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IWES 2021

Autogeneration of code for Middleware: benefits of Model Based Design approach

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Agenda

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Introduction

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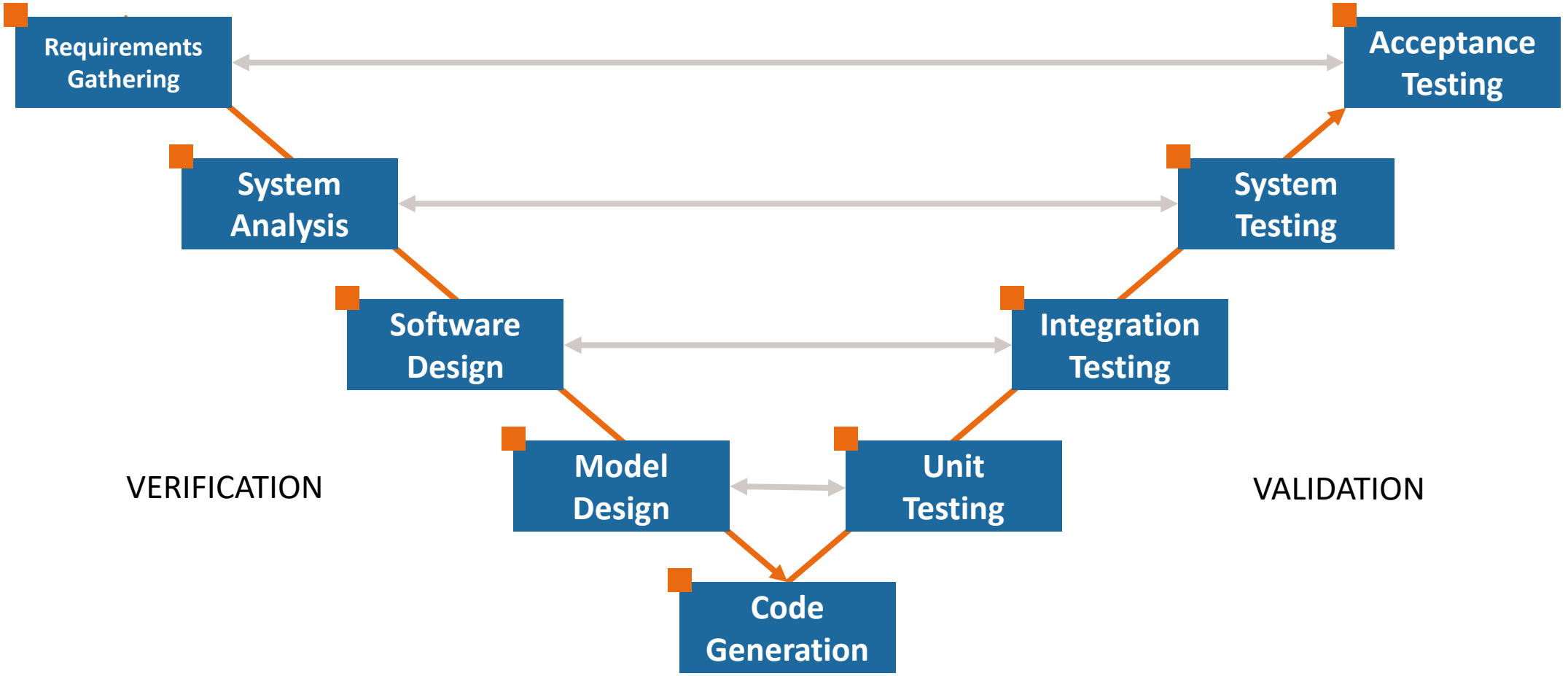
Model Based Design

The **MBD** approach is usually applied to the development of **Application SW Components** (control logics, monitoring, diagnostics, recovery), while, traditionally, the development of the other SW layers is *hand-coded*.

Todays' increasing demand of safety trusted SW deeply impacts on the development process in order to be compliant with **Safety Standards**, hence with **coding guidelines**, **coverage** and **traceability requirements for all SW layers.**

Introduction

MBD AND THE V-MODEL



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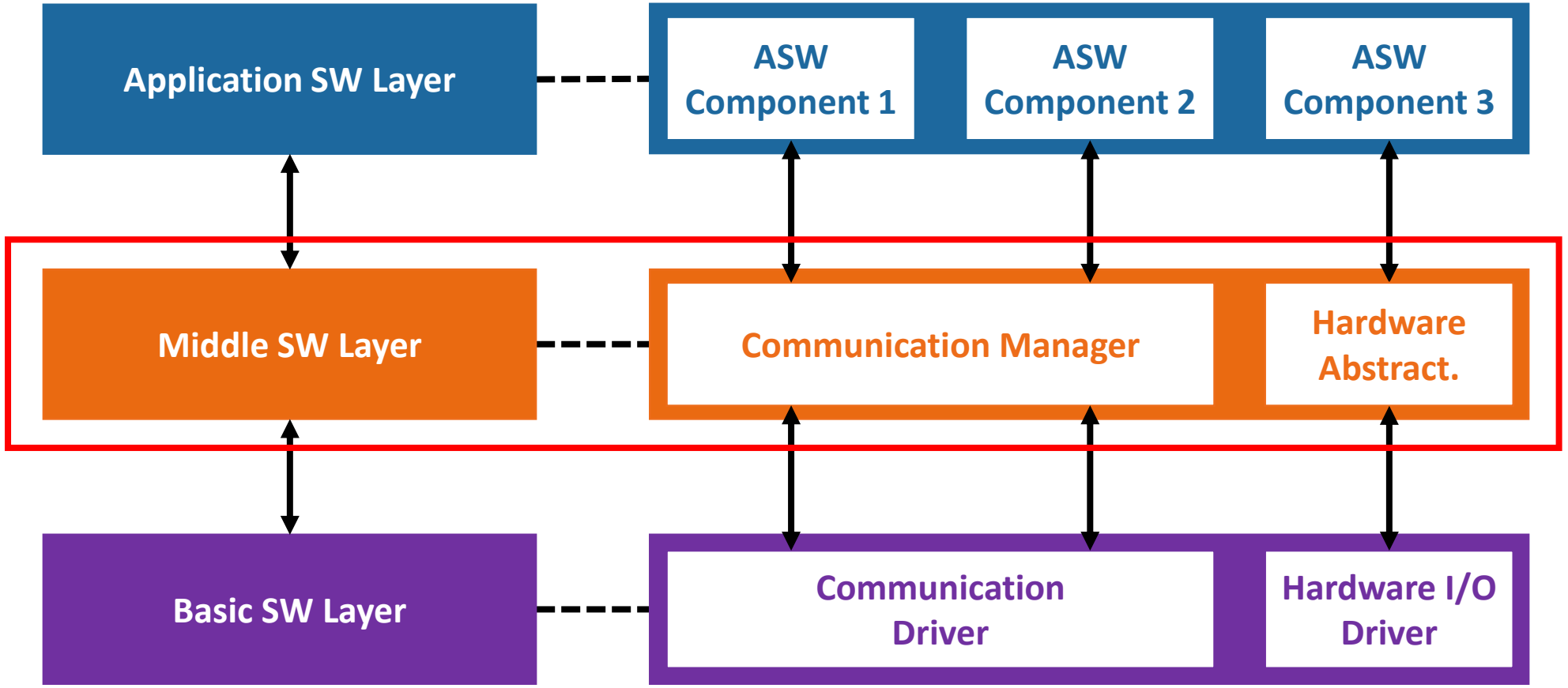
1. Architecture

