Optimization and Implementation of Embedded Signal Processing Algorithms

Jonas Rutström
Senior Application Engineer

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Two important questions in embedded design...

1. What’s your algorithm?

Two important questions in embedded design...

2. What’s your target?

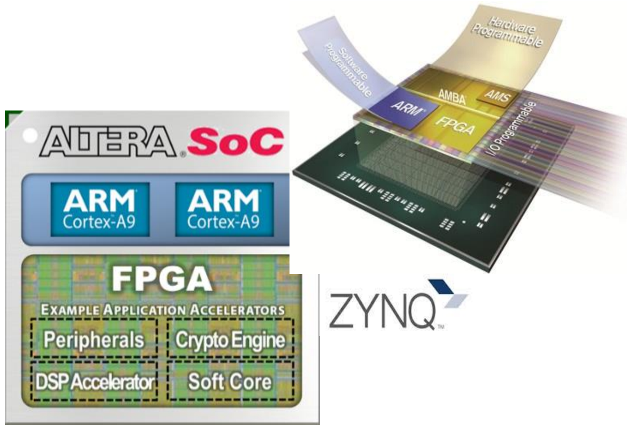
Targets are very different...

The embedded hardware might be very different...

DSP

MCU

SoC/FPGA

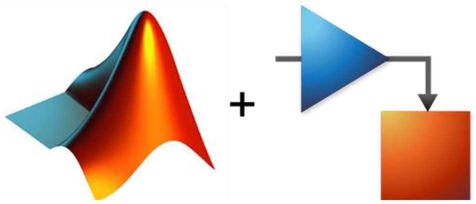


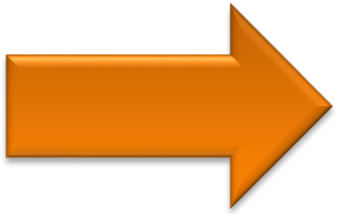
Workflow | Idea to implementation

Workflow | Idea to implementation

Prototyping

Workflow | Idea to implementation





Accelerate the Design and Prototyping of Signal Processing Algorithms

15:00–15:30

In this session we show how you can use MATLAB® for designing and prototyping an algorithm that operates on streaming data. This way of working makes simulations fast and memory efficient. We also show how to test algorithms against data coming from low-cost hardware such as a smartphone or Raspberry Pi™. In the session Optimization and Implementation of Embedded Signal Processing Algorithms, we integrate the algorithm in a larger system that is targeted for a specific hardware platform.

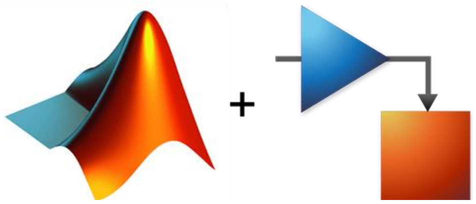
You will see how to:

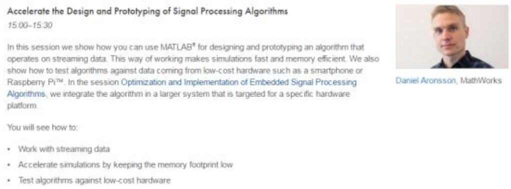
- Work with streaming data
- Accelerate simulations by keeping the memory footprint low
- Test algorithms against low-cost hardware

Daniel Aronsson, MathWorks

Prototyping

Workflow | Idea to implementation

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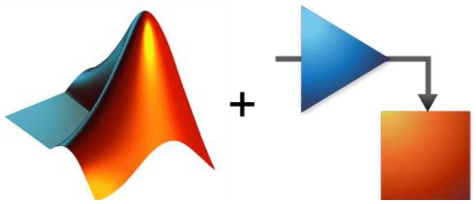
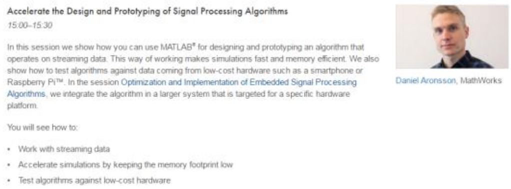
Prototyping

Production

Workflow | Idea to implementation

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Prototyping

Production

Workflow | Idea to implementation

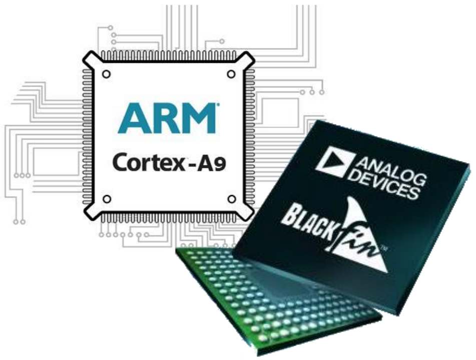
Prototyping

Production

Let’s take a step back...

What do we mean with optimization?

Speed	Memory	Readability	Target

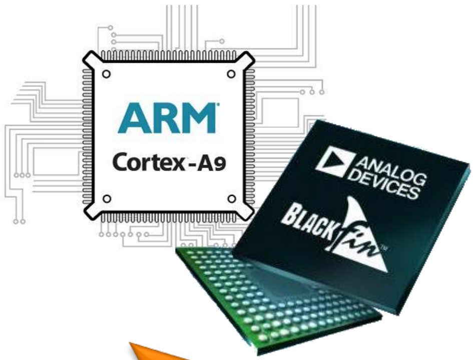


Speed

Memory

Readability

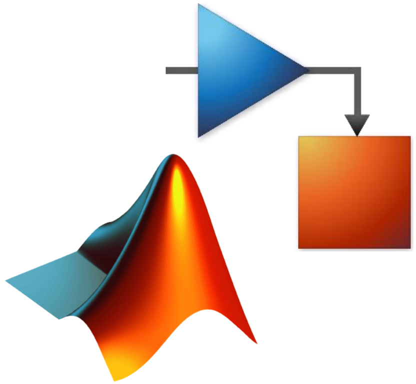
Target



Fixed point

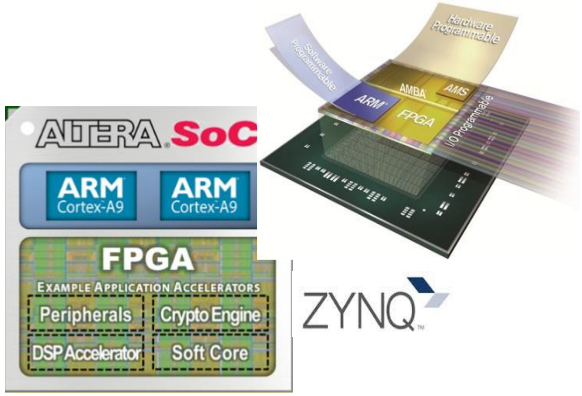
Optimization at different phases in the development...

Prototyping



C

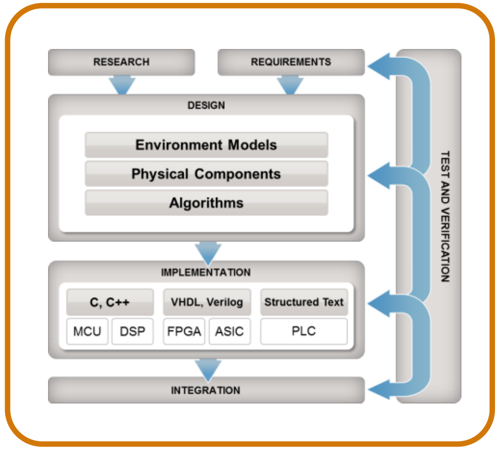
SoC/FPGA



Optimization at different phases in the development...

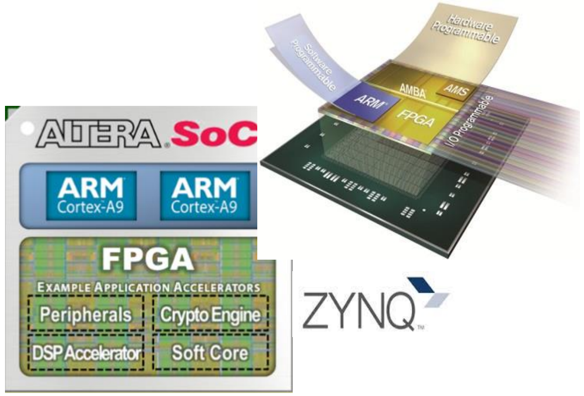
Model-Based Design

Prototyping



C

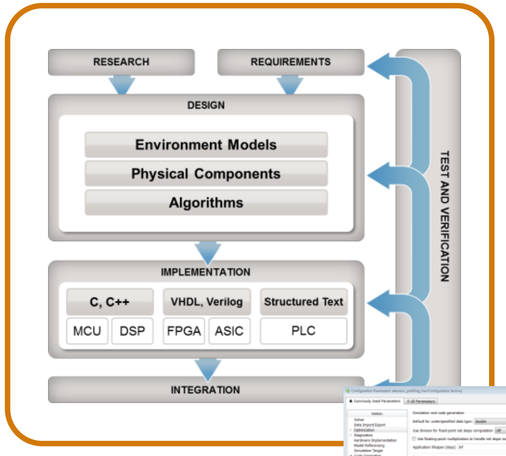
SoC/FPGA

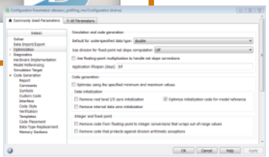


Optimization at different phases in the development...

