ESE Back End 2.0

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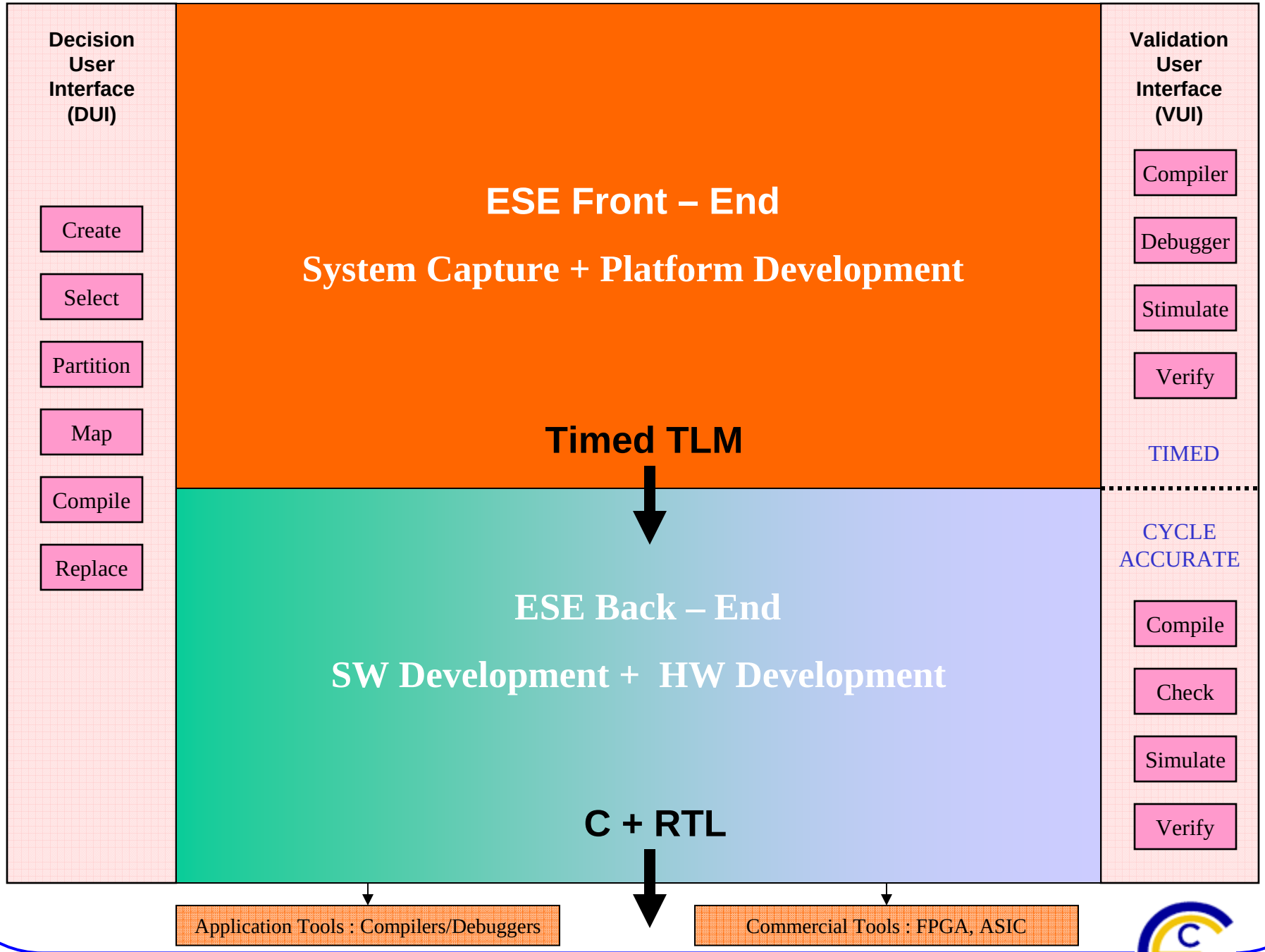
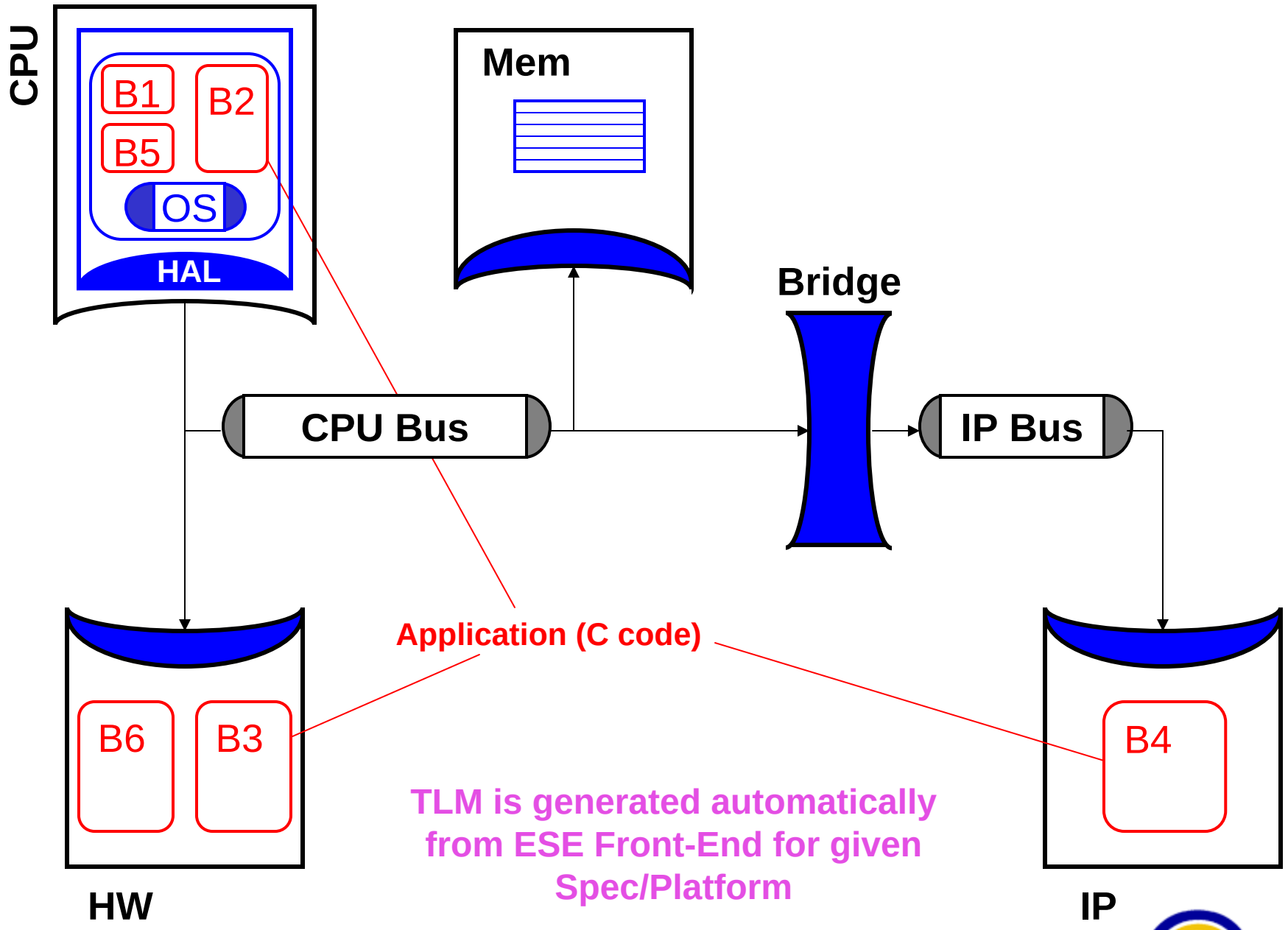
Technology advantages

- **No basic change in design methodology required**
  - ES methodology follows present manual design process
- **Productivity gain of more than 1000X demonstrated**
  - Designers do not write models
- **Simple change management: 1-day change**
  - No rework for new design decisions
- **High error-reduction: Automation + verification**
  - Error-prone tasks are automated
- **Simplified globally-distributed design**
  - Fast exchange of design decisions and easy impact estimates
- **Benefit through derivatives designs**
  - No need for complete redesign
- **Better market penetration through customization**
- **Shorter Time-to-Market through automation**

ES Environment



Input: Transaction Level Model (TLM)

