Modelica Association Project "Distributed Co-Simulation Protocol"

Martin Krammer DCP MAP Leader martin.krammer@v2c2.at



Federal Ministry of Education

and Research

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FFG Austrian

Research Promotion Agency

TEA3

Outline

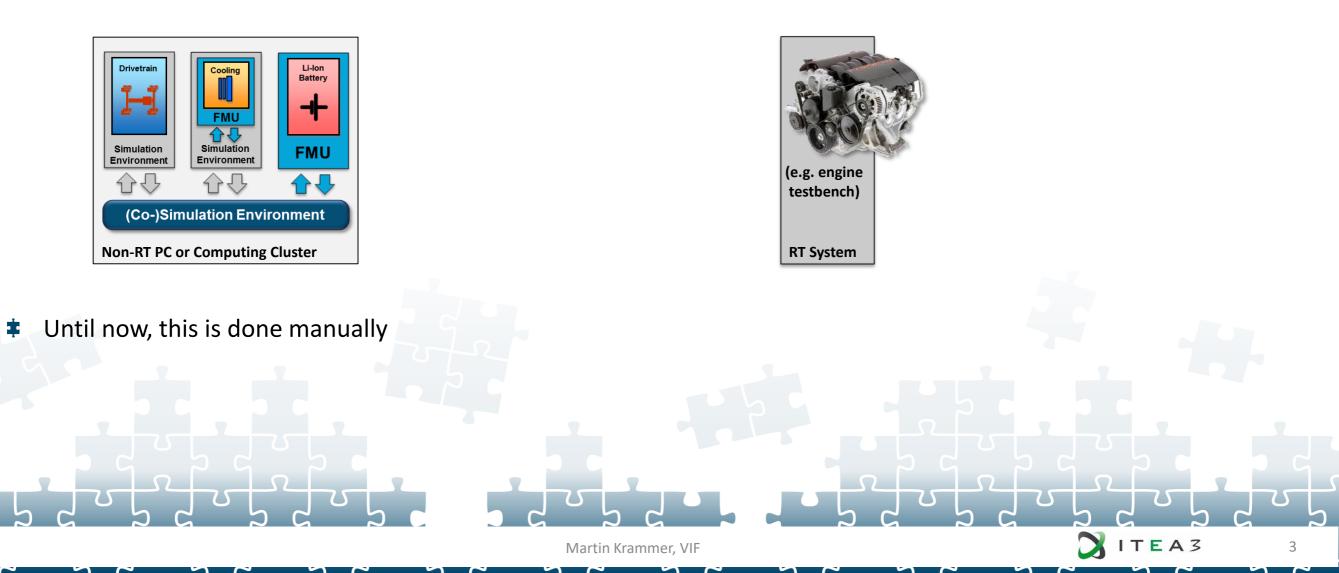


- Introduction
- The Distributed Co-Simulation Protocol (DCP)
 - Communication Protocol
 - Architecture Description
 - Operating Modes
 - State Machine
 - Exchange of Input and Output Data
 - Use Case
- The Future of DCP



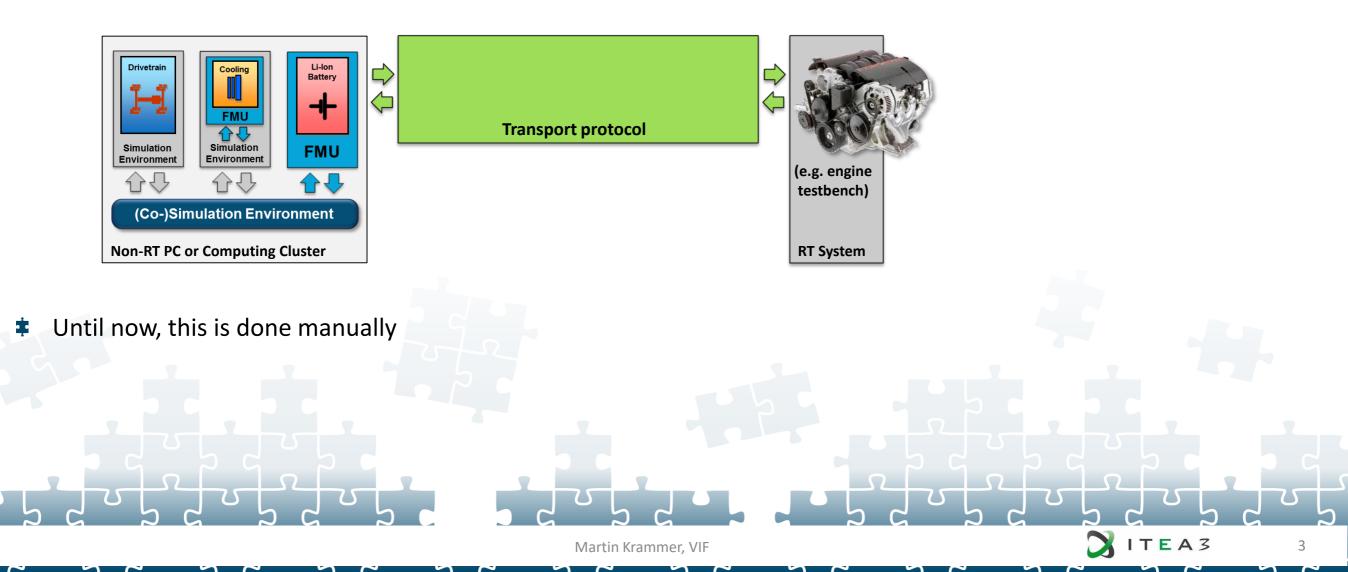


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- But what about distributed setups?





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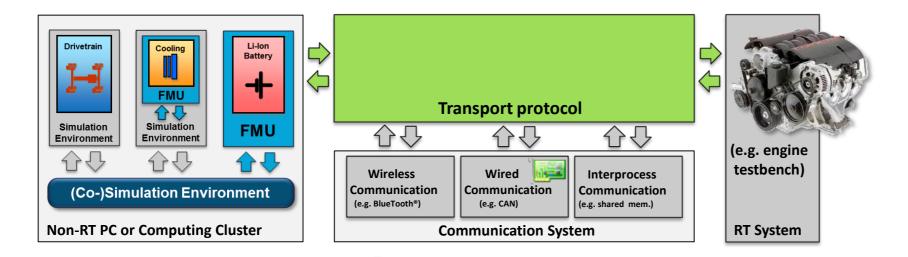




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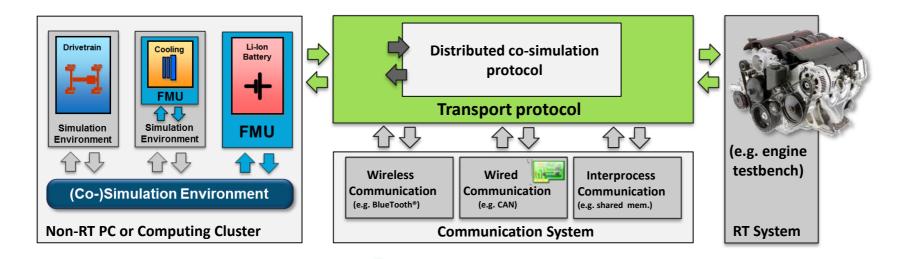
Until now, this is done manually



