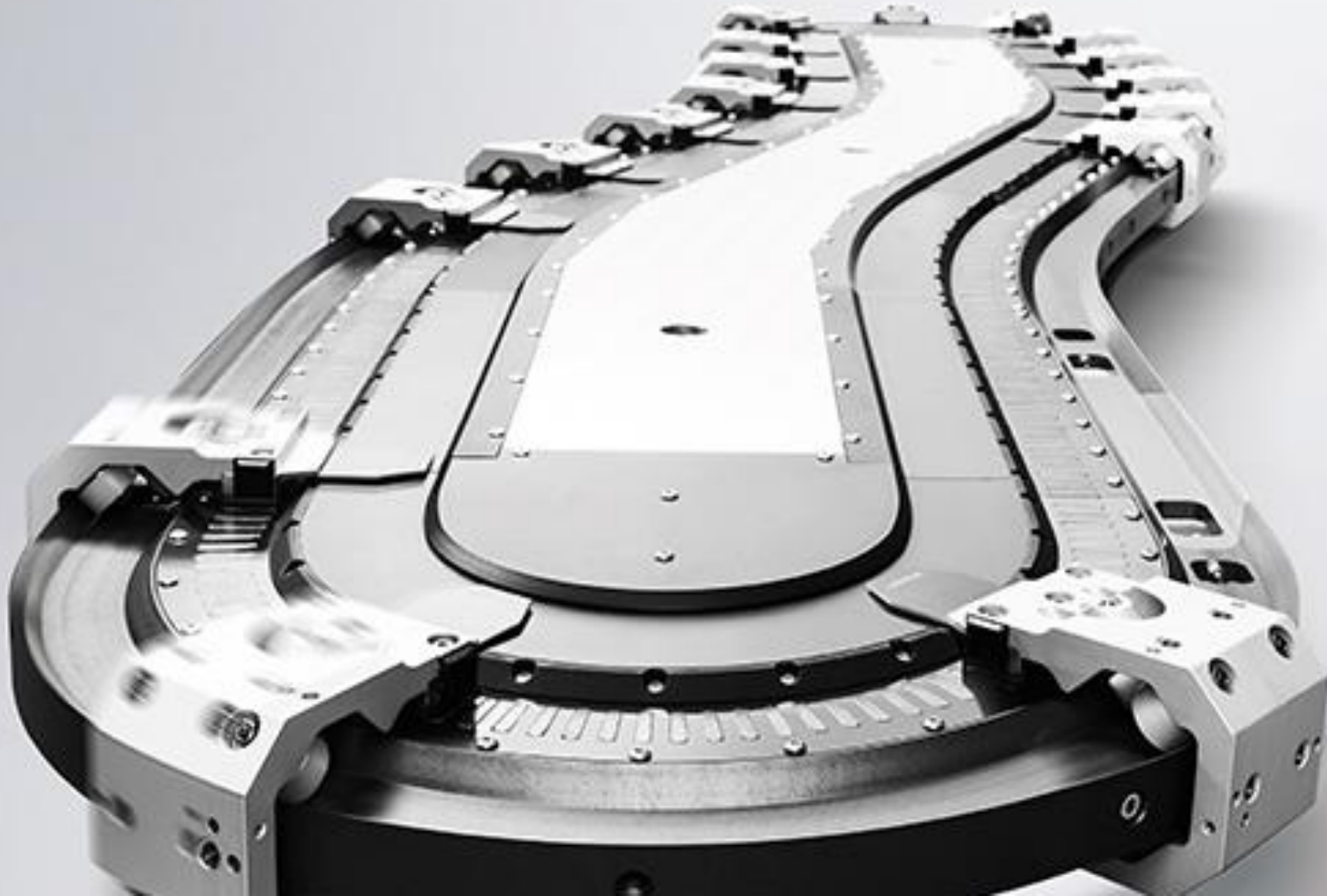


## **XTS TRANSPORT LAYER – a station based approach**

**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. License

## 1. Introduction

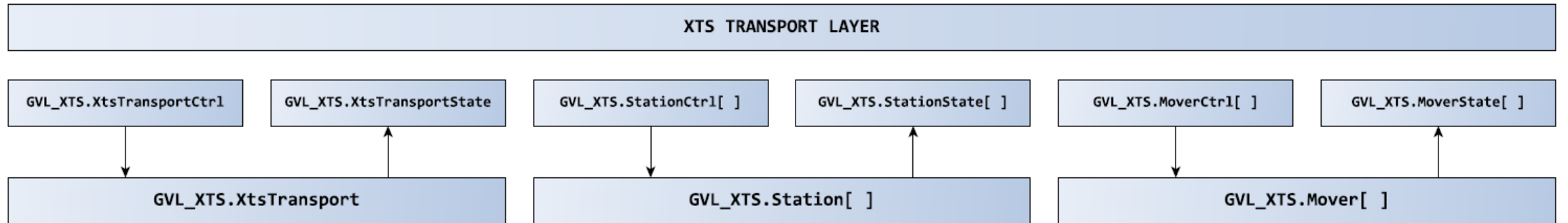
- This project collection is intended to convey the idea of a stand alone XTS transport layer to use in heterogen environments / applications.
- The main idea is that for every process a corresponding position on the xts exists.
- In order to reduce the amount of repetitive work when implementing a XTS into a machine, this project collection may help to put a transport layer in place
- 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 or for a certain task
- A transport layer shall have an interface for setting-up or clearing the CollisionAvoidance Group