Model-Based Design

Prototyping





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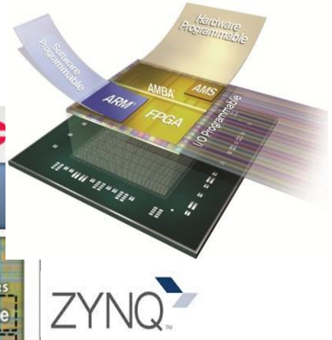
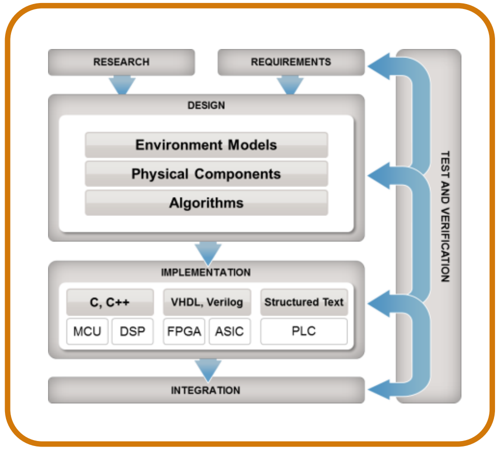


Optimization at different phases in the development...

Prototyping



How can I analyze performance and optimize code in MATLAB/Simulink?

Profiling!

Profiling in MATLAB

How long did it take?

- tic/toc

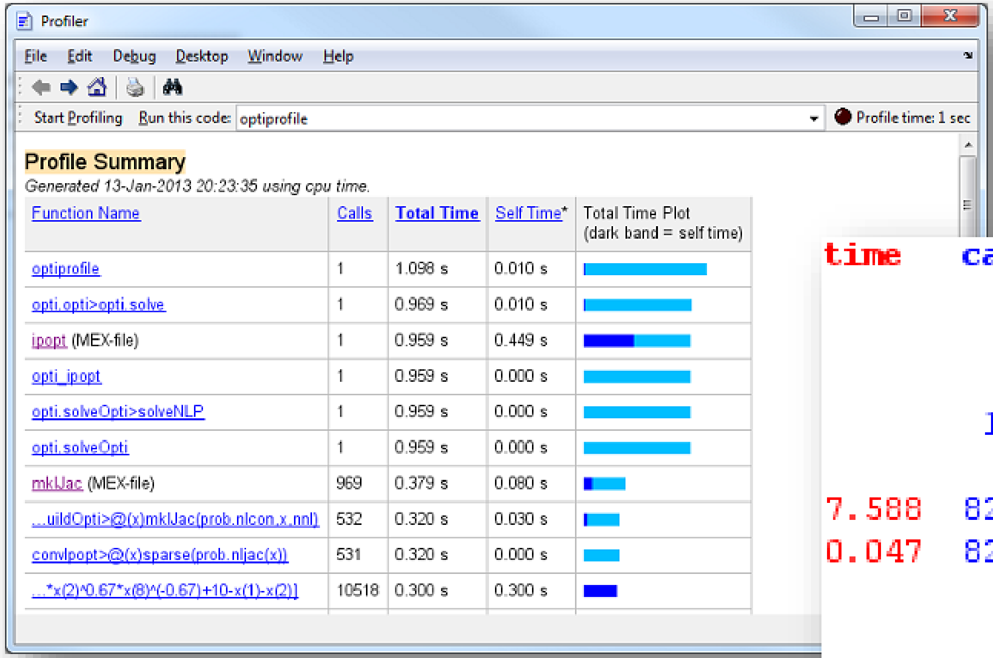
```
% start timer
tic

% execute code
out = myFunction(in);

% stop timer (and store
% elapsed time)
et = toc;
```

Where are the bottlenecks?

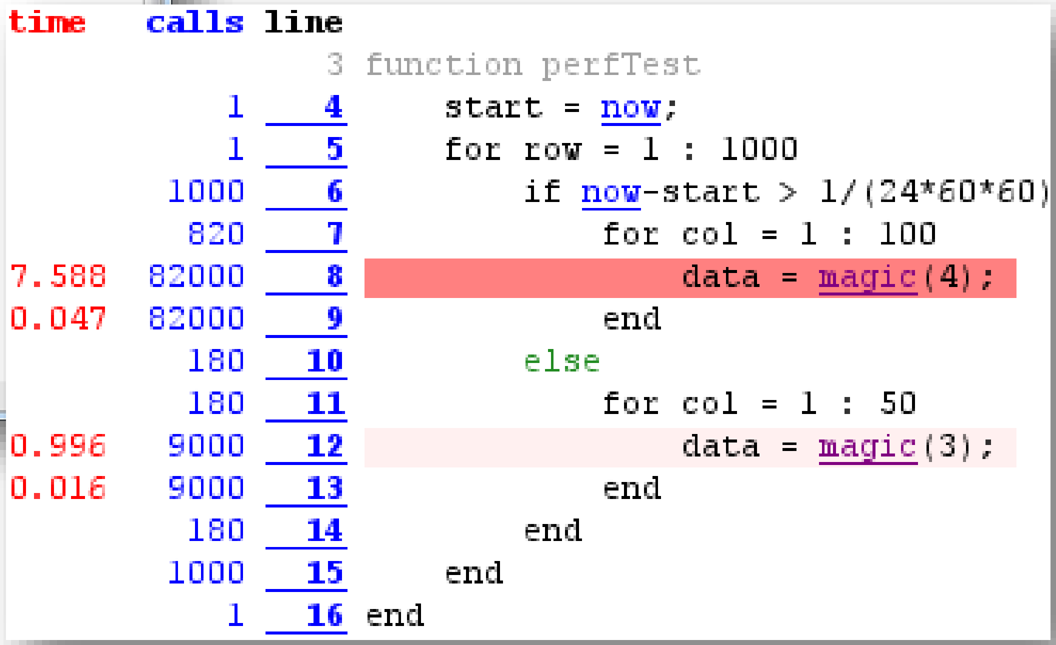
- profile

```
% turn on profiler
profile on

% execute code
out = myFunction(in);

% turn off profiler
profile off
% open html report
profile report
```

Profiling in MATLAB



Function Name	Calls	Total Time	Self Time*	Total Time Plot (dark band = self time)
optiprofile	1	1.098 s	0.010 s	
opti.opti>opti.solve	1	0.969 s	0.010 s	
ipopt (MEX-file)	1	0.959 s	0.449 s	
opti_ipopt	1	0.959 s	0.000 s	
opti.solveOpti>solveNLP	1	0.959 s	0.000 s	
opti.solveOpti	1	0.959 s	0.000 s	
mklJac (MEX-file)	969	0.379 s	0.080 s	
...uildOpti>@(x)mklJac(prob.nlcon,x,nnl)	532	0.320 s	0.030 s	
convIpopt>@(x)sparse(prob.nljac(x))	531	0.320 s	0.000 s	
...*x(2)^0.67*x(8)^(-0.67)+10-x(1)-x(2)]	10518	0.300 s	0.300 s	



```
time    calls  line
                  3  function perfTest
            1     4      start = now;
            1     5      for row = 1 : 1000
         1000     6          if now-start > 1/(24*60*60)
          820     7              for col = 1 : 100
7.588   82000     8                  data = magic(4);
0.047   82000     9              end
          180    10          else
          180    11              for col = 1 : 50
0.996    9000    12                  data = magic(3);
0.016    9000    13              end
          180    14          end
         1000    15      end
            1    16  end
```

Profiling in Simulink

Web Browser - Simulink Profiler Report

Simulink Profiler Report

Summary | Function Details | Simulink Profiler Help | Clear Highlighted Blocks

Simulink Profile Report: Summary

Report generated 05-Apr-2016 11:07:29

Total recorded time:	6.49 s
Number of Block Methods:	32
Number of Internal Methods:	5
Number of Model Methods:	11
Clock precision:	0.00000004 s
Clock Speed:	2601 MHz

To write this data as model1ProfileData in the base workspace click here

Function List

Name	Time		Calls	Time/call	Self time		Location (must use MATLAB Web Browser to view)
simulate(model1)	6.48964160	100.0%	1	6.4896416000	0.00000000	0.0%	model1
initializationPhase	2.41801550	37.3%	1	2.4180155000	1.17000750	18.0%	model1
simulationPhase	2.29321470	35.3%	1	2.2932147000	0.46800300	7.2%	model1
model1.Start	1.24800800	19.2%	1	1.2480080000	0.00000000	0.0%	model1
compileAndLinkPhase	1.17000750	18.0%	1	1.1700075000	1.17000750	18.0%	model1
model1.Outputs.Major	0.95160610	14.7%	39	0.0244001564	0.00000000	0.0%	model1
model1.Update	0.87360560	13.5%	39	0.0224001436	0.00000000	0.0%	model1
model1/Spectrum Analyzer1 (SpectrumAnalyzer.Start)	0.63960410	9.9%	1	0.6396041000	0.63960410	9.9%	model1/Spectrum Analyzer1
terminationPhase	0.60840390	9.4%	1	0.6084039000	0.51480330	7.9%	model1
model1/Spectrum Analyzer1 (SpectrumAnalyzer.Update)	0.56160360	8.7%	39	0.0144000923	0.56160360	8.7%	model1/Spectrum Analyzer1
model1/Spectrum Analyzer (SpectrumAnalyzer.Start)	0.42120270	6.5%	1	0.4212027000	0.42120270	6.5%	model1/Spectrum Analyzer
model1/Time Scope (Scope.Outputs.Major)	0.42120270	6.5%	39	0.0108000692	0.42120270	6.5%	model1/Time Scope
model1/Detector/MATLAB System (MATLABSystem.Outputs.Major)	0.39000250	6.0%	39	0.0100000641	0.39000250	6.0%	model1/Detector/MATLAB System

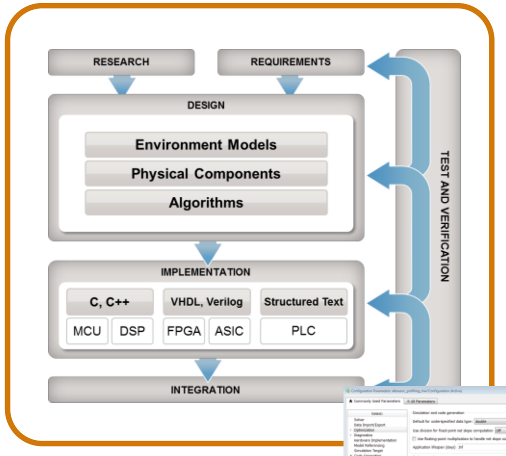
Example

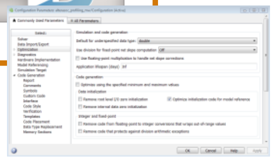
(Profiling when prototyping in MATLAB)

Optimization at different phases in the development...