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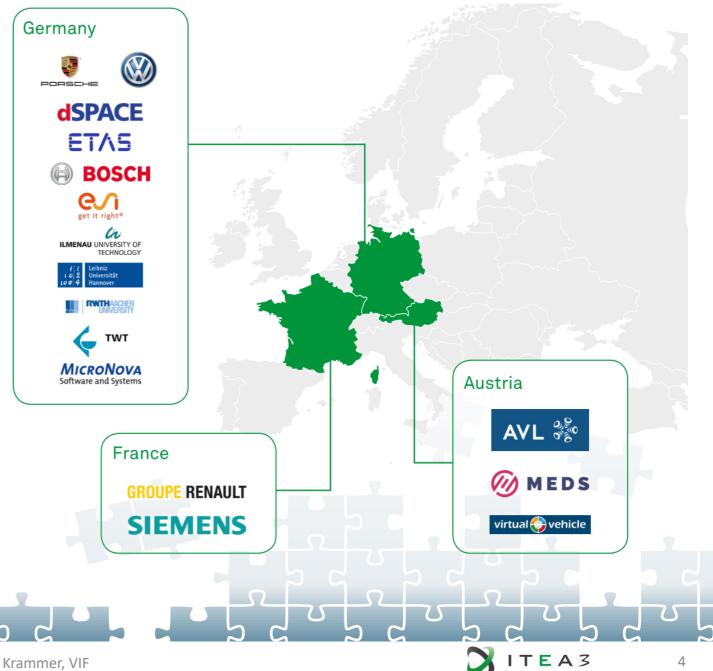
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Until now, this is done manually

History - The ACOSAR Project

- The ACOSAR project ŧ
 - Advanced Co-Simulation Open System Architecture
 - Duration: 09/2015-08/2018
 - Costs: 8,123k€
 - Effort: 60 PY
- ACOSAR focuses on integration of ŧ
 - Real-time and real-time, and
 - Real-time and non-real-time systems
- Primary goal: Negotiate technical specification of ÷ communication protocol intended for standardization







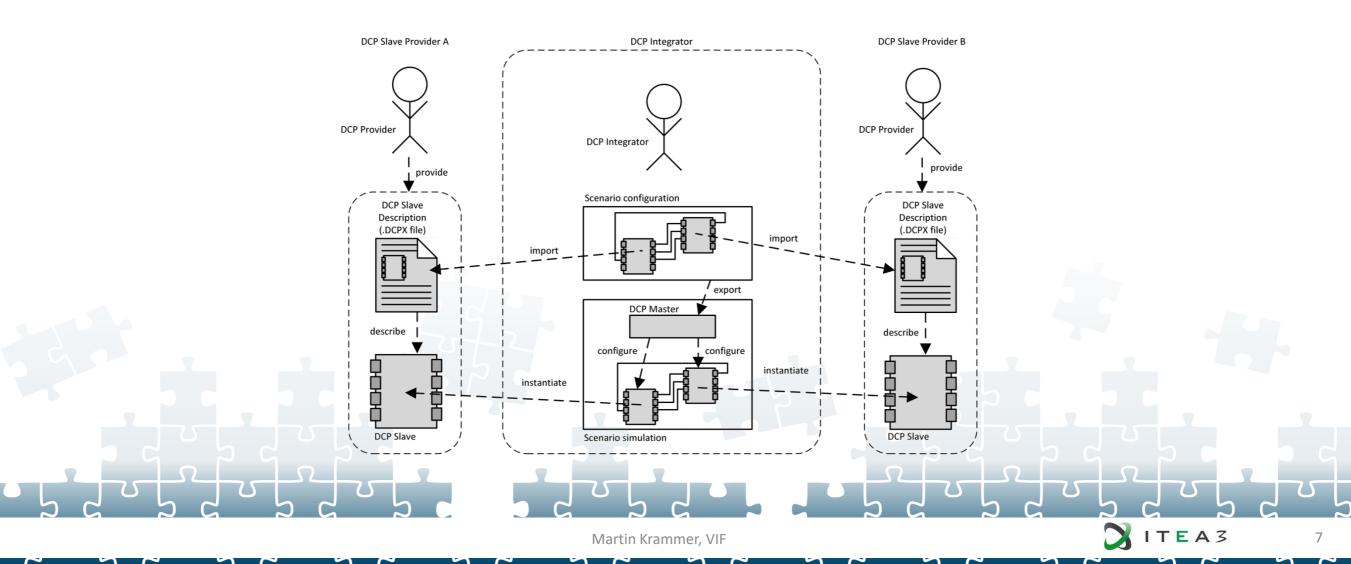


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- Main design aspects
 - Interoperability
 - Define a communication protocol
 - Goal: Pursue standardization with a recognized standardization body
 - Compatibility
 - Support a broad range of systems, from small microcontrollers to large test rigs
 - Targets: Low overhead, low memory footprint
 - Integration
 - Develop methodology for application in development processes
 - Master-Slave concept
 - Communication
 - Support multiple transport protocols
 - Initially: UDP, CAN, USB, Bluetooth, and EtherCAT
 - Economy
 - Reduce development time
 - Decrease computing cost
 - Accelerate time-to-market

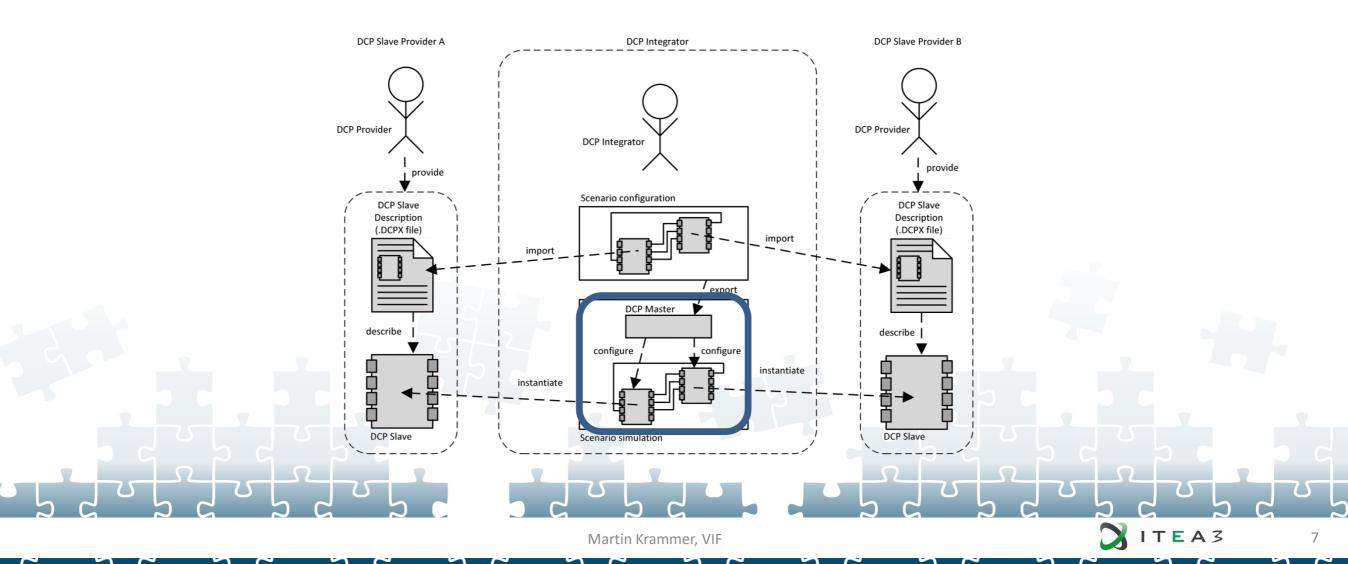


- Default integration methodology
- Relies on DCP slave description file (.dcpx)
- Defines provider-integrator relationship



