Software and Tools for EtherCAT® Master Controller Development

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EtherCAT Software Solutions for Machine Builder Controller

Machine Builders

- Motion Control, CNC, Material Handling
- Surgical Robotics, Simulators
- Test benches, Semiconductor tooling

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EC Master
EtherCAT Master Stack Software Development Kit

EC Engineer
EC Simulator
EtherCAT Configuration, Diagnosis and Simulation Tools

Customer

Machine + Controller with
EtherCAT Master Library

Customer´s customer

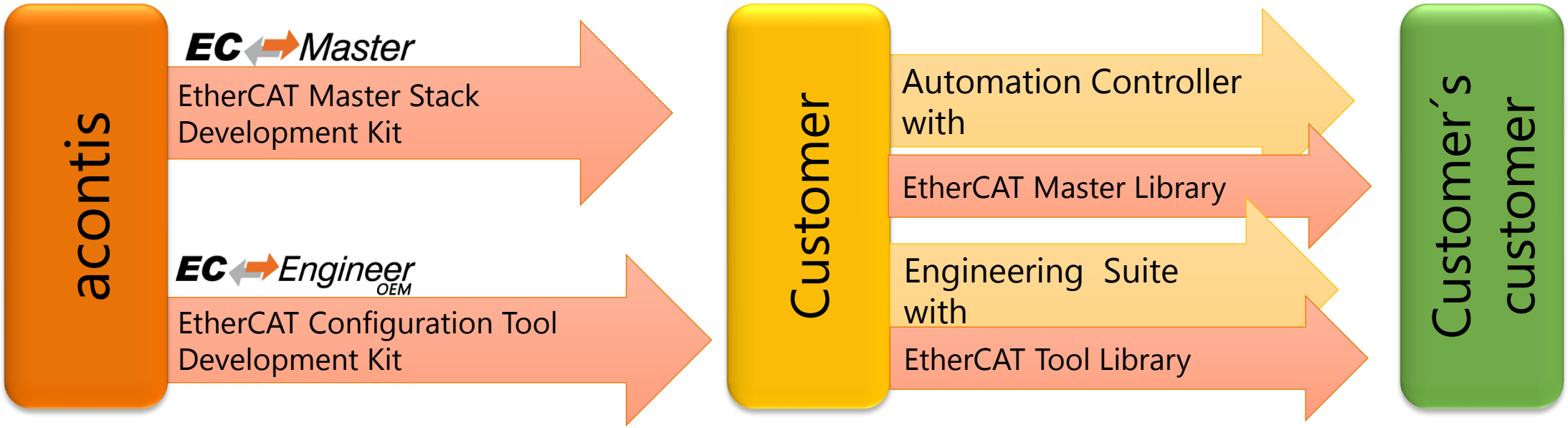
Machine Builder Controller Development Life Cycle

Phase	Task	Product
Software Development	• Integration of EtherCAT Master	EC Master
System Engineering Design/Planning	• EtherCAT Network Configuration • Define topology and device features	EC Engineer
Quality Assurance	• Test extended scenarios, e.g., simulate topology changes • Simulate slave and network errors, simulate huge networks	EC Simulator
Virtual Commissioning	• EtherCAT real-time network/slave simulation • Test and validate application software based on digital twin	EC Simulator
Commissioning	• Monitor and force process data, change slave parameters • Analyze communication problems	EC Engineer
Service and Maintenance	• Provide firmware updates for devices • Diagnosis and network condition monitoring	EC Engineer

EtherCAT Software Solutions for Automation Controller Manufacturers

Automation Controller Manufacturers

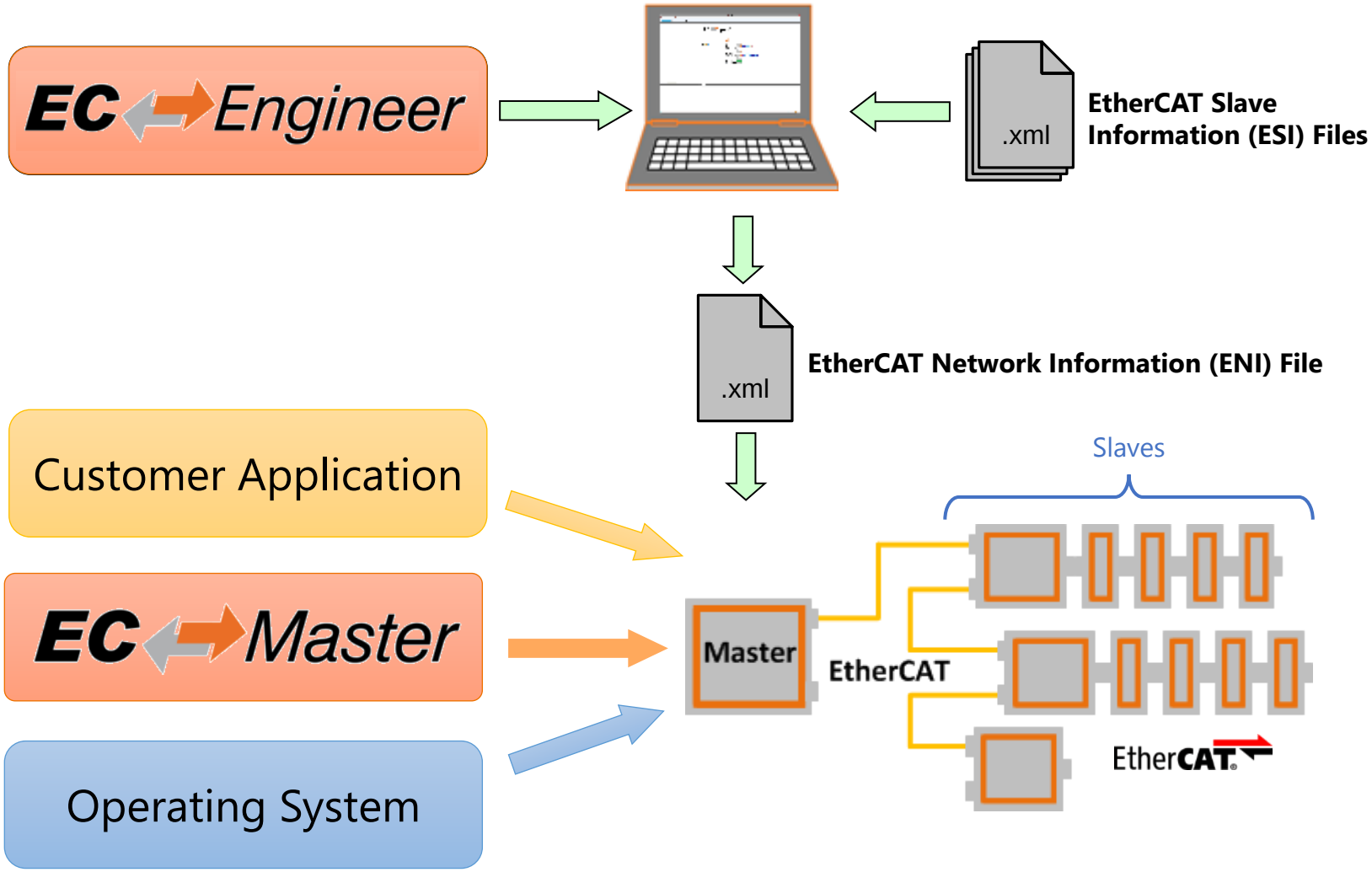
- Programmable Logic/Automation Controller (PLC/PAC)
- Motion Controllers (MC), Measurement Controllers
- HMI with controller



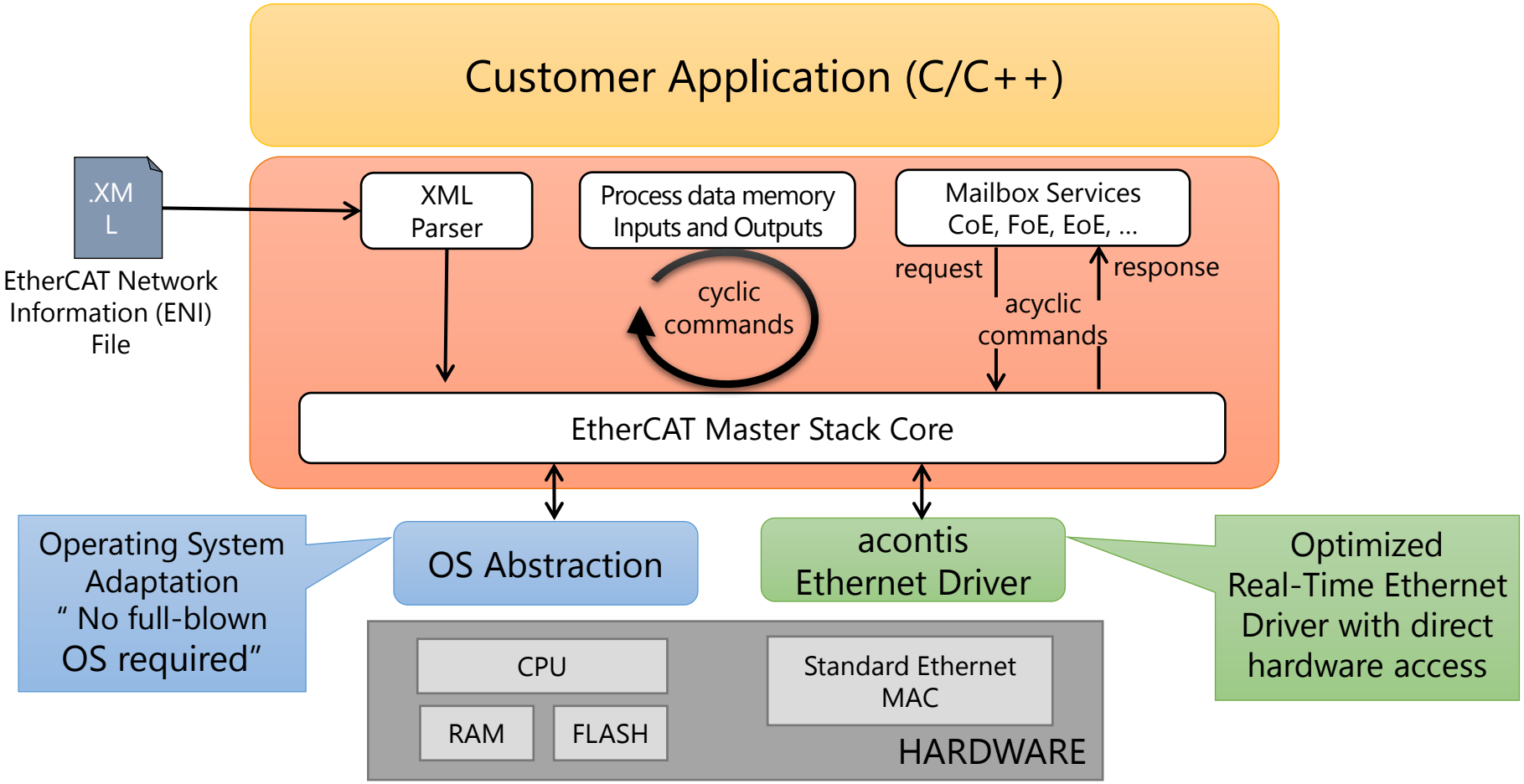
Automation Controller Manufacturers Development Life Cycle

Phase	Task	Product
Software Development Controller	• Integrate Master Stack	EC Master
Software Development Engineering Tool	• Integrate OEM Edition of EtherCAT Configuration and Diagnosis Tool into OEM development environment	EC Engineer OEM
Software Development Simulation	• Integrate Network Simulation software to create a machine simulation environment for virtual commissioning/digital twin	EC Simulator
Quality Assurance	• Test extended scenarios, e.g., simulate topology changes • Simulate devices and network errors, simulate huge networks	EC Simulator
End Customer Support	• Investigate end customer issues, monitor network condition • Supply software updates	EC Engineer OEM

