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Bundesministerium
für Wirtschaft
und Technologie

FESTO

Scientific work of Dipl.-Ing. Christian Gerber

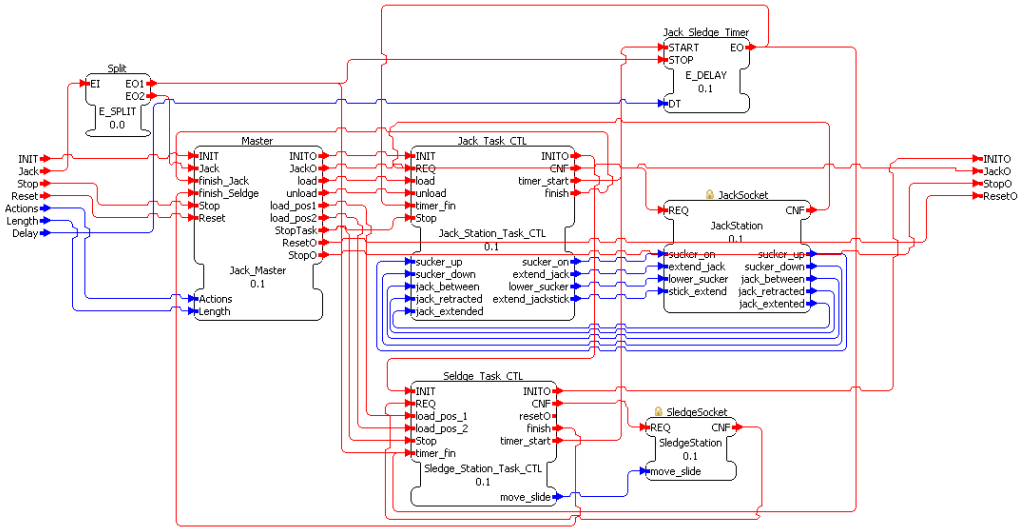
# Implementation of control systems and future trends at the Martin-Luther-University using 4DIAC

# Implementation of Distributed Control Systems

- Using several testbeds
  - Festo Manufacturing System
  - EnAS-Demonstrator
  - Simulation of a Servo-Control-System

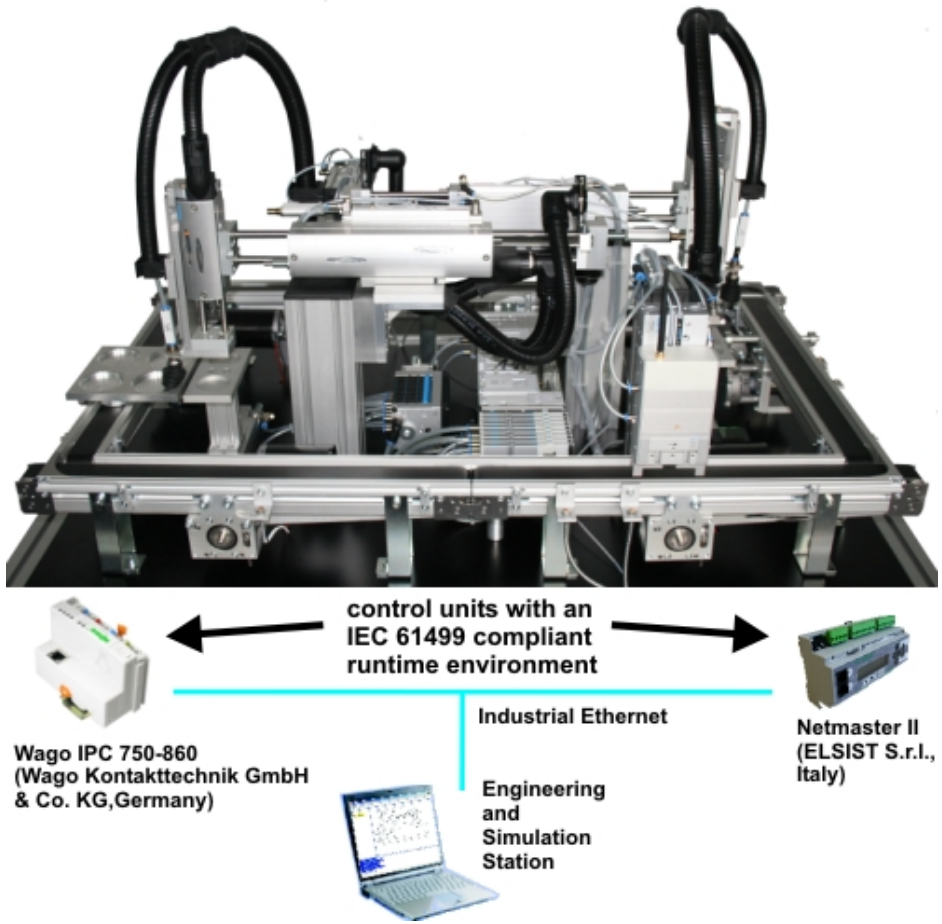
- Using different Engineering Environments and Hardware
  - Function Block Development Kid (FBDK)
  - Framework for Distributed Industrial Automation and Control (4DIAC)
  - FBench
  - Corfu ESS
  - ISAGraph

- Usability test of several control implementation approaches
  - Central-Controller
  - Master-Task-Controller
  - Parametrised Master-Task-Cont
  - Workpiece-Controller



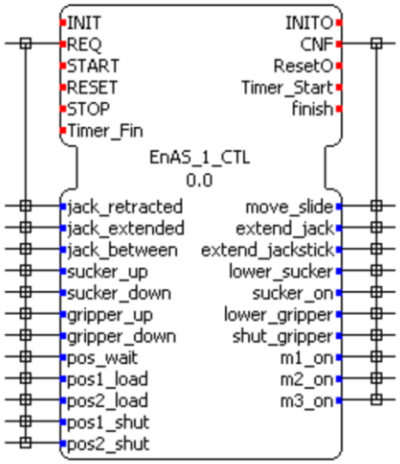
# Energy autarkic Actuator Sensor System Demonstrator