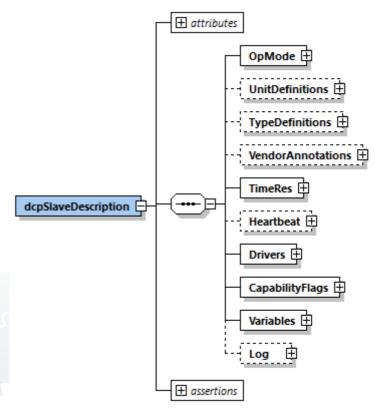


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- DCP Slave Description
 - DCP slave description accompanies DCP slave
 - Specified as XSD 1.1 schema definition
 - XML instance .dcpx File
- Assertions
 - Used to enforce specifications
 - Avoid incorrect definitions
- Available transformation strips assertions and generates XSD 1.0 schema



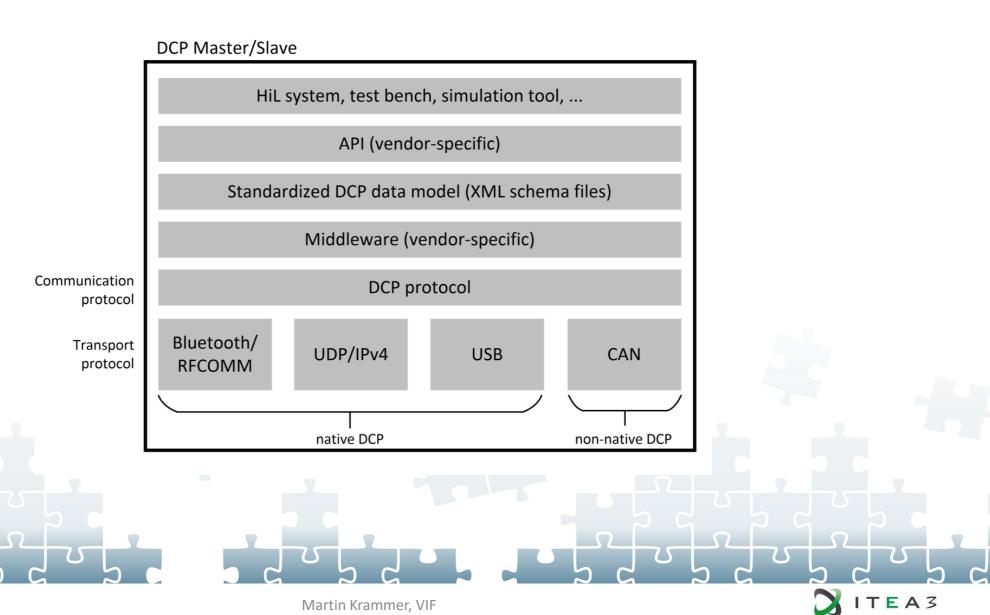
Operating mode Units Types Vendor specific annotations Time resolution Heartbeat definitions Transport protocol Capability flags Variables (inputs/outputs/parameters) Logging definitions

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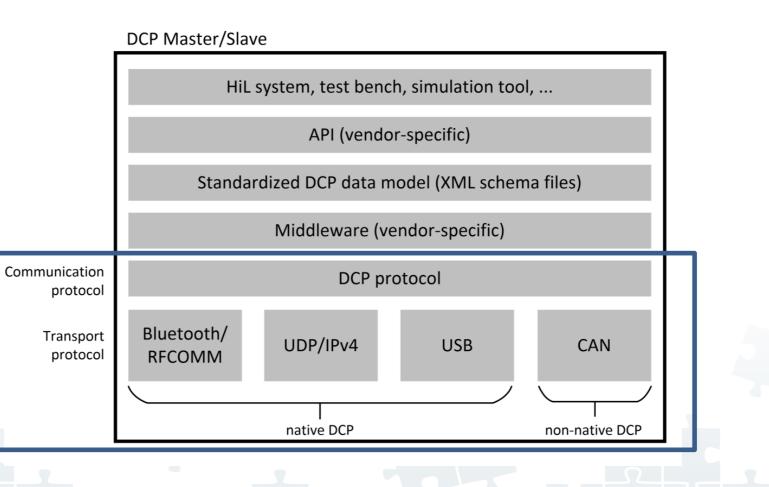
ţ Architecture Description





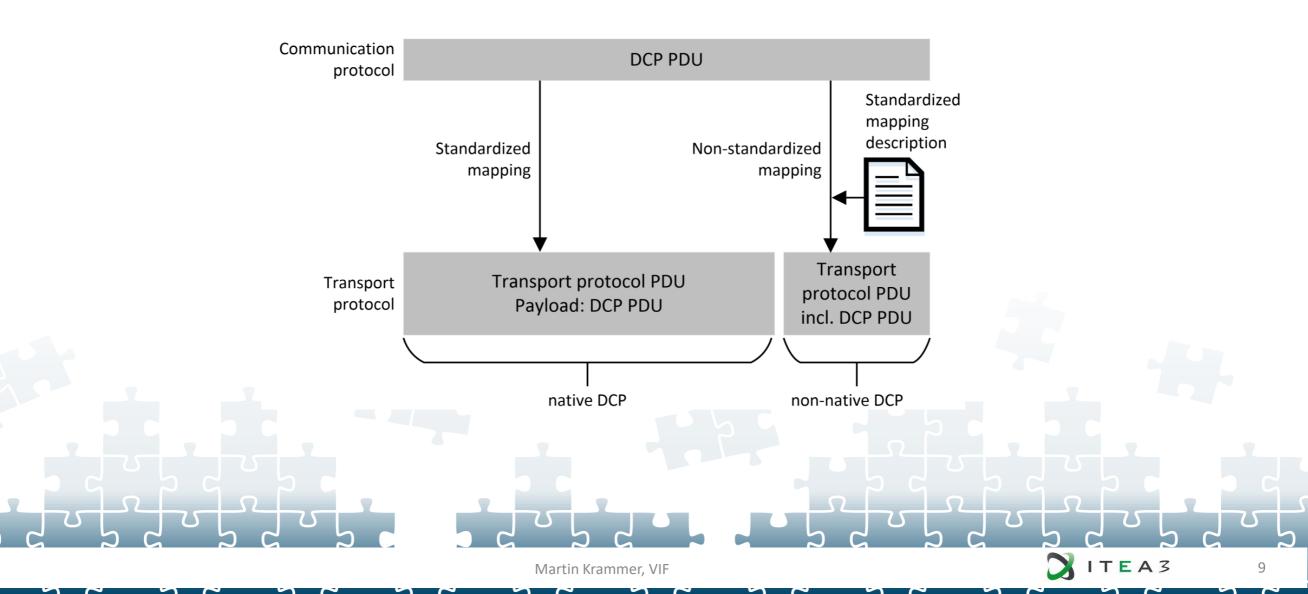
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Architecture Description





