International Standards for Open Distributed Automation

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by:

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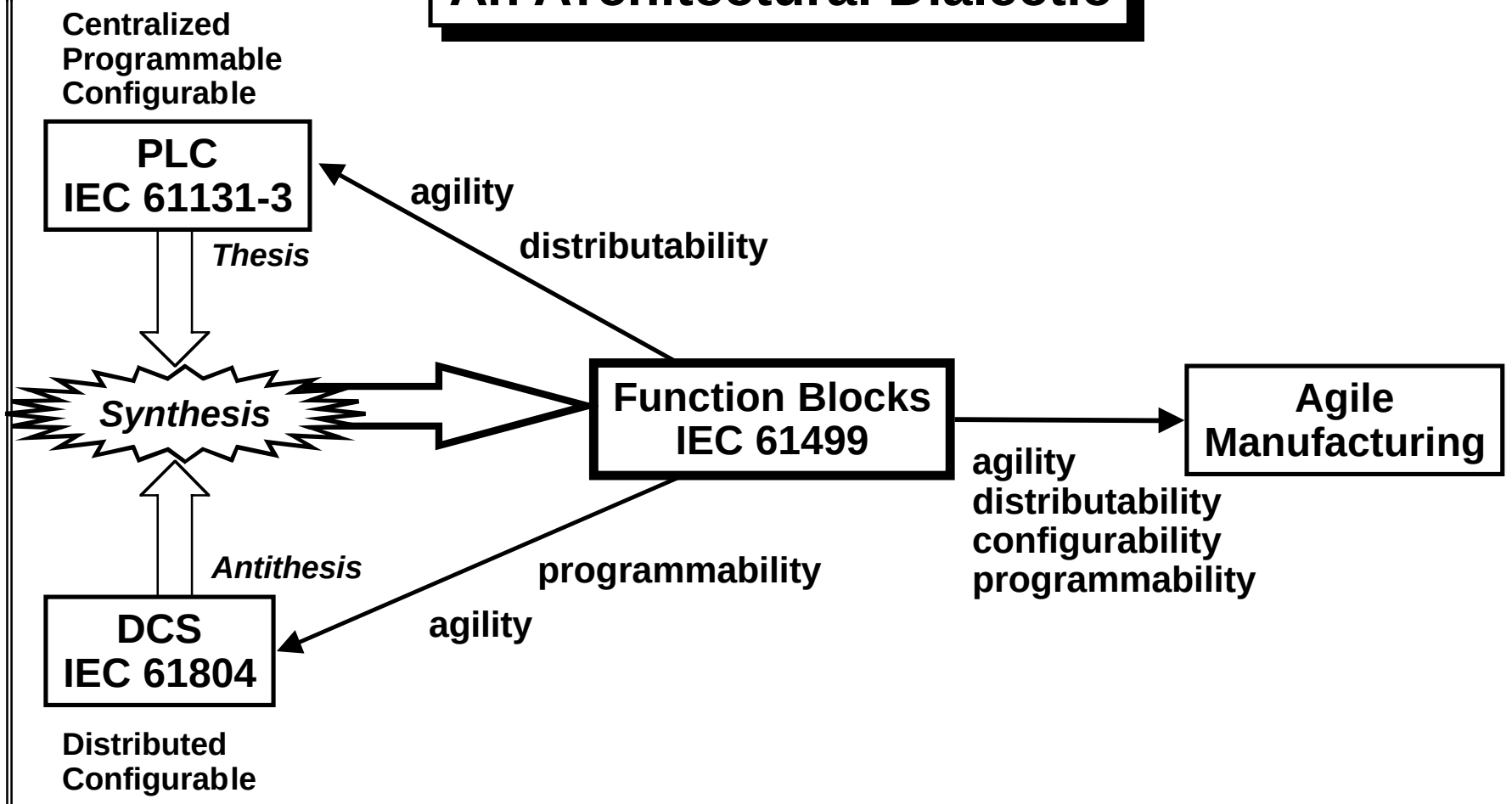
The Challenge of Agile Manufacturing

- **Past: The Vision** (Iacocca Institute, 1991)
  - **Production to Order**
  - **Lot/Batch size ≥ 1 Unit**
  - **Information intensive**
  - **"Reprogrammable, reconfigurable, continuously changeable"**
- **Present: The Reality**
  - **Production to Order Possible**
  - **Order-to-delivery delay: 3-6 months(cars), 1 week (PCs)**
- **Near Future**
  - **Japanese Vision: "3-day car"**
  - **Toyota/Canada (planned): "5-day car" (limited customizability)**

The Challenge to Automation Systems

- **Agility Requires Dynamic Reconfiguration!**
- **Physical Reconfiguration**
  - **Requires Distributed Automation**
- **Logical Reconfiguration**
  - **Dynamic Reorganization of Control Plans**
  - **Minimum Human Intervention (zero preferred)**
  - **Maintain Configuration Control**
- **Not just Parameterization!**
  - **Leads to Large, Complex Software Modules**
  - **Reduces Distributability, Flexibility, Reliability**

Distributed Automation: An Architectural Dialectic



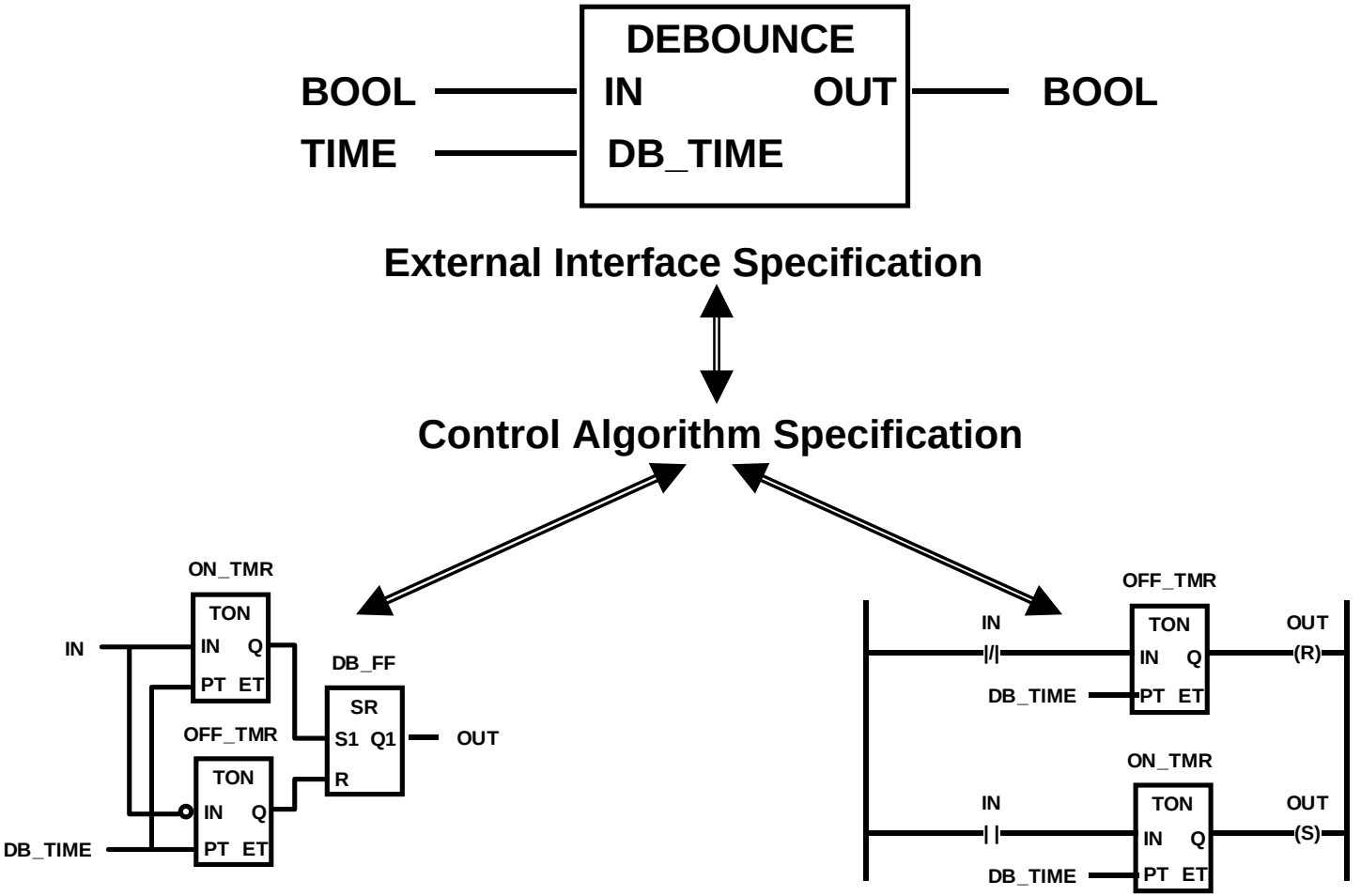
Issues in the Architectural Dialectic

- Execution scheduling
- Communication/execution interaction
- Response time requirements
- Alternative algorithm selection
- State machine design
- Software encapsulation and reuse
- Agility (≡ Dynamic Reconfiguration)