## 1. Introduction

- The XTS transport system enables a flexible product transport for various processes.
- In combination with the Collision Avoidance library positioning of movers does not require extra monitoring of the axis
- 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, so 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 you to control XTS Transport Layer through fieldbus or network.
- Use of interface pointers for cross communication between classes.

## 1. Introduction

- designed for use with extern cyclic or non cyclic flow control
- station based approach with individual targeting 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)



## 1. Introduction

### Planning requirements for use of fb\_Station:

- Put the Modulo turn anywhere, **BUT NOT** within WaitPos, StopPos, ReleaseDistance of a station. The code does not support crossing the modulo turn within a station.
- The Use of LinkedList methods (AddTail, GetHead) requires thought about when the mover is entered into the target station.
- a. parallel stations for a process:
  - P1 uses XTS\_STN[1] to XTS\_STN[4] → rReleaseDistance of STN[4] shall be shortest, all other stations follow accordingly.
- b. 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: STATION\_MOVER\_SEND.
- c. deactivating stations:
  - Make sure the queue is empty before deactivating, since the waiting mover will hold up all the others in case of required deactivation while movers are in the queue:
  - handshake mover with E\_STATION\_CTRL.STATION\_MOVER\_SEND to new target station
  - Do not send any new mover to the station in question
    - disable station
    - preceeding stations continue workflow with changed ST\_STATION\_CTRL.nTargetStation

## 1. Introduction

### **Planning requirements for use of fb\_Station:**

- know thyself
  - all coordinates are modulo values, from station to station only forward, within station limits backward movement by use of negative nest offset or use of ST\_MOVER\_CTRL.
- IF move backwards you have to make sure that there is room for it  
--> distance between PosWait and PosStop

- XtsTransport
  - Access to CA group function blocks (interface pointer)
  - Access to Stations (interface pointer)
  - Access to Movers (interface pointer)
  - 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
  - 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
  - Access to movers for group commands
  - Get Group Info Data
  - Implements interface pointer

- 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
  - Interface pointer for access from:
    - TransportUnit
    - Station

- Station
  - Handshake mover transport with extern control
  - Close observation of movements with feedback to extern control
  - List for movers in queue
  - Cyclic interface for access from extern control
    - Ctrl (write): command and parameter
    - State (read): response to command and information about mover and queue
  - Uses Mover interface pointer

- Namespace GVL\_XTS
  - **Station**
    - Handshake with Process for mover transport
  - **XtsTransport**
    - Main command interface to extern control
  - **XpuCtrl**
    - Access to TcCOM Objects
    - Cyclic plausibility checks
  - **CaGroup**
    - Access to CA library
  - **MoverCtrl**
    - Access to MC and CA library

<<global>>	
<b>GVL_XTS</b>	
StationStart	ST_STATION_PARAMETER
Station	ARRAY [1..MAX_STATION] OF fb_Station
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