EtherCAT System Architecture

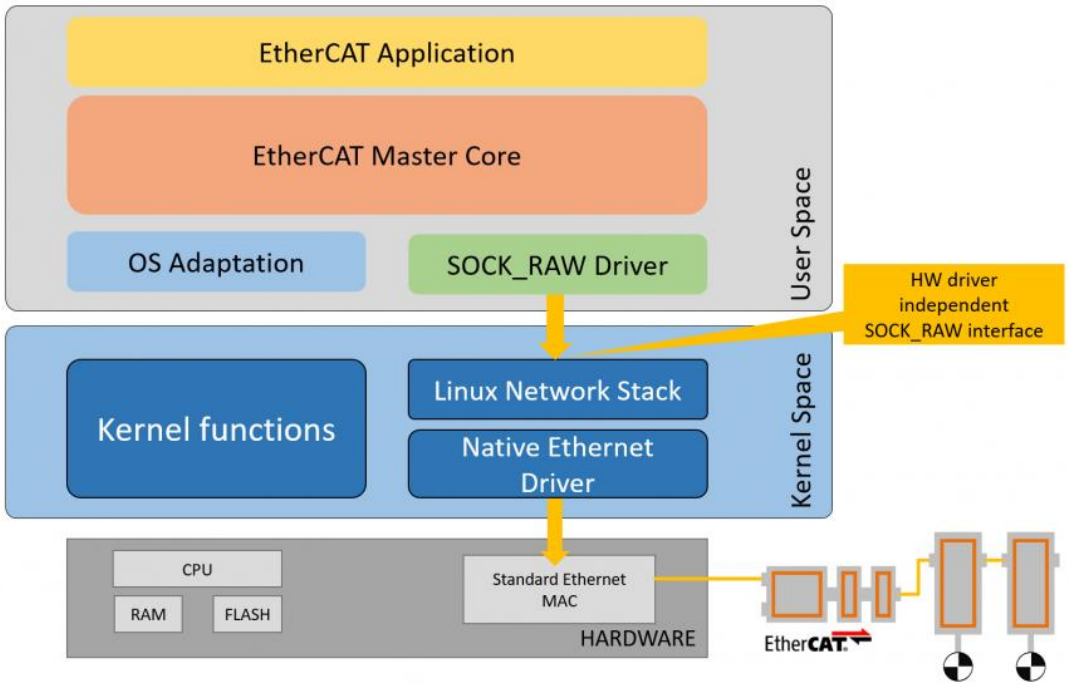


EC-Master Software Architecture

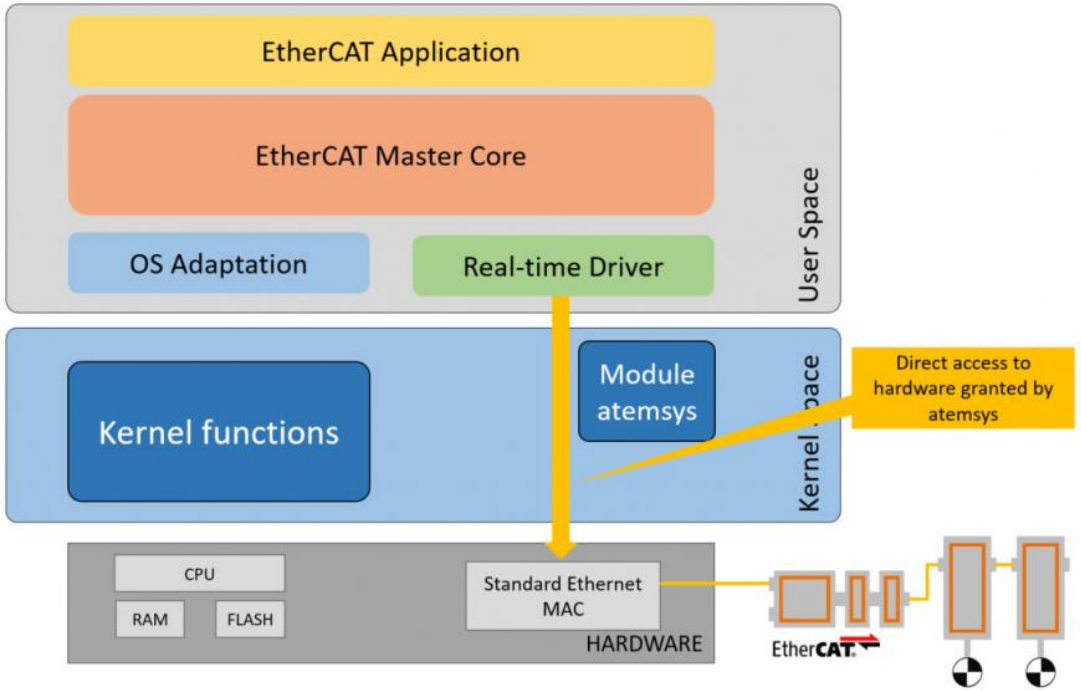


EC-Master Architecture on Linux

Architecture 1: **Linux Network Driver**



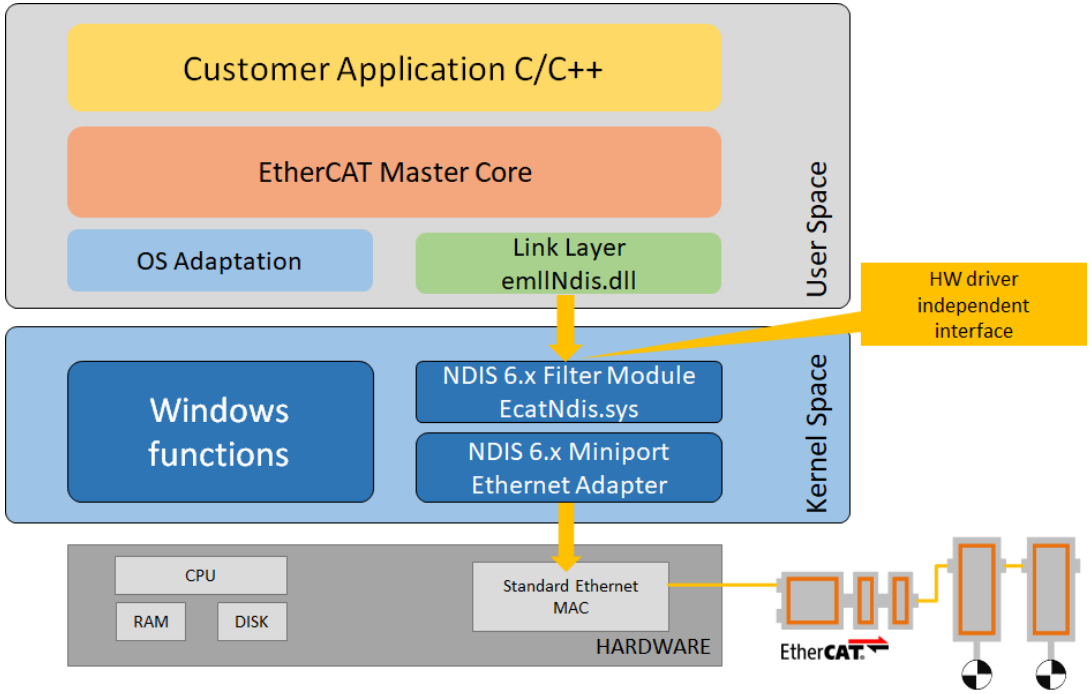
Architecture 2: **acontis Real-time Ethernet Driver**



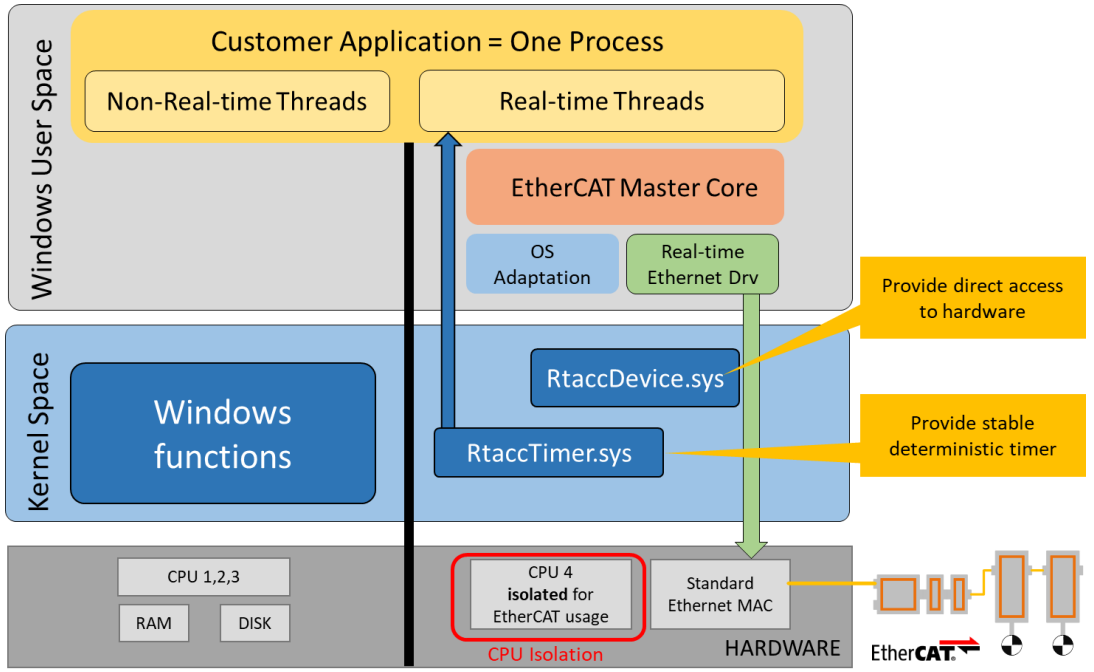
More Information: https://www.acontis.com/en/ethercat-master-linux.html

EC-Master Architecture on Windows (1)
Solution 1 Off-the-Shelf & 2 CPU Isolation

Architecture 1: **Off-the-shelf**
with acontis NDIS Filter Driver
No reliable cycle time: >= 4 ms



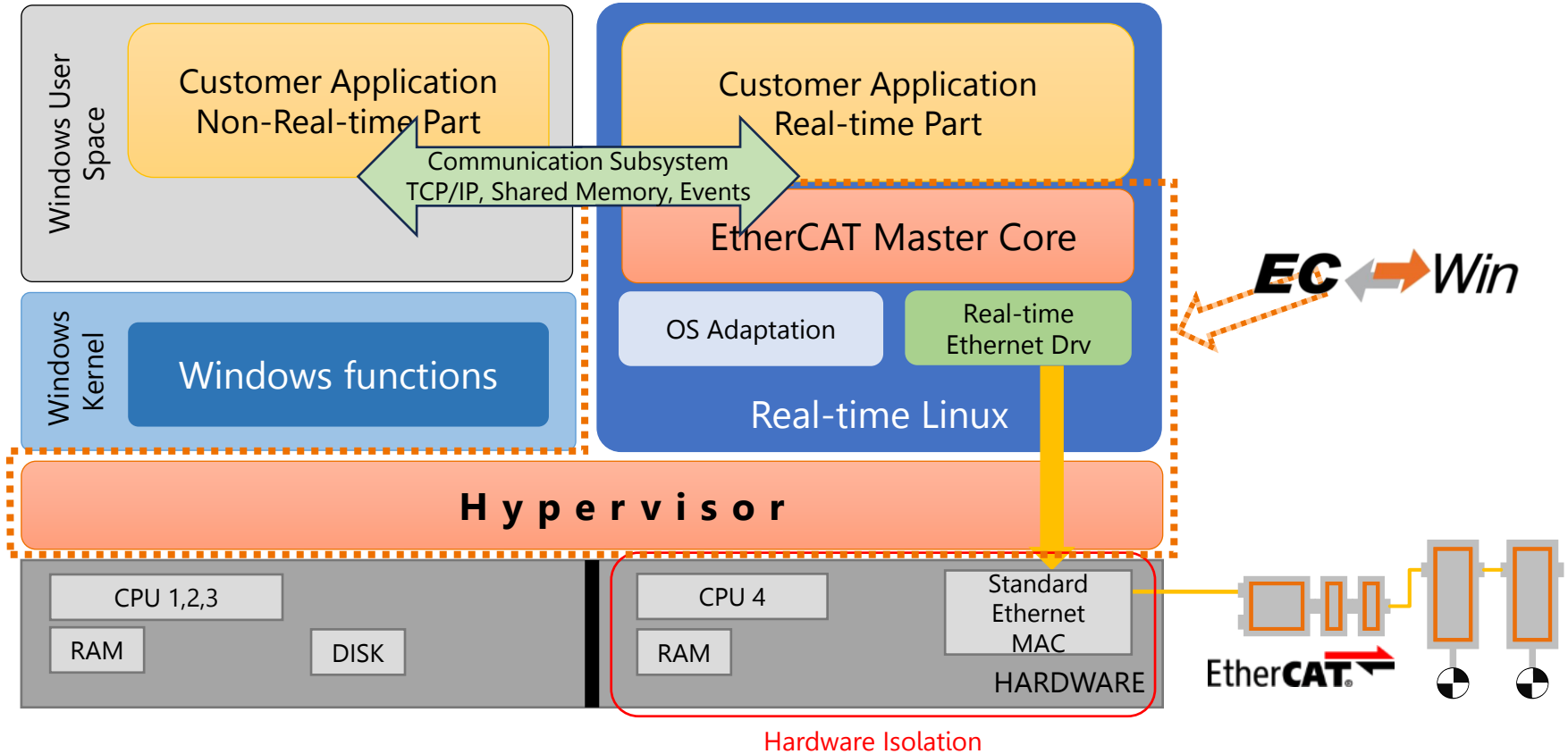
Architecture 2: **CPU Isolation**
with acontis RtaccWin
Guaranteed cycle time: >= 1 ms