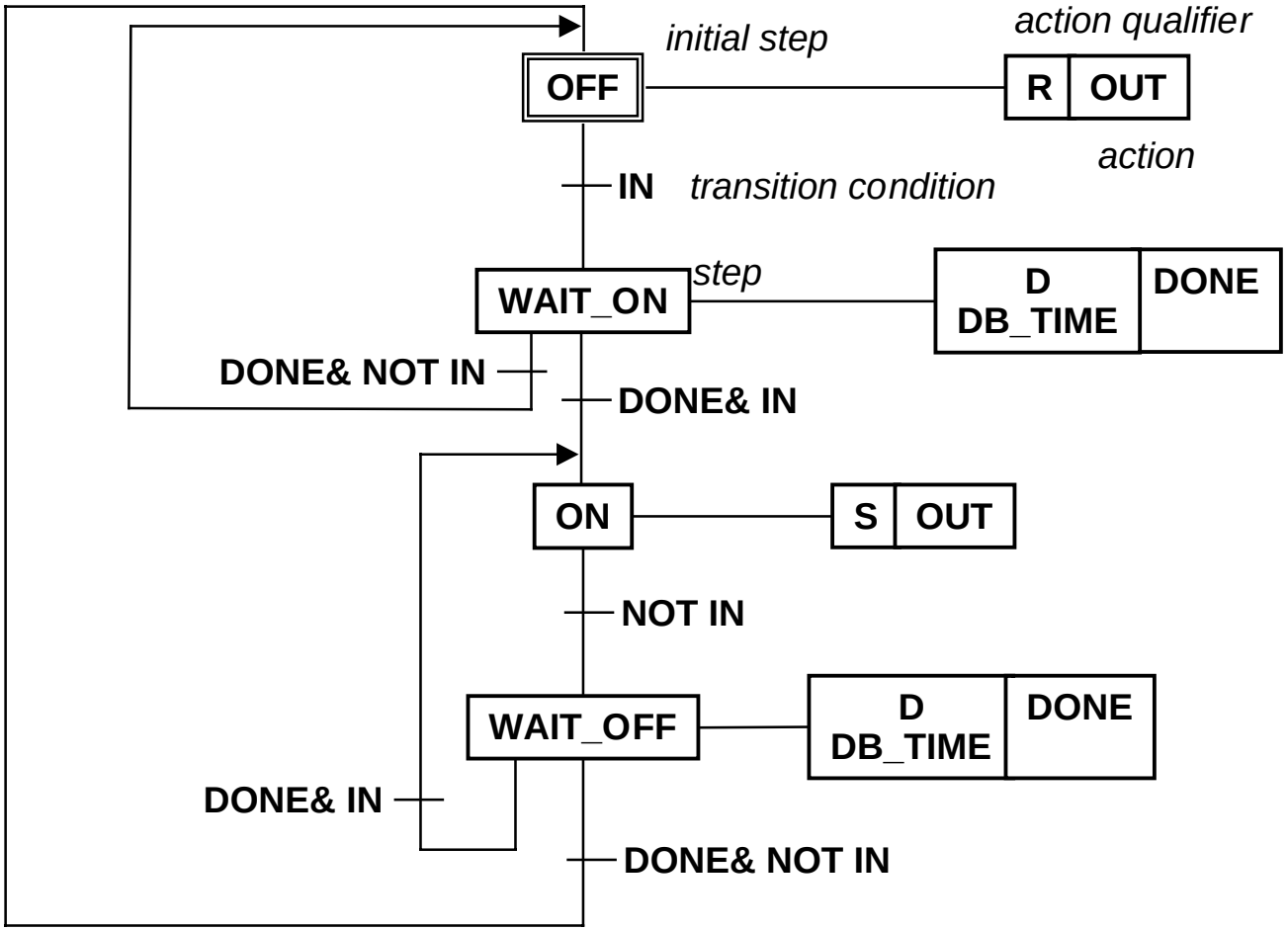
IEC 1131-3: Modern Software Engineering for Automation and Control

- **Encapsulation/Reuse Mechanisms**
  - **Function Blocks, Functions, Data Types, Programs**
- **Application-adapted Languages**
  - Ladder Diagram (LD) for logic control (“power flow”)
  - Function Block Diagram (FBD) for regulatory control (“data flow”)
  - Sequential Function Chart (SFC) for state-machine control (“internationalized GRAFCET”)
  - Structured Text (ST) for information processing
  - Instruction List (IL) for assembly-level programming
- **A Mature, Internationally Adopted Standard**
  - First edition: 1993
  - Second edition: 2000

Software Encapsulation and Reuse in IEC 61131-3



State Machine Control in IEC 61131-3: Sequential Function Charts (SFCs)

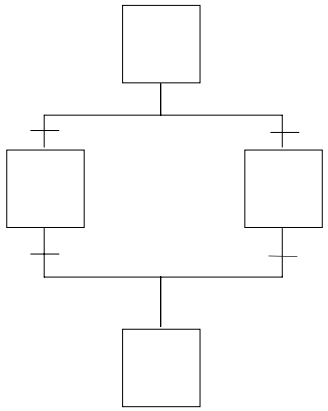


Sequential Function Chart (SFC) Features

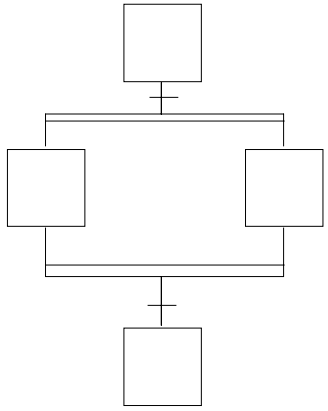
Action Qualifiers

No.	Qualifier	Explanation
1	None	Non-stored (null qualifier)
2	**N**	**N**on-stored
3	**R**	overriding **R**eset
4	**S**	**S**et (**S**tored)
5	**L**	time **L**imited
6	**D**	time **D**elayed
7	**P**	**P**ulse
8	**SD**	**S**tored and time **D**elayed
9	**DS**	**D**elayed and **S**tored
10	**SL**	**S**tored and time **L**imited
11	**P1**	**P**ulse (rising edge)
12	**P0**	**P**ulse (falling edge)

