*Middle Eastern Partnership in Sustainable Engineering – Tempus project*

**LLL Workshop**

# Course 3: Automation and Control

## Computer Numerical Control of Machine-Tools

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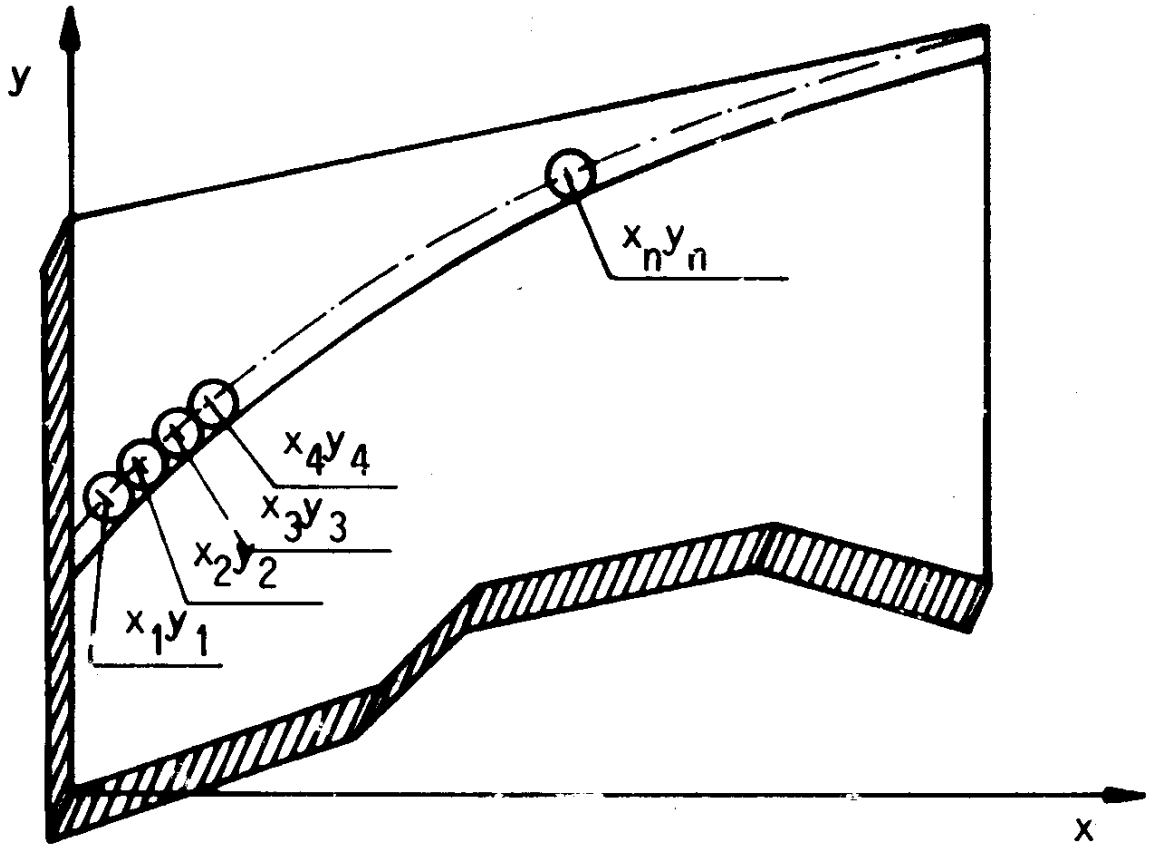
# Content

- Introduction
- Fundamentals od Computer Numerical Control (CNC)
- Development of a reconfigurable and lean flexible machining system RMS/FMS LAKOS 250
- Desktop CNC engraving machine tool LAKOS 150
- Conclusion

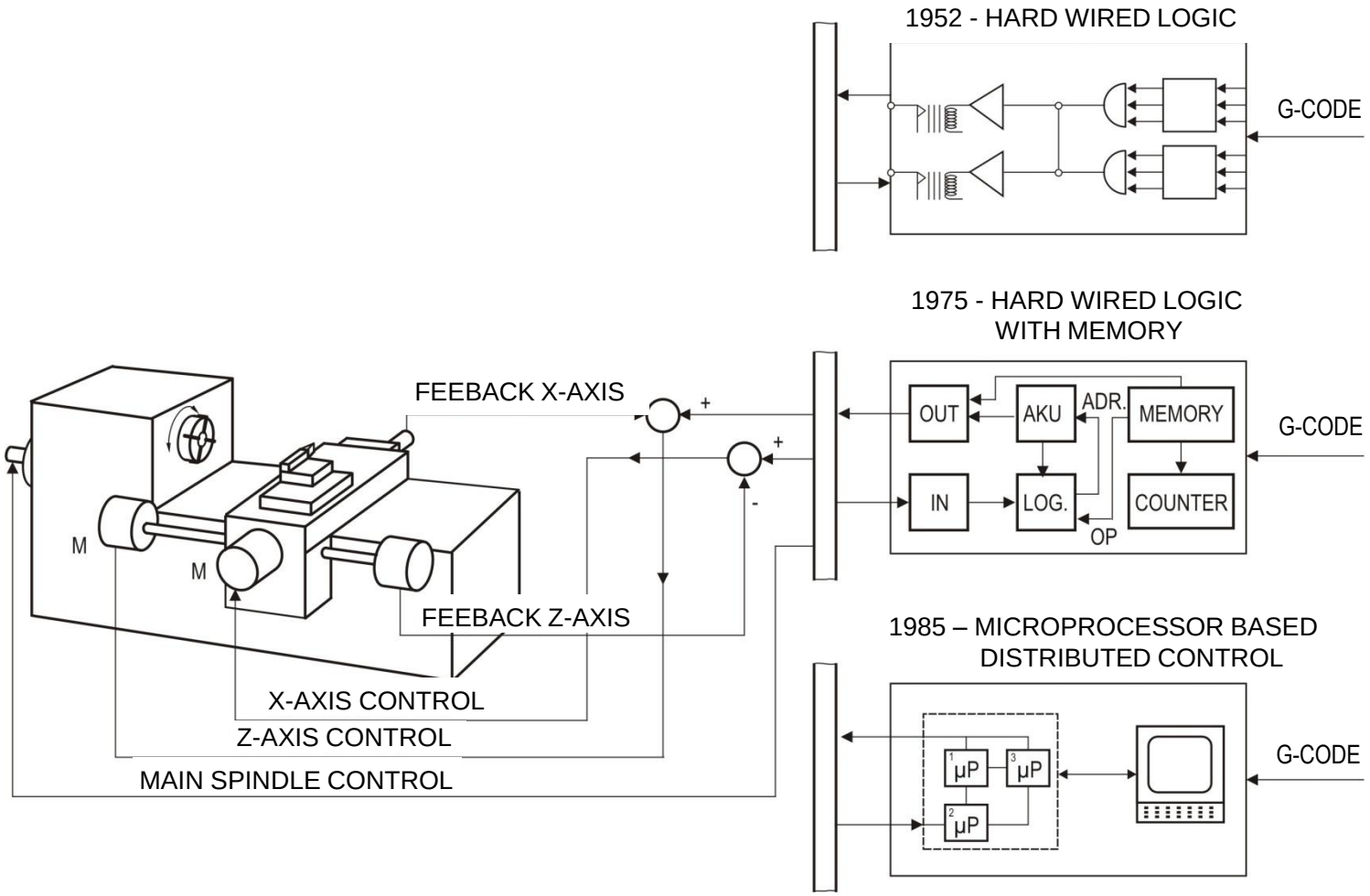
# FUNDAMENTALS OF COMPUTER NUMERICAL CONTROL

# Parsons' concept of numerical control




Source: J.T. Parsons: Motor Controlled Apparatus for Positioning Machine Tool, US Patent, filed in May, 1952)

