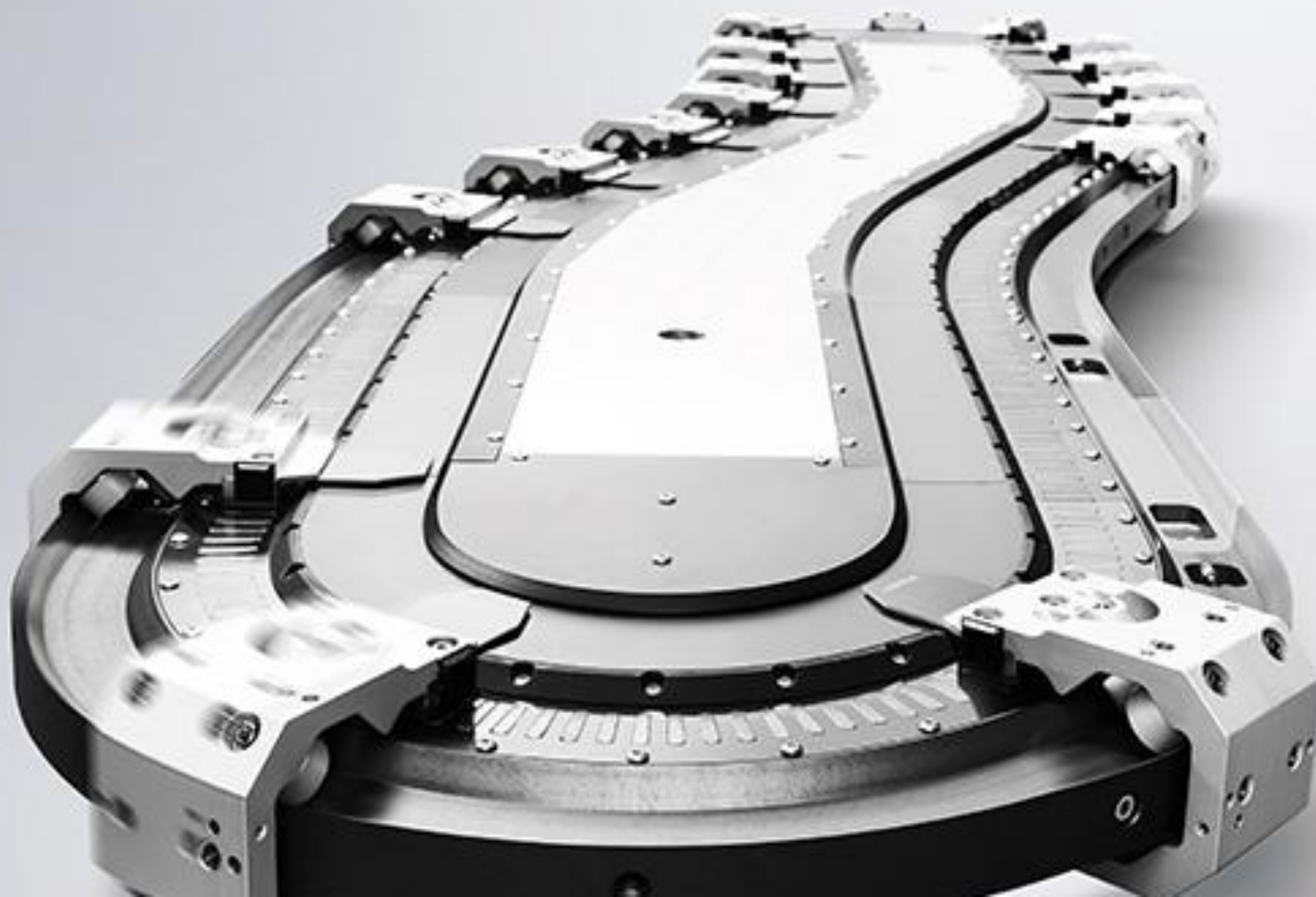


## **XTS TRANSPORT LAYER – a station-based approach**

**BECKHOFF**



1. Introduction
2. Requirements
  - XtsTransport (main control)
  - Xpu (XTS Processing Unit)
  - CaGroup (Collision Avoidance)
  - Mover (MC and CA)
  - Station (process handshake)
3. Design
  - use with any cyclic runtime
  - use with non-cyclic software
4. Examples
5. License

## 1. Introduction

- This project collection is intended to convey the idea of a stand alone XTS transport layer to use in heterogeneous environments / applications.
- One main idea is that for every process you require, a corresponding position on the XTS exists.
  - The station
- Another fundamental principle is that before anybody does anything, they must know what to do and that everybody involved in transport gets a list with atomic RW access.
  - The **sending** of movers runs parallel to **sending** information
    - This rids us from stations needing to talk to each other

## 1. Introduction

- A transport layer shall have a data driven way to manipulate a stations behaviour
- A transport layer shall work a combination of discrete processes and continuous processes
- A transport layer shall have an interface for guiding a mover through a process station
- A transport layer shall have an interface to manipulate a mover within a station
- A transport layer shall have an interface for setting-up or clearing the CollisionAvoidance Group
- A transport layer shall provide higher level layers for grouping of stations and coding of transport logic
- **This transport layer shall enable use of all, or some layers provided.**

## 1. Introduction

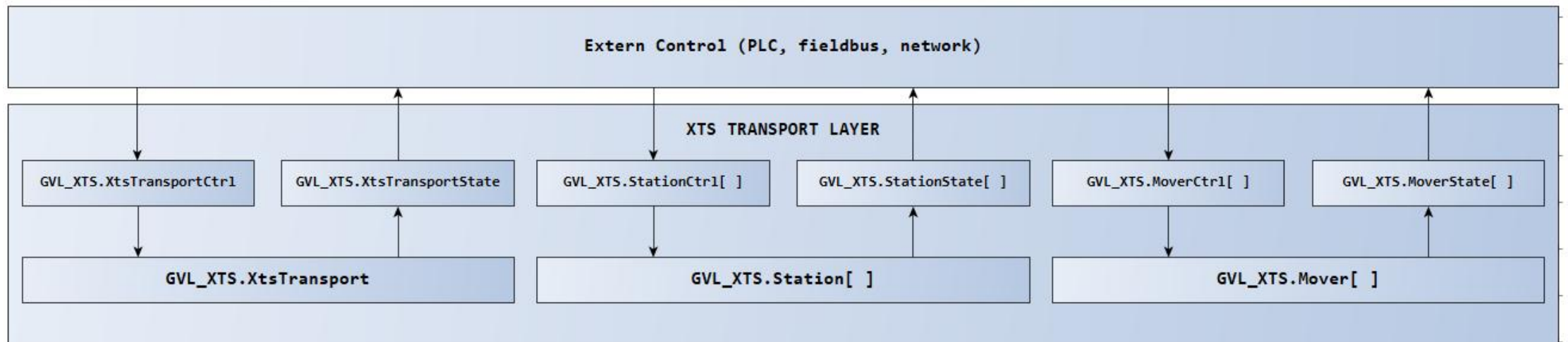
- In combination with the Collision Avoidance library, sending movers does not require extra monitoring of the movement. The Collision Avoidance Group (CA Group) is controlling the gap between movers. The gap is an input parameter of the CA motion function blocks.
- Can be used for a station-based approach, in which a station class is available for interaction with your process control.
- Can be used for a mover-based approach, your process control has a direct connection to every mover.
- Can be used as a combination of station based and mover-based approach.
- The use of predefined datafields enables control of XTS TRANSPORT LAYER via fieldbus or network.

## 1. Introduction

- The XTS transport system enables a flexible product transport for various use cases.
- This transport layer deliberately tackles a specific subset of the flexibility of the XTS system.
- This subset is working on:
  - One closed loop
  - One Track
  - Constant Mover count
- As all movers are bound to the same rail:
  - No passing at all times
  - A station table seems like a good choice
- This transport layer will focus on enabling high throughput and high flexibility process flow
  - Layered approach to offer you granular BlackBox building.

## 1. Introduction

- designed for use with any cyclic or non-cyclic flow control (PLC, EtherCAT, **any** network)
  - Ctrl / State datafields for extern to access
- station based approach and individual manipulation of mover
- handshake in station with extern process flow (ST\_STATION\_CTRL / ST\_STATION\_STATE)
- individual cyclic mover interface with given set of movement functionalities (ST\_MOVER\_CTRL / ST\_MOVER\_STATE)



- TransportUnit
  - Access to CA group function blocks (interface pointer)
  - Access to Stations (interface pointer)
  - Access to Movers (interface pointer)
  - Commands for getting all members to defined state
  - Cyclic interface for access from extern control
    - Ctrl (write): command
    - State (read): response to command
      - information from Xpu
      - Information from CA Group



- Xpu (XTS Processing Unit)
  - Check Init Parameter
  - Check Online Parameter
  - Get Module Info Data
  - Connect TcCOM Objects to instances from XTS\_Utility.lib function blocks
  - Provide interface pointers from XTS\_Utility.lib for advanced features
  - Cyclic plausibility checks
    - Mover ID detection after init
  - Cyclic interface for access from main control
    - Ctrl (write): command
    - State (read): response to command
    - Info (read): details from cyclic checks

- CaGroup
  - Access to group function blocks
    - Build Group
    - Clear Group
    - Reset Group
  - Access to movers for group commands
    - Mover interfaces must be available
  - Get Group Info Data
    - Cyclic check of GroupState
  - Must implement interface for use in
    - TransportUnit

- Mover
  - Access to MC function blocks
  - Access to CA function blocks
  - Cyclic interface for access from extern control
    - Ctrl (write): command
    - Data (write): command parameter
    - State (read): response to command
  - Implements Interface pointer for access from:
    - TransportUnit
    - Station
    - CaGroup

- Station
  - Handshake mover transport with extern control
  - Close observation of movements in station with feedback to extern control
  - Linked List for movers in queue for infeed into station
  - Access to Linked List of target station for outfeed of mover
  - Cyclic interface for access from extern control
    - Ctrl (write): command and parameter
    - State (read): response to command and information about mover and queue
  - requires interface pointer to Mover / CA functionblocks

### 3. Design

#### ■ Namespace GVL\_XTS

##### – Station

- Handshake with Process for mover transport

##### – XtsTransport

- Main command interface to extern control

##### – Xpu

- Access to TcCOM Objects
- Cyclic plausibility checks

##### – CaGroup

- Access to CA library

##### – Mover

- Access to MC and CA library

| <<global>><br>GVL_XTS |  |
|-----------------------|--|
| StationStart          | ST_STATION_PARAMETER   |
| StationStartIndex     | UINT   |
| Station               | ARRAY [1..MAX_STATION] OF fb_StationProcess                                  |
| StationGearIn         | ARRAY [1..MAX_STATION] OF fb_StationGearInPos                                |
| StationList           | ARRAY [1..MAX_STATION] OF fb_Station_LinkedListCtrl                          |
| StationQueue          | ARRAY [1..MAX_STATION] OF ARRAY [1..MAX_LIST_NODES] OF ST_STATION_MOVER_DATA |
| StationListItf        | ARRAY [1..MAX_STATION] OF I_Station_LinkedList                               |
| StationCtrlItf        | ARRAY [1..MAX_STATION] OF I_XtsTransport_Station                             |
| StationCtrl           | ARRAY [1..MAX_STATION] OF ST_STATION_CTRL                                    |
| StationState          | ARRAY [1..MAX_STATION] OF ST_STATION_STATE                                   |
| StationParameter      | ARRAY [1..MAX_STATION] OF ST_STATION_PARAMETER                               |
| PositionOffset        | ARRAY [1..MAX_STATION] OF T_NEST_OFFSET                                      |
| XtsTransport          | fb_TransportUnit   |
| XtsTransportCtrl      | ST_XTS_TRANSPORT_CTRL  |
| XtsTransportState     | ST_XTS_TRANSPORT_STATE   |
| Xpu                   | fb_XpuCtrl   |
| XpuCtrl               | ST_XPU_CTRL  |
| XpuState              | ST_XPU_STATE   |
| XpuInfo               | ST_XPU_INFO  |
| XpuModules            | ARRAY [1..MAX_MODULE] OF Tc3_XTS_Utility.ST_InfoDataView                     |
| CaGroup               | FB_CaGroup   |
| CaGroupItf            | I_XtsTransport_CaGroup   |
| CaGroupRef            | Tc3_McCoordinatedMotion.AXES_GROUP_REF                                       |
| CaGroupInfo           | ST_GROUP_INFO  |
| Mover                 | ARRAY [1..MAX_MOVER] OF fb_MoverCtrl   |
| MoverCtrl             | ARRAY [1..MAX_MOVER] OF ST_MOVER_CTRL  |
| MoverState            | ARRAY [1..MAX_MOVER] OF ST_MOVER_STATE                                       |
| MoverItf              | ARRAY [1..MAX_MOVER] OF I_XtsTransport_Mover                                 |
| LastPosition          | ARRAY [1..MAX_MOVER] OF LREAL  |
| LastGap               | ARRAY [1..MAX_MOVER] OF LREAL  |
| MoverInfo             | ARRAY [1..MAX_MOVER] OF ST_MOVER_INFO  |
| MoveData              | ARRAY [1..MAX_MOVER] OF ST_MOVE_DATA   |
| GearData              | ARRAY [1..MAX_MOVER] OF ST_GEAR_DATA   |
| AxisRefMover          | ARRAY [1..MAX_MOVER] OF Tc2_MC2.AXIS_REF                                     |

### ▪ Yes, ...but why?

- The ‚WHYs‘ for the station explains the rest of the design
  - I focus on stations first, since they are the center of attention when production runs
- The goal is to build maintainability into the transport layer  
(e.g. in case MC3 becomes available in the stable feed of the package manager)
- This transport layer is intended to be flexible in complexity and application
  - This is why you‘ll discover ABSTRACT classes
- Who‘s down with OOP? (... Yeah you know me!) **it makes XTS so much easier.**
  - Please try to overcome the reflex of it ‚being too much‘ for PLC programming
  - it is not 1993 anymore, OOP is around for over 12 years now (IEC 61131-3:2013)
  - It is the reason this collection of projects is so easy.