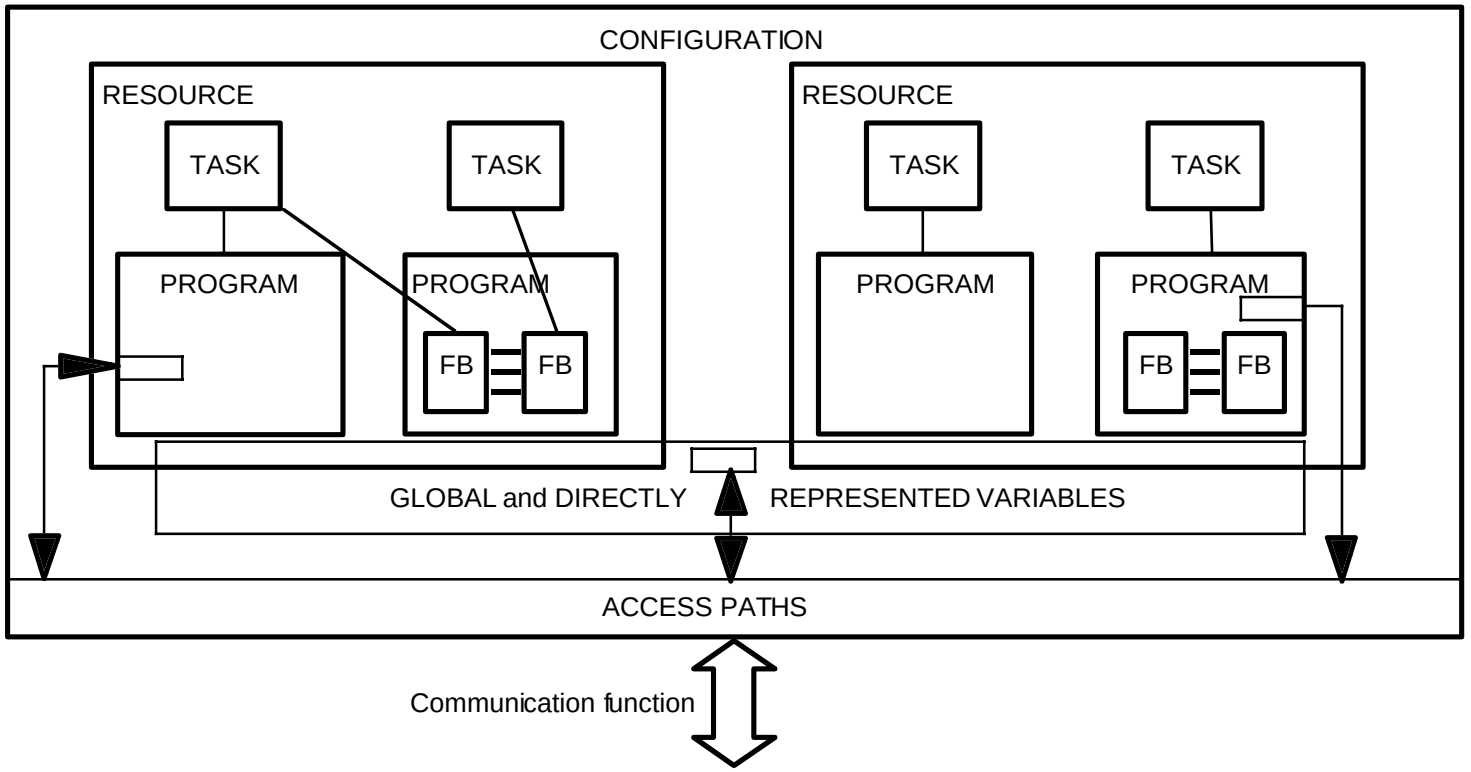
Sequence Selection



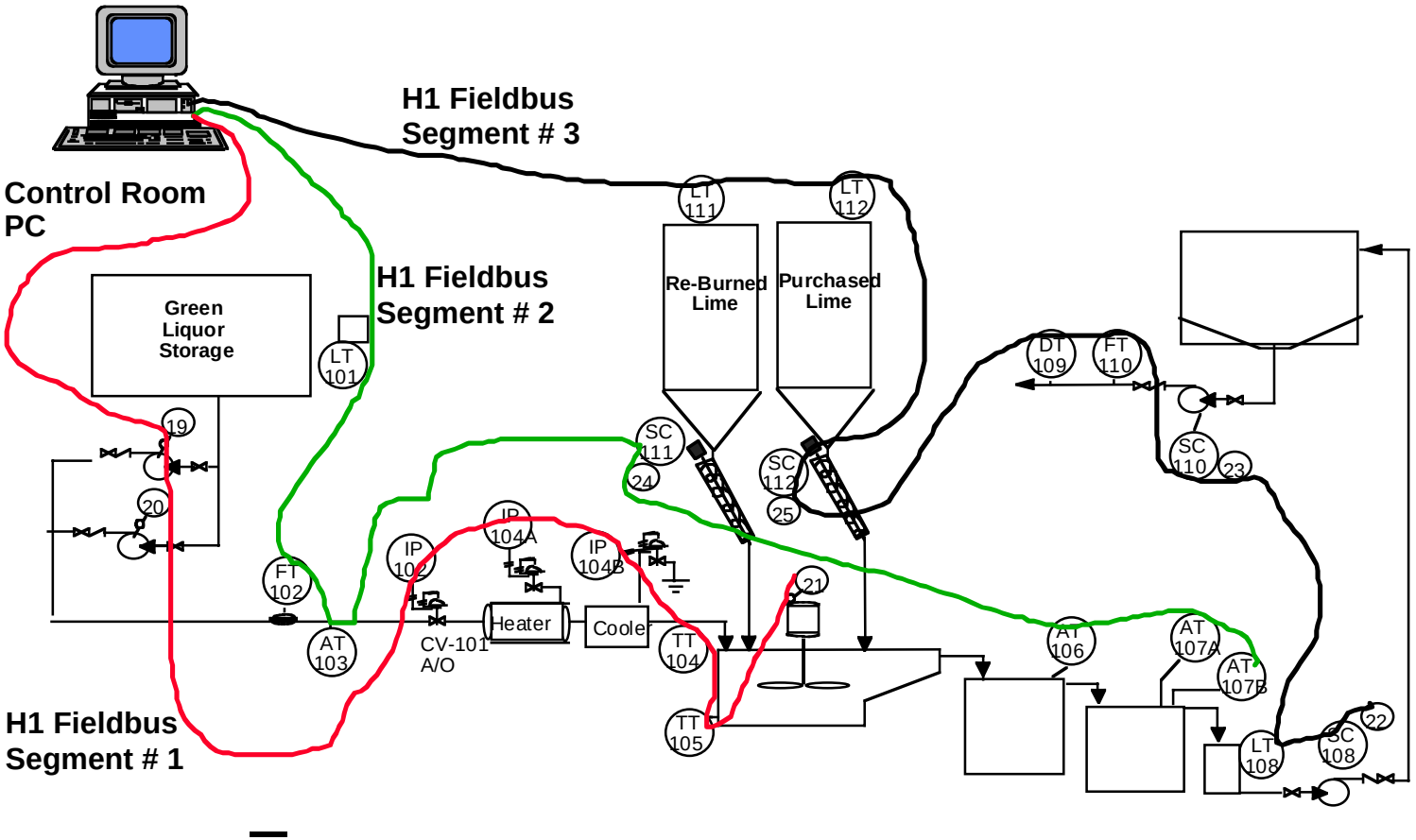
Simultaneous Sequences



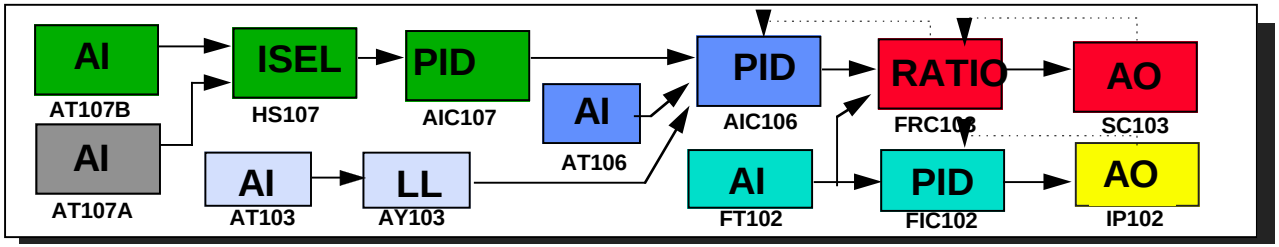
Centralized System Configuration in IEC 61131-3

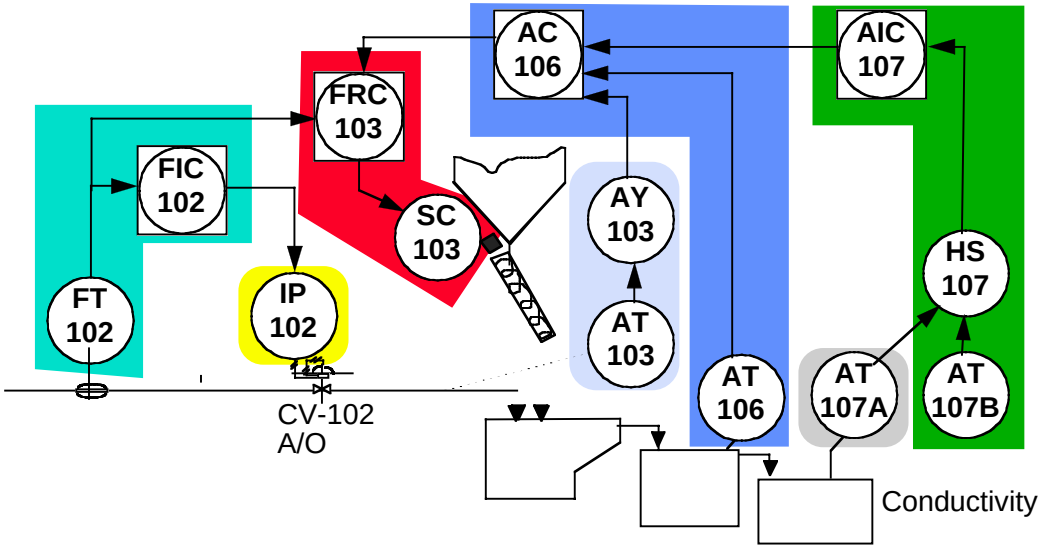


Distributed Configuration in IEC 61804 (Physical View)

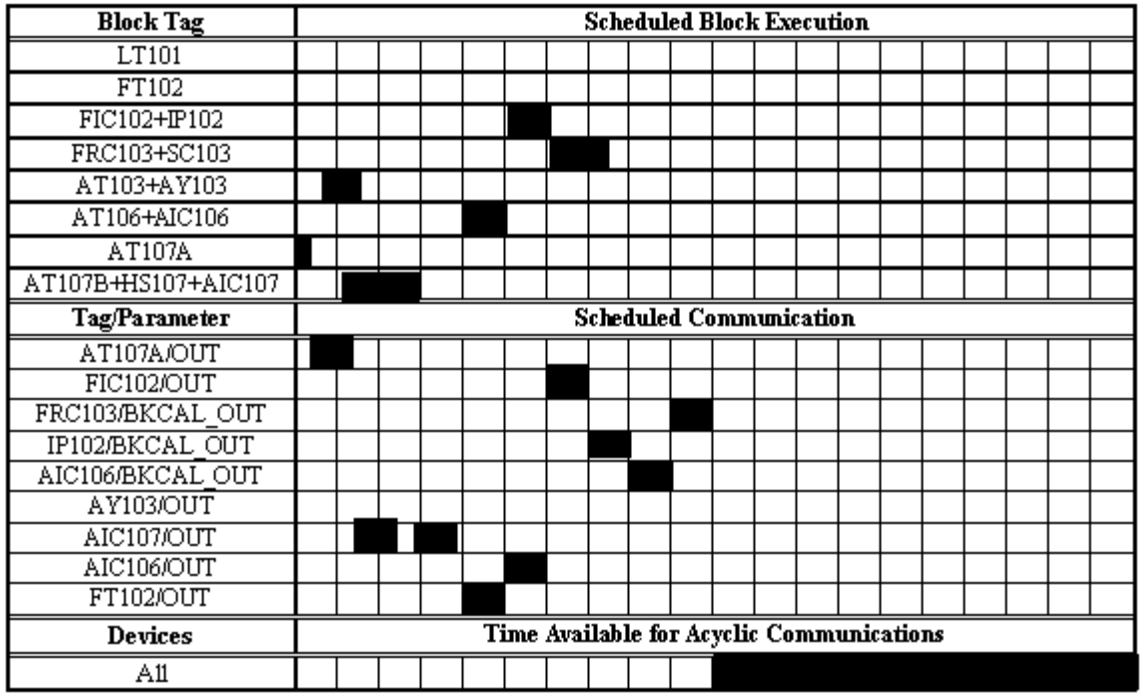


Distributed Configuration in IEC 61804 (Logical View)





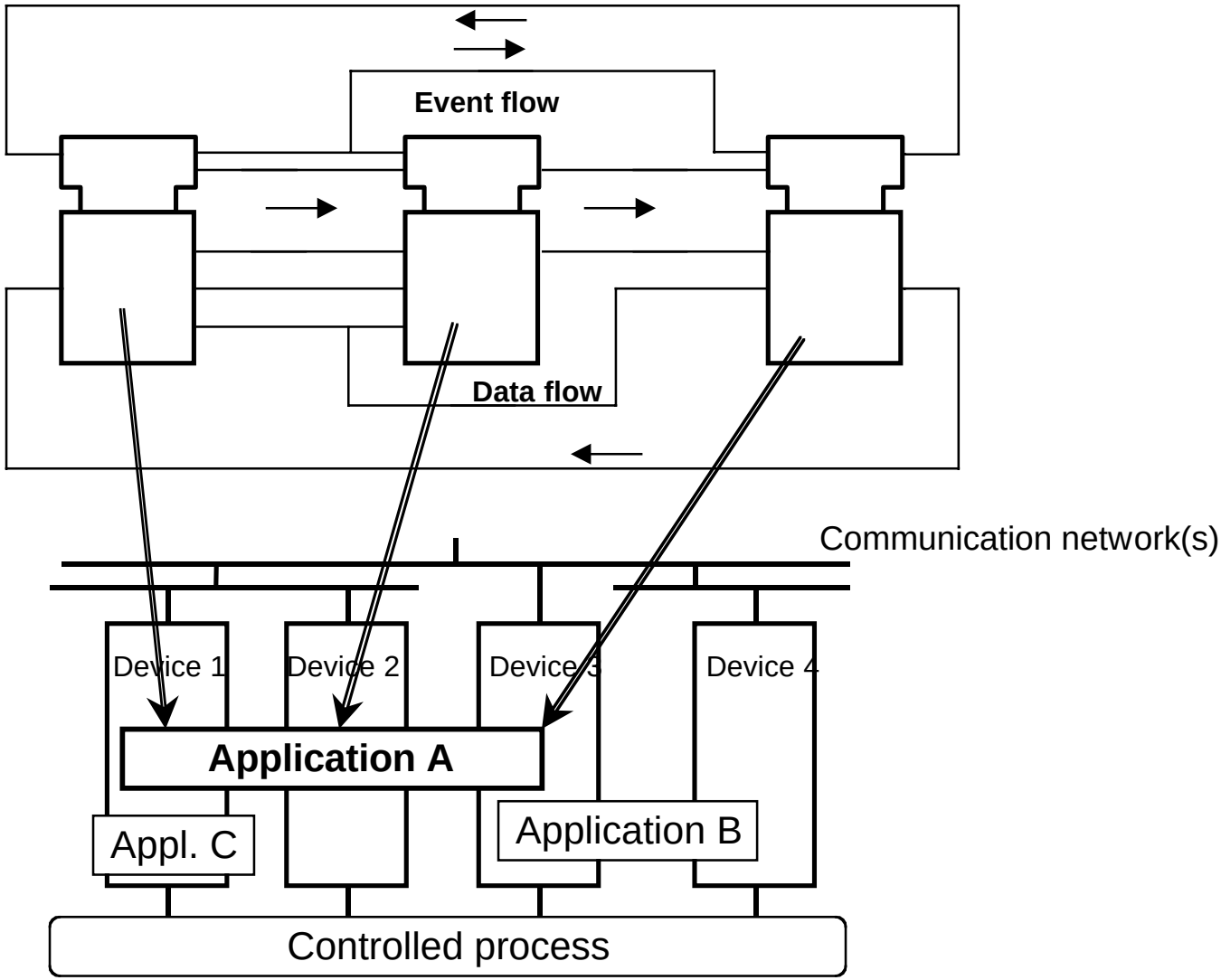
Distributed Configuration in IEC 61804 (Scheduling View)



