CME Group

MAXELER Technologies
MAXIMUM PERFORMANCE COMPUTING

Going to the wire:
The next generation financial risk management platform

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CME Group

CME Group is the world's leading and most diverse derivatives marketplace – handling 3 billion contracts worth approximately $1 quadrillion annually, on average. We bring buyers and sellers together through our CME Globex electronic trading platform and our trading facilities in Chicago and New York.

Global Products

CME Group exchanges offer the widest range of global benchmark products across all major asset classes, including futures and options based on interest rates, equity indexes, foreign exchange, energy, agriculture commodities, metals, weather and real estate.

Clearing

CME Group operates CME Clearing, one of the world's leading central counterparty clearing providers.

We are the guarantor of every transaction that happens in our markets, providing unparalleled safety and soundness for our customers.

Electronic Trading

Through our CME Globex electronic trading platform, users worldwide are able to access the broadest array of the most liquid financial derivatives markets available anywhere. In addition, CME Globex offers speed of execution, transparency anonymity and market integrity. This makes up around 80% of all trades at CME.

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Forging Partnerships to Expand Distribution, Build 24-Hour Liquidity, and Add New Customers

Partnerships include:

- *Equity investments*
- *Trade matching services*
- *Joint product development*
- *Order routing linkages*
- *Product licensing*
- *Joint marketing*
- *European clearing services*

- **Developing capabilities globally**
- **Expanding upon global benchmark products**
- **Positioned well within key strategic closed markets**

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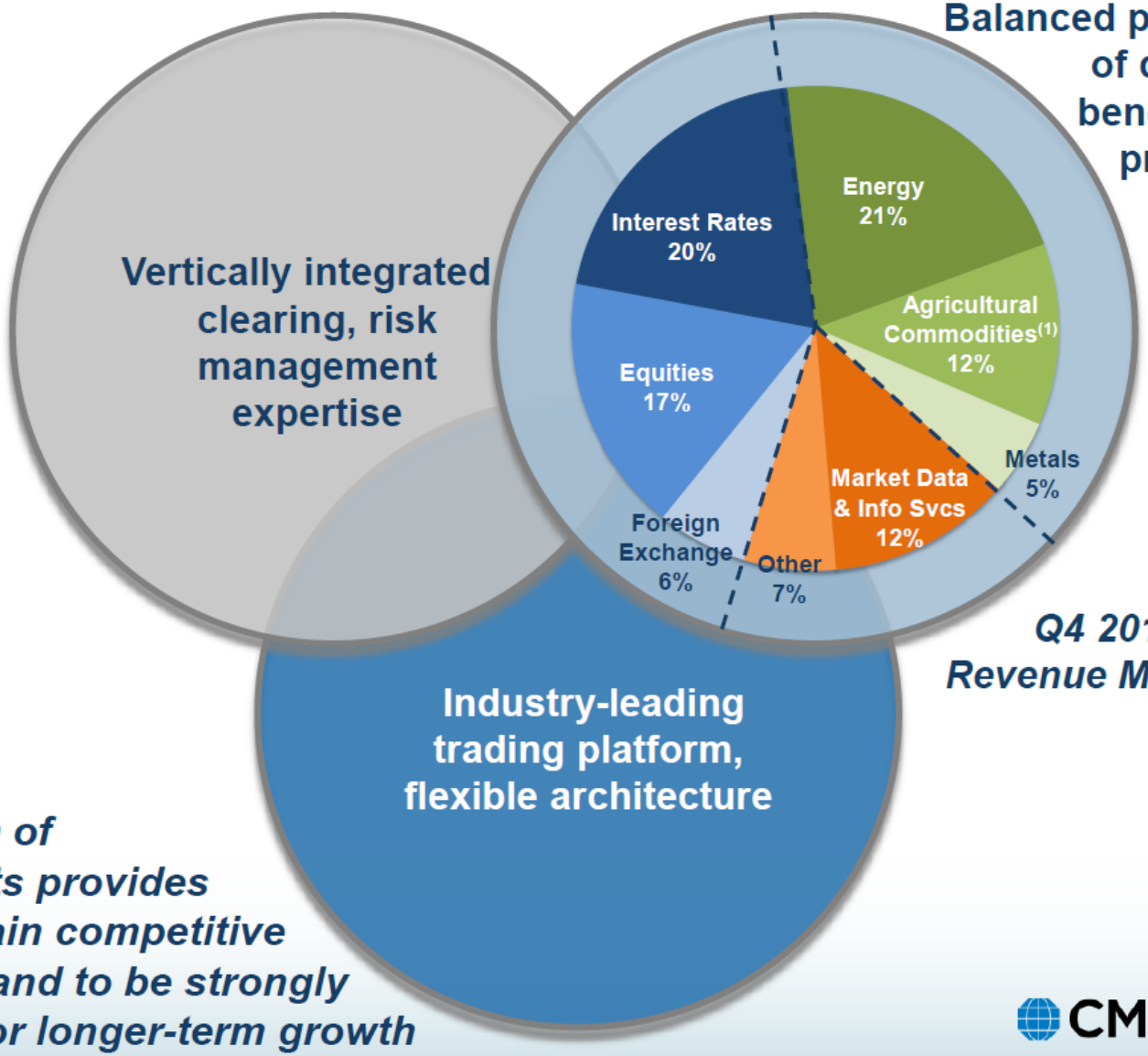
Most Attractive, Valuable and Diverse Franchise in the Exchange Sector



Combination of unique assets provides ability to retain competitive advantages and to be strongly positioned for longer-term growth