‡ Architecture Description

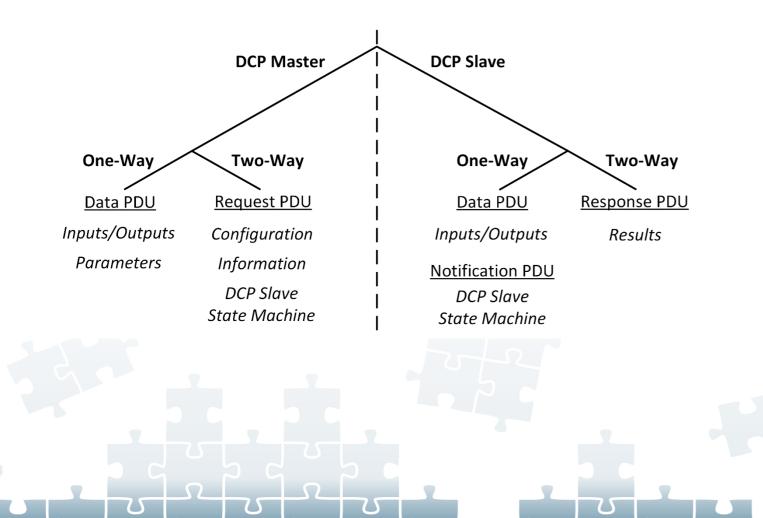




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- Taxonomy of Protocol Data Units (PDU)
 - "PDU Families"



					DCP Fram																
					type_id	pdu_seq_id	resp_seq_id	sender	receiver	param_id	data_id	sod	target_vr	source_vr	source_data_type	transport_protocol	state_id	numerator	denominator	steps	op_mode
				CFG_set_time_res	0x20	y			y									v	v		
				CFG_set_steps	0x21	ý			ý		у							,	,	v	
				CFG_config_input	0x22	ý			ý		ý	у	у		у					ŕ	
				CFG_config_output	0x23	ý			ý		ý	ý	,	y	ŕ						
				CFG_config_clear	0x24	ý			ý		ŕ	ŕ		<i>,</i>							
			Configuration		0x25	ý			ý		у					У					
			(CFG)	CFG_set_source_network_information	0x26	y			y		y y					y y					
				CFG_set_parameter	0x27	y			y		<i>'</i>				у	/					
				CFG_set_config_tunable_parameter	0x28	y y			y y	у		y			y y						
				CFG_set_param_network_information	0x29	y y			y y	y y		,			,	v					
			2	CFG_set_logging	0x2A	y y			y	,						<i>y</i>					
		÷		CFG set scope	0x2B	y v			y y		у										
		Request		STC_register	0x01	y y			y y		<i>'</i>						у				у
		Rec		STC_unregister	0x02	ý			ý								ý				, í
2	2		State change (STC)	STC_configure	0x03	y			y								y y				
비	Control			STC_initialize	0x04	y			y								y				
Protocol Data Unit (PDU)	니				0x05	y			y								y y				
ata				STC reinitialize	0x06	y			y								y y				
Ä				STC_do_step	0x07	y			y								y			у	
ö				STC_send_outputs	0x08	y			y								y			,	
r d				STC_stop	0x09	y y			y y								y y				
				STC_reset	0x0A	y y		7	y y								y y				
				INF_state	0x80	y y			y y								,				
			Information	INF_error	0x81	y y			y y												
			(INF)	INF_log	0x82	y y	-		y y												
	ł		1	RSP_ack	0xB0	,	у	у	,												
				RSP_nack	0xB1		y y	y y													
			Response	RSP_state_ack	0xB2		y	y							4		у				
			(RSP)	RSP_error_ack	0xB3		y y	y y									,				
				RSP_log_ack	0xB4		y	y y													
Notification (NTF)				NTF_state_changed	0xE0		,	y									у				
			ification (NTF)	NTF_log	0xE1			y	_								,				
, F				DAT_input_output	0xF0	у					у										
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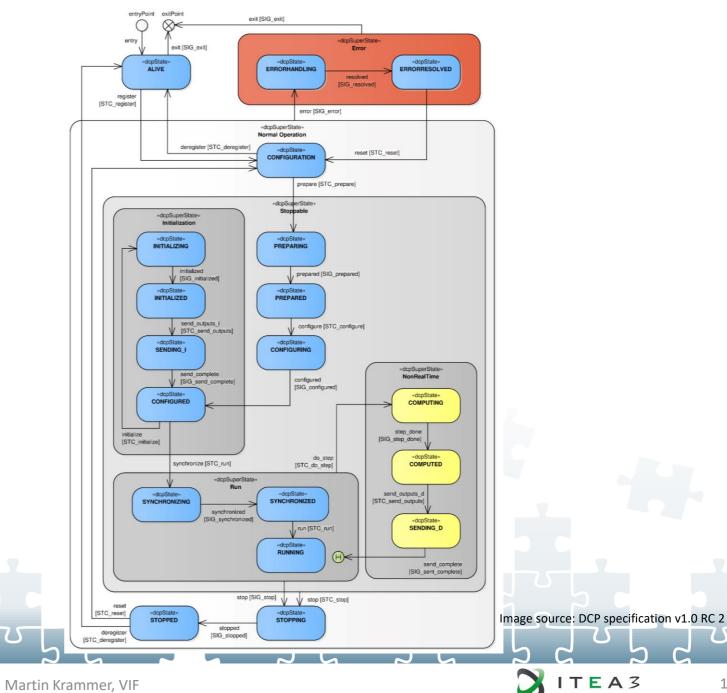
- Operating Modes
 - The DCP covers three different time domains

Operating mode	Description
Soft real-time (SRT)	Synchronous to absolute time, tolerant to RT violations
Hard real-time (HRT)	Synchronous to absolute time, intolerant to RT violations
Non-real-time (NRT)	Independent of absolute time



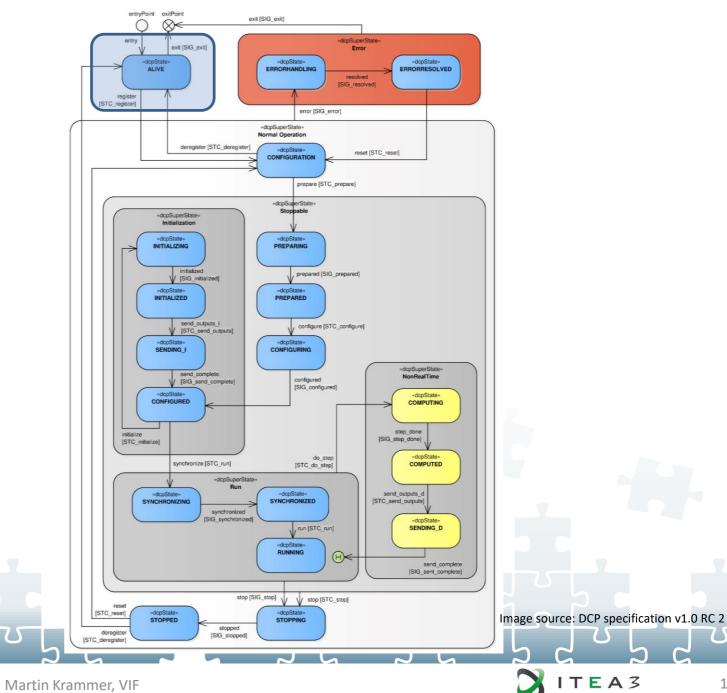


- ŧ DCP slave state machine for simulation control
- A typical simulation cycle ÷
 - Registration 1.
 - Configuration 2.
 - 3. Initialization
 - Run/Compute 4.
 - Stop 5.
 - 6. (Error)