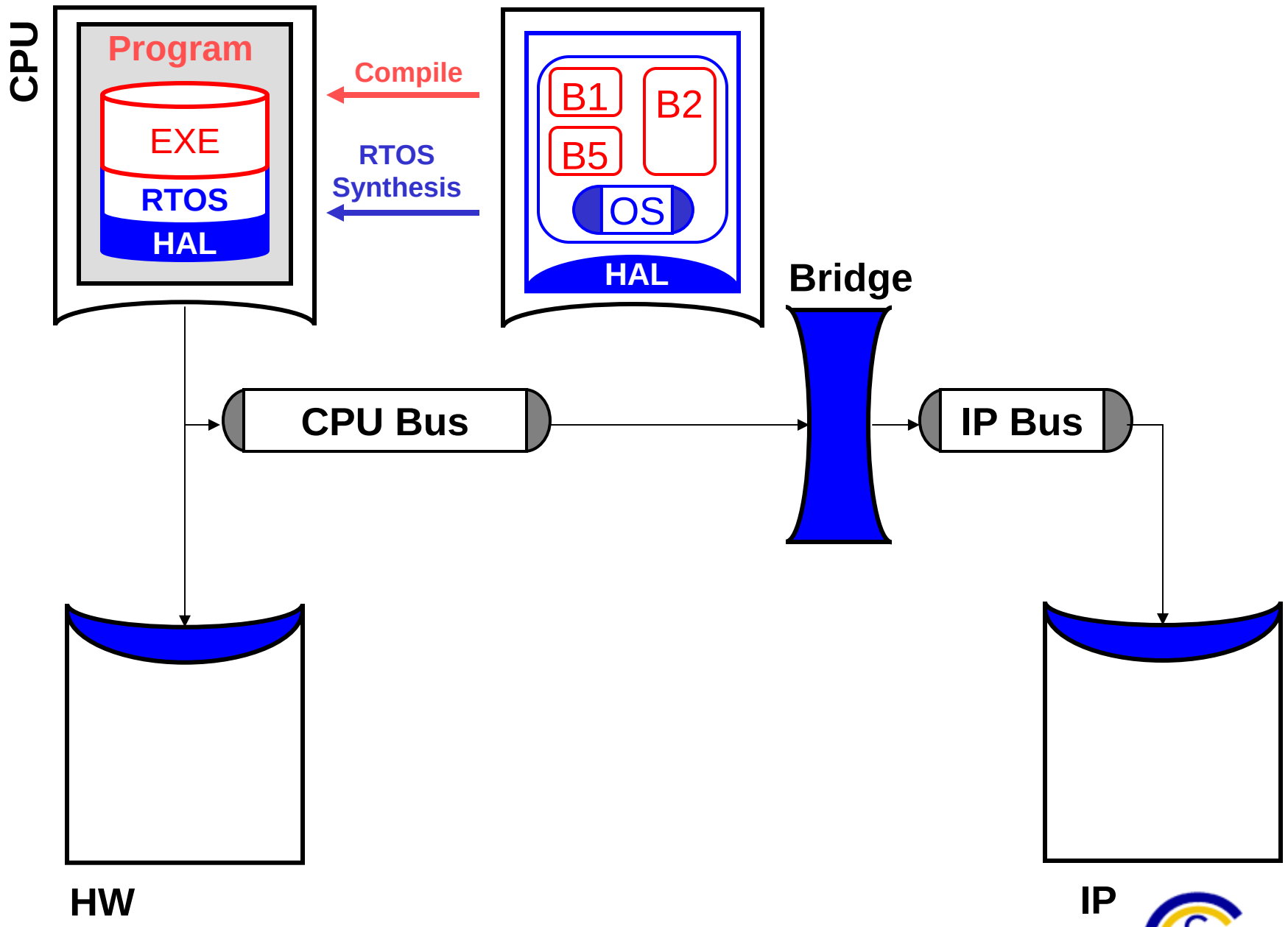


TLM is generated automatically from ESE Front-End for given Spec/Platform

TLM Features

- **Universal Bus Channel (UBC)**
  - Bus is modeled as universal channel with send/recv, read/write functions
  - Well defined functions for routing, synchronization, arbitration and transfer
- **SW modeling**
  - Application SW is modeled as processes in C
  - A RTOS model or real RTOS is used for dynamic scheduling of processes
  - Communication with peripherals, memory or other IP is done using UBC
- **HW modeling**
  - Application HW is modeled as processes written in C
  - Communication with processor, memory or other IP is done using UBC
- **Memory modeling**
  - Memory is modeled as array in C
  - Controller is modeled by function in UBC

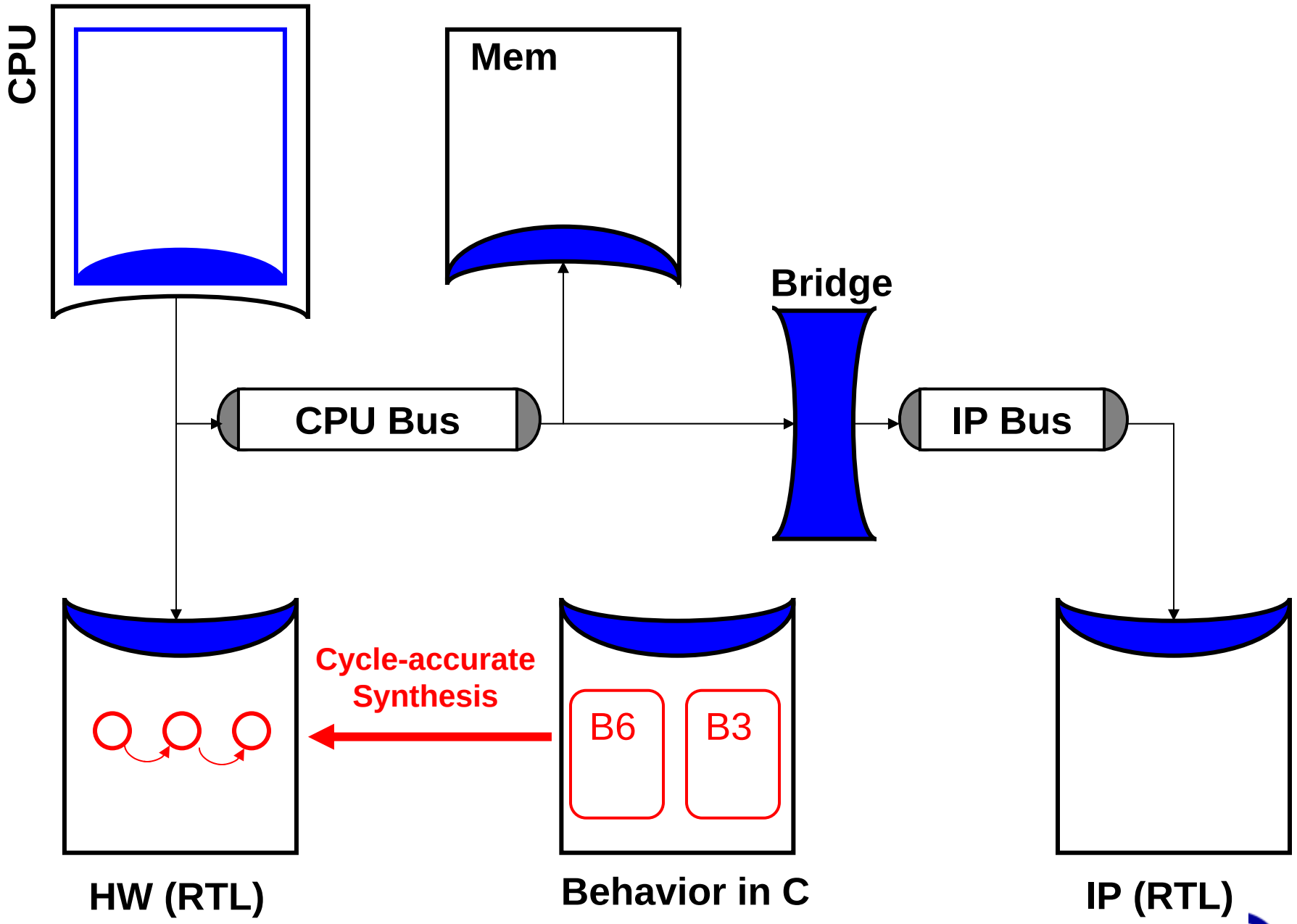
Cycle-Accurate Software Synthesis



SW Synthesis Issues

- **Compiler selection**
  - The designer specifies which compiler is used for the SW
- **Library selection**
  - Libraries are selected for SW support such as file systems, string manipulation etc.
  - Prototype debugging requires selection of additional libraries
- **RTOS selection and targeting**
  - Designer selects an RTOS for the processor
  - RTOS model is replaced by real RTOS and SW is re-targeted
- **Program and data memory**
  - Address range for SW program memory is assigned
  - Address range for data memory used by program is assigned
  - For large programs or data, off-chip memory may be allocated