More Information: https://www.acontis.com/en/ethercat-master-linux.html

EC-Master Architecture on Windows (2)
Solution 3: Full Isolation, based on Hypervisor

Architecture 3: **Hypervisor** with hardware separation, enabling RT-Linux & Windows on one computer
Split real-time and non-real-time part
Controller App and Master stack run in Real-time Environment with **up to 10kHz Cycle**



EC-Master
Out of the box for many Platforms

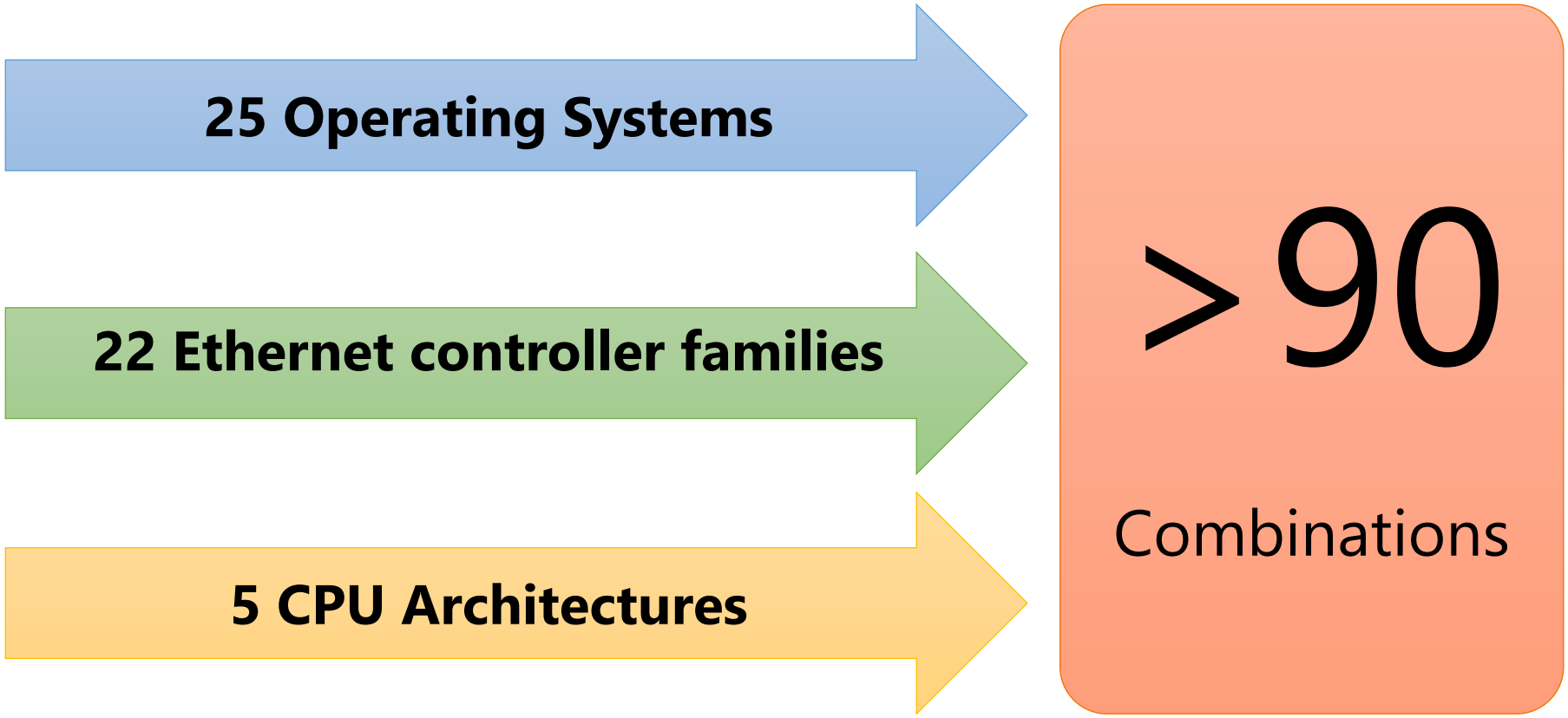
OS Abstraction

Ethernet Controllers

Intel Pro/1000	Xilinx GEM
Realtek Gigabit	NXP FEC, eTSEC
Renesas RZ Family	TI Sitara CPSW, ICSS-PRU
Intel Elkhart Lake	SMSC 9218
Beckhoff CCAT	and more

X86 32-Bit | X64 64-Bit | ARM 32-Bit | Aarch64 64-Bit | PowerPC

EC-Master Available for Many Platforms



EC-Master Building Blocks

Class B Core

- Compare network configuration
- Cyclic process data exchange
- Slave to slave communication
- Mailbox protocols CoE, SoE
- Mailbox protocols EoE, FoE
- Mailbox protocols AoE, VoE

Class A Core

- All Class B Features
- **Distributed Clocks with master synchronization**

Feature Packs = Options

Cable Redundancy, Hot Connect, Superset ENI,
External Synchronization, EoE Gateway, Master Redundancy, …

EC-Master broad CPU support

BROADCOM	BCM2711 - Raspberry Pi 4 (Cortex-A72)
Infineon	XMC4800 (Cortex M4)
intel	Core-i Atom Atom® x6000E (Elkhart Lake) Altera Cyclone V Celeron, Xeon
NVIDIA	Jetson TX2 (Quad Cortex-A57)
NXP	i.MX6 (Cortex-A9) i.MX7 (Cortex-A7), iMX RT1064 (Cortex M7) i.MX8 (Cortex-A53) Layerscape 1021A QorIQ P-Series MPC8548 PowerQUICC
Qualcomm	QRB5165 with Kryo 585 CPU (Octo Cortex-A77)

RENESAS	RIN32, RZ-T, RZ-N, RZ-G (Cortex-A55) RZ-A (Cortex-A9)
Rockchip 瑞芯微电子	RK3328 (Quad Cortex A53) RK3399 (Dual Cortex-A72) RK3588s (Quad Cortex-A76) RK3568 (Quad Cortex-A55)
life.augmented	STM32MP1 (Dual Cortex-A7) STM32H7 (Cortex M7) STM32F769 (Cortex M7)
TEXAS INSTRUMENTS	Sitara AM335x (Cortex-A8) Sitara AM437x (Cortex-A9) Sitara AM57xx (Dual Cortex-A15) Sitara AM64x (Dual Cortex-A53) Jacinto TDA4VM (Dual Cortex A72 / Quad Cortex R5F)
XILINX®	Zync-7000 (Dual Cortex-A9) Zynq UltraScale+ (Quad Cortex-A53)

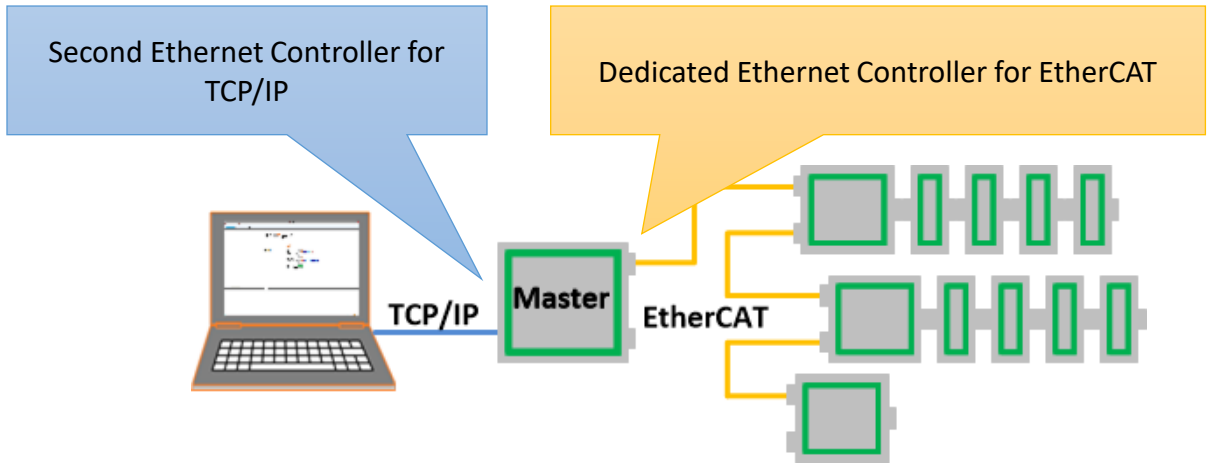
Hardware Requirements

32 Bit or 64 Bit CPU

Footprint

ROM (FLASH or DISK): Between 400 and 900 Kbyte

RAM: Starting with 300 Kbyte up to several Megabyte.
Highly depending on the number and type of slaves!



Key benefits

- **Out-of-the-box** for the most popular operating systems
  ⇨ Get it running on your system in one day!
- **Reliable** and **robust** implementation
  ⇨ Field proven in several 100000 systems per year!
- Sophisticated **diagnosis** functions
  ⇨ Detect state change problems and frame loss errors easily
  ⇨ More than 300 different error codes
- High **performance** and **hard real-time**
  ⇨ Low CPU load due to acontis real-time Ethernet drivers
- **Easy** to integrate
  ⇨ Various example applications and comprehensive user manuals

Additional information

- EC-Master Operating Systems and Real-time Ethernet Drivers
  https://www.acontis.com/en/os.html
- EC-Master user manual and quick start guide
  https://developer.acontis.com/ec-master
- Request for EC-Master feature pack slides
- Request for EC-Master technical details slides
- Request for evaluation software
  https://www.acontis.com/en/ethercat-support-eval-request.html

