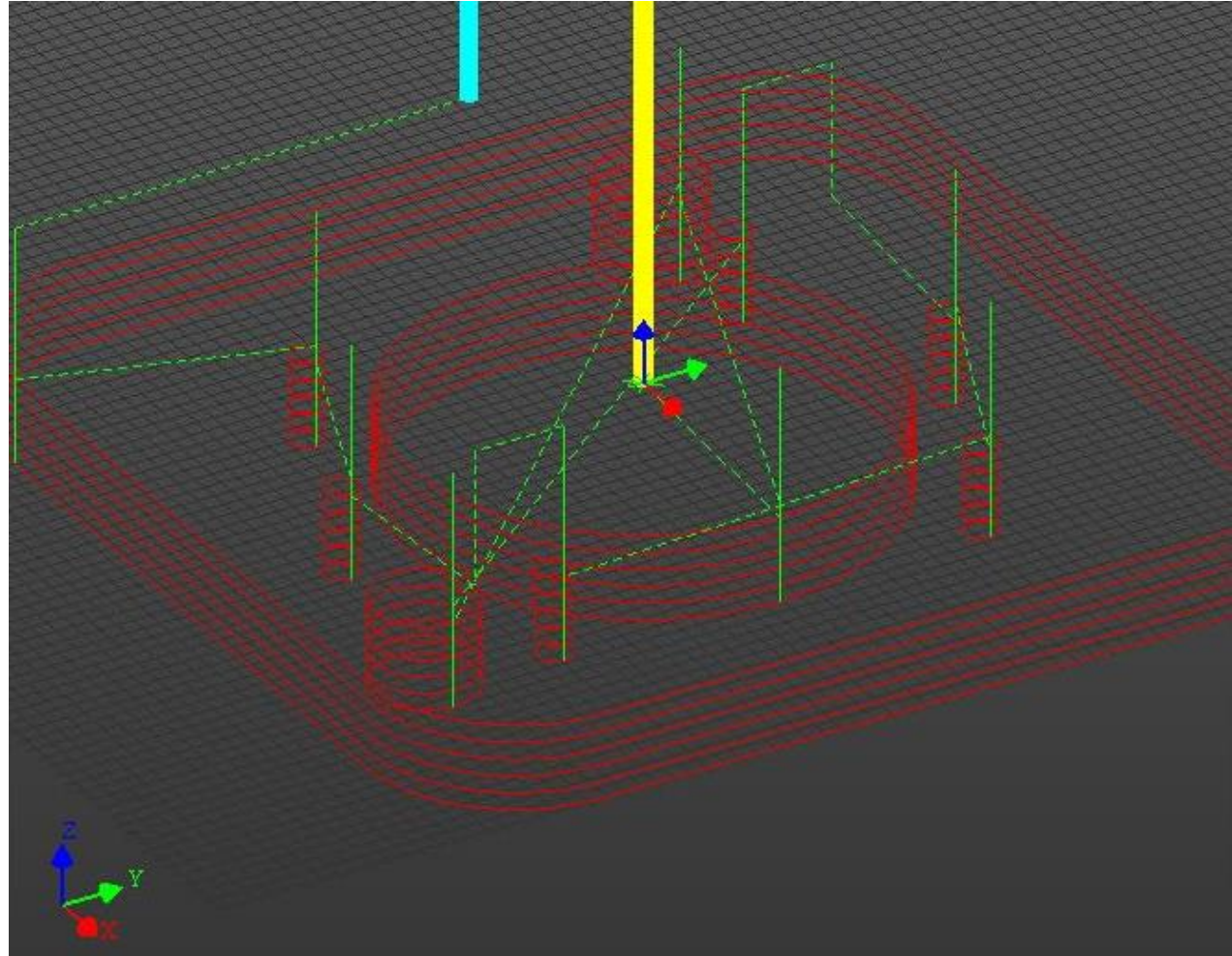


# CAM - Prinzip

CAD



CAM



# CAM - PyCAM

## CAM für Fräse



- Cross Platform (Python)
- G-Code aus 2D und 3D
- Komplexe Fräspfade möglich
- License: CPLv3

<https://sourceforge.net/projects/pycam/>

# CAM – DXF2GCode



**CAM für Fräse, Scheidplotter**

- **Cross Platform (Python)**
- **G-Code aus 2D (DXF)**
- **Korrektur für Schleppmesser**
- **License: CPLv3**