Model-Based Design

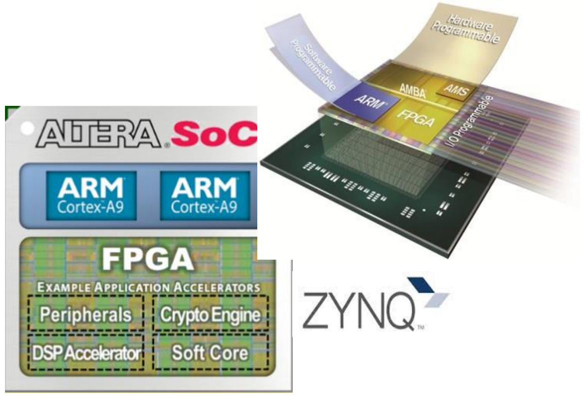
Prototyping





C

SoC/FPGA



Now, lets take a closer look of the workflow in embedded design!

Example: Workflow for embedded design

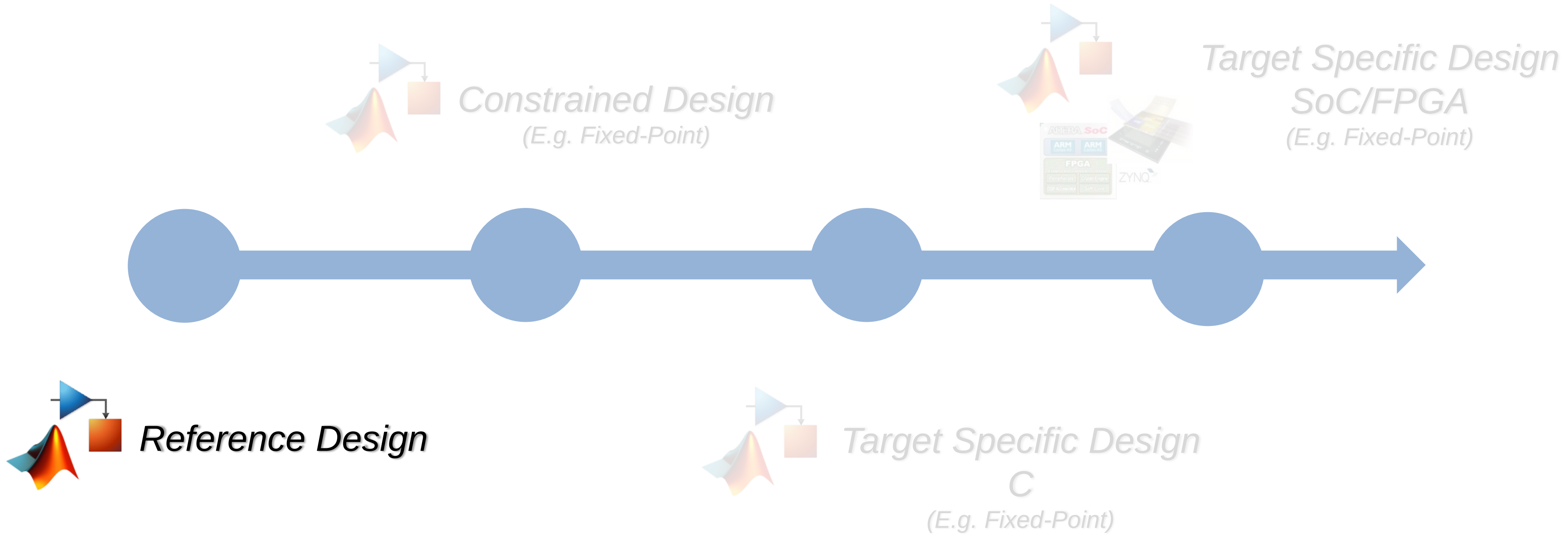
Constrained Design
(E.g. Fixed-Point)

Target Specific Design
SoC/FPGA
(E.g. Fixed-Point)

Reference Design

Target Specific Design
C
(E.g. Fixed-Point)

Example: Workflow for embedded design



Key Detection Algorithm

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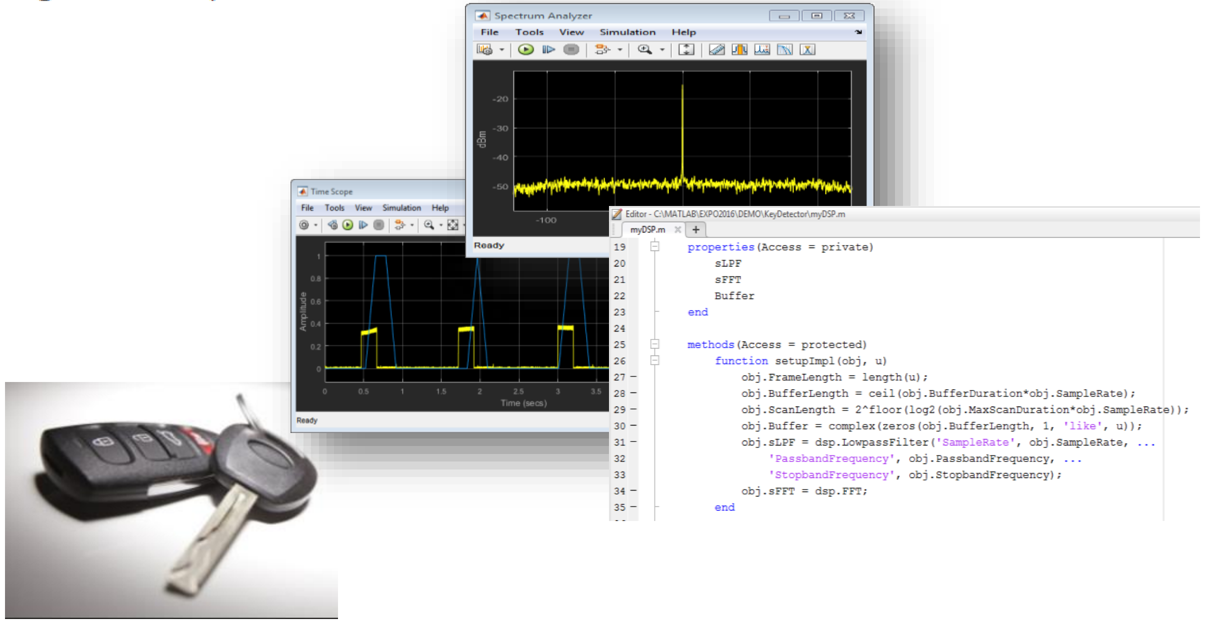
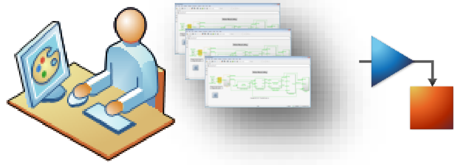


