CO405H

Computing in Space with OpenSPL
Topic 4: DataFlow Engines (DFEs)

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CO405H course page: http://cc.doc.ic.ac.uk/openspl15/
WebIDE: http://openspl.doc.ic.ac.uk
OpenSPL consortium page: http://www.openspl.org

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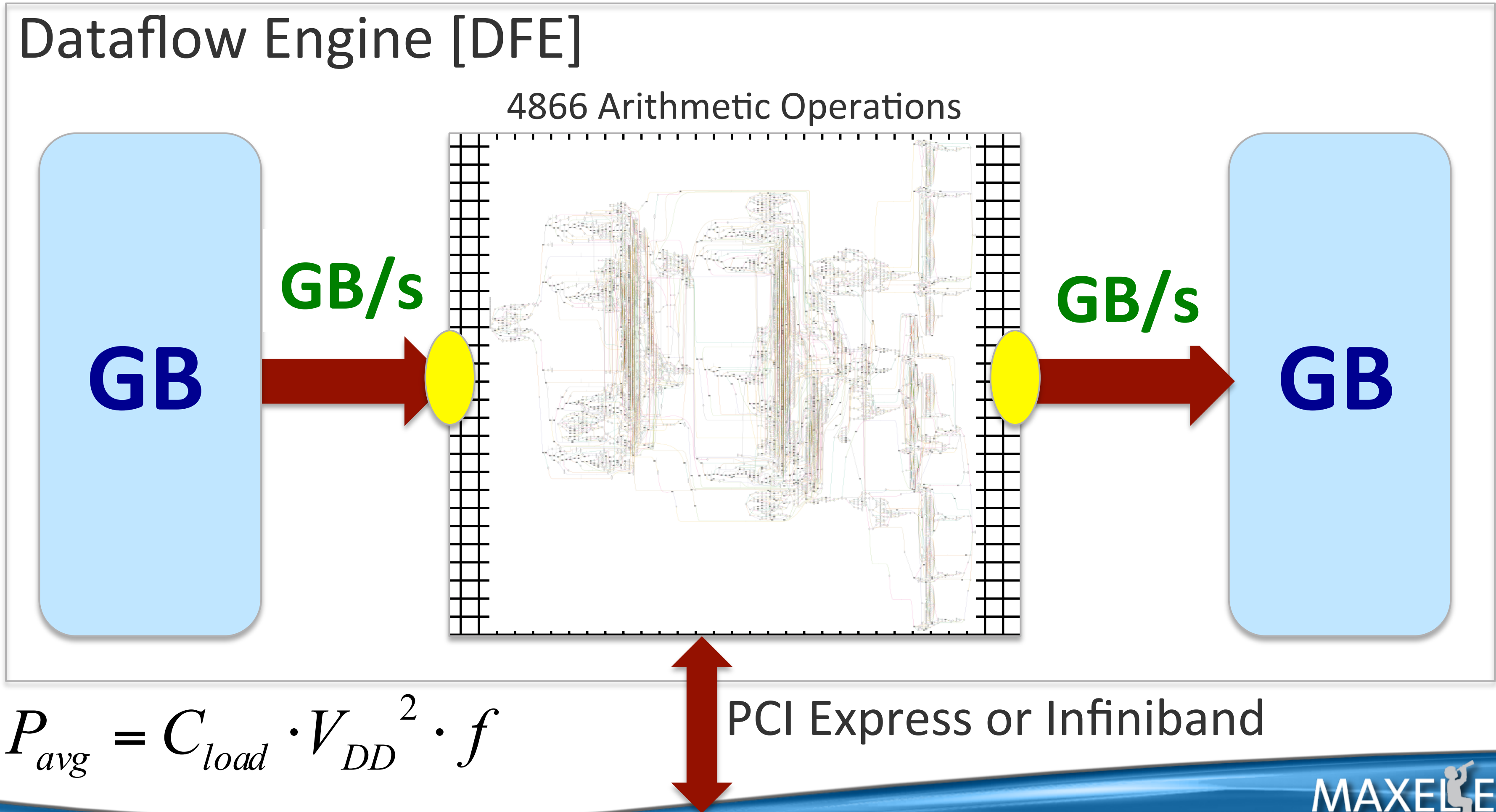
Overview

- Real OpenSPL SCS instantiation – Maxeler's DFEs
- Architecture and Programming Model
- SLIC: Using DFEs from MatLab, Python and more

Maxeler Multiscale Dataflow Computing

$T_{compute}$=**GB**/[**GB/s**] for up to 10K operations
computing on the stream within a window of 7 MB