**<https://sourceforge.net/projects/dxf2gcode/?source=recommended>**

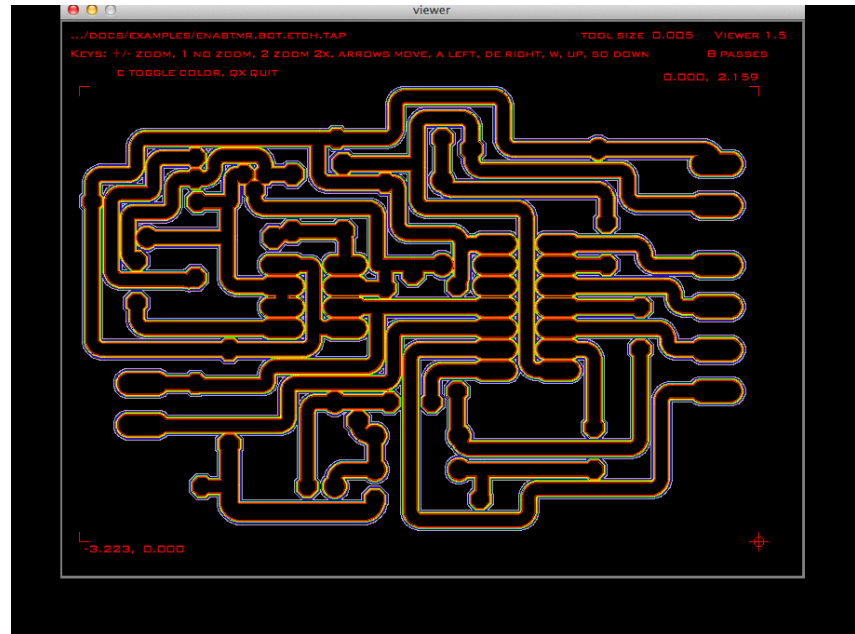
# CAM – PCB-GCode

## CAM für Eagle-Layout

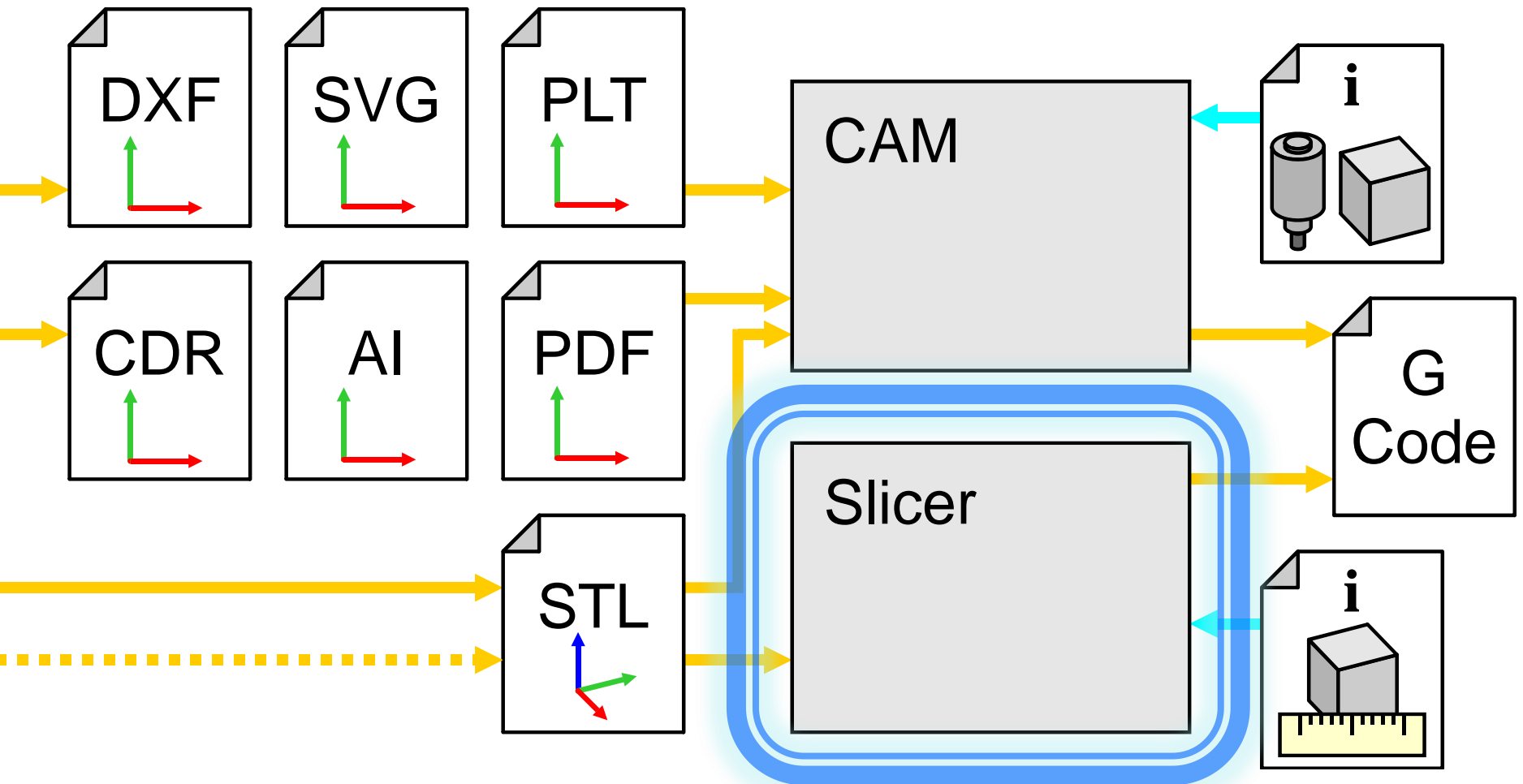