- Yes, ...but why?

| Fb / Class | Concern  | Solution  |
|------------|--|---|
| Station    | Manipulation of one mover  | <b>I_Transport_Mover[nMoverDetected]</b>  |
|            | Handshake process-flow with external entity                            | Ctrl / State pair   |
|            | Where does the mover come from?<br>Who cares, I'll just take the first | Use of Interface of LinkedList and struct datafields for tickets: <b>I_Station_LinkedList</b> |
|            | Access to ST_STATION_PARAMETER of all stations                         | Pointer/Reference to table of stations  |
|            | Who am I?  | MAIN injects loop counter:<br>GVL_XTS.Station[nStation]. <b>StationId</b> := nStation;        |
|            | Where am I?  | ST_STATION_PARAMETER[StationId]   |
|            | Where am I precisely?  | Pointer to static offset datafields[MAX_STATION, MAX_MOVER, MAX_NESTS]                        |

- Namespace XTS\_Parameter
  - Project constants must match configuration:
  - Copied from ParameterList in: Tc3\_XTS\_Utility.TcIoXtsEnvironmentParameterList

```
MAX_MOVER           : UINT := TO_UINT(Tc3_XTS_Utility.TcIoXtsEnvironmentParameterList.MaxXtsMoversPerXpu);
MAX_MODULE          : UINT := TO_UINT(Tc3_XTS_Utility.TcIoXtsEnvironmentParameterList.MaxModulesPerPart);
MAX_PART            : UINT := TO_UINT(Tc3_XTS_Utility.TcIoXtsEnvironmentParameterList.MaxXtsPartsPerXpu);
MAX_TRACK           : UINT := TO_UINT(Tc3_XTS_Utility.TcIoXtsEnvironmentParameterList.MaxXtsTracksPerXpu);
MAX_GROUP           : UINT := TO_UINT(Tc3_XTS_Utility.TcIoXtsEnvironmentParameterList.MaxXtsCaGroup);

MAX_INFO_SERVER     : UINT := TO_UINT(Tc3_XTS_Utility.TcIoXtsEnvironmentParameterList.MaxXtsInfoServer);
MAX_INFO_STATION    : UINT := TO_UINT(Tc3_XTS_Utility.TcIoXtsEnvironmentParameterList.MaxXtsInfoStation);
MAX_INFO_STOP_POS   : UINT := TO_UINT(Tc3_XTS_Utility.TcIoXtsEnvironmentParameterList.MaxXtsStopPositionsPerStation);

MAX_PARAMETER_SET   : UINT := TO_UINT(Tc3_XTS_Utility.TcIoXtsEnvironmentParameterList.MaxXtsParameterSet);

MAX_NCT_BASE_UNIT   : UINT := TO_UINT(Tc3_XTS_Utility.TcIoXtsEnvironmentParameterList.MaxXtsNctBaseUnitInterfaces);

MAX_STATION         : UINT := 2;

MAX_STATION_NEST    : UINT := TO_UINT(SIZEOF(ST_STATION_STATE.nMask)*8);

MAX_LIST_NODES      : UINT := MAX_MOVER;
MAX_MASTER          : UINT := 1;
```



- GVL\_XTS.Station
  - **fb\_StationBase**
    - Abstract base class
    - Allowing for user defined XtsStations
    - Provides datafields and properties
    - Cycle placeholder; override with your station logic when extending this base class

| <i>fb_StationBase</i>             |   |
|-----------------------------------|---|
| _nStationId                       | UINT  |
| _sState                           | STRING(255)   |
| _eInitList                        | E_PROGRESS  |
| _eFatalError                      | E_STATION_STATE   |
| _stCtrl                           | REFERENCE TO ARRAY [1..MAX_STATION] OF ST_STATION_CTRL      |
| _stState                          | REFERENCE TO ARRAY [1..MAX_STATION] OF ST_STATION_STATE     |
| _eCmd                             | E_STATION_CTRL  |
| _eCmdOld                          | E_STATION_CTRL  |
| _ItfStation                       | REFERENCE TO ARRAY [1..MAX_STATION] OF I_Station_LinkedList |
| _ItfMover                         | REFERENCE TO ARRAY [1..MAX_MOVER] OF I_XtsTransport_Mover   |
| _rMoverOffset                     | REFERENCE TO ARRAY [1..MAX_STATION] OF T_NEST_OFFSET        |
| _stParameter                      | REFERENCE TO ARRAY [1..MAX_STATION] OF ST_STATION_PARAMETER |
| _Mover                            | REFERENCE TO ARRAY [1..MAX_MOVER] OF AXIS_REF               |
| _stListEnter                      | ST_STATION_LIST_RESULT                                      |
| _stListTarget                     | ST_STATION_LIST_RESULT                                      |
| _stListDelete                     | ST_STATION_LIST_RESULT                                      |
| _stMoverDataSend                  | ST_STATION_MOVER_DATA                                       |
| _stMoverData                      | ST_STATION_MOVER_DATA                                       |
| _stInfeed                         | ST_MOVE_DATA  |
| _stOutfeed                        | ST_MOVE_DATA  |
| _Result                           | E_PROGRESS  |
| _eStateProgress                   | E_PROGRESS  |
| _stMsg                            | ST_Message  |
| _eMessageLevel                    | E_MessageType   |
| + Check()                         | BOOL  |
| + Cycle()                         |   |
| + DelBitWord(...)                 | WORD  |
| + GetBitWord(...)                 | BOOL  |
| + Init()                          | e_progress  |
| + SetBitWord(...)                 | WORD  |
| + Ctrl Set(...)                   |   |
| + ItfMover Set(...)               |   |
| + ItfStations Set(...)            |   |
| + MessageLevel Set(...)           |   |
| + Mover Set(...)                  |   |
| + MoverOffset Set(...)            |   |
| + State Set(...)                  |   |
| + StationId Set(StationId : UINT) |   |
| + StationId Get()                 | UINT  |
| + StationParameter Set(...)       |   |
| + TargetWindow Set(...)           |   |
| + TargetWindow Get()              | LREAL   |

- GVL\_XTS.Station

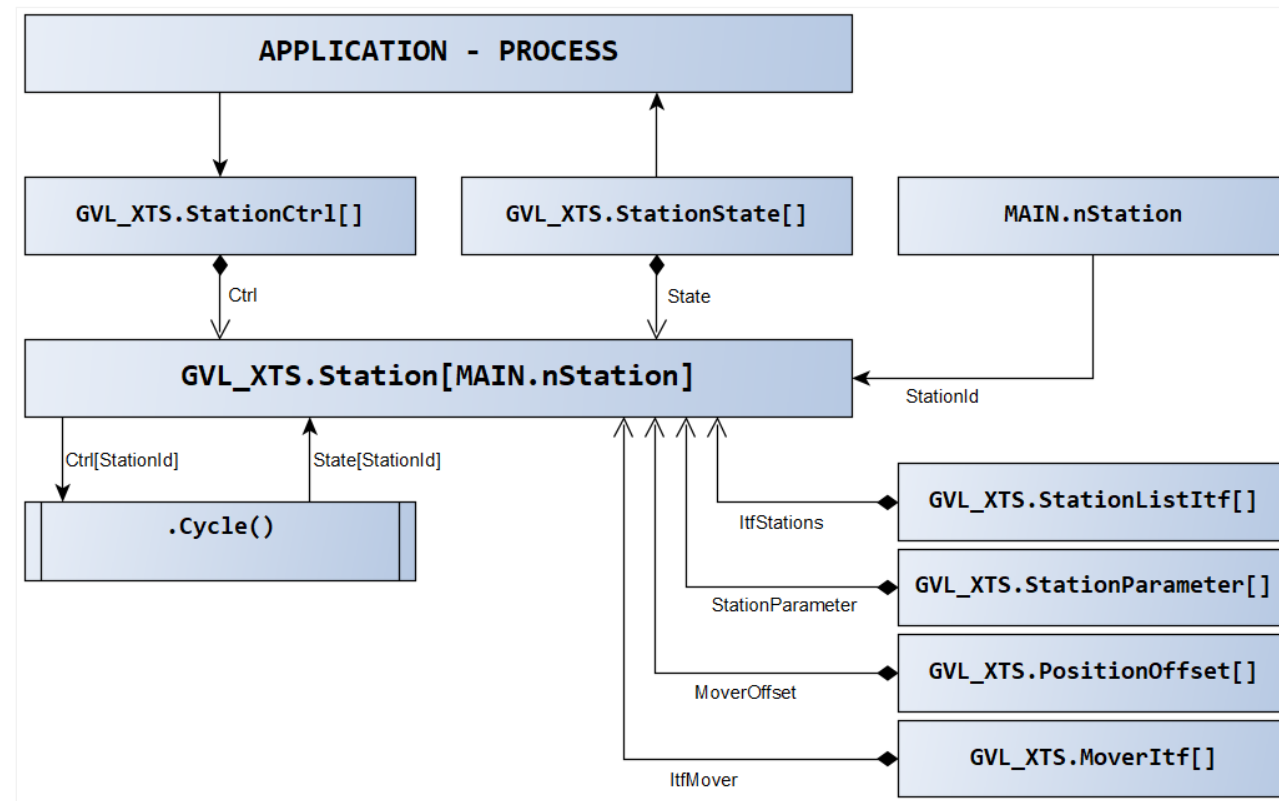
- fb\_StationProcess[].Cycle
  - State machine for handshaking with extern control (check example pdf in [doc] folder)
    - Init (clears everything in station)
    - Enable
    - Mover Enter
    - Stop Position(s)
    - Mover Out
    - Empty

- GVL\_XTS.Station

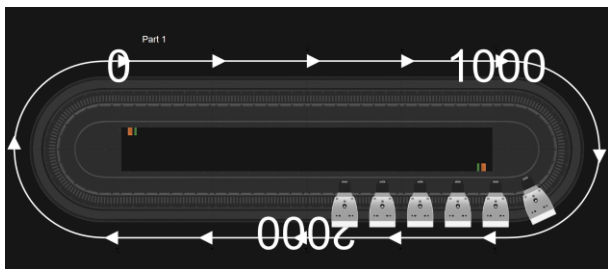
- fb\_StationProcess[].Cycle
  - Control writes ticket for mover
    - MoverId
    - TargetStation
    - Mask
    - Offset

### 3. Design

- GVL\_XTS.Station
  - nStation index is passed as value from caller
  - Global datafields are passed as references (REF=) into fb\_StationBase properties
    - **Ctrl / State:** handshakes
    - **ItfStations:** interface pointer to linked list methods for getting and setting of mover data
    - **StationParameter:** Coordinates and dynamic constraint of XtsStation
    - **MoverOffset:** correction values for every mover in every station with every nest (PosStop[])
    - **ItfMover:** interface pointer to CA movements



- **GVL\_XTS.Station**
  - **Planning requirements for use of fb\_StationProcess**
    - **One station: one mover**
      - If you require multiple movers for your process (e.g. this one's a slow one):
        - Work in parallel → multiplication of the same task:
          - → fb\_StationCollector and fb\_ProcessCollector will help grouping the stations to a single Ctrl/State interface.  
(see example **XTS\_DEMO\_APPLICATION\_108**)
    - **Station to Station: only forward**
      - We're on a closed loop (the defining part of the subset my focus lies on)



- **GVL\_XTS.Station**

- **Planning requirements for use of fb\_StationProcess**

- Put the Modulo turn anywhere, **BUT NOT** within PosWait, PosStop, ReleaseDistance of a station. The code does not support crossing the modulo turn within a station.
    - Since the project is designed for stations to **send** movers to a flexible target, with flexible nest positions, the control struct of a station you have to use, to forward those parameters. The MoverId is forwarded by the Station in possession of the mover.
      - **ST\_STATION\_CTRL.nMask:** commands the nest count and nest position of the mover in target station
      - **ST\_STATION\_CTRL.nTargetStation:** index of station in GVL\_XTS.StationParameter[]
      - **ST\_STATION\_CTRL.rOffset:** optional dynamic inline offset (added to every nest)

- **GVL\_XTS.Station**
  - Planning requirements for use of **fb\_StationProcess**
    - The Use of **LinkedList** methods (AddTail, GetHead) **requires thought** about **when** the mover is entered into the target station.
      - → why? → The targets' list must stay sorted → see examples on next pages
    - **fb\_StationProcess.Cycle()** is built in a way (see handshake flowcharts for this) that the movers' ticket is written via the list interface of the target station **after** having moved **rReleaseDistance** (a station parameter):
      - The movement:→

```
//-----  
//  
// ckeck if mover has left the station  
// enter mover data into list of target station  
//-----  
CASE _stState[_nStationId].eState  
OF  
E_STATION_STATE.STATION_MOVER_RELEASE:  
    _ItfMover[_stMoverData.nMoverId].MessageLevel := SEL(_bMatchMessageLevel, E_MessageType.eMessageError, _eMessageLevel);  
  
    _Result := _ItfMover[_stMoverDataSend.nMoverId].SendToModuloPosCa(TRUE, _stOutfeed);  
  
    IF (_Result = E_PROGRESS.PROGRESS_DONE)  
    THEN  
        // regular outfeed  
        _stState[_nStationId].eState := E_STATION_STATE.STATION_MOVER_WRITE_TARGET;  
  
    ELSIF (_stCtrl[_nStationId].eCmd = E_STATION_CTRL.STATION_MOVER_GONE) // in case outfeed has to be terminated by ctrl  
    THEN  
        // in order to finish the outfeed, ticket data has to be written to target station  
        _stState[_nStationId].eState := E_STATION_STATE.STATION_MOVER_WRITE_TARGET;  
  
    ELSIF (_Result = E_PROGRESS.PROGRESS_ERROR)  
    THEN  
        _stState[_nStationId].eState := E_STATION_STATE.STATION_ERROR_OUTFEED_ERROR; // ctrl has to fix this, go tell ctrl  
        _stMsg.eType := E_MessageType.eMessageError;  
        LogState(_stMsg.eType);  
    END_IF  
END_CASE
```

- **GVL\_XTS.Station**
  - Planning requirements for use of **fb\_StationProcess**
    - The Use of **LinkedList** methods (AddTail, GetHead)  
**requires thought** about **when** the mover is entered into the target station.
      - → why? → The targets' list must stay sorted → see examples on next pages
    - **fb\_StationProcess.Cycle()** is built in a way (see handshake flowcharts for this) that the movers' **ticket is written** via the list **interface** of the target station after having moved **rReleaseDistance** (a station parameter):
      - The ticket:→

```
//-----  
//  
// write mover ticket in target station list  
//  
//-----  
CASE _stState[_nStationId].eState  
OF  
  E_STATION_STATE.STATION_MOVER_WRITE_TARGET:  
    // add entry in target station list  
    _stListTarget := _ItfStation[_stMoverDataSend.nTargetStation].AddTailValue(_stMoverDataSend);  
  
    IF (_stListTarget.wState <> 0)  
    THEN  
      // adding mover in target list was NOT successful  
      _stState[_nStationId].eState := E_STATION_STATE.STATION_ERROR_LIST_ADD_TAIL_FAULT; // fatal error  
      _stMsg.eType := E_MessageType.eMessageError;  
      LogState(_stMsg.eType);  
  
    ELSE  
      // mover data successfully added to target station list  
      IF (_eMessageLevel > E_MessageType.eMessageWarning)  
      THEN  
        _stMsg.eType := E_MessageType.eMessageInfo;  
        _stMsg.eSubdevice := e_Subdevice.StationAddTail;  
        _stMsg.iErrorNumber := _stState[_nStationId].nMoverId;  
        _stMsg.sText := concat('TargetStation: ', TO_STRING(_stListTarget.stData.nTargetStation));  
        f_MessageSet(_stMsg);  
      END_IF  
      _ItfMover[_stMoverDataSend.nMoverId].SendToModuloPosCa(FALSE, _stOutfeed);  
  
      _stState[_nStationId].eState := E_STATION_STATE.STATION_MOVER_GONE; // go tell ctrl that station is empty  
  
      IF (_eMessageLevel = E_MessageType.eMessageVerbose)  
      THEN  
        _stMsg.eType := _eMessageLevel;  
        LogState(_stMsg.eType);  
      END_IF  
    END_IF  
  END_CASE
```