### 3. Design

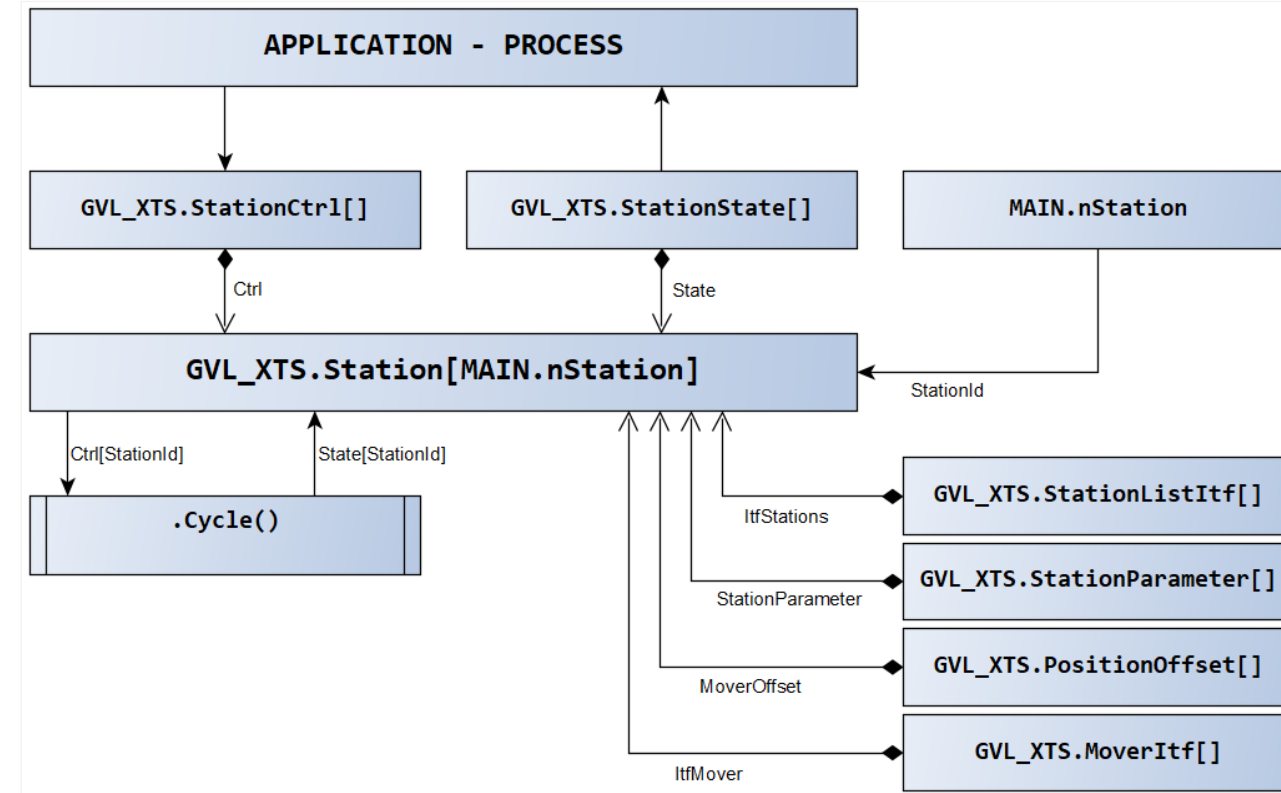
BECKHOFF

- GVL\_XTS.Station
  - fb\_Station[].Cycle
    - State machine for handshaking with extern control
      - Init (clears everything in station)
      - Enable
      - Mover Enter
      - Stop Position(s)
      - Mover Out
      - Empty
  - Control writes ticket for mover
    - MoverId
    - TargetStation
    - Mask
    - Offset

fb_Station	
_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
_stStationCtrl	ST_STATION_CTRL
_stStationState	ST_STATION_STATE
_lItfStation	REFERENCE TO ARRAY [1..MAX_STATION] OF I_Station_LinkedList
_lItfMover	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
_stMoveData	ST_MOVE_DATA
_Result	E_PROGRESS
_eState	E_PROGRESS
_nNest	UINT
_nMoverDetected	UINT
_nMoverInStation	UINT
_nTargetStation	UINT
_ix	UINT
_rModActPosFetch	LREAL
_stMsg	ST_Message
_eMessageLevel	E_MessageType
Ctrl	REFERENCE TO ARRAY [1..MAX_STATION] OF ST_STATION_CTRL {property}
lItfMover	REFERENCE TO ARRAY [1..MAX_MOVER] OF I_XtsTransport_Mover {property}
lItfStations	REFERENCE TO ARRAY [1..MAX_STATION] OF I_Station_LinkedList {property}
MessageLevel	e_messageType {property}
Mover	REFERENCE TO ARRAY [1..MAX_MOVER] OF AXIS_REF {property}
MoverOffset	REFERENCE TO ARRAY [1..MAX_STATION] OF T_NEST_OFFSET {property}
State	REFERENCE TO ARRAY [1..MAX_STATION] OF ST_STATION_STATE {property}
StationId	UINT {property}
StationParameter	REFERENCE TO ARRAY [1..MAX_STATION] OF ST_STATION_PARAMETER {property}
Check()	BOOL
Cycle()	
DelBitWord(...)	WORD
GetBitWord(...)	BOOL
Init()	e_progress
LogState(...)	
MoveData()	
MoverOut()	
SetBitWord(...)	WORD

### 3. Design

- GVL\_XTS.Station
  - nStation index is passed as value from caller
  - Global datafields are passed as references (REF=) into fb\_Station 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 (StopPos[])
    - ItfMover: interface pointer to CA movements