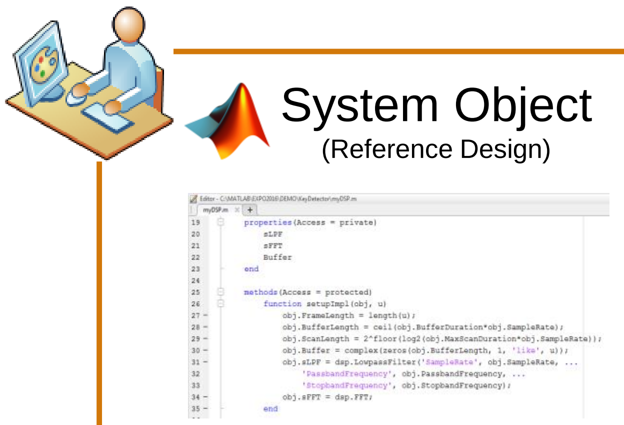
Component Integration

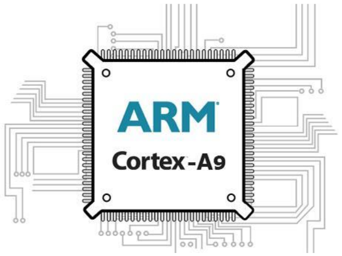
System Design



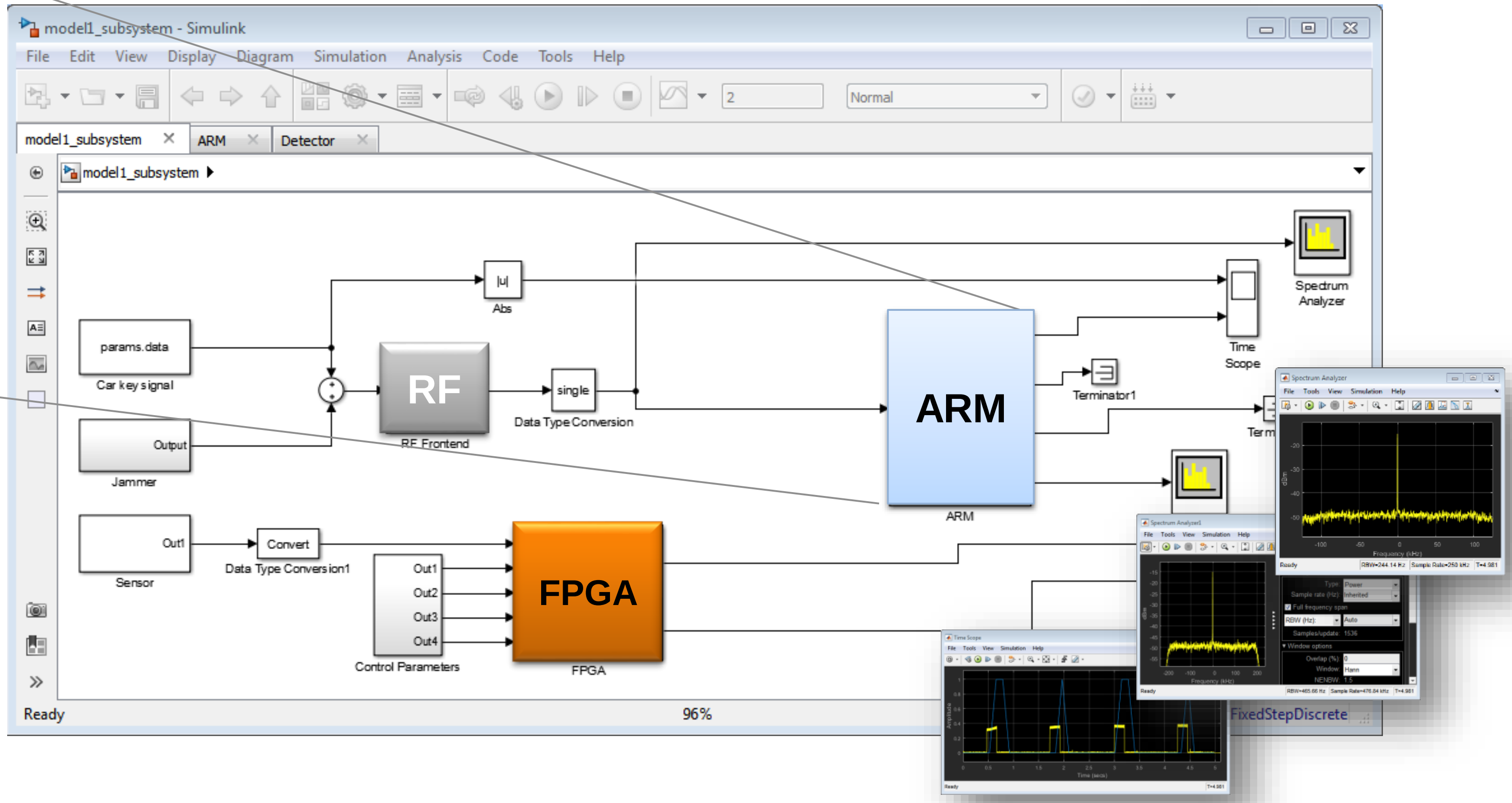
System Object

(Reference Design)

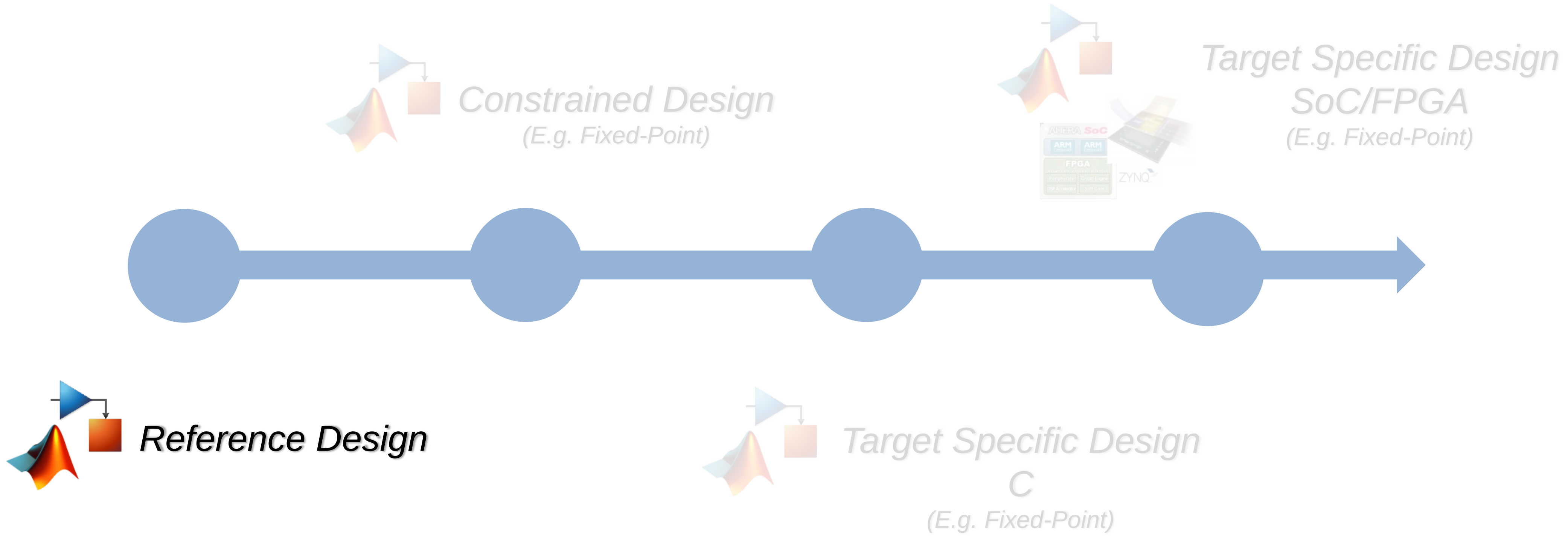




Optimize



Example: Workflow for embedded design



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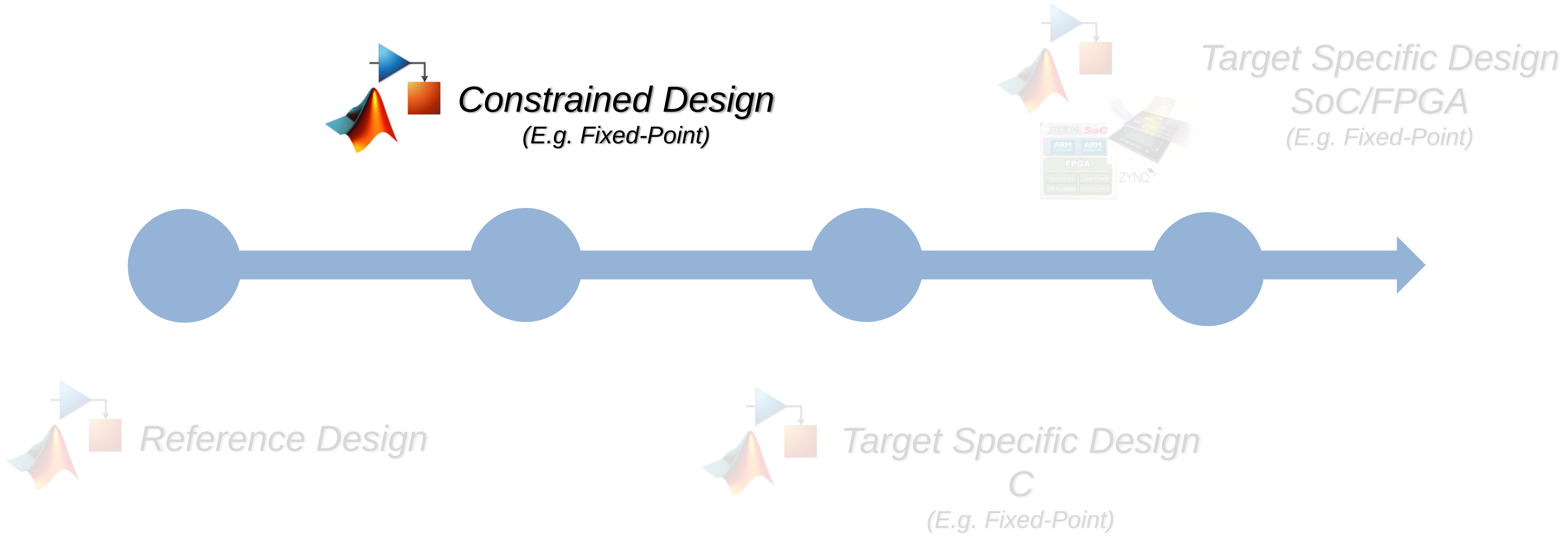

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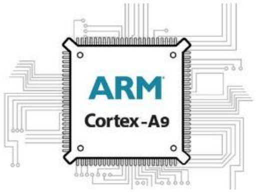

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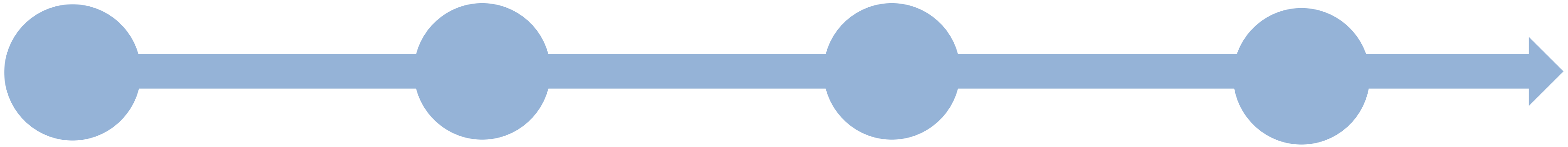
(E.g. Fixed-Point)