# Development of Numerical Control



# Computer Numerical Control

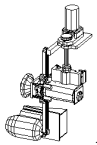
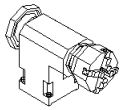
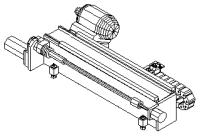
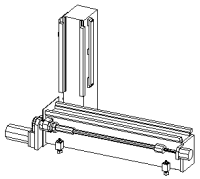
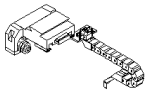
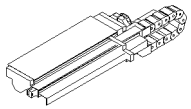
- Computer Numerical Control (CNC) of machine-tools is a mature and widely used technology.
- Its historical development has undergone a long way since the first concept was proposed by John T. Parsons and the first prototype was developed at MIT in the fifties.
- Two important innovation pushes happened after the first steps (1) the introduction of the computer technology in the late sixties and (2) the invention of microprocessors in the seventies.
- For a long period of time this technology had been a much closed domain of a few specialized companies which governed the development and the market.
- In the nineties a new concept of so-called open architecture was proposed.
- The STEP-NC control concept was proposed a decade ago.
- In the last few years also the open source movement touched the field.

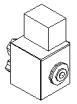
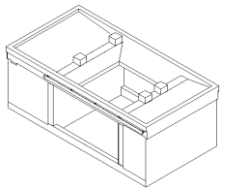
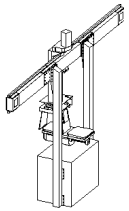
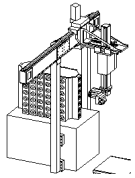
# DEVELOPMENT OF A RECONFIGURABLE AND LEAN FLEXIBLE MACHINING SYSTEM RMS/LFMS LAKOS 250

# Objectives and motivation

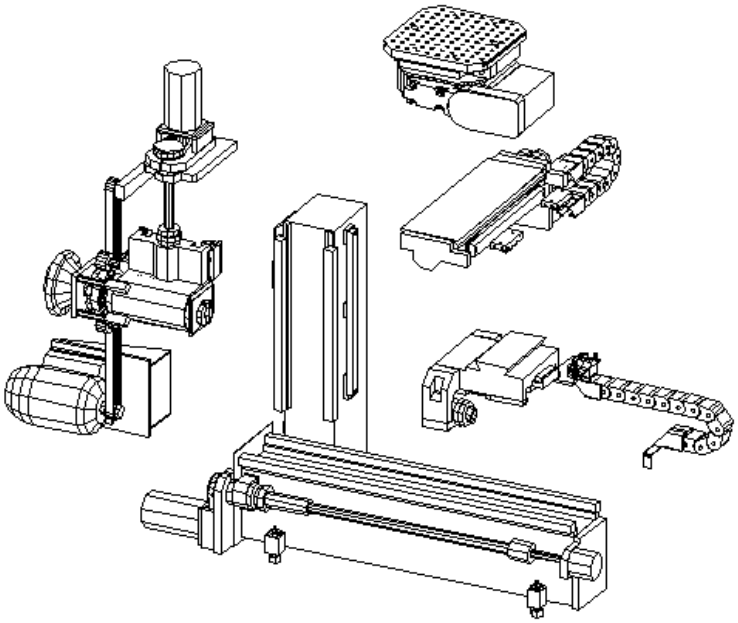
- LAKOS had developed the first CNC control system in 1993 implemented on a standard personal computer (PC) with an embedded motion control card and dadicated software running in the DOS operating environment.
- The idea behind was to develop a modular, reconfigurable machining system named LAKOS 250 capable of being configured for various machining processes.
- One of the objectives was also to develop modules and control solutions which would enable integration of several machining systems into a lean flexible manufacturing system - LFMS.
- Further developments included a CNC controller implemented in the Windows environment, remote control over the Internet, integration with adaptive process control, etc. The LAKOS controllers had been implemented on various machining systems.

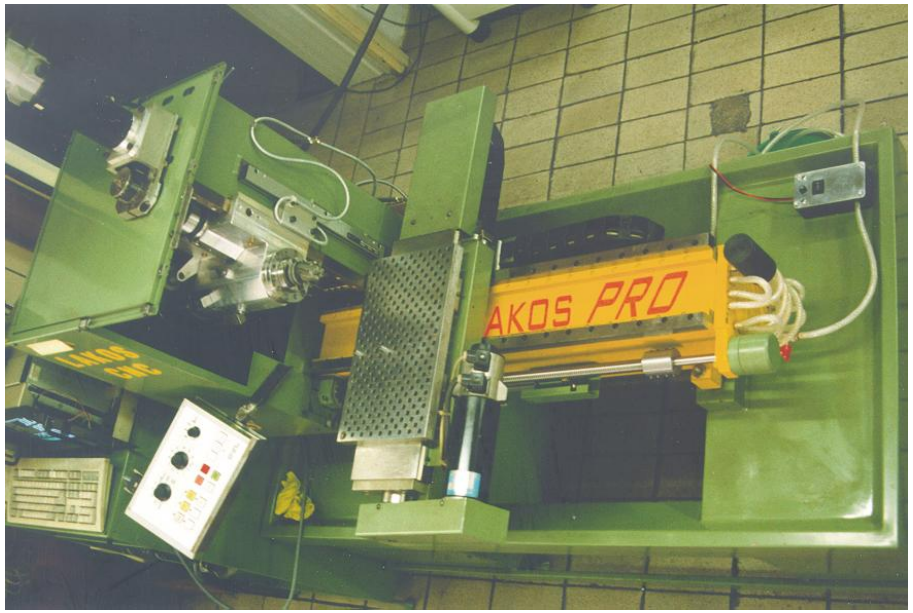
# Modules of the RMS/LFMS LAKOS 250

| Module type | | Sketch | Characteristics |
|---|---|---|---|
| Main spindle drives | Milling spindle |  | 0 - 3000 rev/min<br>1,1 kW<br>SK 30 |
| | Turning spindle |  | 0 - 2000 rev/min<br>2,0 kW<br>clamping head<br>max ϕ150 mm |
| Structural elements | Bed |  | Linear slides |
| | Bed with column |  | Linear slides |
| Positioning/feed drives | Longitudinal |  | 0 - 400 mm<br>0 - 8 m/min |
| | Transversal |  | 0 - 320 mm<br>0 - 8 m/min |
| | Rotational |  | 300 x 300 mm |