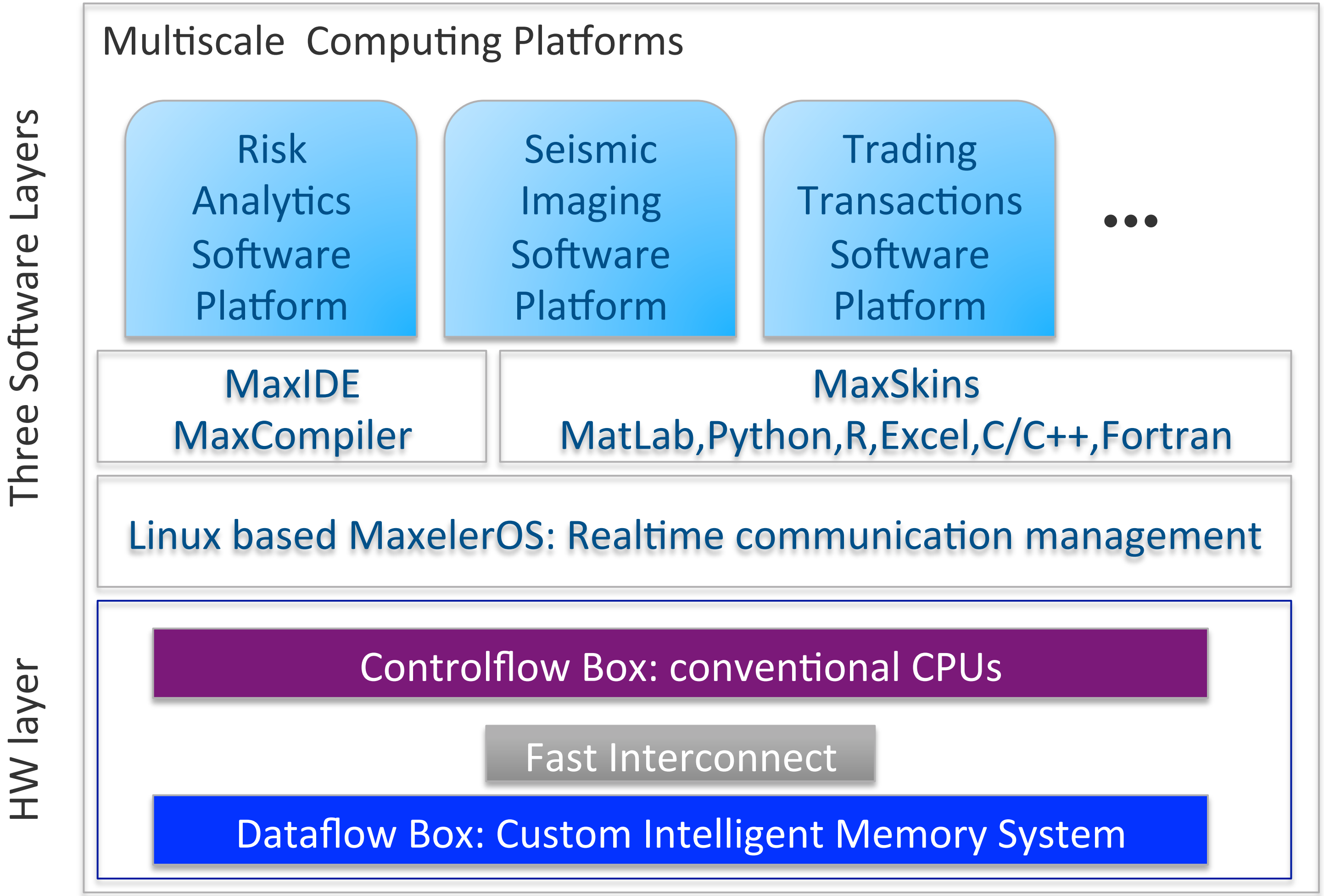
$$P_{avg} = C_{load} \cdot V_{DD}^2 \cdot f$$

Mapping SCS to DFE

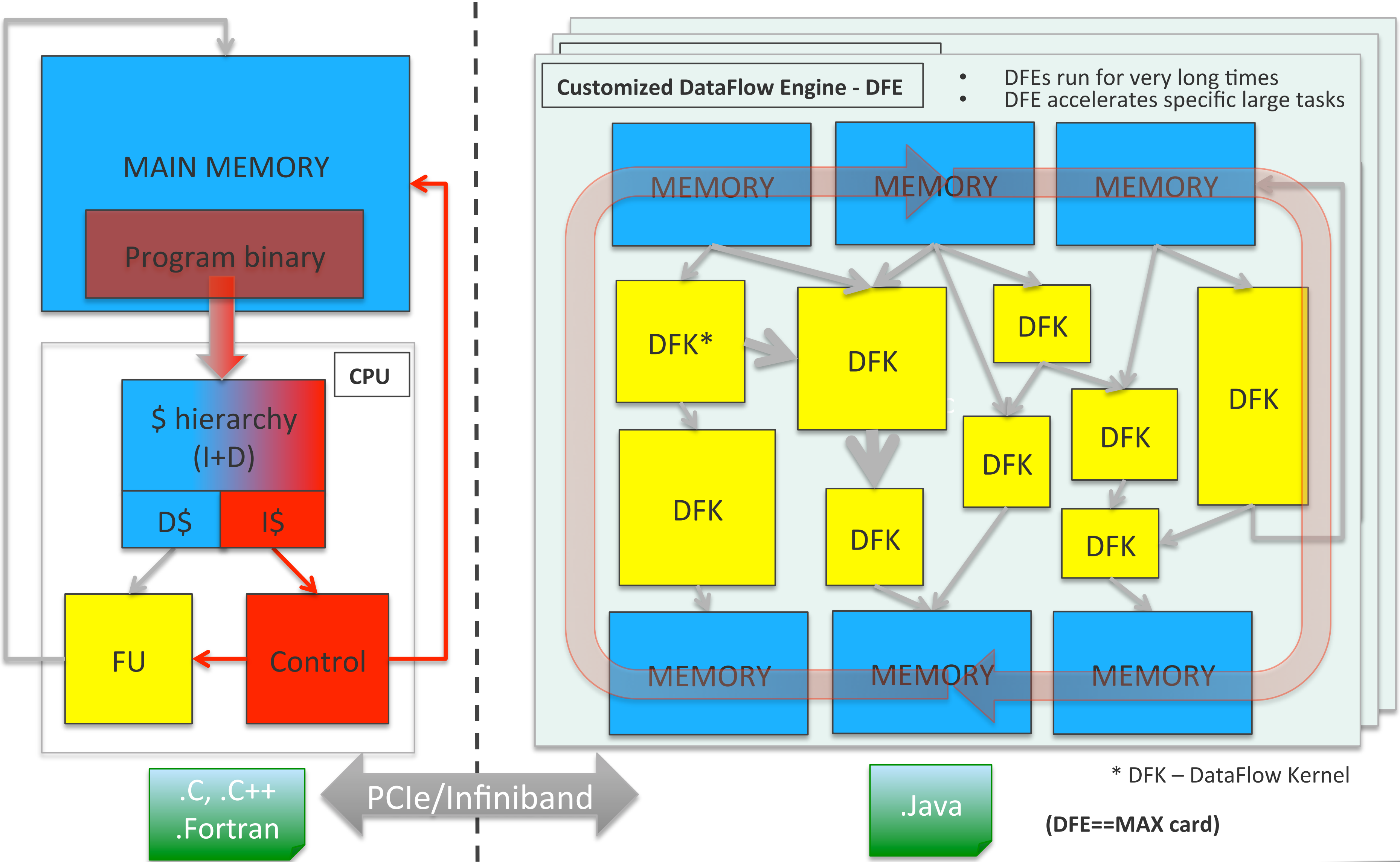
- SCS → DFE for Multiscale Computing Platforms
- Spatial Configurable Technology → (largest conf. dev.)
- High-level language used Java
- OpenSPL Compiler → MaxCompiler
- OpenSPL OS → MaxOS
- OpenSPL data movement managed by “Manager.maxj”
- Domain specific support (too big to mention here), e.g., Finite Differences