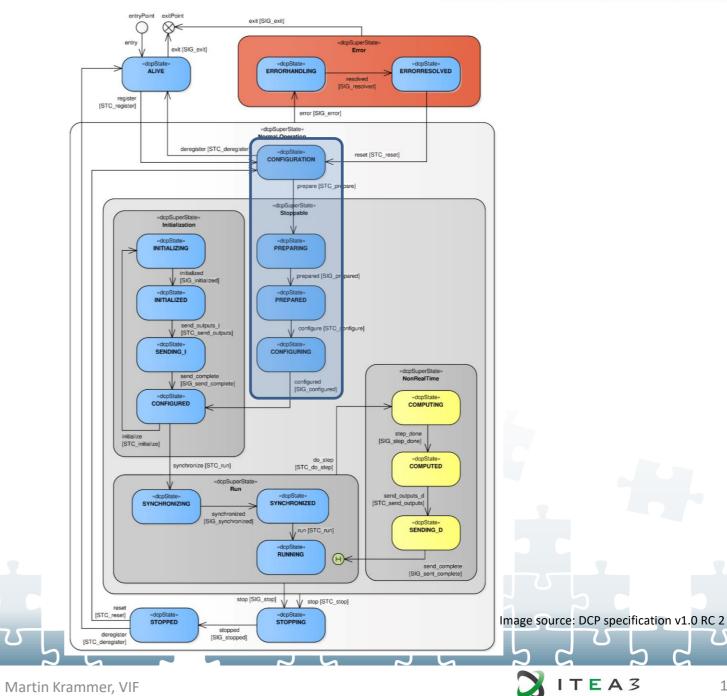


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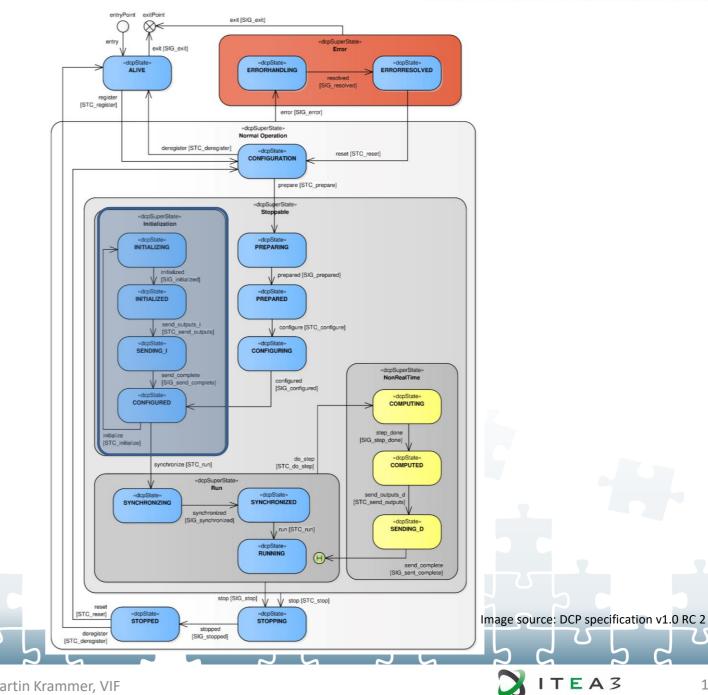
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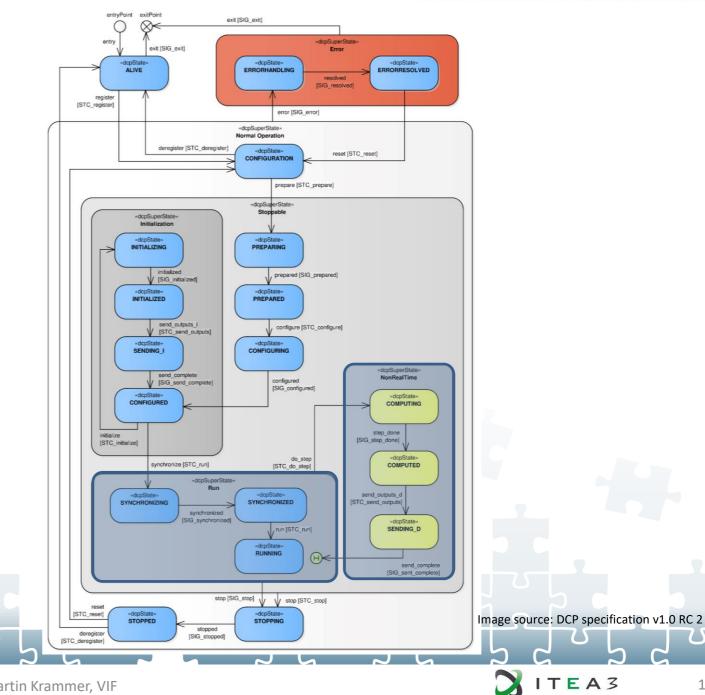


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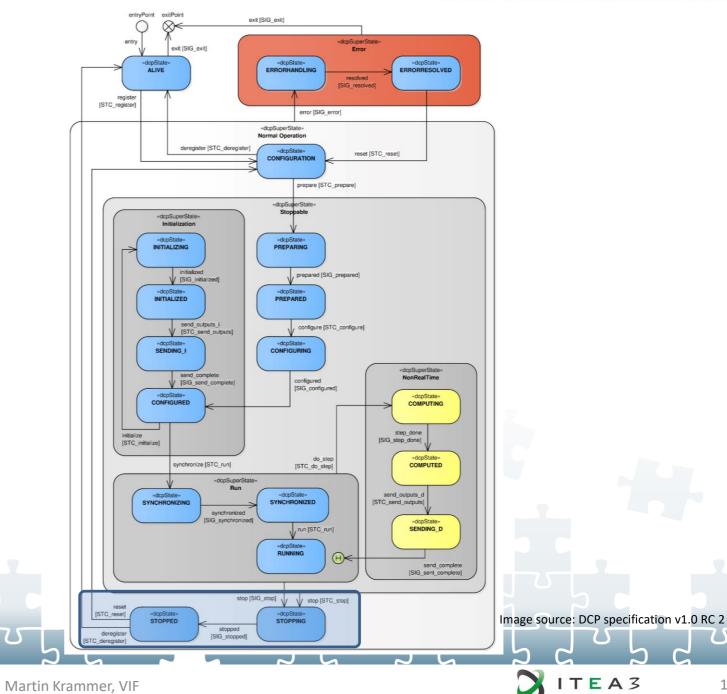


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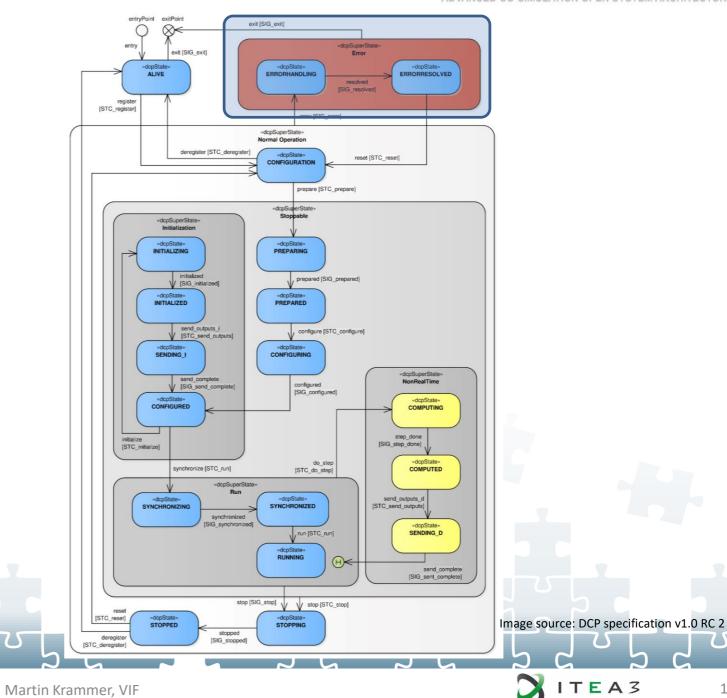