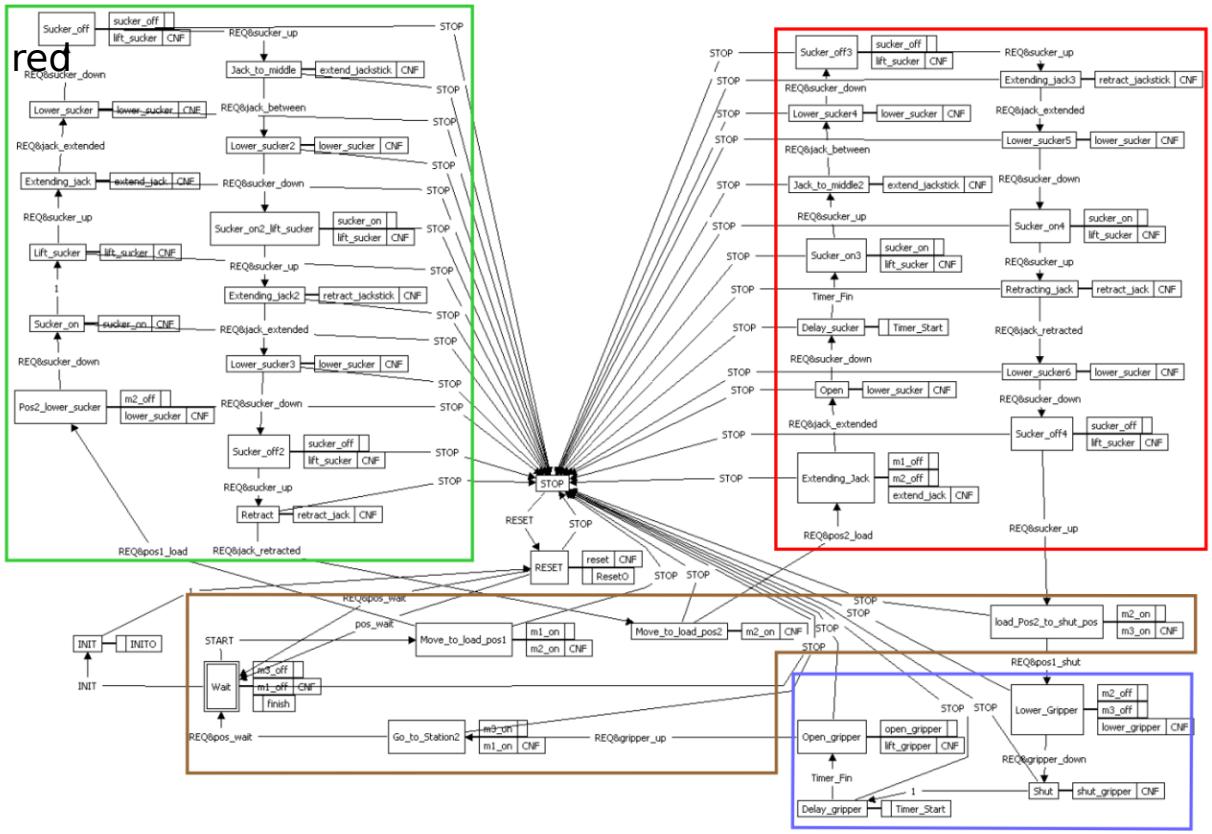
- testbed, equipped with a wireless actuator/sensor system (2007-09) ➔ new SIFB
- Base Station + Sensor-Actuator Modules
  - 2,4 GHz with frequency adaptation to the gaps of WLAN
  - 1st phase – initialisation, get all Sensor-Actuator Modules
  - 2nd phase – real time wireless communication – time sliced
- Control and Base Station exchange messages as follow: 76 00 03 52 FF 00 FF 00 FF 00
  - 1. Byte - Identifier the following data is an array (76)
  - 2. & 3. Byte - Length of the array (data values)
  - 4. Byte - datatype of the contained values (52)
  - 5. & 6. Byte - Low and HighByte SAM0 (FF 00)
  - 7. & 8. Byte - Low and HighByte SAM1 (FF 00)
  - 9. & 10. Byte - Low and HighByte SAM2 (FF 00)



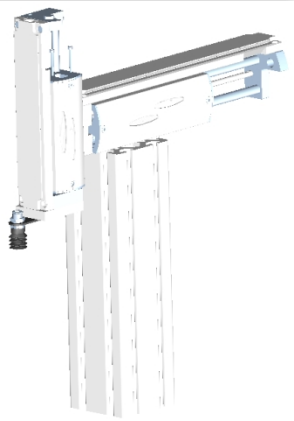
# Central-Controller Approach

- Central-Controller of the left plant part
  - No reconfiguration possibility or reusability (one monolithic FB)
  - Load Workpiece into tin– green
  - Unload Workpiece from tin – red
  - Close a tin - blue
  - Move conveyor - brown