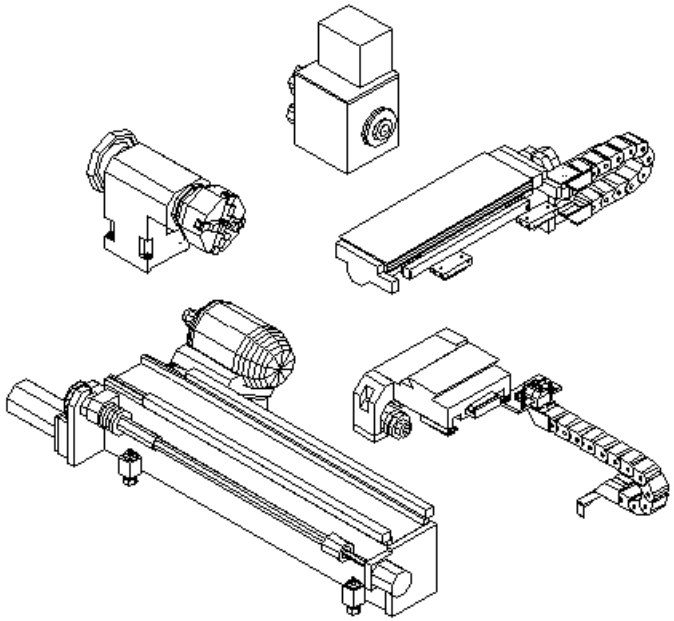
| Module type | | Sketch | Characteristics |
|---|---|---|---|
| System el | Tool holder |  | Turning tools<br>h = 20 mm |
| Auxiliary | Support |  | 1500 x 800 x 600 |
| Material flow | Pallet changer |  | Exchange of two pallets<br>250 x250 mm |
| | Tool magazine with changer |  | Tool storage<br>max 99 tools<br>SK 30 |

# Case 1: Reconfigurable milling/drilling machine LAKOS 250M

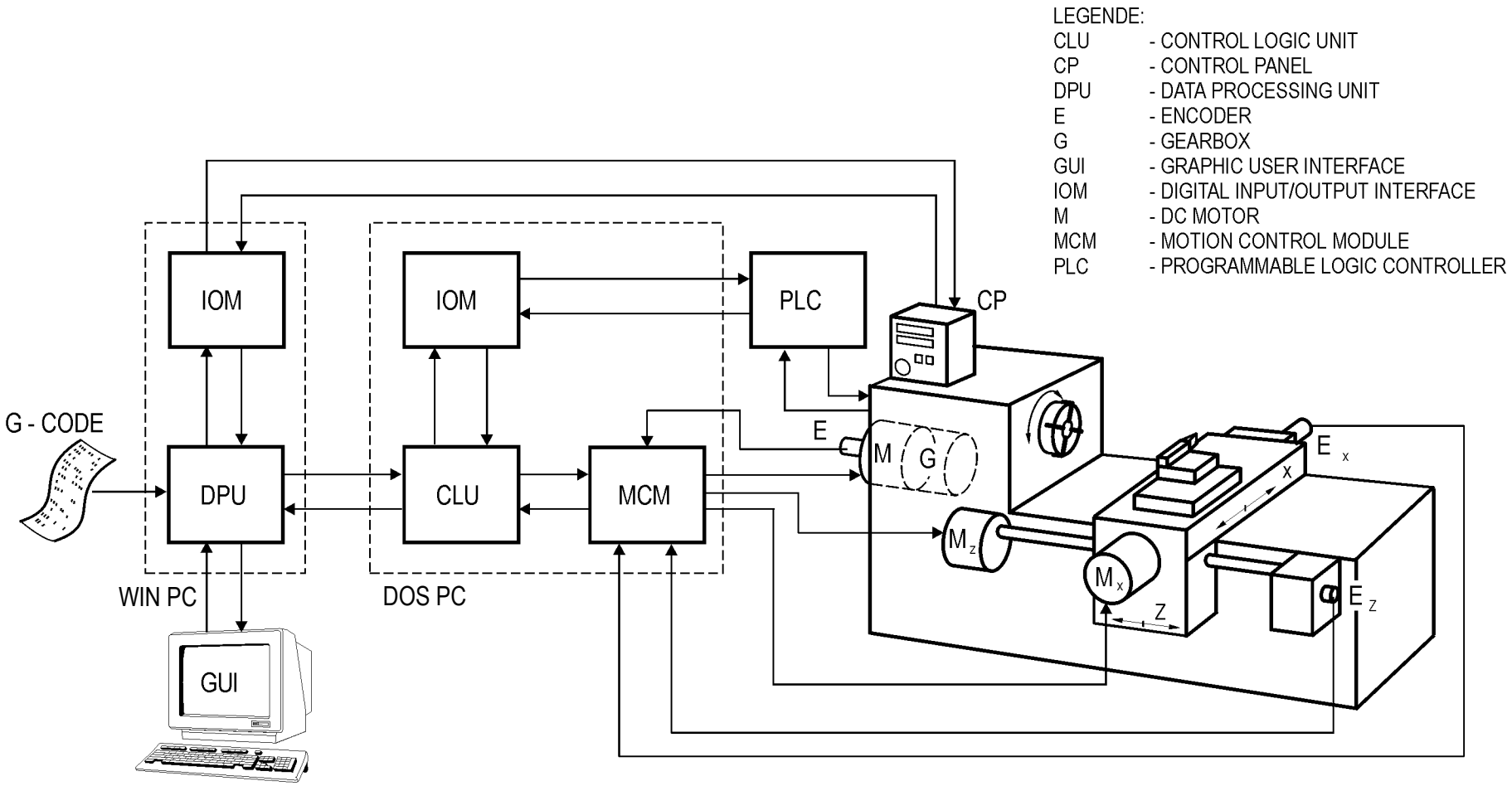




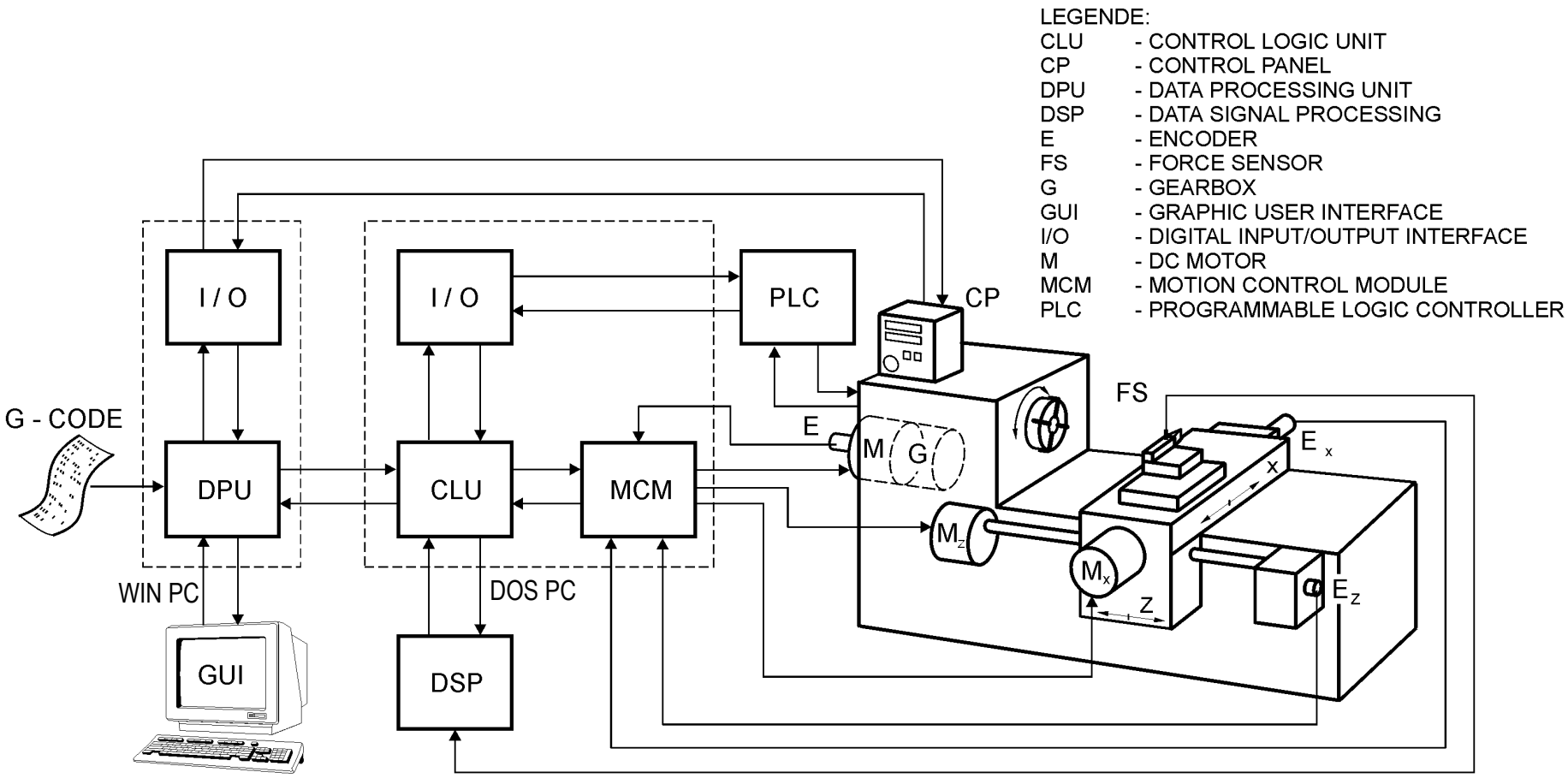
# Case 2: Reconfigurable lathe LAKOS 250T