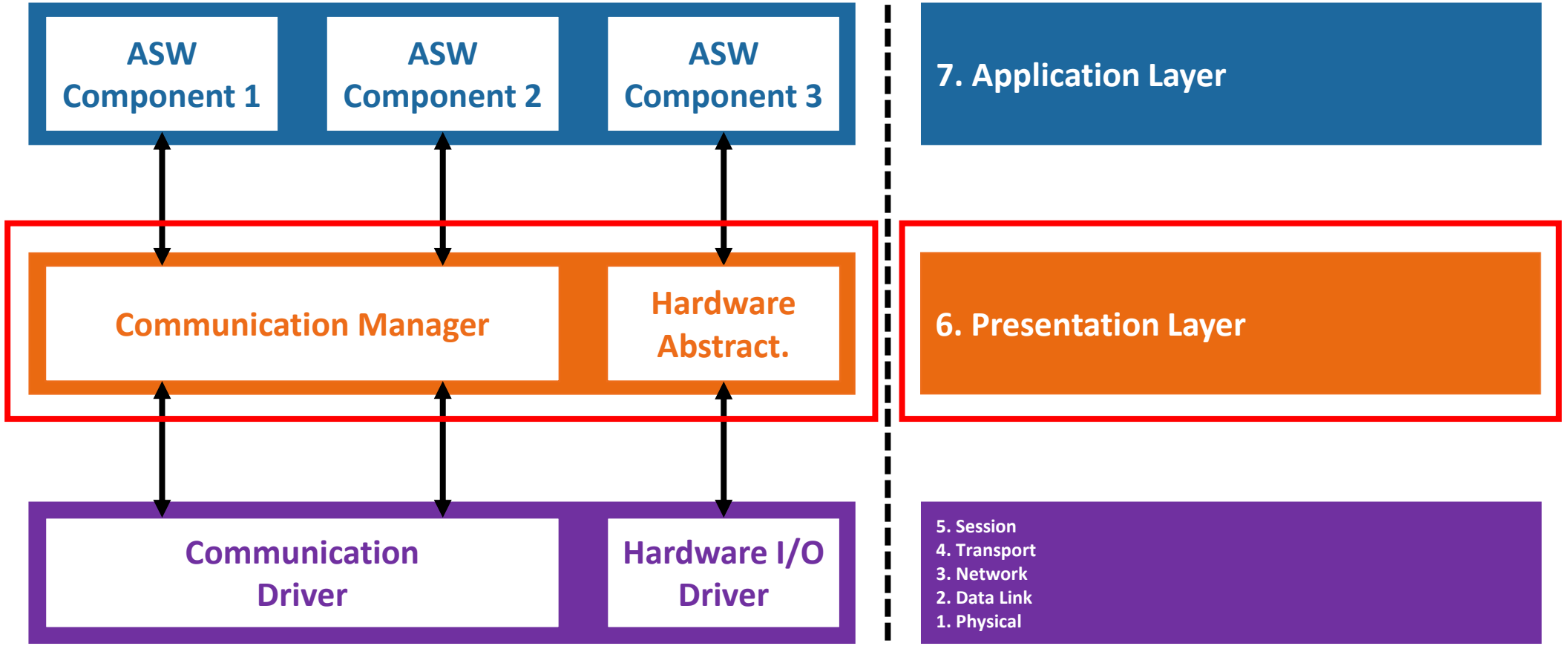
1. Architecture

Code Generation for Middle SW Layer



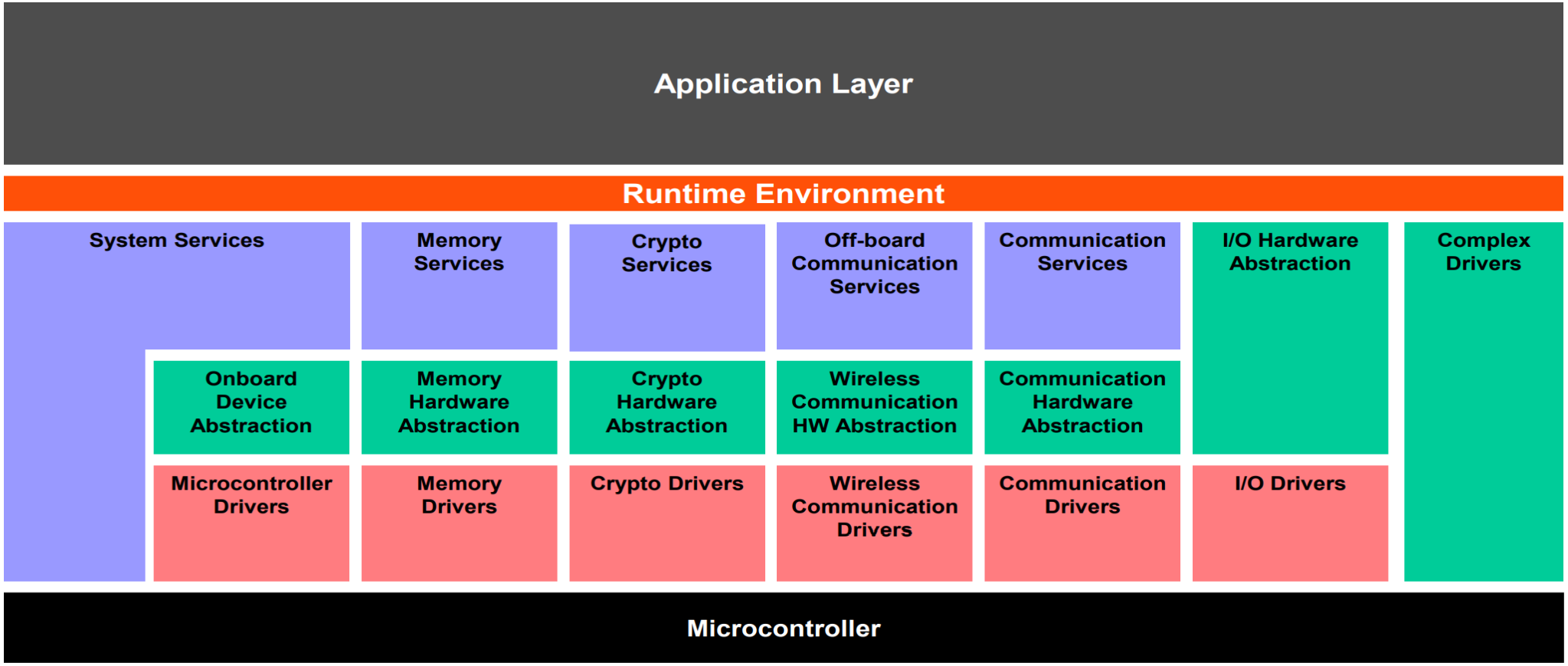
1. Architecture

ISO/OSI Comparison



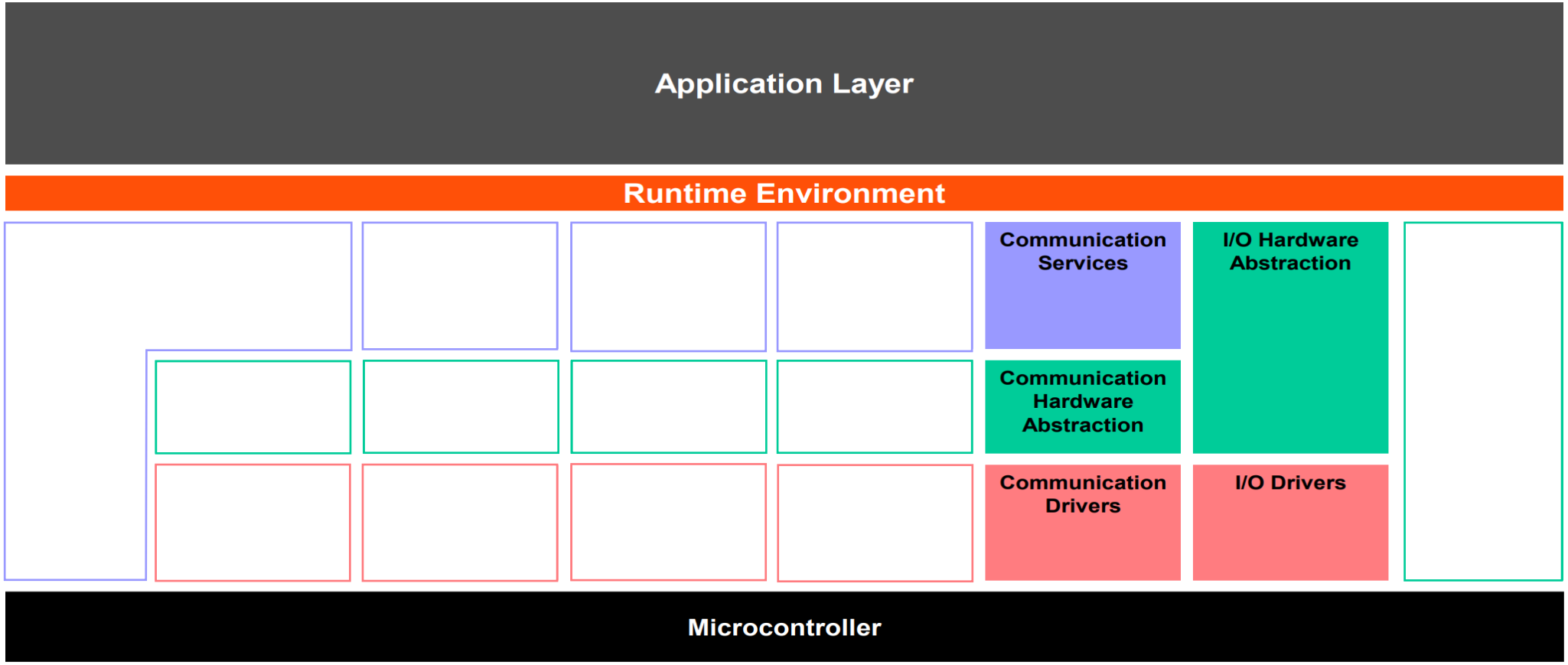
1. Architecture

AUTOSAR COMPARISON



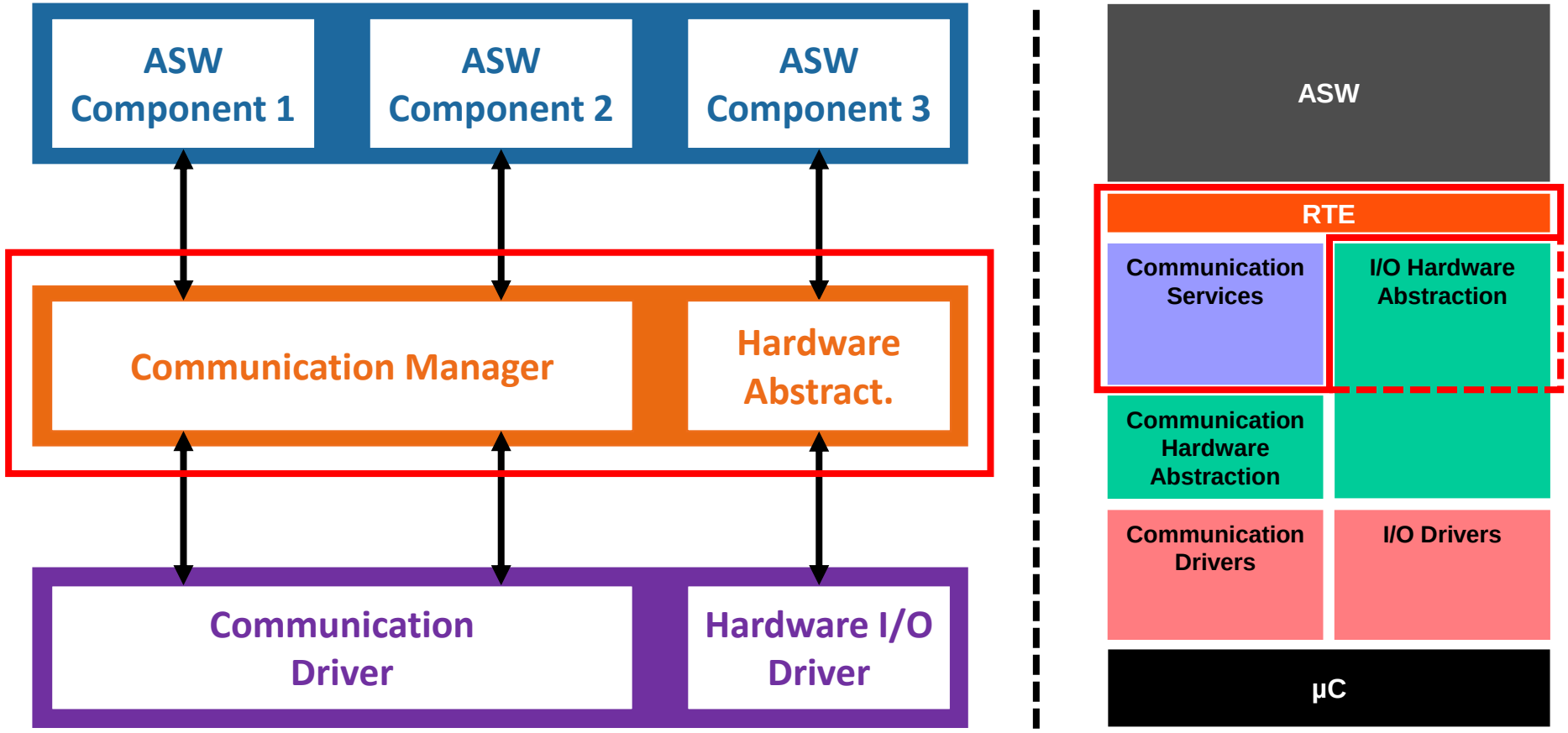
1. Architecture

AUTOSAR COMPARISON



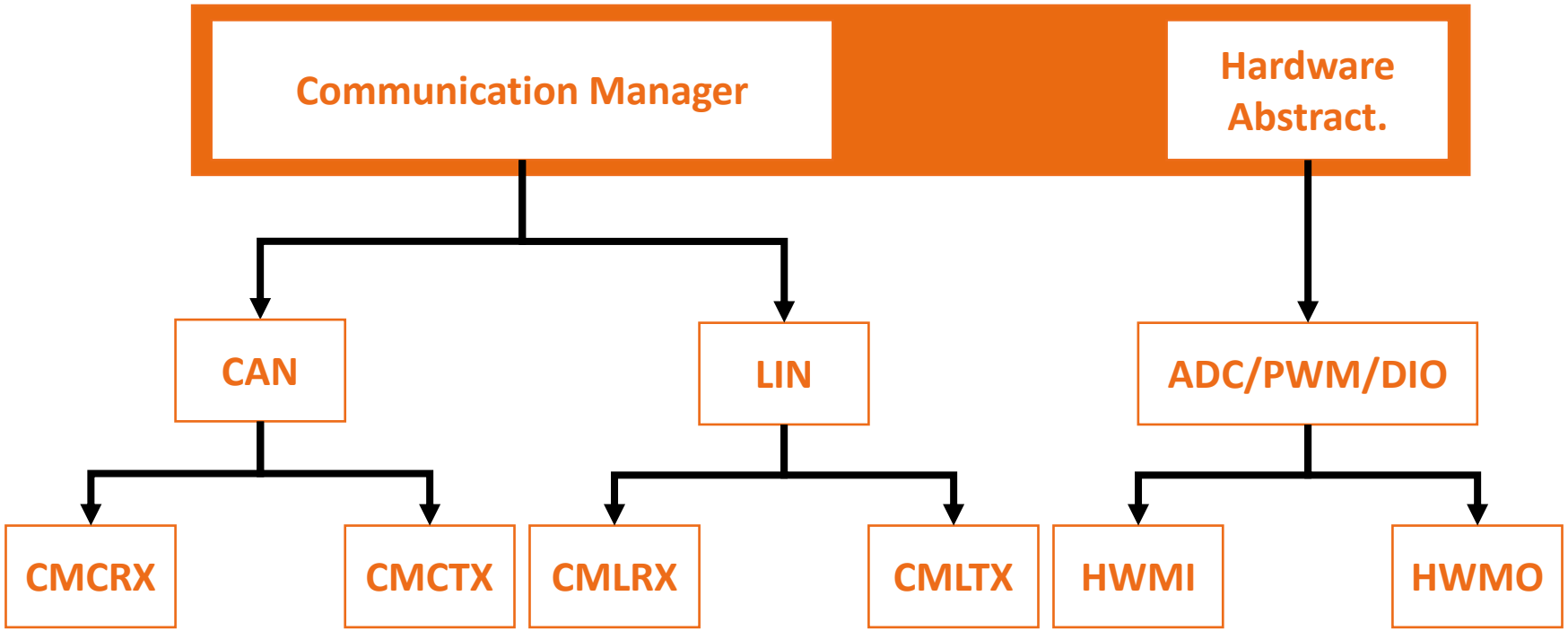
1. Architecture

AUTOSAR COMPARISON



1. Architecture

Middleware Components



1. Architecture

Middleware Components: CAN

CMCRX

Communication Manager CAN Receive

This module is responsible for:

- Scheduling of CAN frames processing;
- PDU info gathering;
- Frame data-field unpack (single and multi-packet);
- Data integrity verification (Checksum, CRC, range check);
- Time-out management;
- Recovery;
- Broadcast to ASW.

CMCTX

Communication Manager CAN Transmit

This module is responsible for:

- Packaging of ASW variables in frame data-field (single and multi-packet);
- Recovery;
- Data encryption for integrity checks (Checksum, CRC);
- PDU info update;
- Enabling/disabling of CAN frames transmission.

1. Architecture

Middleware Components: LIN

CMLRX

Communication Manager LIN Receive

This module is responsible for:

- Scheduling of LIN frames processing;
- PDU info gathering;
- Frame data-field unpack;
- Data integrity verification (Checksum, CRC, range check);
- Time-out management;
- Recovery;
- Broadcast to ASW.

CMLTX

Communication Manager LIN Transmit

This module is responsible for:

- Packaging of ASW variables in frame data-field;
- Recovery;
- Data encryption for integrity checks (Checksum, CRC);
- PDU info update;
- Enabling/disabling of LIN frames transmission.

1. Architecture

Middleware Components: HW

HWMI

Hardware Manager Input

This module is responsible for:

- Conversion of the acquired analog and digital input signals;
- Broadcast to ASW.

HWMO

Hardware Manager Output

This module is responsible for:

- ASW variables conversion;
- Output of Digital, PWM and H-Bridge signals to control actuators and motors.

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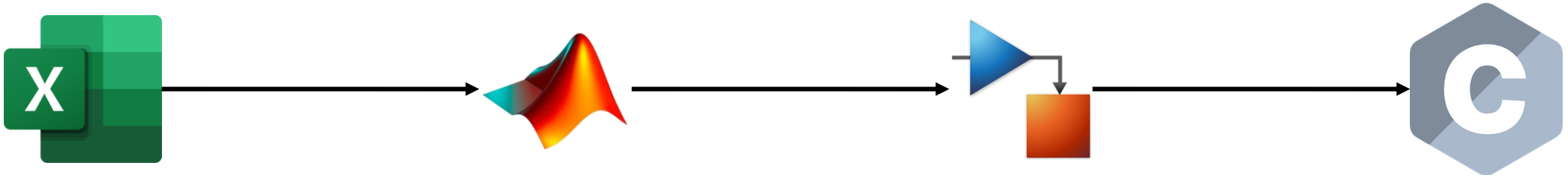
2. Workflow

2. Workflow

Process steps and Artefacts