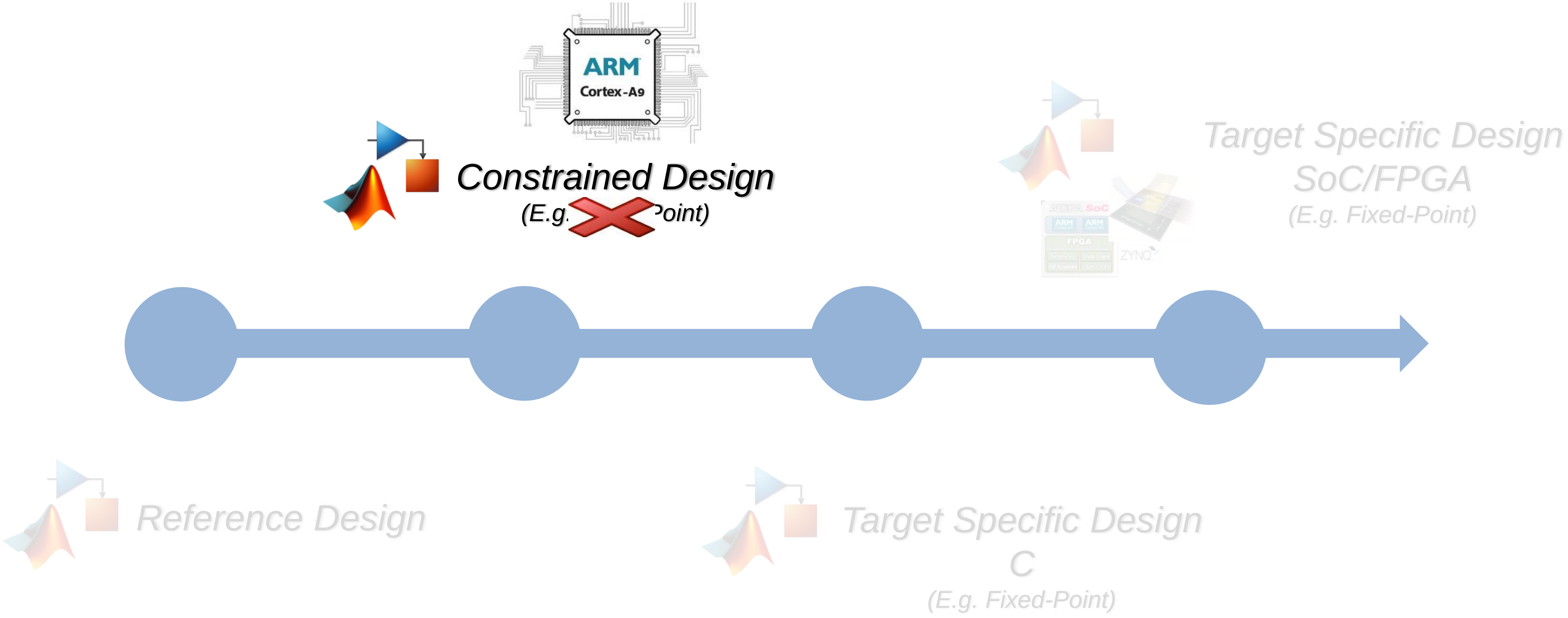
Target Specific Design
SoC/FPGA
(E.g. Fixed-Point)



Reference Design

Target Specific Design
C
(E.g. Fixed-Point)

Example: Workflow for embedded design



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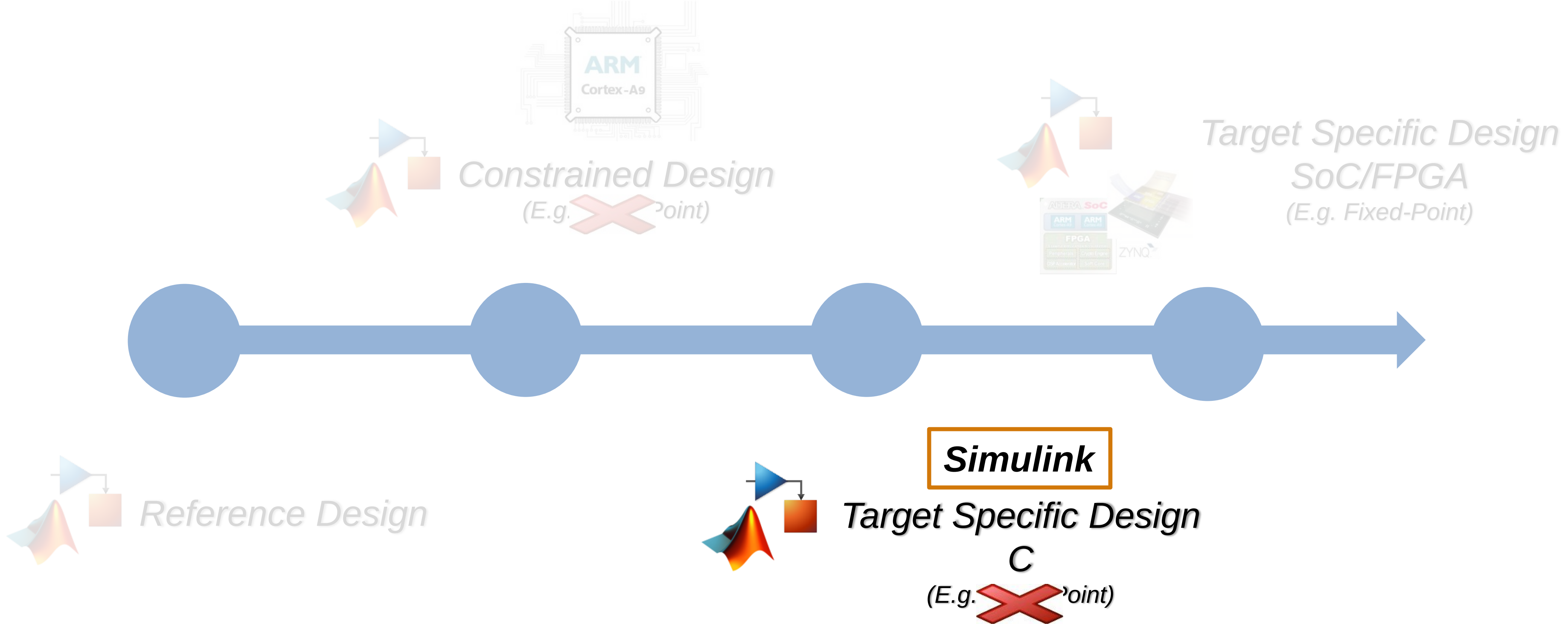
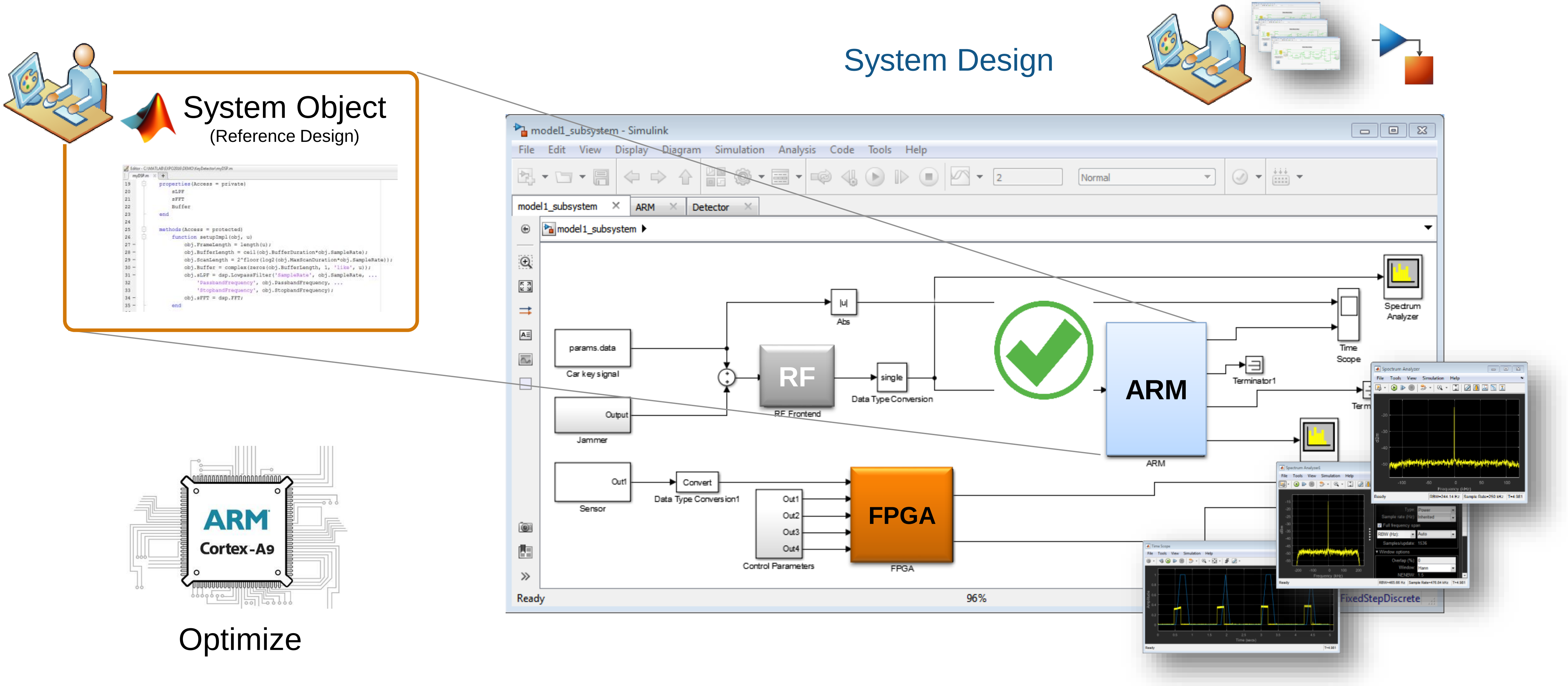