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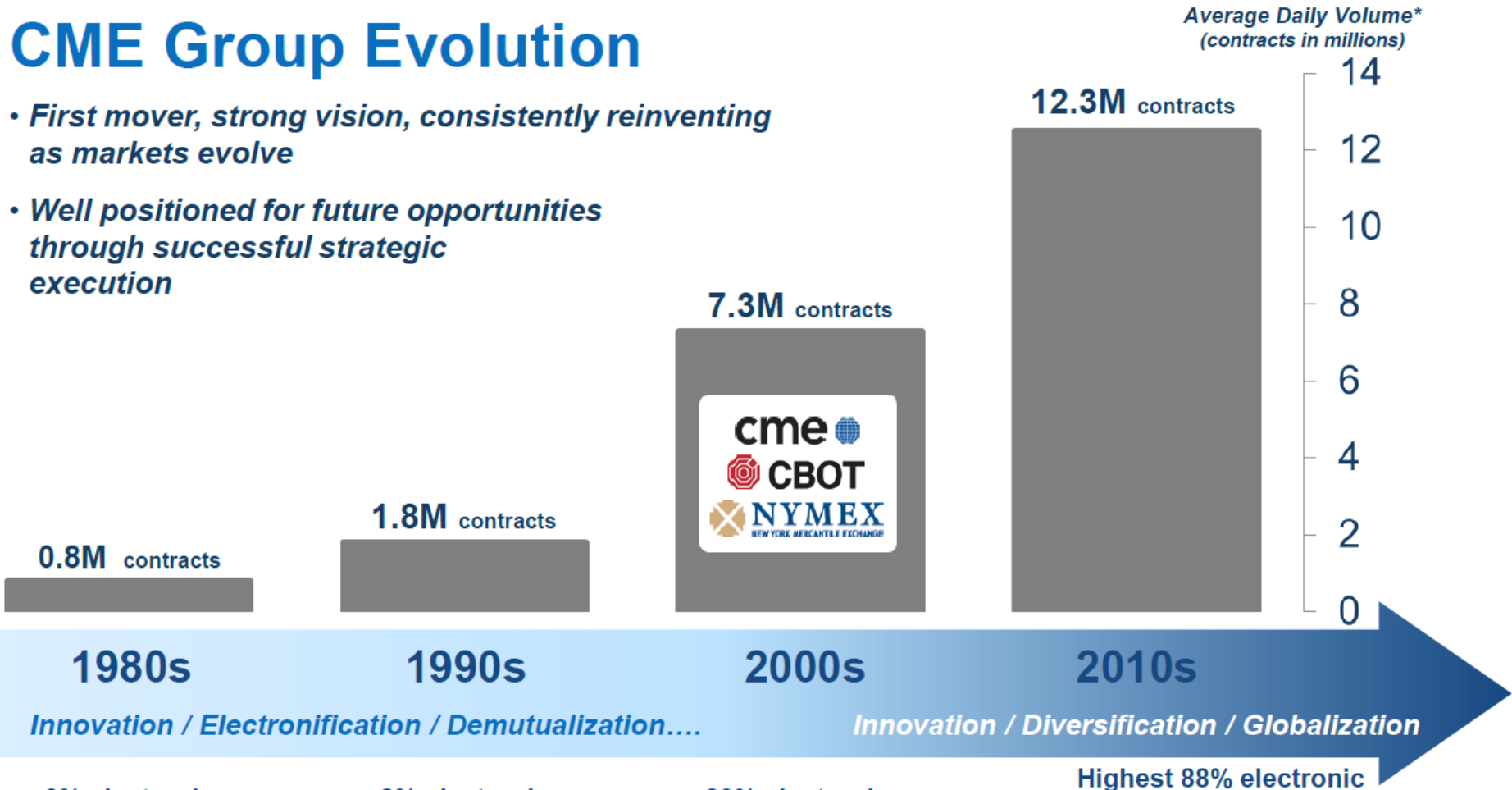
CME Group Evolution

- ***First mover, strong vision, consistently reinventing as markets evolve***
- ***Well positioned for future opportunities through successful strategic execution***



1980s

0% electronic

- Chicago-based open outcry trading floor
- Mutual Offset System w/SGX
- Anticipating electronification

1990s

8% electronic

- Launch of CME Globex trading platform
- Product innovation – i.e. E-mini S&P 500 contract
- Less than 5 employees outside of U.S.

2000s

80% electronic

- Diversifying product and venue
- CME first U.S. exchange to go public
- CBOT demutualizes / goes public
- CME / CBOT merge
- CME Group acquires NYMEX
- CME Group partners w/BM&FBOVESPA

2010s

Highest 88% electronic
Averaging 6% privately negotiated/OTC

- OTC clearing capability growth / offering expansion beyond energy base
- Numerous global partnerships / building out global offices
- Diversify beyond futures transaction-related sources of revenue
  - CME Group / Dow Jones / McGraw Hill partner on index services business
  - Launch Co-Location Services

An Era of Convergence across Multiple Industries Enabled by Technology

* Devices	+ Mobility	→	Single Mobile Device
Telephone, Video, Television, Movies, Music, Books, …	+ Internet	→	Digital Streaming Media
Infrastructure, Software, …	+ Internet	→	Cloud Computing
Trading Order Entry	+ Market Controls	→	Enhanced Pre-Trade Risk Management
Software	+ Hardware	→	High Performance Computing
OTC and Portfolio Margining	+ Central Counterparty Clearing	→	Enhanced Post-Trade Risk Management

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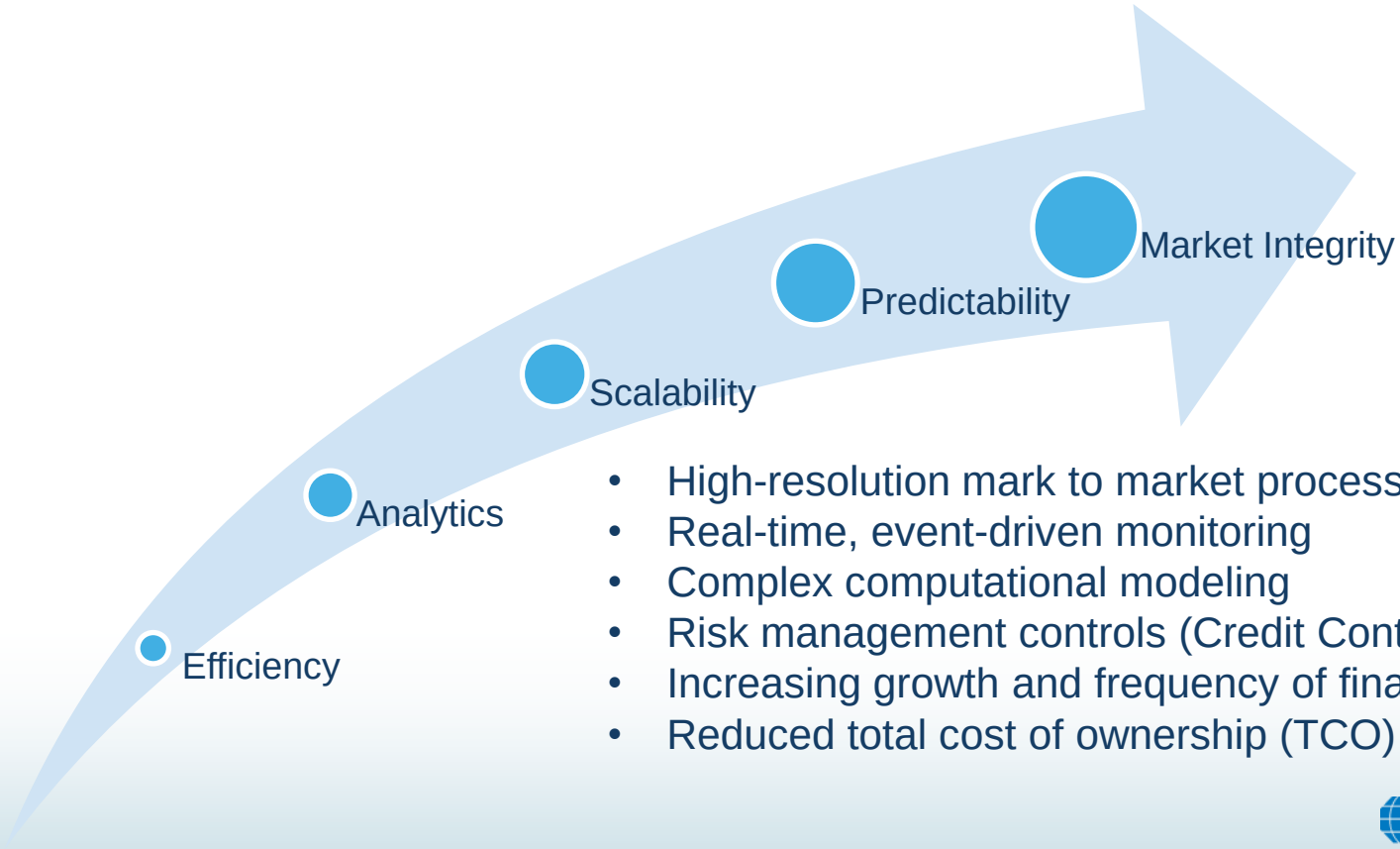
Next Generation Risk Management Enables the Future of Financial Industry Convergence