Data sheet:

- CAN/LIN
- ADC
- PWM
- DIO

Scripting:

- Data dictionary creation
- Modelling automation

Model Based Design:

- Code generation
- ISO-26262 Qualification Process

Result:

- Safety-trusted C code
- ISO-26262 artefacts

2. Workflow

Data sheet Content: Interface definition

The starting point for the development process is an excel file which includes a detailed description of the communication manager interface and the ECU hardwired interface.
High level information are collected in the following files:

- **Ifc_ComRx.xlsx/Ifc_ComTx.xlsx** – CAN and LIN frames info, including detailed description of variables in the data section of each frame;
- **Ifc_HWIn.xlsx/Ifc_HWOut.xlsx** – Pinout-based description of all input and output signals (ADC, PWM, DIO).

	A	B	C	D	E	
1	BUS_Type	BUS_Name	PDU_ID	PDU_IDOnBus	PDU_Name	PD
2	CAN	PWTDB	1	0xC00003A	TSC1_3A	So
3	CAN	PWTDB	2	0xC0000B2	TSC1_B2	So
4						

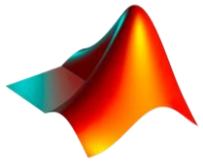
PDU Info

	A	B	C	D	E
1	PDU_Name	DATA_SWVarNameArr	DATA_SWVarDescription	DATA_StartBitArr	DATA_LengthAr
2	TSC1_3A	ComRx_stTSC13AEngOcm_u8	Source node: RADAR. J1939-71, PGN 0, SPN 695.	0	2
3	TSC1_3A	ComRx_stTSC13AOcmPrio_u8	Source node: RADAR. J1939-71, PGN 0, SPN 897.	4	2
4	TSC1_3A	ComRx_pcTSC13AEngTrqLim_fx8	Source node: RADAR. J1939-71, PGN 0, SPN 518.	24	8
5	TSC1_3A	ComRx_stTSC13ATransmRate_u8	Source node: RADAR. J1939-71, PGN 0, SPN 3349.	32	3
6	TSC1_3A	ComRx_stTSC13ACtrlPurp_u8	Source node: RADAR. J1939-71, PGN 0, SPN 3350.	35	5
7	TSC1_3A	ComRx_pcTSC13AEngTrqLimHR_fx8	Source node: RADAR. J1939-71, PGN 0, SPN 4191.	40	4
8	TSC1_3A	ComRx_stTSC13AMsgCnt_u8	Source node: RADAR. J1939-71, PGN 0, SPN 4206.	56	4
9	TSC1_3A	ComRx_stTSC13AMsgCks_u8	Source node: RADAR. J1939-71, PGN 0, SPN 4207.	60	4
10	TSC1_B2	ComRx_stTSC1B2EngOcm_u8	Source node: ABS. J1939-71, PGN 0, SPN 695.	0	2
11	TSC1_B2	ComRx_stTSC1B2OcmPrio_u8	Source node: ABS. J1939-71, PGN 0, SPN 897.	4	2
12	TSC1_B2	ComRx_pcTSC1B2EngTrqLim_fx8	Source node: ABS. J1939-71, PGN 0, SPN 518.	24	8
13	TSC1_B2	ComRx_stTSC1B2MsgCnt_u8	Source node: ABS. J1939-71, PGN 0, SPN 4206.	56	4
14	TSC1_B2	ComRx_stTSC1B2MsgCks_u8	Source node: ABS. J1939-71, PGN 0, SPN 4207.	60	4
15					