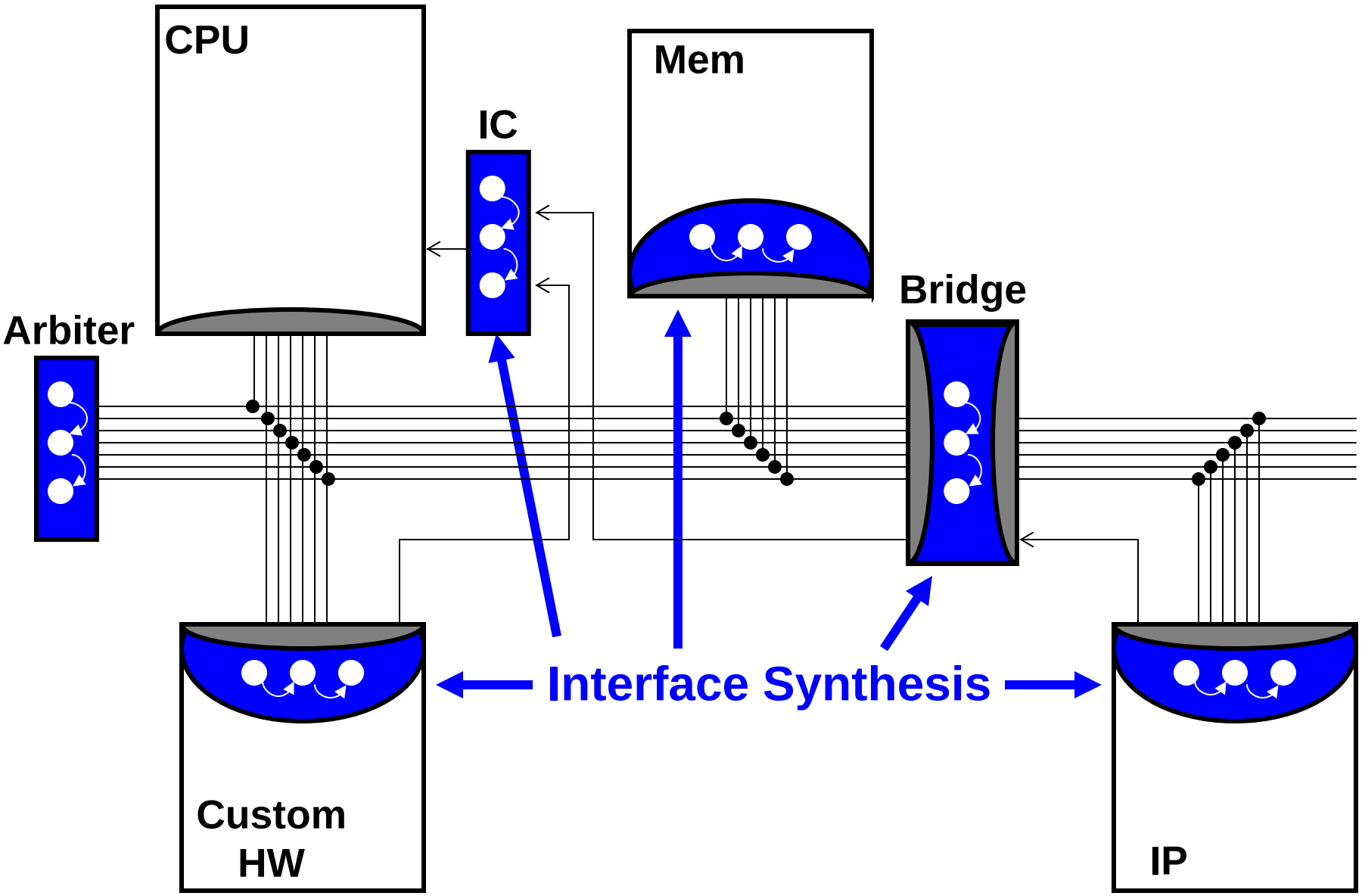
Cycle-Accurate Hardware Synthesis



HW Synthesis Issues

- **IP insertion**
  - C model of HW is replaced with pre-designed RTL IP, if available
- **RTL synthesis tool selection**
  - RTL synthesis tool must be selected for custom HW design
- **SystemC code generation**
  - C/SystemC code for input to RTL synthesis tool is generated
- **Synthesis directives**
  - RTL architecture and clock cycle time is selected
  - UBC calls are treated as single cycle operations, to be later expanded during interface synthesis
- **HDL generation**
  - RTL synthesis result in cycle accurate synthesizable Verilog code

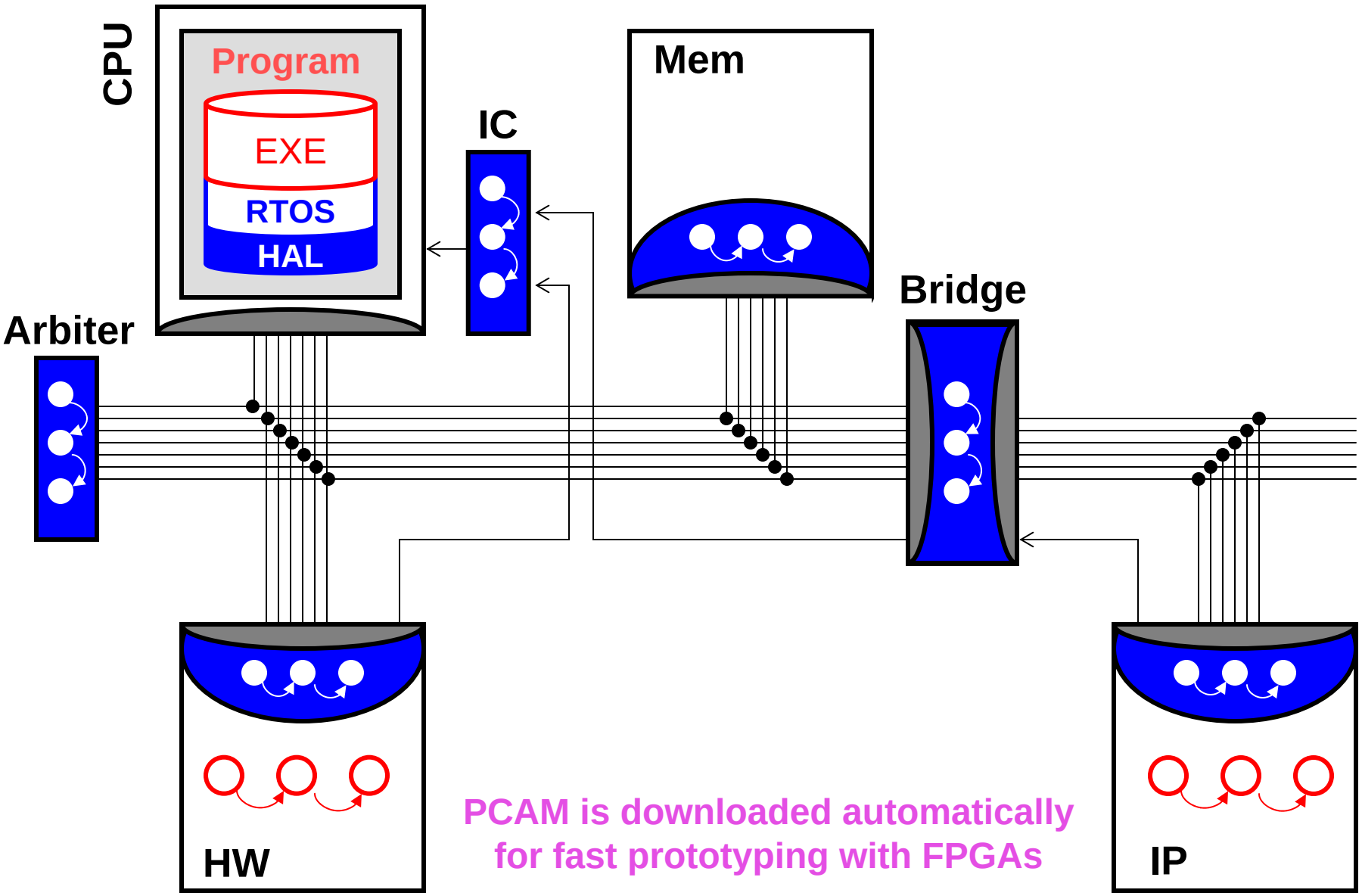
Cycle-Accurate Interface Synthesis



Interface Synthesis Issues

- **Synchronization**
  - UBC has unique flag for each pair of communicating processes
  - Flag access is implemented as polling, CPU interrupt or interrupt controller
- **Arbitration**
  - Selected from library or synthesized to RTL based on policy
- **Bridge**
  - Selected from library or synthesized using universal bridge generator
- **Addressing**
  - All communicating processes are assigned unique bus addresses
- **SW communication synthesis**
  - UBC functions are replaced by RTOS functions and assembly instructions
- **HW communication synthesis**
  - DMA controller in RTL is created for each custom HW component
  - Send/Recv operations are replaced by DMA transfer states