The Platforms

decoupling the data plane and control plane



Maxeler Accelerator Architecture



* DFK – DataFlow Kernel

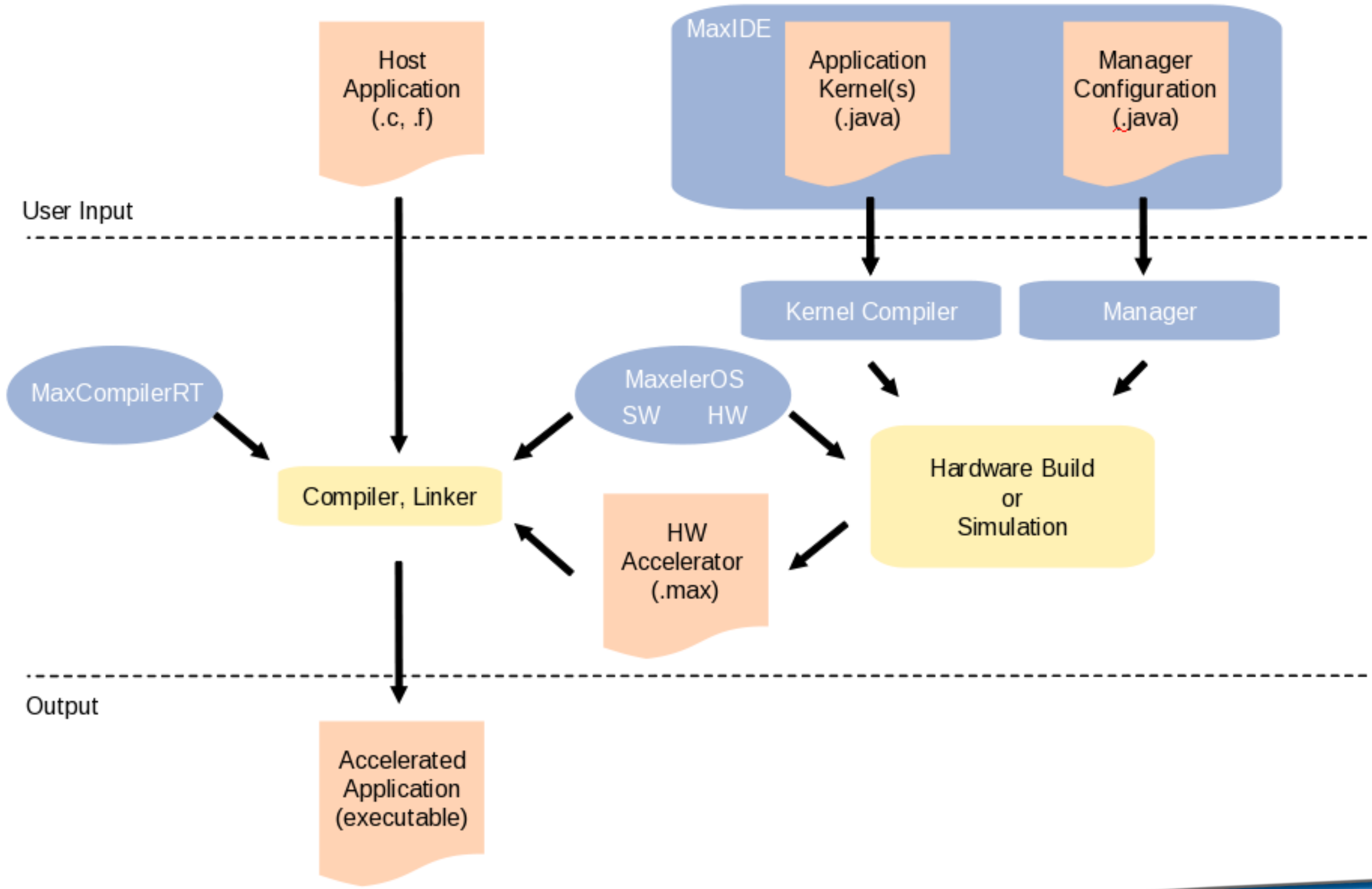
(DFE==MAX card)