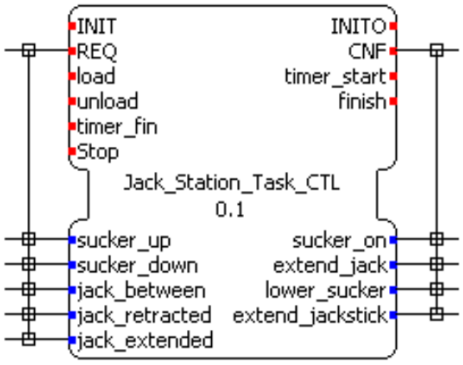


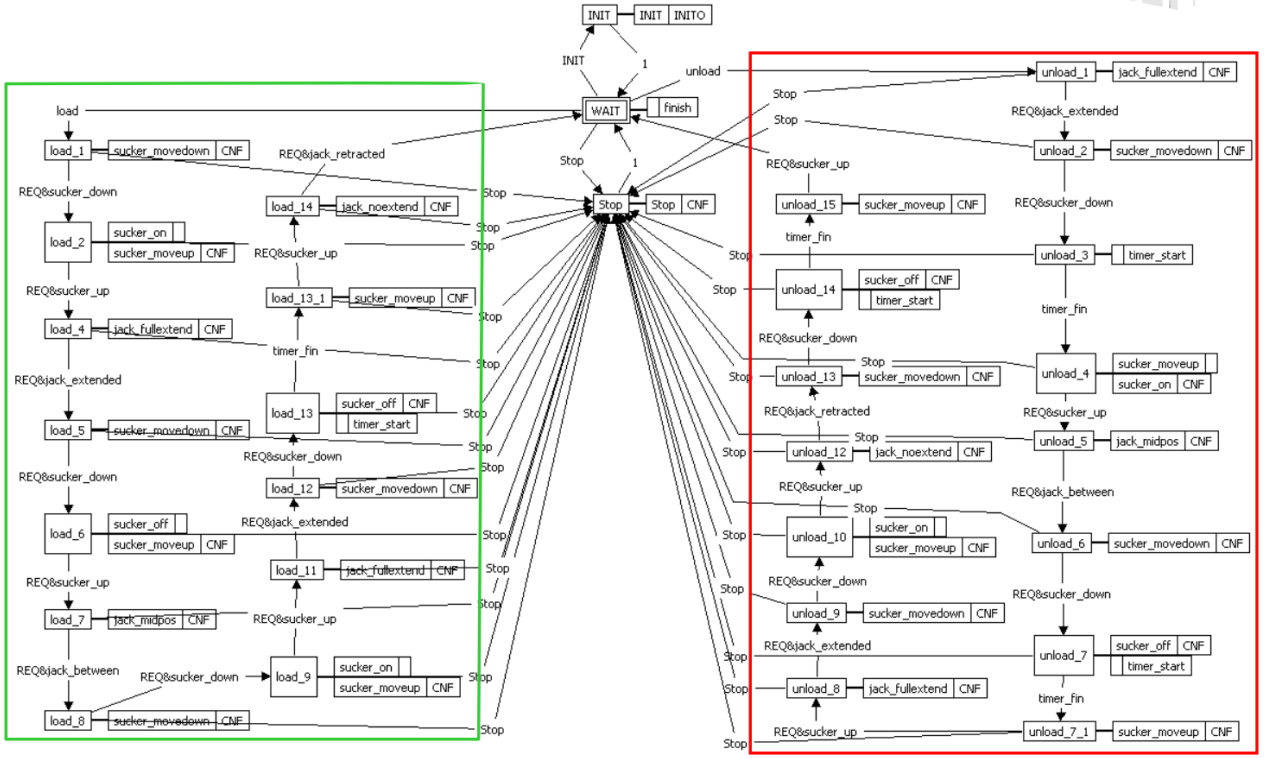



# Parameterized Master-Task-Controller



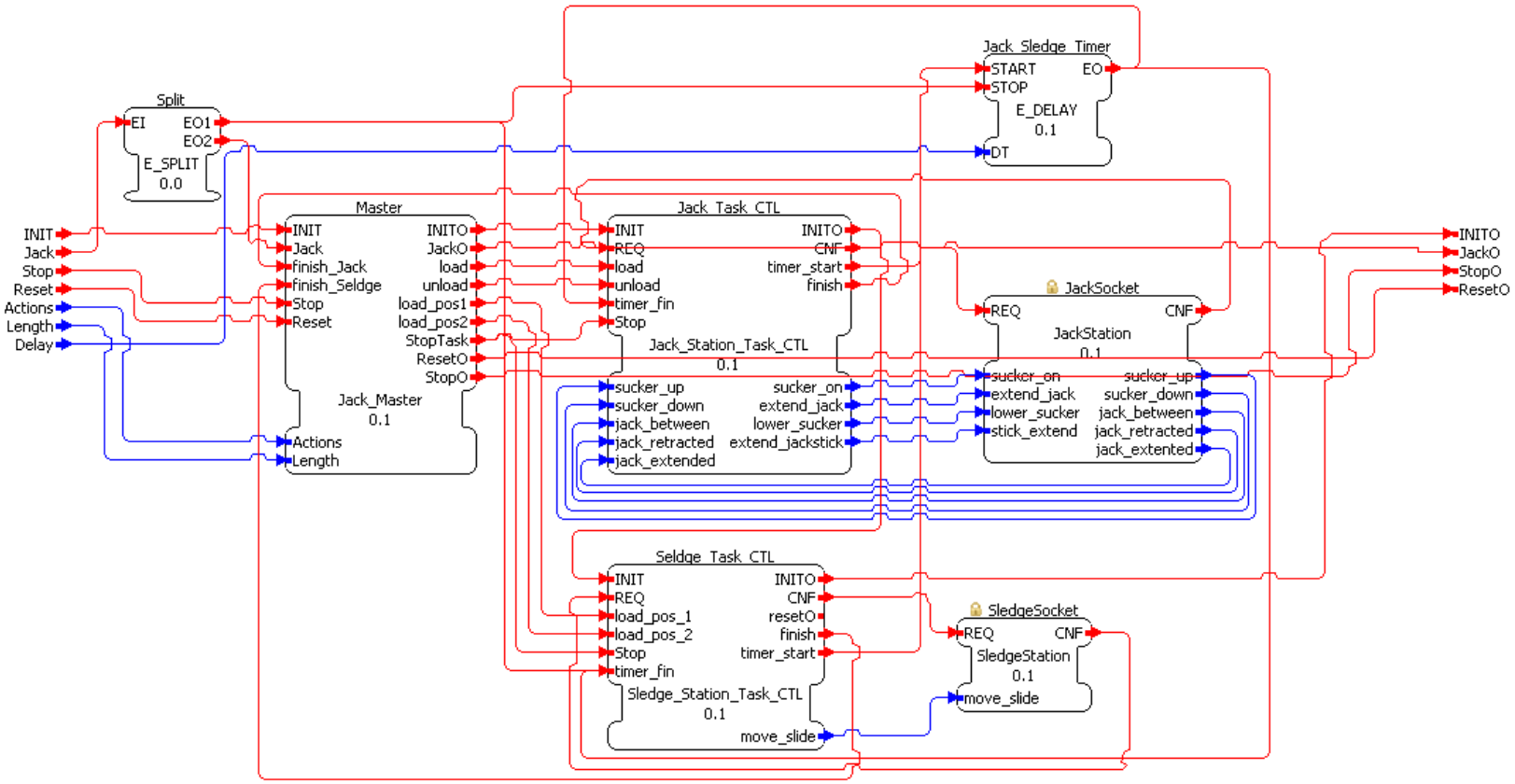
- Task-Controller of the Jack Station
  - Reuseable, if the component is used again
  - Load Workpiece into tin – green
  - Unload Workpiece from tin – red



# Parameterized Master-Task-Controller

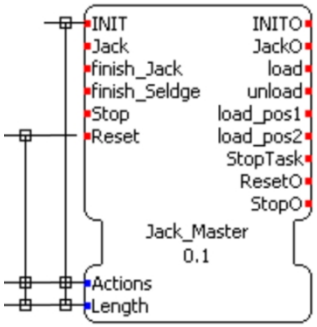
- Function Block Network of the Master and Task-Controller controlling the Jack-Station
  - Using Adapter Interfaces as Sockets

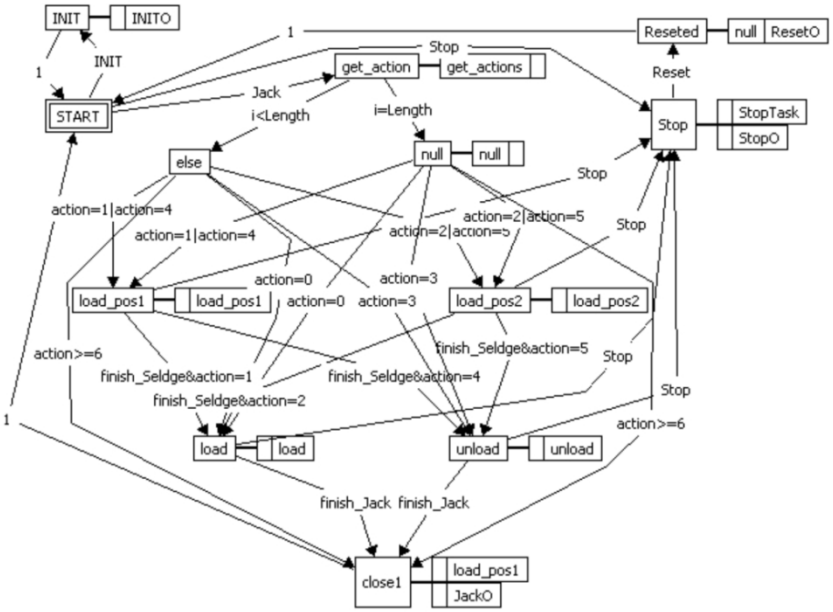


# Parameterized Master-Task-Controller

- Master-Controller
  - Reconfiguration by implementing all production possibilities and parameterize the production scenario
  - Actions – Array (sequence) of actions to perform
  - Length – amount of sequenced actions

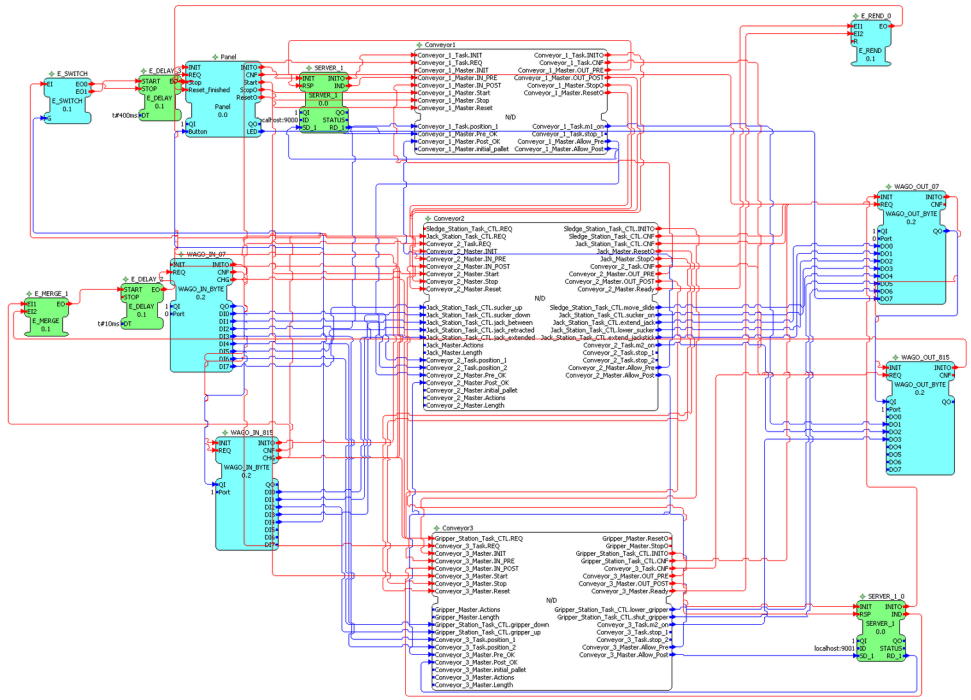
| action | decrciption |
|---|---|
| 0 - load | load a workpiece into the tin |
| 1 - load_pos1 | load a workpiece into the tin from the first sledge position |
| 2 - load_pos2 | load a workpiece into the tin from the second sledge position |
| 3 - unload | unload a workpiece from the tin |
| 4 - unload_pos1 | unload a workpiece from the tin to the first sledge position |
| 5 - unload_pos2 | unload a workpiece from the tin to the second sledge position |