Pin/Cycle-Accurate Model



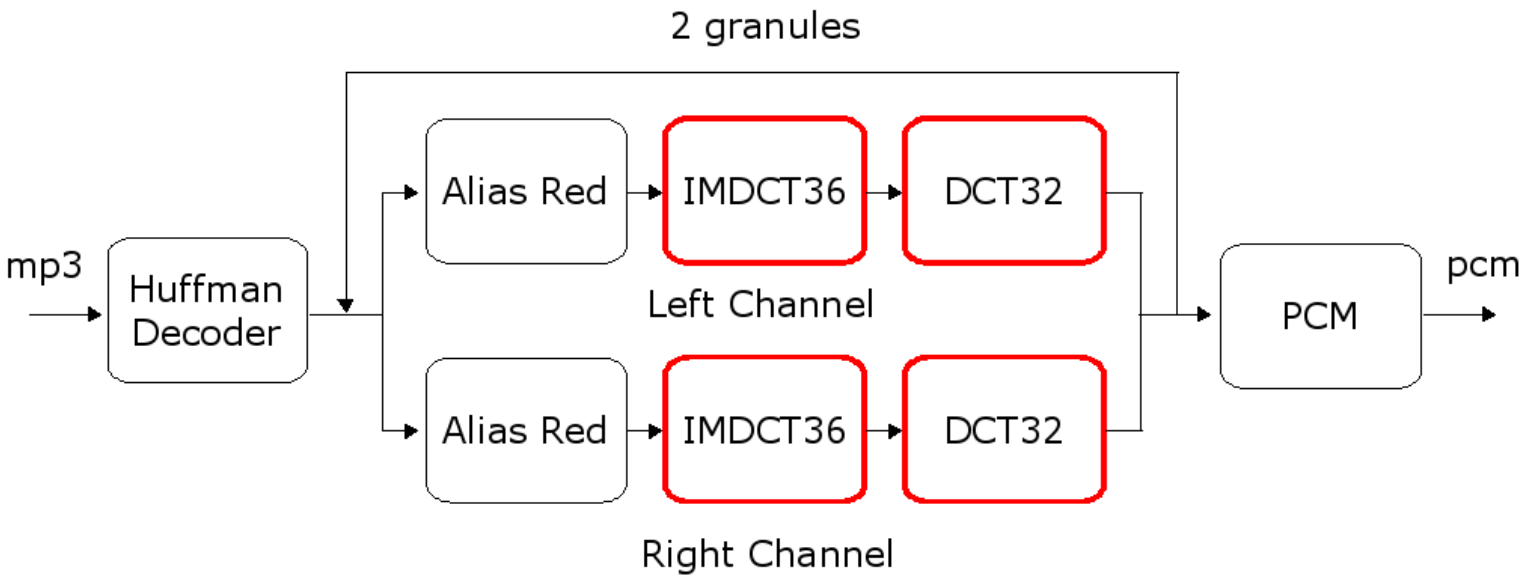
PCAM is downloaded automatically for fast prototyping with FPGAs

MP3 Player Prototyping with ESE Back-end

- **TLM Input**
  - TLM is generated by ESE front-end for MP3 application and platform
- **Interface synthesis**
  - Polling or interrupt mechanism is selected for synchronization
  - Arbiter is selected for busses with multiple masters
  - Bridge between CPU bus and peripheral bus is created by Bridge Generator
- **SW synthesis**
  - Compiler/RTOS for SW is selected and addresses are generated for memories
- **HW synthesis**
  - RTL is generated for custom HW cores by NISC compiler or C→RTL tools
- **Export to FPGA design tools**
  - Files are generated for creating complete project for FPGA tools
- **FPGA download and test**
  - FPGA design tools create bit-stream for programming the board
  - MP3 player prototype runs directly on FPGA board