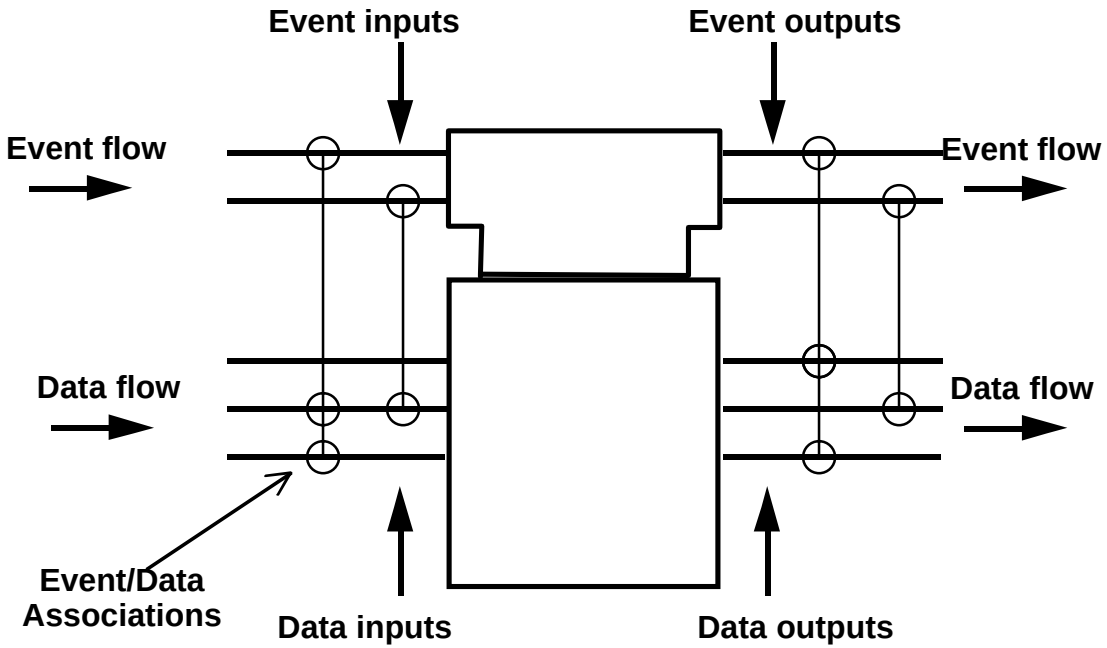
Basic Concepts of IEC 61499

- Distributed applications
- Event and data interfaces
- Software encapsulation and reuse
- Event-driven state machines
- Service interfaces
- Management services
- Software portability

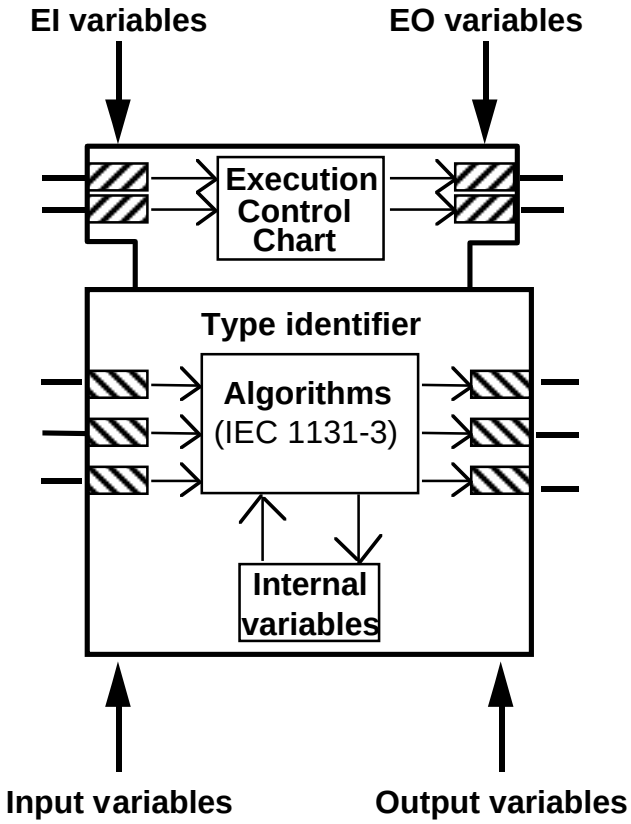
Distributed Applications



Event and Data Interfaces

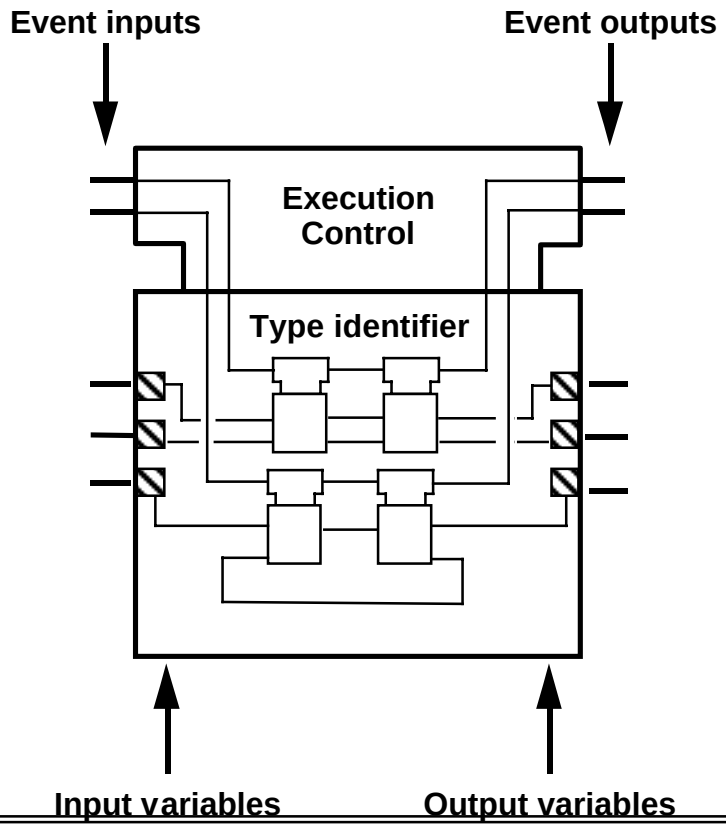


Software Encapsulation and Reuse in IEC 61499: Basic Function Block Types

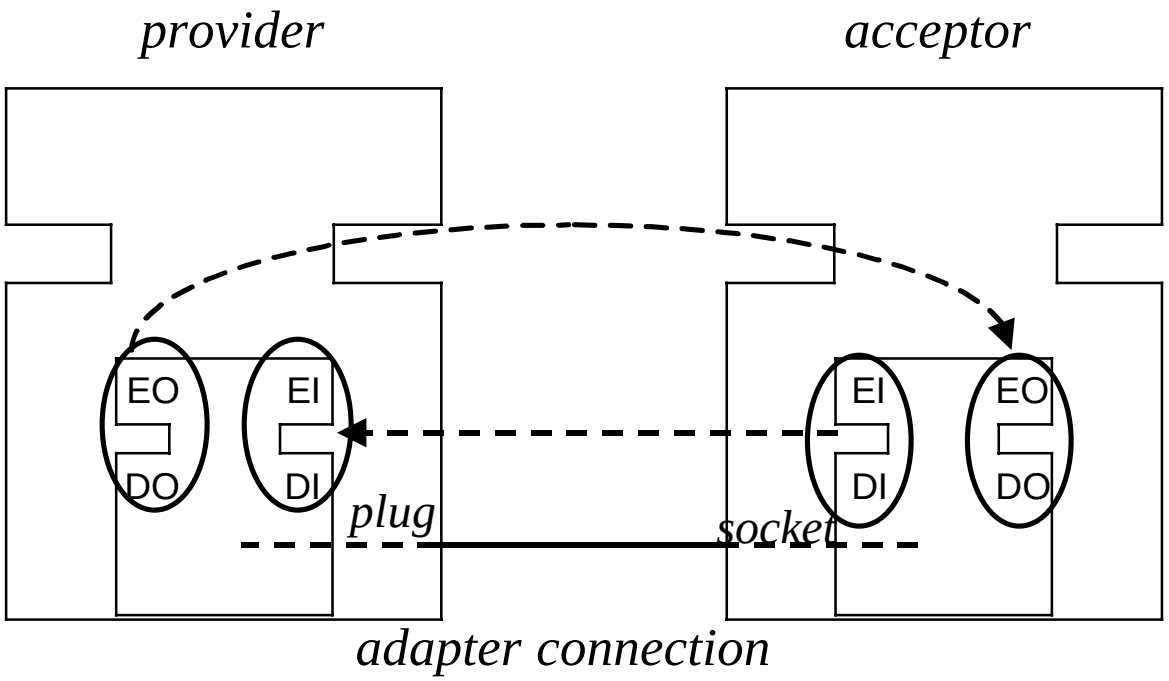


Software Encapsulation and Reuse in IEC 61499: Composite Function Block Types

- Functional composition
- Reusable
- Atomic (not distributable)