DEMO

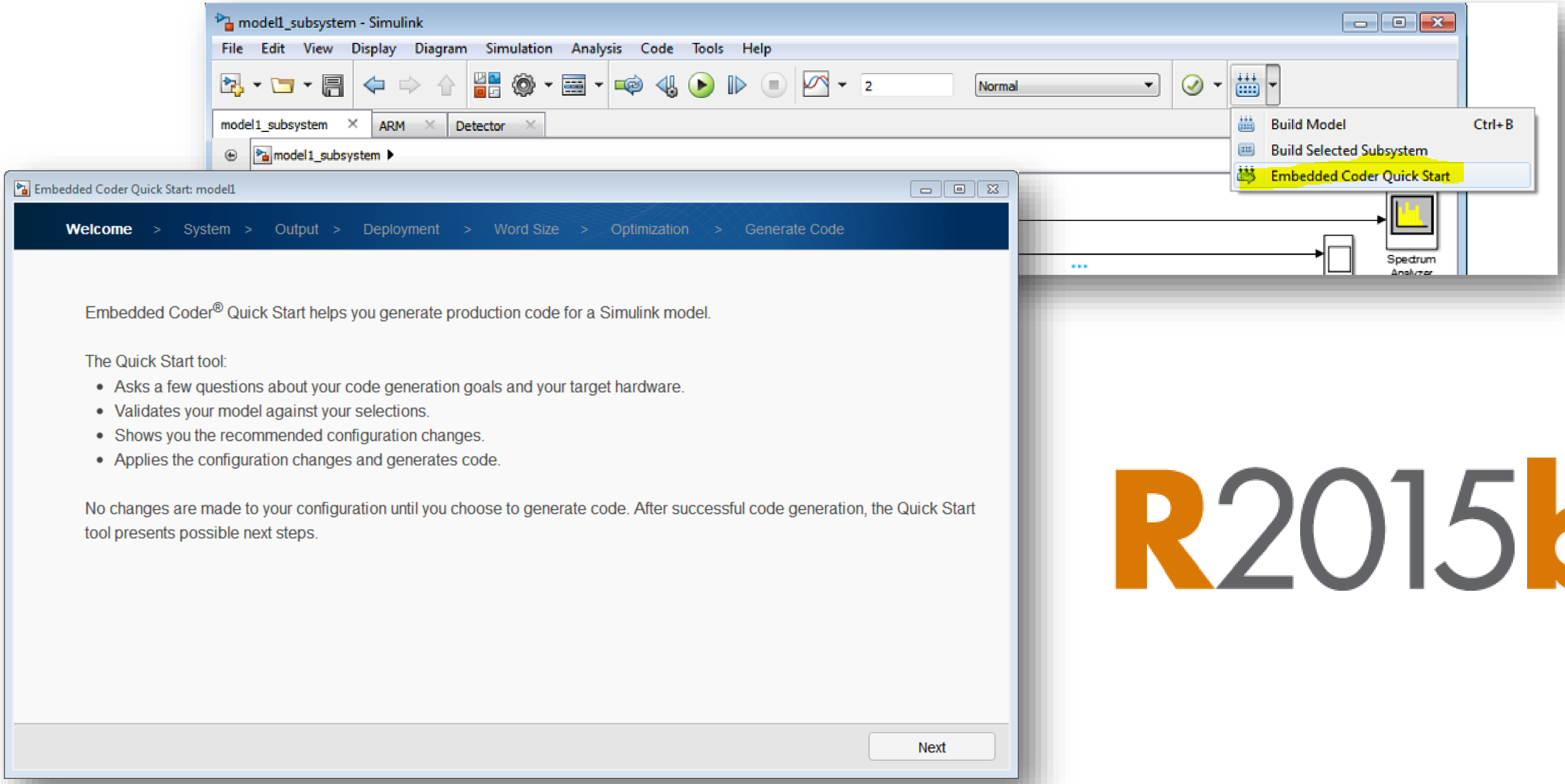
(System Integration and Generating Code for ARM Cortex A9 from Simulink)
(Including verification with PIL)

Component Integration



A few words about Embedded Coder...

Embedded Coder Quick Start



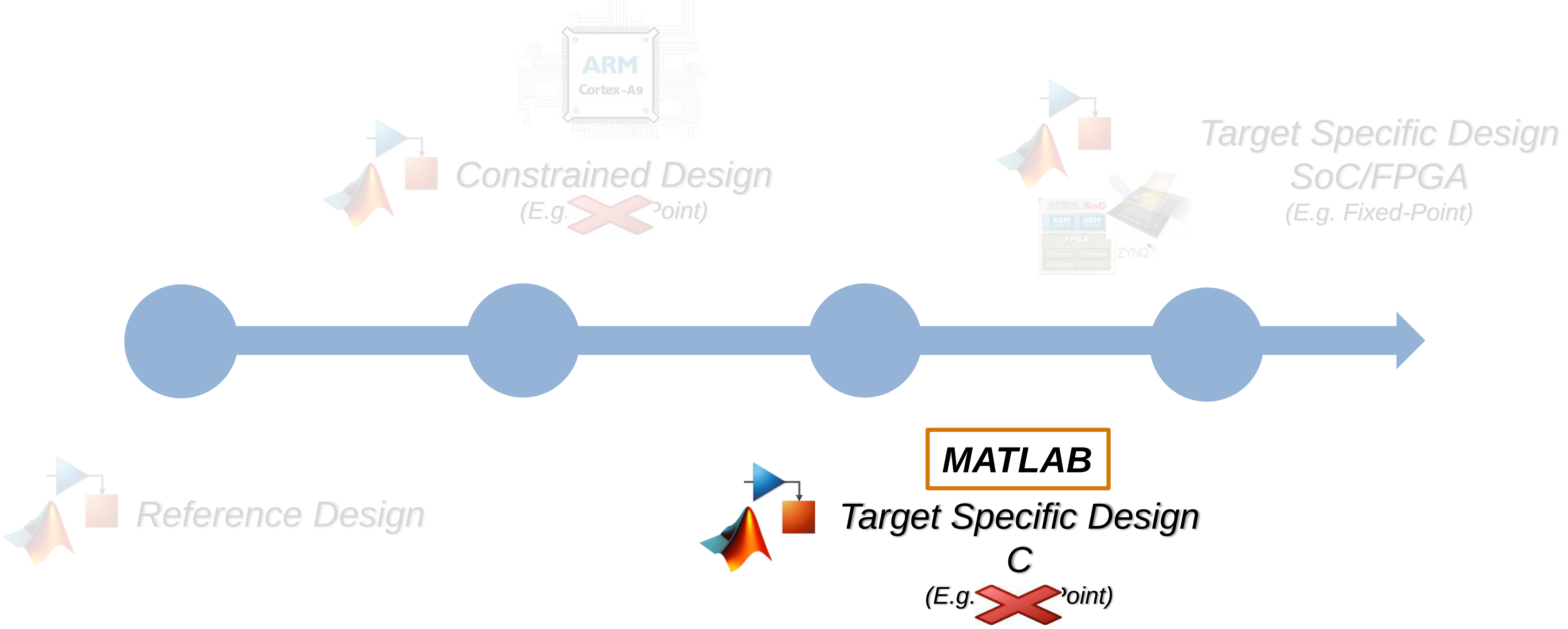
R2015b

DEMO

(Embedded Coder Quick Start)

Another use case...

