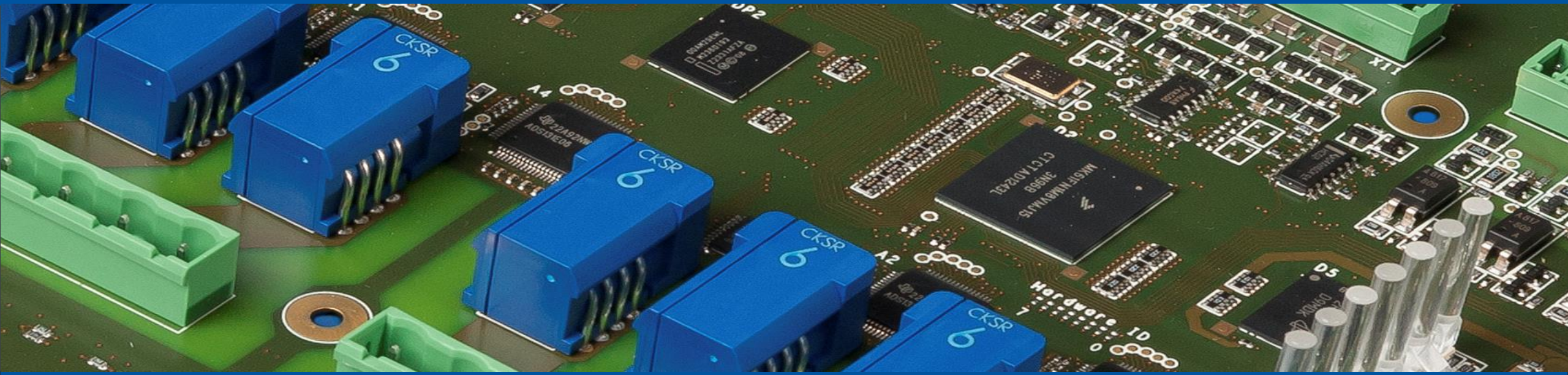
3T electronics & embedded systems

CO-DEVELOPMENT MANUFACTURING INNOVATION & SUPPORT



High-Level and Model-Based Design

Targeting FPGAs and SoCs

Sander Ter Burg, FPGA System Engineer

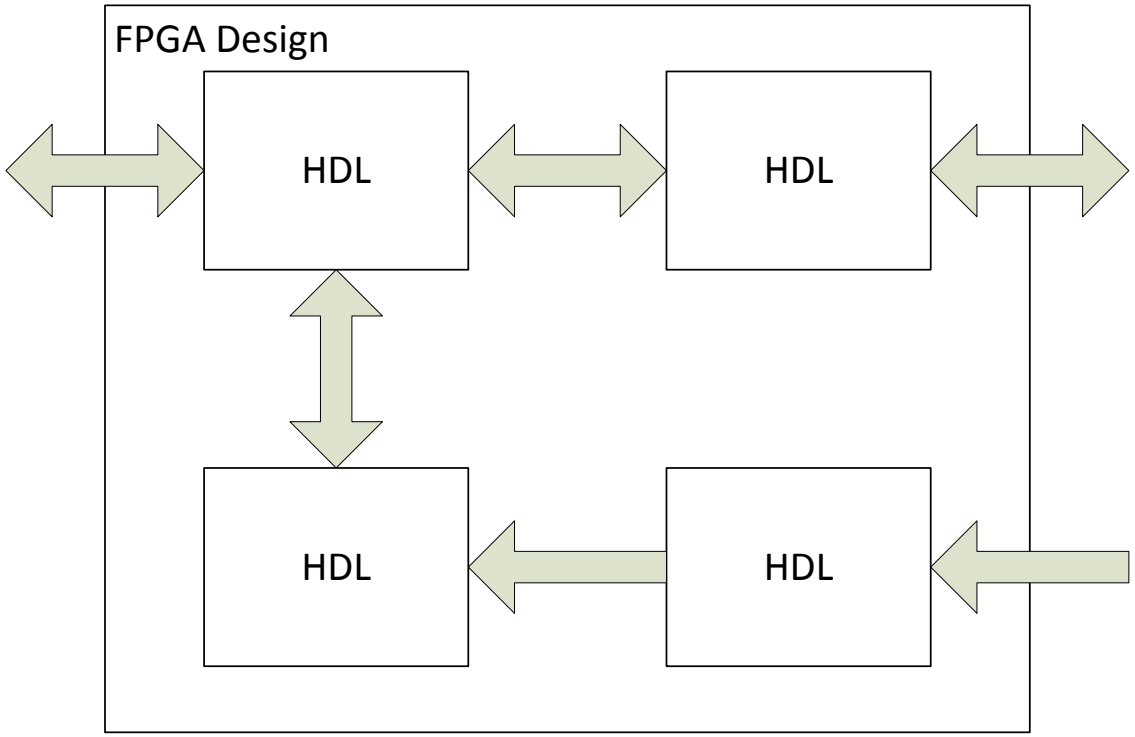
3T B.V.