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



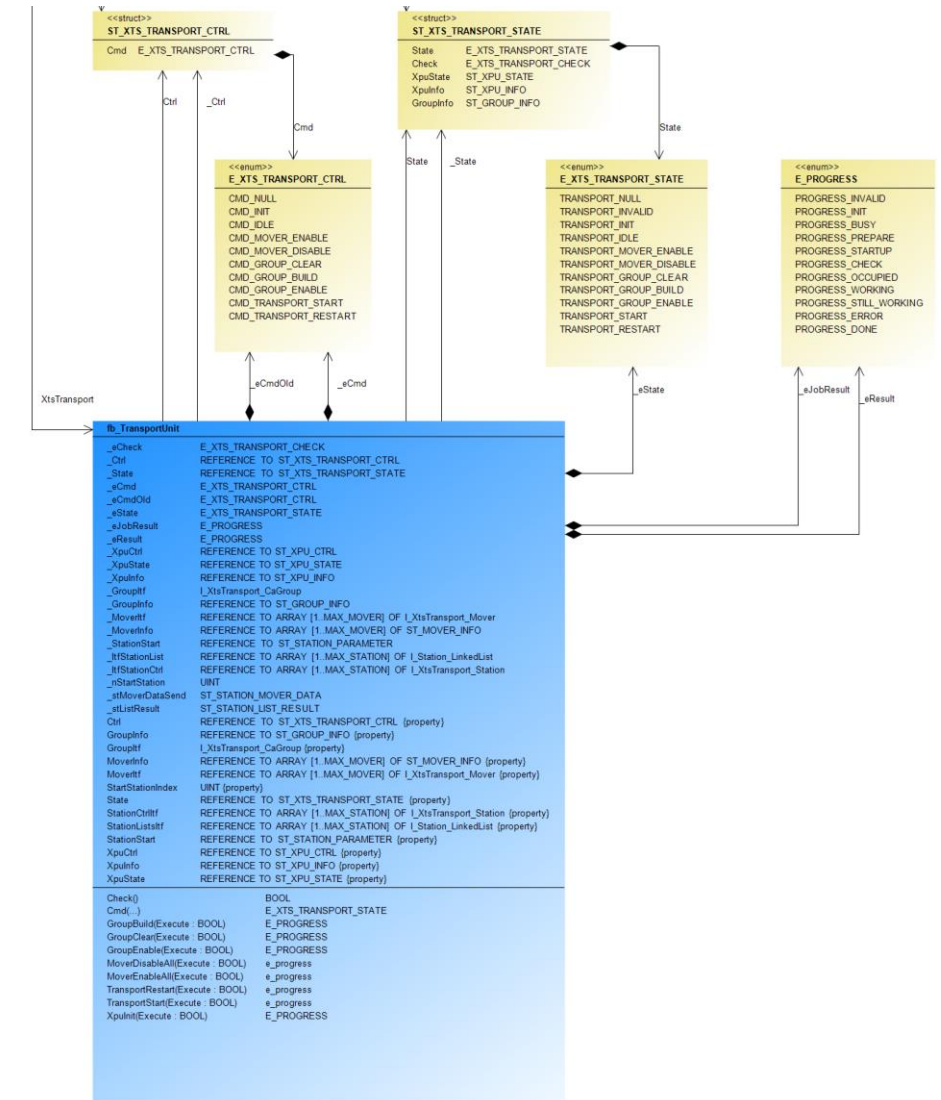
- GVL\_XTS.Station
  - State[nStation] : ST\_STATION\_STATE
    - eState :
      - Enumeration for active station state, Ctrl has to react to
  - nMask :
    - Bitmask for active PosStop[] (nest)
  - nMoverId :
    - Active mover index in station
  - rMoverModPos :
    - Modulo position of active mover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

- GVL\_XTS.StationParameter
  - 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 has to stop at in XtsStation
  - rPosStop[] :
    - Relative to rPosWait