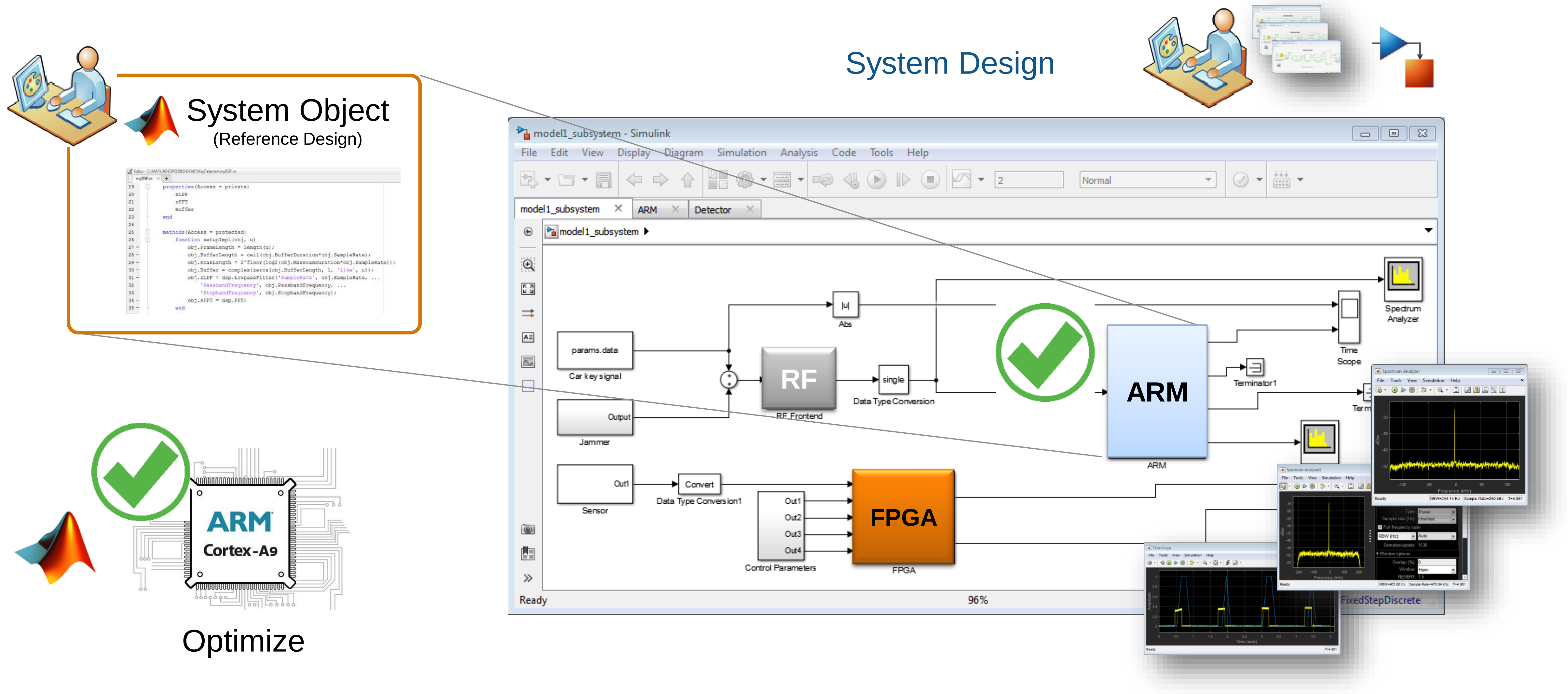
Example: Workflow for embedded design



Example

(Generating Code ARM Cortex A9 from MATLAB)

Component Integration



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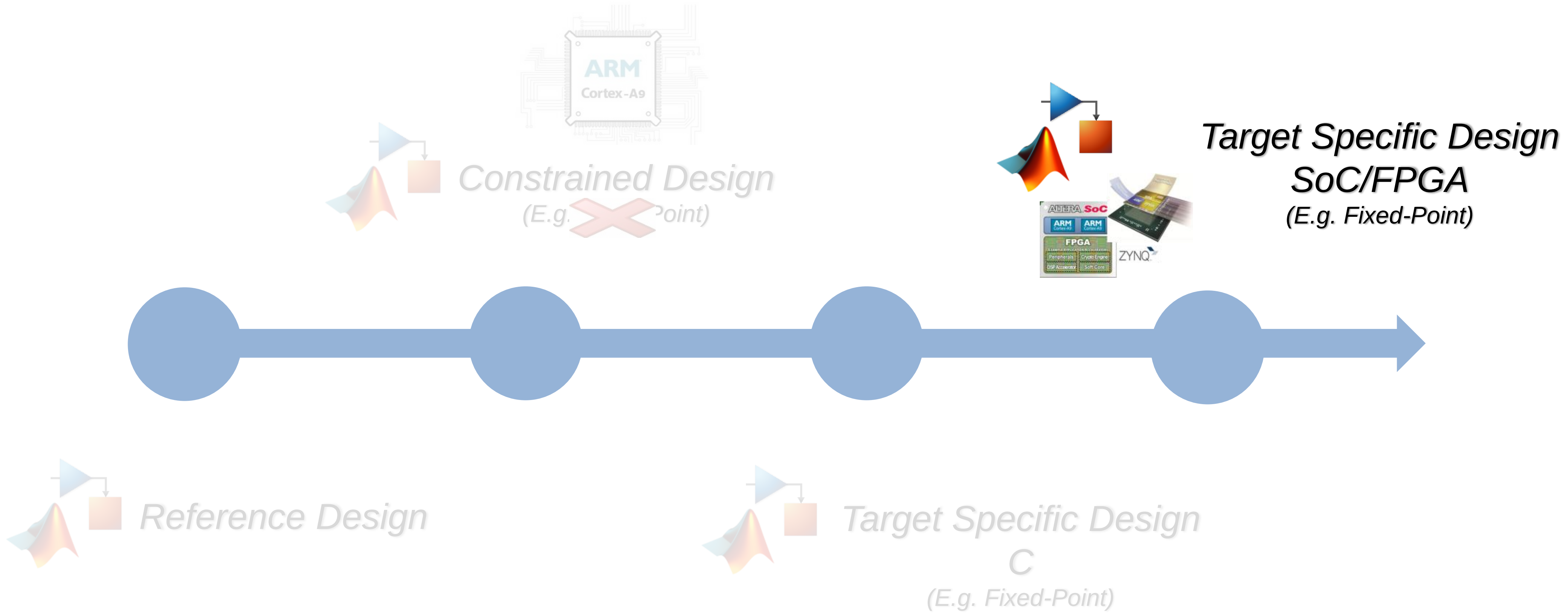

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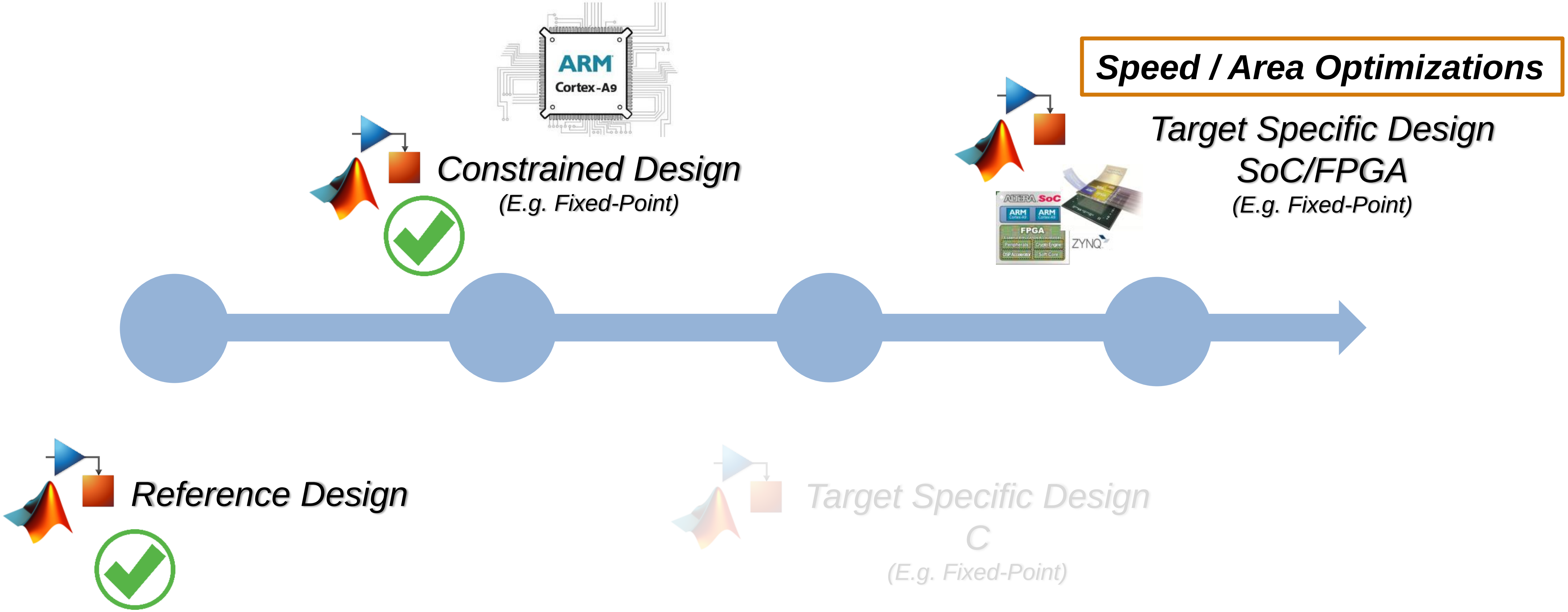
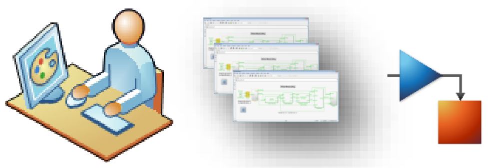
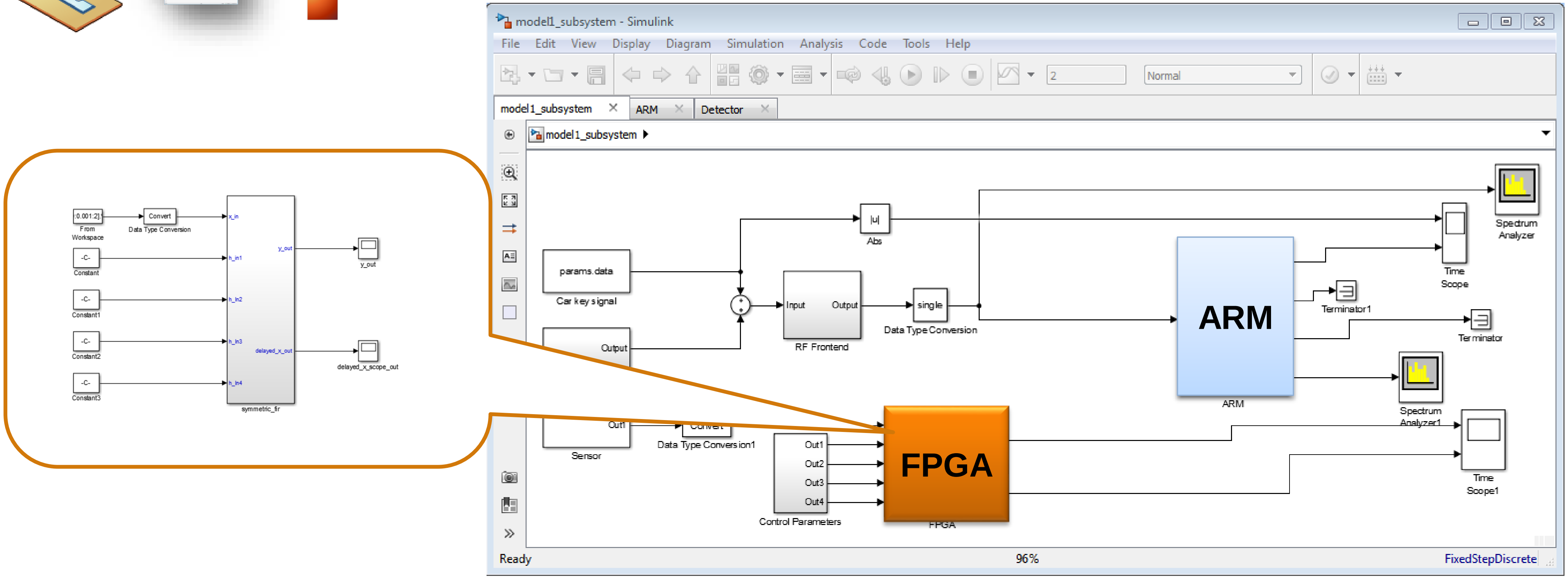