CME Group is uniquely positioned as a global leader in the derivatives marketplace to lead the next generation of risk management in support of enhanced market controls and the global mandates for central clearing



- High-resolution mark to market processes
- Real-time, event-driven monitoring
- Complex computational modeling
- Risk management controls (Credit Controls)
- Increasing growth and frequency of financial market data
- Reduced total cost of ownership (TCO)

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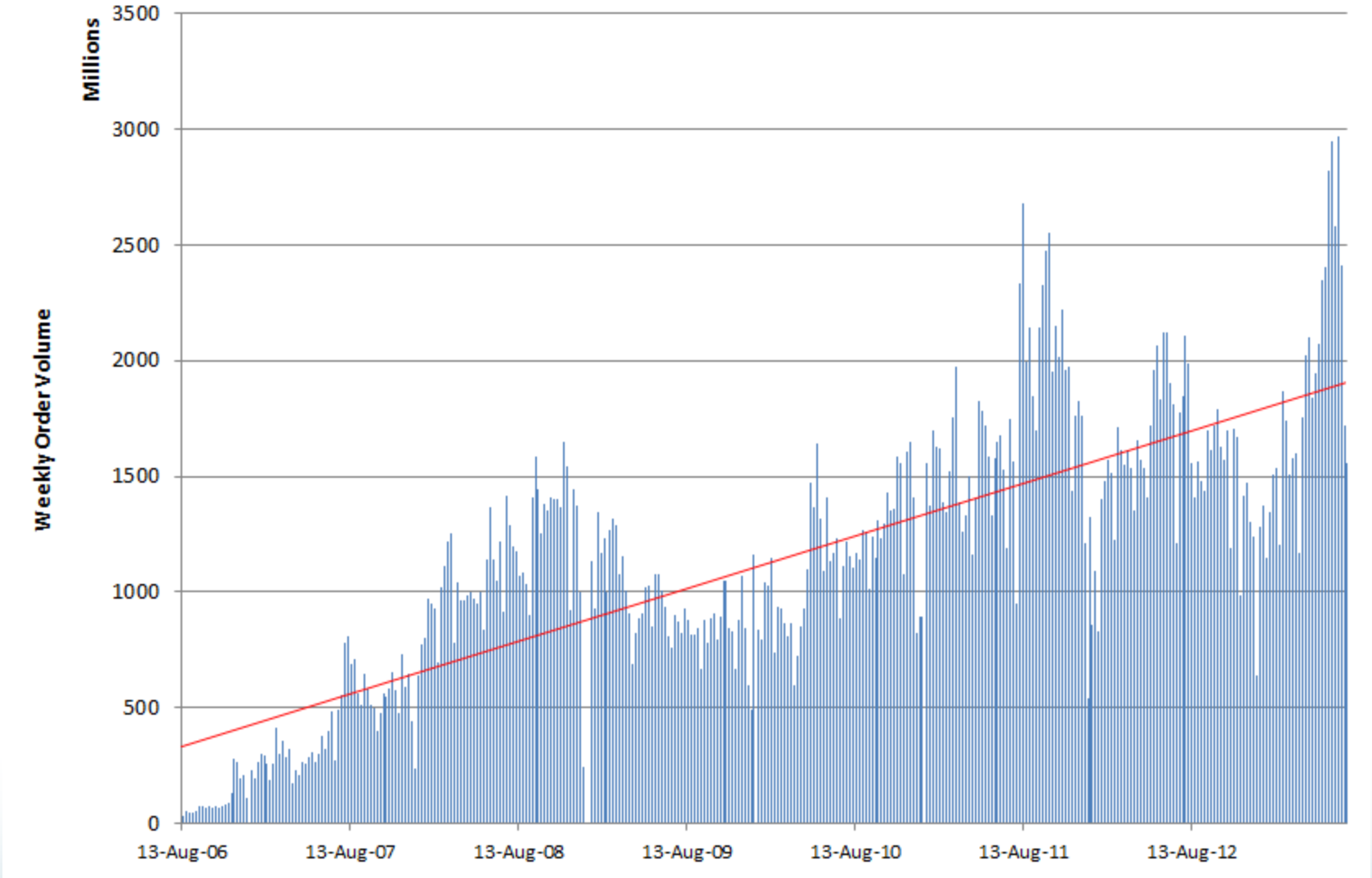
How To Handle The Growing Data Trend…



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FPGA Dataflow Engines (DFEs) Enable the Next Generation of Financial Risk Management

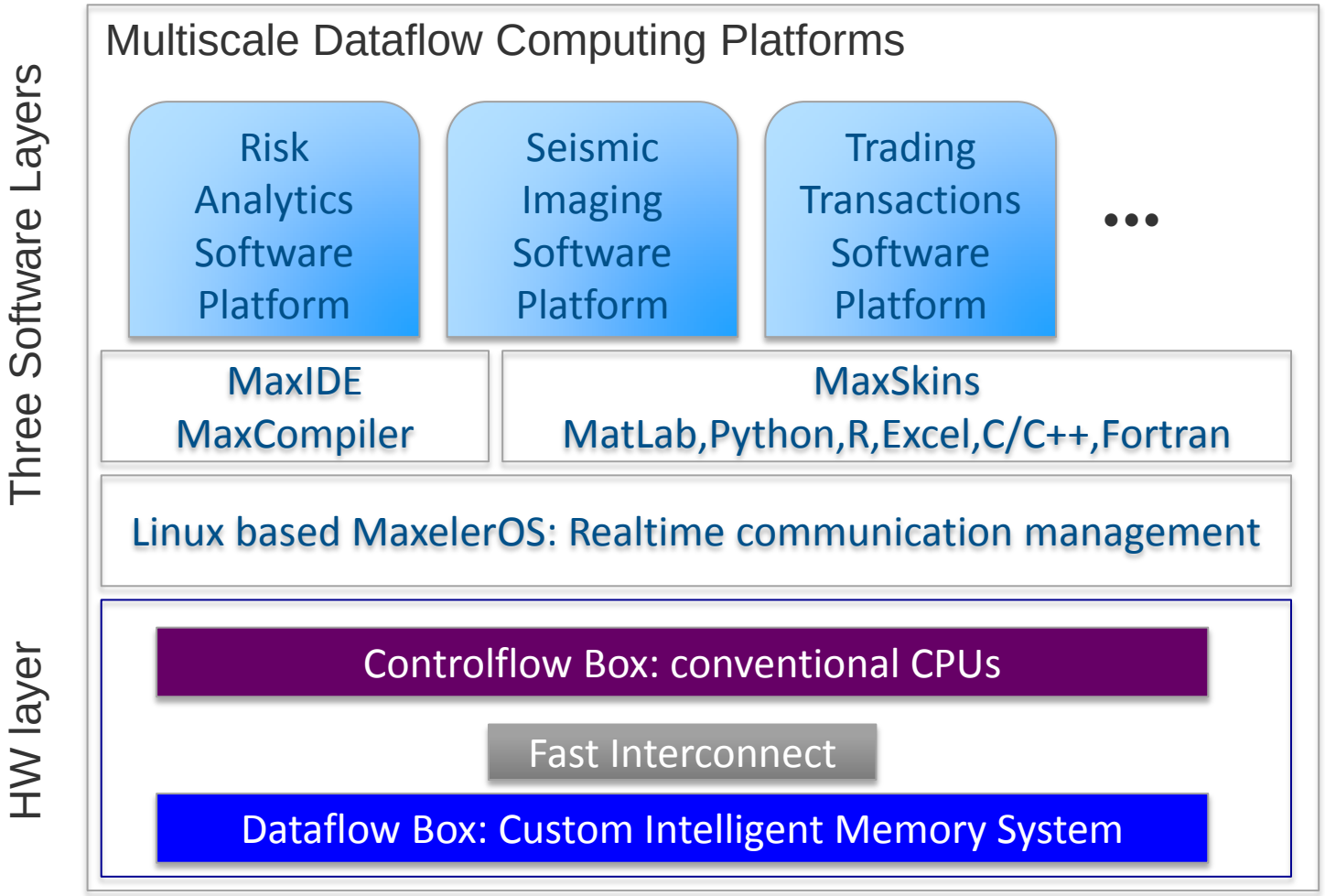
Maxeler's MaxCompiler facilitates the convergence of hardware and software without the traditional tradeoffs for Advanced Risk Management