### 3. Design

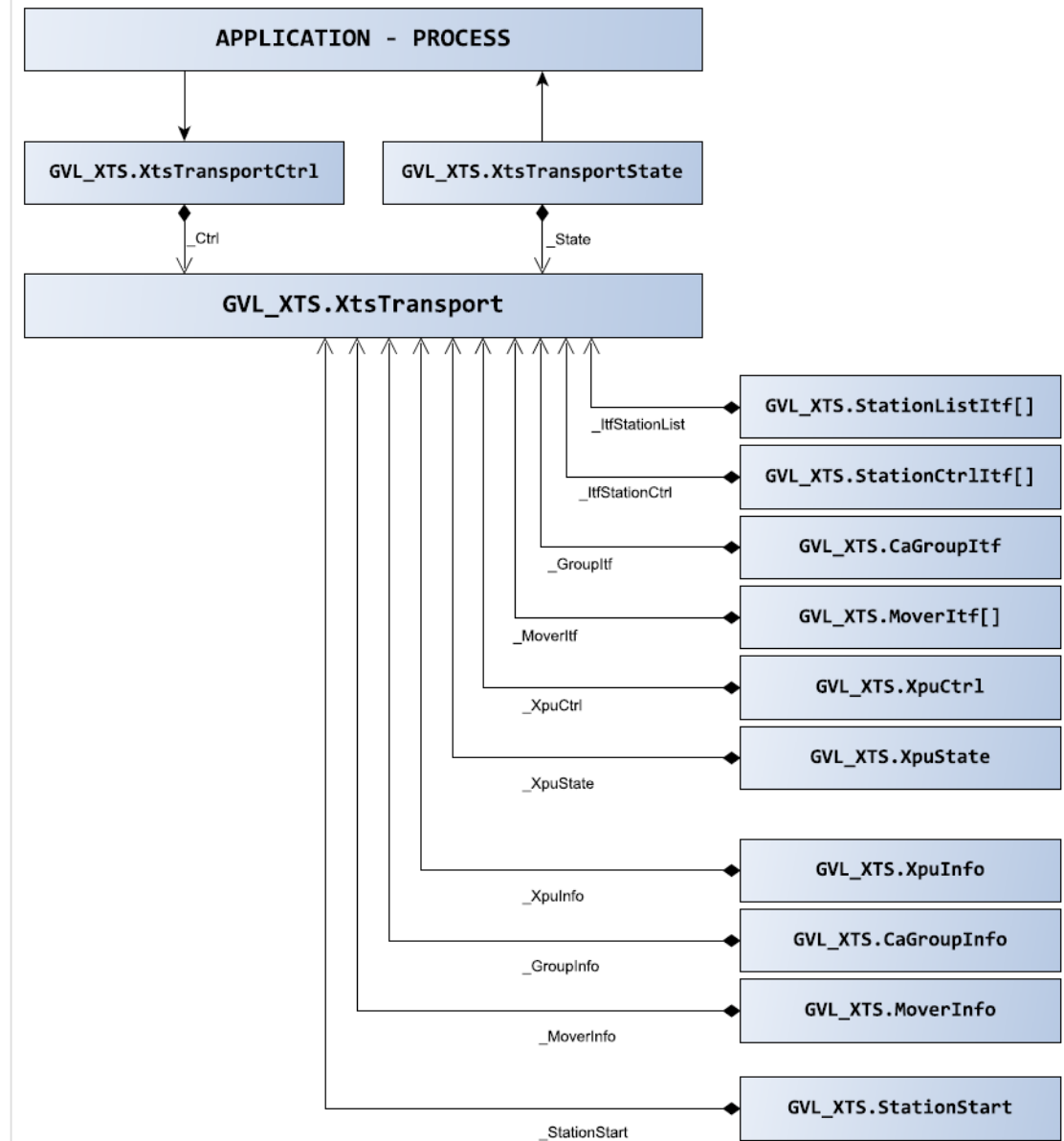
#### ■ TransportUnit

- Fb\_TransportUnit():
  - Top level control of XtsTransport
  - Cycle check for change of command:
    - E\_XTS\_TRANSPORT\_CTRL.
      - CMD\_INIT
      - CMD\_IDLE
      - CMD\_MOVER\_ENABLE
      - CMD\_MOVER\_DISABLE
      - CMD\_GROUP\_CLEAR
      - CMD\_GROUP\_BUILD
      - CMD\_GROUP\_ENABLE
      - CMD\_TRANSPORT\_START