DATA Specification

2. Workflow

MATLAB: AUTOMATION SCRIPTS

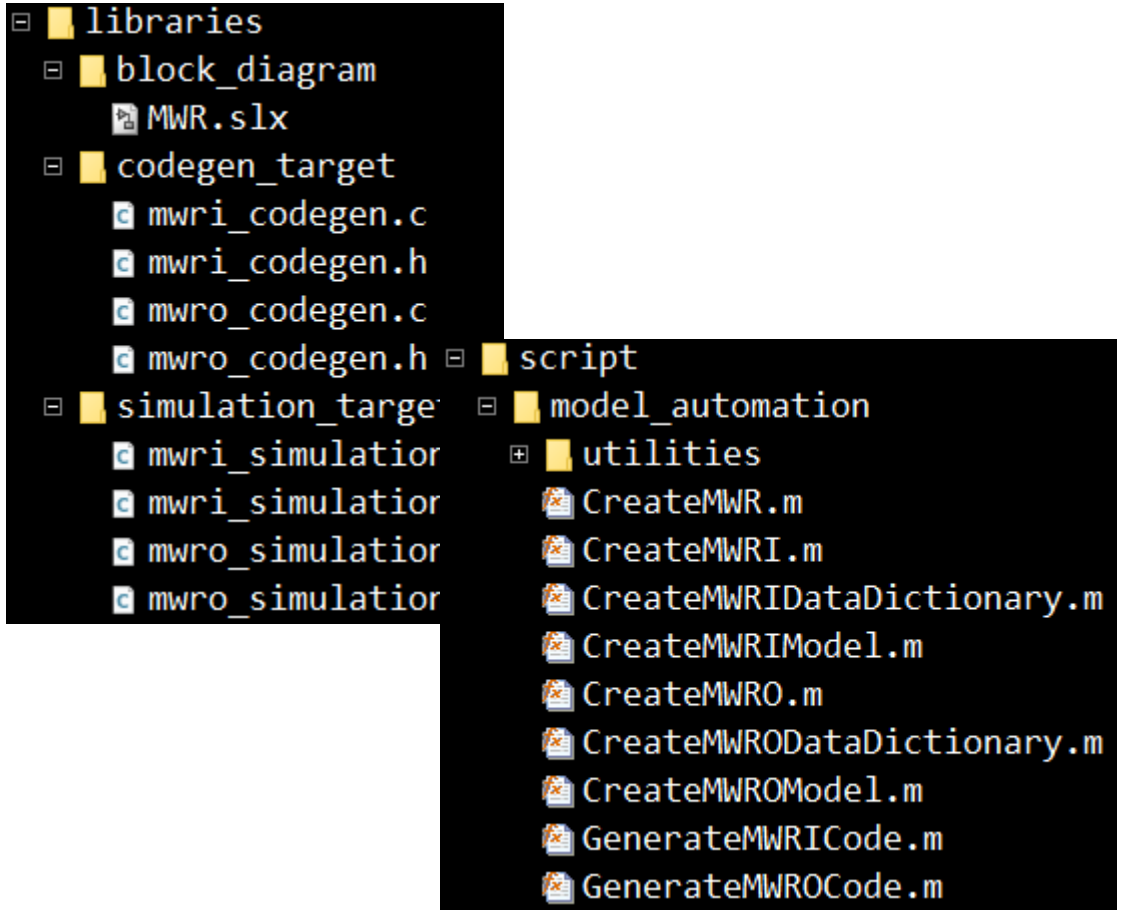


At this step the goal is to produce the models and the related data dictionaries via an automatic process. To achieve this task, we developed several scripts, functions and libraries (for block-diagram, simulation and code generation).

The development was carried out according to:

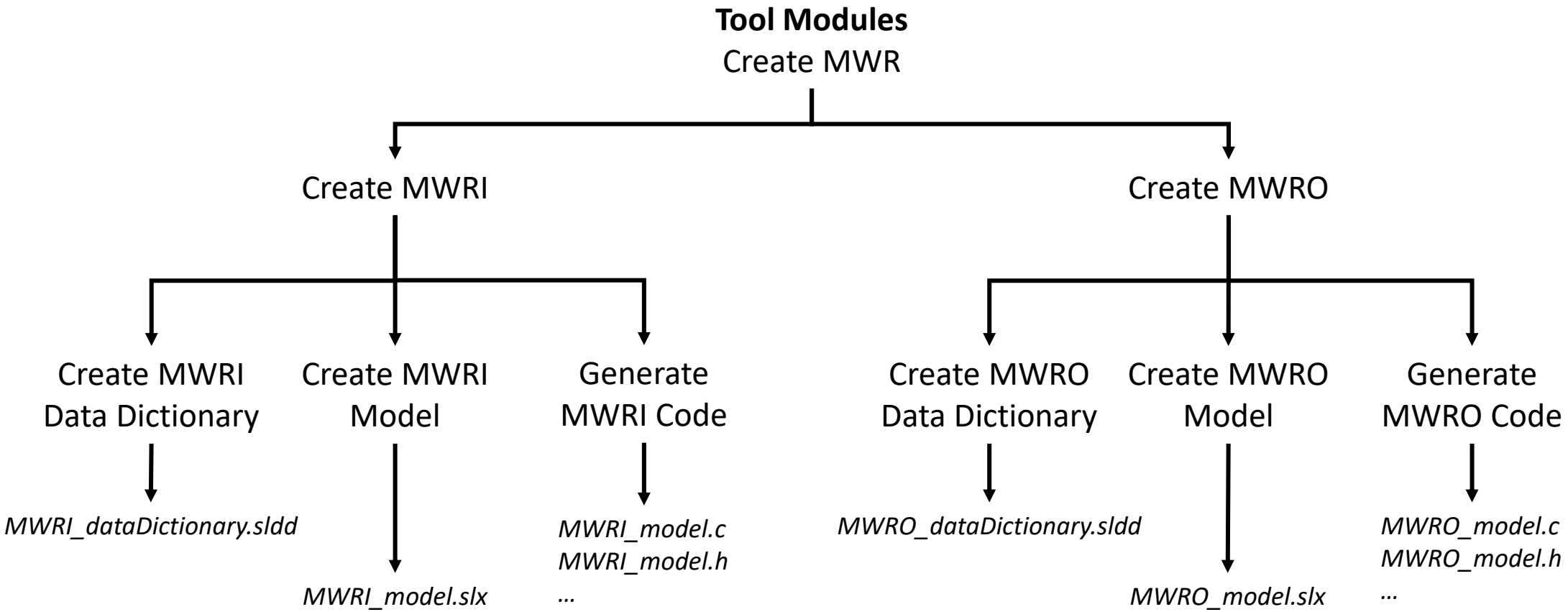
- **modularity**
- **repeatability**
- **portability**

In the next slide the hierarchical structure of the automation tool is displayed.