Area Optimization for FPGA implementation





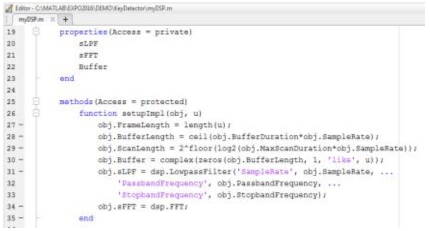
Example

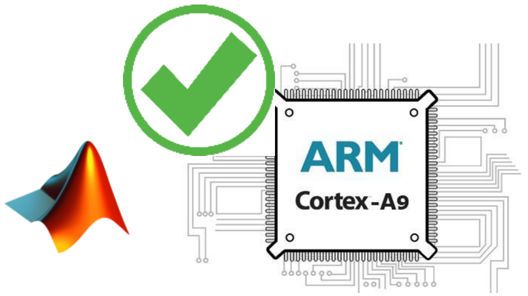
(Area Optimization for FPGA Implementation)

Component Integration

System Object

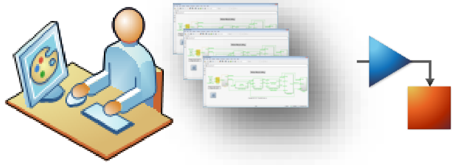
(Reference Design)

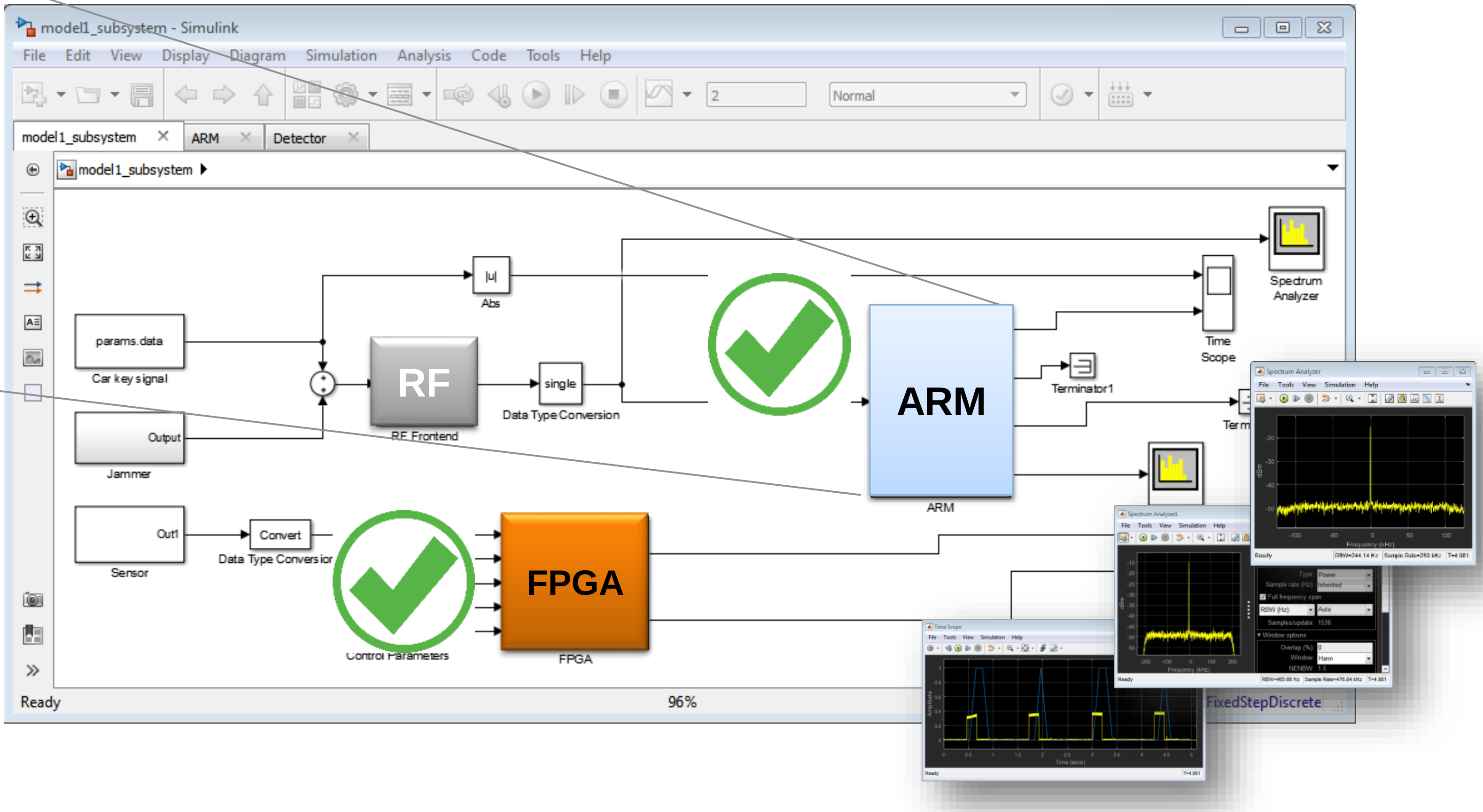




Optimize

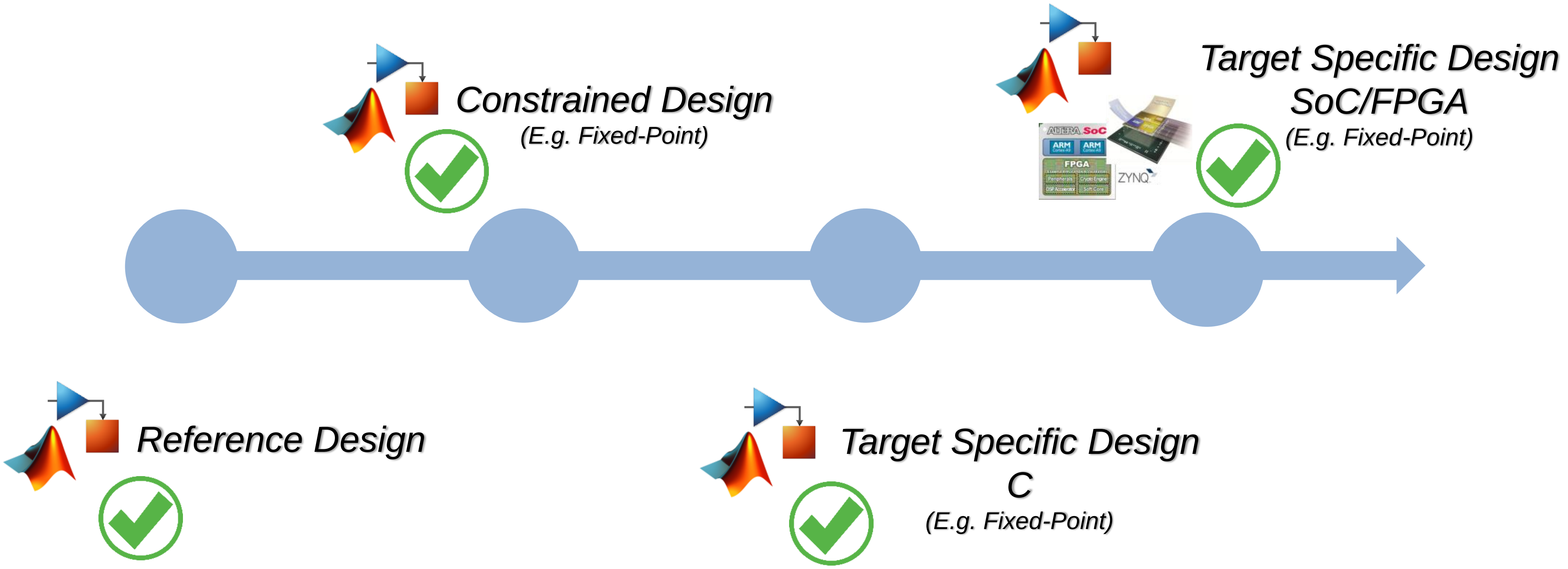
System Design





Summary

Optimization and Implementation of Embedded Signal Processing Algorithms



Questions?