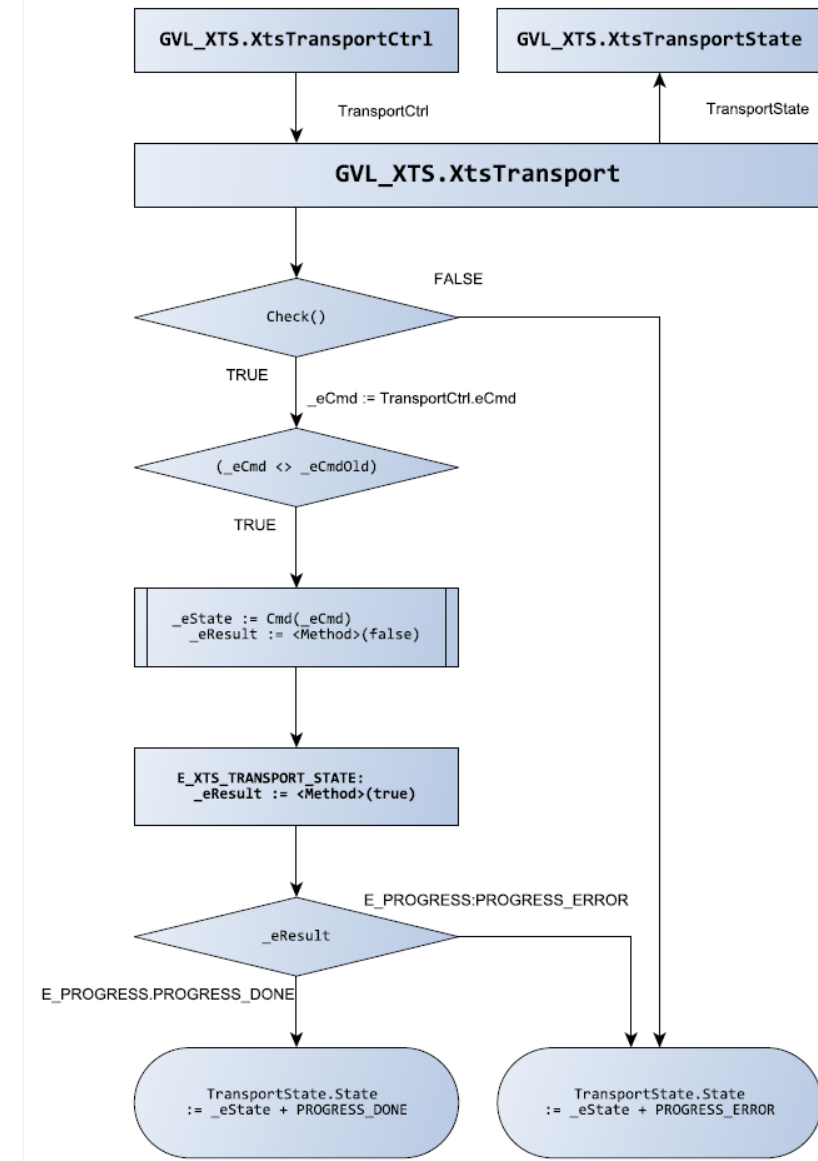
### 3. Design

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



## 3. Design

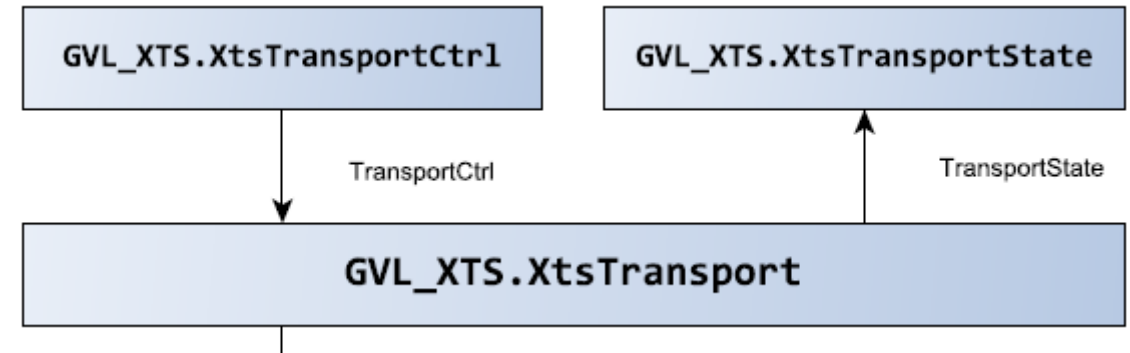
- TransportUnit
  - Fb\_TransportUnit():
    - Change of command triggers execution
    - Execution result is added to state
    - Extern control needs to react to BUSY, DONE or ERROR