**PCB-GCODE**

- Plugin für Eagle
- Leiterbahnen umfräsen
- License: CPLv3

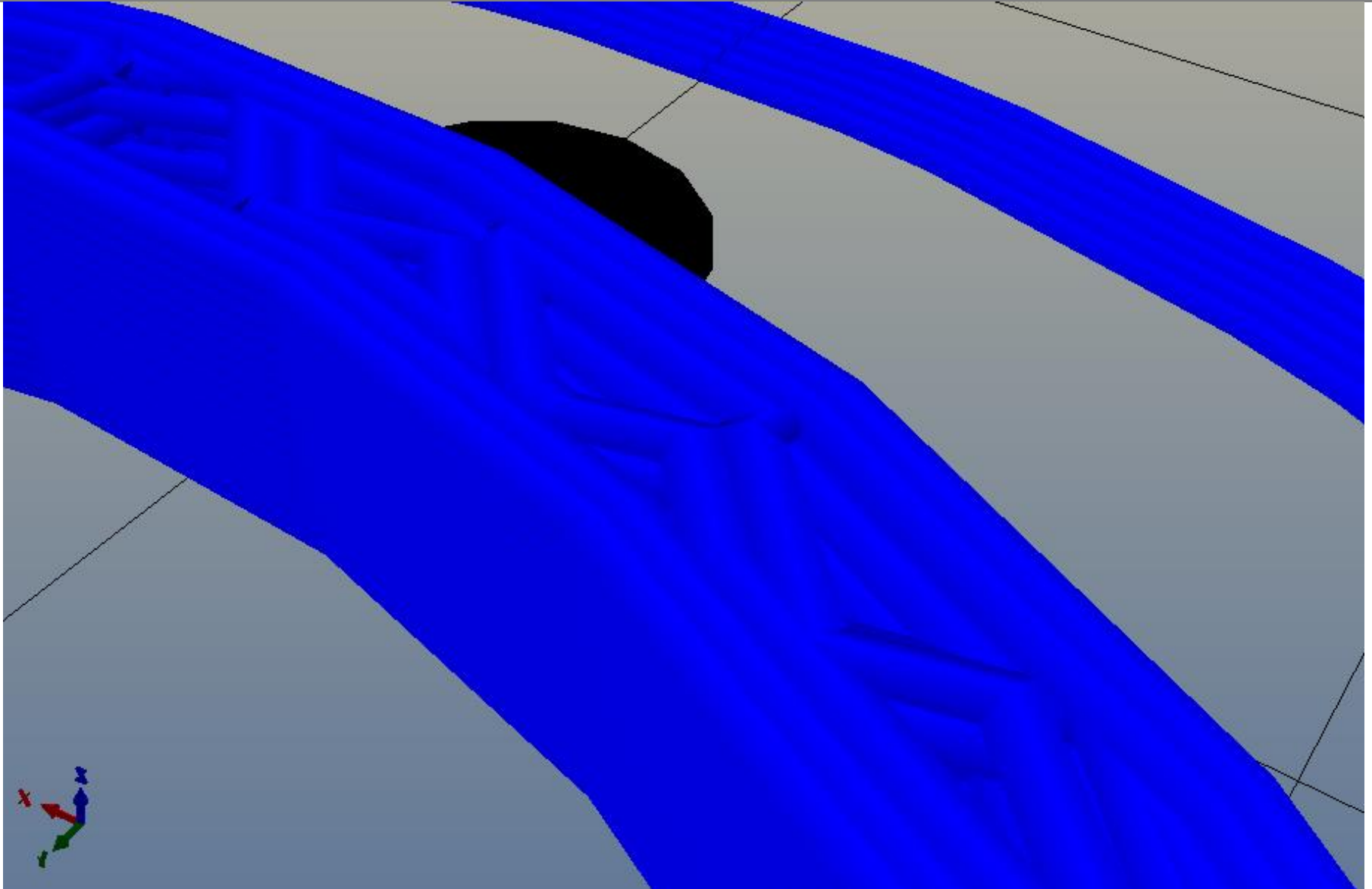
<http://pcbrcode.org/>



# CAM (Computer Aided Manufacturing)



# Slicer – Prinzip





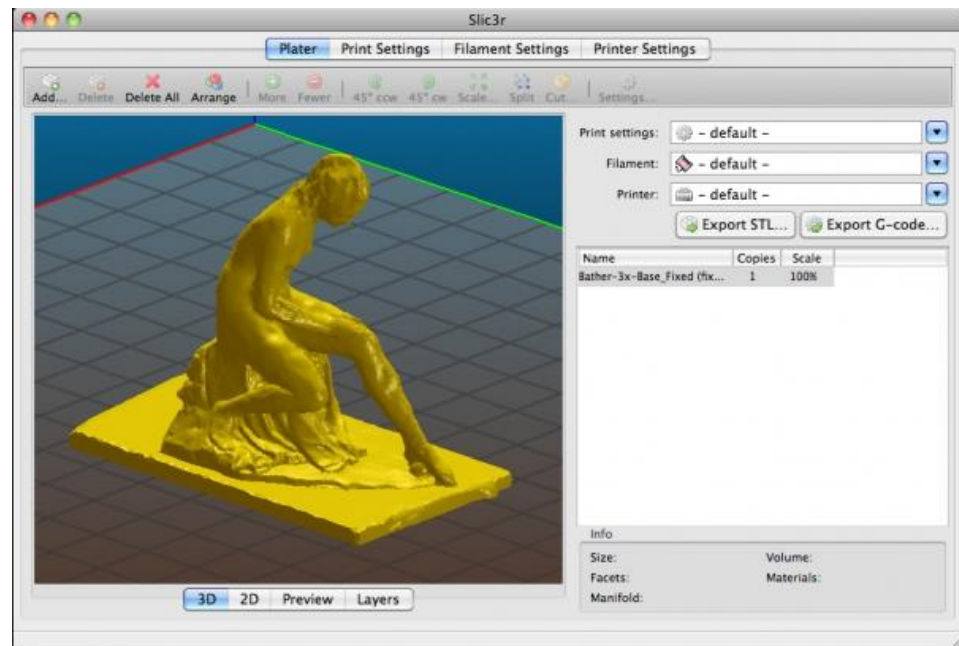