MaxCompiler

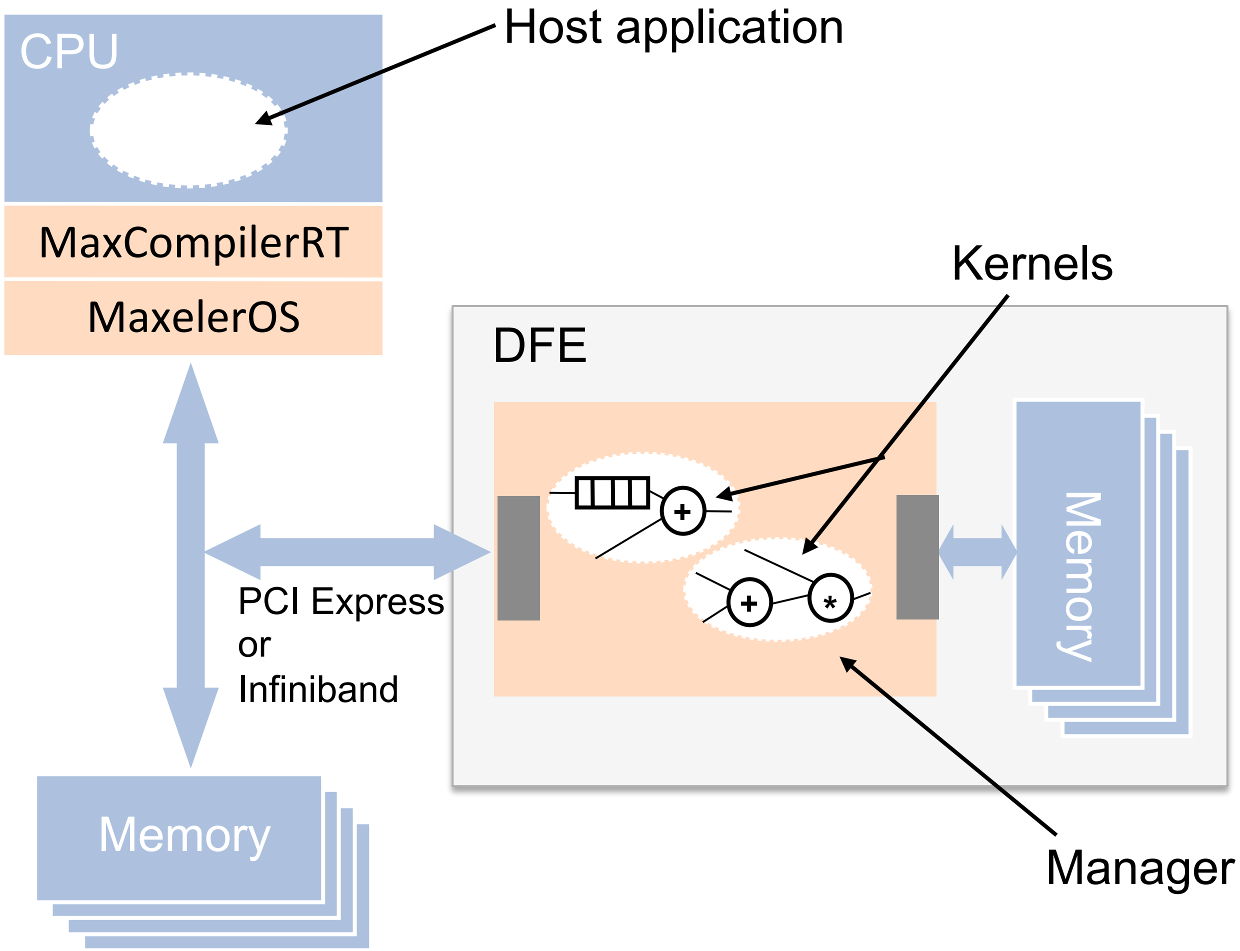
- Complete development environment for Maxeler DFE accelerator platforms
- Write *MaxJ* code to describe the dataflow accelerator
  - *MaxJ* is an extension of Java for MaxCompiler
  - *Execute* the Java → *generate* the accelerator
- C software on CPUs *uses* the accelerator

```
class MyAccelerator extends Kernel {
    public MyAccelerator(…) {
        DFEVar x = io.input("x", dfeFloat(8, 24));
        DFEVar y = io.input("y", dfeFloat(8, 24));

        DFEVar x2 = x * x;
        DFEVar y2 = y * y;
        DFEVar result = x2 + y2 + 30;

        io.output("z", result, dfeFloat(8, 24));
    }
}
```

MaxCompiler Architecture



Application Components

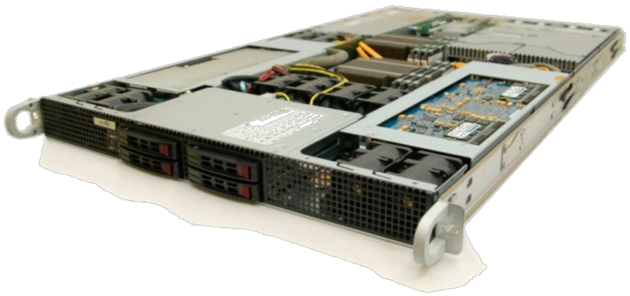


DFE based systems

MPC C Series

High Density DFEs

Intel Xeon CPU cores and up to 6 DFEs with 288GB of RAM



MPC X Series

The Dataflow Appliance

Dense compute with 8 DFEs, 384GB of RAM and dynamic allocation of DFEs to CPU servers with zero-copy RDMA access

MPC N Series

The Low Latency Appliance

Intel Xeon CPUs and 4 DFEs with direct links to up to six 10Gbit Ethernet connections