EtherCAT Configuration and Diagnosis Tool

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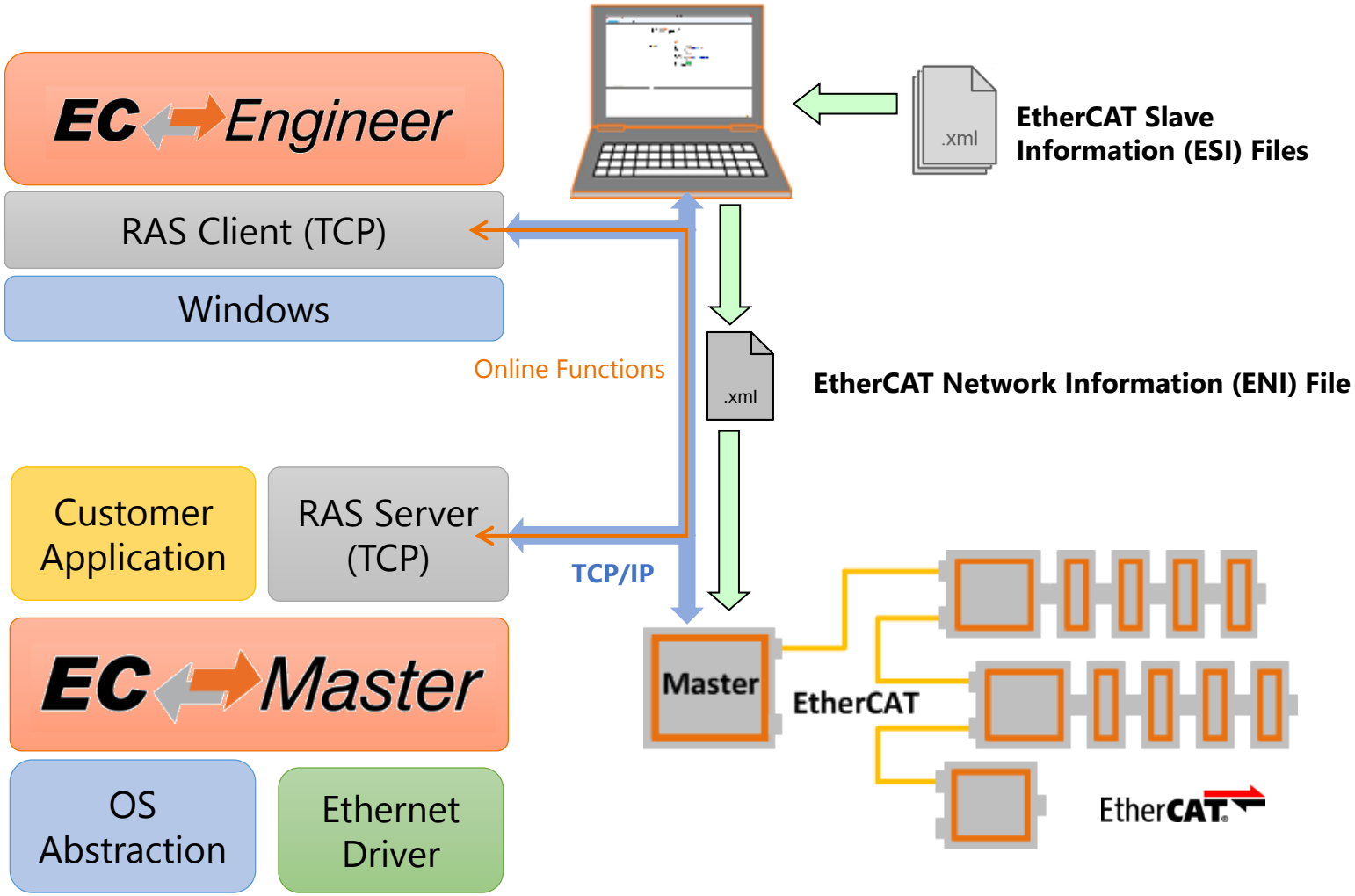
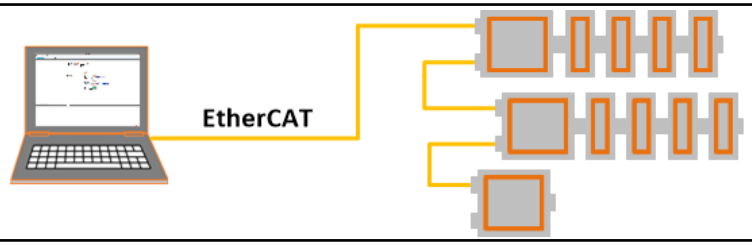
EtherCAT System Architecture



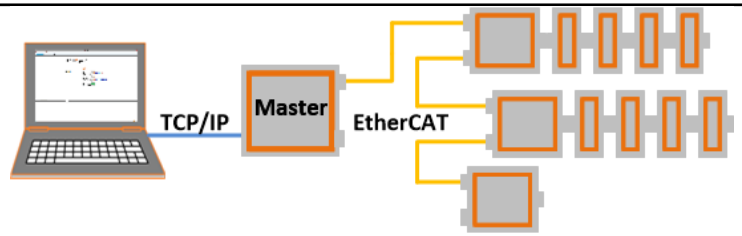
Operating Modes

Offline **Configuration**:
(In the Office)

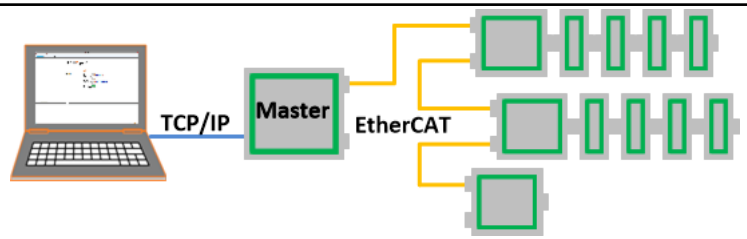
Online **Configuration**:
Slaves connected to
Engineering System



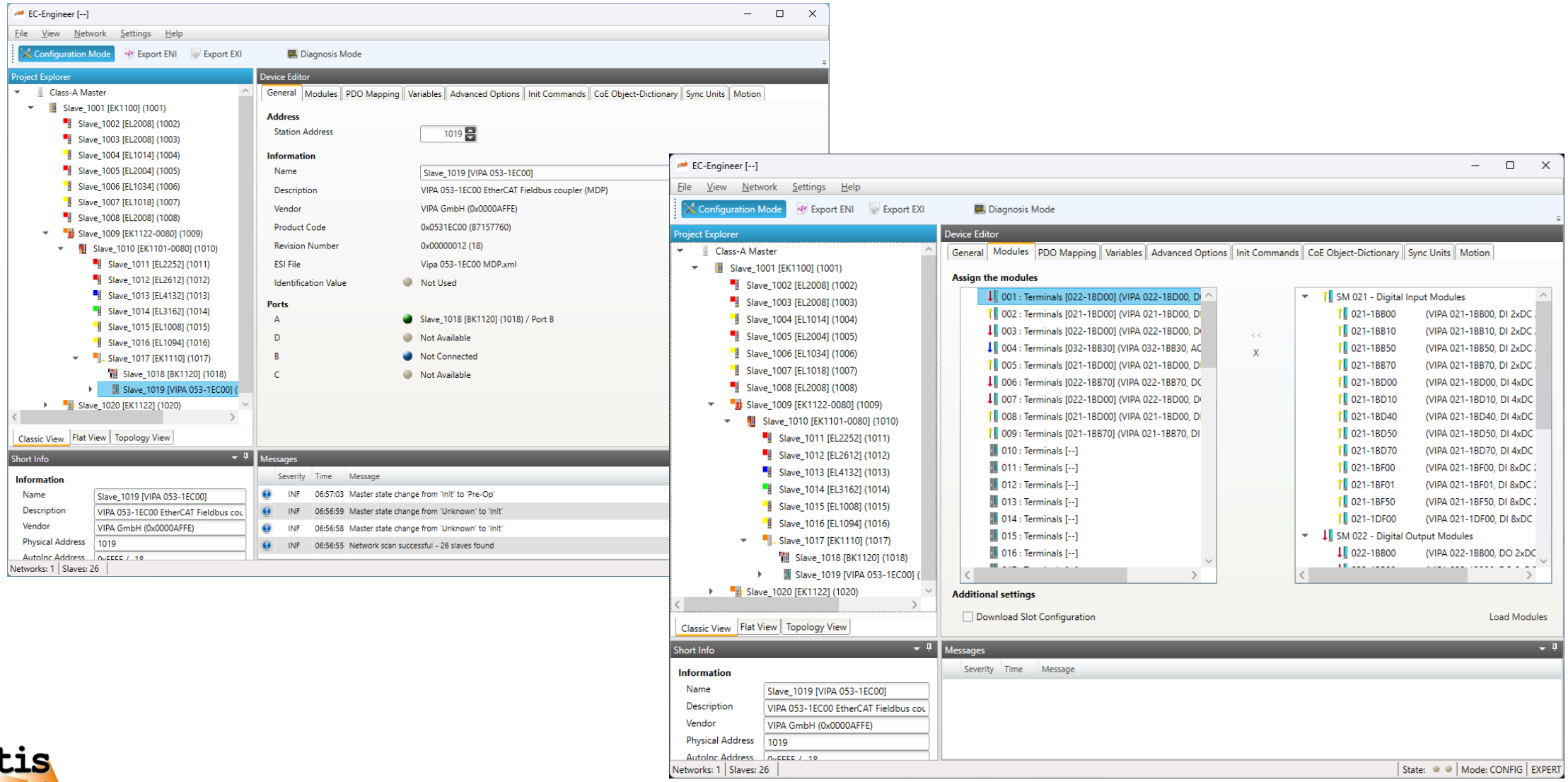
Remote **Configuration**:
Slaves connected to
Target System