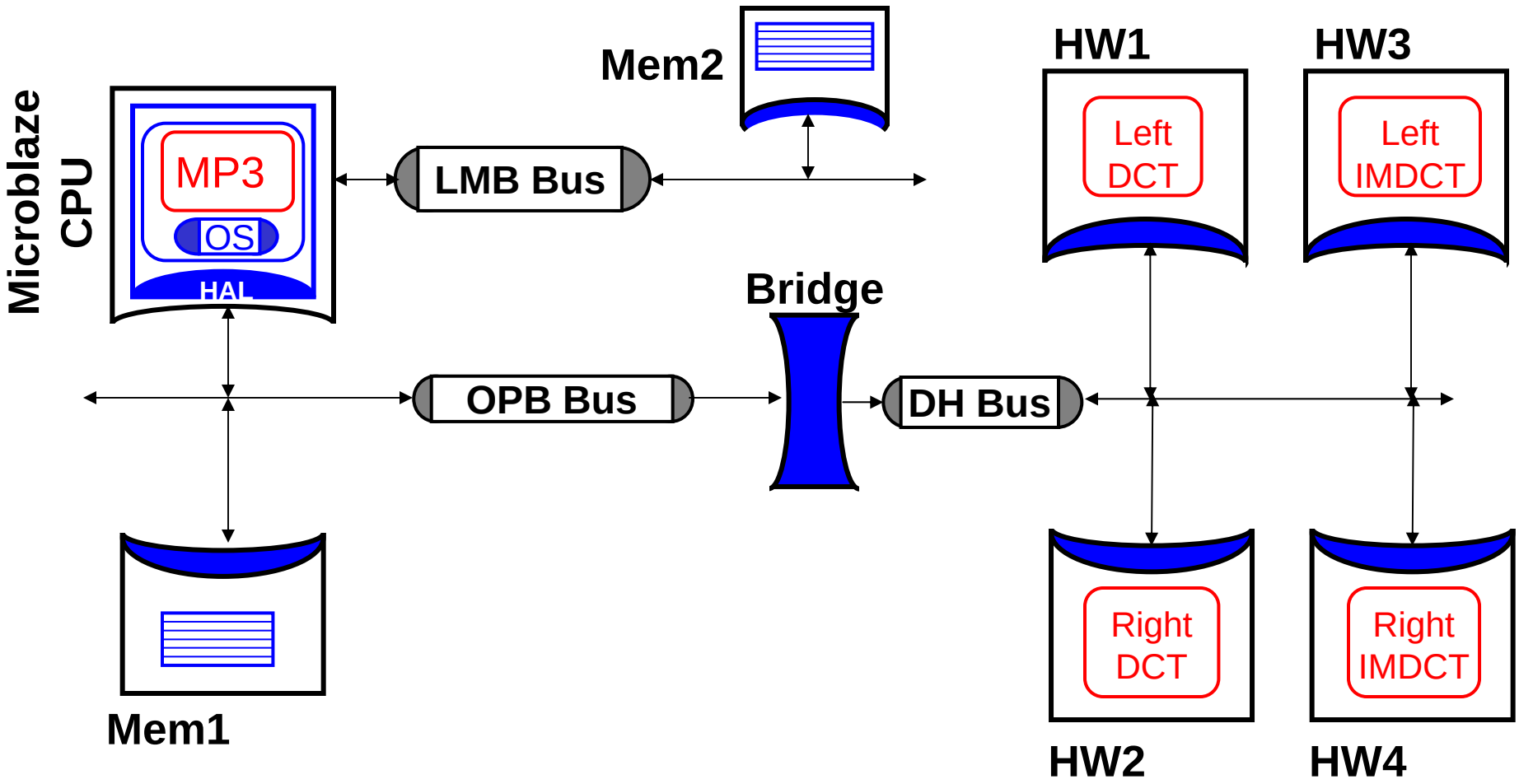
MP3 Decoder Application

- **Functional block diagram (major blocks only)**



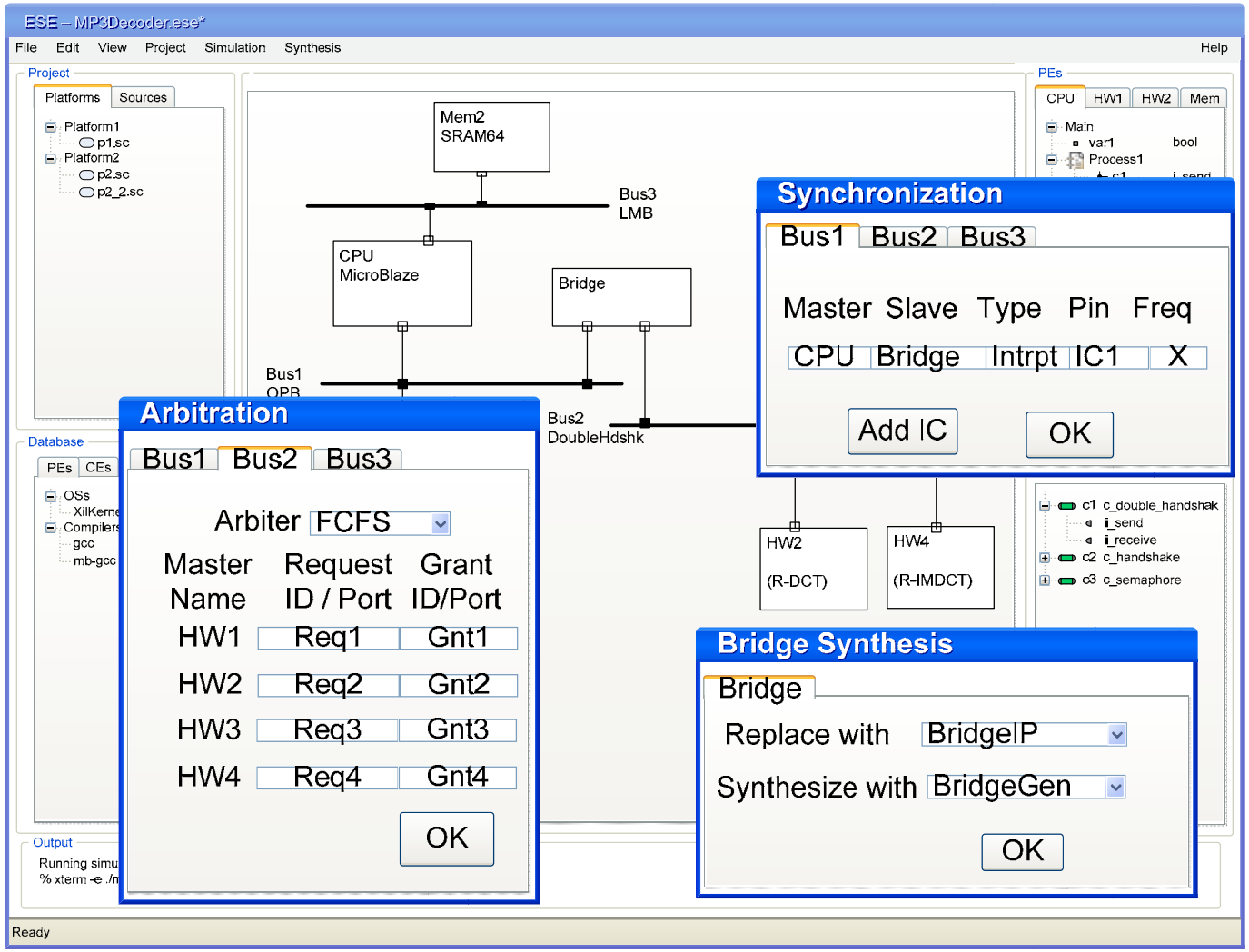
- **Application features**
  - **12K lines of C code**
  - **IMDCT and DCT are compute intensive**
    - **Candidates for HW implementation**
  - **Left channel and right channel are data independent**
    - **Concurrent execution possible**

MP3 Player TLM (SW+4HW)



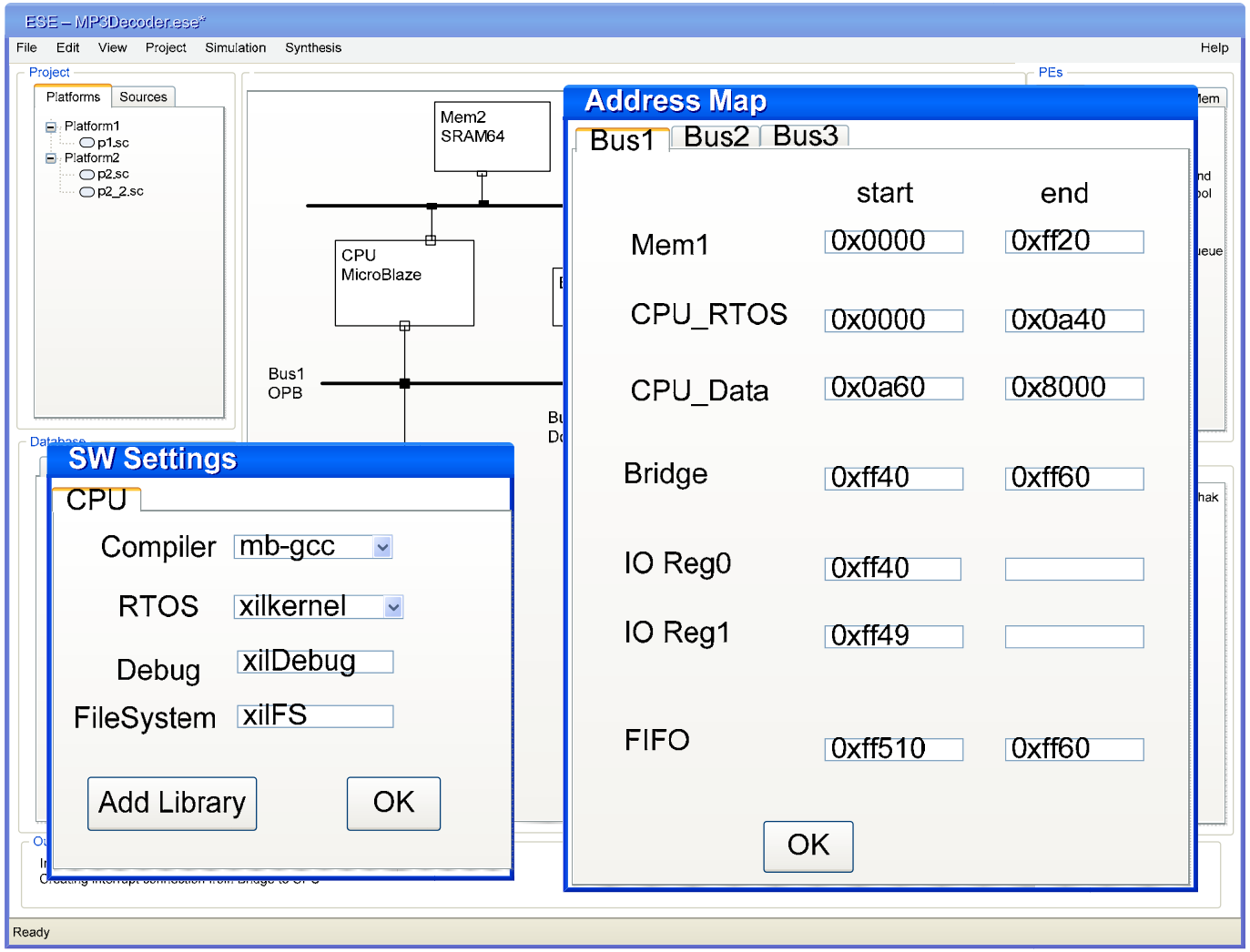
- MP3 encoder mapped to SW (MicroBlaze), DCT and IMDCT to HW
- Mem1 (on OPB bus) for program, Mem2 (on LMB bus) for data
- Custom HWs on DoubleHdshk (DH) bus, with bridge to OPB