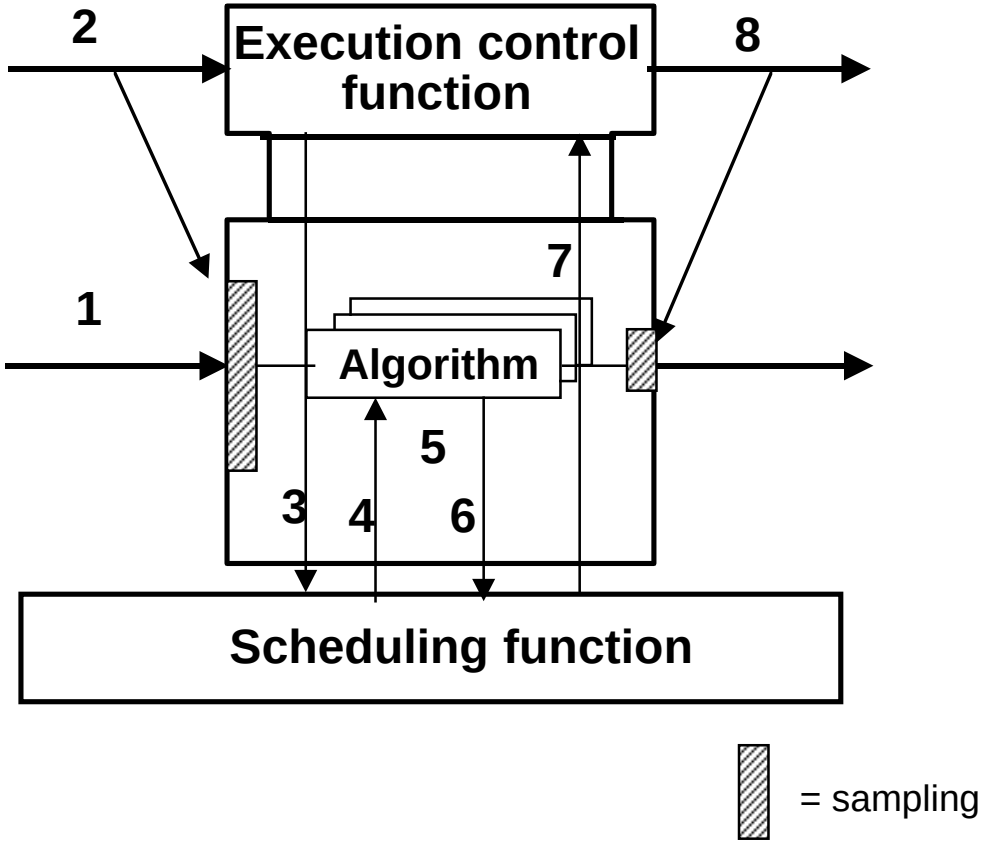


Software Encapsulation and Reuse in IEC 61499: Adapter Interfaces

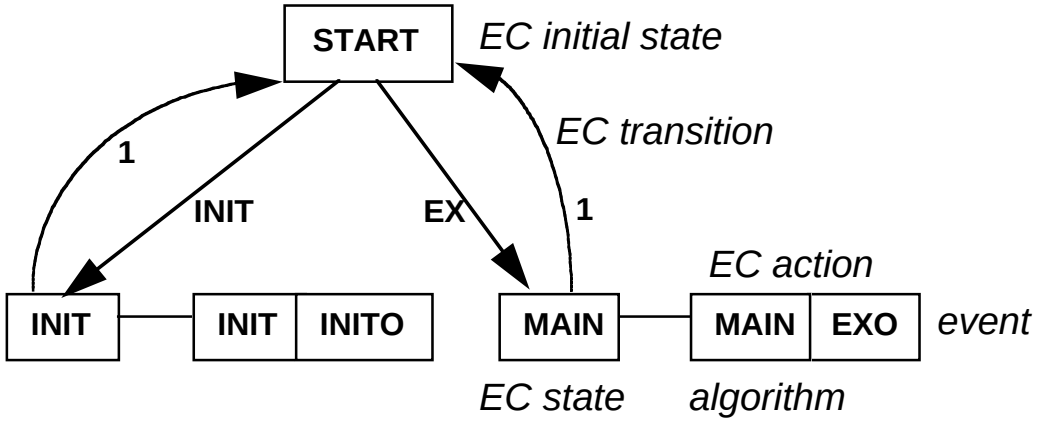


- **Reduce diagram clutter**
- **Simplify transducer interface**
- **Capture patterns of interaction**

Event-Driven Execution Control

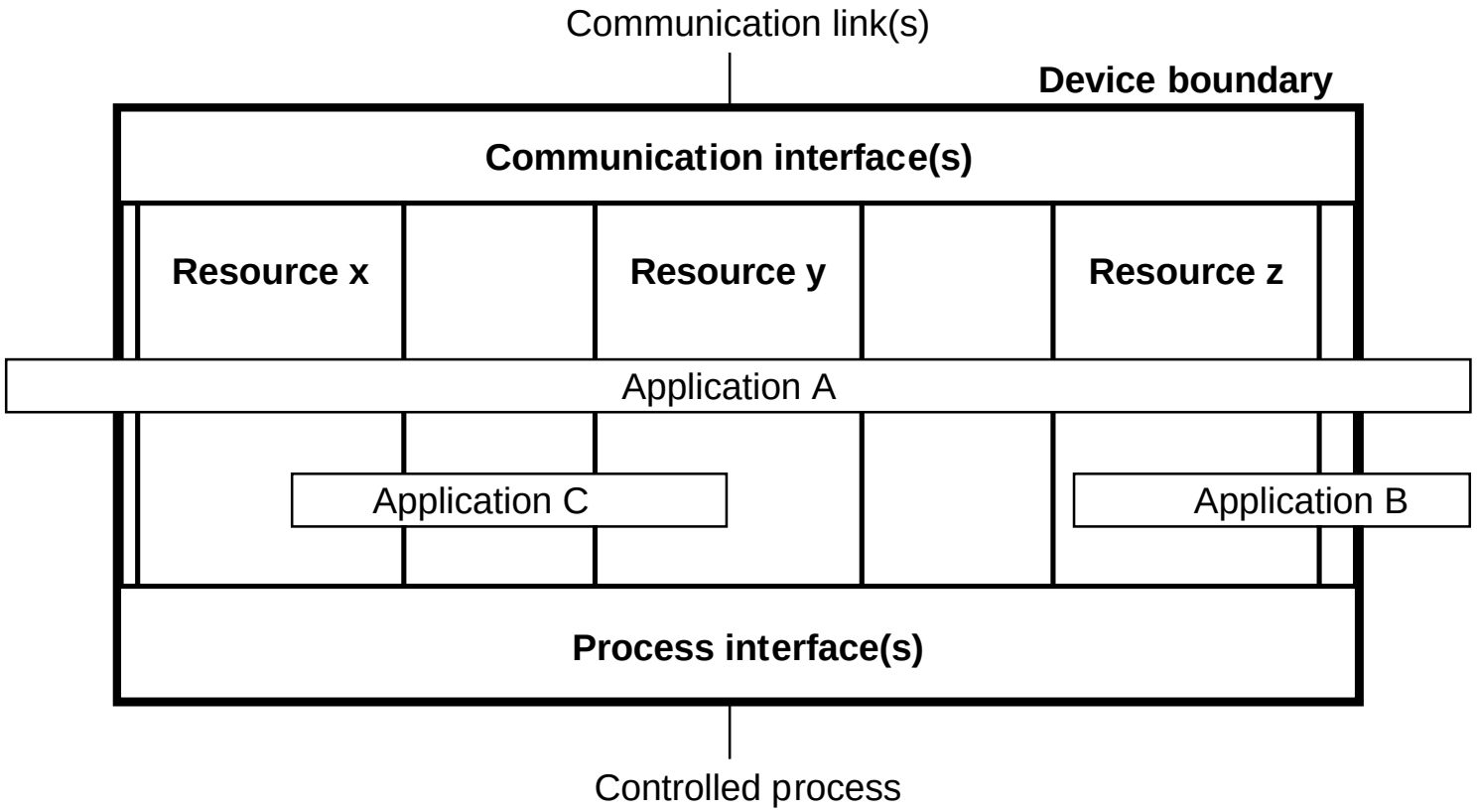


The Execution Control Chart (ECC): An Event-Driven State Machine



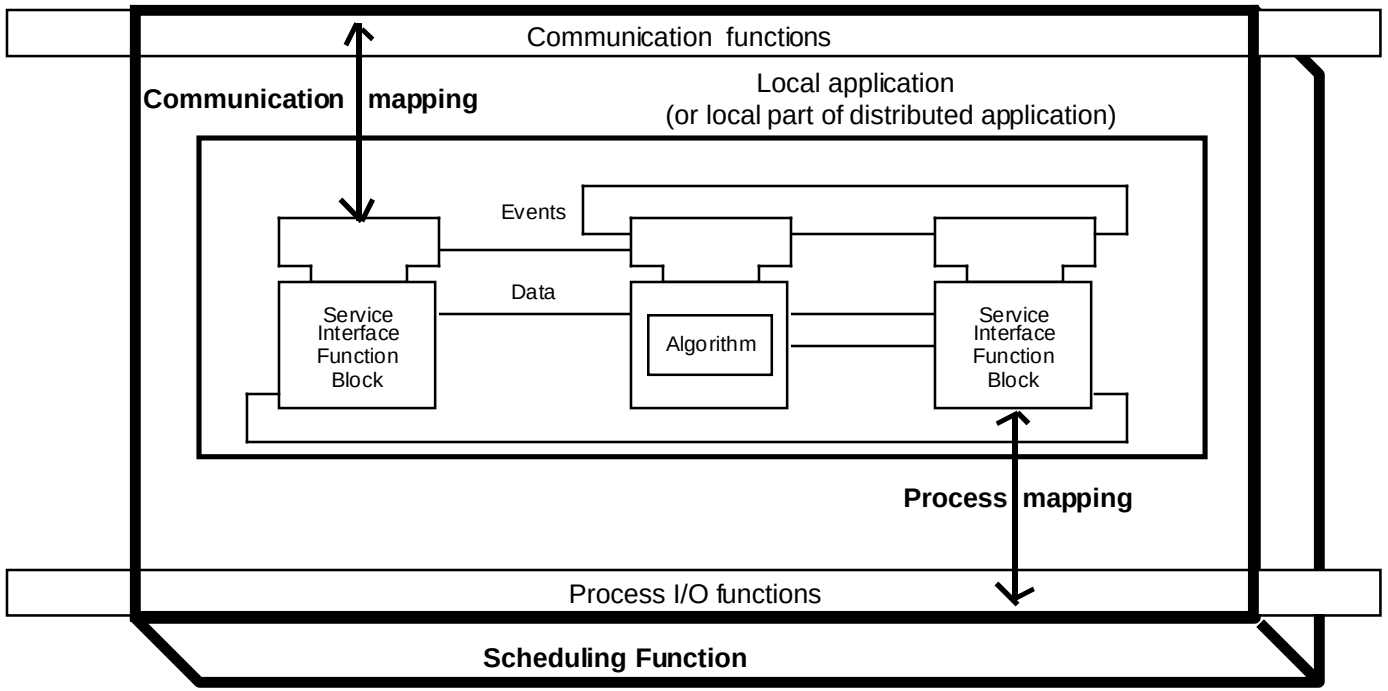
IEC 61499 Device Model

- **Device = Container for Resources**
- **Device provides Communications & Process Interfaces**