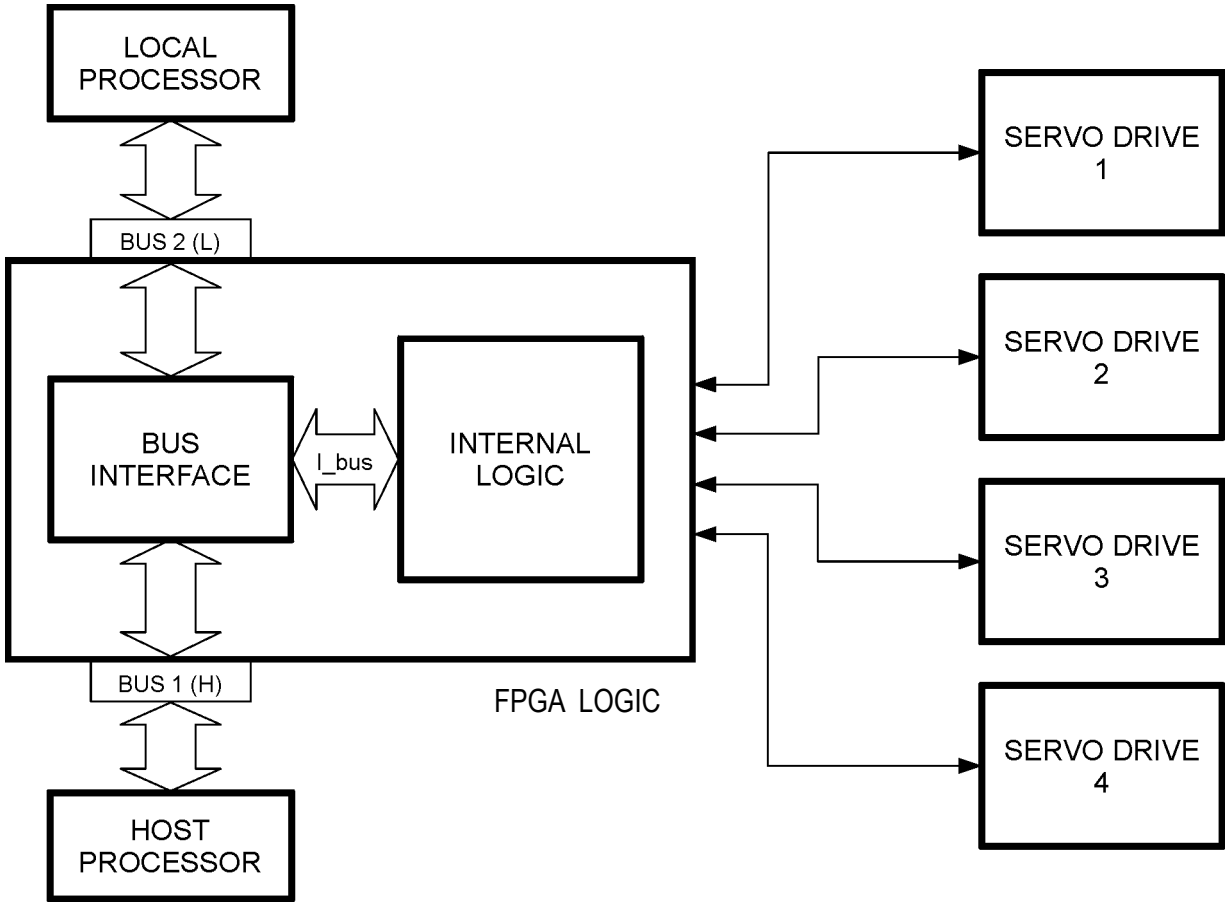
# Structure of CNC controller LAKOS applied on a lathe



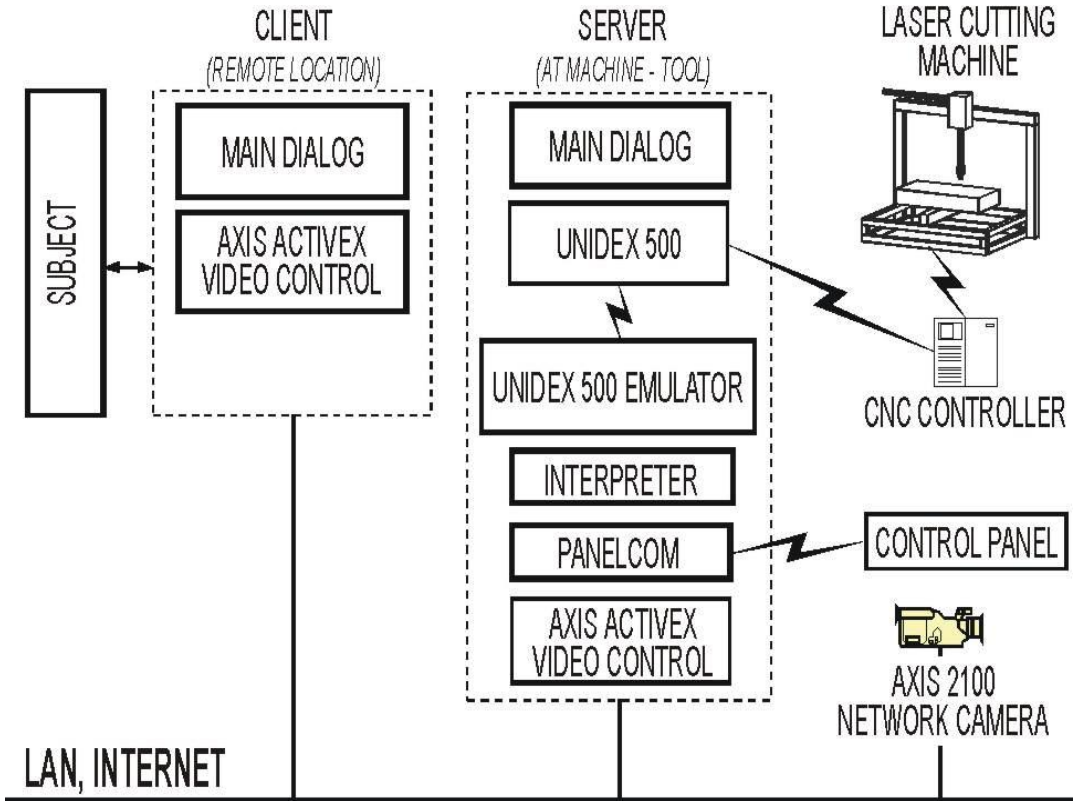
# Structure of CNC controller LAKOS integrated with an adaptive process controller AC applied on a lathe