Remote **Diagnosis**:
Slaves connected to
Target System

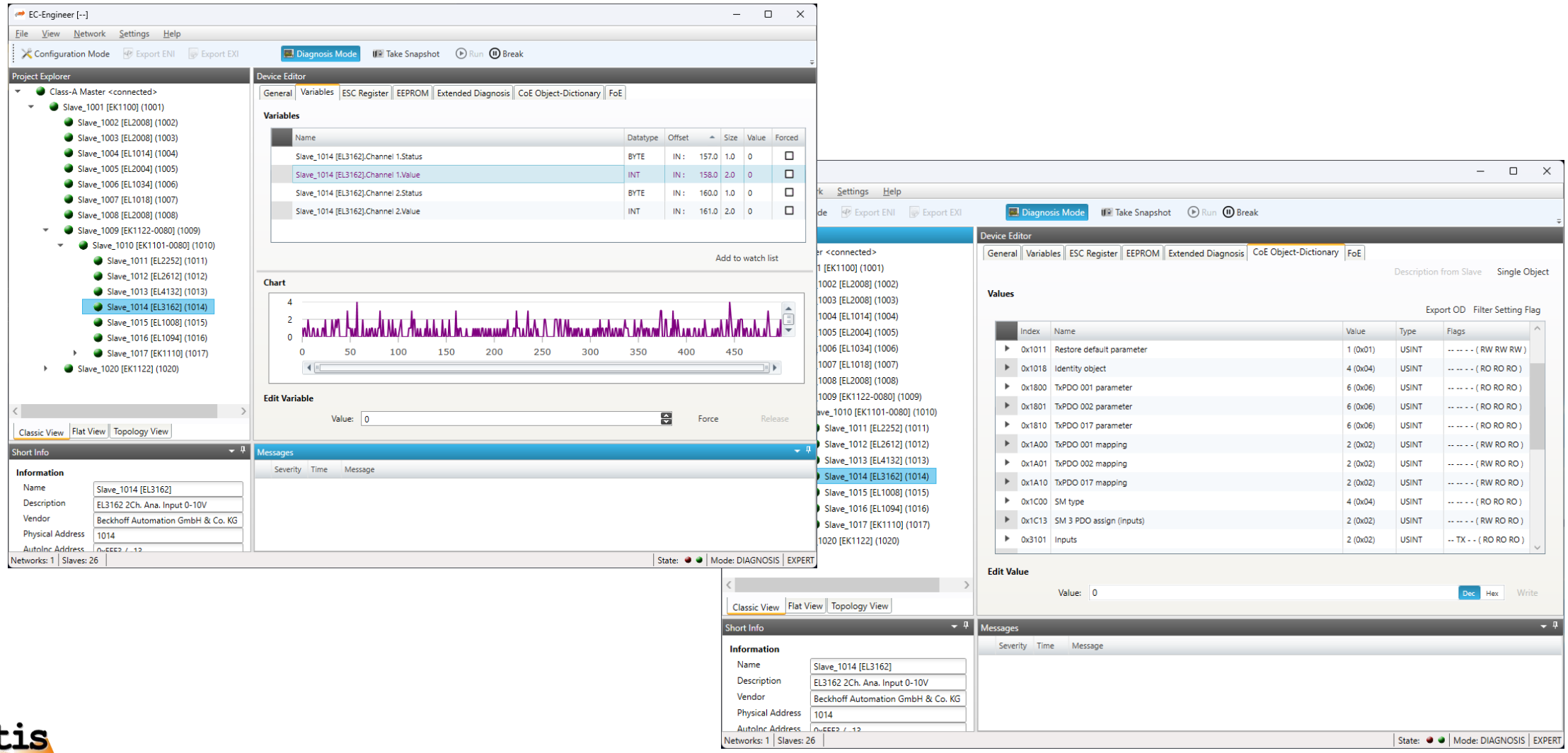


Build a configuration in less steps



Comprehensive diagnostic: Monitor and force process data

EC Engineer



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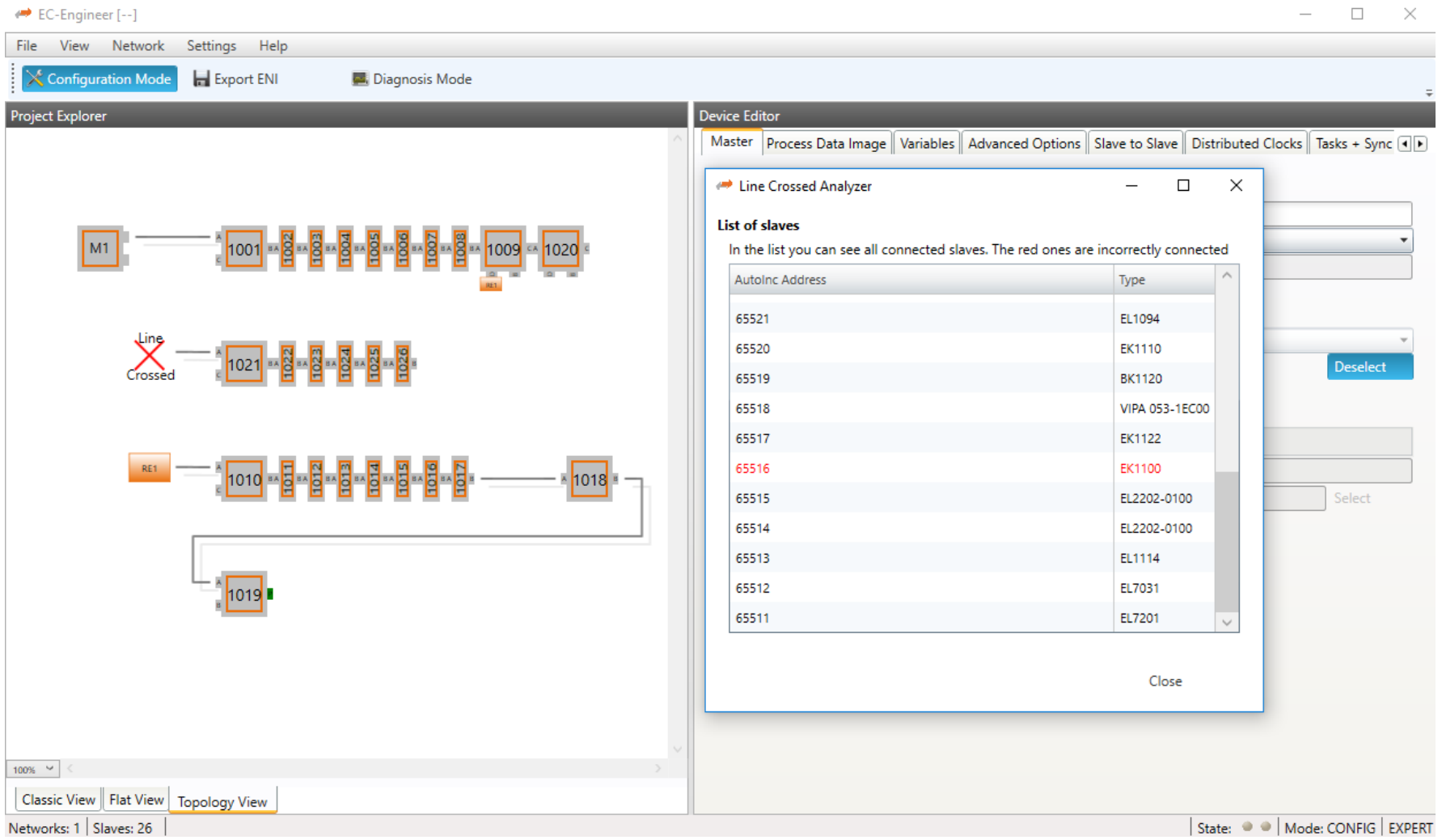
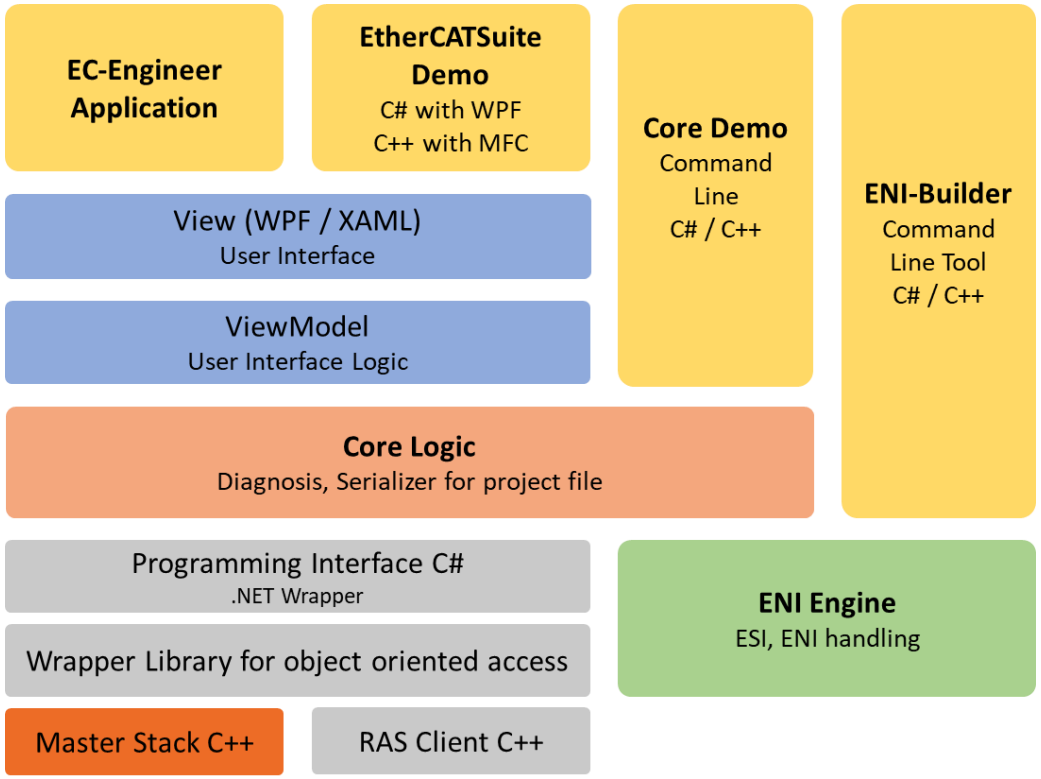
Comprehensive diagnostic: Powerful “Line crossed” detection

EC Engineer



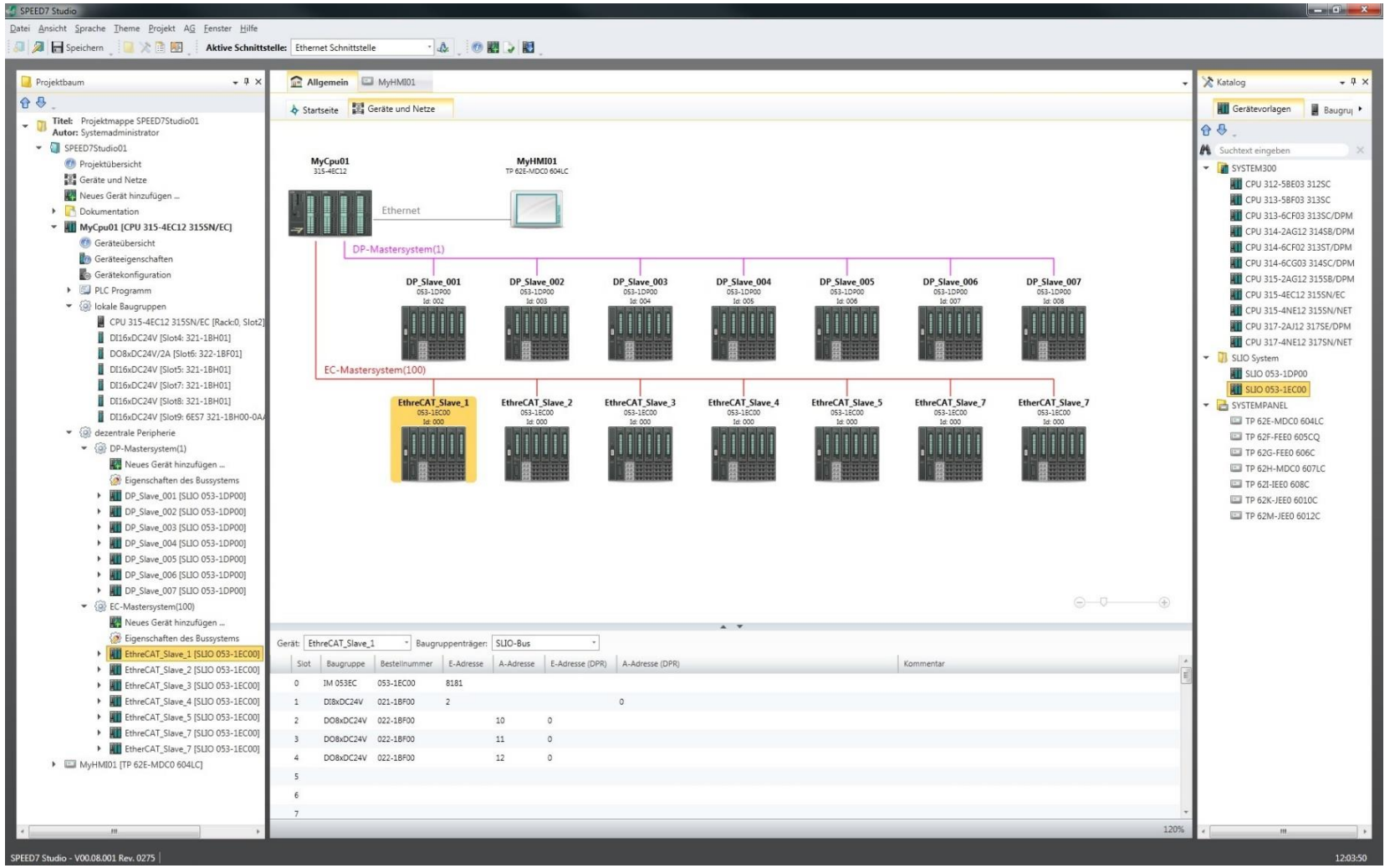
EtherCAT Configuration Tool Software Development Kit (SDK)



EC Engineer OEM

- SDK for adding EtherCAT configuration and diagnosis features to an (existing) customer engineering tool
- Modular architecture offers various levels of integration
- Available for Windows and Linux
- Graphical User Interface (GUI) based on WPF for Windows
- Graphical User Interface (GUI) based on Web technology for Windows and Linux

Example: Integration into PLC programming tool YASKAWA SPEED7 Studio



Key benefits

- **Easy** to use - **modern** design
  - ⇨ Build a configuration in less steps
  - ⇨ Only reasonable settings and options are visible, expert settings visible only if required
- **Powerful online functions** together with EC-Master
  - ⇨ Network scan local & remote, compare configured and found slaves (network mismatch view)
  - ⇨ Access to states, variables, object dictionary, ESC register, EEPROM, etc.
  - ⇨ Figure out the location of communication errors (bad cables and connectors, vibrations, etc.)
- **EtherCAT Master Information** (EMI) file for specifying master device features
  - ⇨ The configuration tool offers only supported features of the selected EtherCAT controller
  - ⇨ E.g. maximum number of EtherCAT SubDevices or process data size or cycle time limitations
- **Software Development Kit** available
  - ⇨ Adjust to customer needs or integrate into customer engineering environment

Additional information

- EC-Engineer tutorials and user manual
  https://developer.acontis.com/ec-engineer
- Request for EC-Engineer technical details slides
- Request for evaluation software
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Web Edition

EtherCAT Configuration and Diagnosis using a Browser

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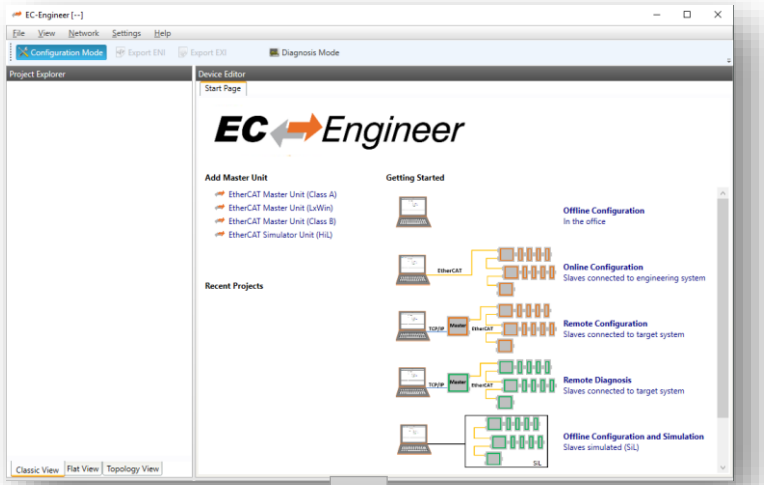
EC-Engineer vs EC-EngineerWeb