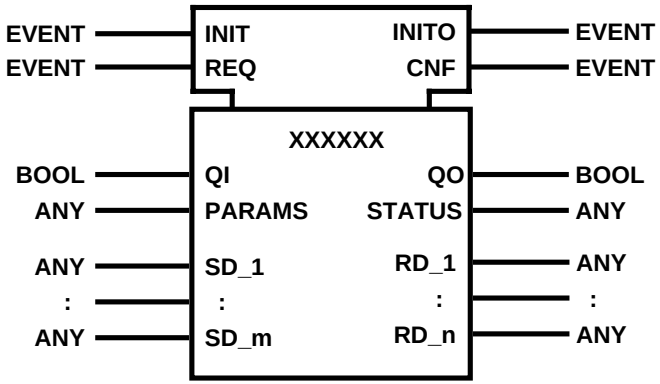
IEC 61499 Resource Model

- **Resource schedules & executes FB algorithms**
- **Resource maps Communications & Process I/O Functions to Service Interface Function Blocks**

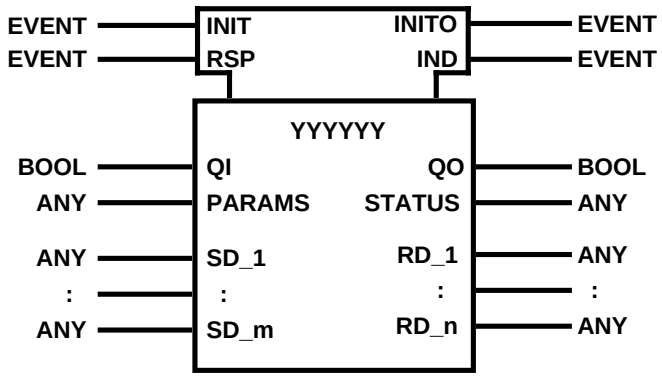


Service Interface Function Blocks

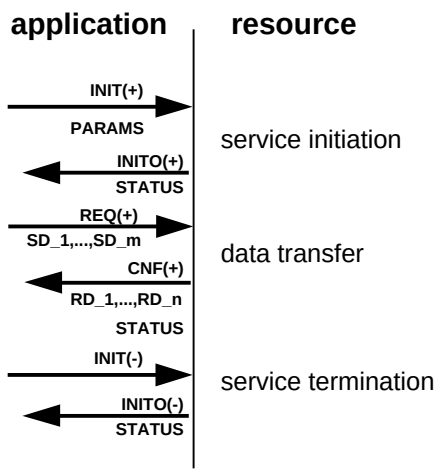
- **Access to Resource functionality**
- **Modeled as sequences of *service primitives*** per ISO/IEC TR8509

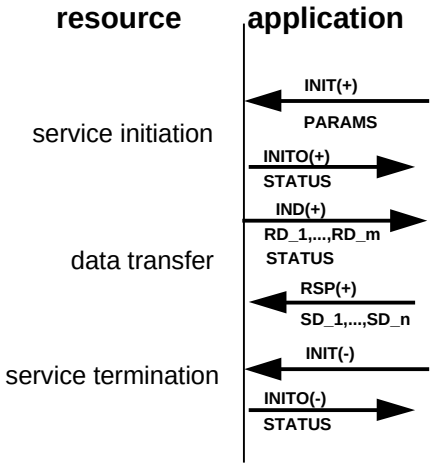


(application-initiated transactions)

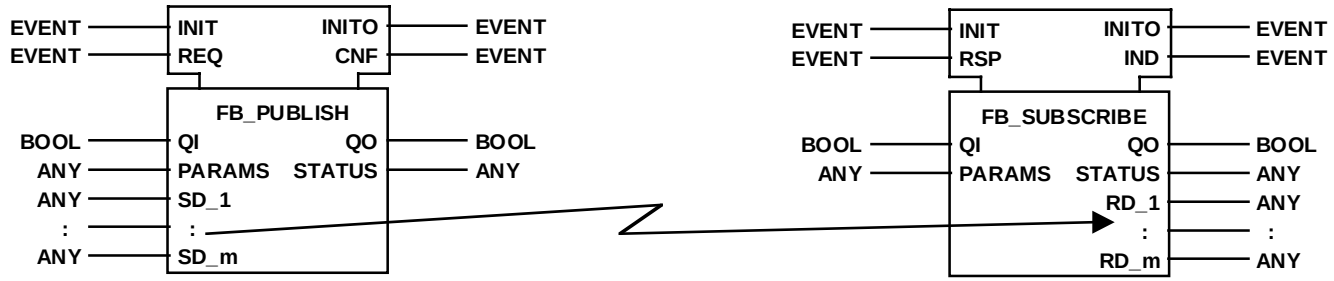


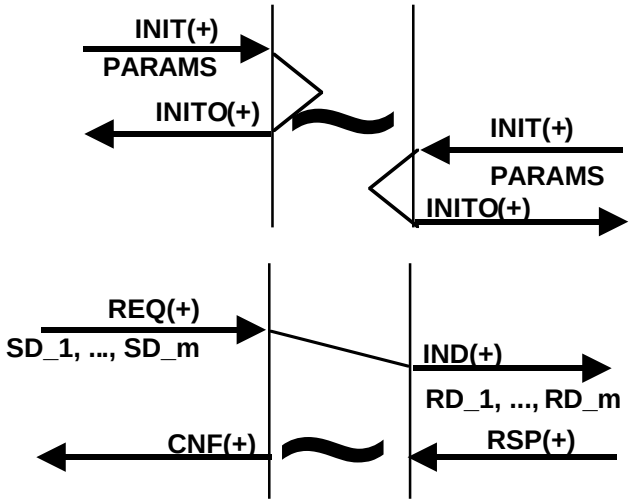
(resource-initiated transactions)



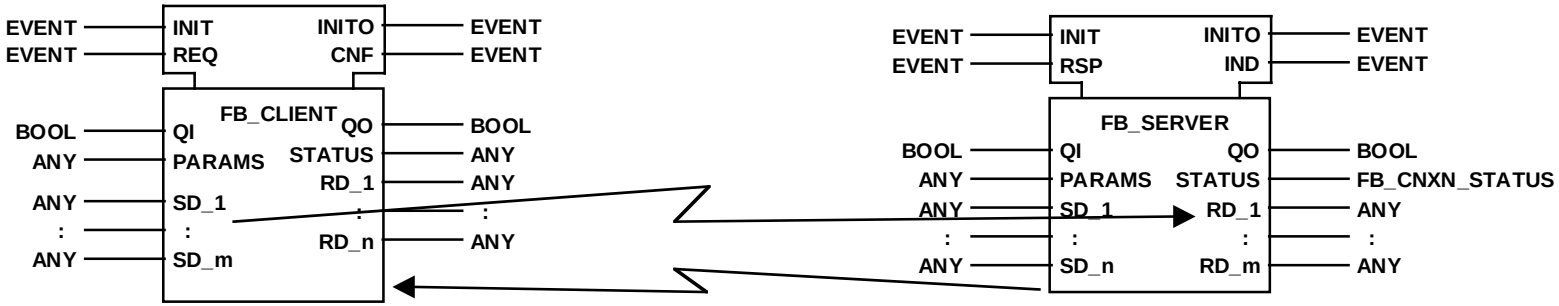


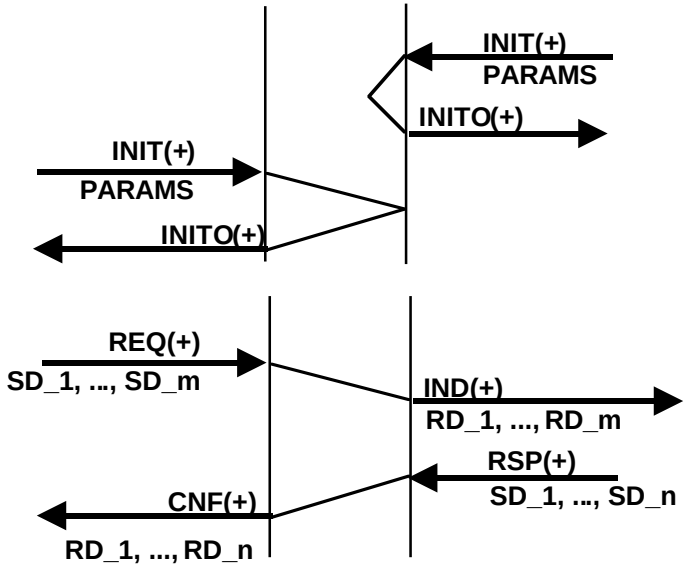
Communication Service Interfaces: Publish/Subscribe Model