# Motion control module MCM

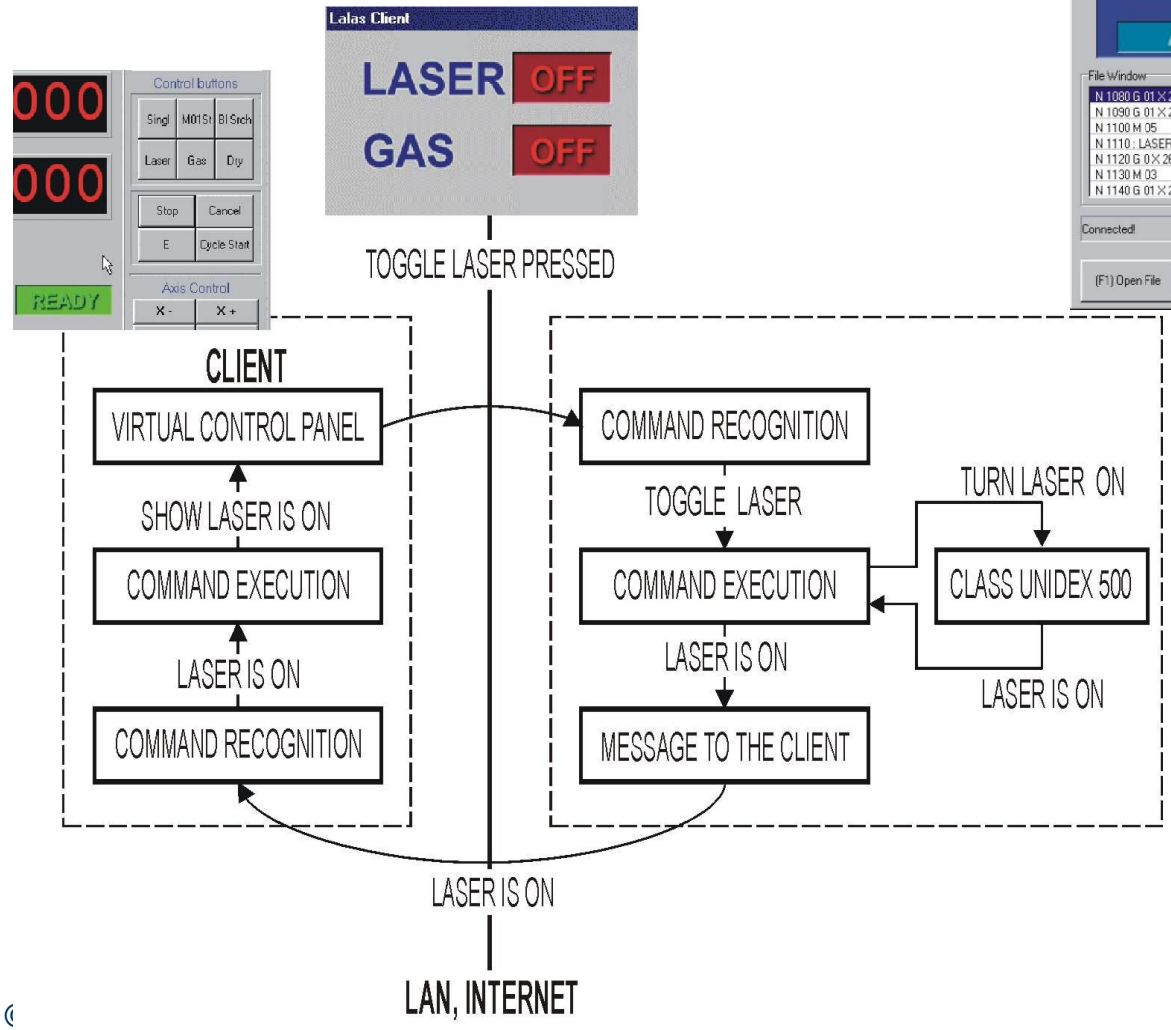


# Remote control over the internet implemented on a laser sheet metal cutting machine LAKOS 250LC – Telemanufacturing




# Telemanufacturing in operations


GRAPHICAL USER INTERFACE AT REMOTE SITE



# DESKTOP ENGRAVING MACHINE-TOOL LAKOS 150G

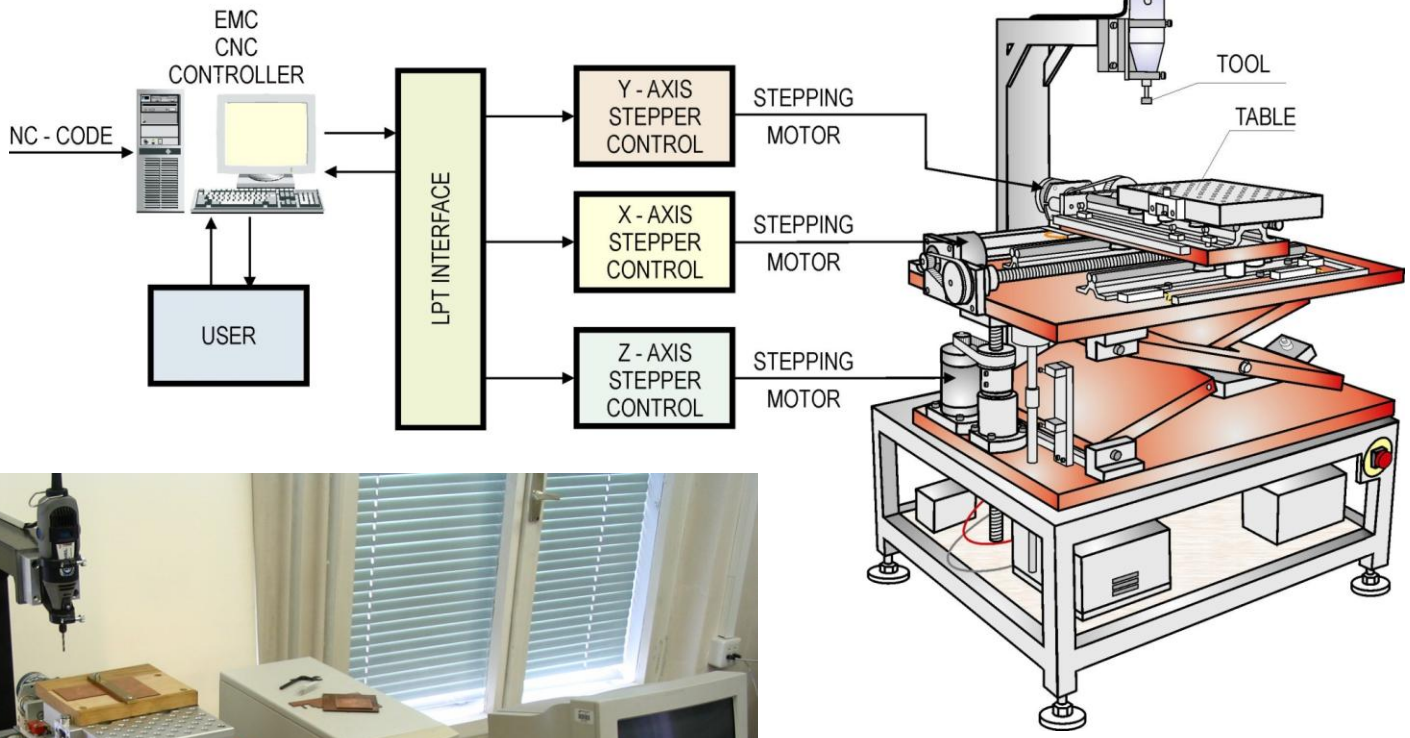
# Open architecture control

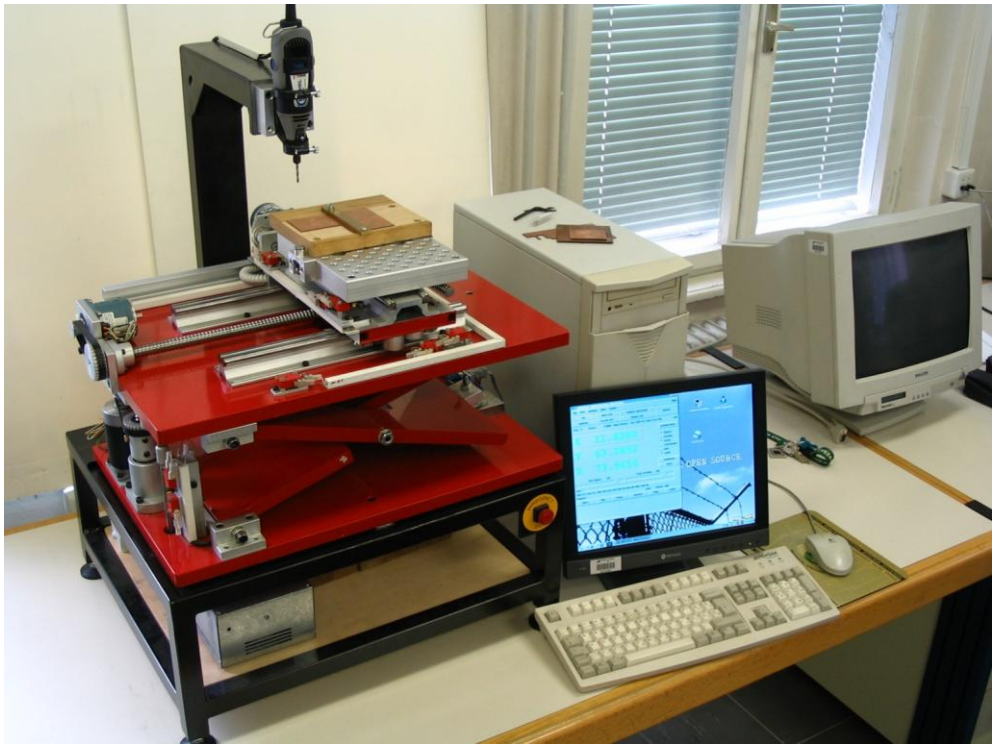
- At the early stage of the technology, the CNC controllers were closed systems. They did not allow any adaptation and thus blocked further development.
- To overcome this situation, Open Architecture Control (OAC) was proposed by the research community as a concept for easy implementation and integration of customer-specific controls by means of open interfaces and configuration methods in a vendor neutral, standardized environment (Pritschow, et al., 2001).
- The OAC concept defines a clear description of the controller's structure, its components, interfaces with internal and external units and data protocols used in that interfaces.
- The benefits of the open architecture:
  - more independent of the hardware platform (usually a PC platform)