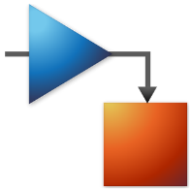
2. Workflow

MATLAB: AUTOMATION SCRIPTS



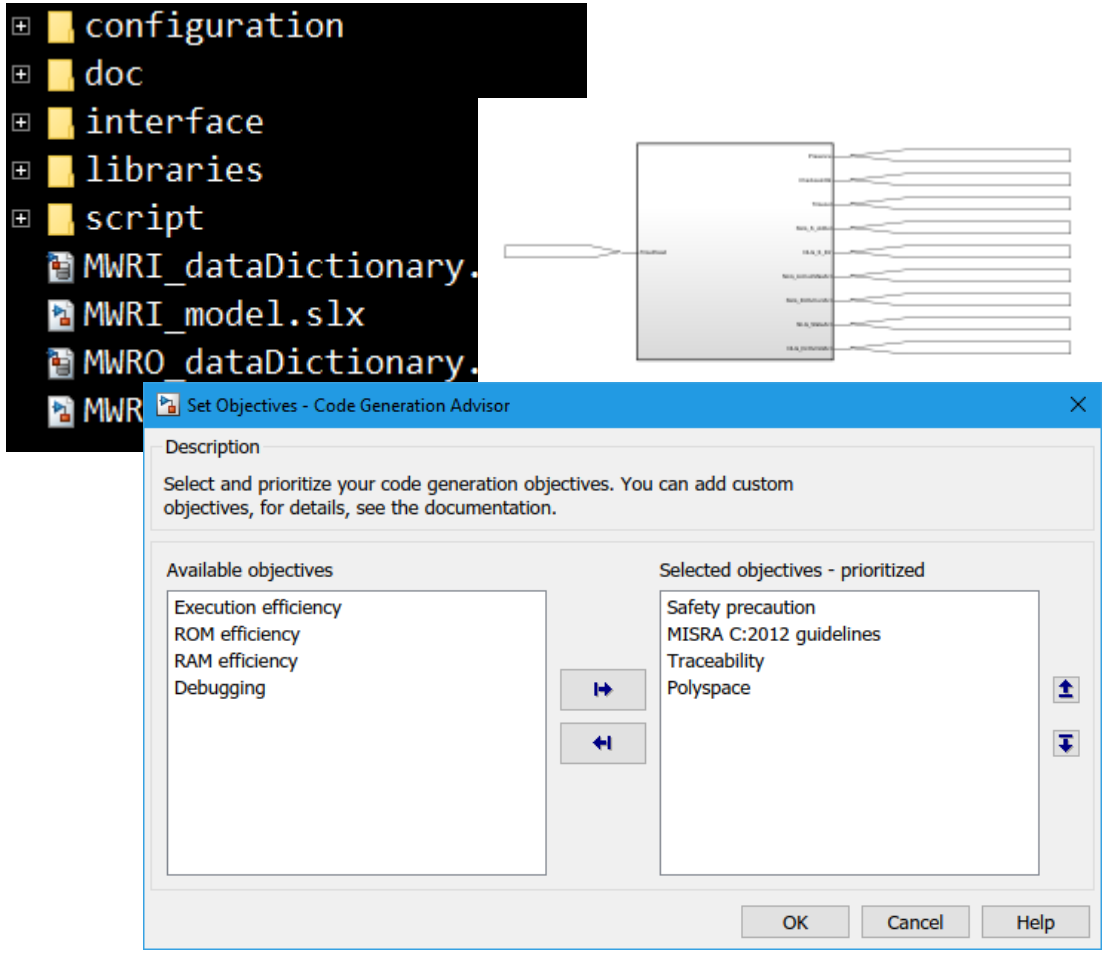
2. Workflow

SIMULINK: MODELS AND DATA DICTIONARIES



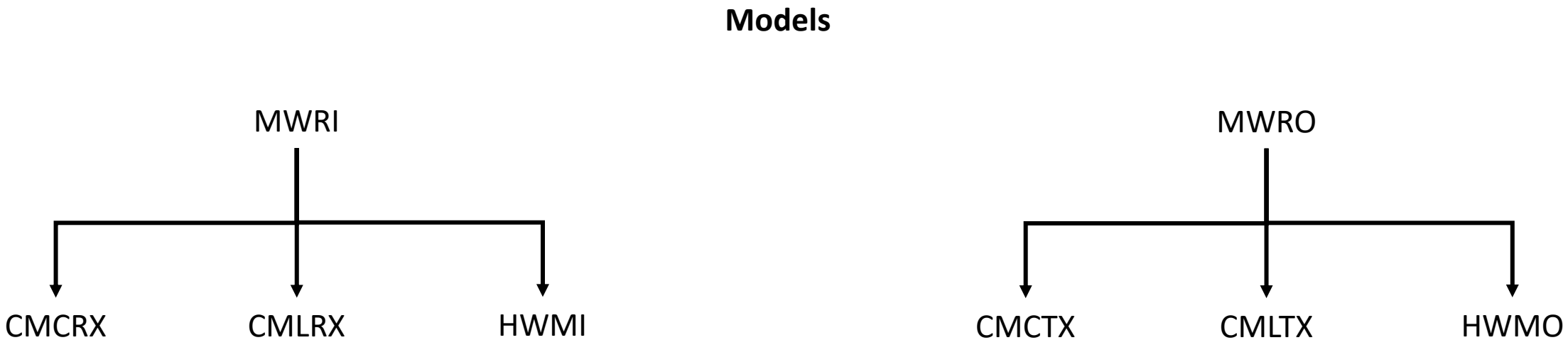
After the automation process, models and data dictionaries are ready to be used for simulation, code-generation and safety verification.
The models have been configured in compliance with the following standards:

- **Safety (ISO-26262)**
- **MISRA C: 2012 guidelines**
- **Traceability**
- **Polyspace**



2. Workflow

SIMULINK: MODELS' HIERARCHY



Each model communicates with basic software via dedicated API's in order to get raw data from buses and I/O pins.

In case of timeout or range check failure raw data are replaced with recovery values before being broadcasted to application layer for what concern MWRI, to basic software for what concern MWRO.

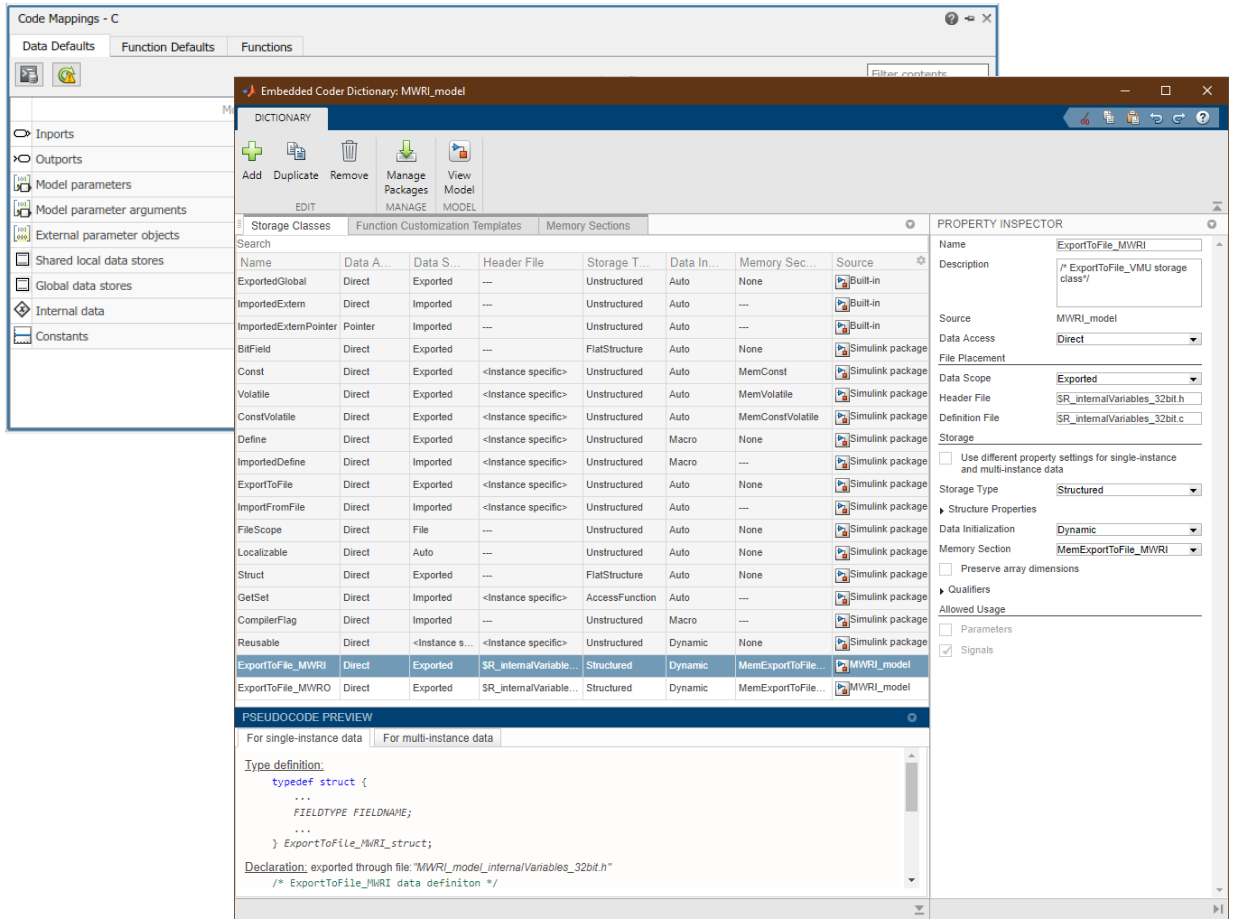
2. Workflow

SIMULINK: CODE GENERATION

The code generation objective for **safety precaution** deeply impacts on the automatic code optimization carried out by Simulink Coder and Embedded Coder. A large number of *"optimizable"*, hence *"unnecessary"*, variables are generated.

So, an important part of the Embedded Coder Dictionary configuration consists of defining **custom storage classes** and **custom memory sections**: we have been able to automatically manage memory allocation for model internal variables and calibrable parameters.

In the definition of a memory section, basing on the interface with basic software, we defined all the statements to be used for memory allocation (pre-compiling directives) and also the way the related variables should have been grouped (i.e. group per data-type for compact data allocation).