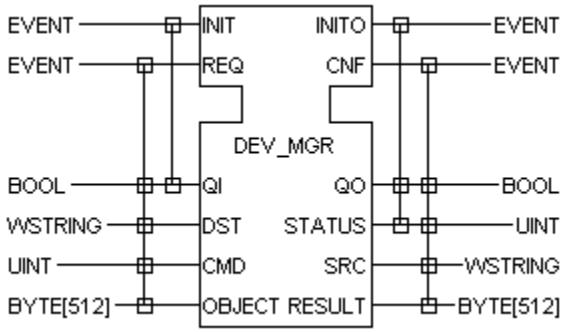


Communication Service Interfaces: Client/Server Model



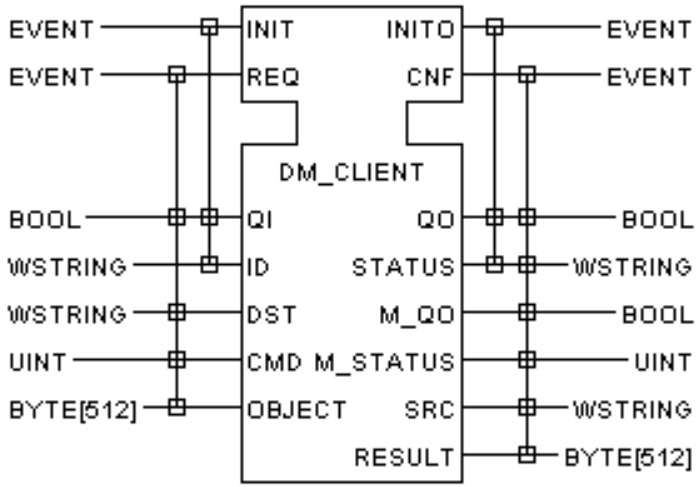


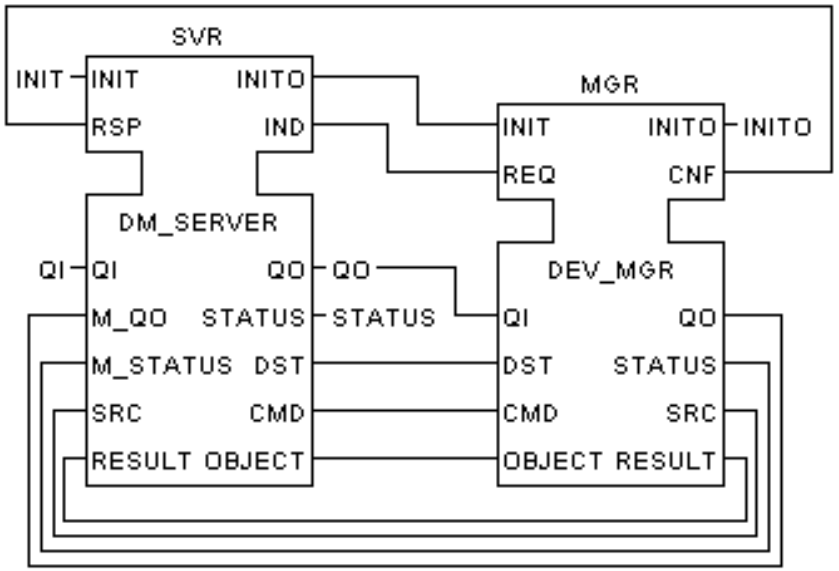
A Device Management Service Interface



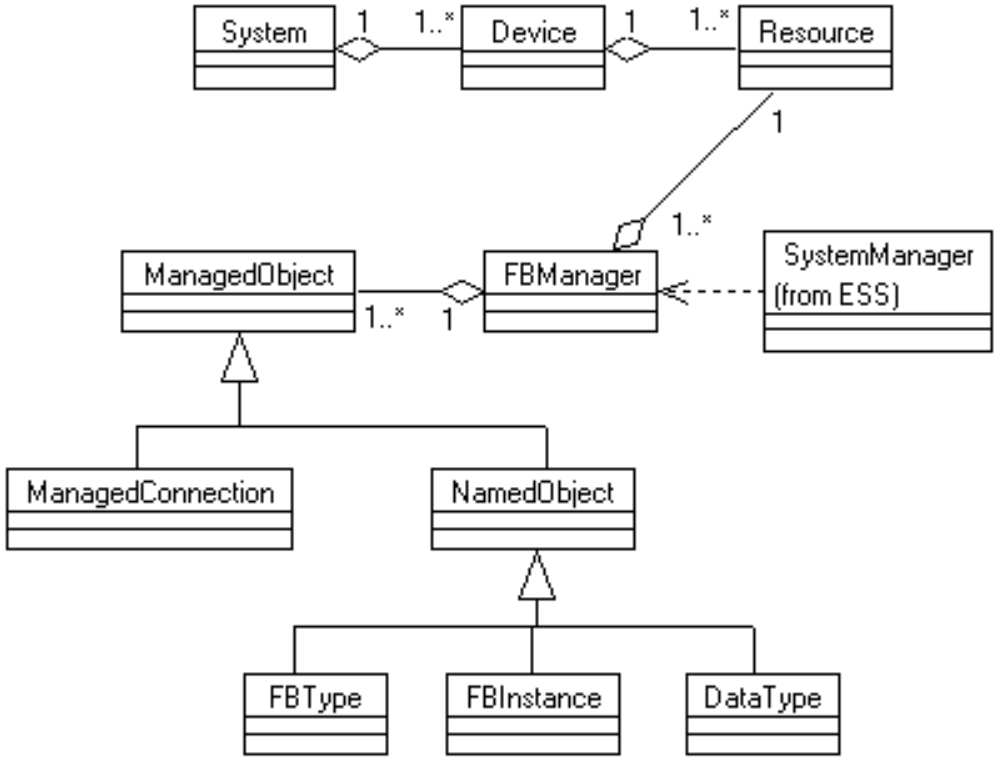
- **Command syntax examples:**
  - **CREATE functionBlockInstance**
  - **CREATE functionBlockType**
  - **QUERY dataTypeName**
  - **CREATE connection**
  - **START functionBlockInstance**
  - **STOP functionBlockInstance**
  - **DELETE connection**
  - **DELETE functionBlockInstance**

A Remote Device Management Model





System Management Model



Open Distributed Systems: The IEC 61499 Vision

KEY:
Existing & Normative in IEC 61499
Existing but non-Normative in IEC 61499
To be done

Project Repository

DeviceNet EDSs
Fieldbus DDs
etc.

import

Engineering Toolsets

XML

PORTABILITY

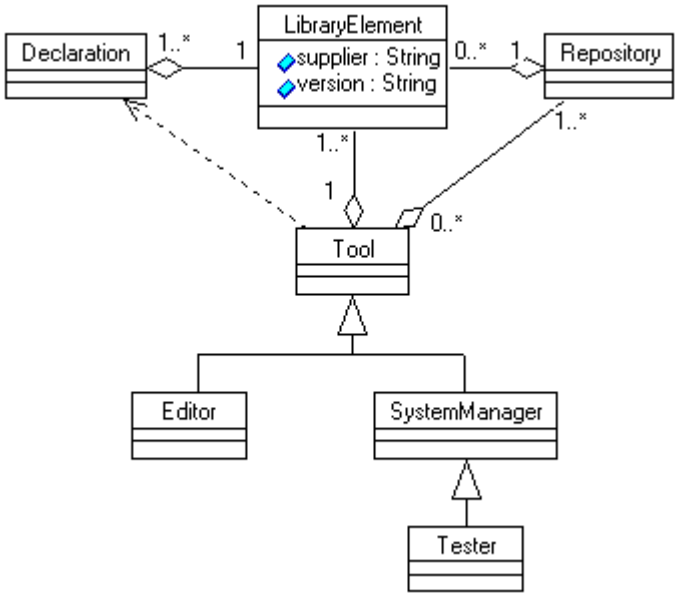
Libraries:
IEC 61915
IEC 61499
IEC 61131-3
Application Frameworks

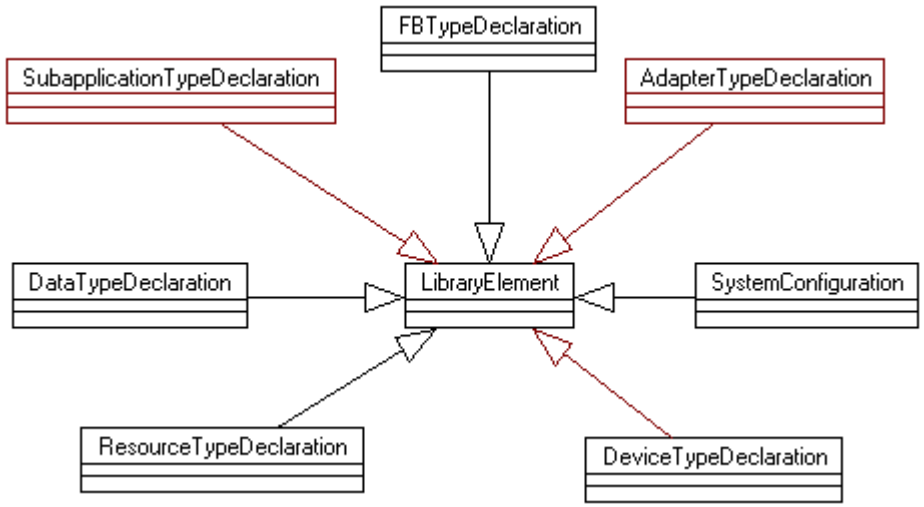
Standard management protocols: CONFIGURABILITY

Standard data transfer protocols: INTEROPERABILITY

Distributed intelligent devices & controllers

Engineering Tool Models

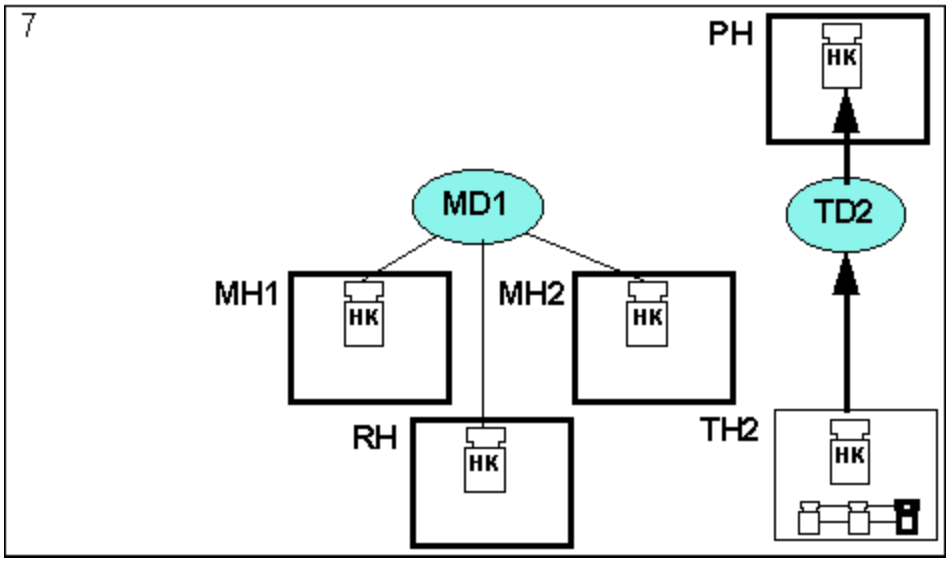


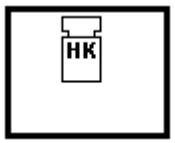


IEC Project 61499 Status & Future

- **IEC 61499-1, *Architecture***
  - **PAS (Publicly Available Standard) issued for Voting**
- **IEC 61499-2, *Engineering Task Support***
  - **2nd CD (Committee Draft) issued for Technical Review**
  - **PAS projected: 2000**
- **2-year trial use period**
  - **Incorporate lessons learned from trial implementations**
  - **DIS projected: 2002-07-01**
- **Home Page**
  - **ftp://ftp.cle.ab.com/stds/iec/sc65bwg7tf3/html/news.htm**