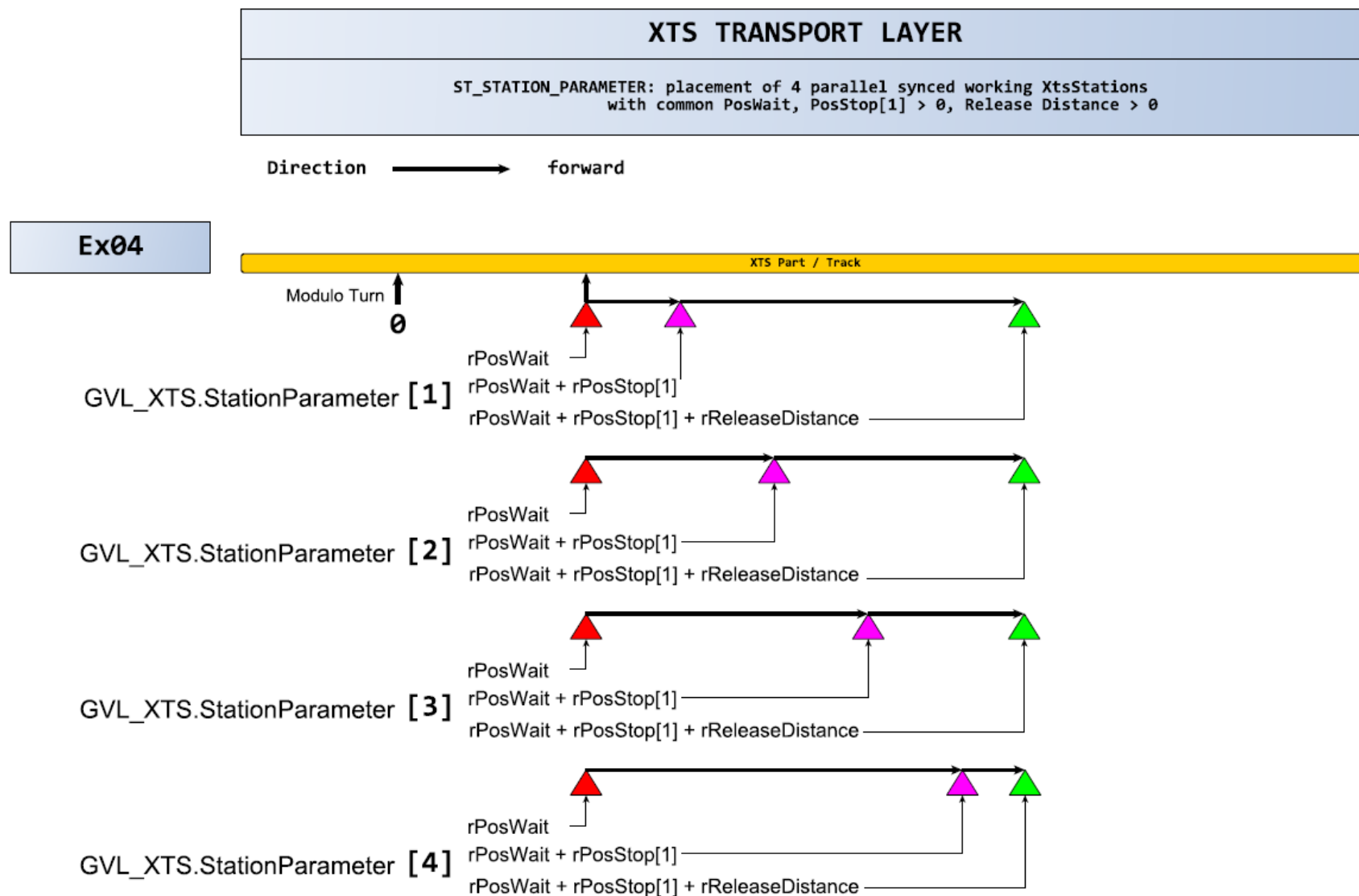
- **GVL\_XTS.Station - Planning requirements for use of fb\_StationProcess**
  - all coordinates are modulo values,
    - from station to station only forward
    - within station: movement by use of nest offset(PosStop[]) or use of **ST\_MOVER\_CTRL**.
    - Within station: all kind of MC functions (CAM, NCI)
  - **IF** move backwards is required you have to make sure that there is room for it by setting ST\_STATION\_PARAMETER so the movement of the movers match your process requirements for each station
    - Check PosStop[]
    - Each PosStop[] is **relative** to PosWait



- GVL\_XTS.Station (Example)
- **ST\_STATION\_PARAMETER**: parallel Xts stations for a process with common waiting position
  - Process uses GVL\_XTS.Station[1] to GVL\_XTS.Station[4]
    - Define PosWait(Queue position)
      - **[1].rPosWait := 100**
      - **[2].rPosWait := 100**
      - **[3].rPosWait := 100**
      - **[4].rPosWait := 100**
    - Define how many rPosStop(nests) the stations may have (configured count)
      - **[1].nConfiguredStopCount := 1 (default)**
      - **[2].nConfiguredStopCount := 1**
      - **[3].nConfiguredStopCount := 1**
      - **[4].nConfiguredStopCount := 1**
  - Process uses GVL\_XTS.Station[1] to GVL\_XTS.Station[4]
    - Define the process position(s) relative to rPosWait
      - **[1].rPosStop[1] := 100**
      - **[2].rPosStop[1] := 200**
      - **[3].rPosStop[1] := 300**
      - **[4].rPosStop[1] := 400**
    - The ReleaseDistance of **the last station shall be shortest**, all other stations follow accordingly.
      - **[1].rReleaseDistance := 40**
      - **[2].rReleaseDistance := 30**
      - **[3].rReleaseDistance := 20**
      - **[4].rReleaseDistance := 10**

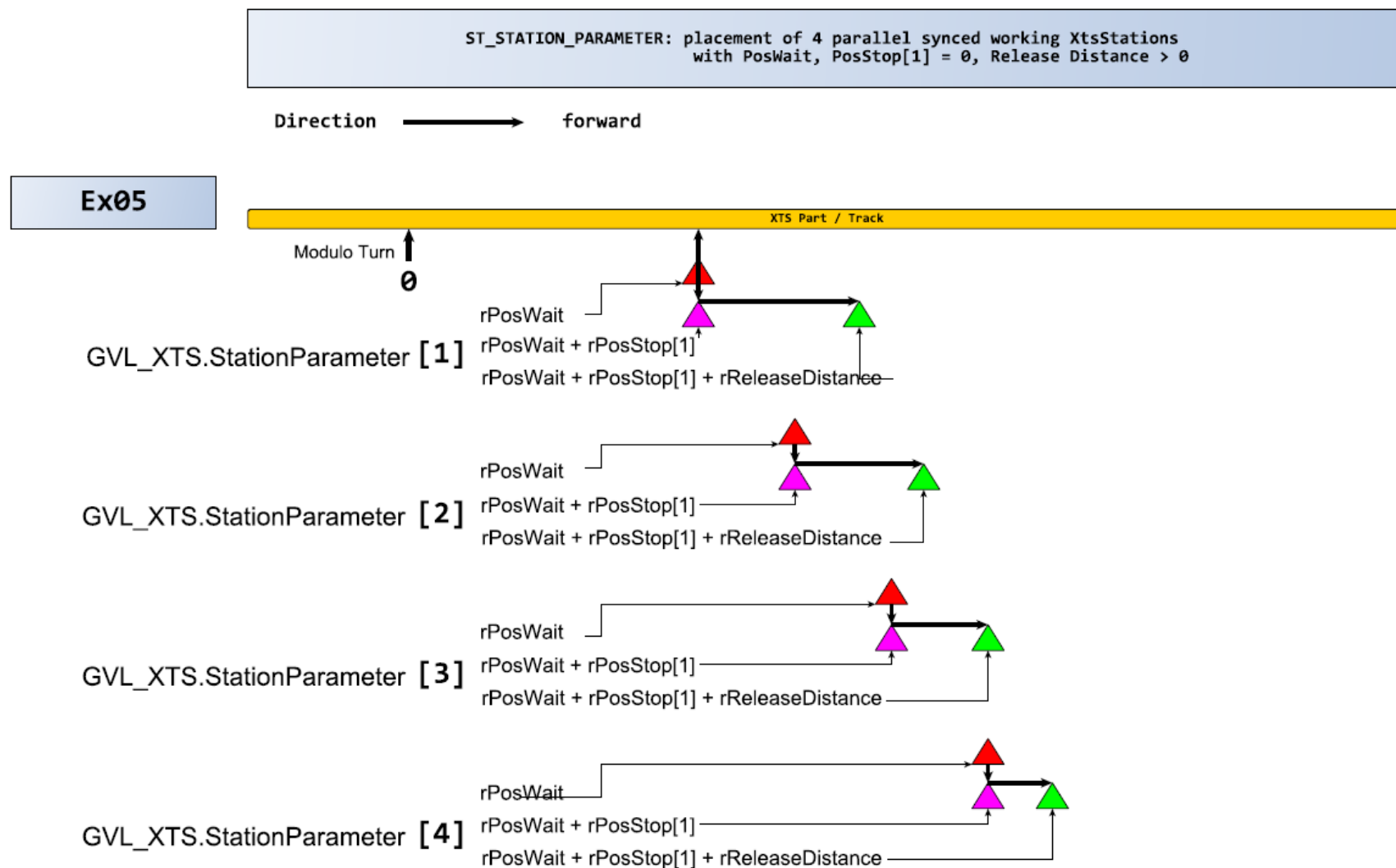
### 3. Design

- GVL\_XTS.Station  
(Example)
- What it may look like:  
parallel Xts stations for a  
process with common waiting  
position
  - drawings are not to  
scale, the possible  
configurations shall be  
illustrated
  - **Ex04:**  
This configuration is  
useful if you require the  
working area to be  
completely empty before  
pulling in movers. (move  
something other than  
your directly involved  
process mechanics out  
of the way of the mover  
etc.)



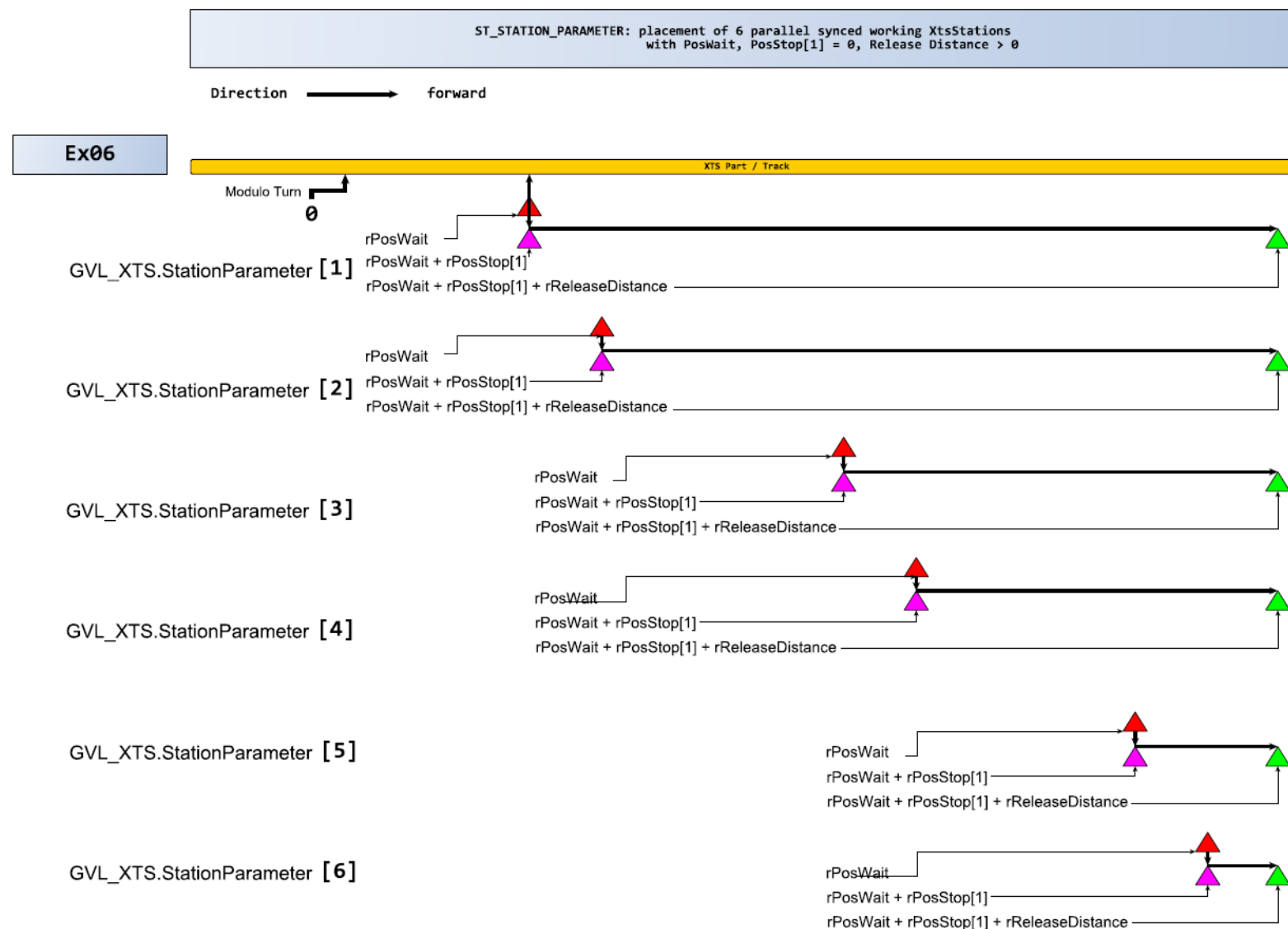
### 3. Design

- GVL\_XTS.Station  
(Example)
- What it may look like:  
parallel Xts stations for a  
process with common waiting  
position
  - drawings are not to  
scale, the possible  
configurations shall be  
illustrated
  - **Ex05:**  
This configuration is  
useful if you require high  
throughput with minimal  
stops of the mover.  
 $rPosWait[1-4]$  are  
already commanded by  
the sending station.



### 3. Design

- GVL\_XTS.Station  
(Example)
- What it may look like:  
parallel Xts stations for a  
process with common waiting  
position
  - drawings are not to  
scale, the possible  
configurations shall be  
illustrated
  - **Ex06:**  
This configuration is  
useful if you require high  
throughput and **irregular  
spacing** with minimal  
stops of the mover.  
 $rPosWait[1-6]$  are  
already commanded by  
the sending station.