- What we do:
  - Electronic and Embedded Systems
  - Co-Development and Re-design
  - Manufacturing (together with production partners)
  - Consulting & Support
- Where we are:
  - Enschede + Eindhoven
- More info:
  - www.3T.nl
  - info@3T.nl

Summary

- High-Level Design and Synthesis
- Model-Based Design
- Model-Based Design Examples
  - SCARA Robot Braking Controller
  - Radar Tracking Module

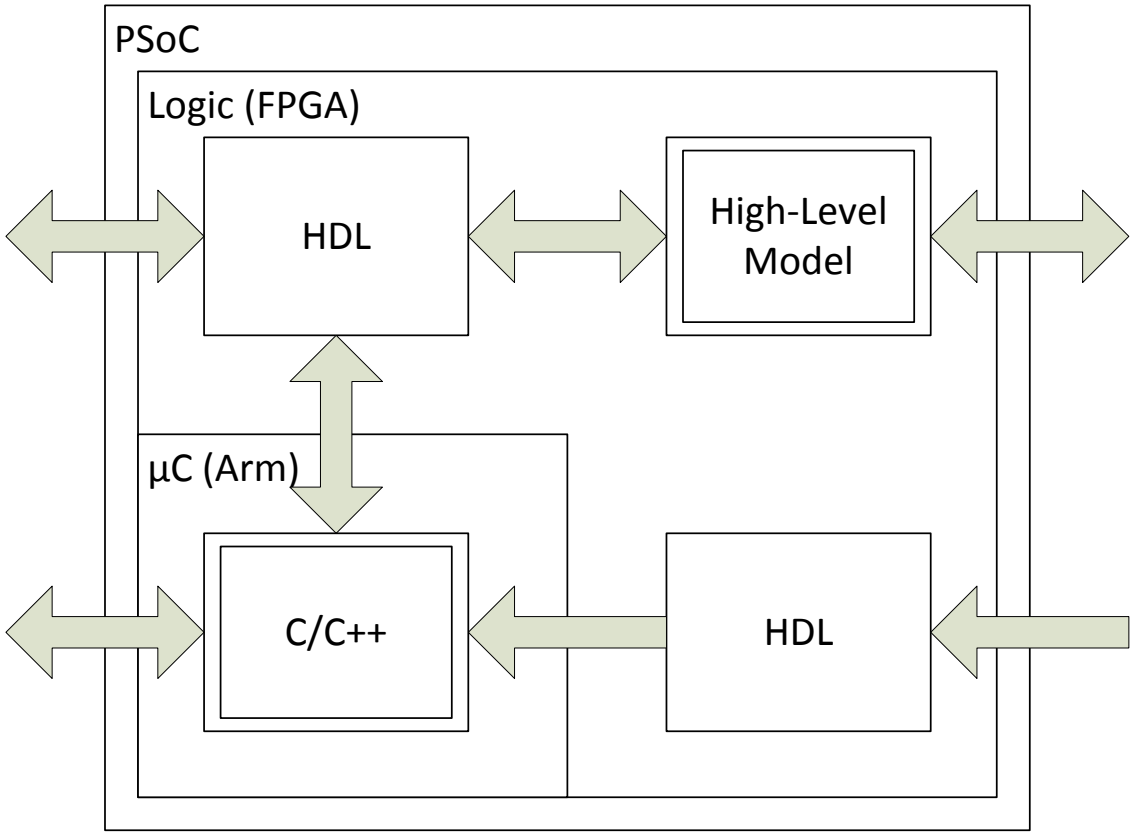
Traditional HDL Design example



- All code written in HDL
- No CPUs on-board
- HDL to Low Level Logic

HDL = Hardware Description Language

High(er)-Level Design example



Higher Level Design Blocks

- High-Level Model to HDL
- C/C++ code running on a CPU

HLS examples

- C/C++ to HDL + synthesis
- MATLAB to HDL + synthesis
- … to HDL + synthesis

High Level Design Tools

For FPGA devices:

- Vivado HLS (Xilinx)
- HLS Compiler (Intel)
- HDL Coder (MathWorks)
- and more…

For SoC devices:

- SDSoC (Xilinx)
- SDK for OpenCL (Intel)
- Embedded Coder (MathWorks)
- and more…

High Level Design Pros …

- Well suited for complex mathematical problems
- Fast Functional Iterations
- Freedom of implementation (CPU and/or Logic)
- Simulation time reduction (in software)
- Early resource estimation
- HDL Co-Simulation in software environment
- Software Engineers can now write Hardware 😱