### 3. Design

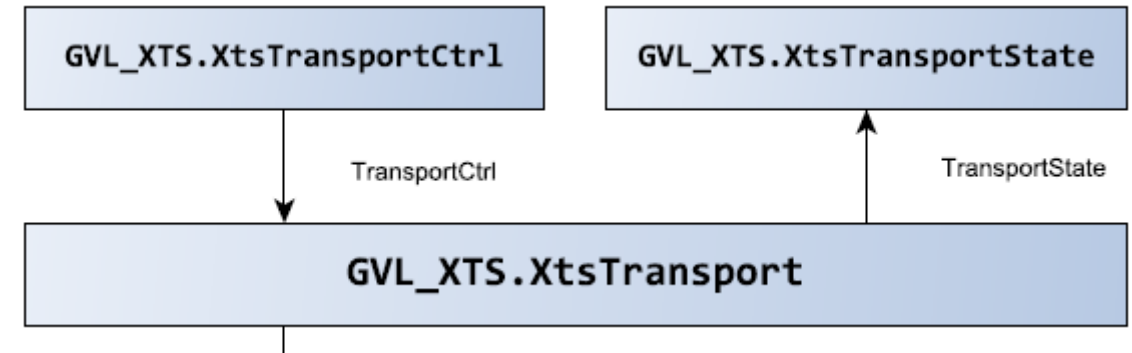
- TransportUnit
  - GVL\_XTS.XtsTransportCtrl:  
ST\_TRANSPORT\_UNIT\_CTRL
    - Struct for commanding  
FB\_TransportUnit
  - eCmd : E\_XTS\_TRANSPORT\_CTRL

```
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

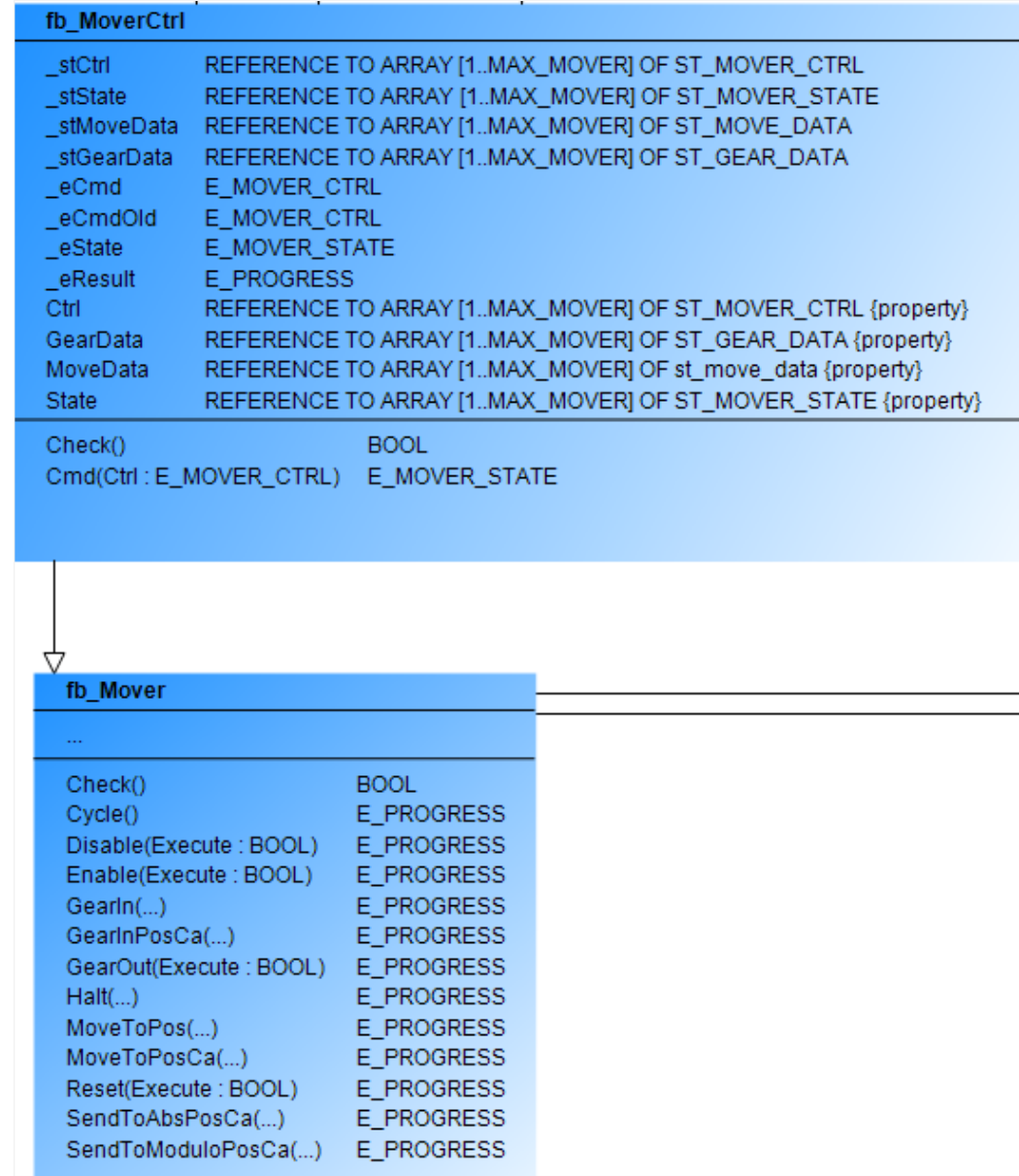
- TransportUnit
  - GVL\_XTS.XtsTransportState:  
ST\_TRANSPORT\_UNIT\_STATE
  - State: combines active command and result
  - Check: cyclic pointer checks
  - XpuState: state from fb\_Xpu
  - XpuInfo: cyclic plausibility checks to  
TcCOM Objects
  - GroupInfo: cyclic information from  
FB\_CaGroup



```
ST_XTS_TRANSPORT_STATE -> X
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

- fb\_MoverCtrl:
  - Inherits fb\_Mover
    - Access to MC function blocks in library
    - Implements Interface for use in other classes
  - Contains cyclic interface
    - Ctrl datafield for setting commands
    - State data field for checking responses
    - Parameter datafields for using motion functions