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3. Example: Rx CAN Frame

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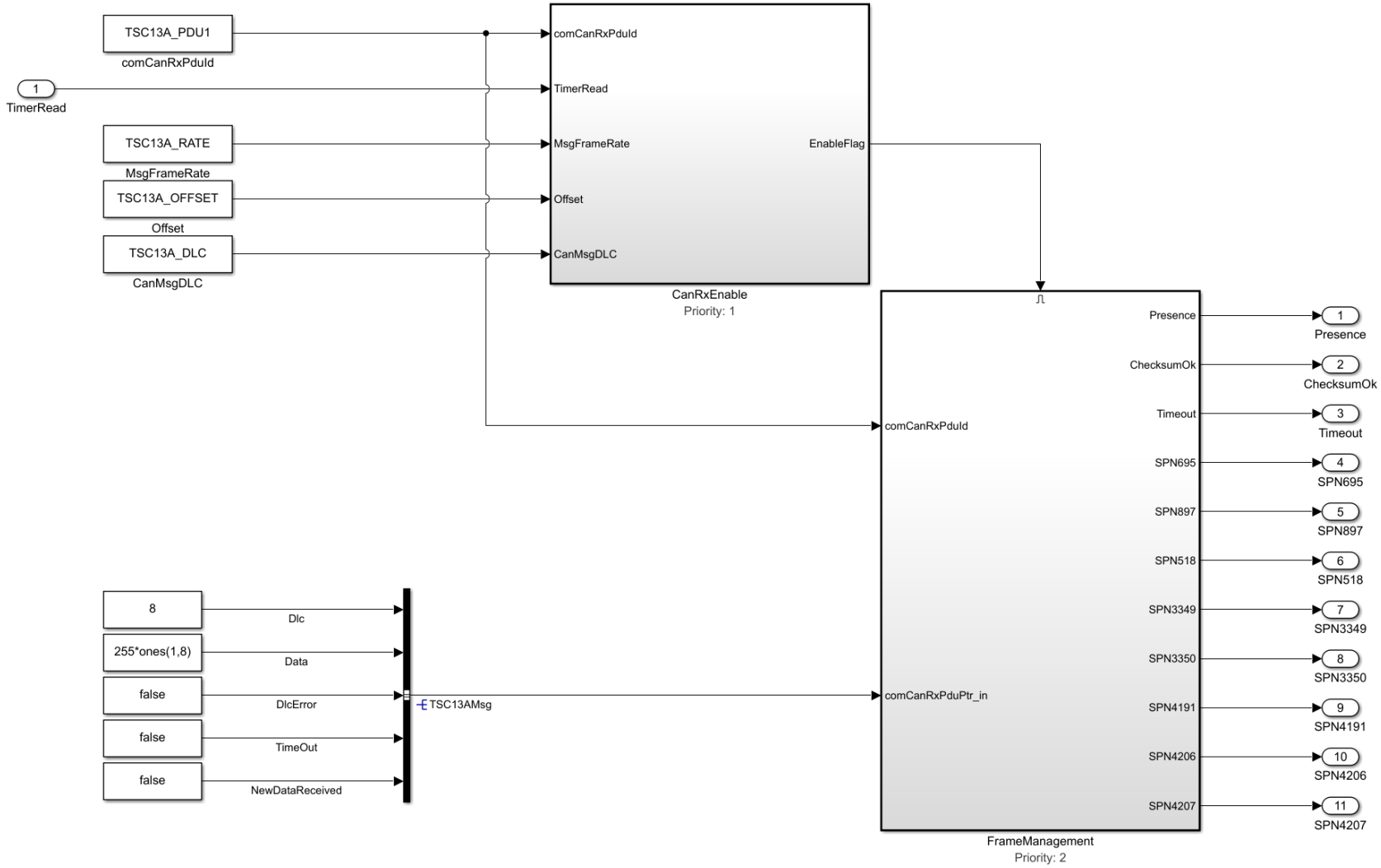
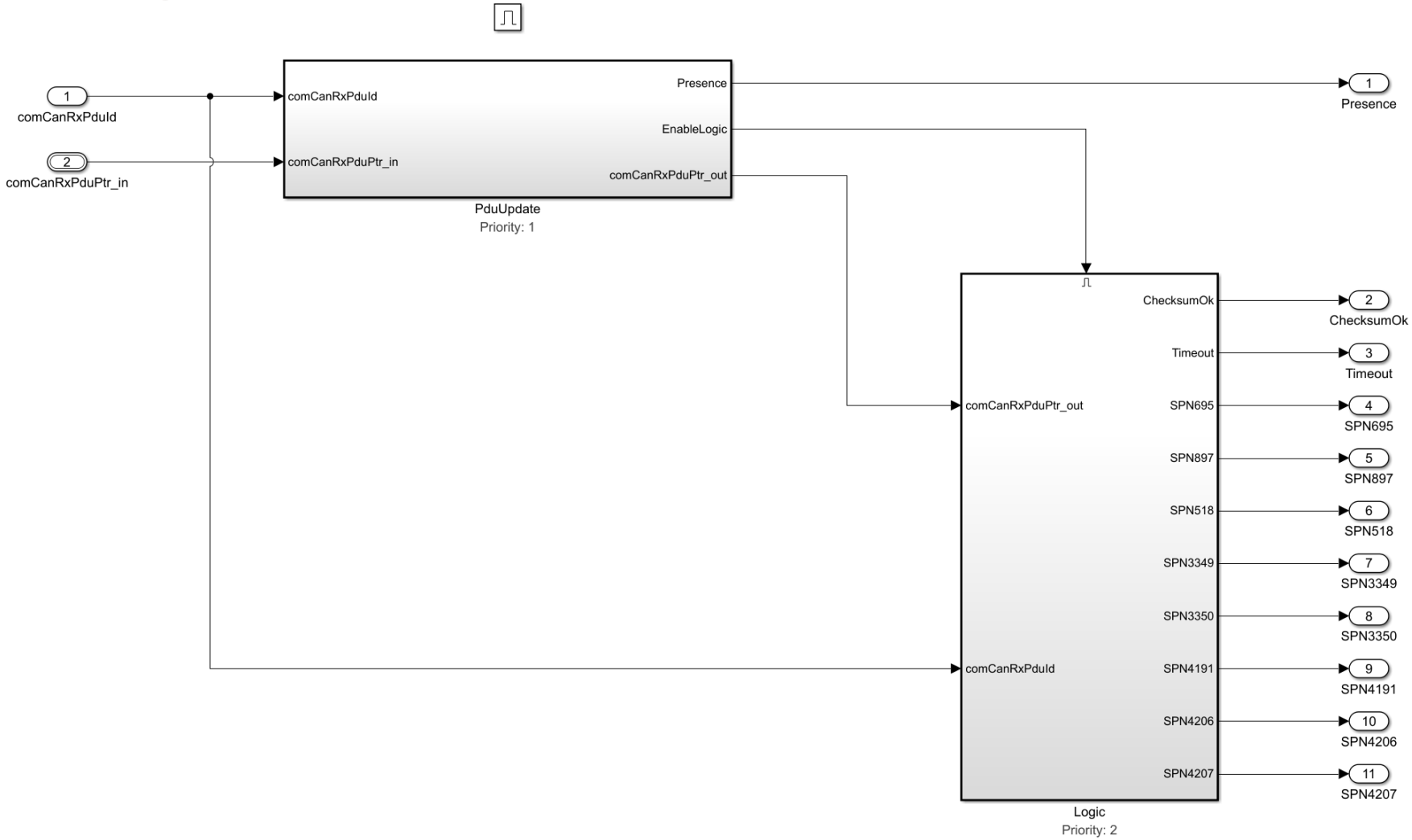
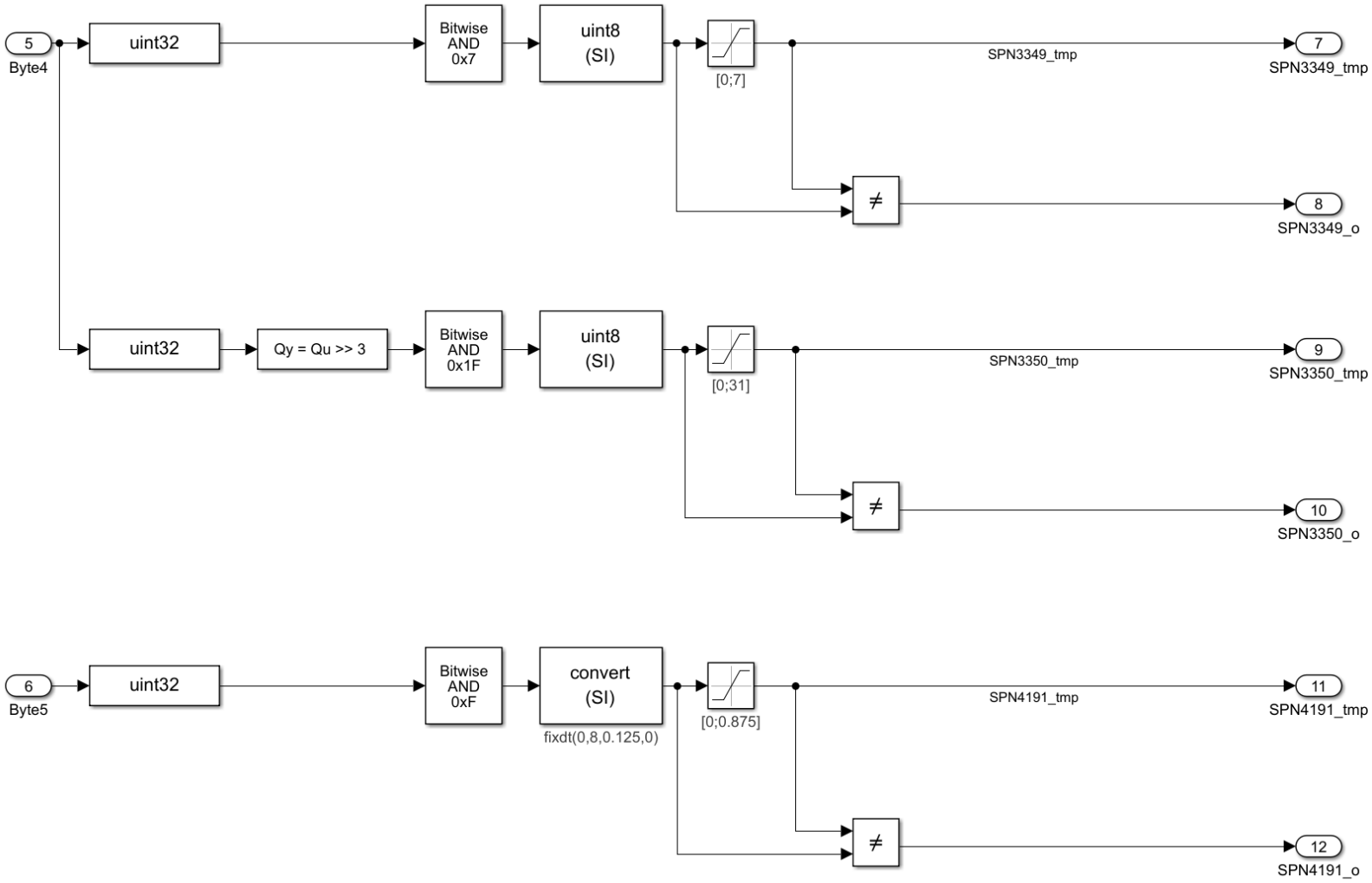