  - components can be replaced and upgraded
  - allows modification and addition of a new functionality when needed. The user specific technological knowledge about manufacturing processes can be integrated.

# Open source for CNC

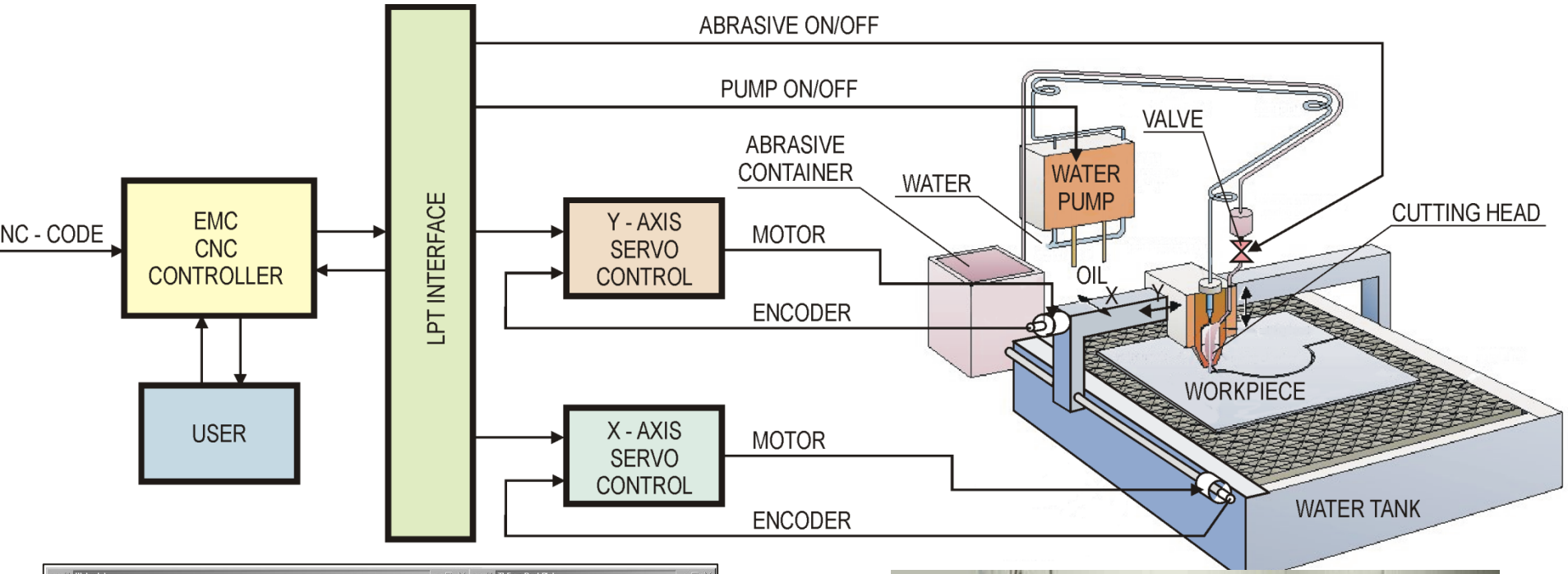
- Most software producers consider source code as valuable intellectual property and make it unavailable.
- The concept of open source software (OSS) is different. OSS programs give any interested party access to the source code, leading to a distributed innovation platform in which users actively participate in the product's development .
- Open source controller EMC (Enhanced Machine Controller – now called LinuxCNC) is a software system that implements numerical control functionality on standard PC computers for controlling machine-tools.
- The development was started in the nienties from NIST in USA and later opened as open source software, which is available under general GNU licence. It has been further developed by several volunteer developers at LinuxCNC.org
- We implemented EMC on a waterjet and desktop engraving machine.