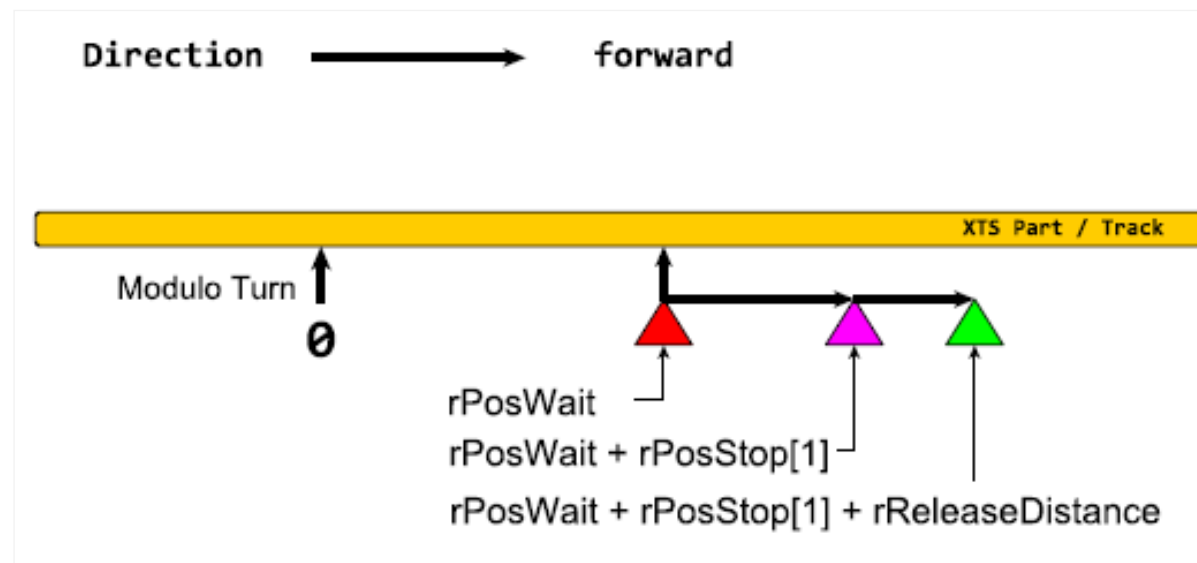
- **GVL\_XTS.Station** (Example)
- **using stations sparsely:**
  - In this case it is easiest to always handshake the stations and use the forwarding command if a station shall be skipped.
  - On Infeed state of mover, use: **E\_STATION\_CTRL.STATION\_MOVER\_SEND**.
    - There are different handshake 'routes' → see pdfs **GVL\_XTS.Station\_Example\_\*.pdf**
- **deactivating stations:**
  - Make sure the queue is empty before deactivating, since the waiting mover will hold up all other, in case of required deactivation while movers are in the queue:
    - handshake mover with **E\_STATION\_CTRL.STATION\_MOVER\_SEND** to new target station if mover in queue cannot be processed
  - Handshake regular infeed if mover in queue can still be processed.
  - Do not send any new mover to the station in question
    - If queue of station is empty: **E\_STATION\_CTRL.STATION\_DISABLE**
    - preceding stations continue workflow with changed **ST\_STATION\_CTRL.nTargetStation**

- GVL\_XTS.Station
  - Ctrl[nStation] : **ST\_STATION\_CTRL**
    - **eCmd (E\_STATION\_CTRL):**
      - enumeration for handshakes with State[nStation].eState (**E\_STATION\_STATE**)
    - **nMask (BYTE):**
      - bit mask to be used with multiple stop positions within a XtsStation.  
This mask tells the target station which PosStop[] (nest) has to be worked.
    - **nTargetStation (USINT):**
      - target to send mover to GVL\_XTS.Station[nTargetStation].rPosWait
    - **rOffset (REAL):**
      - Optional offset for mover, used in target station in addition to static offset

- GVL\_XTS.Station
  - State[nStation] : **ST\_STATION\_STATE**
    - **eState (E\_STATION\_STATE):**
      - Enumeration for active station state, Ctrl has to react to
    - **nMask (BYTE):**
      - Bitmask for active PosStop[] (nest)
    - **nMoverId (USINT):**
      - Active mover index in station
    - **rMoverModPos (LREAL):**
      - Modulo position of active mover
    - **nQueue (USINT):**
      - Count of movers, which were sent to XtsStation

## ■ GVL\_XTS.StationParameter

- **eType:**
  - STATION\_PROCESS
  - STATION\_GEAR\_IN\_POS
- **sText :**
  - Description only
- **rPosWait :**
  - start of station, a sending station is using this value to send mover to
- **rReleaseDistance :**
  - distance mover has to travel (from ActPos) in order for station to go back to mover detection
- **rGap :**
  - Active gap on infeed and outfeed of station
- **rVelo :**
  - Active velocity on infeed and outfeed of station
- **rAccDec :**
  - Active dyn constraint
- **rJerk :**
  - Active dyn constraint
- **nConfiguredStopCount :**
  - Count of PosStop (nests) a mover may has to stop at in XtsStation
- **rPosStop[] :**
  - Relative to rPosWait





### 3. Design

# BECKHOFF

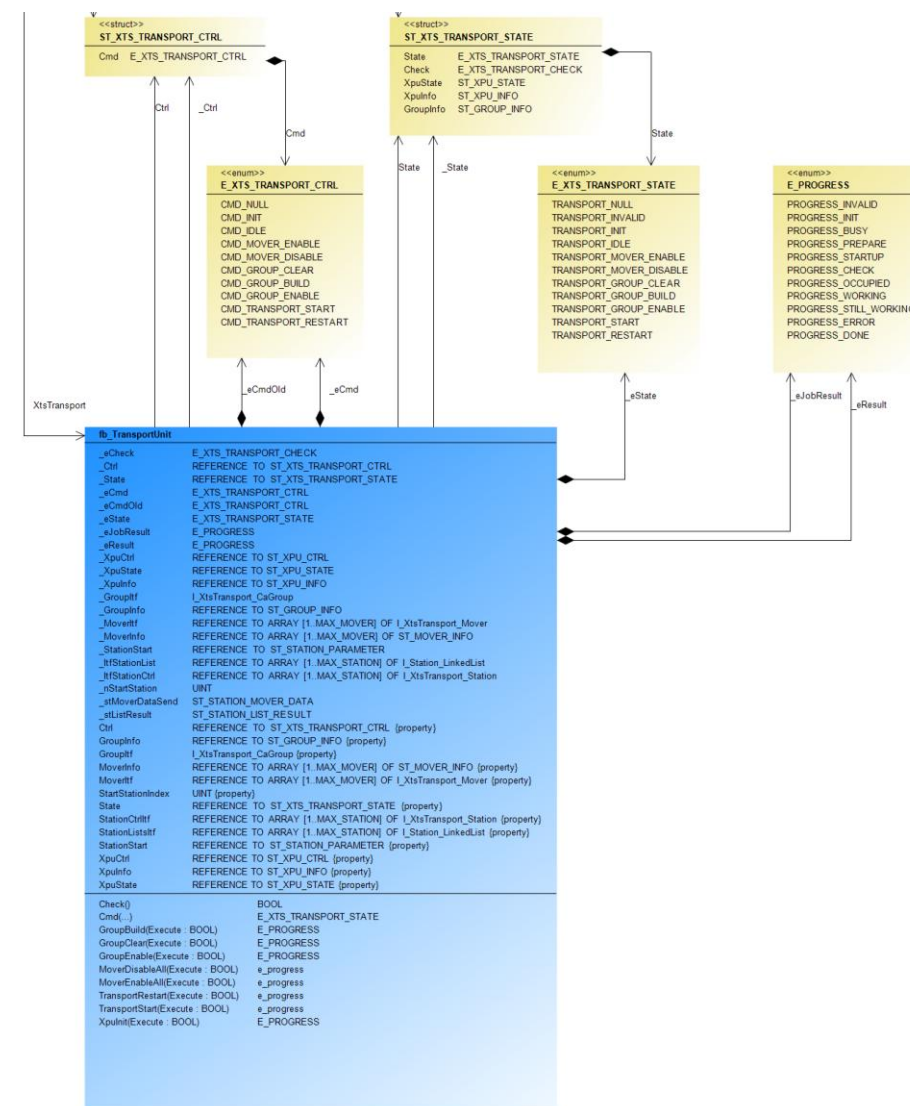
- TransportUnit

- Fb\_TransportUnit():
  - Top level control of XtsTransport
  - Cycle check for change of command:
    - **E XTS TRANSPORT CTRL:**

```

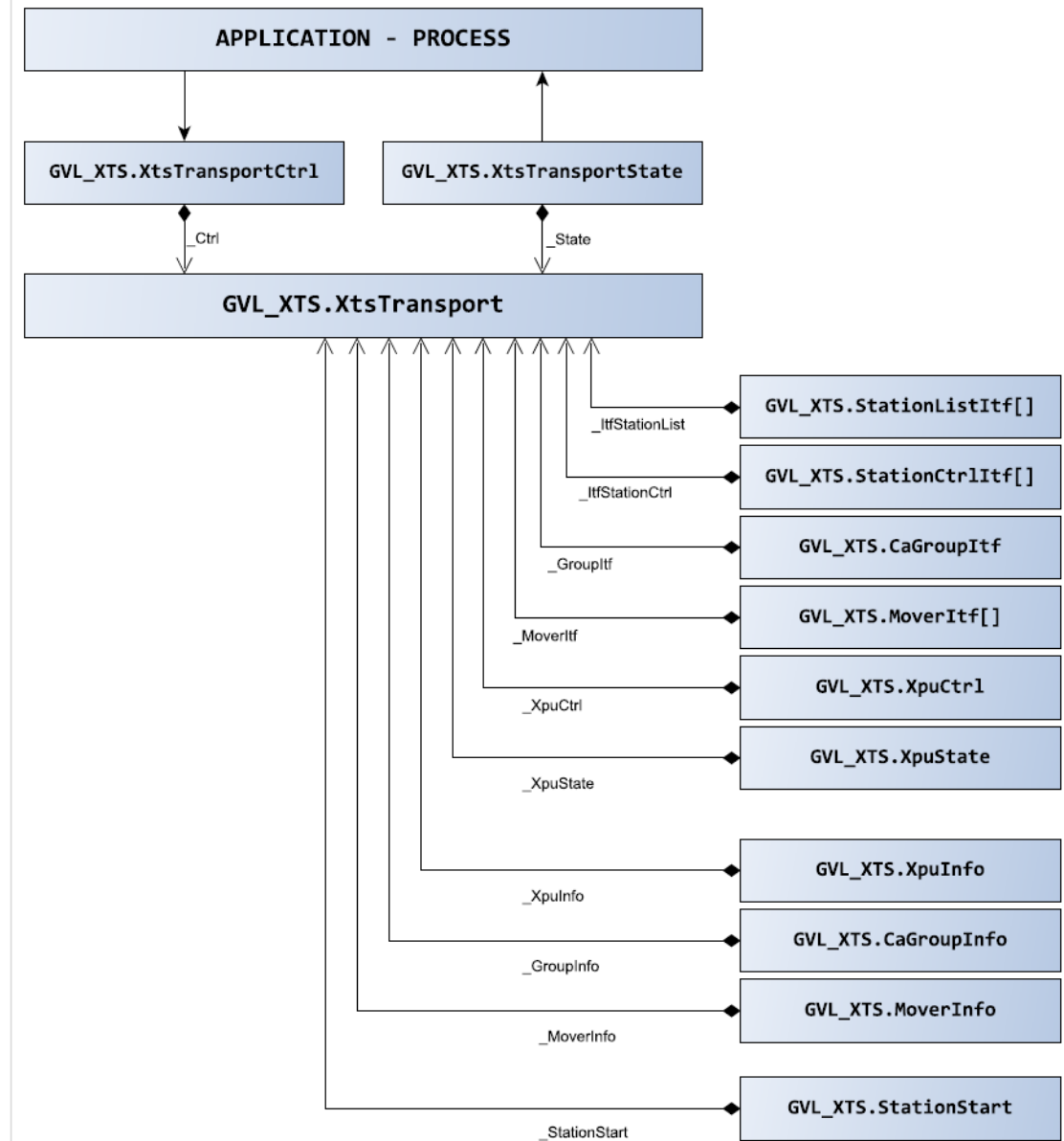
1 {attribute 'strict'}
2 {attribute 'to_string'}
3 TYPE E_XTS_TRANSPORT_CTRL :
4 (
5     CMD_NULL,
6     CMD_INIT := 10,
7     CMD_IDLE,
8
9     CMD_MOVER_ENABLE := 20,
10    CMD_MOVER_DISABLE,
11    CMD_MOVER_HALT_CA,
12    CMD_MOVER_STOP,
13
14    CMD_GROUP_CLEAR := 30,
15    CMD_GROUP_BUILD,
16    CMD_GROUP_ENABLE,
17    CMD_GROUP_STOP,
18
19    CMD_TRANSPORT_START := 40,
20    CMD_TRANSPORT_RESTART
21
22 )UINT;
23 END_TYPE
24

```



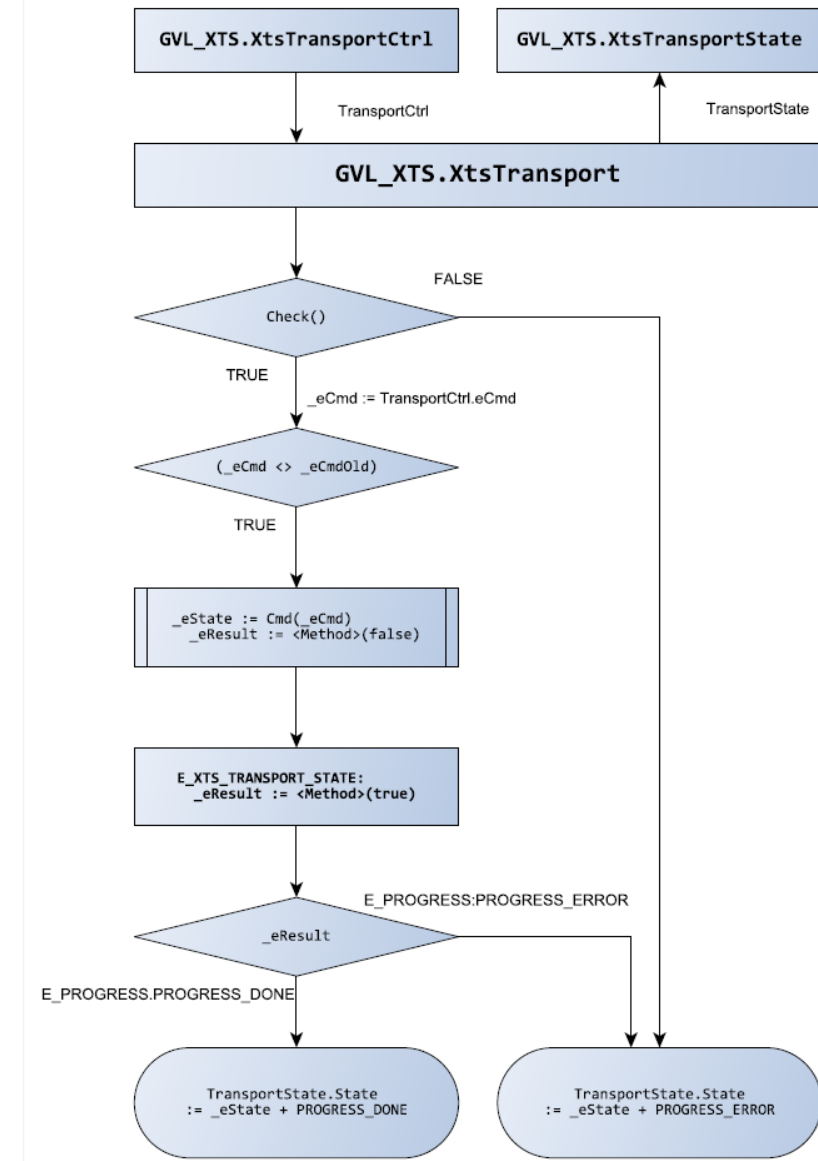
### 3. Design

- TransportUnit
  - Fb\_TransportUnit():
  - Members:



## 3. Design

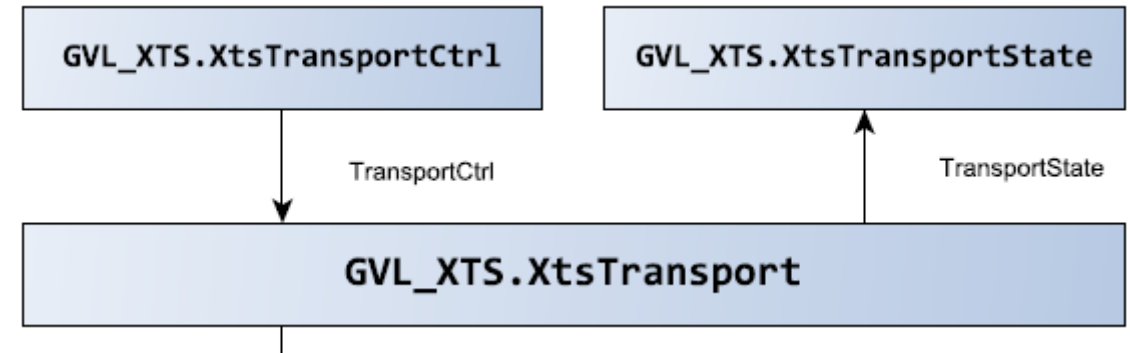
- TransportUnit
  - Fb\_TransportUnit():
    - Change of command triggers execution
    - Execution result is added to state
    - Extern control needs to react to BUSY, DONE or ERROR



### 3. Design

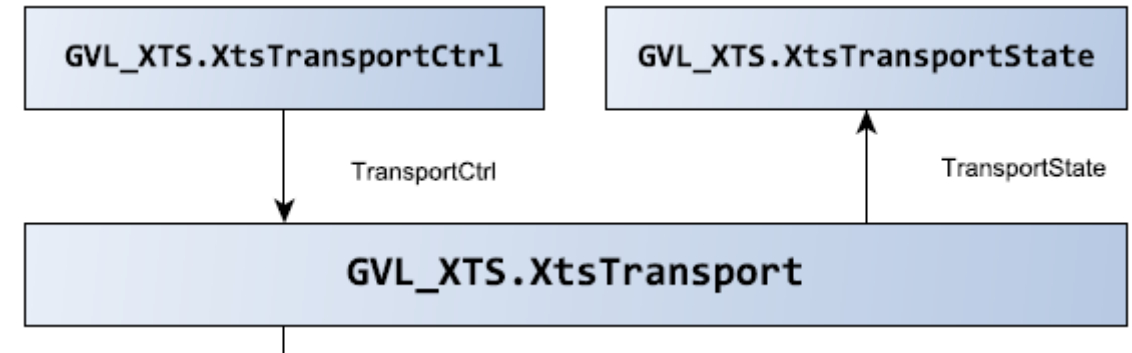
- TransportUnit
  - GVL\_XTS.XtsTransportCtrl:  
**ST\_TRANSPORT\_UNIT\_CTRL**
  - Struct for commanding  
FB\_TransportUnit
  - eCmd : E\_XTS\_TRANSPORT\_CTRL

```
ST_XTS_TRANSPORT_CTRL  ▢ ×  
1  TYPE ST_XTS_TRANSPORT_CTRL :  
2  STRUCT  
3      Cmd      : E_XTS_TRANSPORT_CTRL;  
4  END_STRUCT  
5  END_TYPE  
6
```



### 3. Design

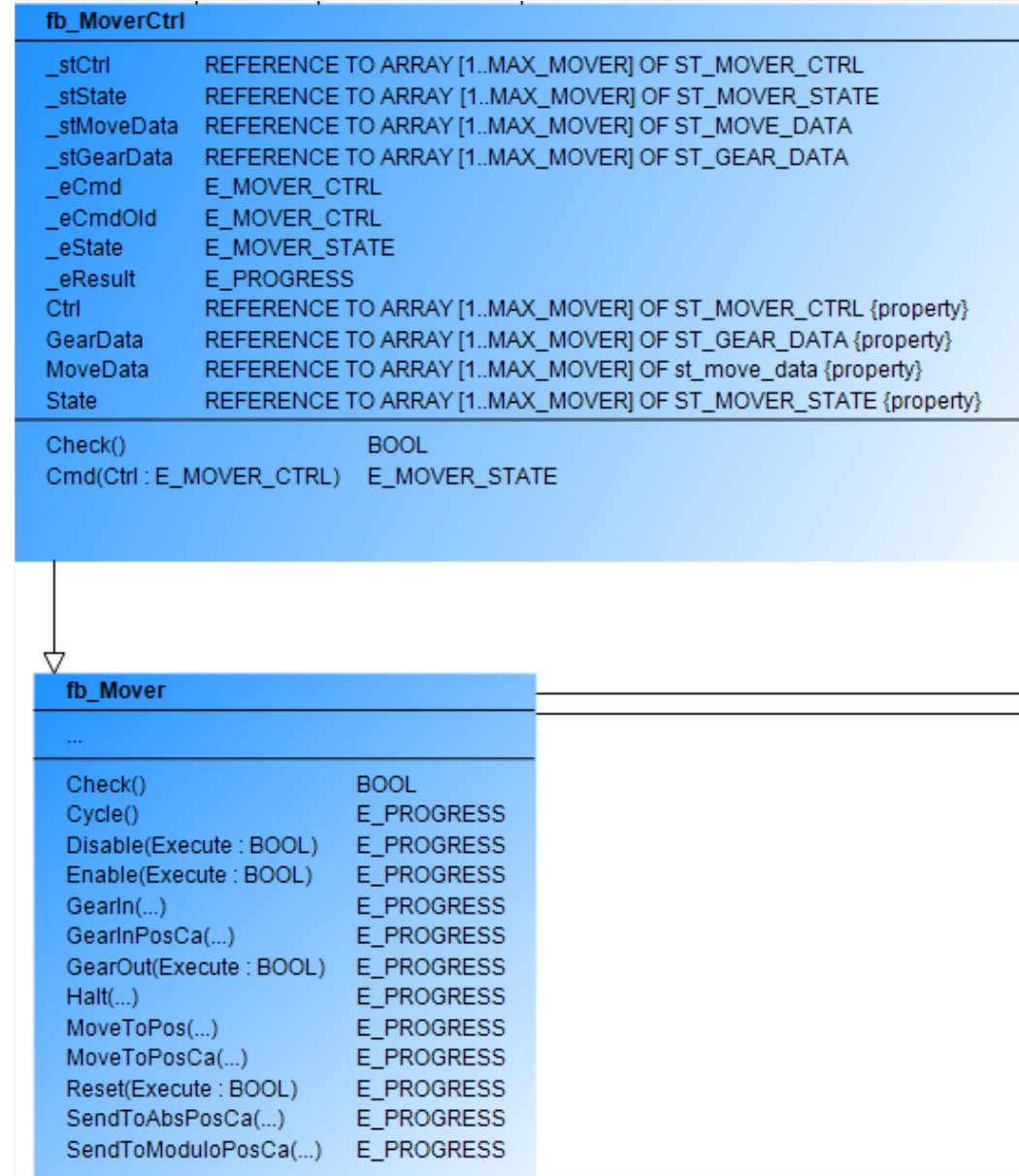
- TransportUnit
  - GVL\_XTS.XtsTransportState:  
**ST\_TRANSPORT\_UNIT\_STATE**
  - State: combines active command and result
  - Check: cyclic pointer checks
  - XpuState: state from fb\_Xpu
  - XpuInfo: cyclic plausibility checks to TcCOM Objects
  - GroupInfo: cyclic information from FB\_CaGroup



```
ST_XTS_TRANSPORT_STATE  ➤ ✕
1  {attribute 'pack_mode' := '2'}
2  TYPE ST_XTS_TRANSPORT_STATE :
3  STRUCT
4      State          : E_XTS_TRANSPORT_STATE;
5      Check          : E_XTS_TRANSPORT_CHECK;
6
7      XpuState       : ST_XPU_STATE;
8      XpuInfo        : ST_XPU_INFO;
9      GroupInfo      : ST_GROUP_INFO;
10 END_STRUCT
11 END_TYPE
12
```

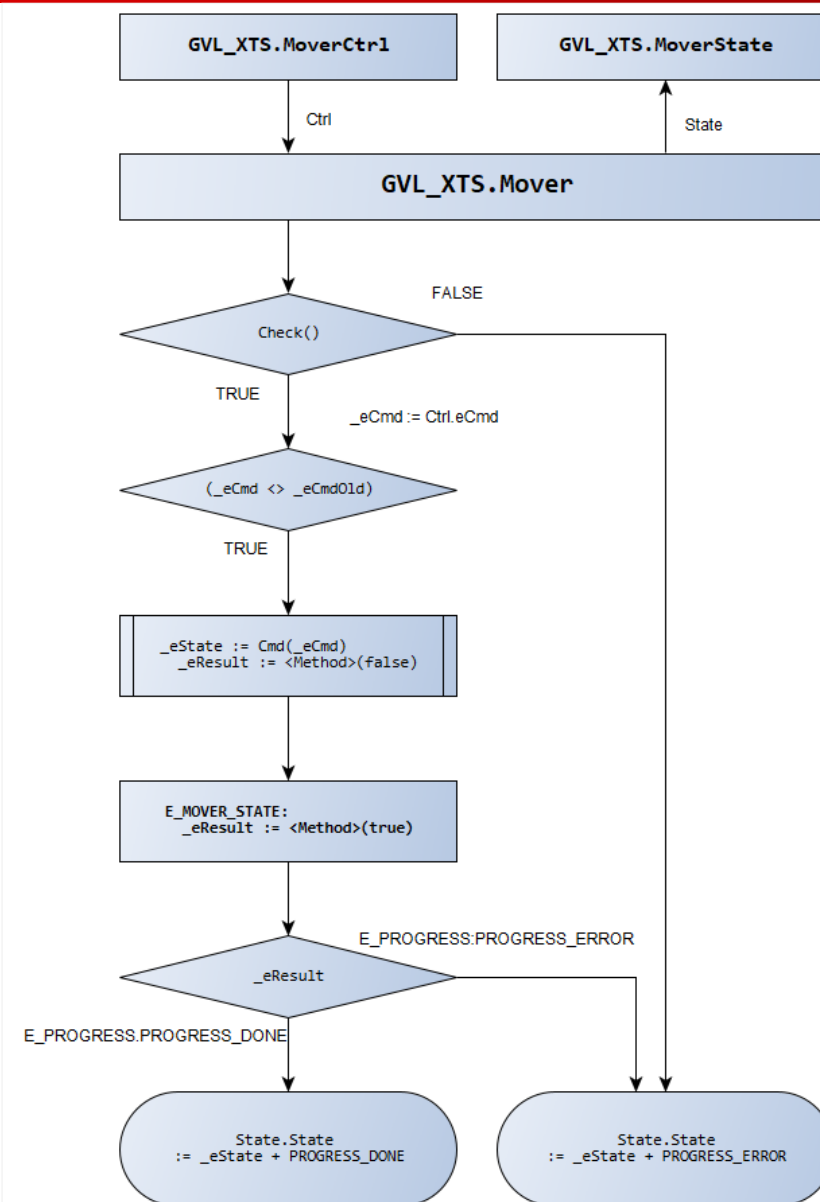
### 3. Design

- GVL\_XTS.Mover[] (**fb\_MoverCtrl**)
  - Inherits **fb\_Mover**
    - Access to MC function blocks in library
    - Implements Interface for use in other classes
  - Contains cyclic interface
    - OnChange check of command
    - Ctrl datafield for setting commands
    - State data field for checking responses
    - Parameter datafields for using motion functions



### 3. Design

- fb\_MoverCtrl:
  - Mover index is passed as value from caller
  - Global datafields are passed as references (**REF=**) into fb\_MoverCtrl properties
    - OnChange Ctrl / State: handshakes
      - standard return value for method (**E\_PROGRESS**)
    - OnExec log LastPosition of CA/MC function
    - OnExec log LastGap on CA function





### 3. Design

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- fb\_CaGroup:
  - Collision Avoidance class wrapper
  - Implements **I\_Transport\_CaGroup**
  - Cyclic information from **AXES\_GROUP\_REF**
  - Mover commands via interface **I\_XtsTransport\_Mover**

| FB_CaGroup            |  |
|-----------------------|--|
| GROUP_HALT_JERK       | LREAL  |
| GROUP_HALT_DEC        | LREAL  |
| _eCheck               | E_GROUP_CHECK  |
| _bError               | BOOL   |
| _GroupRef             | REFERENCE TO Tc3_McCoordinatedMotion.AXES_GROUP_REF                    |
| _GroupCommon          | MCTOPLC_GROUP_COMMON_PART  |
| _AxisRefMover         | REFERENCE TO ARRAY [1..MAX_MOVER] OF Tc2_MC2.AXIS_REF                  |
| _MoverItf             | REFERENCE TO ARRAY [1..MAX_MOVER] OF I_XtsTransport_Mover              |
| _stMoveData           | ST_MOVE_DATA   |
| _fbAddAxisGroup       | ARRAY [1..MAX_MOVER] OF Tc3_McCoordinatedMotion.MC_AddAxisToGroup      |
| _fbRemoveAxisGroup    | ARRAY [1..MAX_MOVER] OF Tc3_McCoordinatedMotion.MC_RemoveAxisFromGroup |
| _fbGroupDisable       | Tc3_McCoordinatedMotion.MC_GroupDisable                                |
| _fbGroupEnable        | Tc3_McCoordinatedMotion.MC_GroupEnable                                 |
| _fbGroupErrorRead     | Tc3_McCoordinatedMotion.MC_GroupReadError                              |
| _fbGroupStatusRead    | Tc3_McCoordinatedMotion.MC_GroupReadStatus                             |
| _fbGroupReset         | Tc3_McCoordinatedMotion.MC_GroupReset                                  |
| _stGroupInfo          | ST_GROUP_INFO  |
| _rtrigGroupStatusRead | Tc2_Standard.R_TRIG  |
| _rtrigGroupErrorRead  | Tc2_Standard.R_TRIG  |
| _stMsg                | ST_Message   |
| _eMessageLevel        | E_MessageType  |
| AxisRef               | REFERENCE TO ARRAY [1..MAX_MOVER] OF Tc2_MC2.AXIS_REF {property}       |
| GroupInfo             | REFERENCE TO ST_GROUP_INFO {property}                                  |
| GroupRef              | REFERENCE TO Tc3_McCoordinatedMotion.AXES_GROUP_REF {property}         |
| MessageLevel          | e_messageType {property}   |
| MoverItf              | REFERENCE TO ARRAY [1..MAX_MOVER] OF I_XtsTransport_Mover {property}   |

...