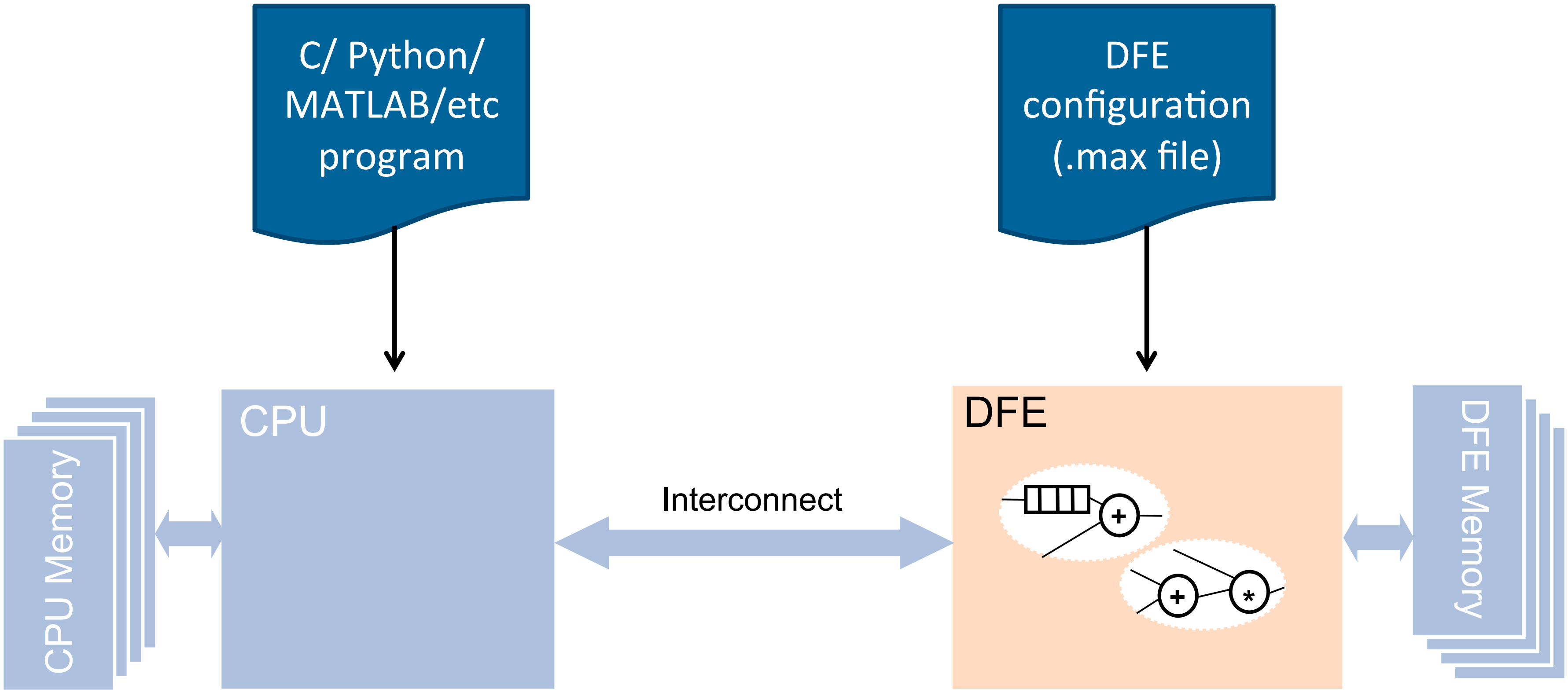
MaxWorkstation

Desktop dataflow development system

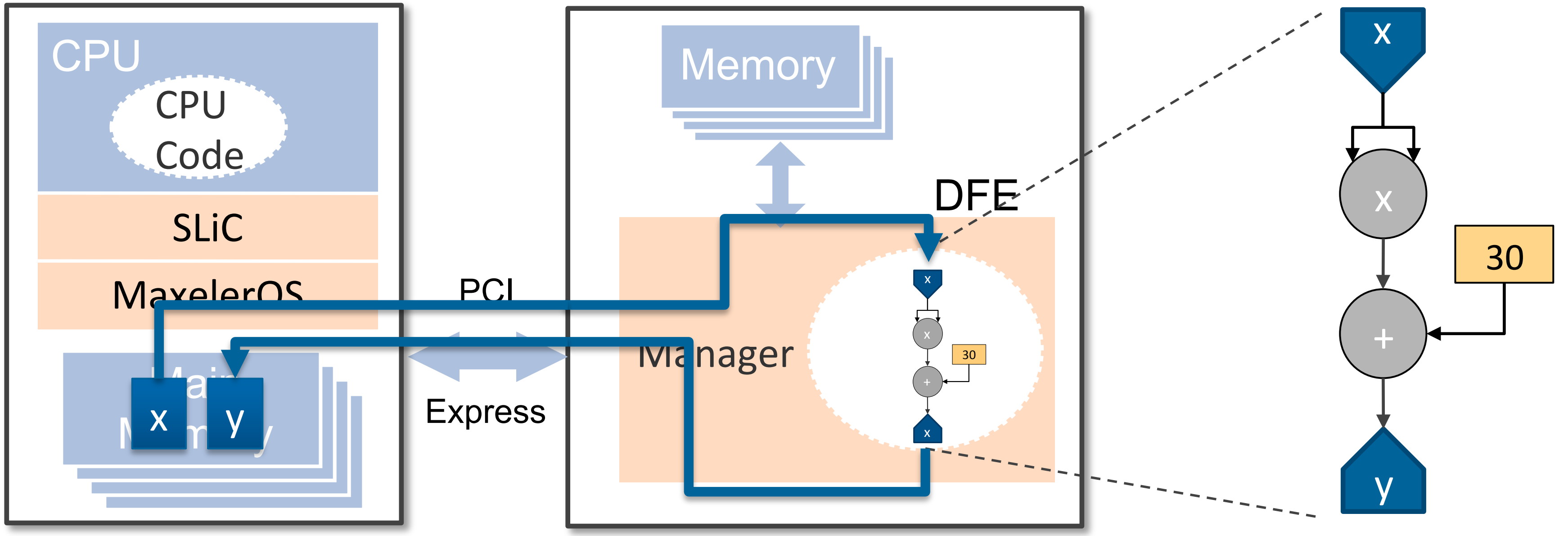
Dataflow Engines

48GB DDR3, high-speed connectivity and dense configurable logic

Using DFEs


C/ Python/
MATLAB/etc
program
DFE
configuration
(.max file)
CPU Memory
CPU
Interconnect
DFE
+
+
*
DFE Memory

Development Process



Host Code (.c)

```
int*x, *y;
for (int i =0; i < DATA_SIZE; i++)
    y[i]= x[i] * x[i] + 30;
              y, DATA_SIZE*4);
```

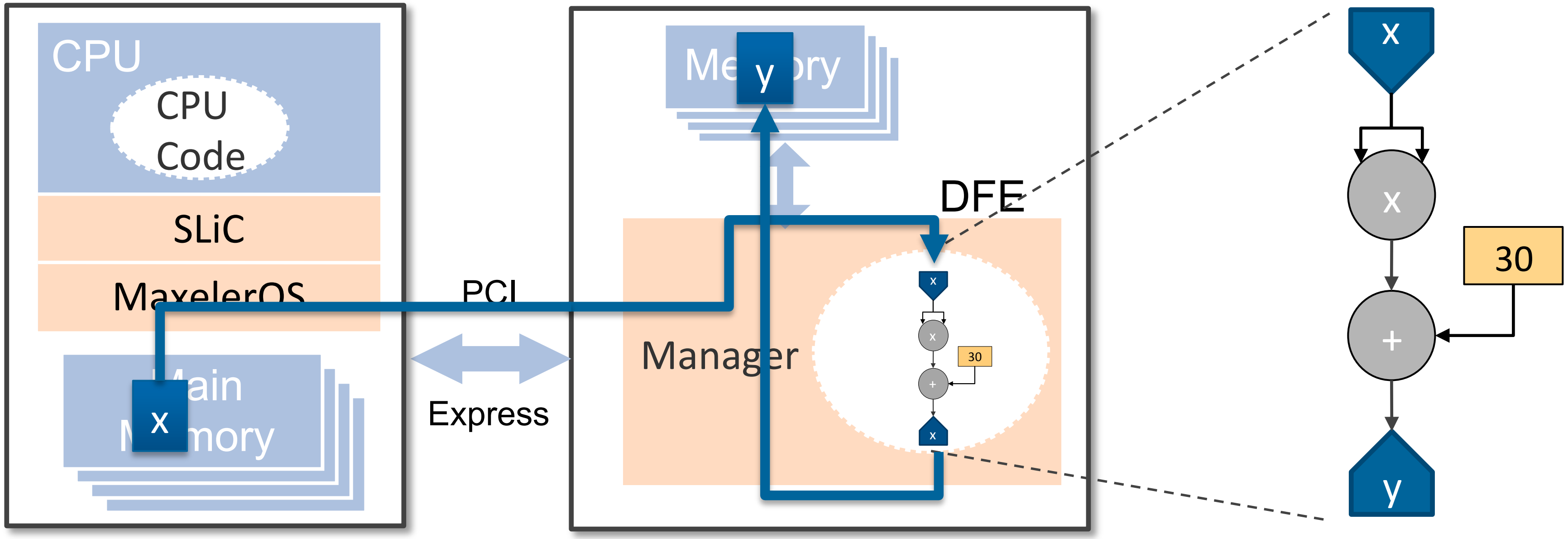
MyManager (.maxj)

```
Manager m = new Manager();
Kernel k =
    new MyKernel();

m.setKernel(k);
m.setIO(
   link(“x", CPU),
   link(“y", CPU));
m.build();
```

