CONTROLLER'S & SIMULATION SOFTWARE RESEARCH AND ANALYSIS

Controller Options Analysis :

Best Choice Based on Use Case :

- For simple wafer counting and edge detection → Arduino Mega 2560
- For real-time and industrial-grade processing → STM32F407
- For high-speed counting with Ethernet support → Teensy 4.1
- For advanced AI and wireless connectivity → ESP32-S3
- For general-purpose applications with HMI support → Raspberry Pi 5

STM32F407 (Powerful 32-bit Microcontroller) :

Specifications:

- **Processor:** ARM Cortex-M4, 168 MHz
- **I/O Ports:** 82 GPIO, ADC, DAC, I2C, SPI, UART
- **Communication:** USB, CAN, Ethernet (via external module)
- **Programming:** STM32CubeIDE (C/C++)
- **Real-Time Processing:** RTOS supported

Pros:

- High processing speed for real-time edge detection
- Low power consumption compared to Raspberry Pi
- Industrial-grade reliability

Cons:

- Requires STM32CubeIDE or Keil for programming
- Steeper learning curve compared to Arduino
- Simulation Platform: STM32CubeMX, Proteus, Keil uVision

Arduino Mega 2560 (Best for Simple Applications) :

Specifications:

- **Processor:** ATmega2560 (8-bit, 16 MHz)
- **I/O Ports:** 54 digital I/O, 16 analog inputs
- **Communication:** UART, SPI, I2C
- **Programming:** Arduino IDE (C++)
- **Real-Time Processing:** No RTOS support (limited multitasking)

Pros:

- Easy to program and widely supported
- Good for simple edge detection and counting
- Low power consumption

Cons:

- Not suitable for high-speed processing
- No Ethernet/Wi-Fi (needs additional modules)
- Simulation Platform: Proteus, Tinkercad, SimulIDE

Here's a breakdown of whether the simulation platforms for each controller are free or paid:

Free Simulation Platforms

- Arduino IDE (Free) → Used for Arduino Mega 2560, Portenta H7, GIGA R1, Teensy 4.1
- Thonny (Free) → Used for Raspberry Pi Pico W (MicroPython)
- ESP-IDF (Free) → Used for ESP32, ESP32-S3
- STM32CubeMX (Free) → Used for STM32F407, STM32H743ZI
- Edge Impulse (Free for basic use) → Used for Portenta H7 (AI/ML applications)
- OpenPLC (Free & Open Source) → Used for Raspberry Pi, BeagleBone Black
- Proteus (Free for limited microcontrollers, paid for advanced features) → Used for Arduino, ESP32, STM32 (basic simulation)

Paid or Limited Free Versions

- Keil uVision (Free with STM32 license, Paid for full features) → Used for STM32F407, STM32H743ZI
- SimulIDE (Mostly free, limited support for newer MCUs) → Used for Arduino, STM32, ESP32
- TIA Portal (Paid, Free Trial Available) → Used for Siemens S7-1200 PLC (if needed in comparison)
- Factory I/O (Paid, Free Trial Available) → Used for Raspberry Pi, OpenPLC (HMI integration)
- Proteus (Paid for full version, free with limited features) → Used for Arduino, ESP32, STM32
- NVIDIA Isaac Sim (Paid, Free for academic use) → Used for Jetson Nano (AI-based edge detection

1.Arduino Mega 2560

🔧 Simulation Options:

- Proteus (Paid, but free trial available)
- Tinkercad (Free, limited to basic Arduino simulations)

💻 Hardware Required?

- Not necessary for simulation (Proteus or Tinkercad can be used)
- Needed for real-world deployment

2. Arduino Portenta H7

🔧 Simulation Options:

- Edge Impulse (for AI applications, free for basic use)
- Mbed OS simulator (limited, some paid tools required)
- Proteus (for basic Arduino functionality, but not full AI support)

💻 Hardware Required?

- Yes, hardware is needed for real-world AI applications
- Limited simulation without hardware

3.STM32F407

🔧 Simulation Options:

- STM32CubeMX (Free)
- Proteus (Paid, free trial available)
- Keil uVision (Free for limited usage, paid for full features)

💻 Hardware Required?

- Not necessary for basic simulations (Keil, Proteus, STM32CubeMX)
- Needed for real-time edge detection with sensors

4.STM32H743ZI

🔧 Simulation Options:

- STM32CubeMX (Free)
- Proteus (Paid, free trial available)
- Keil uVision (Free for limited usage, paid for full features)

💻 Hardware Required?

- Not needed for basic code testing (STM32CubeMX, Keil)
- Needed for full real-time processing

5.ESP32 / ESP32-S3

🔧 Simulation Options:

- ESP-IDF (Free, but complex setup)
- Proteus (Limited support for ESP32, paid)
- Arduino IDE (Free, for ESP32 compatibility mode)

💻 Hardware Required?

- Not needed for basic software testing (ESP-IDF)
- Needed for real-world deployment

6.Raspberry Pi 5

🔧 Simulation Options:

- QEMU (Free, for basic Raspberry Pi emulation)
- Factory I/O (Paid, for industrial simulation with HMI)

💻 Hardware Required?

- Not needed for basic code testing (QEMU)
- Needed for full AI, real-time processing, and HMI integration

Open Source Simulation Options :

STM32

STM32CubeIDE (Free, from ST)

Pros: Cycle-accurate debugging Cons: No camera sensor simulation

Proteus (Paid)

Pros: Full peripheral simulation Cons: $250+ license

ESP32

Wokwi (Free)

Pros: Web-based, easy serial monitoring Cons: No camera simulation

ESP-IDF Simulator (Limited)

Pros: Official tool Cons: Complex setup

Arduino Portenta H7

Wokwi (Free)

Pros: Quick Arduino testing Cons: No M7/M4 core separation

STM32H743ZI (Best for Industrial-Grade Real-Time Control & Ethernet HMI)

✅ Why?

- ✓ Fast Cortex-M7 (480MHz) for real-time wafer counting
- ✓ Built-in Ethernet for industrial HMI
- ✓ Supports FreeRTOS for multitasking
- ✓ Industrial-grade, used in semiconductor automation

💻 Easy Simulation:

- ✓ STM32CubeMX (Free, official STM32 simulation)
- ✓ Keil uVision (Free limited version, paid for full)
- ✓ Proteus (Paid, free trial available)

Arduino Portenta H7 (Best for AI-Based Edge Detection + HMI)

✅ Why?

- ✓ Dual-core (Cortex-M7 & M4) for AI + real-time processing
- ✓ TensorFlow Lite support for advanced wafer edge detection
- ✓ Built-in Wi-Fi & Bluetooth for remote HMI connectivity
- ✓ Industrial-grade Arduino board with Mbed OS & FreeRTOS

💻 Easy Simulation:

- ✓ Edge Impulse (Free, for AI-based simulation)
- ✓ Proteus (Paid, for basic Arduino functions)

ESP32-S3 (Best for Cost-Effective Wireless HMI & IoT Integration)

✅ Why?

- ✓ Dual-core (240MHz) + built-in Wi-Fi & Bluetooth
- ✓ TinyML support for AI-based edge detection
- ✓ Low power, affordable (~$10-15), and widely available
- ✓ Best for IoT-based wafer monitoring & HMI

💻 Easy Simulation:

- ✓ ESP-IDF (Free, for real-time ESP32 simulation)
- ✓ Arduino IDE (Free, supports ESP32 programming)
- ✓ Proteus (Limited ESP32 support, paid)