Area	Software	Hardware	MaxCompiler
Challenges	Interrupts Resource Starvation	Code complexity Skillset availability	
Architecture	Something	Block	Streaming
Design	[Insert Your Best Practice]	RTL Diagrams w/ Flow Control	Manager / Kernel Diagrams
Code Entry	Java	VHDL/Verilog	MaxJ/Java
Unit Tests	JUnit	Simulation Test Vectors	Kernel Tests
Design Debugging	Java Debug	Simulation Design Test	Simulated DFE and MaxDebug
Test / QA	Java	Hardware	DFE + MaxDebug
Deployment	Binary	Flash cards / Cable	Binary

- **Allows existing software & support teams to program in hardware**
- **Supports agile, pure software SDLC**
- **Increases productivity and cost efficiency**

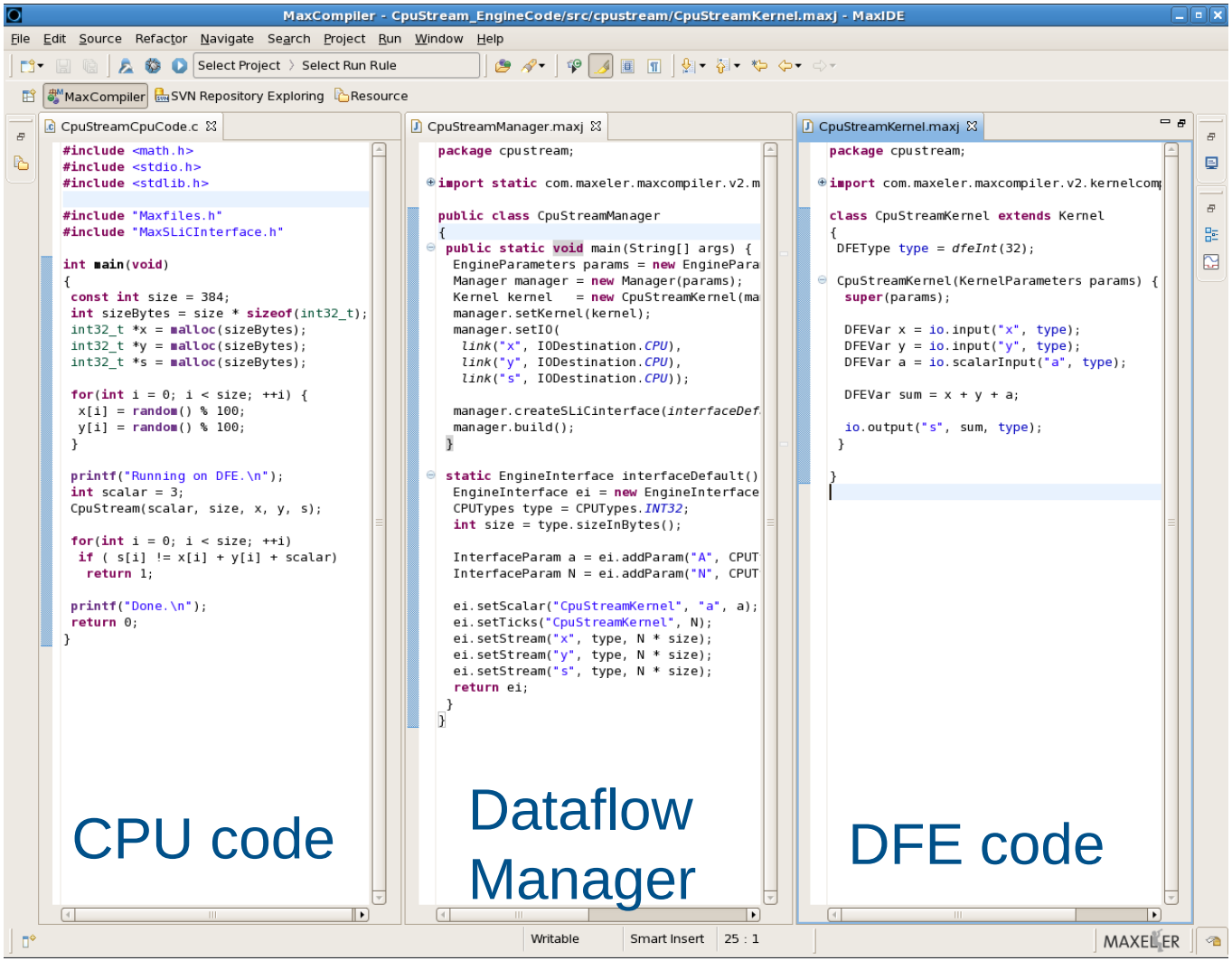
The Multiscale Dataflow Computer

decoupling the data plane and control plane



Software Layer for Programming Dataflow Boxes

- Multiscale hardware design, as simple as writing software
- MaxCompiler is a Dataflow Engine design library which is powered by Java
- It comes with a fully integrated Development Environment based on Eclipse called MaxIDE
- MaxSkins enable runtime integration with almost any language!