3. Example: Rx CAN Frame



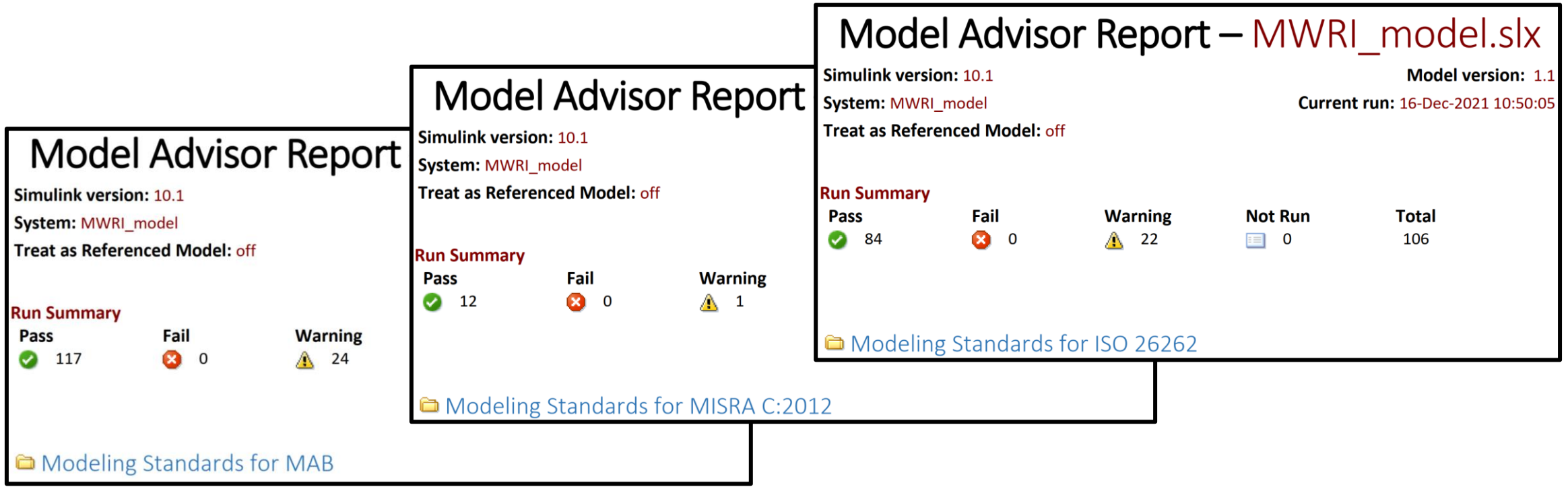
3. Example: Rx CAN Frame



3. Example: Rx CAN Frame

Modelling Standards

Thanks to the repeatability of the automation process, we were able to guarantee the same implementation of the unpacking algorithms for all received messages, thus achieving the objectives for the main modeling standards.



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4. ISO-26262: Qualification Tools

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MATHWORKS TOOLCHAIN FOR SOFTWARE QUALIFICATION

The generated models and code are ready for the verification process with all the dedicated tools in order to produce the required work-products for ISO-26262 certification, such as:

- Model configuration and implementation checks → **Simulink Check**
- Code coverage → **Simulink Coverage**
- Model testing → **Simulink Test**
- Static code analysis → **Polyspace**

The steps above have been outlined basing on the **ISO-26262 documentation** and with the support of dedicated tools for the safety compliant development (**IEC Certification Toolkit**).

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5. Teoresi : Company profile

Job Teoresi - *job@teoresigroup.com*

Teoresi at a Glance.

KEY NUMBERS

1
GROUP
Acting as
a «one stop»
solutions partner

4
COMPANIES
Established
in Italy, United States,
Germany and Switzerland

30+
YEARS OF EXPERTISE
In many industries

850+
PEOPLE
Today

49,8 M€
GROUP REVENUE
December 2020

Teoresi at a Glance.

WHO WE ARE

Teoresi is an **international services group**, headquartered in Turin and operative on the European and United States markets, which acts as a qualified partner to foster customers product and process development through innovative technologies.

Backed up by a global expertise in engineering, we support our customers by providing **design, development and qualified consulting** services, to deliver high performance and innovation in every project challenge.

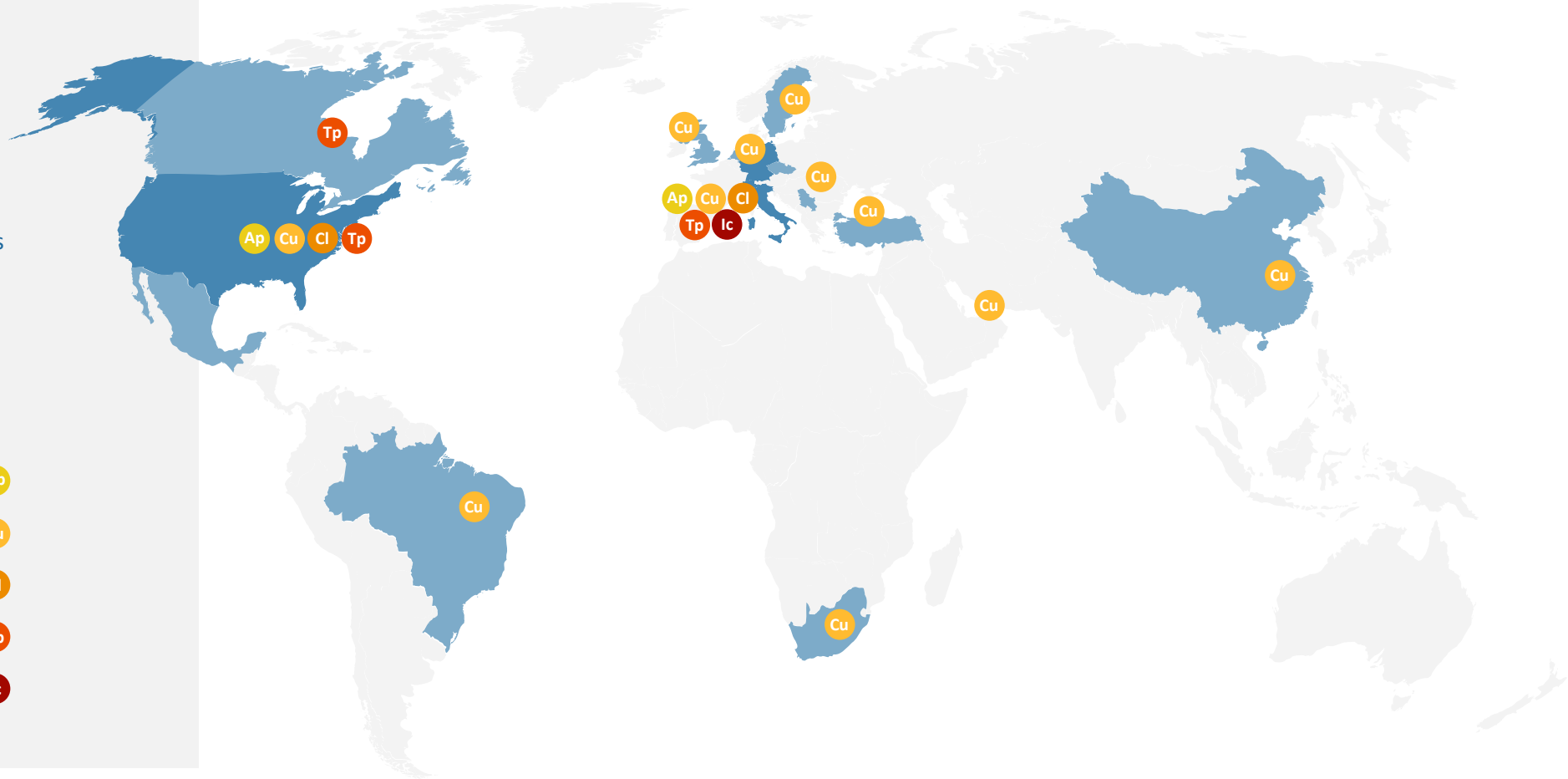
Corporate Guidelines.

OUR CORE VALUES

- **Customer Centricity**
- **People First**
- **Integrity and Credibility**
- **Inspiring Innovation**
- **Continuous Improvement**
- **Global Mindset**

Network Map.

100 +
operative locations
worldwide



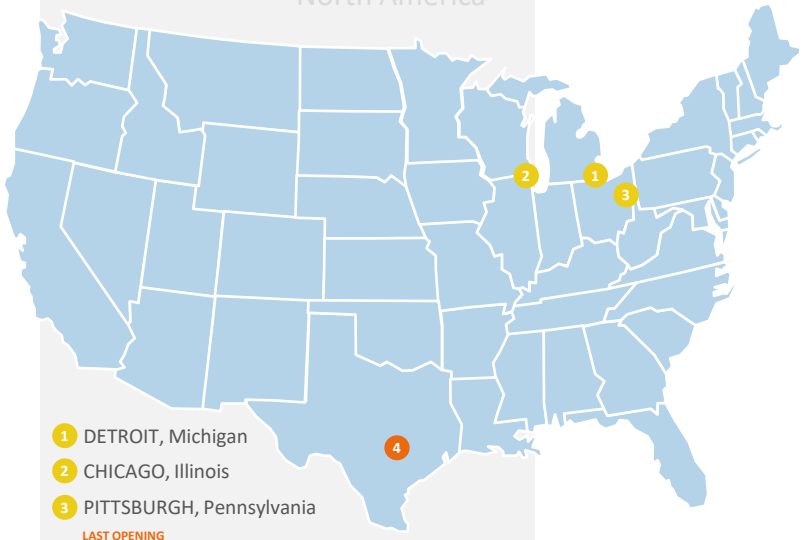
ACADEMIC PARTNERSHIP Ap
CUSTOMER Cu
INDUSTRIAL CLUSTER Cl
TECHNOLOGY PARTNER Tp
INNOVATION CENTER Ic

Operation Operative Regions.