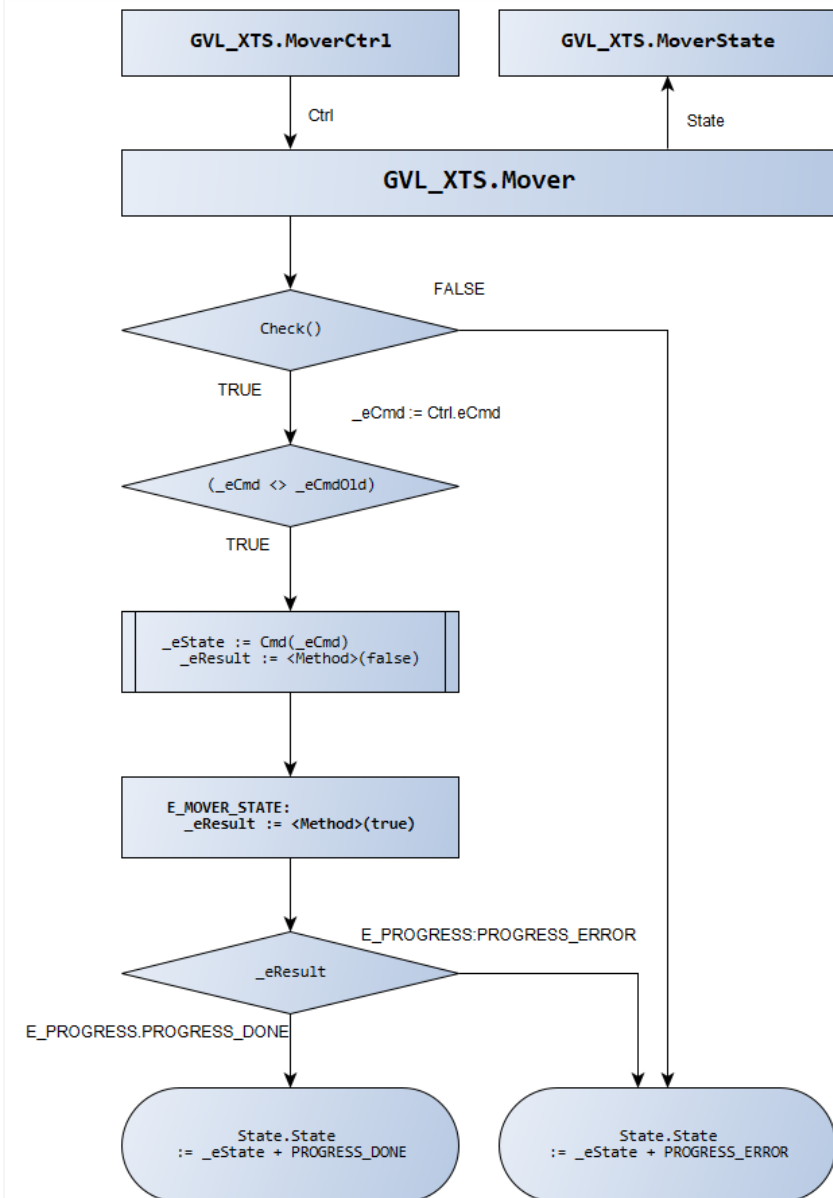




### 3. Design

BECKHOFF

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



### 3. Design

BECKHOFF

- 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

<<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

- fb\_Xpu:
  - Class for interacting with XTS ProcessingUnit
  - Xpulinic()
    - Connects to OTCIDs of XTS TcCOM Objects
  - Cycle
    - Plausibility checks, get module info data
  - ModuleInfoData, used in Cycle

fb_Xpu	
...	
Cycle(...)	E_PROGRESS
GetEnvironment()	I_TcIoXtsEnvironment
IdDetectionModeToString()	STRING(20)
ModuleInfoData(Enable : BOOL)	E_PROGRESS
MoverPositionAssignmentToString()	STRING(20)
OpModeToString()	STRING(20)
Xpulinic(...)	E_XPU_INIT



### 3. Design

- fb\_XpuCtrl:
  - Wraps cyclic execution of fb\_Xpu
  - Cyclic check for command change
  - Commands:

```
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	
_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\_XpuCtrl:
  - 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
20
```

## 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			



### XTS\_TRANSPORT\_LAYER project

MIT License

Copyright (c) 2024 HAUD

Permission is hereby granted, free of charge, to any person obtaining a copy of this software and associated documentation files (the "Software"), to deal in the Software without restriction, including without limitation the rights to use, copy, modify, merge, publish, distribute, sublicense, and/or sell copies of the Software, and to permit persons to whom the Software is furnished to do so, subject to the following conditions:

**The above copyright notice and this permission notice shall be included in all copies or substantial portions of the Software.**

THE SOFTWARE IS PROVIDED "AS IS", WITHOUT WARRANTY OF ANY KIND, EXPRESS OR IMPLIED, INCLUDING BUT NOT LIMITED TO THE WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE AND NONINFRINGEMENT. IN NO EVENT SHALL THE AUTHORS OR COPYRIGHT HOLDERS BE LIABLE FOR ANY CLAIM, DAMAGES OR OTHER LIABILITY, WHETHER IN AN ACTION OF CONTRACT, TORT OR OTHERWISE, ARISING FROM, OUT OF OR IN CONNECTION WITH THE SOFTWARE OR THE USE OR OTHER DEALINGS IN THE SOFTWARE.