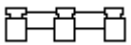
IEC 61499 + Holonic Systems Technology: The Missing Link to Agility





Holons negotiate and coordinate tasks via

Cooperation Domains. Tasks are perfomed by



IEC 61499 Applications, generated “on the fly”**.**

IEC 61499

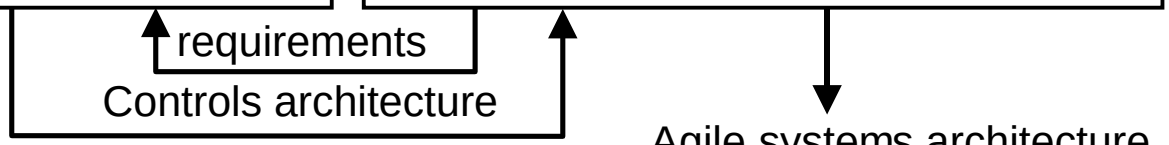
- Parent organization: IEC
- Working group: TC65/WG6
- Goal: Standard model (function blocks) for control encapsulation & distribution
- Started: 10/90
- Trial period: 2000-02
- Completion: 2003

ftp://ftp.cle.ab.com/stds/iec/sc65bwg7tf3/html/news.htm

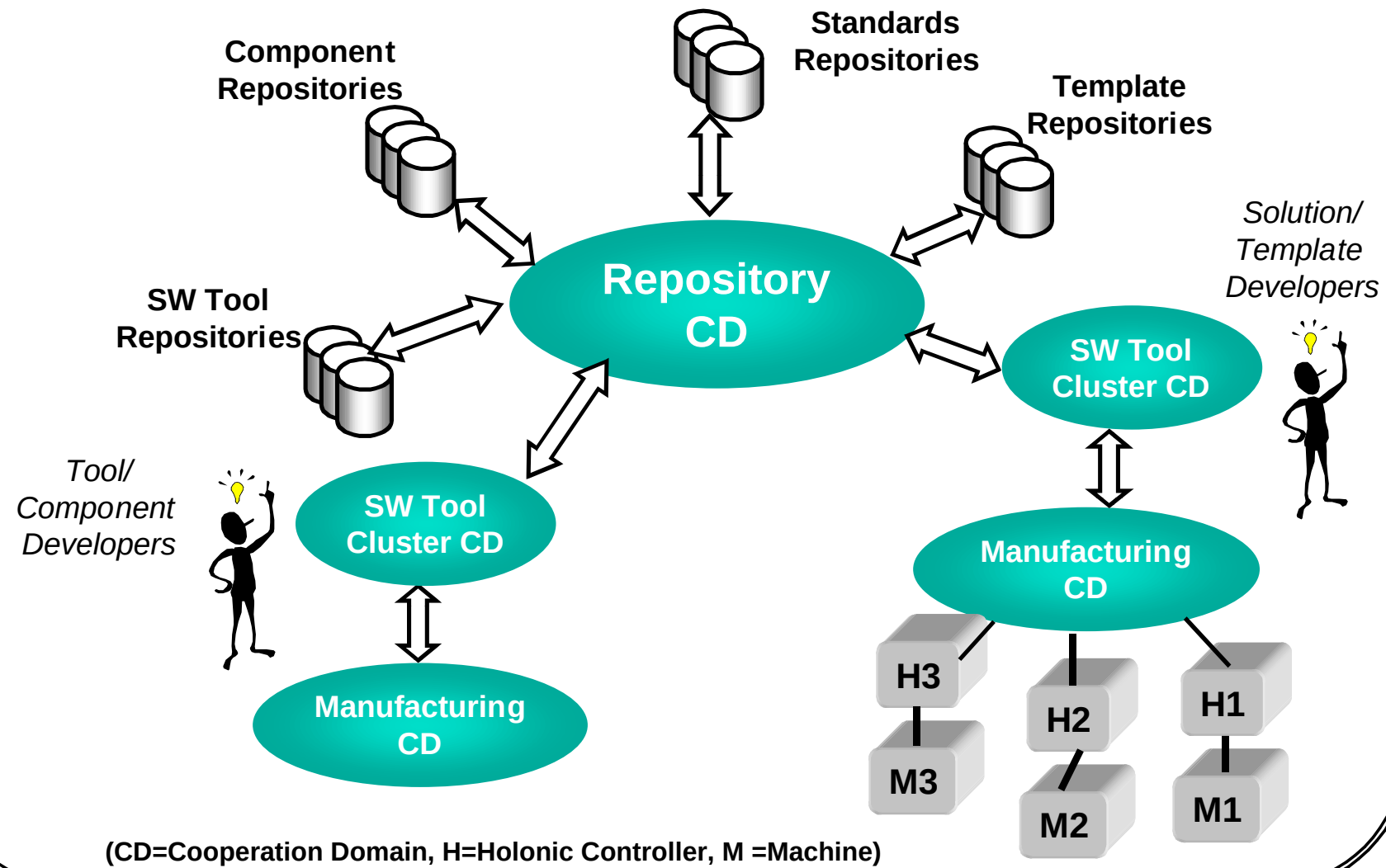
Holonic Manufacturing Systems (HMS)

- Parent organization: IMS
- Working group: HMS Consortium
- Goal: Intelligent manufacturing through holonic (autonomous, cooperative) modules
- Feasibility study: 3/93-6/94
- First phase: 2/96 - 6/00
- Second phase: 6/00-6/03

http://hms.ifw.uni-hannover.de/

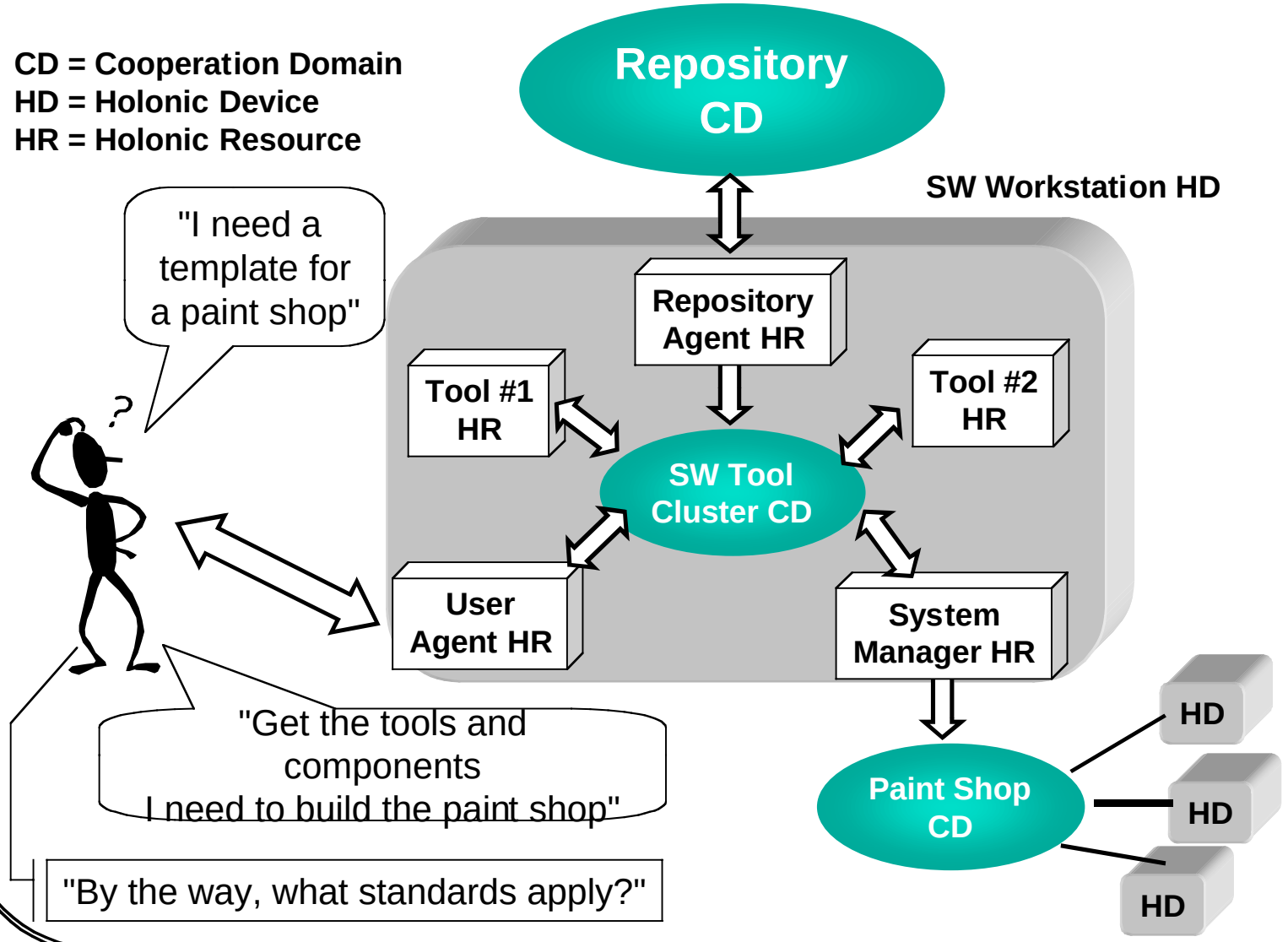


An Infrastructure for HMS Engineering



(CD=Cooperation Domain, H=Holonic Controller, M =Machine)

An HMS Engineering Workstation



The Holon: An Autonomous, Cooperative (sometimes Physical) Agent