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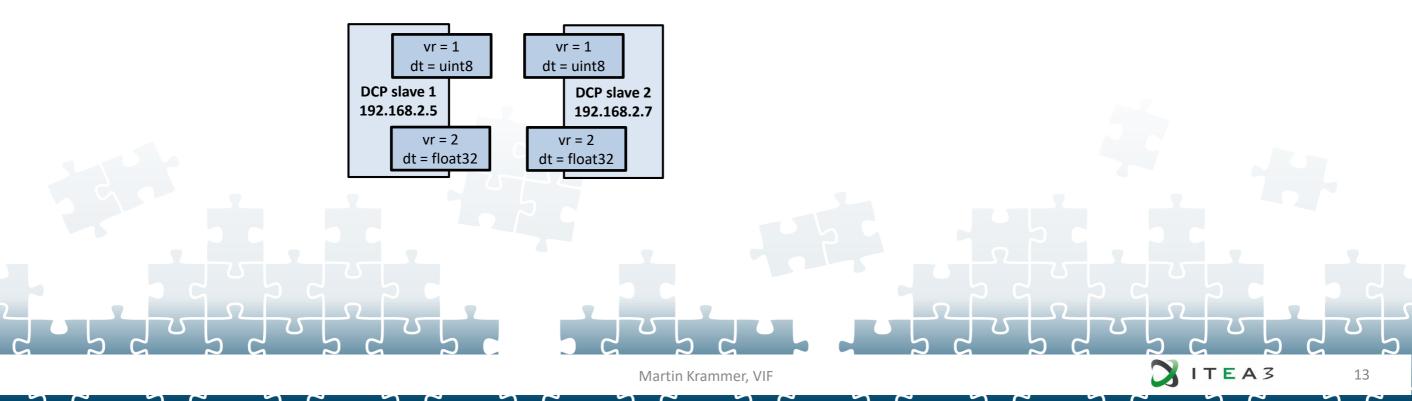


- **‡** Exchange of data during simulation phase
 - 1. Configuration must be generated by DCP master
 - 2. Configuration must be rolled out to DCP slaves prior to simulation
- *Zero run time overhead* during simulation
- **‡** Example:





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- Exchange of data during simulation phase
 - 1. Configuration must be generated by DCP master
 - 2. Configuration must be rolled out to DCP slaves prior to simulation

vr = 1

dt = uint8

vr = 2 dt = float32

DCP slave 1

192.168.2.5

- *Zero run time overhead* during simulation
- **‡** Example:



vr = 1

dt = uint8

vr = 2

dt = float32

DCP slave 2

192.168.2.7

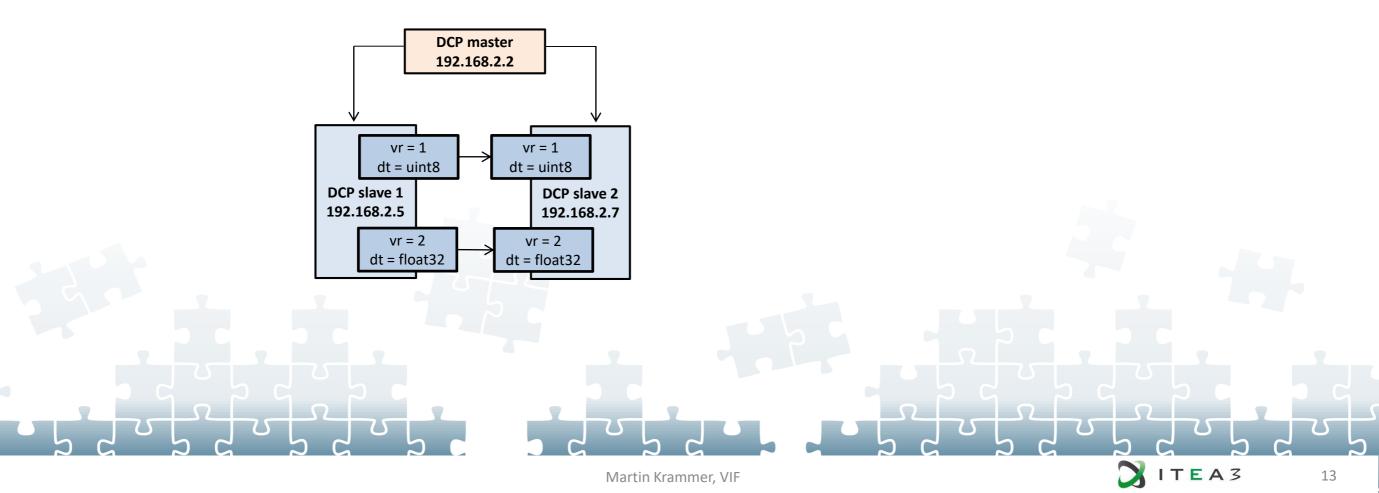


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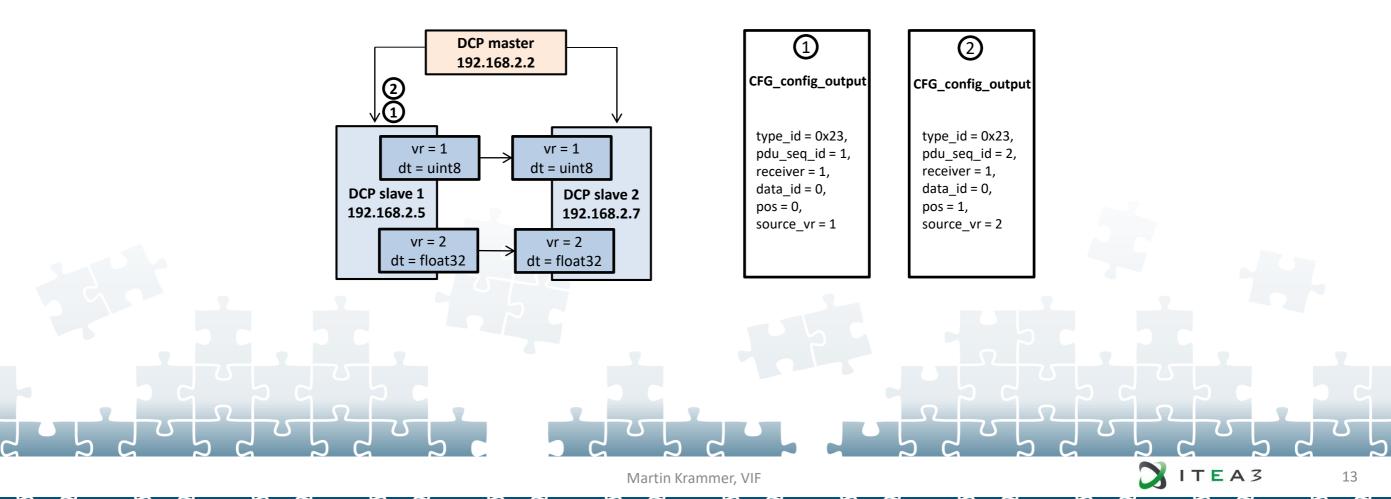
ADVANCED CO-SIMULATION OPEN SYSTEM