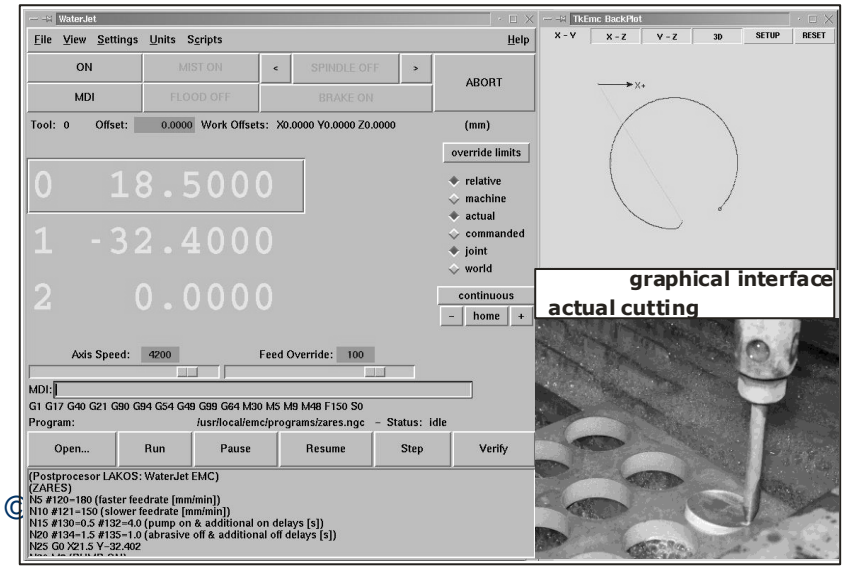
# Implememtation of the open controller architecture and open source controller EMC on a 3-axes desktop machine



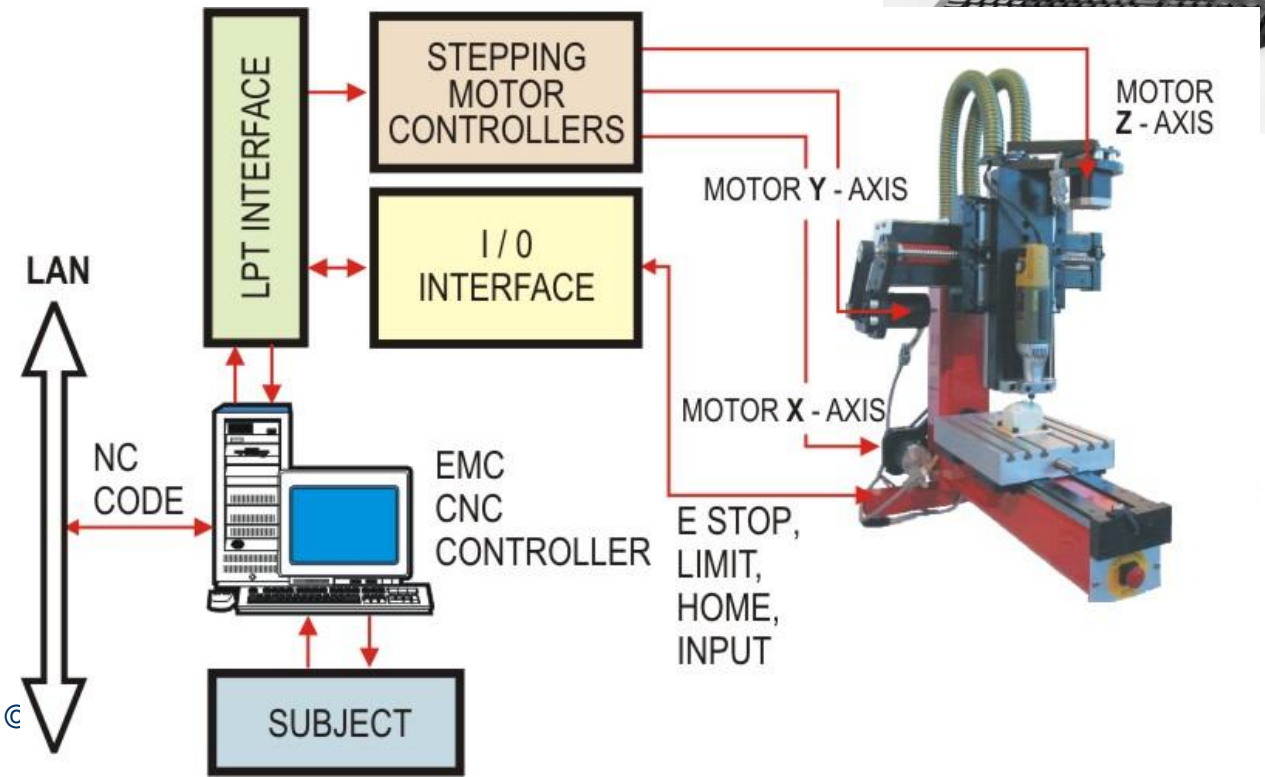



# Implememtation of the open controller architecture and EMC open source controller on a waterjet machine



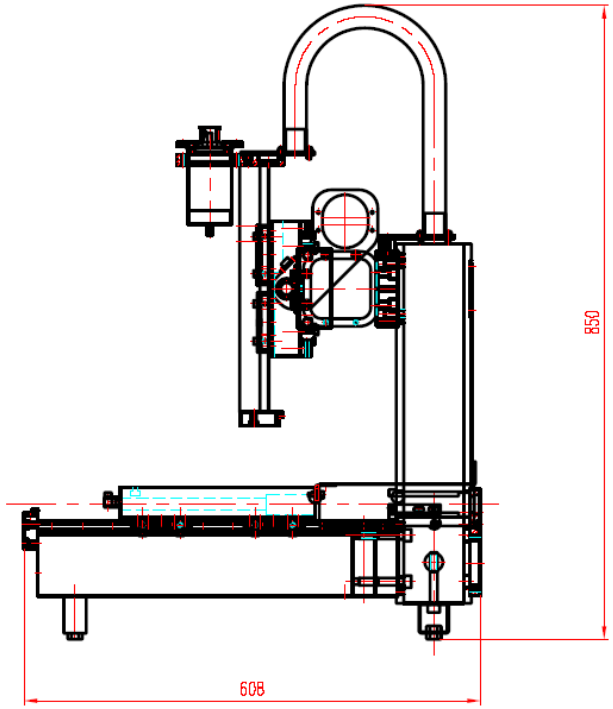

# Desktop CNC engraving machine-tool LAKOS 150G

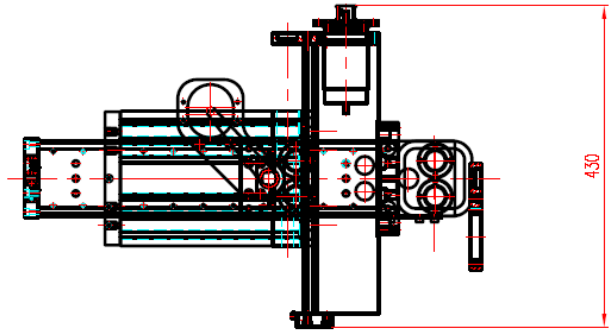



# Desktop CNC engraving machine-tool LAKOS 150G: specifications

**Specifications:**

| | |
|---|---|
| **Number of Axes:** | 3;  X, Y Z |
| **Feed Rates:** | up to 3000 mm/min |
| **Working space:** | X = 200 mm<br>Y = 170 mm<br>Z = 130 mm |
| **Accuracy:** | 0.05 mm (0.02 mm with compensation) |
| **Positioning resolution:** | 0.002 mm |
| **Appropriate machinig materials:** | prototyping materials, plastic, aluminium, wood, etc. |
| **Main spindle power:** | 100 W |
| **RPM:** | 30.000 min-1 |
| **Tool change:** | manual |
| **Control:** | PC with Linux and EMC2 open source CNC software |