MyKernel (.maxj)

```
DFEVar x = io.input("x", dfeInt(32));

DFEVar result = x * x + 30;

io.output("y", result, dfeInt(32));
```

Development Process



Host Code (.c)

```
int*x, *y;
MyKernel( DATA_SIZE,
          x, DATA_SIZE*4);
```

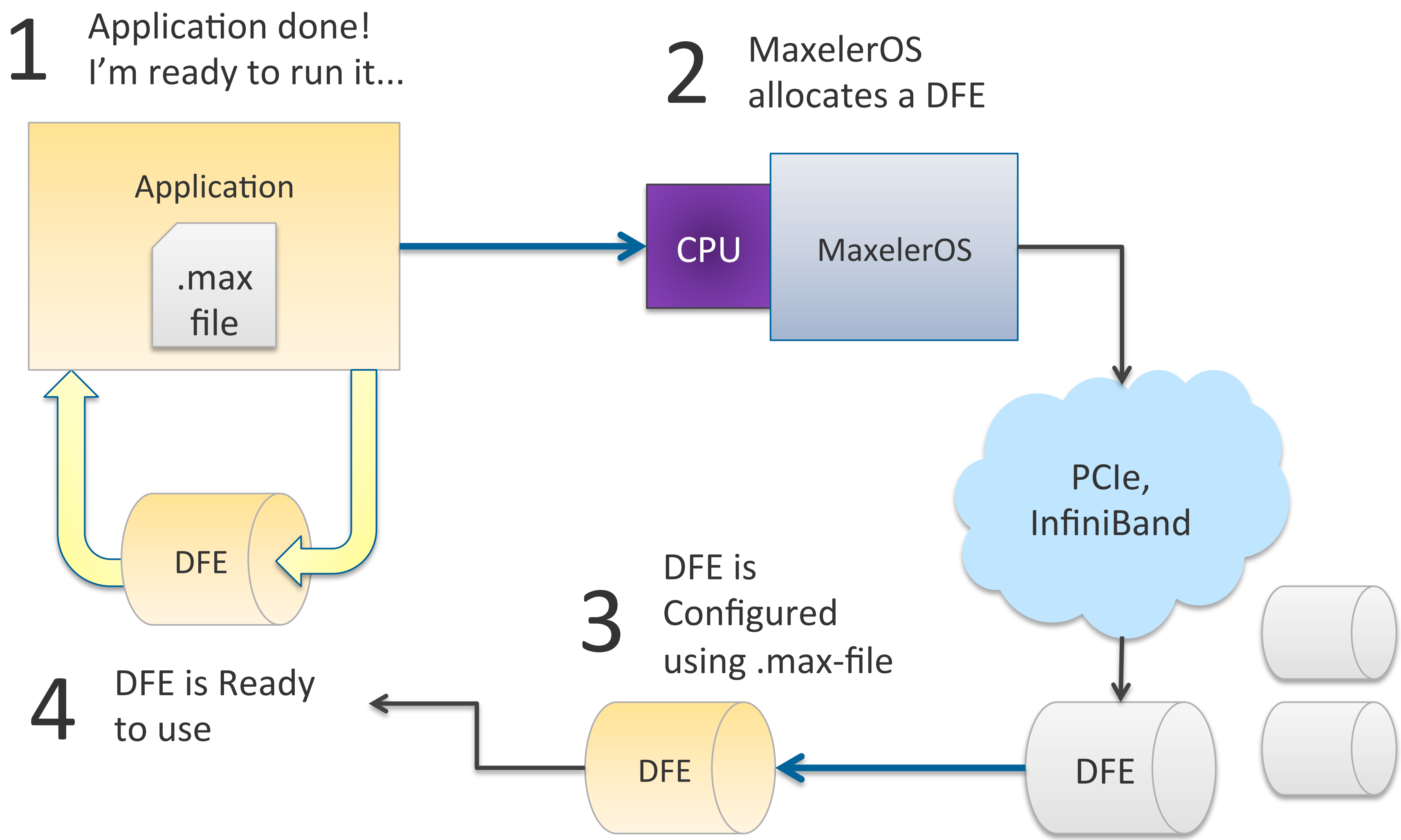
MyManager (.maxj)

```
Manager m = new Manager();
Kernel k =
    new MyKernel();

m.setKernel(k);
m.setIO(
   link(“x", CPU),
   link(“y", DRAM_LINEAR1D));
m.build();
```