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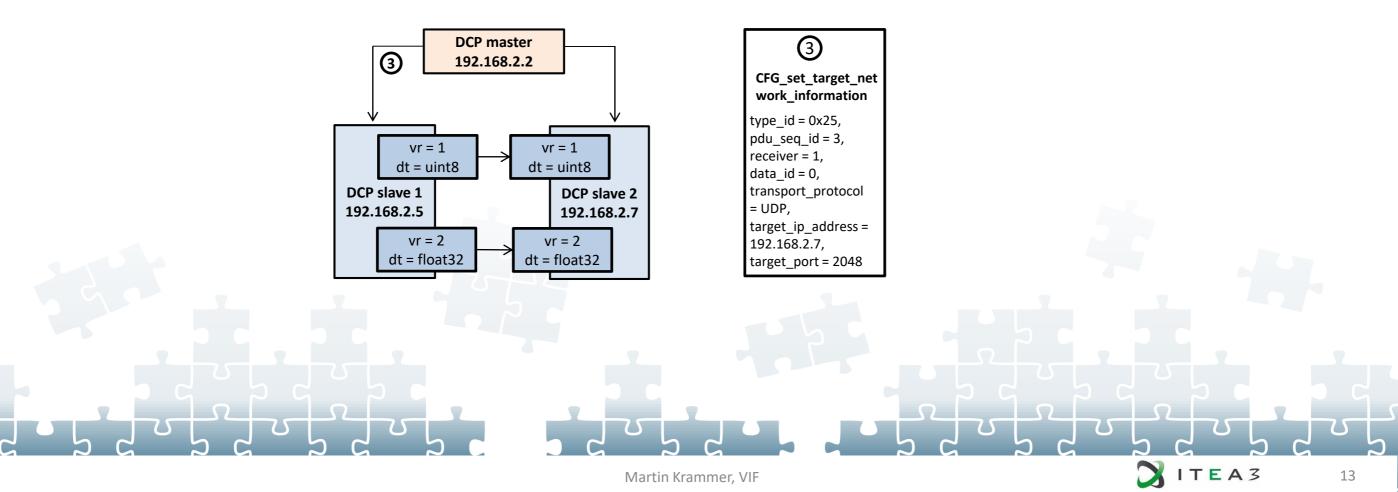




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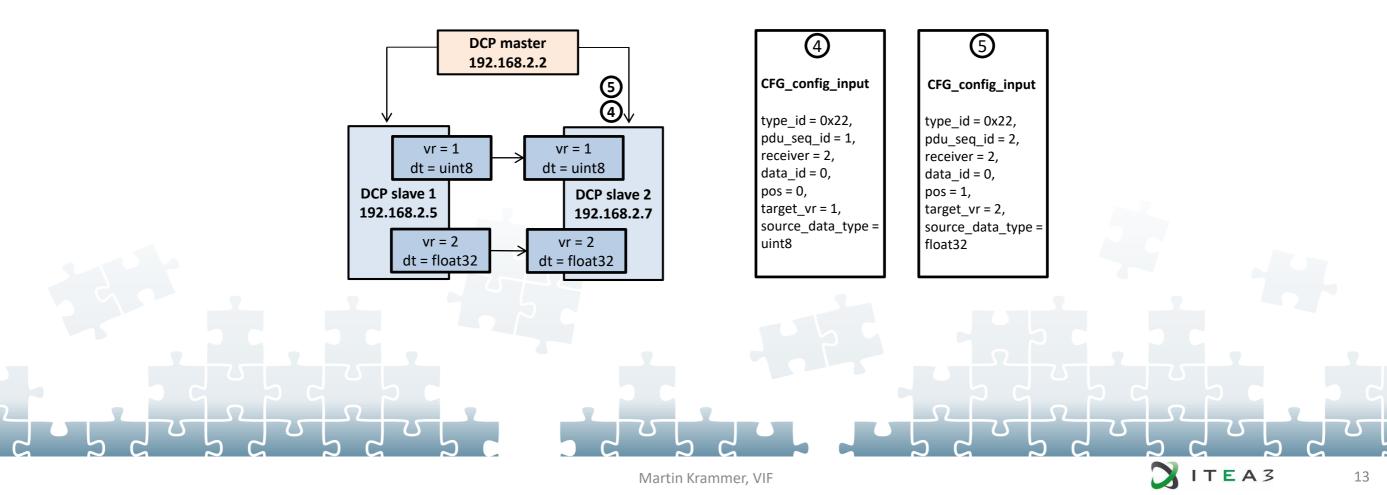
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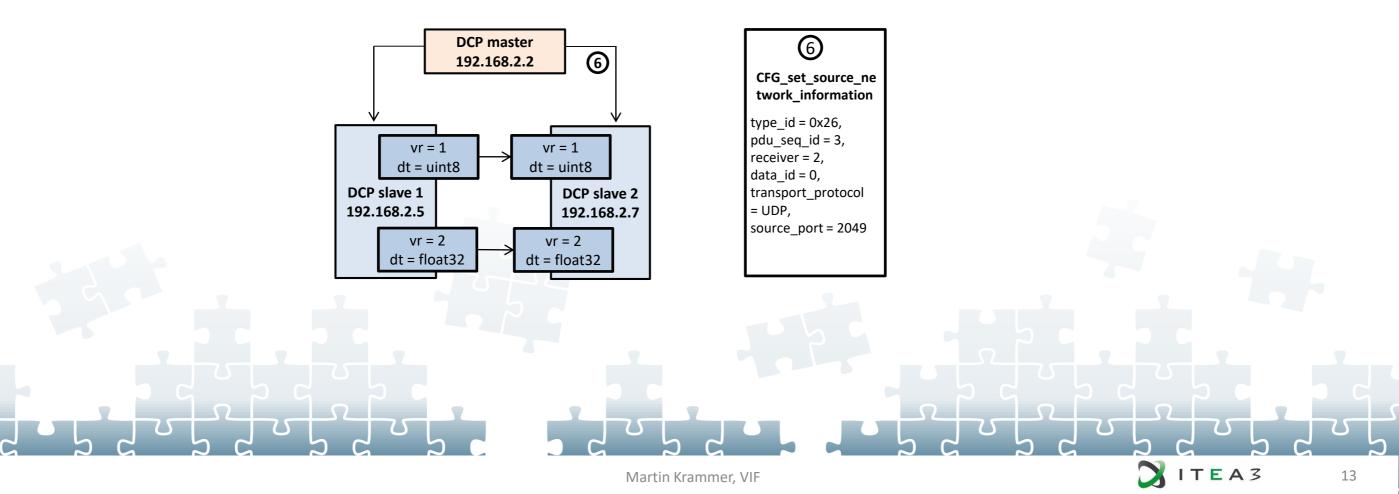