EC Engineer

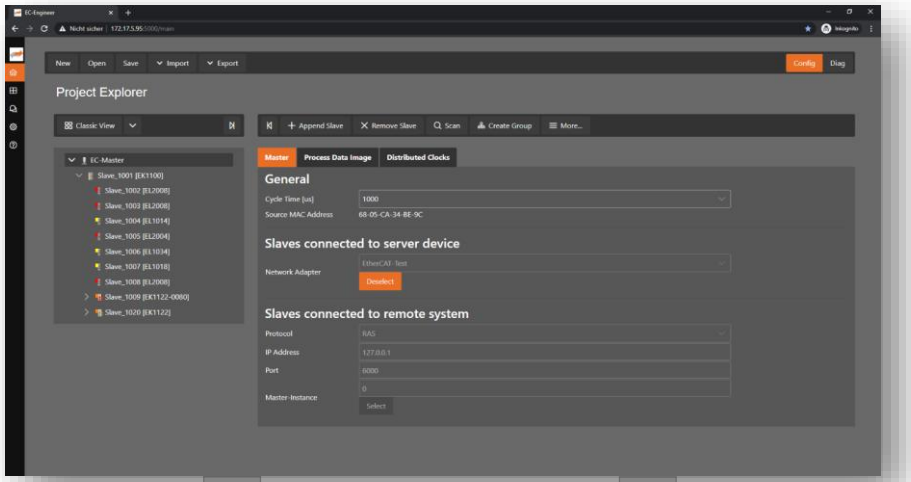


Windows

x86 32-Bit

x64 64-Bit

EC EngineerWeb



Windows

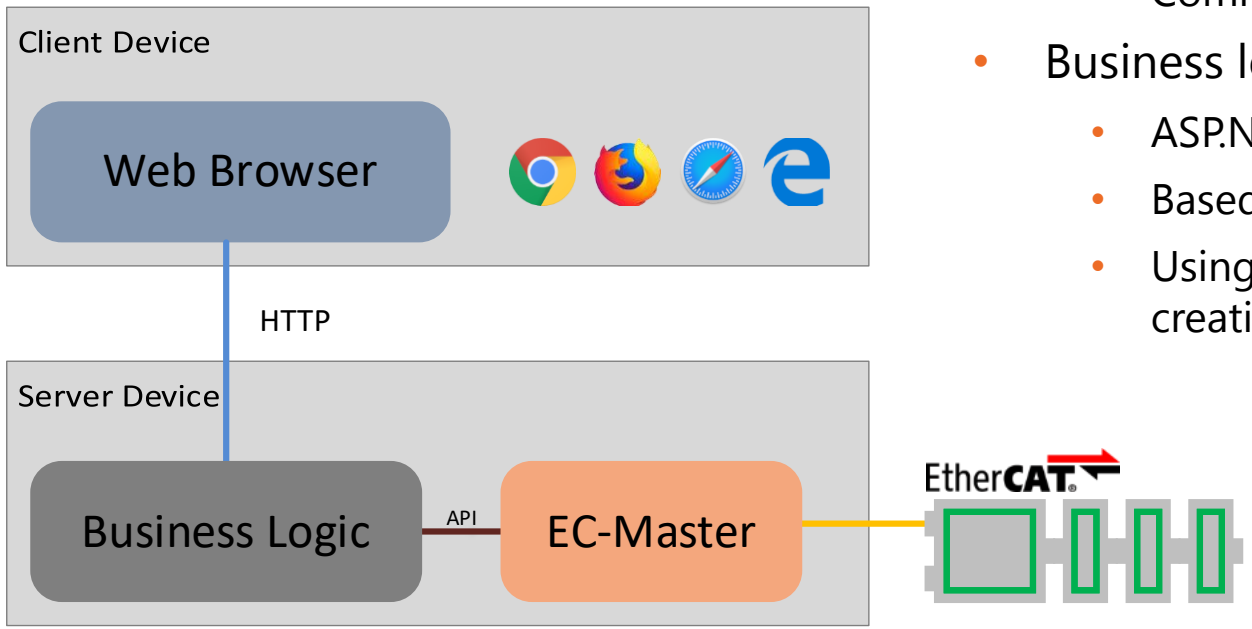
Linux

x64 64-Bit

ARM 32-Bit
ARM 64-Bit

EC-Engineer Web Overview

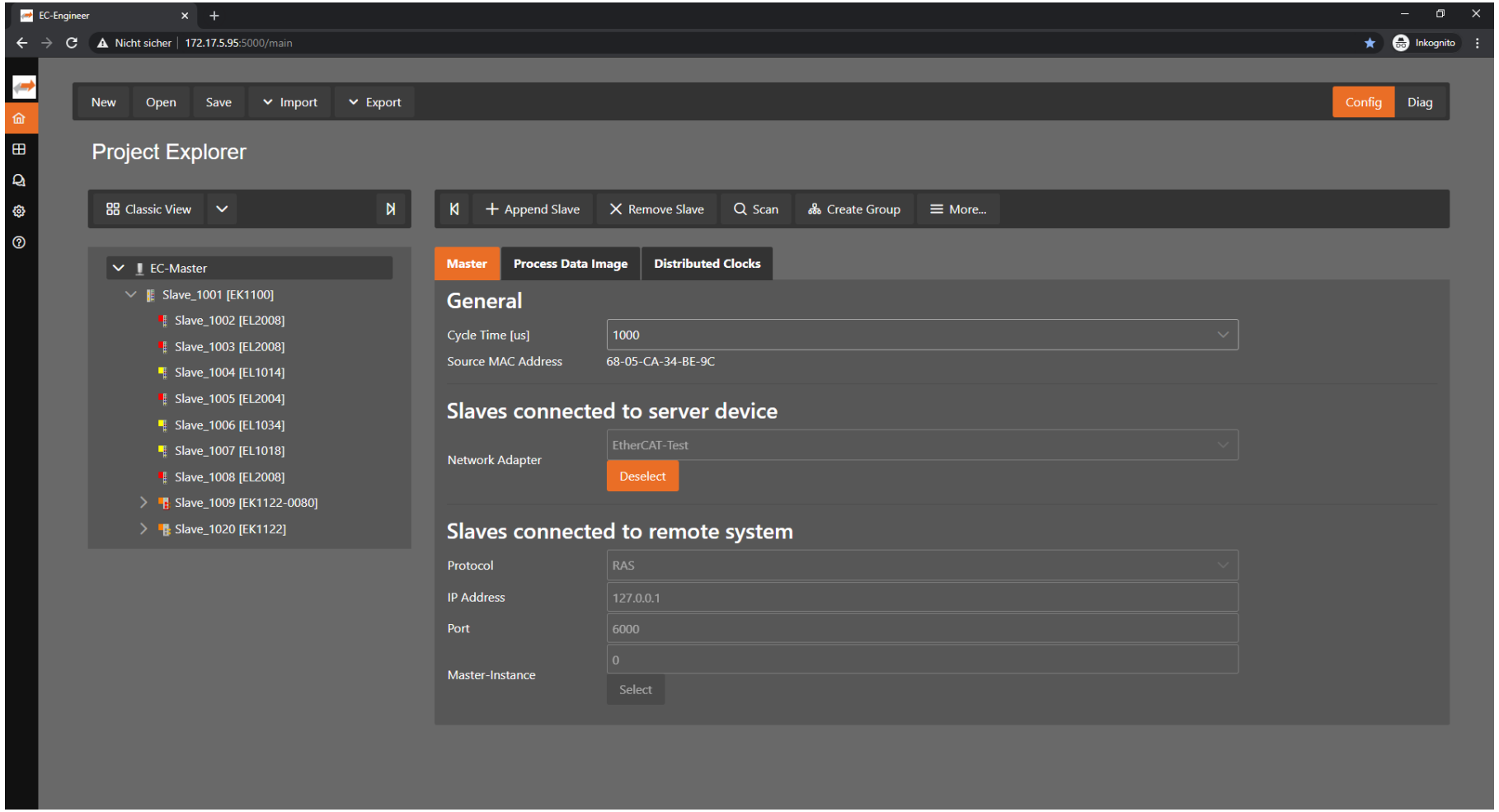
EtherCAT configuration and diagnosis tool using a standard browser as user interface:



- Web Browser with HTML5 and JavaScript support
  - Desktop computer
  - Mobile devices (tablet, smartphone)
  - Communication to backend via HTTP
- Business logic (RACE)
  - ASP.NET Core Web Application
  - Based on Microsoft .NET Core 3.1
  - Using the same, well proven core logic and ENI creation algorithm as EC-Engineer

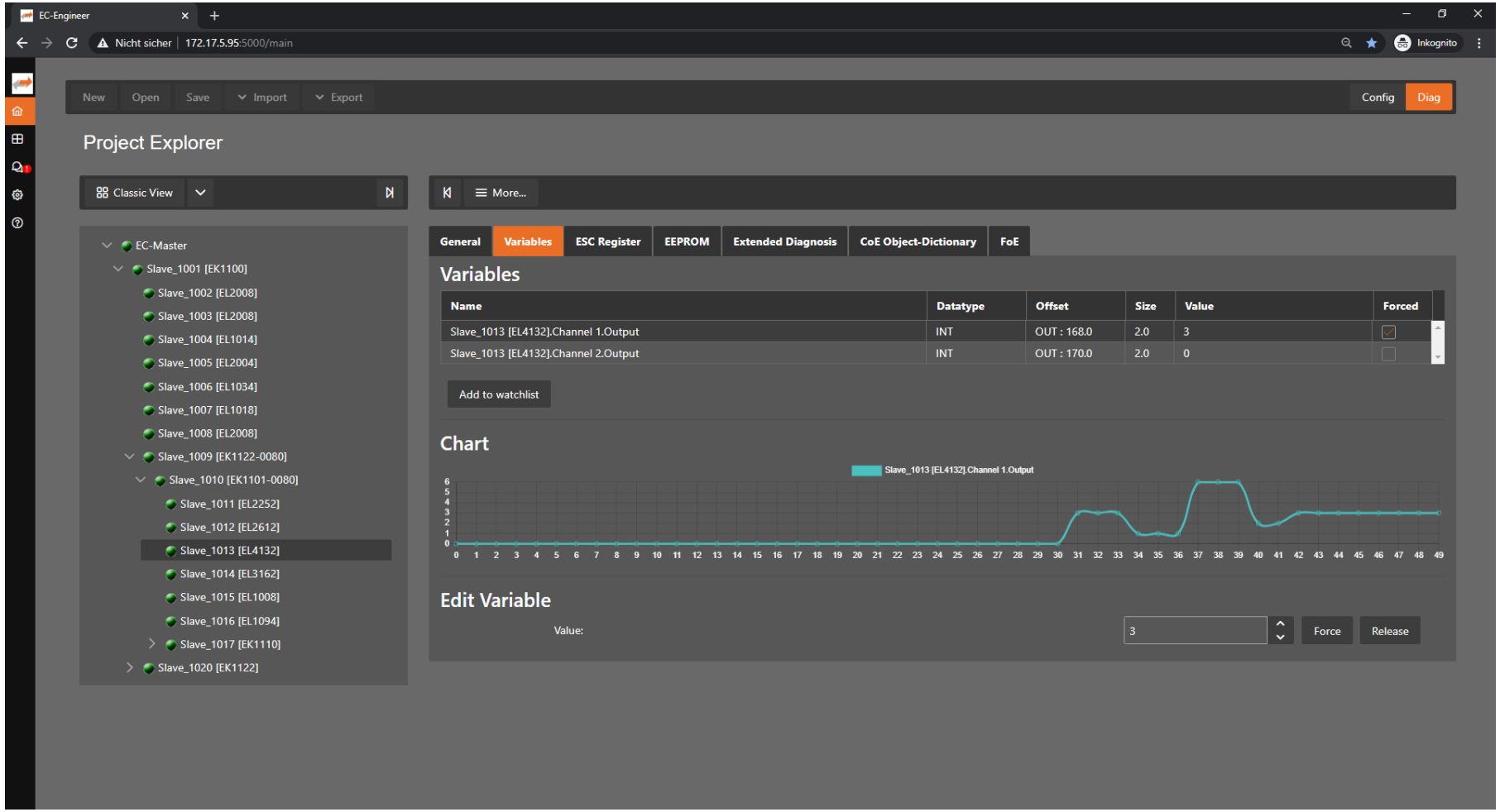
Configuration Mode
Full features including MDP etc.

EC EngineerWeb



Sophisticated Diagnosis Features
Monitoring and forcing of Variables etc.