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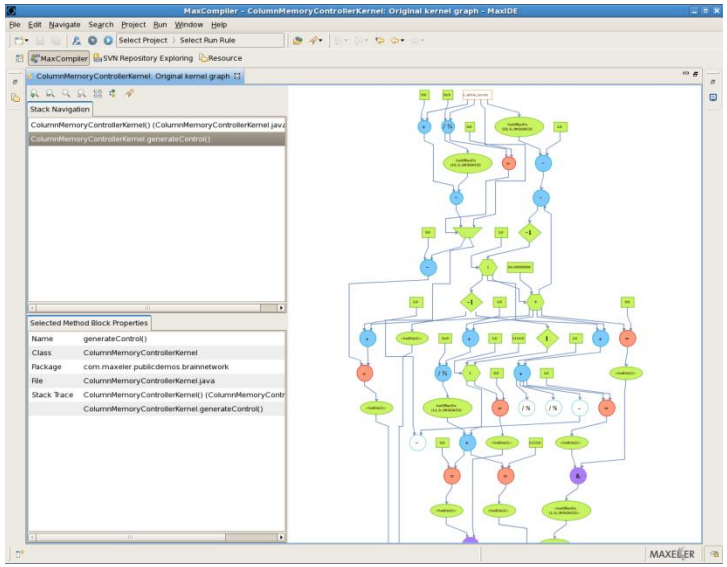
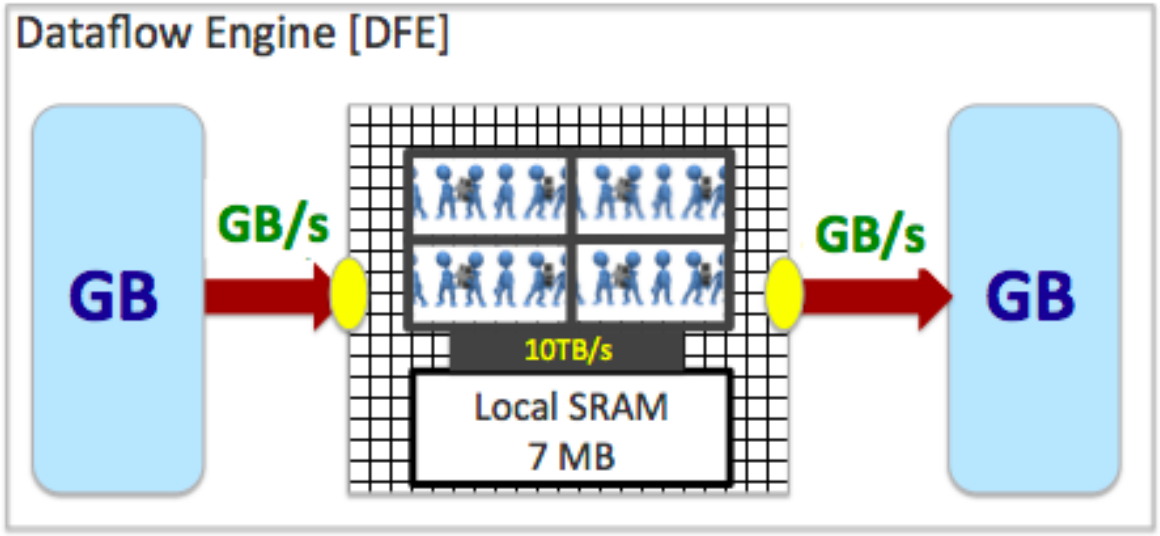
Computing with Multiscale Dataflow Engines (DFEs)

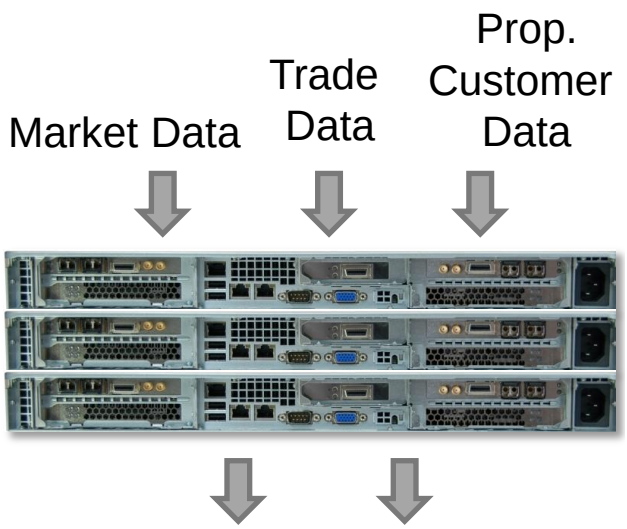




Multiscale Dataflow Computing enables the optimization of Compute intensive applications on the bit level, the architecture level, the memory system level, and the networking level, and the storage level.

Risk Analytics Platform

- Combine Trading and Risk in a unified platform
- Moving risk computations from local overnight to corporation global in real-time, moving traders from looking back to looking forward.

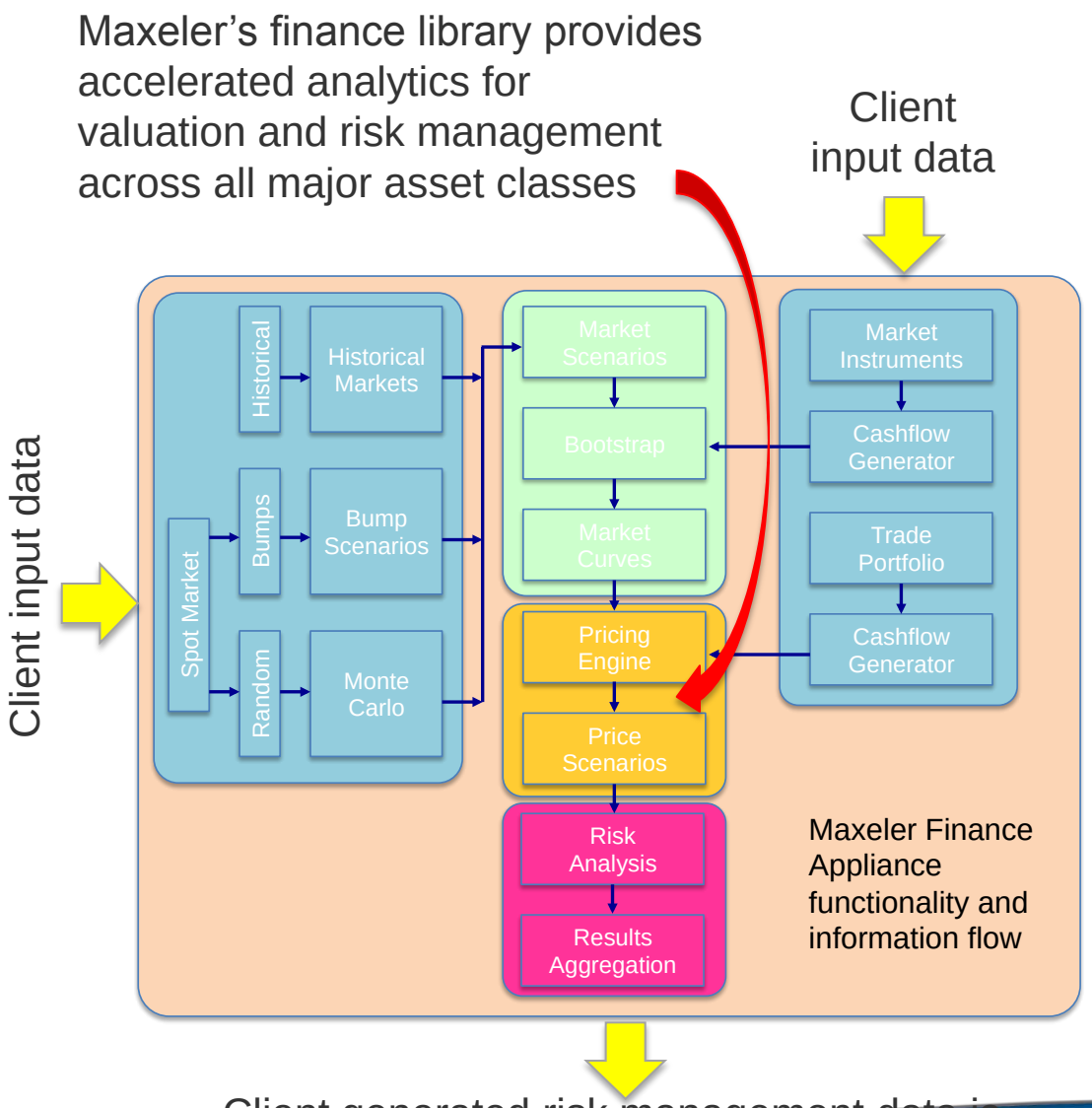


Instrument	CPU 1U-Node	Max 1U-Node	Comparison
European Swaptions	848,000	35,544,000	42x
American Options	38,400,000	720,000,000	19x
European Options	32,000,000	7,080,000,000	221x
Bermudan Swaptions	296	6,666	23x
Vanilla Swaps	176,000	32,800,000	186x
CDS	432,000	13,904,000	32x
CDS Bootstrap	14,000	872,000	62x

Wall Street Journal, Maxeler Makes Waves With Dataflow Design, American Finance Technology Award, New York, Dec 2011

Risk Analytics Platform Architecture

- Maxeler's finance appliance accepts client input data and generates required risk management data at any and all requested levels of aggregation.
- Scenario analysis can be either permutative, combinatorial, ad-hoc or Monte Carlo.
- The finance appliance is fully scalable to client requirements.