High Level Design Cons …

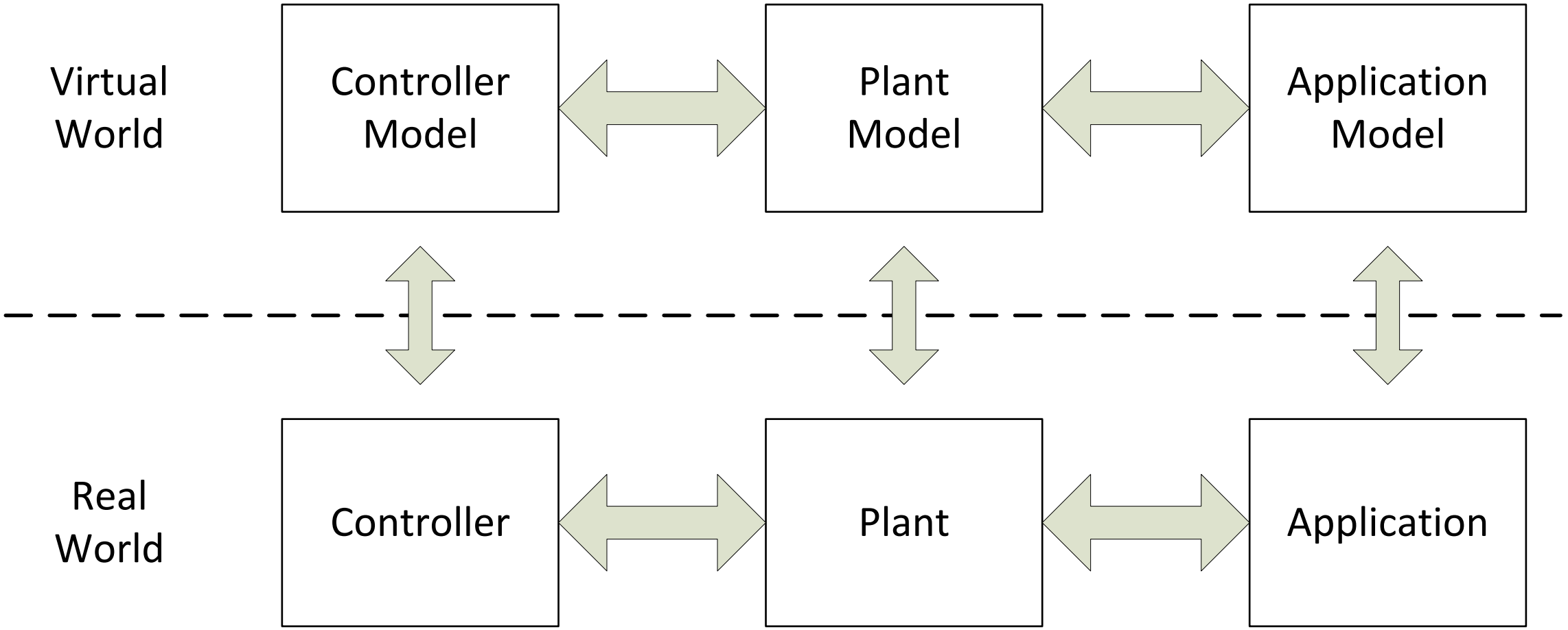
- Hardware mind-set still needed
- Code restructuring needed
- Generated HDL is not very readable
- Less suitable for (peripheral) interface controllers

- But… tools keep getting better

Model-Based Design

- A form of High-Level Designing
- Mathematical and visual design method
- To design:
  - Complex controllers
  - Signal processing
  - Communication systems
- Applications fields examples:
  - Industrial
  - Aerospace
  - Automotive

Real vs. Virtual World



Model-Based Design

- Multidisciplinary Design Approach
- Design with Virtual Models (without hardware)
- Simulation in the Virtual environment
- Models are always a complexity / effort trade-off
- Controller Model as good as your Plant/Appl. Model