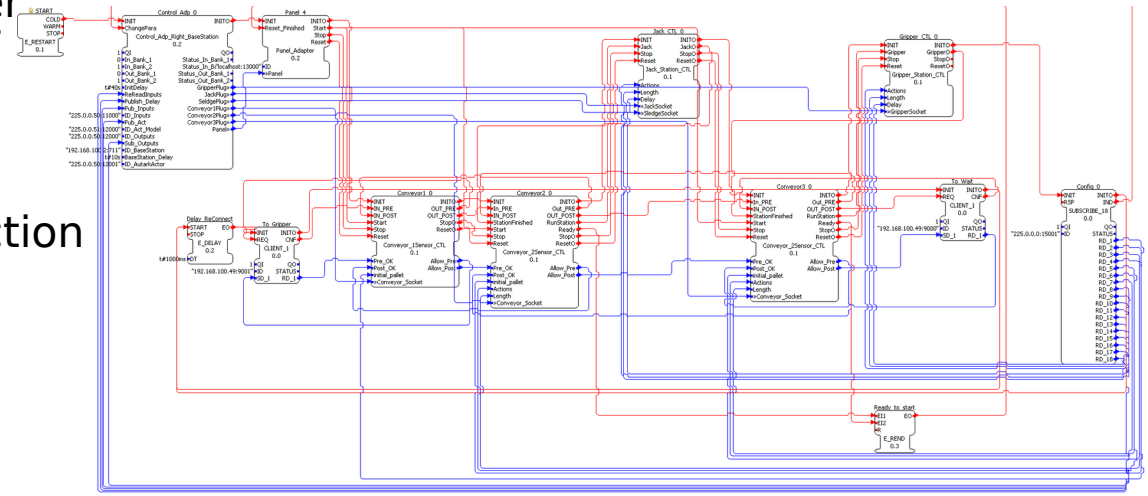
# Parameterized Master-Task-Controller - Resource Mapping

- Without Adapter Interfaces
  - Reconfiguration is missing due to a better visualisation of the FBN
  - Subapplication encapsulates the Master and Task-Controller
  - SIFB to the right and left
  - Everytime a FB is changed, update data connections



- With Adapter Interfaces
  - Each FB provides an adapter corresponding to the one of the I/O-Adapter FB (Process Interface)

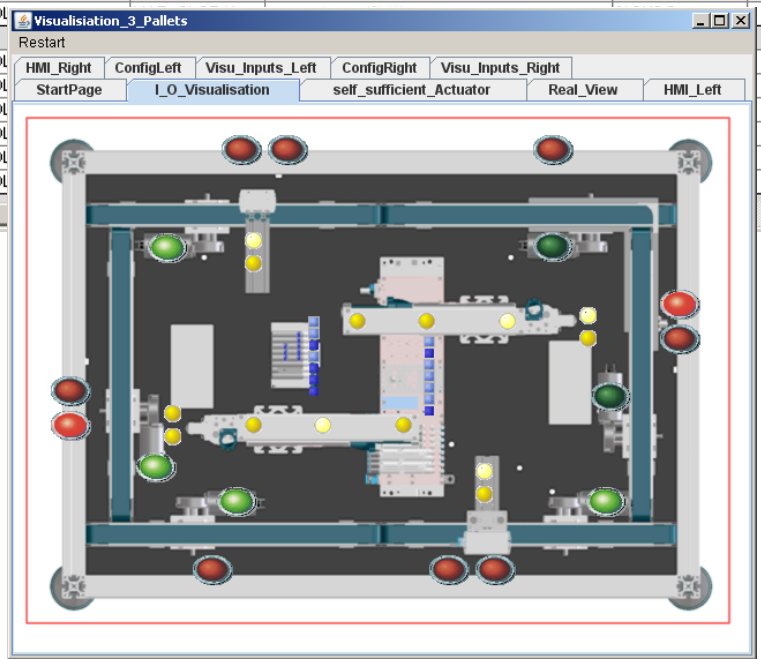
    ➔ only one Adapter Connection if a FB is changed



# Automatic Generation of the I/O-Adapter

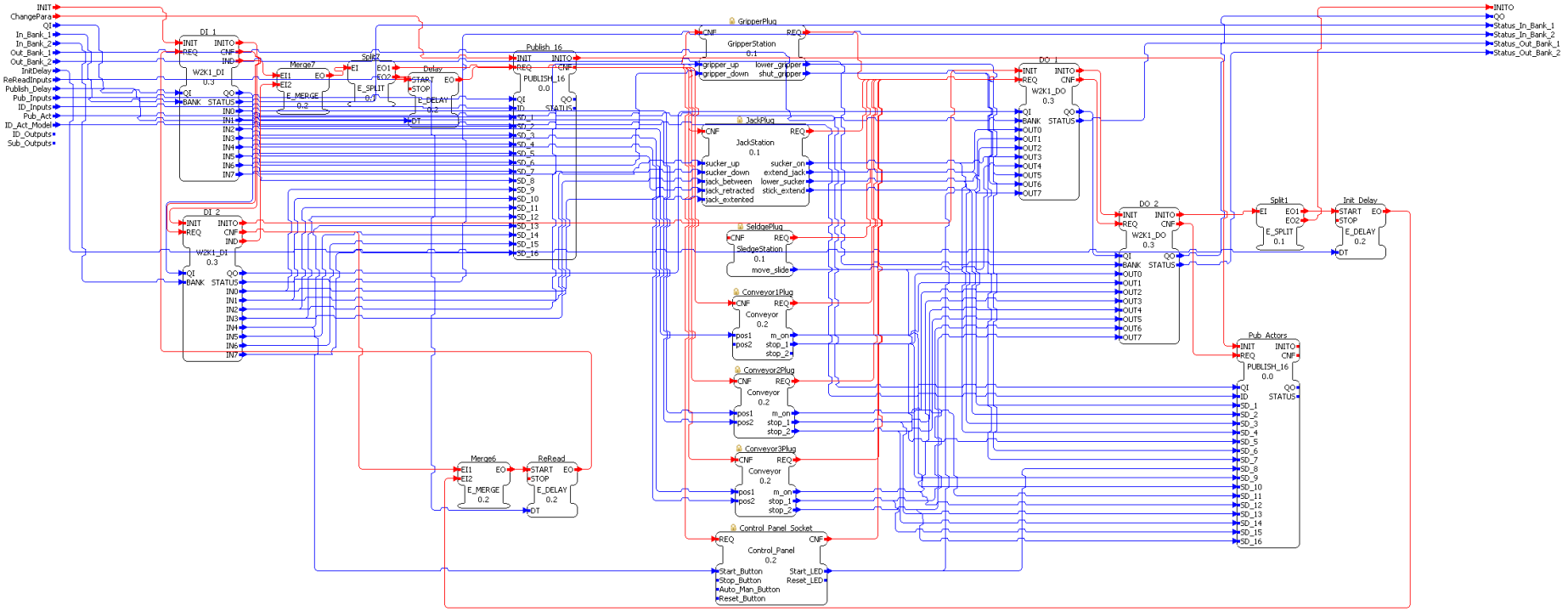
- Eclipse-PlugIn for 4DIAC
- Apdapter inserted from th pallet as new group (grey headline)
  - Inputs and Outputs
  - Comment
  - DataType
- General
  - Define used SIFB
  - PubInputs
  - PubOutputs
  - Time to ReRead the inputs
- Define Adress