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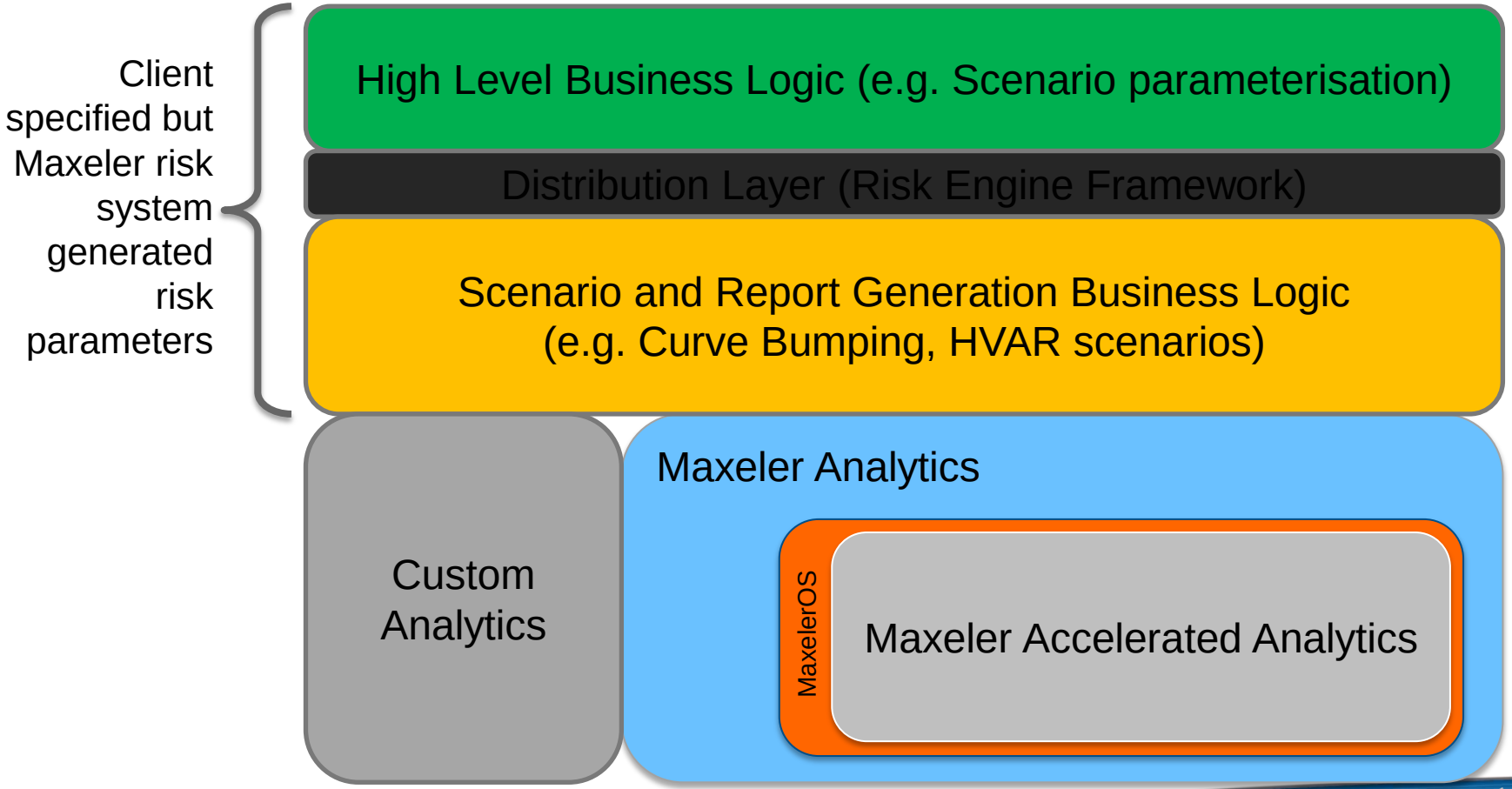
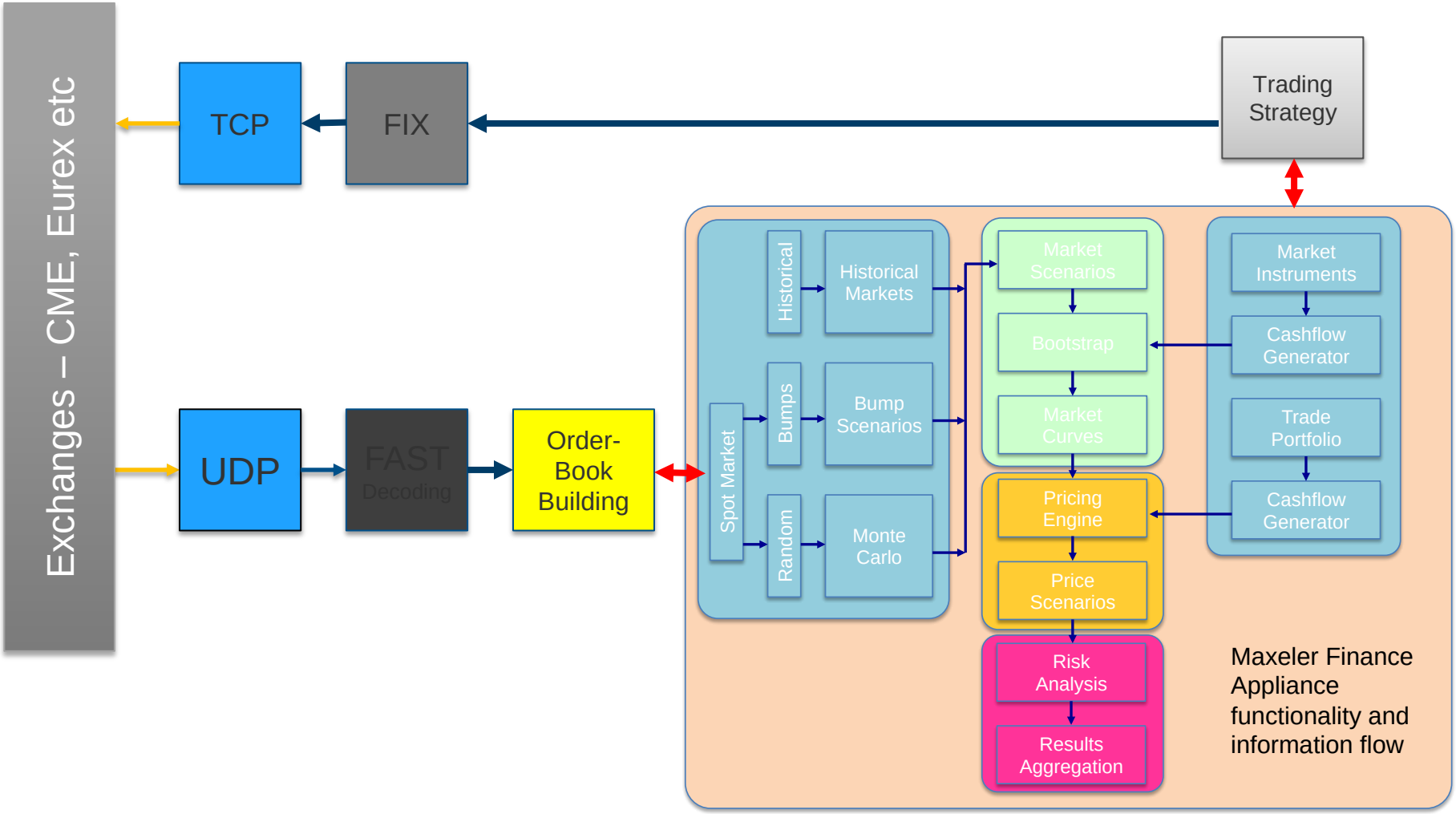
Risk Analytics Platform Architecture