- fb\_CaGroup:
  - Implements **I\_Transport\_CaGroup**
  - Used in fb\_TransportUnit

<<interface>>

**I\_XtsTransport\_CaGroup**

|                            |            |
|----------------------------|------------|
| AddAll(Execute : BOOL)     | E_PROGRESS |
| Disable(Execute : BOOL)    | E_PROGRESS |
| Enable(Execute : BOOL)     | E_PROGRESS |
| McHaltAll(Execute : BOOL)  | E_PROGRESS |
| McResetAll(Execute : BOOL) | E_PROGRESS |
| RemoveAll(Execute : BOOL)  | E_PROGRESS |
| Reset(Execute : BOOL)      | E_PROGRESS |

- fb\_CaGroup:
  - Cyclic information to **ST\_GROUP\_INFO**

|              |   |                               |
|--------------|---|-------------------------------|
| CaGroupInfo  | → | <<struct>>                    |
|              |   | <b>ST_GROUP_INFO</b>          |
| _stGroupInfo | → |                               |
|              |   | GroupStatusValid BIT          |
|              |   | GroupStatusBusy BIT           |
|              |   | GroupMoving BIT               |
|              |   | GroupHoming BIT               |
|              |   | GroupErrorStop BIT            |
|              |   | GroupNotReady BIT             |
|              |   | GroupStandby BIT              |
|              |   | GroupStopping BIT             |
|              |   | GroupDisabled BIT             |
|              |   | AllAxesStanding BIT           |
|              |   | ConstantVelocity BIT          |
|              |   | Accelerating BIT              |
|              |   | Decelerating BIT              |
|              |   | InPosition BIT                |
|              |   | GroupError BIT                |
|              |   | GroupErrorId UDINT            |
|              |   | AxisCount UDINT               |
|              |   | AxisCountEnabled UDINT        |
|              |   | CaGroupOID OTCID              |
|              |   | CaGroupState E_CA_GROUP_STATE |

- GVL\_XTS.Xpu (**fb\_XpuCtrl**)
  - Inherits **fb\_Xpu**:
    - Class for interacting with XTS ProcessingUnit
    - Xpulnit()
      - Connects to OTCIDs of XTS TcCOM Objects
    - Cycle
      - Plausibility checks, get module info data
    - ModuleInfoData, used in Cycle

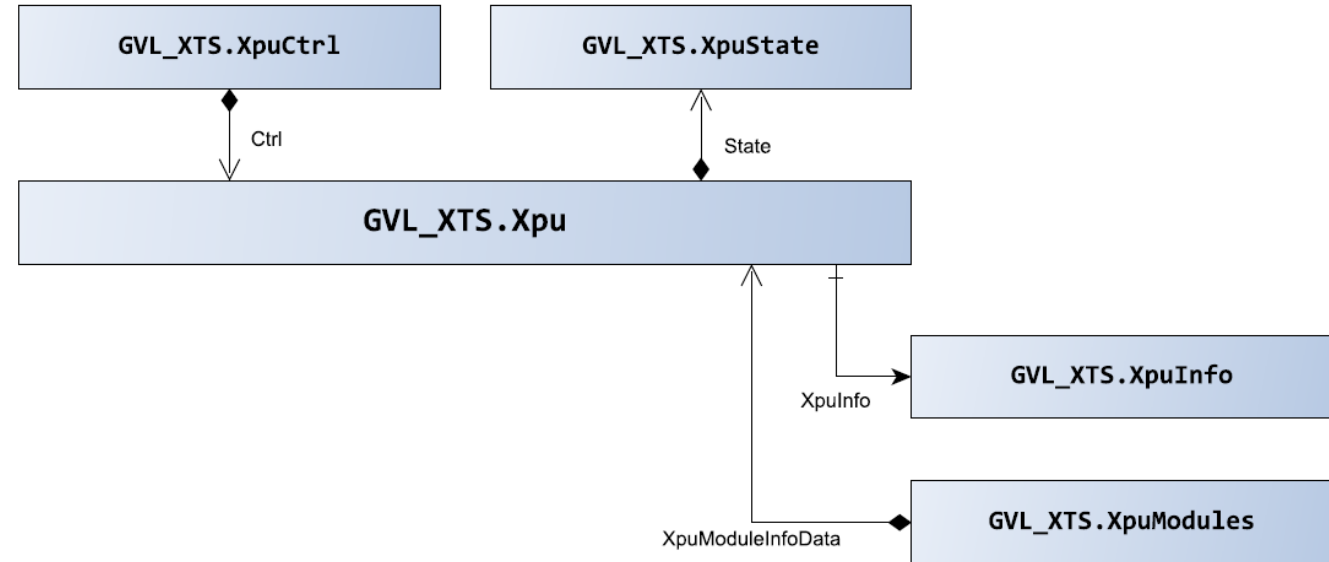
| fb_XpuCtrl                   |                                      |
|------------------------------|--------------------------------------|
| _Ctrl                        | REFERENCE TO ST_XPU_CTRL             |
| _State                       | REFERENCE TO ST_XPU_STATE            |
| _eCmd                        | E_XPU_CTRL                           |
| _eCmdOld                     | E_XPU_CTRL                           |
| _eResult                     | E_PROGRESS                           |
| _eState                      | E_XPU_STATE                          |
| Ctrl                         | REFERENCE TO ST_XPU_CTRL {property}  |
| State                        | REFERENCE TO ST_XPU_STATE {property} |
| Check()                      | BOOL                                 |
| Cmd(Ctrl : E_XPU_CTRL)       | E_XPU_STATE                          |
| DetectMoverId(Enable : BOOL) | E_XPU_CHECK                          |

| fb_Xpu                            |                      |
|-----------------------------------|----------------------|
| ...                               |                      |
| Cycle(...)                        | E_PROGRESS           |
| GetEnvironment()                  | I_TcloXtsEnvironment |
| IdDetectionModeToString()         | STRING(20)           |
| ModuleInfoData(Enable : BOOL)     | E_PROGRESS           |
| MoverPositionAssignmentToString() | STRING(20)           |
| OpModeToString()                  | STRING(20)           |
| Xpulnit(...)                      | E_XPU_INIT           |

### 3. Design

- GVL\_XTS.Xpu (fb\_XpuCtrl)
  - Wraps cyclic execution of fb\_Xpu
  - Cyclic check for command change (ST\_XPU\_CTRL.Cmd)

```
E_XPU_CTRL  ➦ ✕  
1 {attribute 'strict'}  
2 TYPE E_XPU_CTRL :  
3 (  
4   XTS_CMD_NULL,  
5   XTS_CMD_INIT           := 10,  
6   //XTS_CMD_READ_STN_CONFIG := 20,  
7   XTS_IDLE               := 30  
8 )UINT;  
9 END_TYPE
```

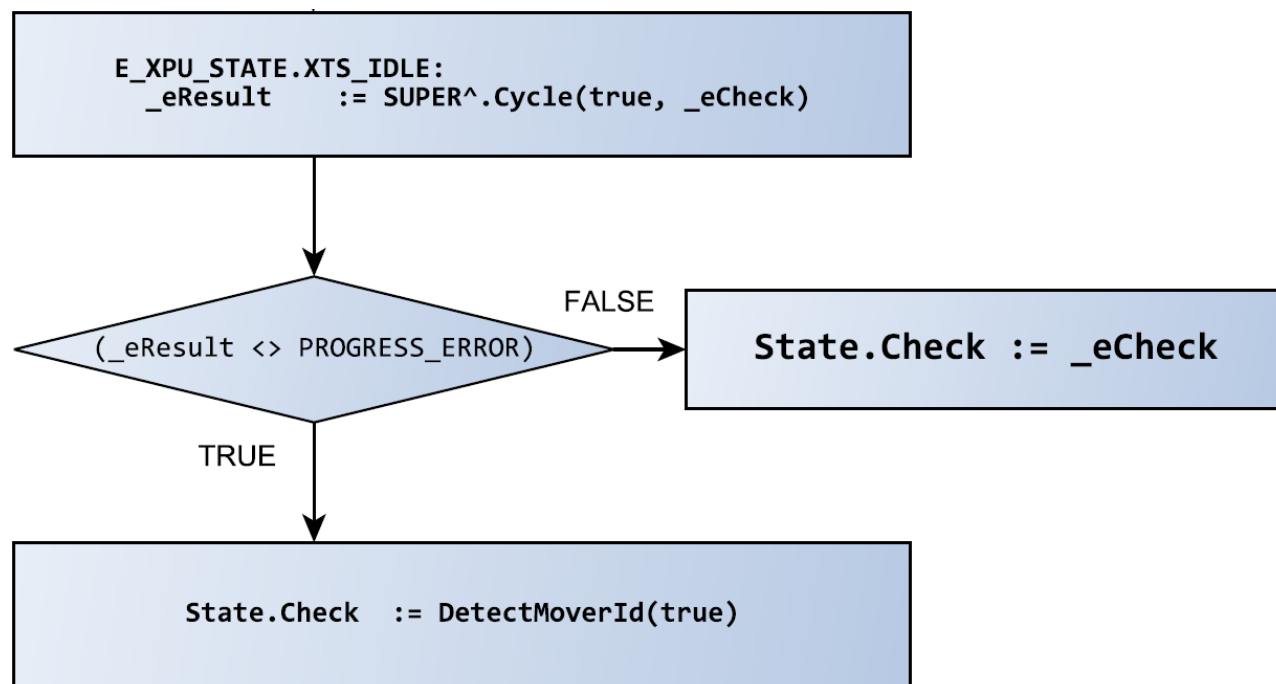


### ■ fb\_XpuCtrl cyclic data:

- **SUPER^.Cycle():**
  - Cyclic plausibility checks
  - Cyclic update motor modules data

### – Cyclic data **ST\_XPU\_INFO**:

```
ST_XPU_INFO  ▢ ×
1 {attribute 'pack_mode' := '2'}
2 TYPE ST_XPU_INFO :
3 STRUCT
4   AllPositionsValid : BIT;
5   IdDetectionError   : BIT;
6   IdDetectionValid   : BIT;
7   IdDetectionActive  : BIT;
8
9   OperationMode      : UINT;
10
11   IdDetectionMode     : UINT;
12   MoverPositionAssignment : UINT;
13
14   nDetectedAxisCount : UINT;
15   nExpectedAxisCount : UINT;
16
17
18 END_STRUCT
19 END_TYPE
~
```



## 3. Design

BECKHOFF

- fb\_XpuCtrl:
  - Cyclic motor module data:

Tc3\_XTS\_Utility = Tc3\_XTS\_Utility, 4.0.10.0 (Beckhoff Automation GmbH) Tc3\_XTS\_Utility 4.0.10.0

Diagnostic

Motor

- ST\_XtsMotorMemoryData
- ST\_XtsMotorModule
- CoE
  - ST\_XtsCoE
  - SubItem
    - AmplifierSetting
    - DiagData
    - DiagHistory
    - I2tDiagData
    - Identity
    - InfoData
      - ST\_InfoData
      - View
        - ST\_InfoDataView
    - VendorData

- Motion
- XTS IO

Inputs/Outputs Documentation

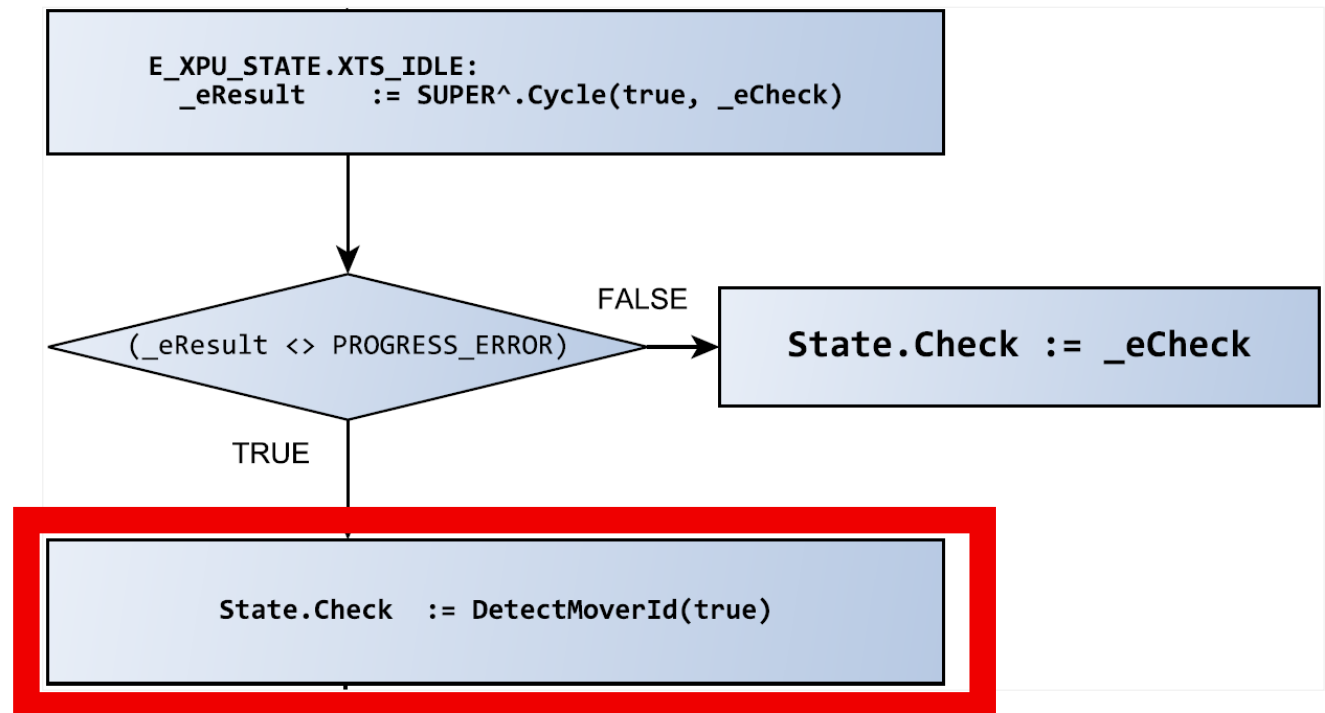
**STRUCT ST\_InfoDataView**

| Name                        | Type  | Inherited from | Address | Initial |
|-----------------------------|-------|----------------|---------|---------|
| byInfoData                  | BYTE  |                |         |         |
| fAuxiliaryVoltage_5V        | LREAL |                |         |         |
| fAuxiliaryVoltage_10V       | LREAL |                |         |         |
| fAuxiliaryVoltage_24V       | LREAL |                |         |         |
| fDcLinkVoltage              | LREAL |                |         |         |
| nCurrentScaling             | INT   |                |         |         |
| nDeviceInfo                 | UDINT |                |         |         |
| fPcbTemp_0                  | LREAL |                |         |         |
| fPcbTemp_1                  | LREAL |                |         |         |
| fPcbTemp_2                  | LREAL |                |         |         |
| fPcbTemp_3                  | LREAL |                |         |         |
| fAverageTemp                | LREAL |                |         |         |
| fOverallCurrent             | LREAL |                |         |         |
| fMaxDCLinkVoltageLast500ms  | LREAL |                |         |         |
| fMaxOverallCurrentLast500ms | LREAL |                |         |         |