| Name | Typ | Verwendung | Beschreibung | Adresse | Anfangsw... |
|---|---|---|---|---|---|
| **General** | | | | | |
| I0 | W2K1_DI | VAR_GLOBAL | | | |
| I1 | W2K1_DI | VAR_GLOBAL | | | |
| Q0 | W2K1_DO | VAR_GLOBAL | | | |
| Q1 | W2K1_DO | VAR_GLOBAL | | | |
| PubInputs | BOOL | VAR_GLOBAL | | | true |
| PubOutput | BOOL | VAR_GLOBAL | | | true |
| ReRead | TIME | VAR_GLOBAL | | | t#5ms |
| **Colour_Detection** | | | | | |
| Workpiece_Not_Black | BOOL | VAR_GLOBAL | work piece not black (3B1) | %IX0.7 | |
| **Control_Panel_Socket** | | | | | |
| StartButton | BOOL | VAR_GLOBAL | start button (S1) | %IX1.0 | |
| StopButton | BOOL | VAR_GLOBAL | stop button (S2) | %IX1.1 | |
| Auto_Man_Button | BOOL | VAR_GLOBAL | auto/manual switch (S3) | %IX1.2 | |
| Reset_Button | BOOL | VAR_GLOBAL | reset button (S4) | %IX1.3 | |
| Start_LED | BOOL | VAR_GLOBAL | start LED (P1) | %QX1.0 | |
| Reset_LED | BOOL | VAR_GLOBAL | reset LED (P4) | %QX1.3 | |
| **Gripper_Socket** | | | | | |
| Pos_Down | BOOL | VAR_GLOBAL | position gripper down (2B1) | %IX0.4 | |
| Pos_Up | BOOL | VAR_GLOBAL | position gripper up (2B2) | %IX0.5 | |
| Workpiece_available | BOOL | VAR_GLOBAL | work piece available (Part_AV) | %IX0.6 | |
| Descend_Gripper | BOOL | VAR_GLOBAL | descent gripper (2Y1) | %QX0.2 | |
| Open_Gripper | BOOL | | | | |
| **Rail_Socket** | | | | | |
| Pos_Previous_Station | BOOL | | | | |
| Pos_Colour_Detection | BOOL | | | | |
| Pos_left_Slide | BOOL | | | | |
| Pos_right_Slide | BOOL | | | | |
| Move_Left | BOOL | | | | |
| Move_Right | BOOL | | | | |



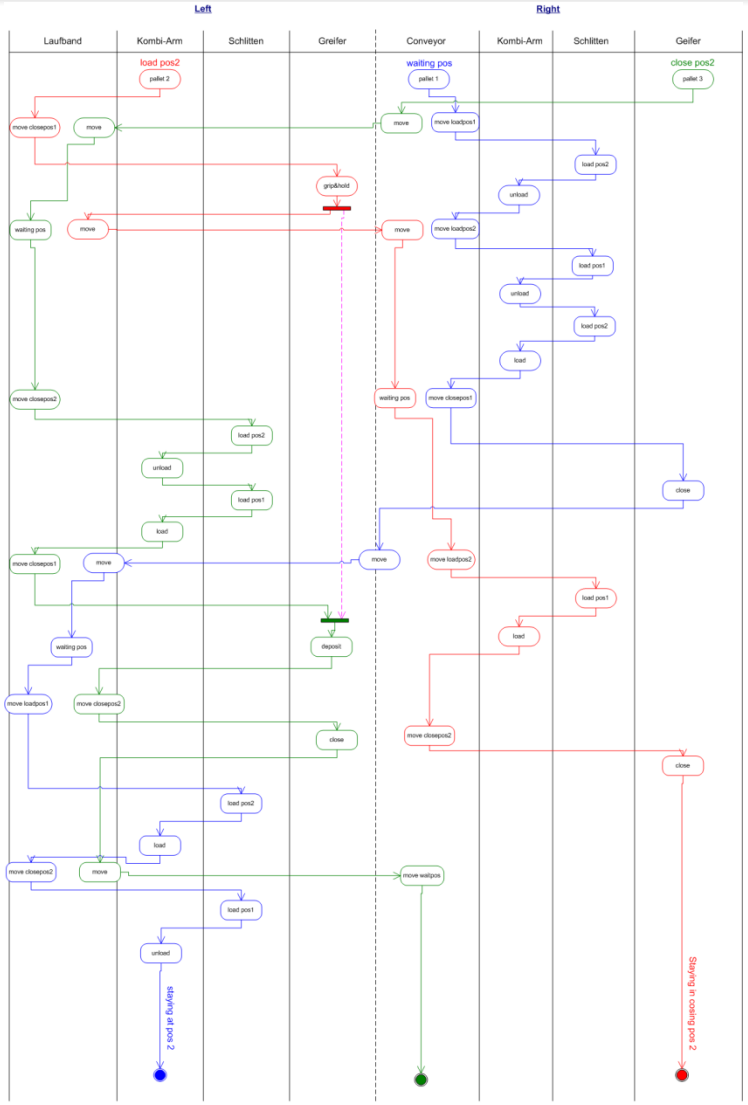
# Automatic Generation of the I/O-Adapter

- Generated I/O-Adapter
  - Textual representation eases maintenance (data connection results from adress)
  - Reconnection by providing a new adress
  - Export to LaTex ➔ PDF generation for documentation



# Developing a Production Scenario

- SysML Activity Diagram
  - Partition for each control of a mechanical component
  - Pallet 1 – blue
  - Pallet 2- red
  - Pallet 3 – green
- Note the actions to be performed
- Array of Actions
  - From top to down
  - Translate to numbers according to the tables
- Parameterize new productoin scenario via HMI
- Complexity shifted from the development of the Master-Controller to the production scenario