Interface Synthesis



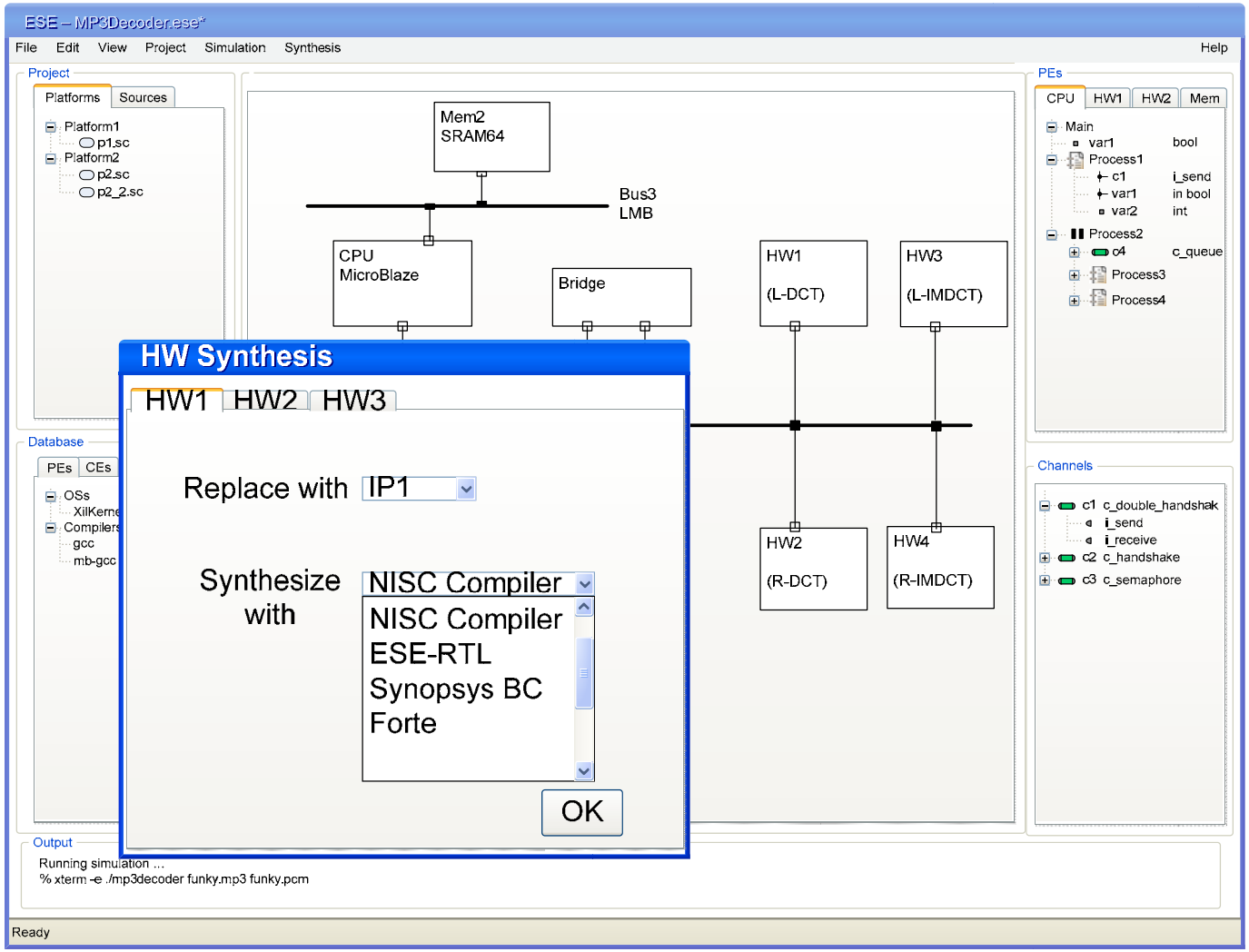
- **Interrupt signals and connections are selected**
- **Arbiter is selected and request / grant pins are connected**
- **RTL code for Bridge is generated using BridgeGen**

SW synthesis



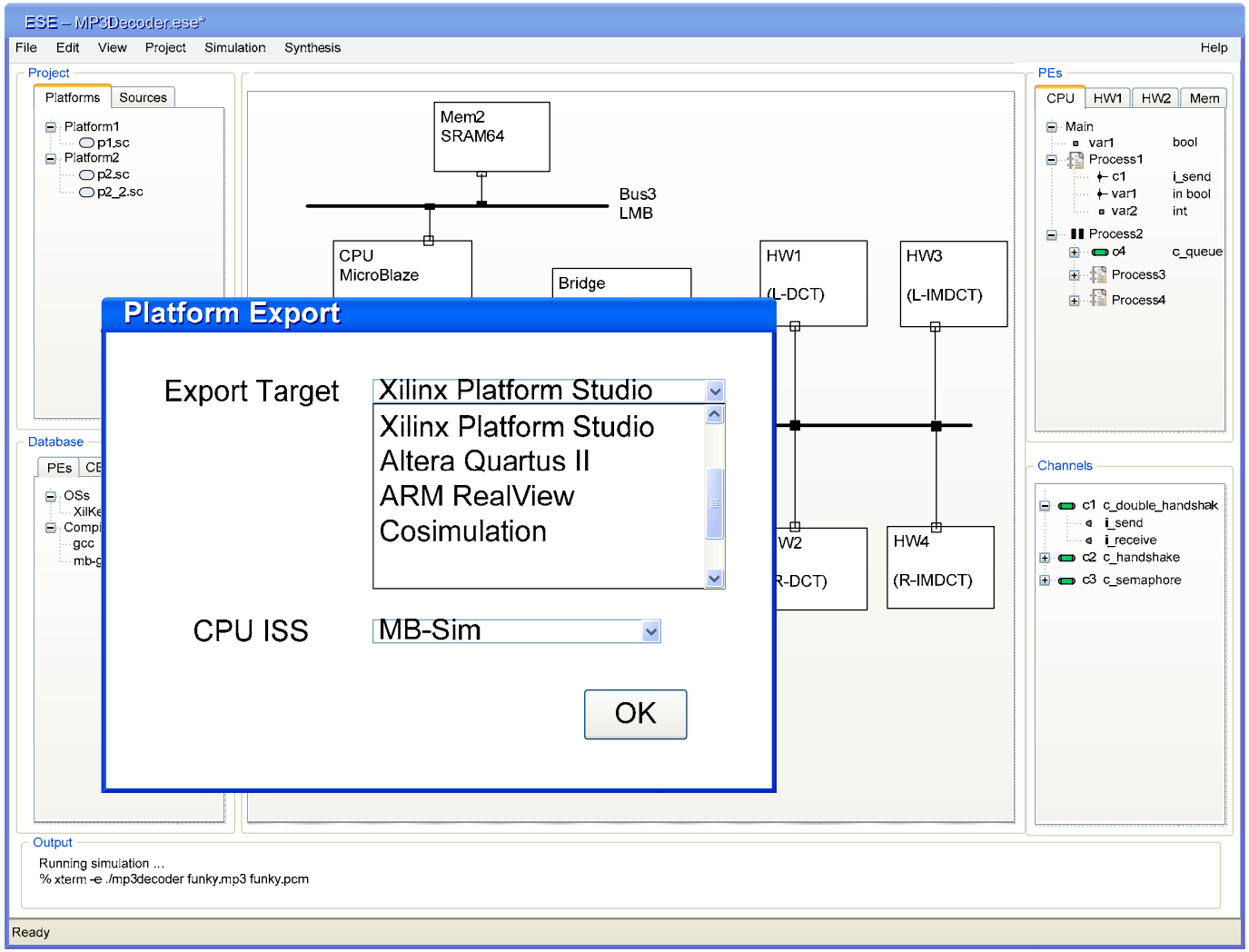
- **Compiler, RTOS and libraries are selected for SW**
- **Default addresses for all addressable memory/bus is generated by ESE**