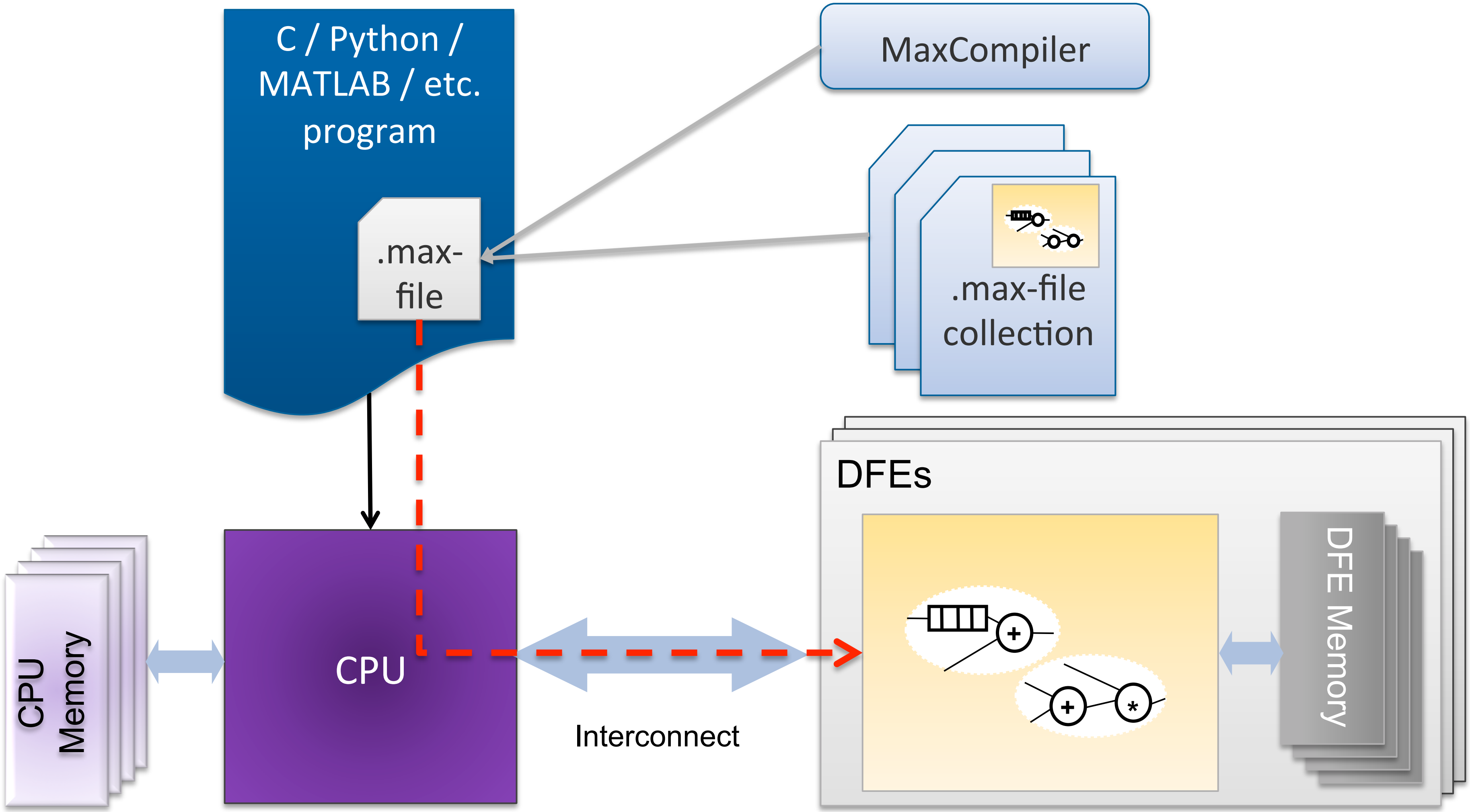
MyKernel (.maxj)

```
DFEVar x = io.input("x", dfeInt(32));

DFEVar result = x * x + 30;

io.output("y", result, dfeInt(32));
```

Application Execution



MaxCompiler – Create exportable DFE Configurations



.max-files

DFE configuration data
OR
DFE simulation model

DFE Interface Info
e.g. List of CPU settable values, number and names of I/O streams, etc.

CPU function code providing 'Engine Interface' APIs specific to .max-file

SLiC Interface: CPU <-> DFE API

- **S**imple **Li**ve **C**PU Interface:

  Combination of fixed software function calls and MaxCompiler-generated code for interacting with DFEs

- SLiC has a layered interface:
  - **Basic Static** – Single function-call to execute and complete a compute action on any appropriate DFE available
  - **Advanced Static** – Can be more specific about which DFE to use and enables use of multiple DFEs at once
  - **Dynamic** – Remove dependency on generated code from MaxCompiler in .max-file for maximum flexibility

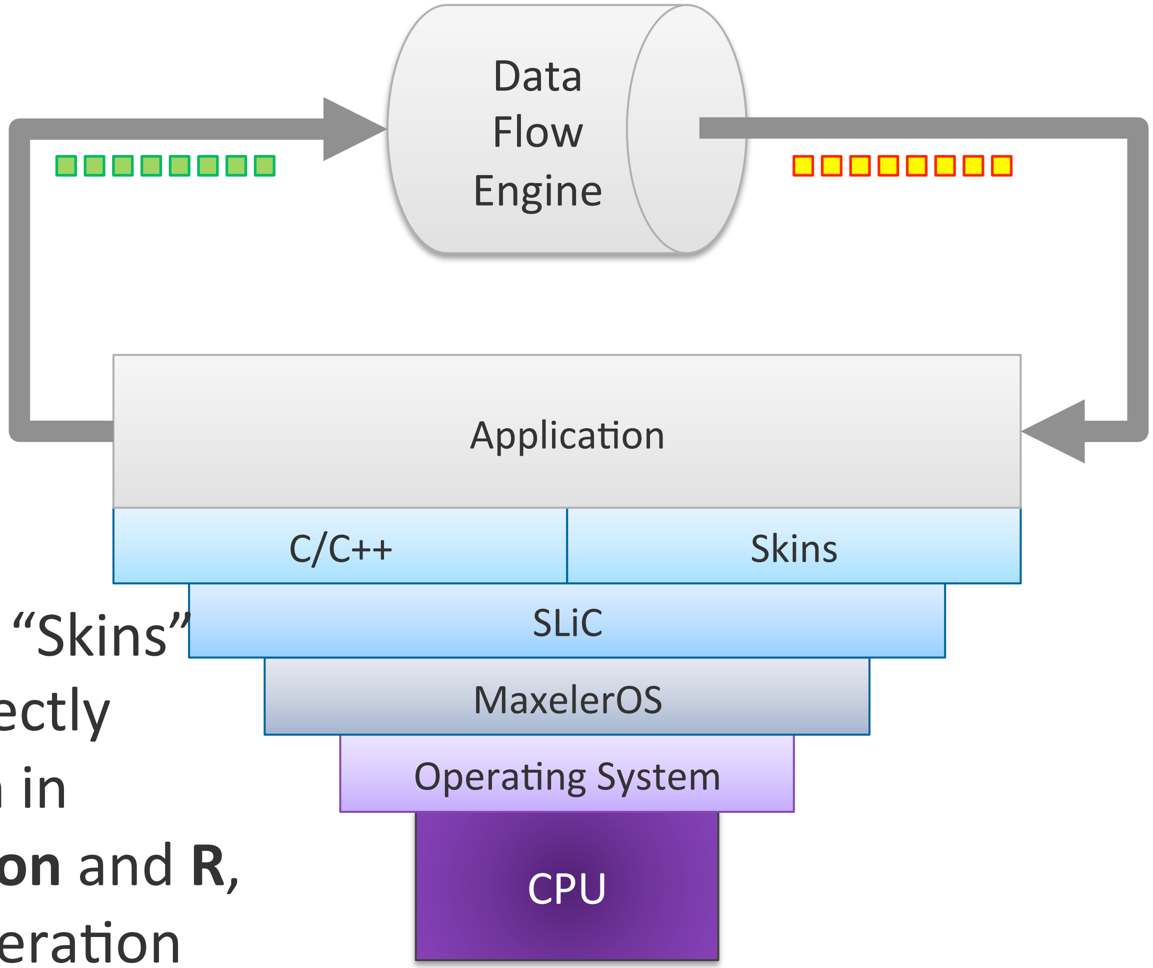
- By default all functions in all layers can be used from C