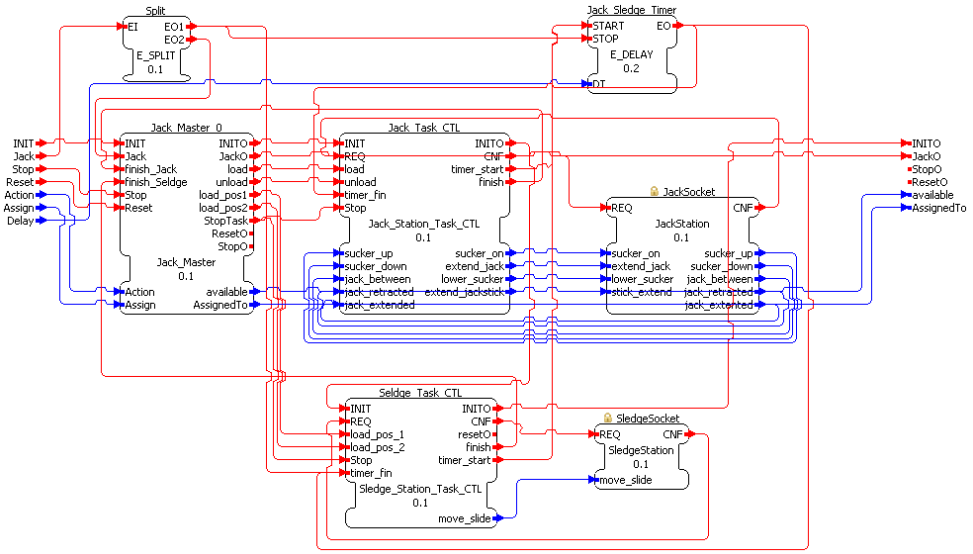


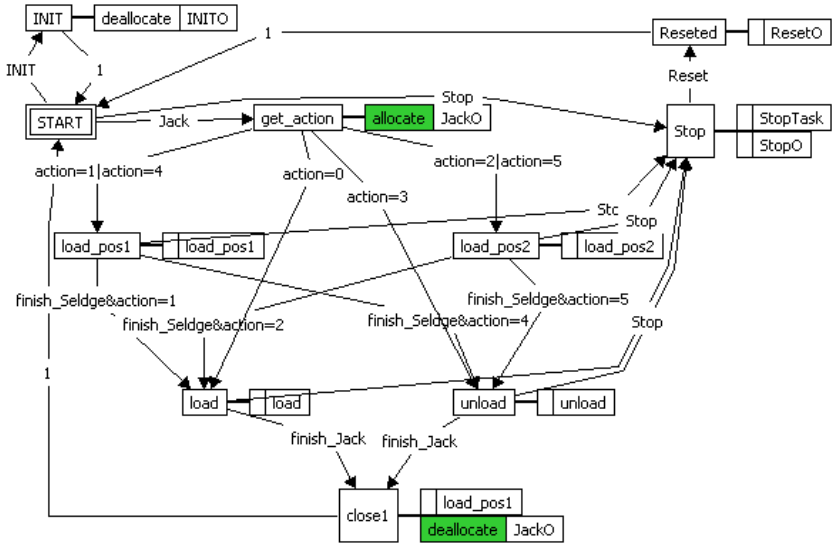

| Sledge-Station | Sledge left | Sledge right |
|---|---|---|
| loading pos 1 | Work piece | empty |
| loading pos 2 | empty | empty |

| Pallet | pallet 1 | pallet 2 | pallet 3 |
|---|---|---|---|
| position 1 | tin closed | tin closed | empty |
| position 2 | tin open | tin closed | tin closed |

# Future Work - Workpiece-Controller

- Improvement of the Parameterized Master-Task Controller approach with an additional coordination layer ➔ The Workpiece-Controller
- Workpiece Controller *allocates /deallocates* Master controller
- Master-Controller is a kind of event multiplexer (see ECC)




- Additional Inputs
  - Actions - [INT] → Action INT
  - Assign – INT
- Additional Outputs
  - Available – BOOL
  - AssignedTo – INT
- Additional Algorithms
  - Allocate

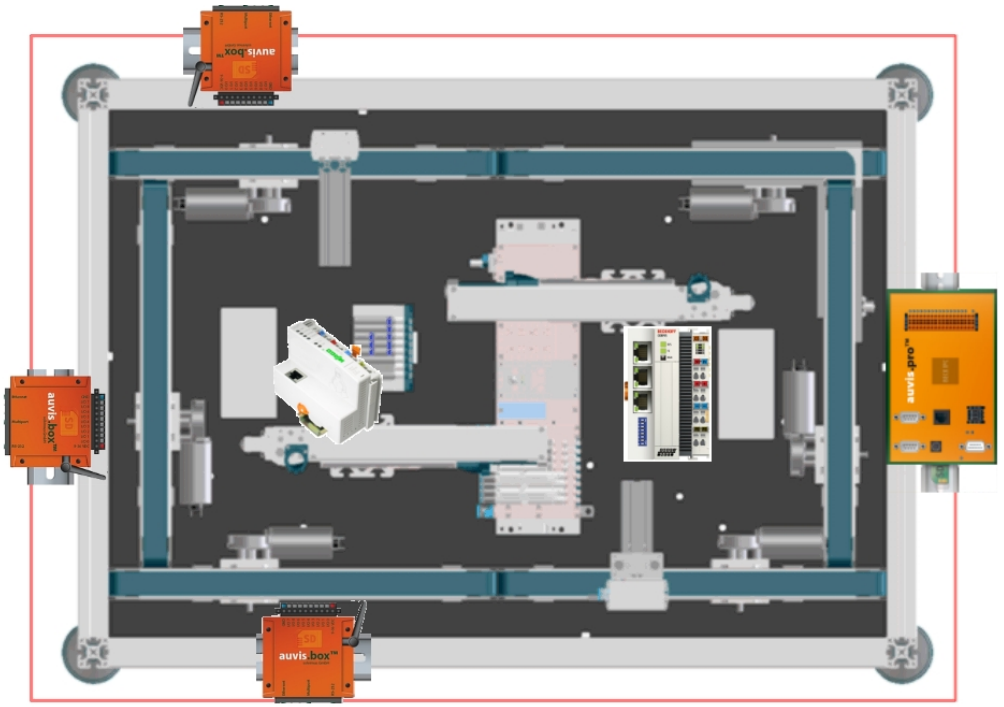
```
Available := False;
AssignedTo := Assign;
```

  - Deallocate

```
Available := True;
AssignedTo := 0;
```

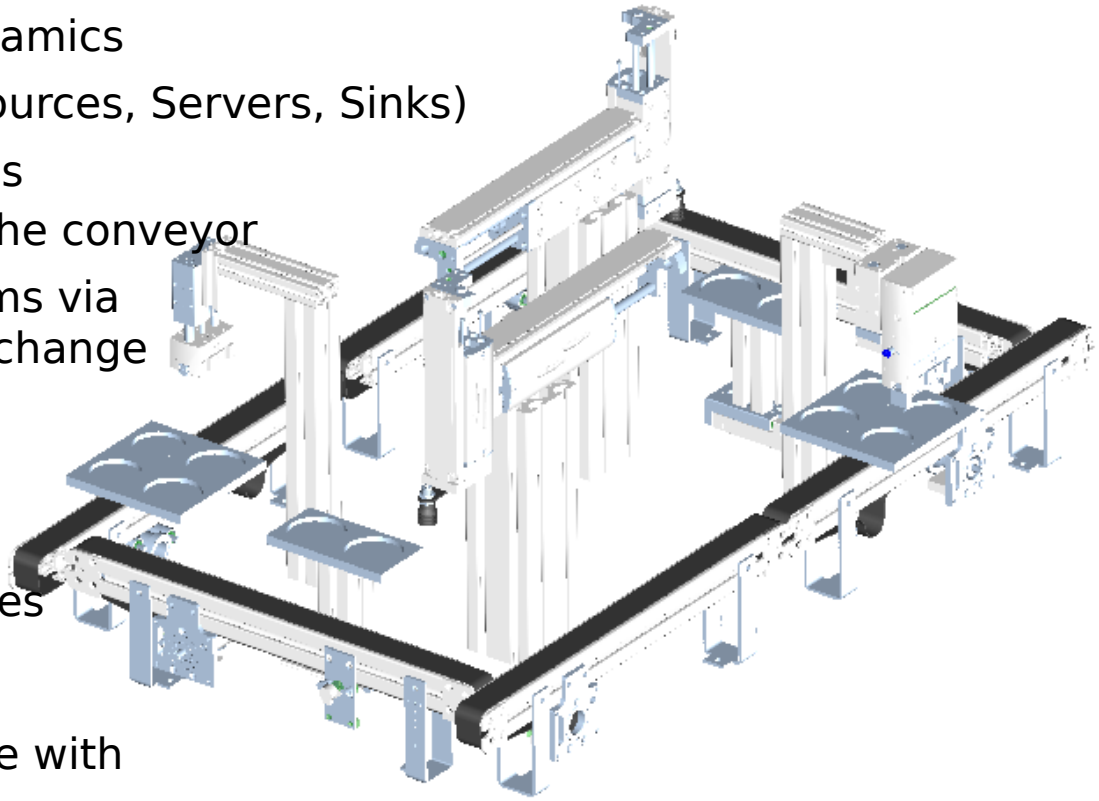
# Future Work - Workpiece-Controller

- Digi-Connect-Wi-Me
  - Workpiece-Controller at the pallet
  - Energy supply ?
- Beckhoff CX8000
  - Jack, Slide and Gripper Station through the wireless auctuator sensor system
- Wago IPC 750-860
  - Jack and Slide Station
- Auvis.pro
  - All 3 left conveyors
- Auvis.box
  - 1 conveyor each as well as the Gripper Station
- WebServer at all of them
  - Linked websites between all