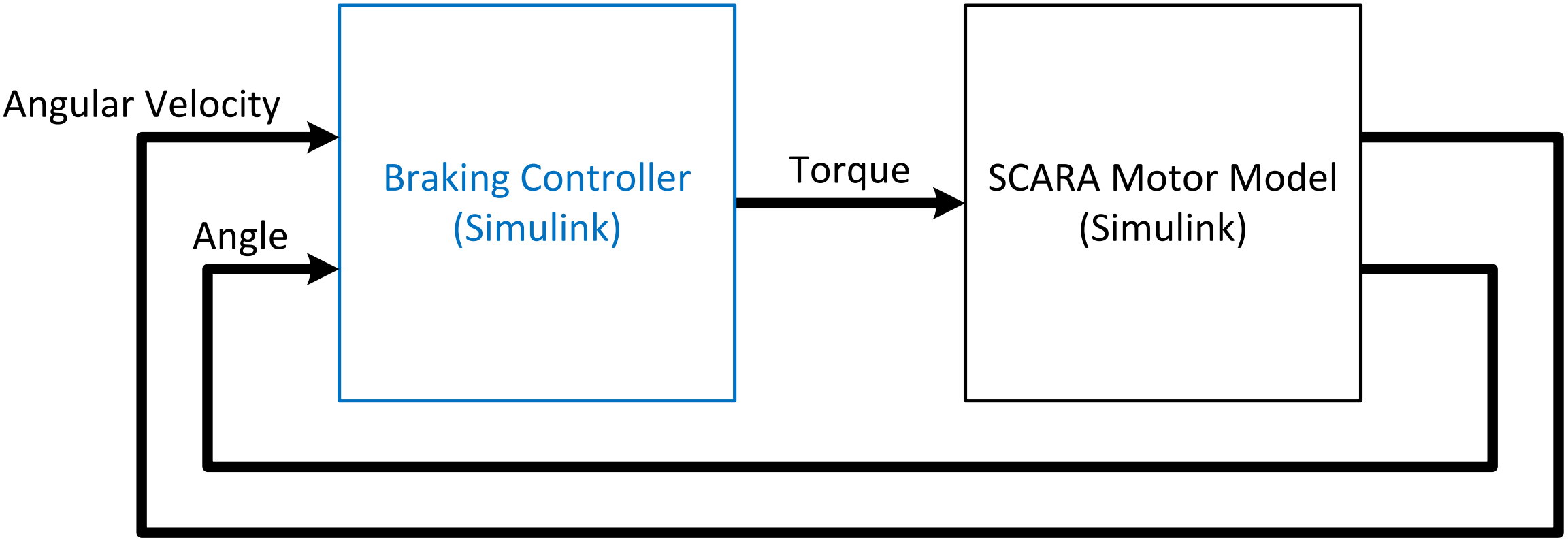
Model-Based Design Examples

- SCARA Robot Braking Controller
- Radar Tracking Module

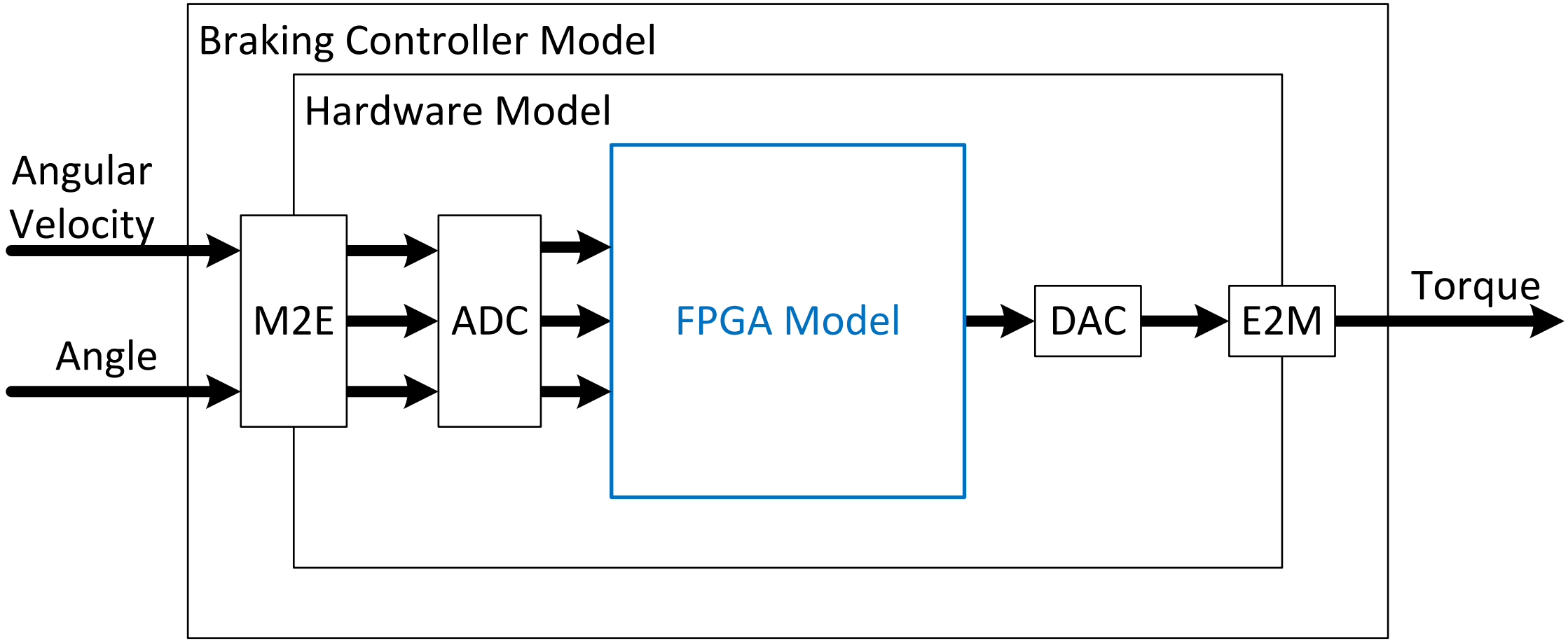
SCARA Robot Braking Application

- Move intermediate semiconductor products
- Controlled emergency braking
- Braking Requirements:
  - Follow robot trajectory while braking
  - Deviation from trajectory < 1mm
  - Rest is under NDA… 😉
- Customer provided Mechanical Models (in MATLAB Simulink)
  - SCARA Motor Model
  - Controller Model