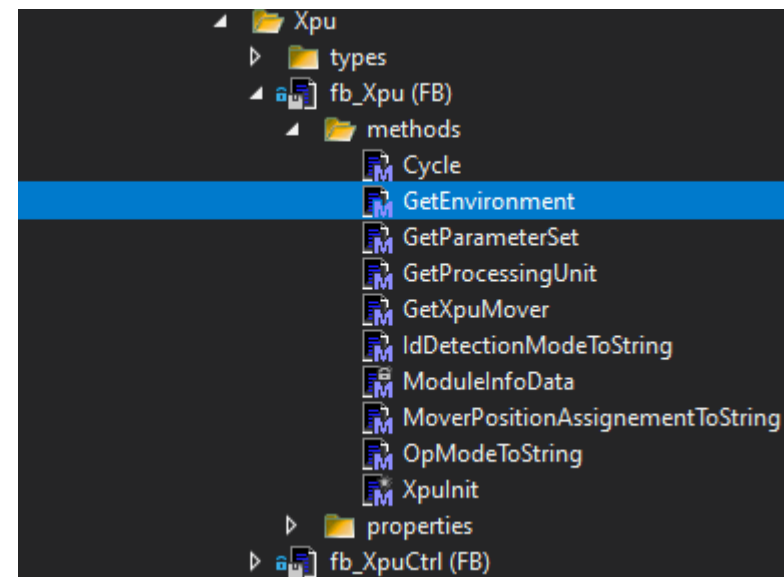
- fb\_XpuCtrl:

- **DetectMoverId:**

- Cyclic checks for valid Mover ID Detection
    - Check pdf flowchart in [doc] folder of project

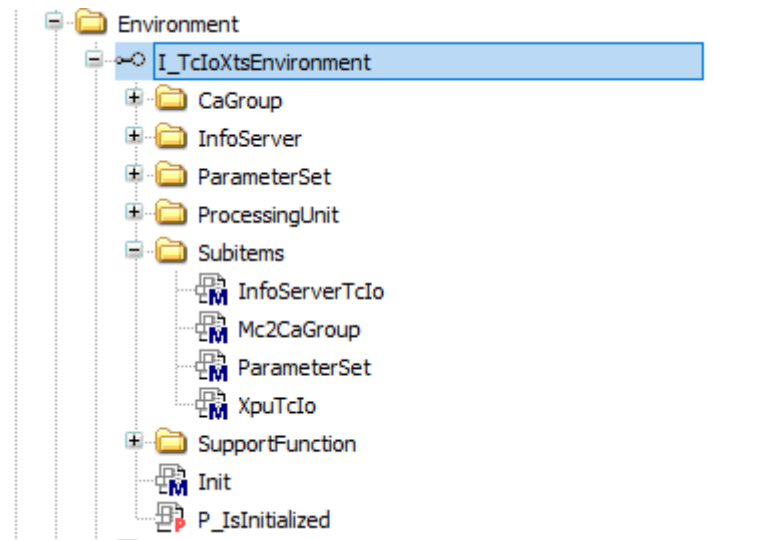


- fb\_Xpu.GetEnvironment():
  - **Interface methods to Tc3\_XTS\_Utility.lib:**
    - GetEnvironment() : I\_TcloXtsEnvironment
      - Startup initialization of \_fbEnvironment is done by fb\_Xpu.Init()
    - Top level interface
      - See interface structure (Library Manager) in order to reach lower level interfaces

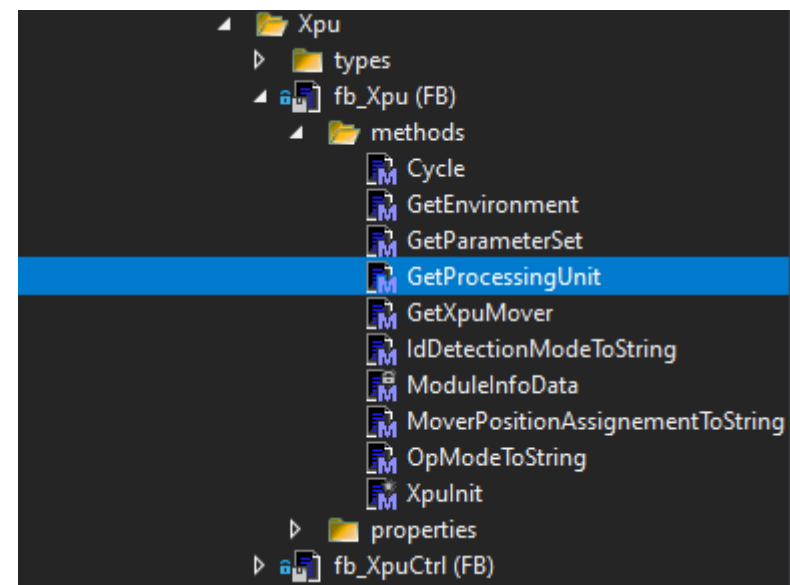




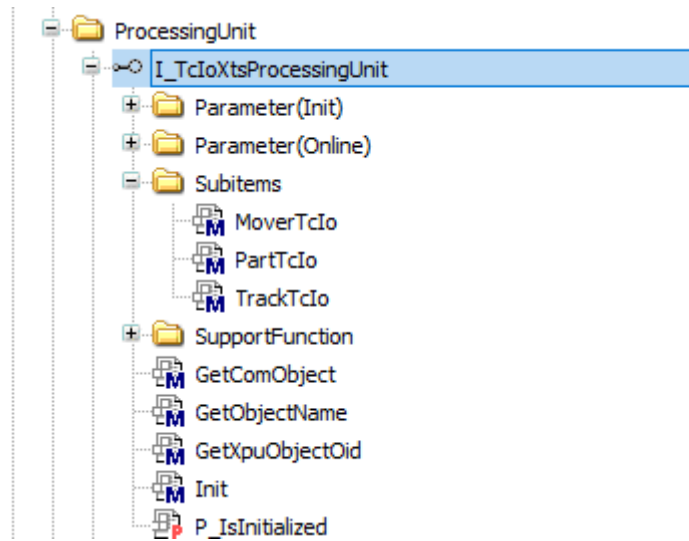
- `fb_Xpu.GetEnvironment()`:
  - **I\_TcIoXtsEnvironment:**
    - See LibraryManager
    - Provides access to members



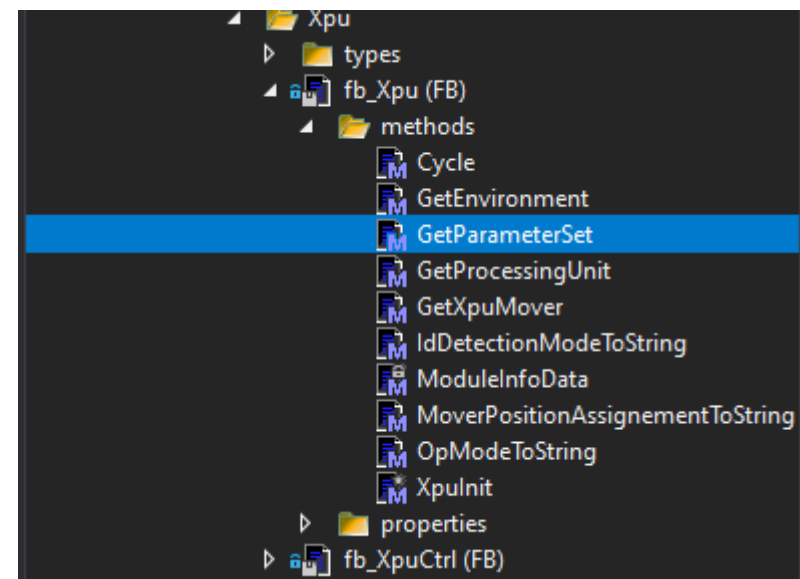
- `fb_Xpu.GetProcessingUnit()`:
  - **Interface methods to Tc3\_XTS\_Utility.lib:**
    - `GetProcessingUnit : I_TcIoXtsProcessingUnit`
      - Startup initialization of `_fbProcessingUnit` is done by `fb_Xpu.Init()`
    - Interface for Processing Unit
      - See interface structure (Library Manager) in order to reach lower level interfaces



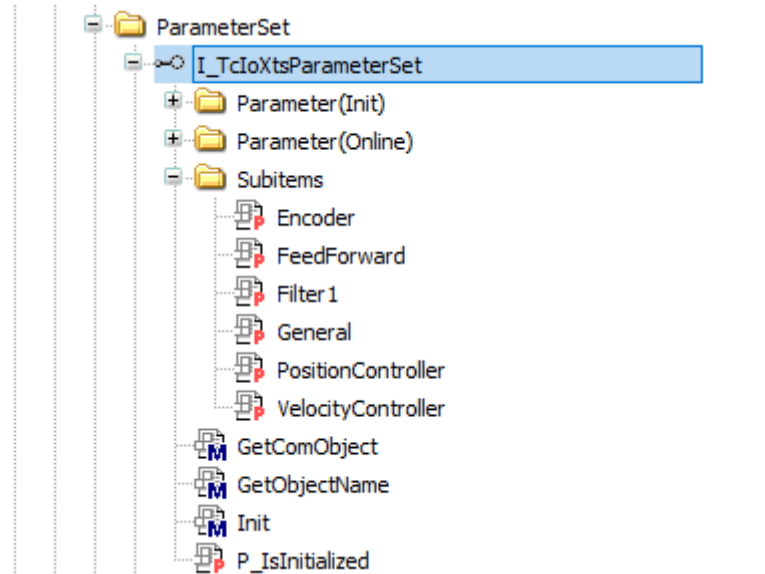
- `fb_Xpu.GetProcessingUnit():`
  - **I\_TcIoXtsProcessingUnit:**
    - See LibraryManager
    - Provides access to members



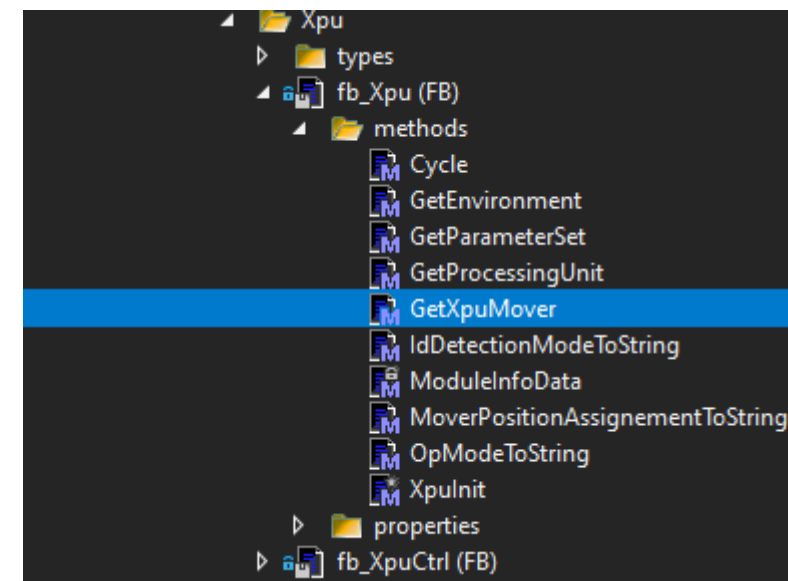
- fb\_Xpu.GetParameterSet(Index):
  - **Interface methods to Tc3\_XTS\_Utility.lib:**
    - GetParameterSet(Index) : I\_TcloXtsParameterSet
      - Startup initialization of \_fbParameterSet[ ] is done by fb\_Xpu.Init()
  - Interface for ParameterSets
    - See interface structure (Library Manager) in order to reach lower level interfaces



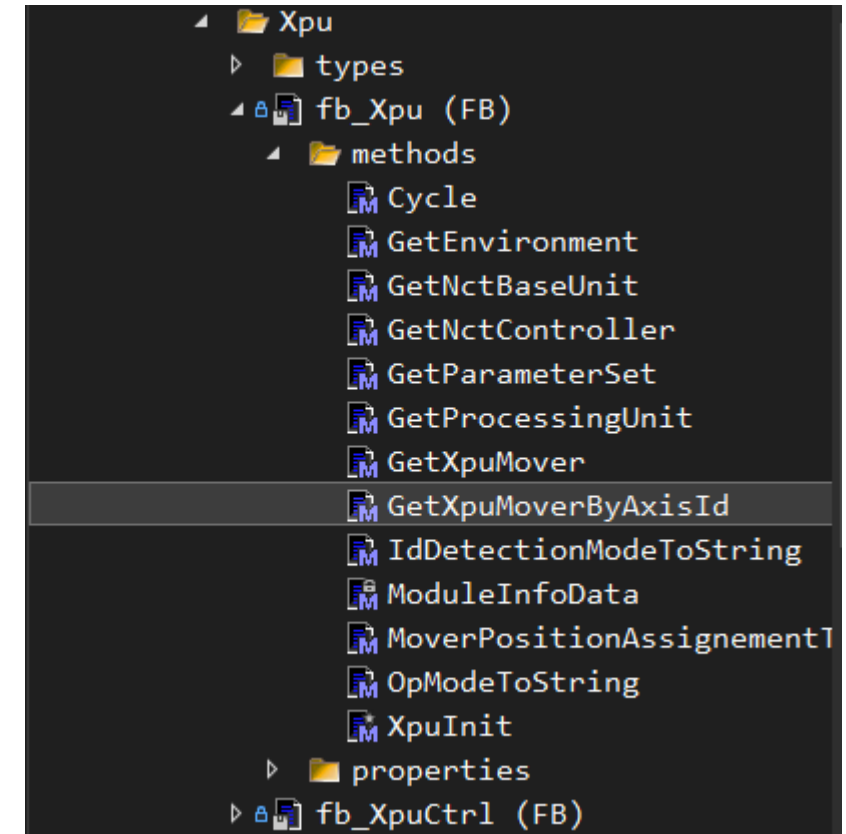
- `fb_Xpu.GetParameterSet(Index):`
  - **`I_TcIoXtsParameterSet:`**
  - See `LibraryManager`
  - Provides access to members