HW synthesis



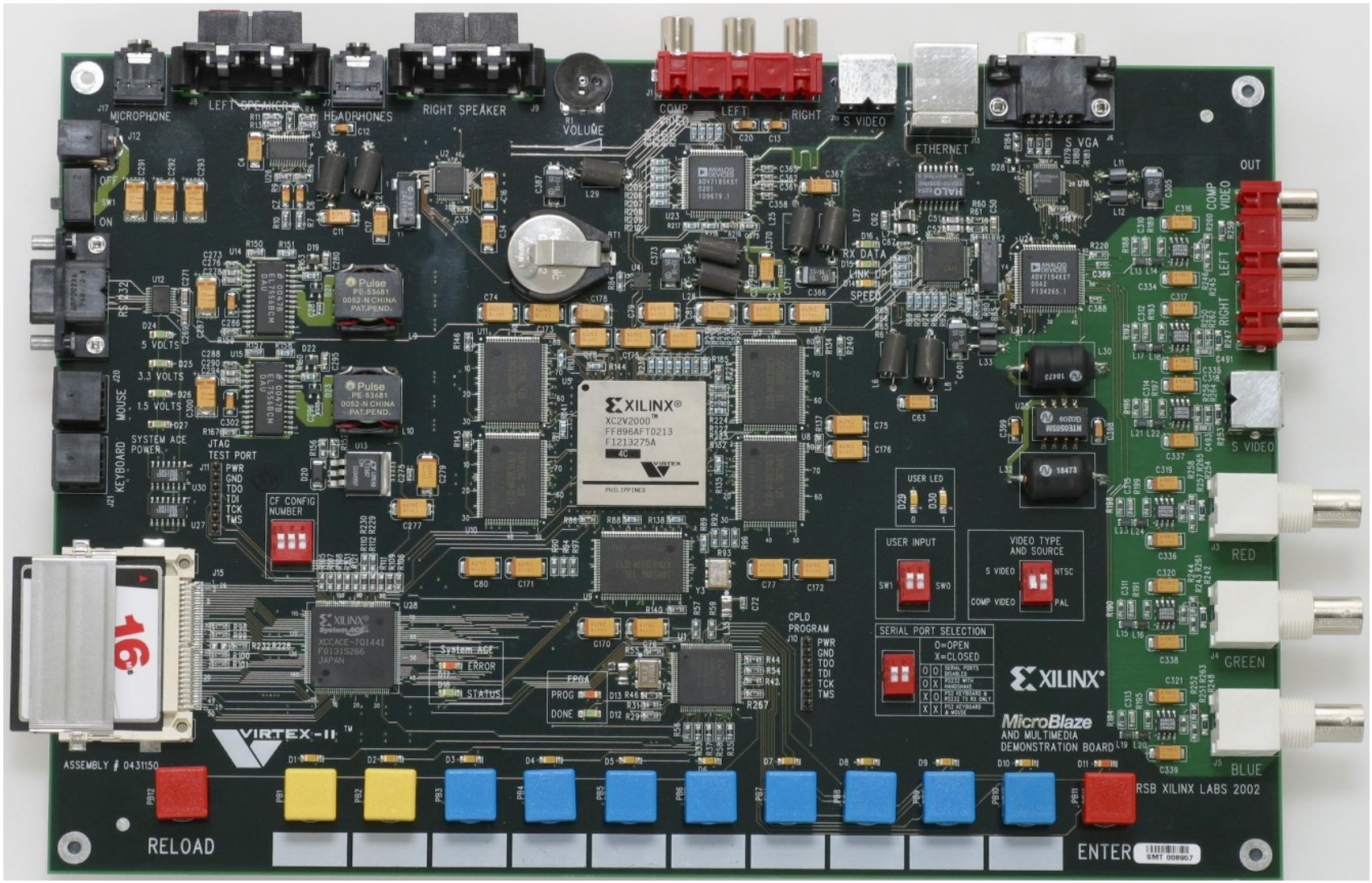
- **RTL code for HW components is generated using C→RTL tools**

Export to FPGA Design Tools



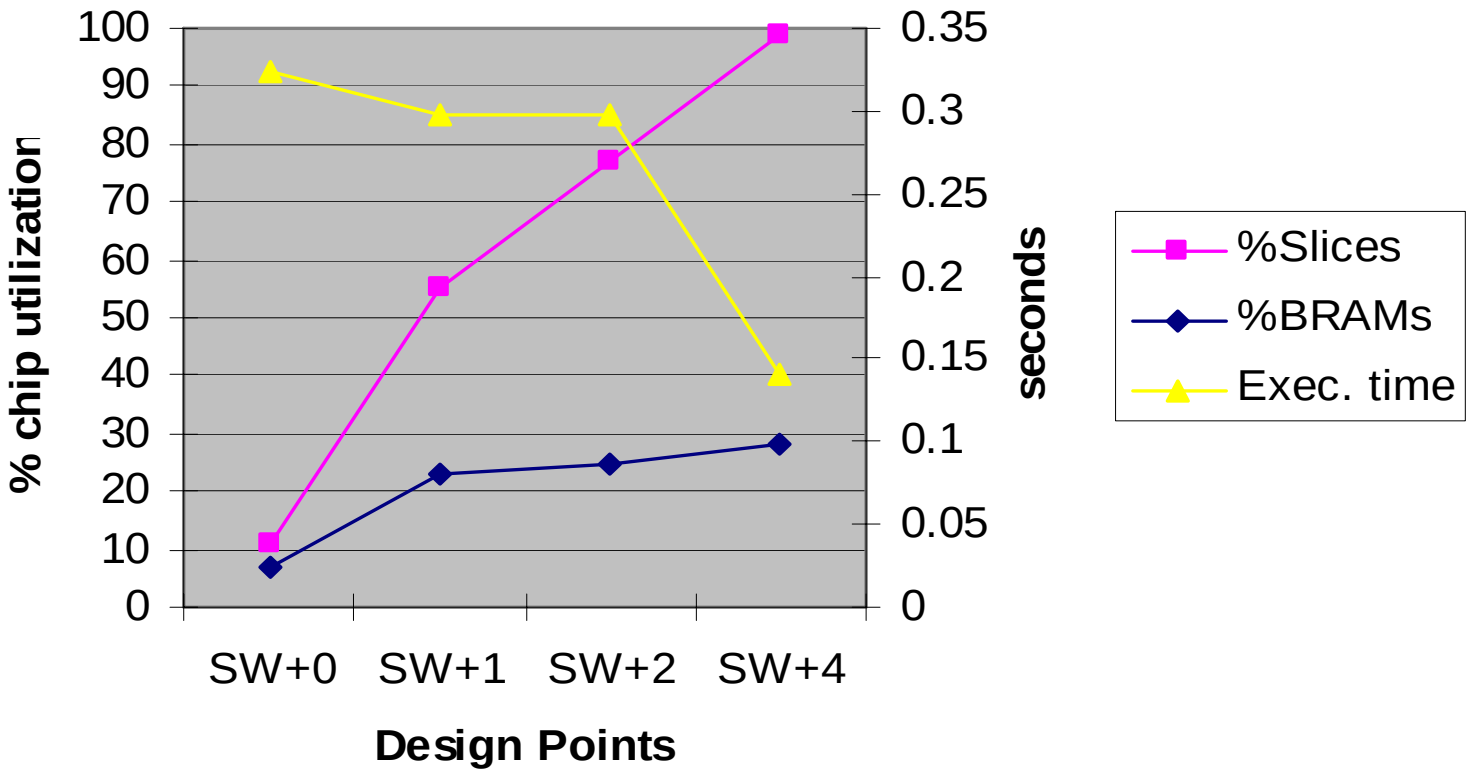
- **Platform and SW specification files are created for FPGA design tools**
- **C code for Microblaze and Verilog for HWs and Bridge is exported**

Benefit: FPGA Prototype in 1 Week



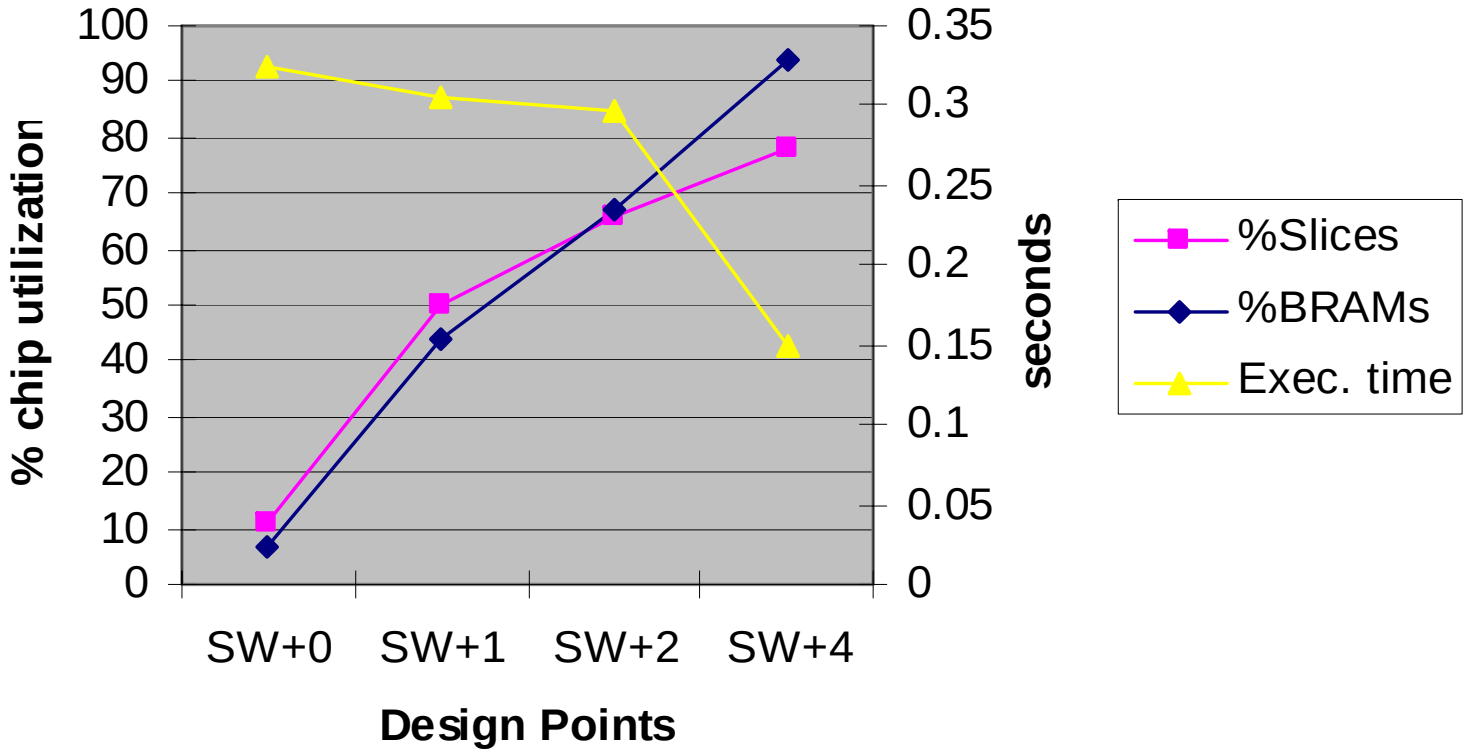
- **Bit stream from FPGA design environment is downloaded to board**
- **Implemented prototype is tested with MP3 music files**