# Slicer – Slic3r



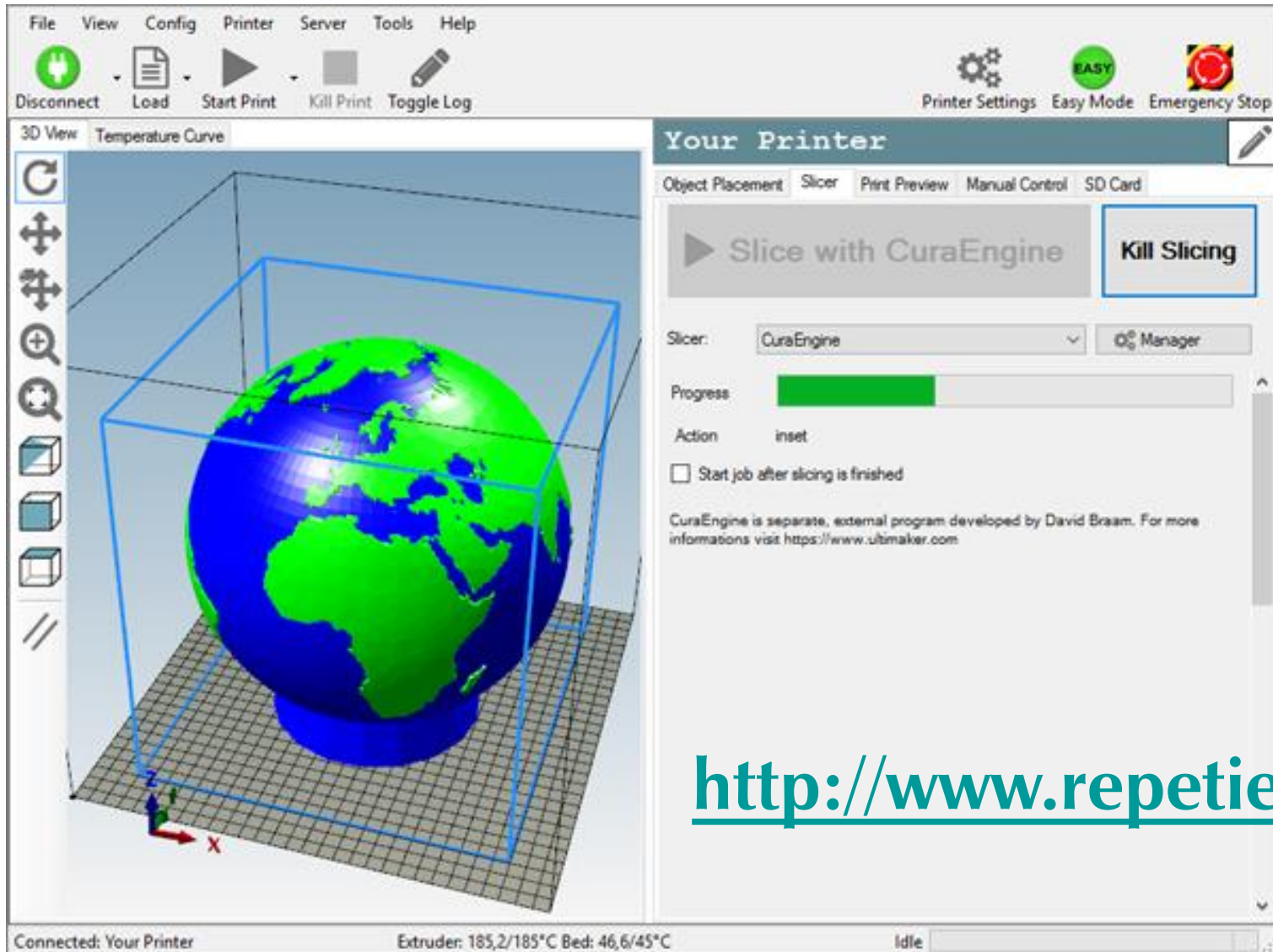
## CAM für 3D-Printer

- **Eigebettet in 3D-Printer-Software**
- **License: CC BY-SA 3.0**

<http://slic3r.org/>