Maxeler's risk management system provides full functionality for users to specify and drive high-level business logic. Integration with existing client data, output and reporting is via a flexible interface layer.

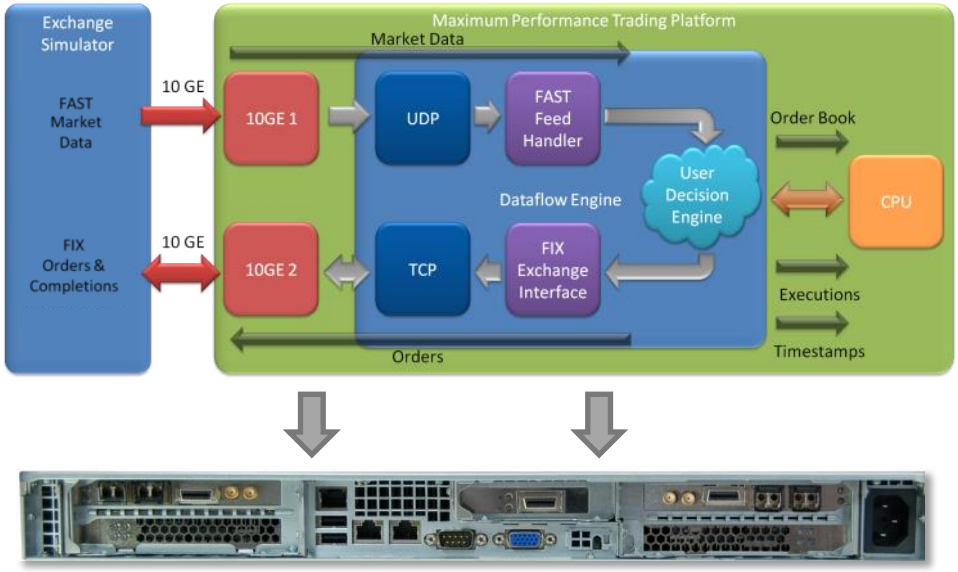


DFE Programming Enables Real-Time Risk Management of Trading Strategies



Financial Gateway Platform

- Maxeler provides Hardware, Software and Exchange/Trading interfaces, as well as financial data infrastructure
- Customers use MaxIDE and Java to write own risk management algorithms, security checks, credit checks that process at line rate
- Public customer: JP Morgan Equities Direct Market Access



- MaxCompiler enables unprecedented programmability of the dataplane.
- User Decision-Engine is fully programmable and executes in 3us
- All infrastructure (TCP/IP, feed-handlers, performance etc.) is managed by Maxeler, allowing the customer to focus on their business.

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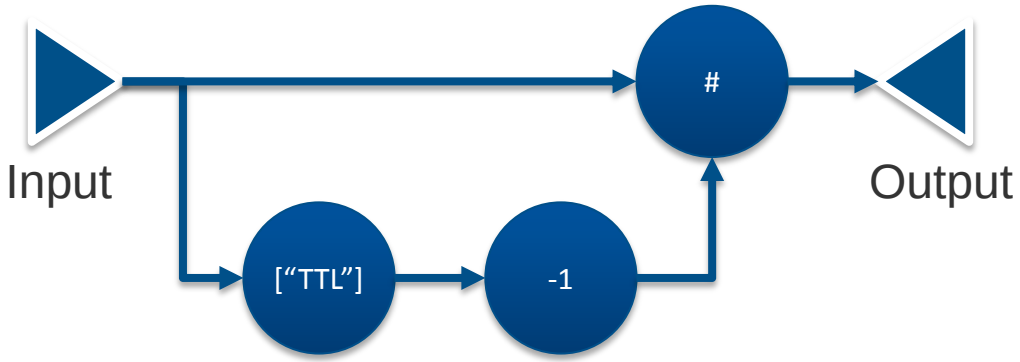
MaxCompiler

- Dataflow kernels using MaxCompiler powered by java

MaxJava Code

```
Output[“TTL”] <==
          Input[“TTL”] - 1;
```

Corresponding Dataflow graph



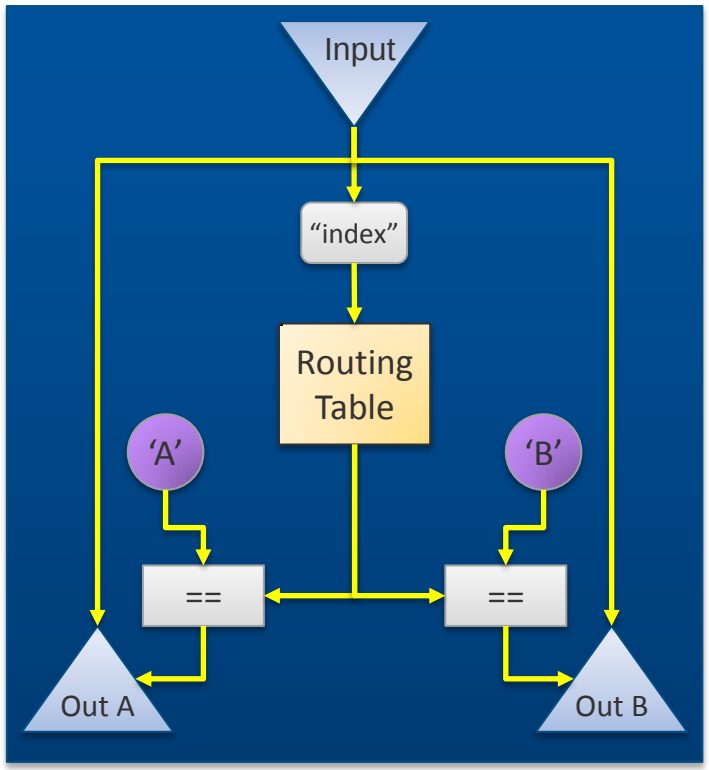
Dataflow Description

```
FrameData<SimpleInput> inputFrame =
 io.frameInput("input",
    simpleInputType, simpleLinkType);


DFEVar index = inputFrame["index"];
DFEStruct routingData =
        mem.romMapped("routingTable",
                        index, routingInfoType);

DFEVar outputPort =
          routingData.get("outputPort");
io.frameOutput("outA",
           outputPort === 'A') <==
inputFrame;
io.frameOutput("outB",
           outputPort === 'B') <==
inputFrame;
```