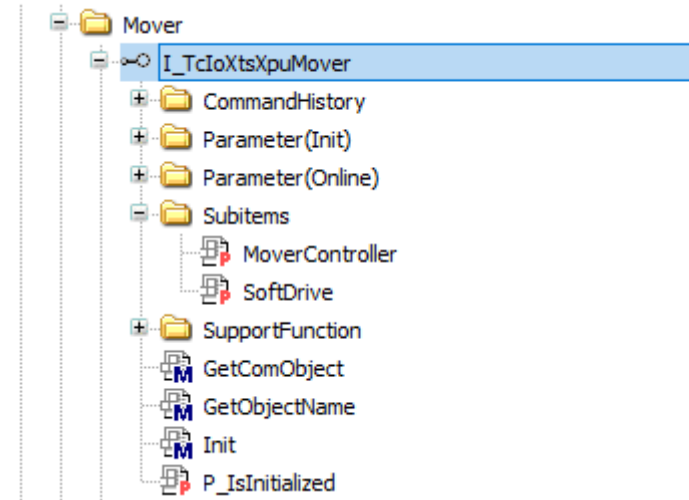
- `fb_Xpu.GetXpuMover(Index):`
  - **Interface methods to Tc3\_XTS\_Utility.lib:**
    - `GetXpuMover(Index) : I_TcloXtsXpuMover`
      - Startup initialization of `_fbMoverXpu[ ]` is done by `fb_Xpu.Init()`
    - Interface for Mover
      - See interface structure (Library Manager) in order to reach lower level interfaces



- fb\_Xpu. GetXpuMoverByAxisId(AxisId):
  - **Interface methods to Tc3\_XTS\_Utility.lib:**
    - GetXpuMoverByAxisId(AxisId): I\_Tc3XtsXpuMover
      - Startup initialization of \_fbMoverXpu[ ] is done by fb\_Xpu.Init()
    - Interface for Mover
      - See interface structure (Library Manager) in order to reach lower level interfaces



- fb\_Xpu.GetXpuMover(Index):
- fb\_Xpu.GetXpuMoverByAxisId(AxisId):
- **I\_TcIoXtsXpuMover:**
  - See LibraryManager
  - Provides access to members

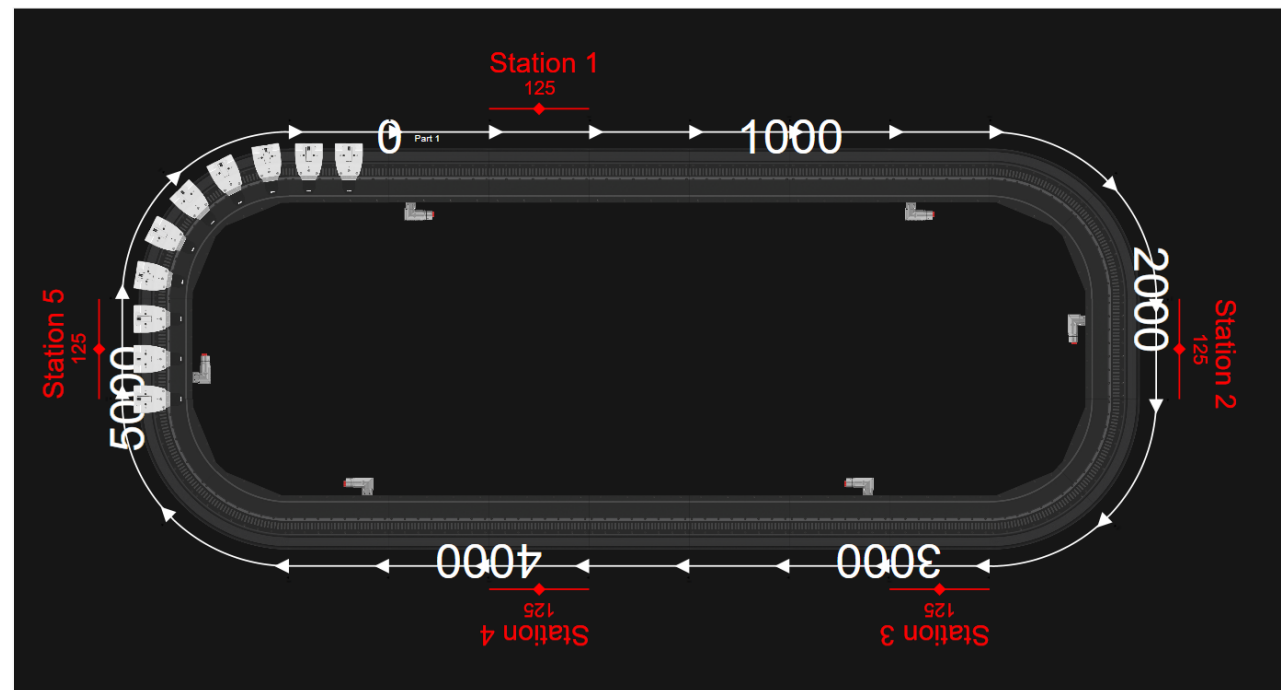




- **Transport Logic can be easy or may be complex**
  - **Examples shall help you to easily build any product transport.**
    - Please contact me via github; the place where you found this repo ;-)
  - All examples consider one specific aspect of the XTS transport system
    - Work as simple IndexTable
    - Work as Index Table where processes may host a number of XtsStations, working in parallel.
    - Complex, lot based decisions in order to achieve maximum production flexibility in one machine
    - Fast and precise for high speed packaging machines
    - Fast, synchronuous and precise for high end sorting and/or assembly machines

## 4. Examples

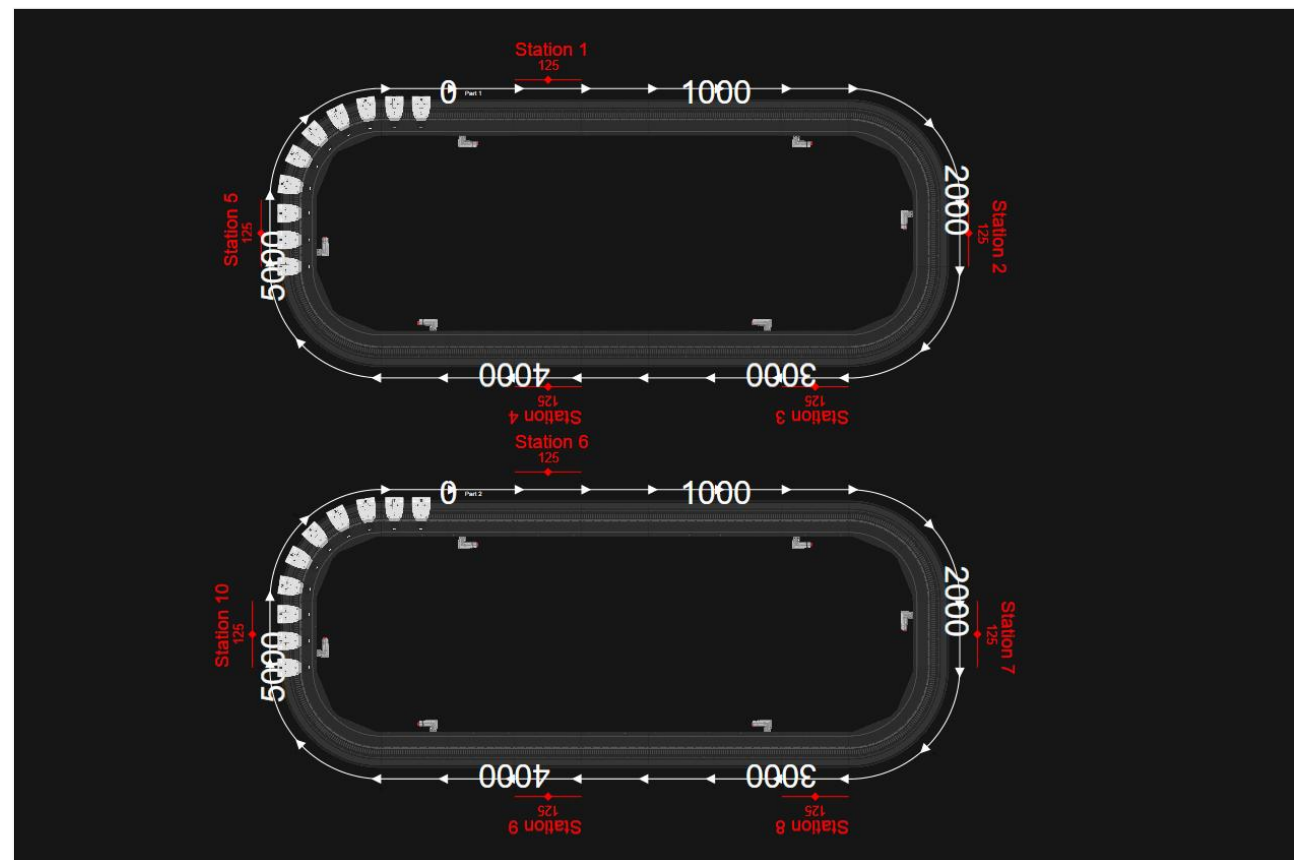
- XTS\_DEMO\_11
  - Single Station, Single Nest
    - ST\_STATION\_CTRL/ST\_STATION\_STATE is used for mover handshakes
  - Easy example for a XTS transport which requires only stations in which a mover stops once.
  - Easy transport logic;  
 $\text{Target}[n] := n+1; n+1 > \text{MAX}; n+1 := 1$



## 4. Examples

BECKHOFF

- XTS\_DEMO\_22
  - Multiple XPU
    - 2 ProcessingUnits in one PLC
  - Single Station, Single Nest
    - ST\_STATION\_CTRL/ST\_STATION\_STATE is used for mover handshakes
  - Easy example for an XTS transport requiring only stations in which a mover stops once.
  - Easy transport logic:  
 $\text{Target}[n] := n+1; n+1 > \text{MAX}; n+1 := 1$



## 4. Examples

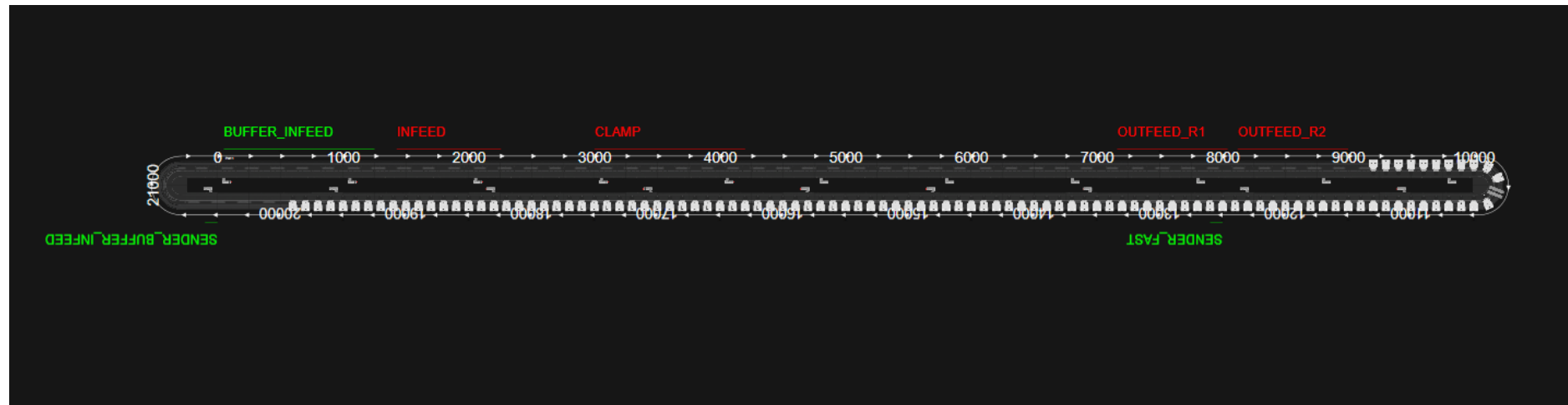
BECKHOFF

### ■ XTS\_DEMO\_APPLICATION\_108

- High volume packaging application
- 450 – 500 Mover/Minute
- INFEED with gaps [1..12] possible
- Any OUTFEED without gaps
  - 12 Movers per outfeed
- 4 OUTFEED scenarios
  - software switch (PLC)
  - R1 or R2
  - R1 and R2
  - R1 xor R2
  - CLAMP

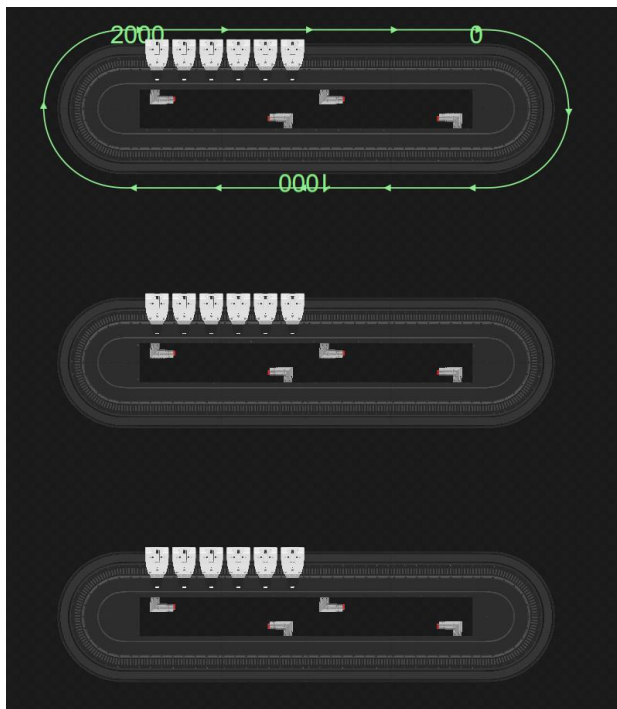
■

- Complex transport logic:
  - fb\_ProcessCollector: grouping of XtsStations
  - fb\_Instance: base class for logic implementation
  - Process\_Instances: extending fb\_Instance with transport details



### ■ XTS\_DEMO\_LASER\_CUT

- Flying Saw application with 3 XPU
- ConveyorBelt MasterAxis
- CutMark detection (simulated in example)
- GearInPosCA for 3 XPU with 6 Movers each
- Use of multiple PLC
  - XtsTransport
  - ExternControl



■

- Complex transport logic:
  - fb\_ProcessCollector: grouping of XtsStations
  - fb\_Instance: base class for logic implementation
  - Process\_Instances: extending fb\_Instance with transport details
  - fb\_GearInPos extends fb\_StationBase
  - Control and Feedback datafields for ADS or fieldbus access

- XTS\_DEMO\_DISPENSING\_MOVER

- Station based example
- Dispensing Station
  - GearIn of Mover in Station (standstill)
  - Select \*.nc file
  - Build NCI Config
  - Activate NCI config
  - Start \*.nc program
  - Use of Mfunc to start dispenser axis
- Use of PLC\_MOTION\_LAYER
  - [https://github.com/haud-ba/PLC\\_MOTION\\_LAYER](https://github.com/haud-ba/PLC_MOTION_LAYER)

- 

- Complex transport logic:
  - fb\_ProcessCollector: grouping of XtsStations
  - fb\_Instance: base class for logic implementation
  - Process\_Instances: extending fb\_Instance with transport details

### XTS\_TRANSPORT\_LAYER project

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