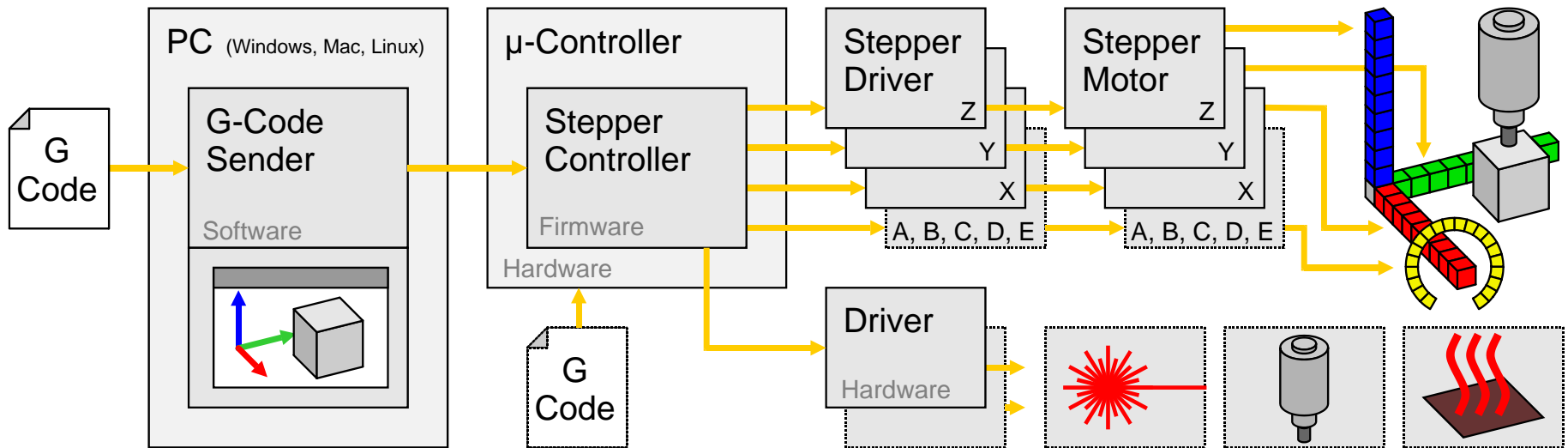
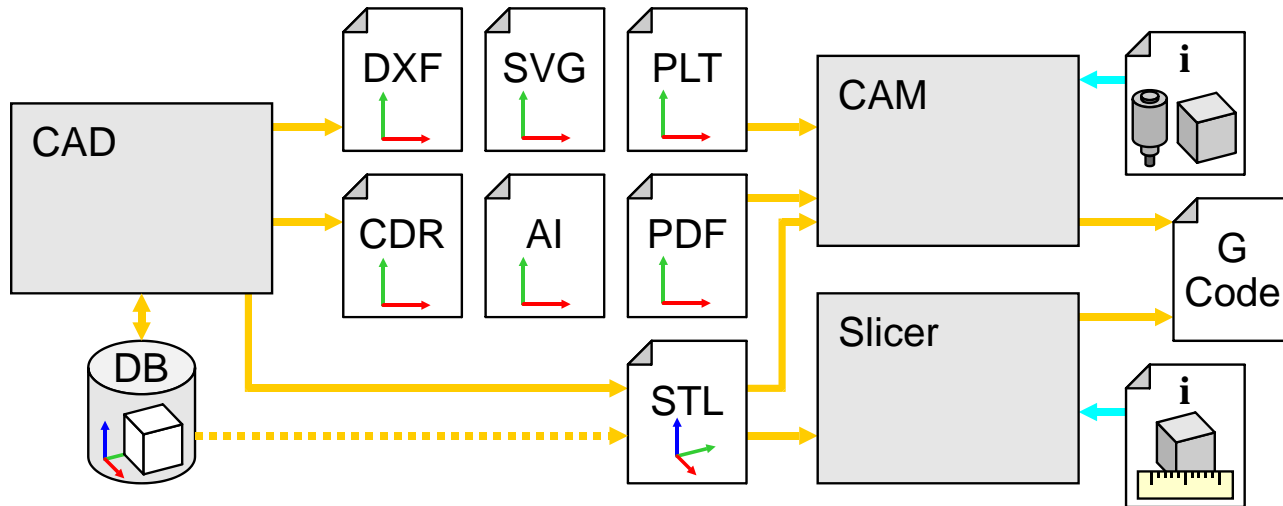


# Slicer – In Repetier Host



<http://www.repetier.com/>

# ...fertig! Fragen?



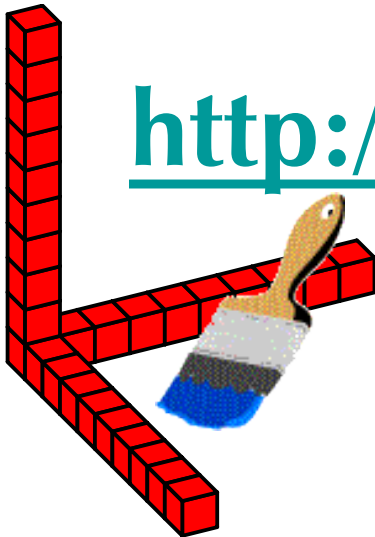
# Experten → FabLabs

<http://www.fablab-nuernberg.de/>

<https://fablab.fau.de/> (Erlangen)

<https://fablab-wuerzburg.de/>

<http://www.fablab-regensburg.de/>





**Alle Logos, Marken und Namen sind Eigentum der jeweiligen Firmen**