Design Quality: Manual



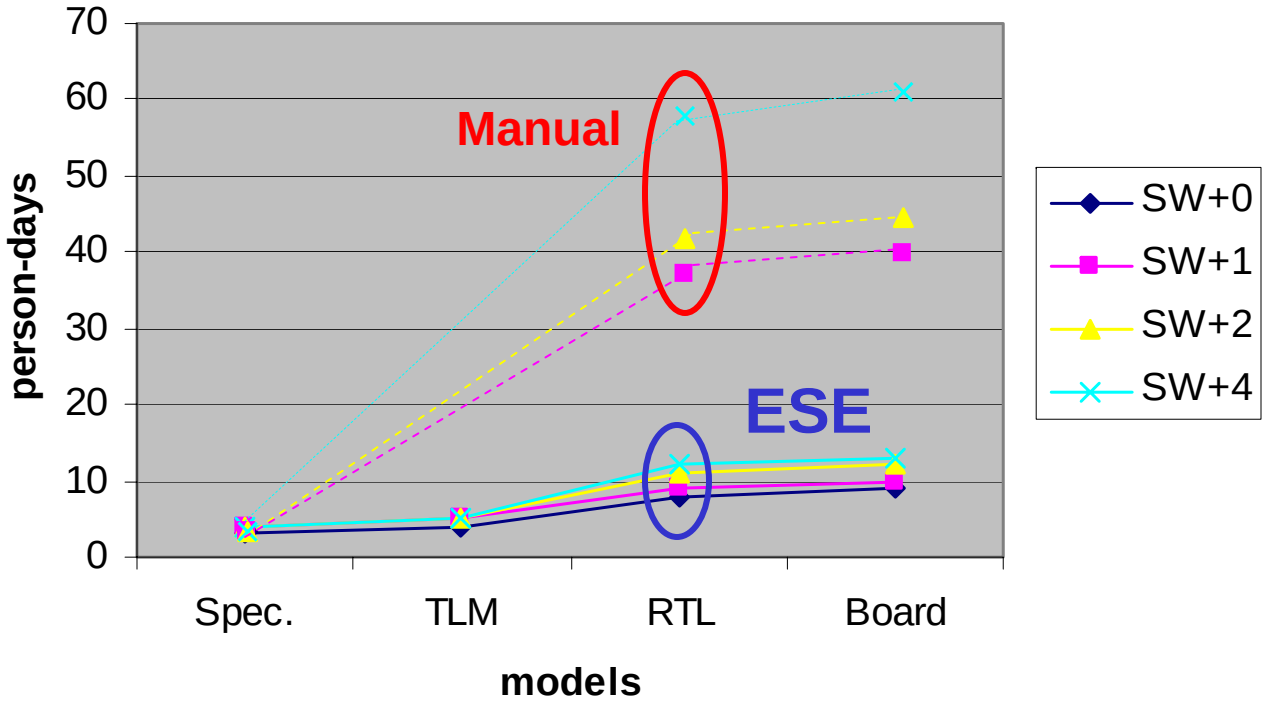
- **Area**
  - % of FPGA slices and BRAMS
- **Performance**
  - Time to decode 1 frame of MP3 data

Design Quality: ESE



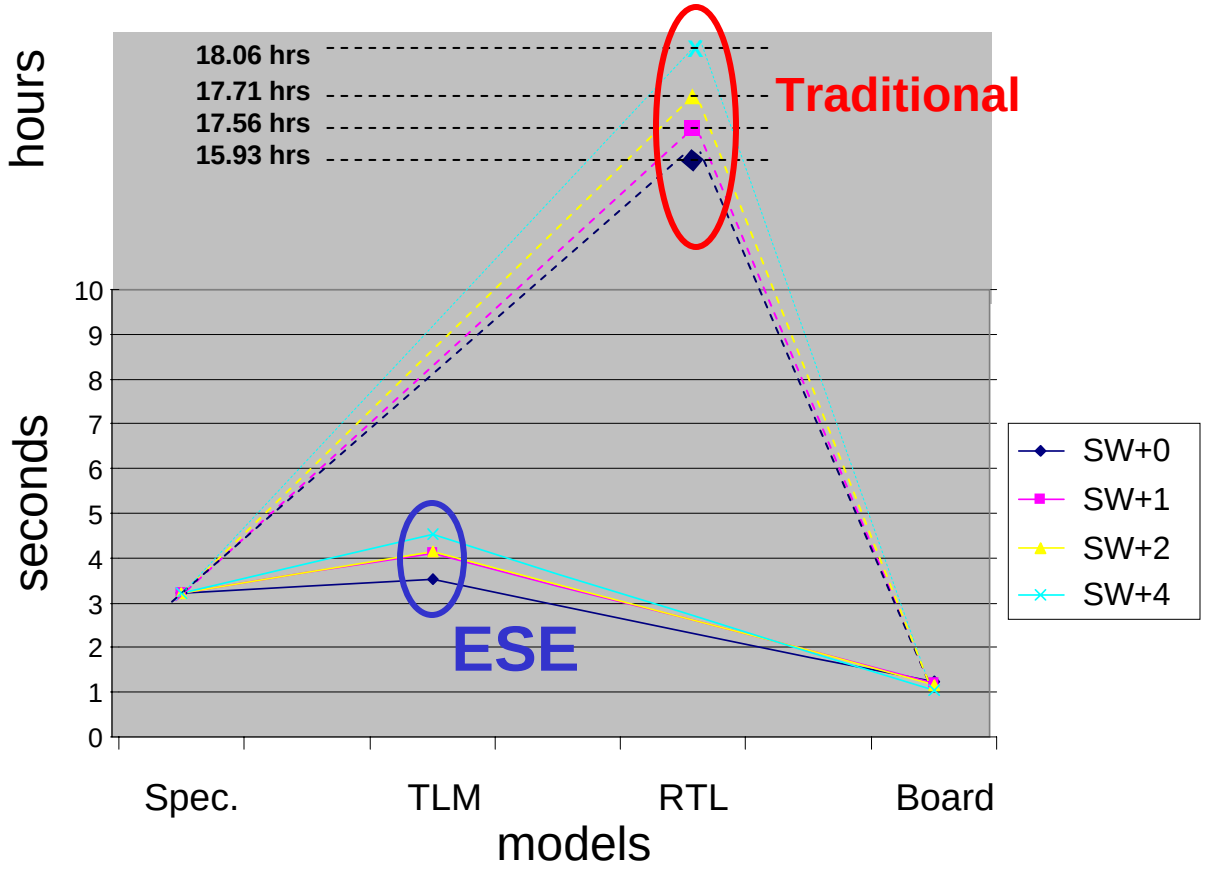
- **Area**
  - ESE designs use fewer FPGA slices and more BRAMs than manual HW
- **Performance**
  - ESE designs execute at same speed as manual designs

Development Time: ESE vs. Manual



- **ESE drastically cuts RTL and Board development time**
  - Manual development includes months of RTL coding
  - Models can be developed at Spec level with ESE
  - TLM, RTL and Board models are generated automatically by ESE

Validation Time: ESE vs. Traditional



- **ESE cuts validation time from hours to seconds**
  - No need to verify RTL models for every design change
  - Designers can perform high speed validation with TLM and board

ESE Back-end Advantages

- HW synthesis in ESE removes the need to code and debug large RTL HDL models
- Transducer and interface synthesis allows flexibility to include heterogeneous IP in the design
- SW driver synthesis removes the need for SW developers to understand HW details
- SW and HW application can be easily upgraded at TL and validated on board
- C and graphical input of TL model allows even non-experts to develop and test HW/SW systems with ESE

Acknowledgments

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  - SpecCharts/SpecSyn (’92): F. Vahid, S. Narayan, J. Gong, S. Bakshi
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