# Future Work - Closed-Loop 3D Simulation

- Export CAD – Data of non-moving and moving parts as 3D Models
  - 3ds files– AutoCAD, Autodesk
  - VRML files – Solid Edge, Solid Works
- Simulation Tool - Enterprise Dynamics
  - Modelling of process flows (Sources, Servers, Sinks)
  - Based on atoms and subatoms
    - e.g. Pallet is a subatom of the conveyor
  - Communication between atoms via channels (listen to events, exchange subatoms)
  - 2D and 3D models



  - Extendable by external libraries
    e.g. communication
    via Profibus to a Siemens PLC
    ➔ new library to communicate with a distributed control system
  - e.g. TCP-Socket encoding and decoding messages according to the compliance profile

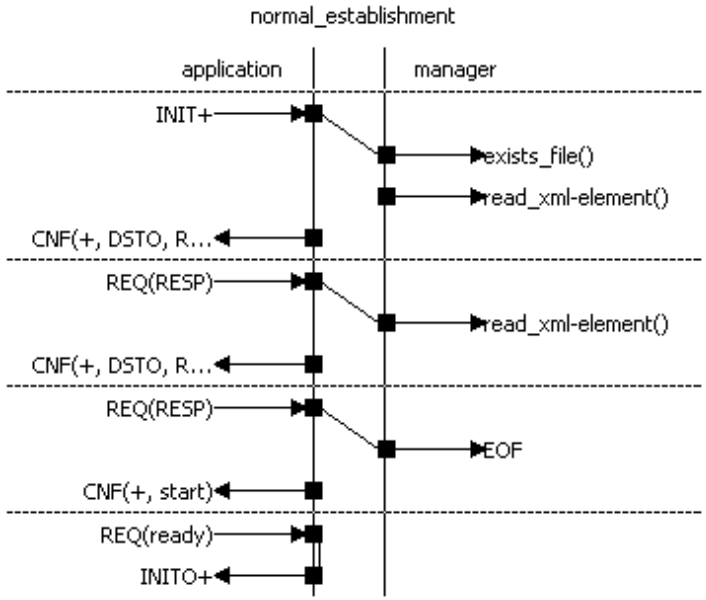
# Future Work - Instant Start-Up after Power Down

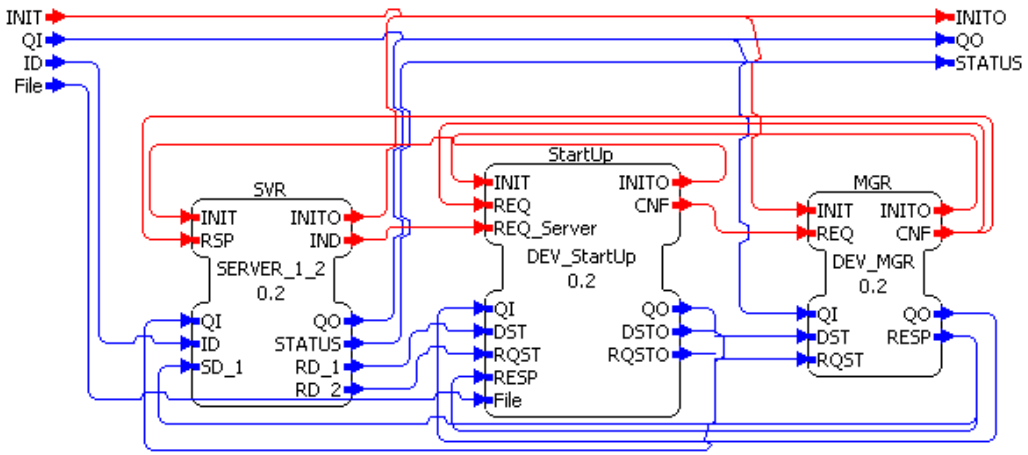
- Extension of the management resource with the FB StartUp of the type DEV_StartUp
- Initialized after the MGR FB

- Checks if the File exists
  - If true - while EOF
    1. read xml-element
    2. encode it to a destination and request
    3. wait for response
    4. Check response
- publish INITO+ ➔ initialize the SVR

- REQ_Server(DST, RQST)
  1. Store DST and RQST at the File
  2. CNF(DSTO, RQSTO)

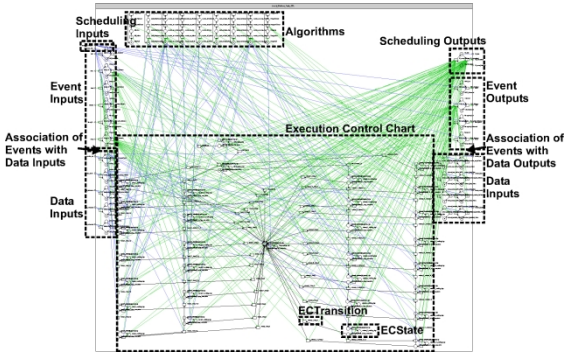
- Device still has the management interface as well as a Start-Up configuration up to the last change



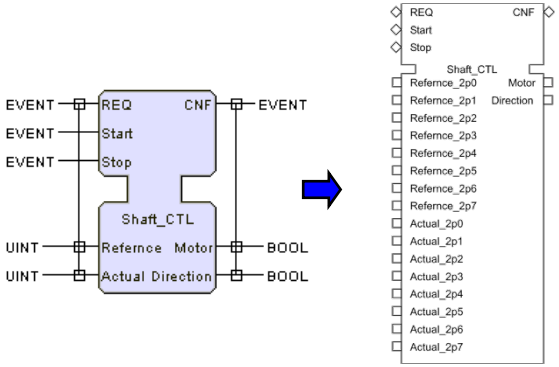



# Formal Controller Modelling

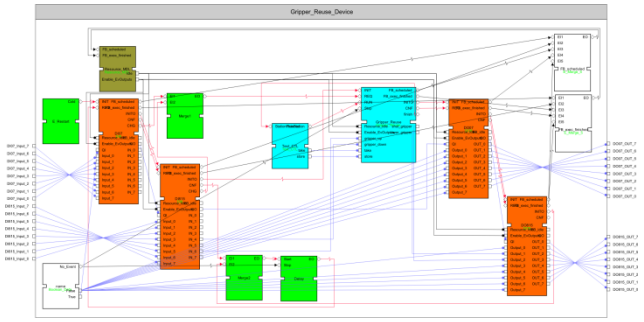
- Definition of several rules to transform
  - simple and basic FBs
  - Function networks and composite FBs as well as application




- Modelling of Process and Communication Interface (SIFB)
  - Service primitives (ISO-IEC 10731)



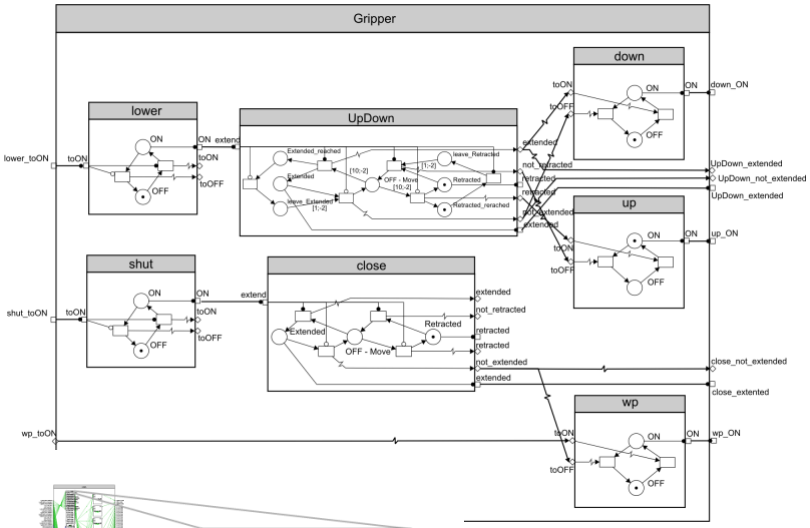

- Modelling of resources
  - Include the different schedulings of FBs (Scheduling Function)