EC EngineerWeb



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EtherCAT® Network Simulation

Run an EtherCAT controller with a simulated network

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Use Cases

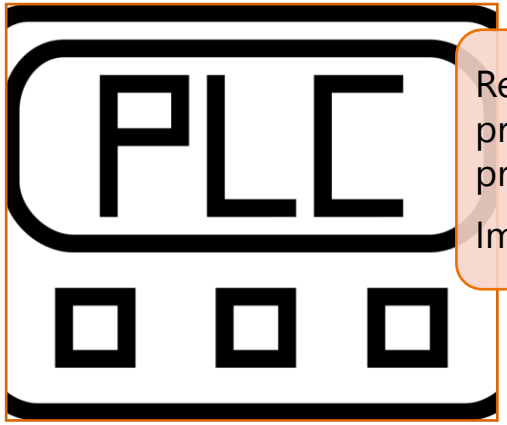
EC Simulator

Master Software Development

Run the Master application without real slaves

Comfortable Debugging of complex topology/slave type scenarios

Fieldbus “Master-Device” Test



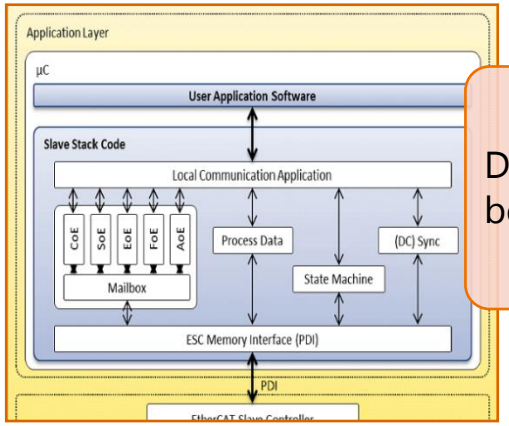
Replace manual test procedures by automatic procedures.

Implement enhanced tests

Virtual Commissioning

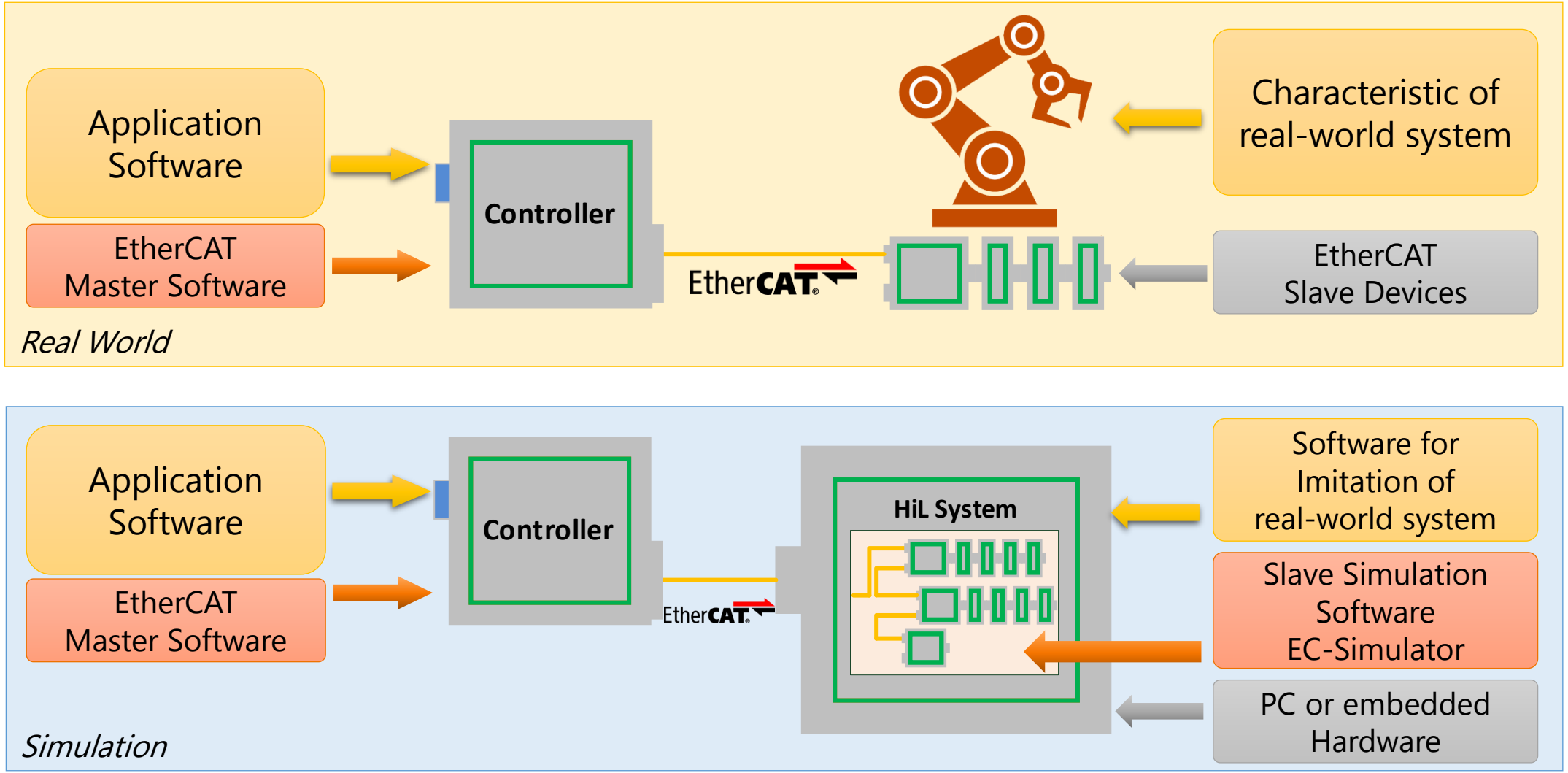
Develop and test applications based on a software emulation of the machine logic

Slave Firmware Development



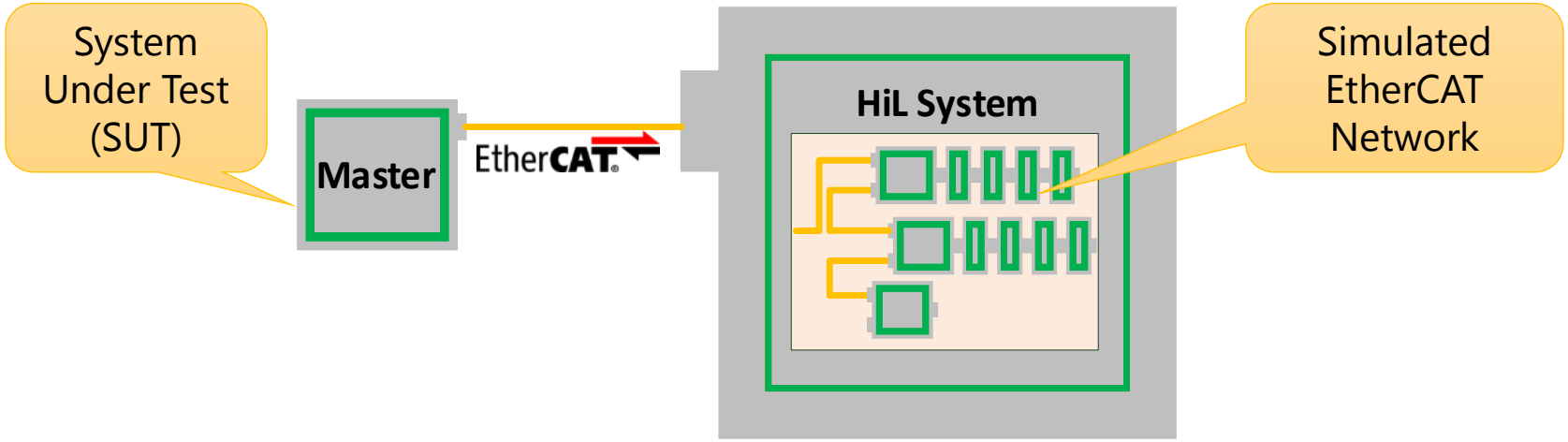
Develop slave firmware before hardware is available

General System Architecture

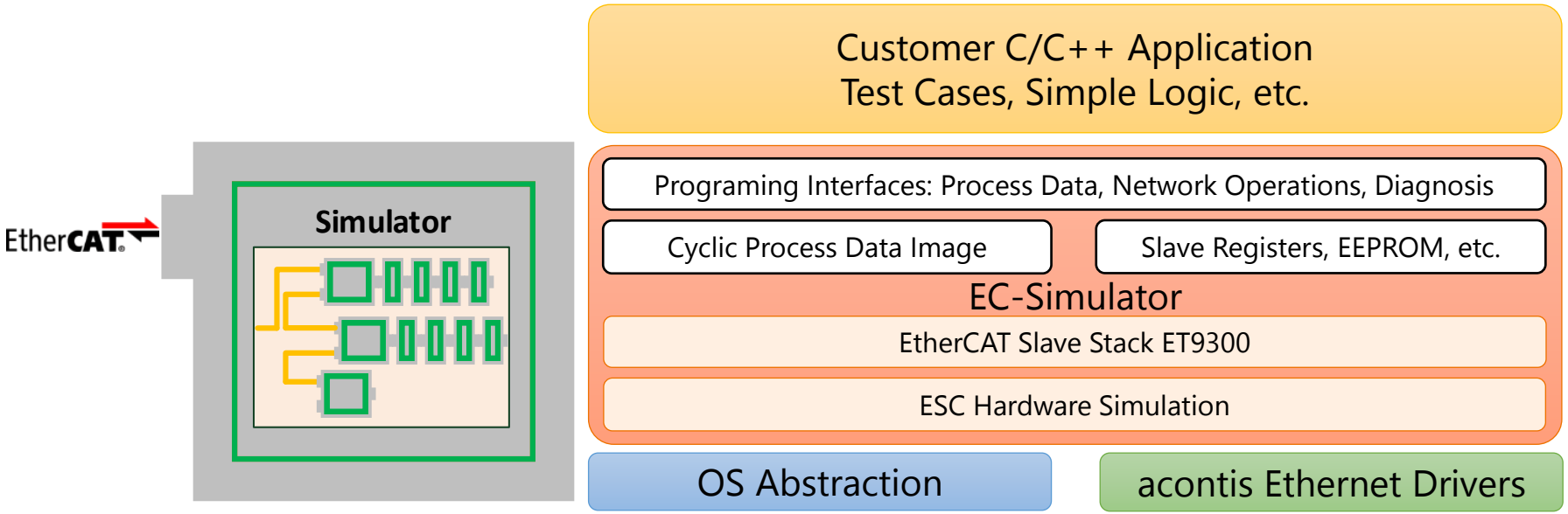


Hardware-in-Loop (HiL) Simulation
All slaves are simulated

- The System-Under-Test (SUT) is communicating via an EtherCAT cable with the EC-Simulator software running on an external hardware, the HiL System.
- HiL System doesn´t require special hardware, a standard Ethernet interface can be used
- In this setup the original application together with the EtherCAT Master can be tested