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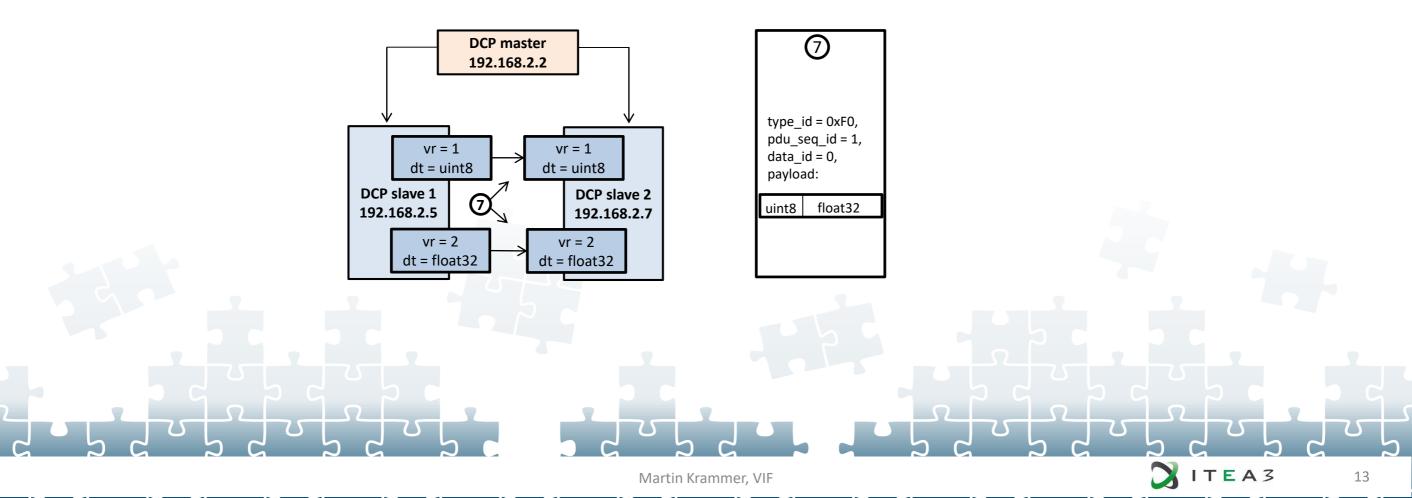
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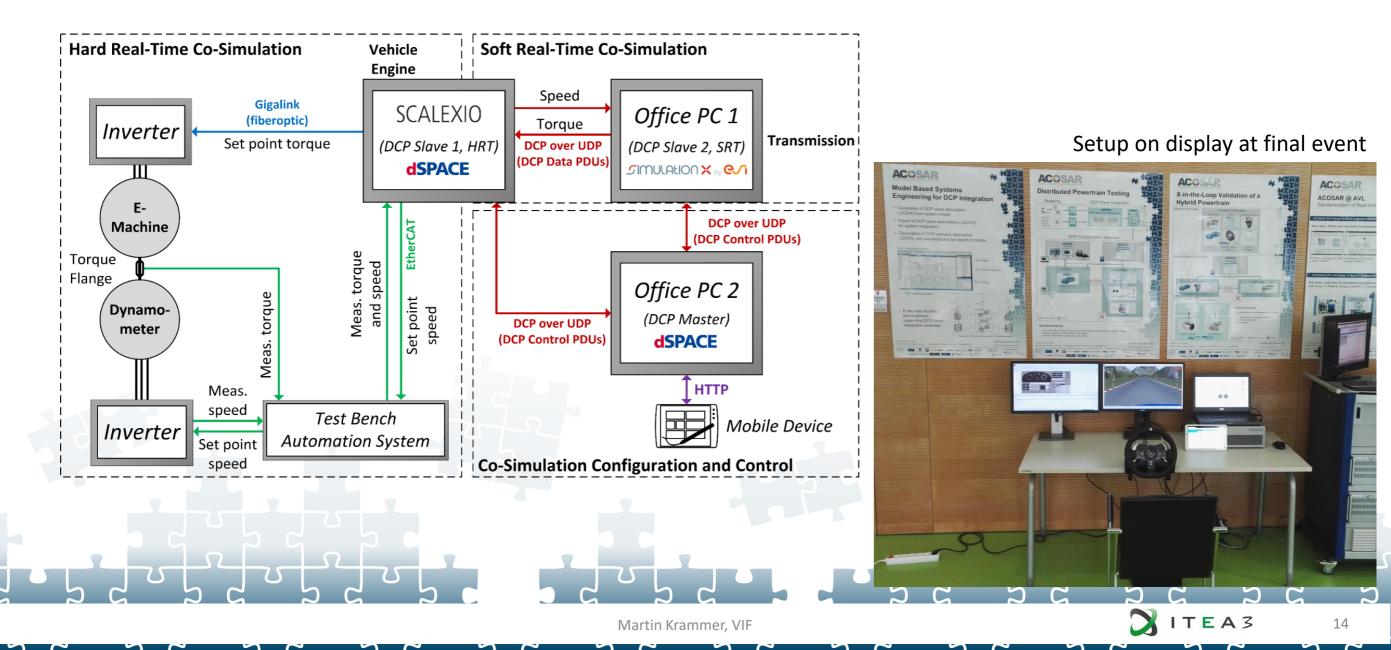


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Use case by dSPACE, RWTH Aachen, ESI-ITI

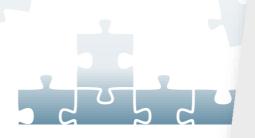


Future of DCP



- The DCP 1.0-RC1 was submitted to **Modelica Association** for standardization ŧ
- Will be maintained as Modelica Association Project (MAP) ŧ
- Sustainable ACOSAR project result ŧ
 - The DCP will be freely available
 - Open for everyone!
- Website: www.dcp-standard.org ÷





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Publication



"The Distributed Co-Simulation Protocol for the Integration of Real-Time Systems and Simulation Environments"

Martin Krammer, Martin Benedikt, Torsten Blochwitz, Khaled Alekeish, Nicolas Amringer, Christian Kater, Stefan Materne, Robert Ruvalcaba, Klaus Schuch, Josef Zehetner, Micha Damm-Norwig, Viktor Schreiber, Natarajan Nagarajan, Isidro Corral, Tommy Spa Serge Klein and Jakob Andert

"Requirements Engineering for Consensus-Oriented Written Technical Specifications"

Martin Krammer, Nadja Marko and Martin Benedikt, accepted for publication at 26th IEEE International Requirements Engineering Conference, August 20-24, Banff, Alberta, Canada

"Master for Simulation Control using the Distributed Co-Simulation **Protocol**"

Martin Krammer, Martin Benedikt, accepted for publication at IEEE 16th International Conference on Industrial Informatics, July 18-20, Porto, Portugal

"Configuration of Slaves Based on the Distributed Co-Simulation Protocol" Martin Krammer, Martin Benedikt, accepted for publication at 23rd International Conference on Emerging Technologies and Factory Automation, September 4th -7th, 2018, Torino, Italy



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	Martin Krammer, Martin Benedikt VIRTUAL VEHICLE Research Center Graz, Austria	ENVIRONMENTS
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Danut	Materne, Rob	Hannover, Germany kater@sim.uni ha
DCP Master/Slave	Stefan Materne, Roberto Ruvalcaba TWT GmbH	-nannover de
DCP Master/Slave HiL system, test bench, simulation	Stuttgart, Germany	Klaus Schuch, Josef Zehetner AVL List Groby
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Standardizeu Oor Middleware (vendor	Micha Damm-Norwig Ks.MicroNorm	Graz, Austria {klaus.schuch.josef.zehetner}@avl.com
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Figure 1: DCP mas		Stuttgart, Germany Isidro.CorralPating @
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systems of difference real-time and hard re	ABSTRACT	wka.rwth-aachen de
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	duce development gets more and more important in m promising approach for modular and interoperable development of heterogeneous systems still require enormous efforts. The interface or protocol specification is available, which allows the col (DCP) which is subject to proposal as a stand-	any industrial de
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