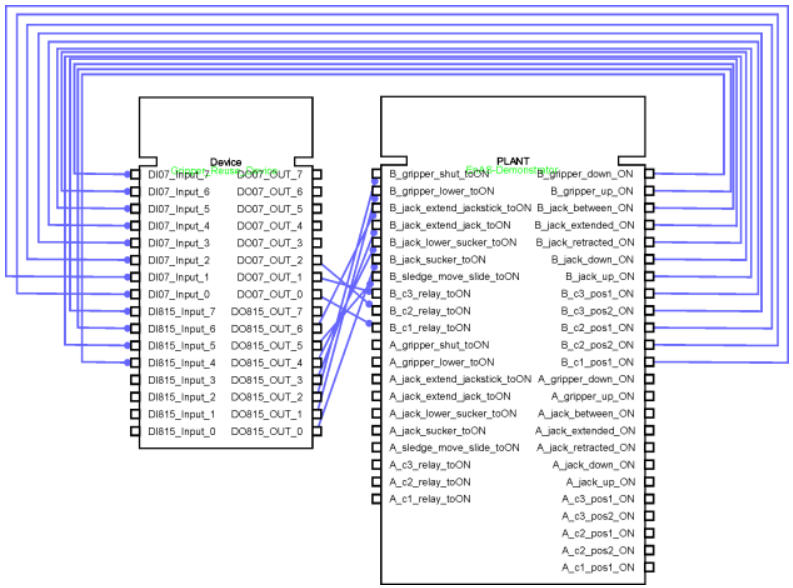


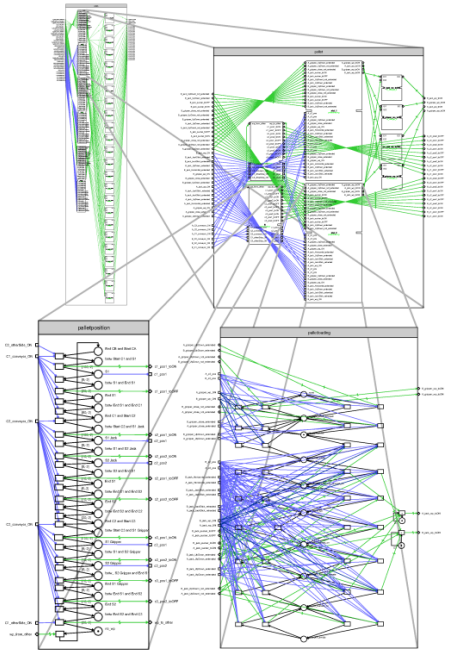
- Modelling of devices

# Formal Plant and Closed-Loop Modelling

- Modelling of the mechanical components
- Modelling of the workpiece behaviour
- Establishing the Closed-Loop

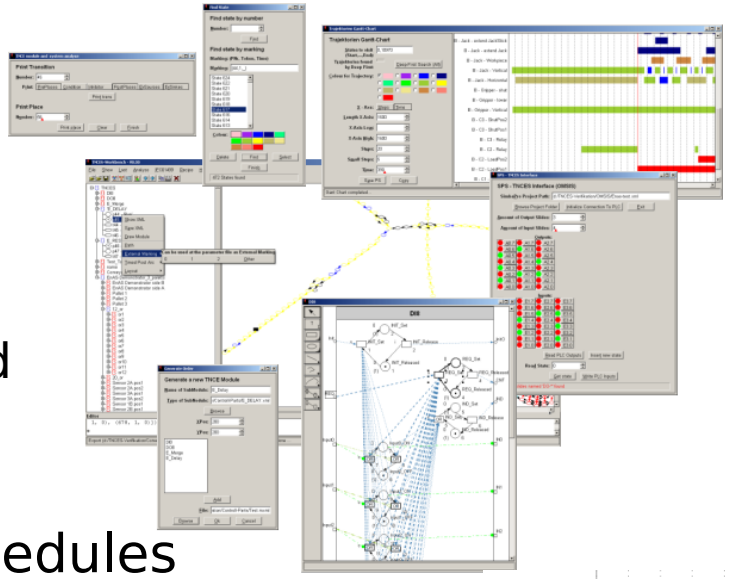


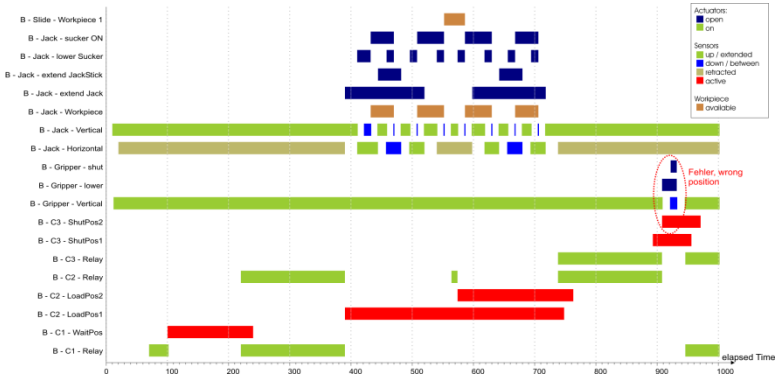



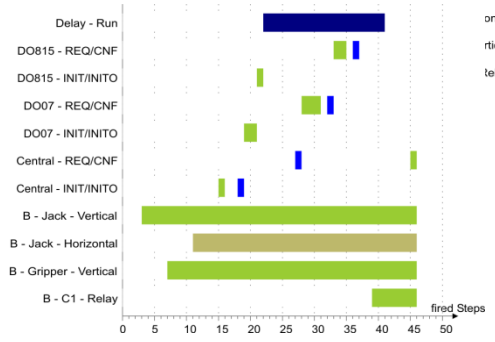



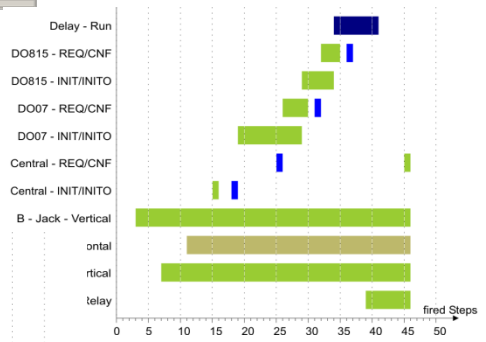
# Verification of the Closed-Loop System

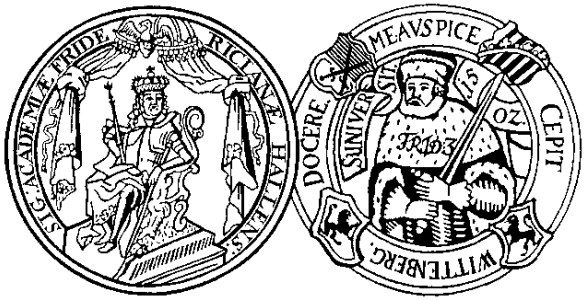
- SWI-Prolog based TNCES-Workbench
  - Model-Checker
  - FB Transformator
  - Search for trajectories and Gantt-Chart Visualisation
  - ...
- Analysis of different FB schedules
- Analysis of counter examples and modifying the control







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  - German Ministry for Commerce and Industry (BMWI)
  - Deutsche Forschungsgemeinschaft (DFG)
  - Festo AG & Co. KG)

# Thanks for your attention!

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30.08.2010

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