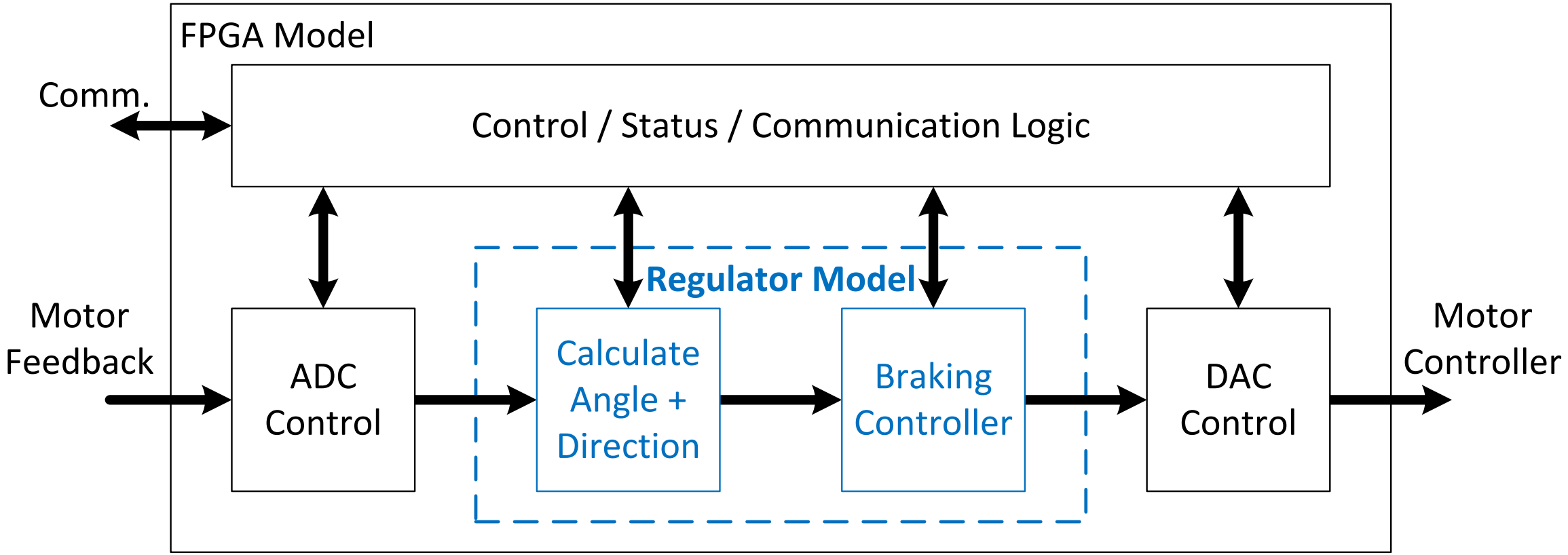
Simulink Model of Plant and Controller



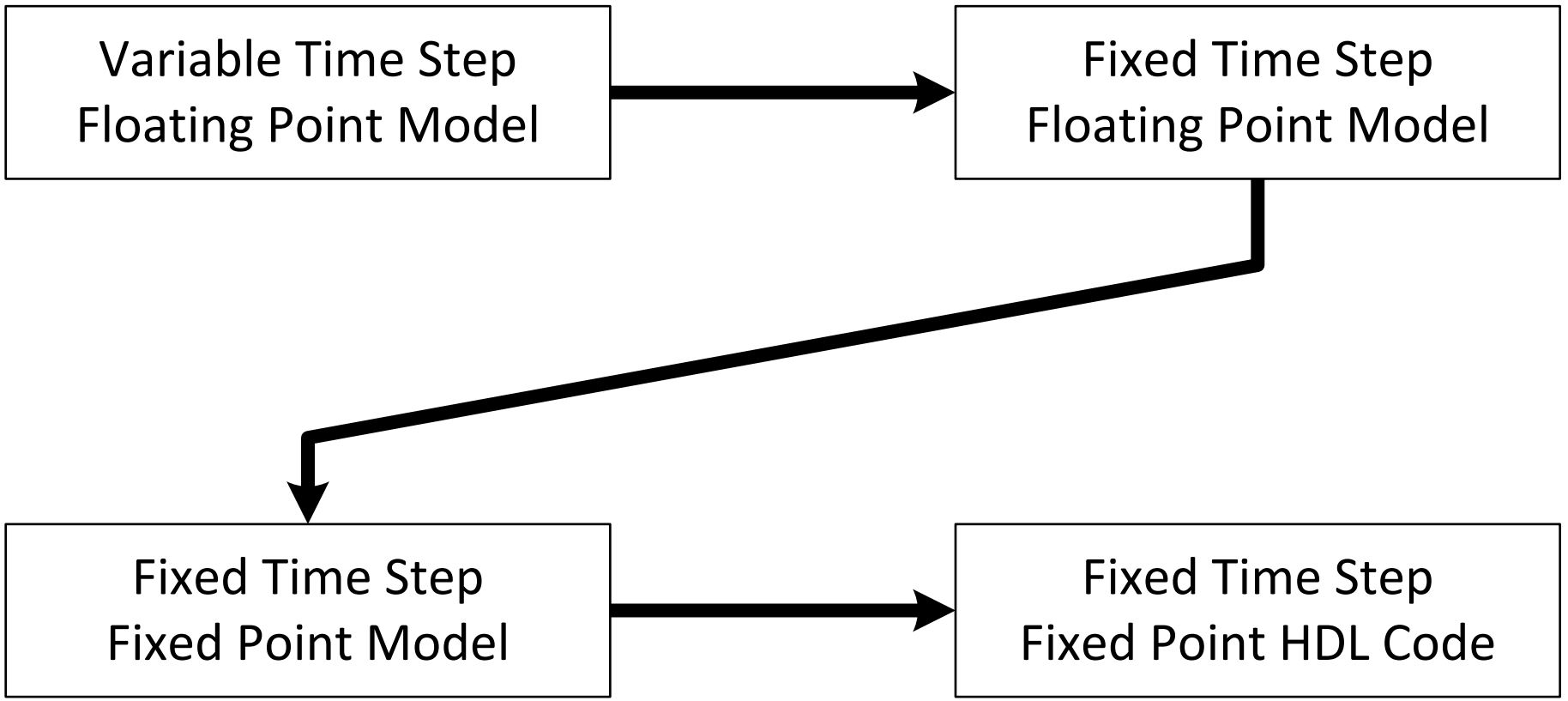
Simulink Braking Controller Model



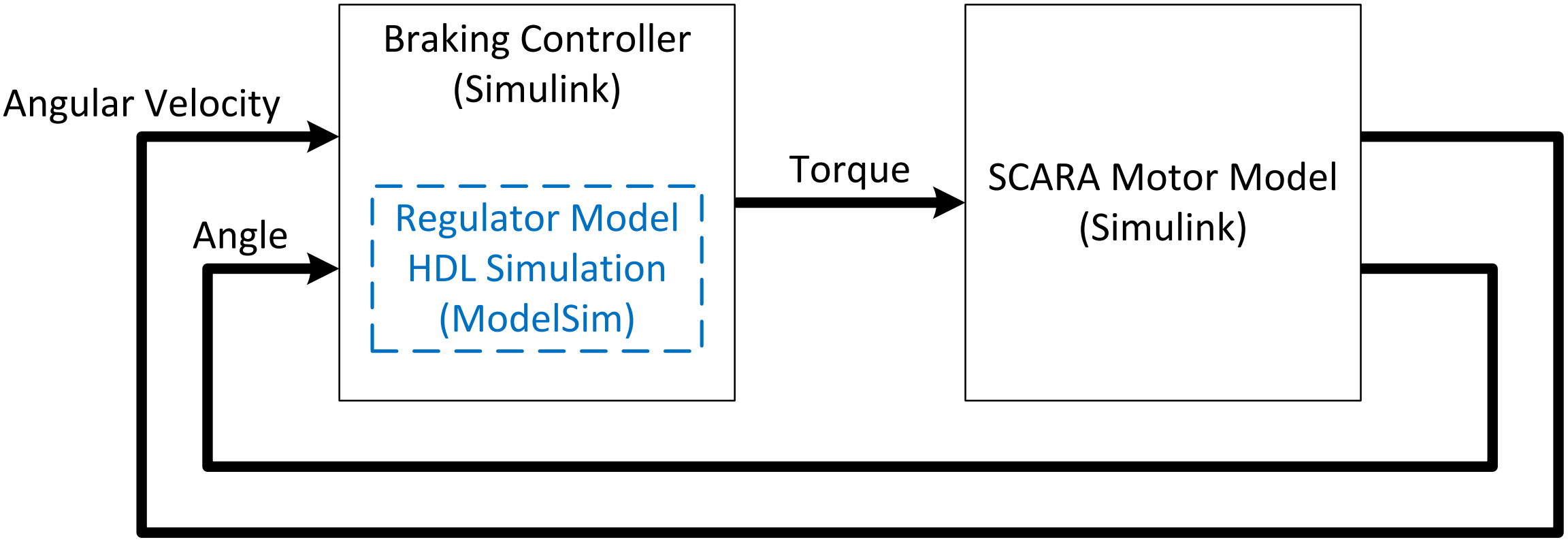
Simulink FPGA Model



Simulink Braking Regulator (Model to HDL)



Braking Regulator HDL Co-Simulation



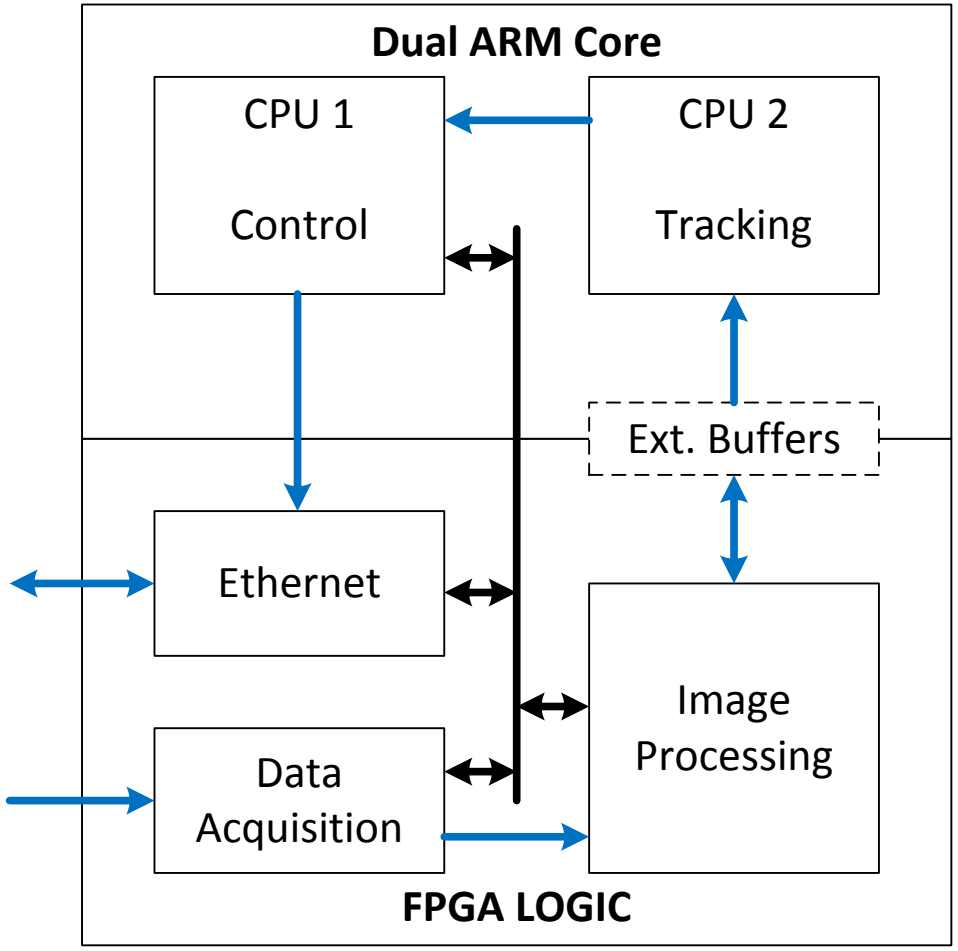
Design and Verification Summary

- From “High Level Model” to “Generated HDL”
  - Various Model Translations
- Generated HDL for Regulator Model (HDL Coder)
  - Angle/Direction Calculation + Braking Controller
- Hardcoded Design Blocks (non HDL Coder)
  - ADC / DAC Control + Control / Status / Communication Blocks
- Design Verification:
  - Co-Simulation + Hardware-in-the-Loop
- Design Fine-tuning:
  - Timing Closure, Resource Sharing,
  - Xilinx IP Instantiation for FFT

Radar Tracking Module example

- For Traffic Data processing
- Customer provided a High-Level Model (MATLAB) including:
  - Radar Module
  - Signal Processing
  - Tracking Algorithm
- System-on-Module Hardware Target
  - Enclustra Mars ZX3