16 offices worldwide

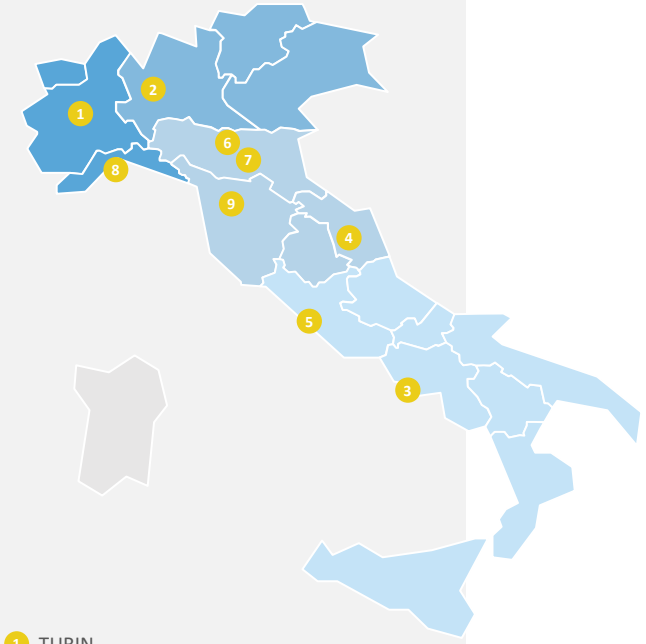
6 operative regions

North America



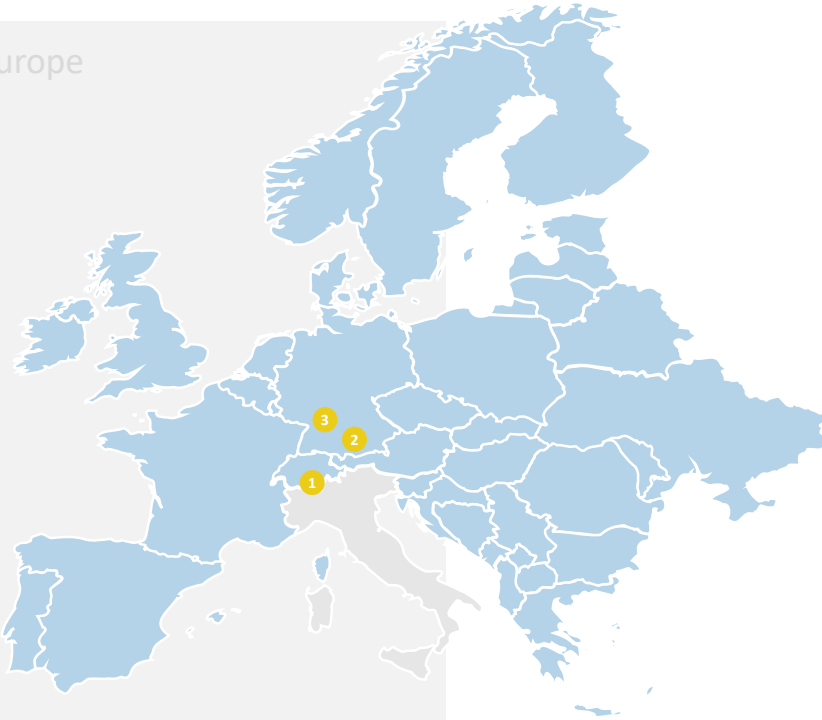
1. DETROIT, Michigan
2. CHICAGO, Illinois
3. PITTSBURGH, Pennsylvania
4. LAST OPENING AUSTIN, Texas

Italy



1. TURIN
2. MILAN
3. NAPLES
4. TOLENTINO
5. ROME
6. MODENA
7. BOLOGNA
8. GENOA
9. FLORENCE

Europe



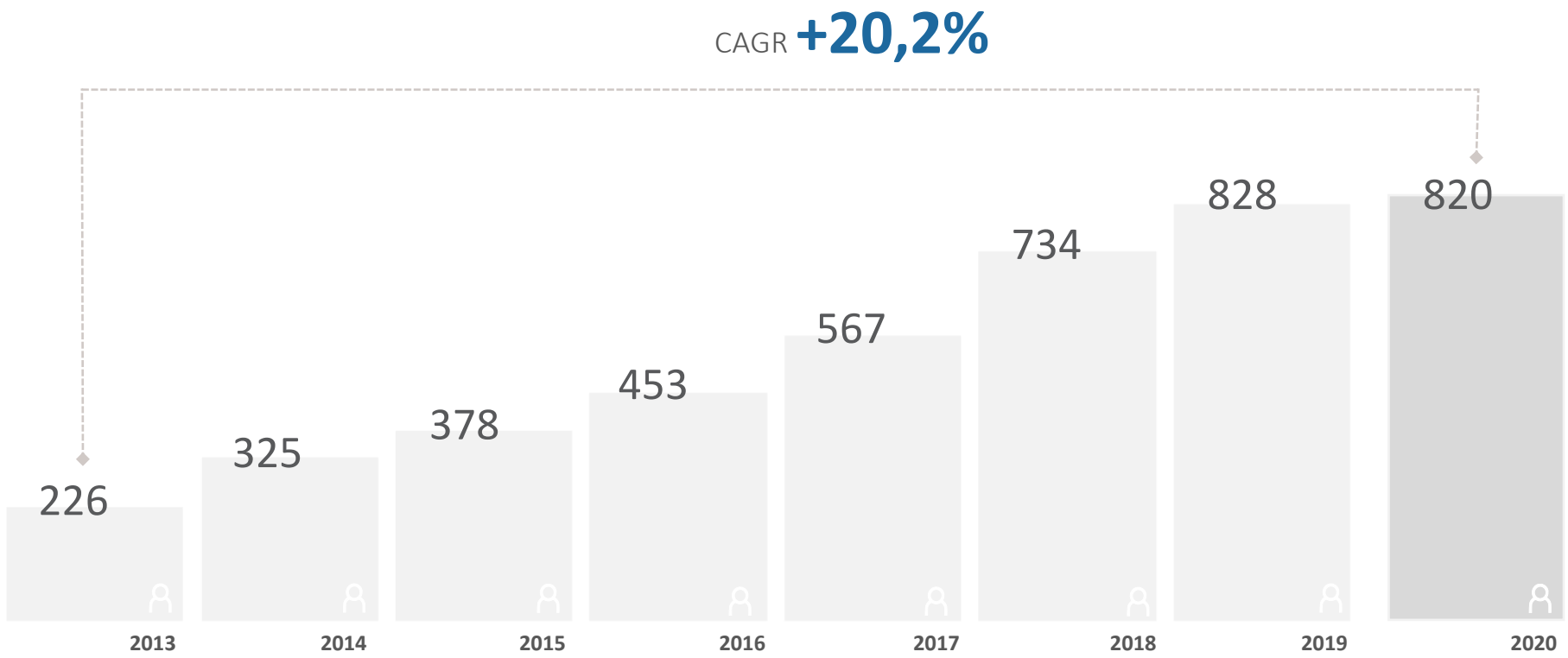
1. LUGANO, Switzerland
2. MUNICH, Germany
3. STUTTGART, Germany

Group Personnel Trend.

PEOPLE TREND

33.
AVERAGE AGE

98%.
LONG TERM CONTRACTS



Teoresi Training Highlights.

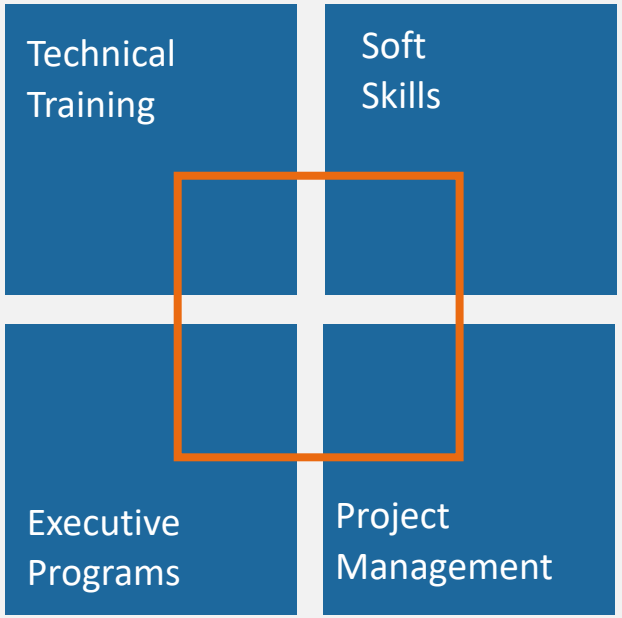
We are a
people company.

15000 Yearly training hours

> 80 Training courses

E-learning platform

In partnership with SDA Bocconi School of Management, PRAXI, truentify, Udemy



Partnerships.

PRODUCT PARTNERS

Geomagic

Reactive Systems, inc

INTREPID CONTROL SYSTEMS

RA CONSULTING

INNOVATION HUB

POLOICT managed by torinowireless

mesap

Centro Regionale Information Communication Technology CERICT SCRL
CeRICT

Consiglio Nazionale delle Ricerche

iit ISTITUTO ITALIANO DI TECNOLOGIA

Partnerships.

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UNIVERSITÀ DEGLI STUDI DI TORINO

POLITECNICO DI TORINO

UNIVERSITÀ DEGLI STUDI DI NAPOLI FEDERICO II

prisma LAB

UNIVERSITÀ degli STUDI di CATANIA

UNIMORE
UNIVERSITÀ DEGLI STUDI DI MODENA E REGGIO EMILIA

UNIVERSITÀ DEGLI STUDI DI SALERNO

ALMA MATER STUDIORUM
UNIVERSITÀ DI BOLOGNA

Università degli Studi della Campania *Luigi Vanvitelli*

UNIVERSITÀ DELLA CALABRIA

Università degli Studi del Sannio

MICHIGAN STATE UNIVERSITY

ILLINOIS
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

Lawrence Technological University

WAYNE STATE UNIVERSITY

UNIVERSITY OF MICHIGAN

Thank you!

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