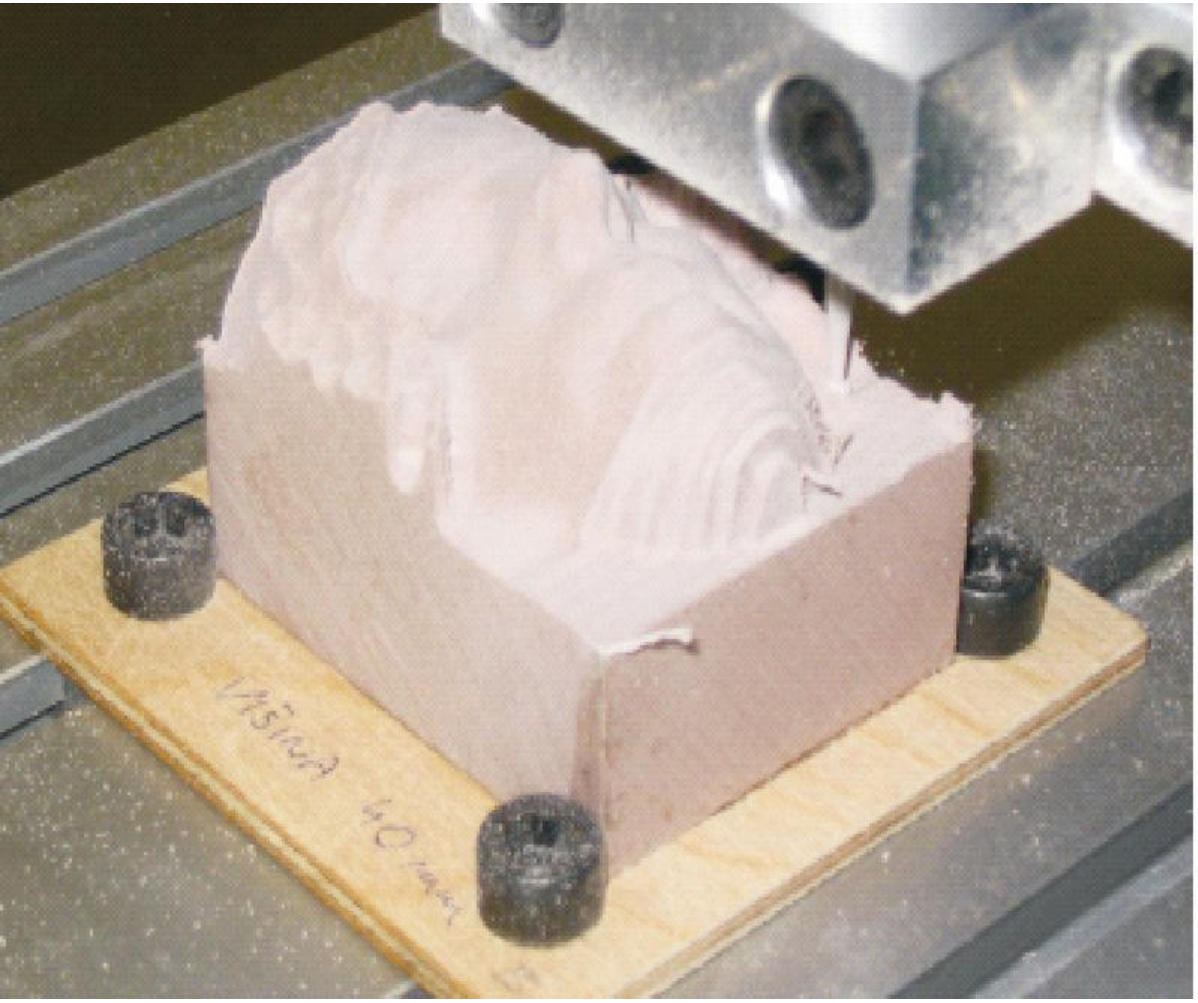


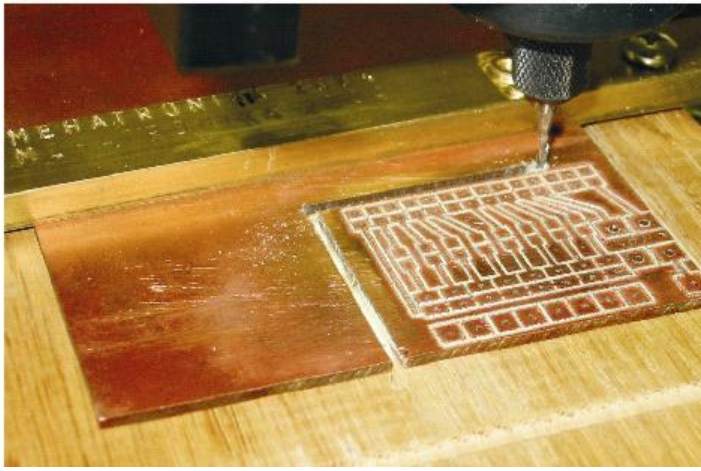



# Desktop CNC engraving machine-tool
# LAKOS 150G: key features

- Open design
- Modular design
- Mobility
- Open control architecture
- Open source software
- Full CNC functionality
- 2D and 3D machining
- Standard G-code input
- Easy operation
- Comprehensive educational instrument for learning and training
- Building block of the Learning Factory and FabLab concepts

# Desktop CNC engraving machine-tool
# LAKOS 150G: 2D and 3D machining examples



# AWARD WINING INNOVATION: LASER MEASUREMENT AND MANUFACTURING OF COMPLEX 3D SHAPES


Referencs:

University of Johannesburg, Johannesburg, South Africa

VITES - High School for Technologies and Systems, Novo mesto, Slovenia

University of Minho, Guimaraes, Portugal

University of Warwick, Coventry, Great Britain

Dublin City University, Dublin, Ireland

Institute Jožef Stefan, Ljubljana, Slovenia

University of Maribor, Maribor, Slovenia

Awards:

- Invited innovation, 4th European Exhibition on Research and Innovation, Paris, June 2008
- Gold award for innovation, Slovene Chamber of Commerce and Industry / regional Chamber Ljubljana, 2008
- Silver award for innovation, Slovene Chamber of Commerce and Industry, 2008
- Selected innovation, 3rd Slovene Innovation Forum, 2008

# Conclusion

- Computer numerical control is mature and widely used technology.
- Contemporary demanding and complex products could not be produced without CNC machine-tools.
- Developments of the laboratory LAKOS in the field were highlighted.
- The desktop engraving machine LAKOS 150G is a comprehensive instrument for engineering education and training.
- One week learning and training course on its design, development, manufacturing, programming and operation could be a beneficial part of the ongoing Tempus project and good starting point for further cooperation between the Birzeit University and University of Ljubljana.