SoC implementation setup



- eCos RTOS on CPU1
  - For real-time Control and Communication
  - Only available RTOS for this SoM
- Tracking Algorithms on CPU2
  - Generated C/C++ from Matlab Model
  - Running bare-metal on CPU2
- Image Processing in FPGA LOGIC
  - 2D Traffic Data Matrices Operations

Radar Tracking Model

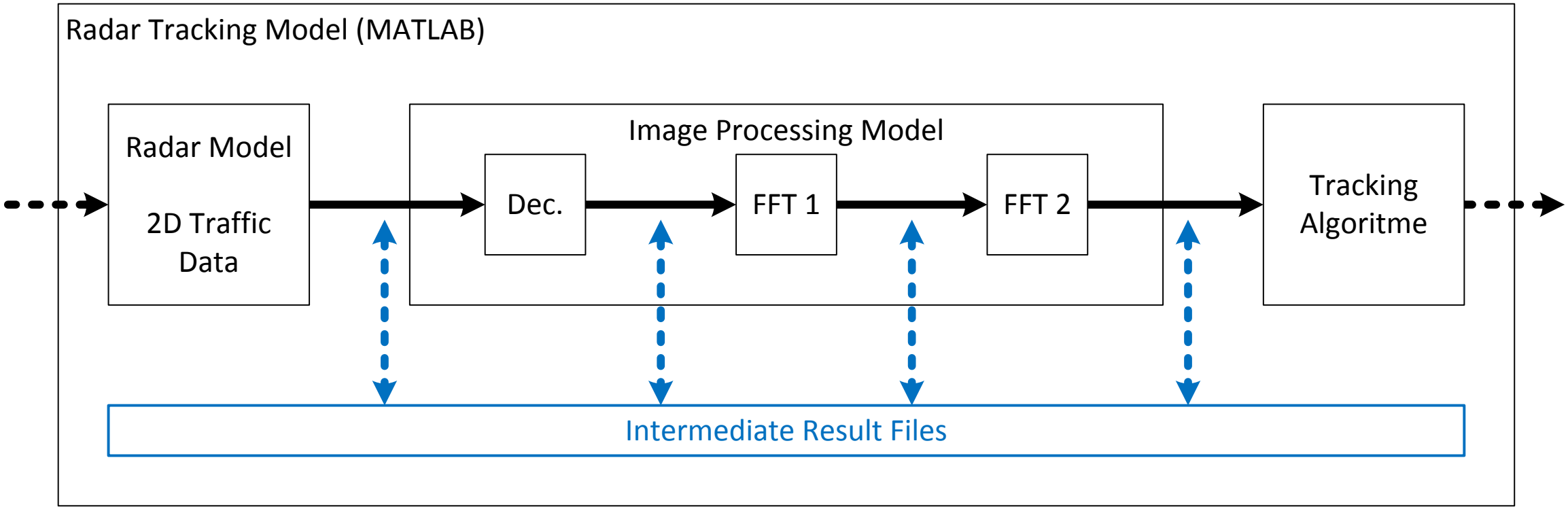
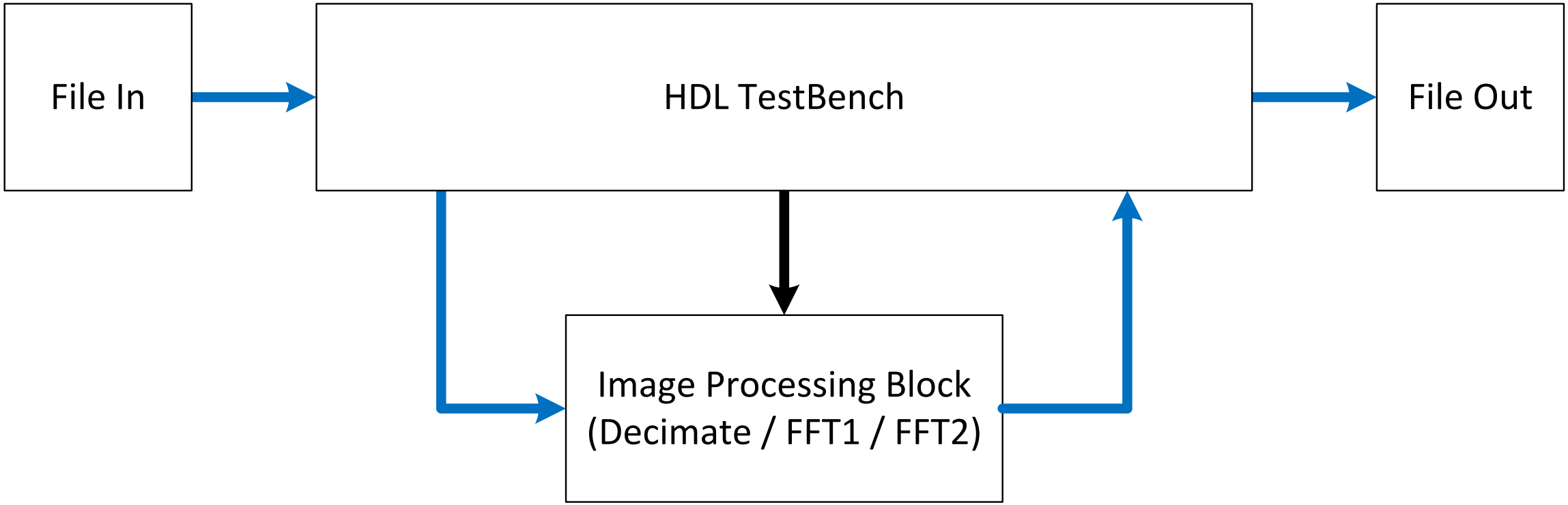
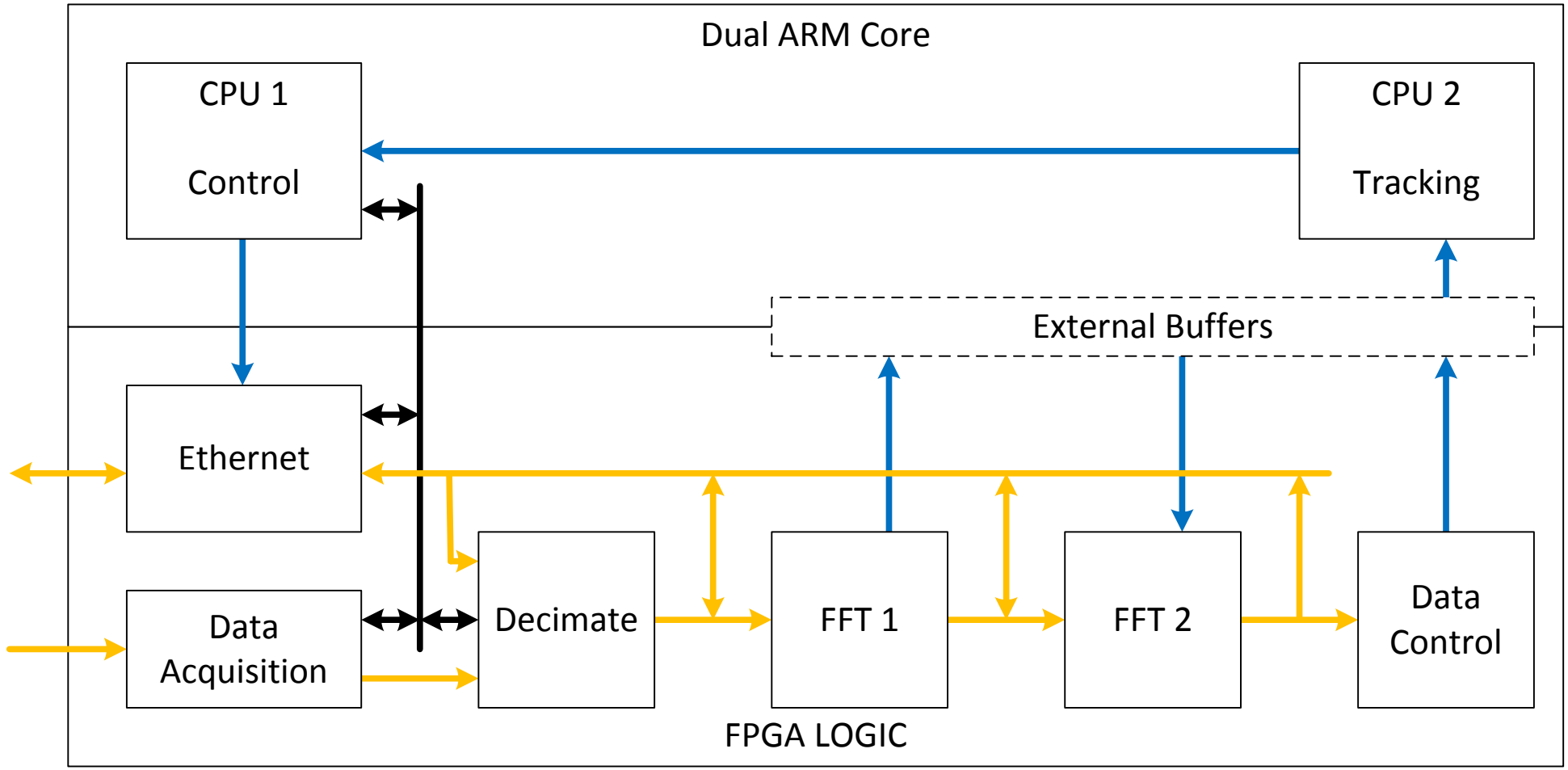