Example SLiC Application

```
#include "Convolve.h"
#include "MaxSLiCInterface.h"

int main(void)
{
  const int size = 384;
  int sizeBytes = size * sizeof(float);
  float *x, *y, *z1, *z2;
  int coeff1 = 3, coeff2 = 5;

  printf("Generating data...\n");
  // Initialize x, y data

  printf("Convolving on DFE...\n");
  Convolve(size, coeff1, x, y, z1);
  Convolve(size, coeff2, x, z1, z2);

  printf("Done.\n");
  return 0;
}
```

- Choose a DFE configuration which gets *linked* into your CPU application
- Call the DFE via standard function calls
- Data will be transferred to/from the DFE automatically to carry out the computation

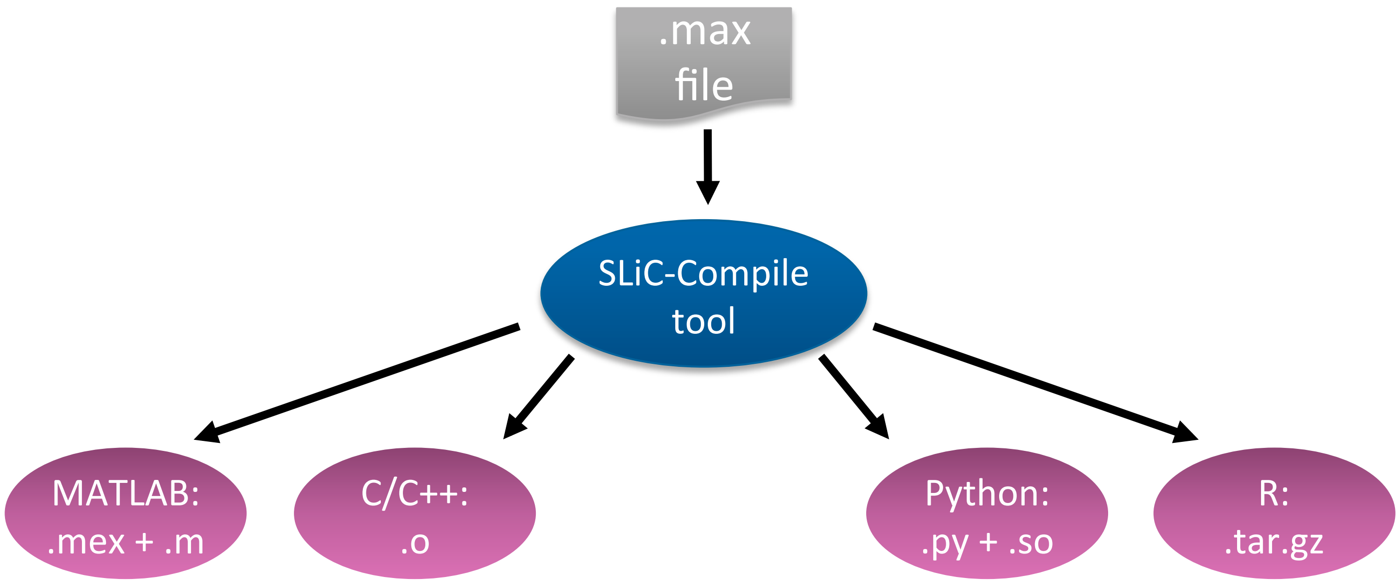
Support for different languages



We **automatically** create “Skins” that let us move data directly from applications written in languages like **Java**, **Python** and **R**, and also from fourth generation environments like **Matlab**

SLiC Skins

- Enable SLiC calls across many languages:
  - Currently: C, Python, MATLAB, R
  - Upcoming: Java, Excel
- Any .max-file usable from any supported language



Skins Example: Python

```
# Import DFEImageLib library functions
from DFEImageLib import *

# Set sharpening parameters
amount = 1.0 # amount of sharpening
sigma  = 0.8 # amount of blurring for generating the mask

# Load image
(h, w, img) = loadPNG("image.png")

# Execute the kernel on the DFE
(mask, sharp_img) = DFEImageLib_sharpen(h, w, amount, sigma, img)
```

Skins Example: MATLAB

```
% Initialize DFE
dfe = DFEImageLib();

% Set sharpening parameters
amount =  1 % amount of sharpening
sigma  = .8 % amount of blurring for generating the mask

% Load image
img = imgread('image.png');

# Execute the kernel on the DFE
[mask, sharp_img] = dfe.sharpen(amount, sigma, img);
```

Skins Example: R (Statistical Modeling)

```
library(jpeg)
# Installed with “R CMD INSTALL DFEImageLib”
library(DFEImageLib)

# Load the image
img <- readPNG("image.png")

# Set sharpening parameters
amount <-  1; # amount of sharpening
sigma  <- .8; # amount of blurring

# Execute the kernel on the DFE
outputs <-
   DFEImageLib_sharpen(amount, sigma, img);

# Extract output from list
mask      <- outputs$outstream_mask;
Sharp_img <- outputs$outstream_usm;
```

Types of Interface

- Basic Static:
  - single-function-call interface for using Maxeler engines
- Advanced Static:
  - fine-grain control over which DFEs to use
  - enables use of groups + arrays
  - asynchronous execution
- Dynamic:
  - all functionality of advanced static interface
  - doesn't require use of statically generated API
  - kernels, scalar I/Os, etc. identified with strings

Summary

- DFEs are the first SCS instantiation
- MaxCompiler and MaxOS together with the Manager and the Chip vendor specific tools (Xilinx or Altera) provide a complete OpenSPL implementation.
- Interfaces to Python, MatLab, C, C++, R and even Fortran…