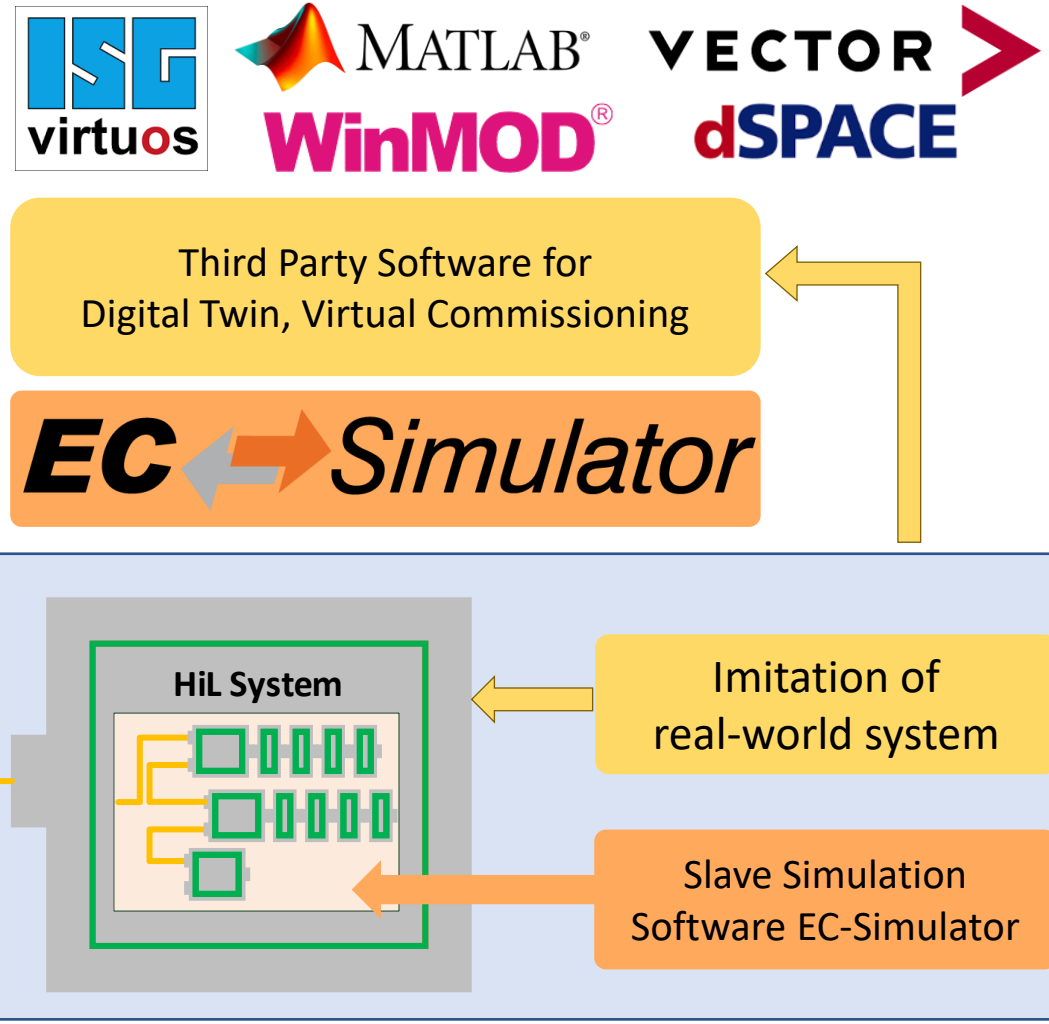
HiL Simulation: Software architecture



- Support for various operating systems, e. g. Linux and Windows
- High performance due to the acontis Real-time Ethernet drivers
- Simulation of EtherCAT Slave Controller (ESC) hardware in software
- Implementation of Beckhoff EtherCAT Slave Stack ET9300
- EC-Simulator offers a “C” language application programming interface (API)

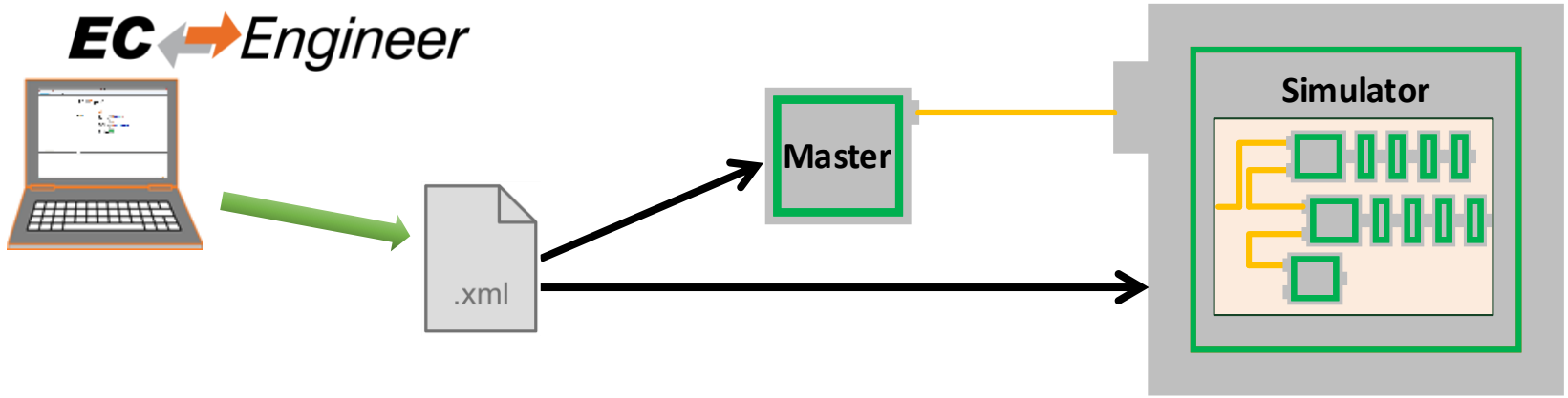
Use Case: Virtual Commissioning

- EC-Simulator together with Digital-Twin Software
- Test and optimize the application during early engineering-stages, without real existing target hardware.
- Test error scenarios which are dangerous and/or lead to damages

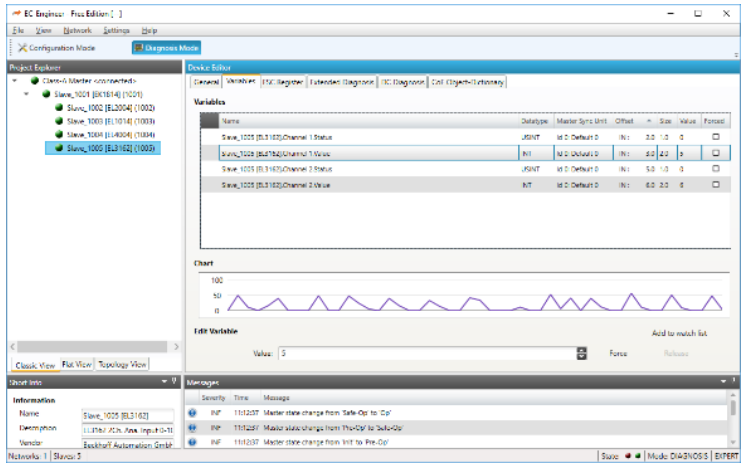


Configuration based on ENI file

- Standard EtherCAT Network Information (ENI) file is used to configure the EC-Simulator software
- ENI can be exported by EC-Engineer or any other configuration software, e. g. Beckhoff TwinCAT, supporting it.



Diagnosis with EC-Engineer



EC Engineer

RAS Client (TCP)

Online Functions

TCP/IP

RAS Server (TCP)

C/C++ Application

EC Simulator

Real-Time Kernel/OS

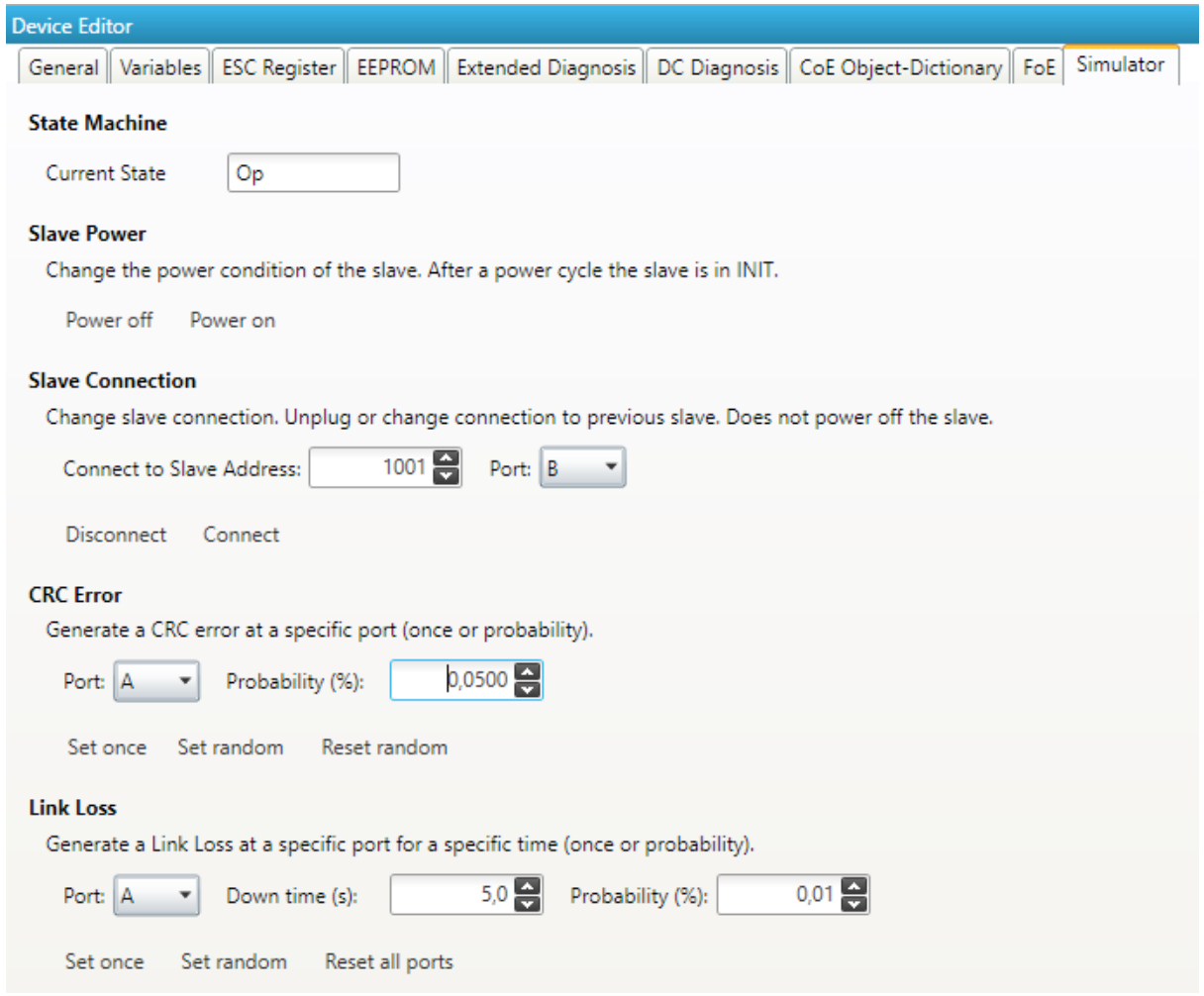
Link Layer

Simulator

Master

EtherCAT

Simulate Power Loss, Link Loss and Frame Errors with EC-Engineer



- Power down/up a specific slave
- Create CRC errors on a specific port (by random)
- Simulate test cases like “Unplugging a cable”

Software-in-Loop (SiL) Simulation

EC Simulator

Setup with real devices only

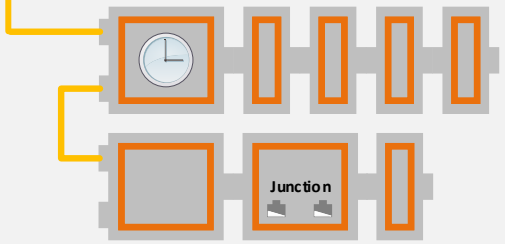
Customer Application C/C++

EC Master

OS Abstraction

Ethernet Driver

Standard Ethernet MAC



Simulated Slaves

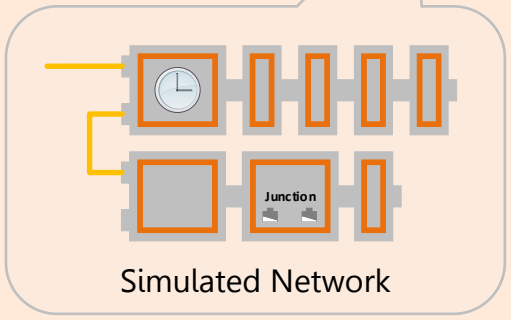
Flexible setup with simulated devices

Customer Application C/C++

EC Master

OS Abstraction

EC Simulator



Simulated Network

Key benefits

- **Hardware-in-the-Loop**:
  - ⇨ Simulate a complete EtherCAT network on a PC or embedded system running Windows, Linux, QNX, etc.
- **Software-in-the-Loop**:
  - ⇨ Simulate a complete EtherCAT network on the EC-Master controller
- Comprehensive functions to **simulate errors**
  - ⇨ Including broken cable, wrong cabling, slave failures
- EC-Simulator **API** is mainly **equal** to EC-Master API
- Integration of **own slave firmware** possible

Additional information

- EC-Simulator product intro video
  https://youtu.be/5ToJh7gJ_Go
- EC-Simulator tutorials and user manual
  https://developer.acontis.com/ec-simulator
- Request for EC-Simulator technical details slides
- Request for evaluation software
  https://www.acontis.com/en/ethercat-support-eval-request.html