Image Processing Module Simulation



- Intermediate Model Results used in HDL TestBench
- HDL TestBench Results verified in the Model

Hardware-in-the-Loop Verification



Tooling

- Mathworks Tools:
  - MATLAB: *Complete Radar Tracking Model*
  - Embedded coder: *Tracking Algorithms Implementation*
  - Instrument Control toolbox: *Hardware-in-the-Loop Verification*
  - Signal processing toolbox: *Digital Filter Design*
- Xilinx Vivado:
  - Xilinx IP: *FFTs for Image Processing*
  - Xilinx IP: *Gbit Ethernet for UDP communication*
  - Custom IP: *Decimate for Image Processing*
- Xilinx to MATLAB: Xilinx FFT C-model converted to MATLAB file

Summary and More Info:

- High-Level Design and Synthesis
- Model-Based Design
- SCARA Robot Braking Controller
- Radar Tracking Module

- Email : Sander@3T.nl
- Web : www.3T.nl
- Stand: 7A108

Next Up:

- Herman Kuster
- Topic Embedded Systems
- Hardware platform for industrial ultrasound steel plate Inspection

3T B.V.
Institutenweg 1
7521 PH Enschede
The Netherlands

Esp 401
5633 AJ Eindhoven
The Netherlands

T. +31 53 4 33 66 33
F. +31 53 4 33 68 69
E. info@3t.nl
W. www.3t.eu