Data Flow Kernel



User defined I/O routing

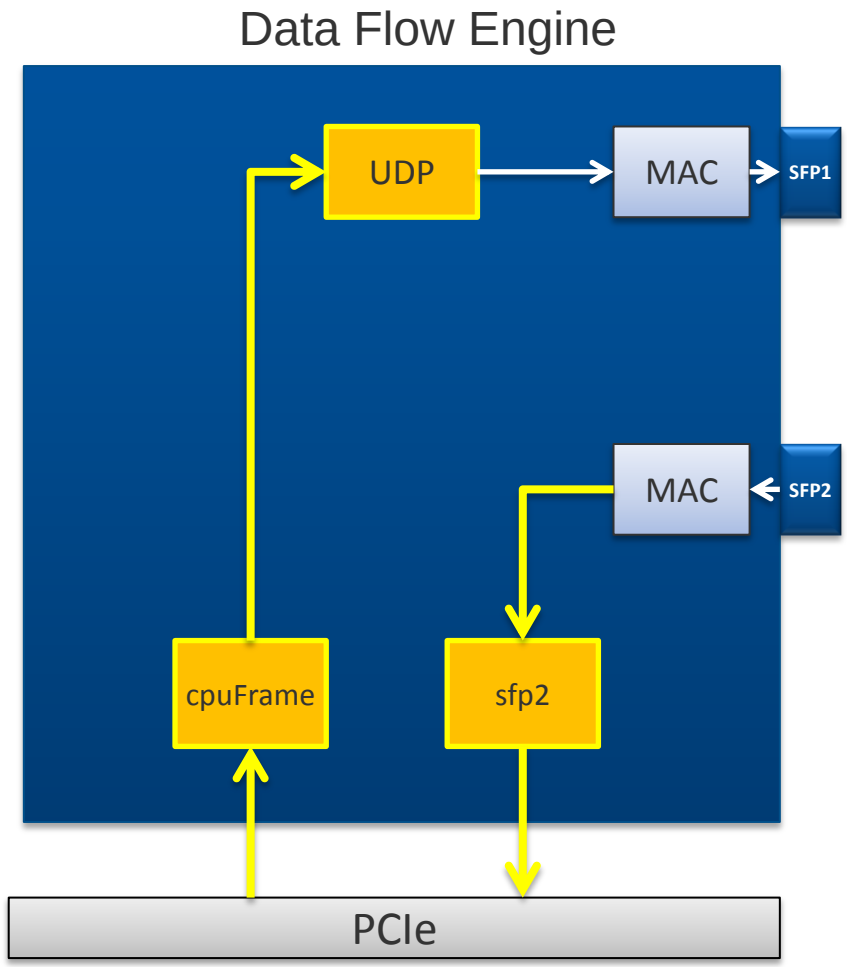
DFELink *cpuFrame* = **addFramedStreamFromCPU**("cpuFrame");

UDPStream *sfp1* = **addUDPStream**("udp", NetworkConnection.SFP1);

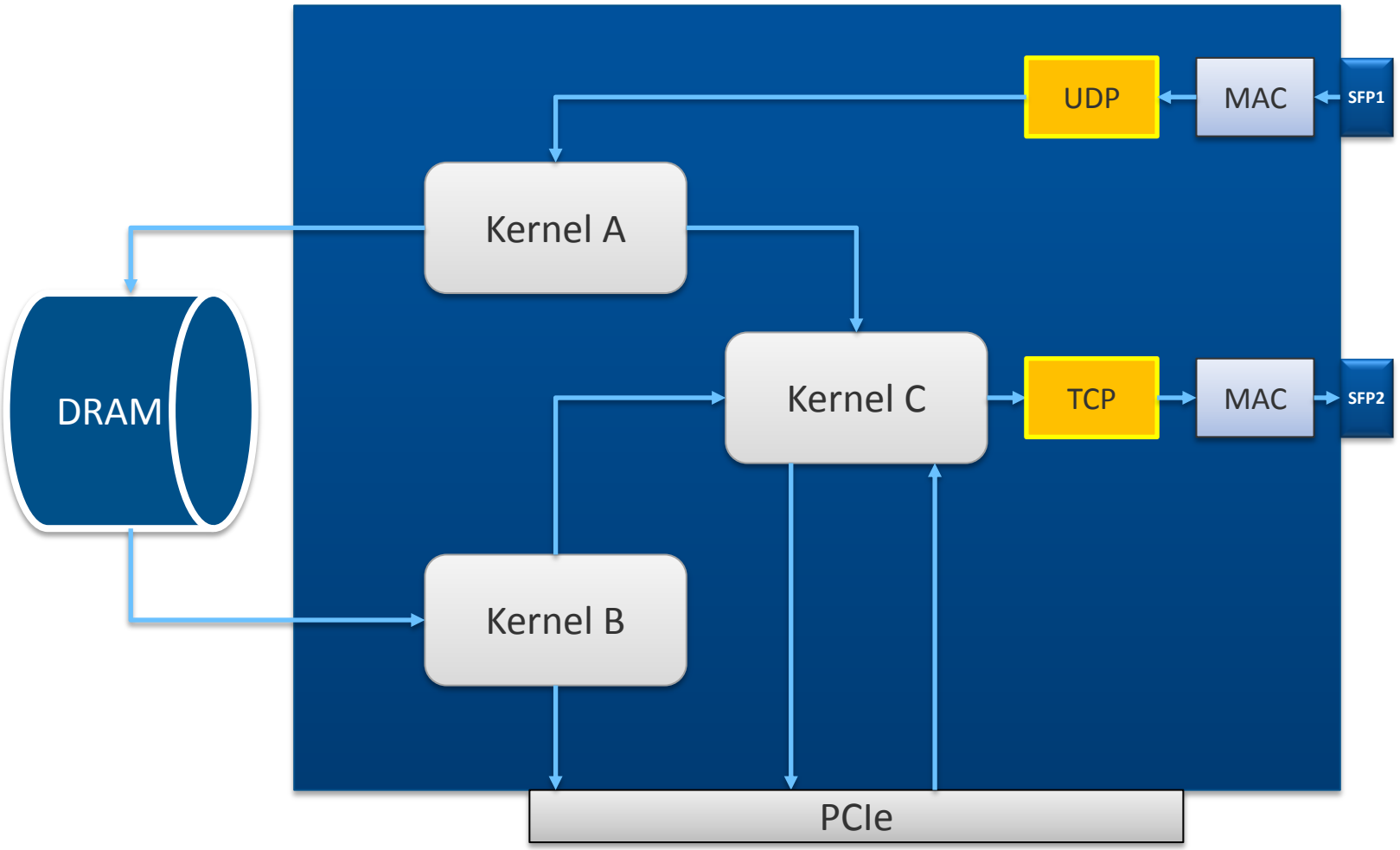
sfp1.**getTransmitStream**() <== *cpuFrame*;

EthernetStream *sniff* = **addEthernetStream**("sniff", NetworkConnection.SFP2);

addFramedStreamToCPU("sfp2") <== *sniff*.**getReceiveStream**();



Mix and Match



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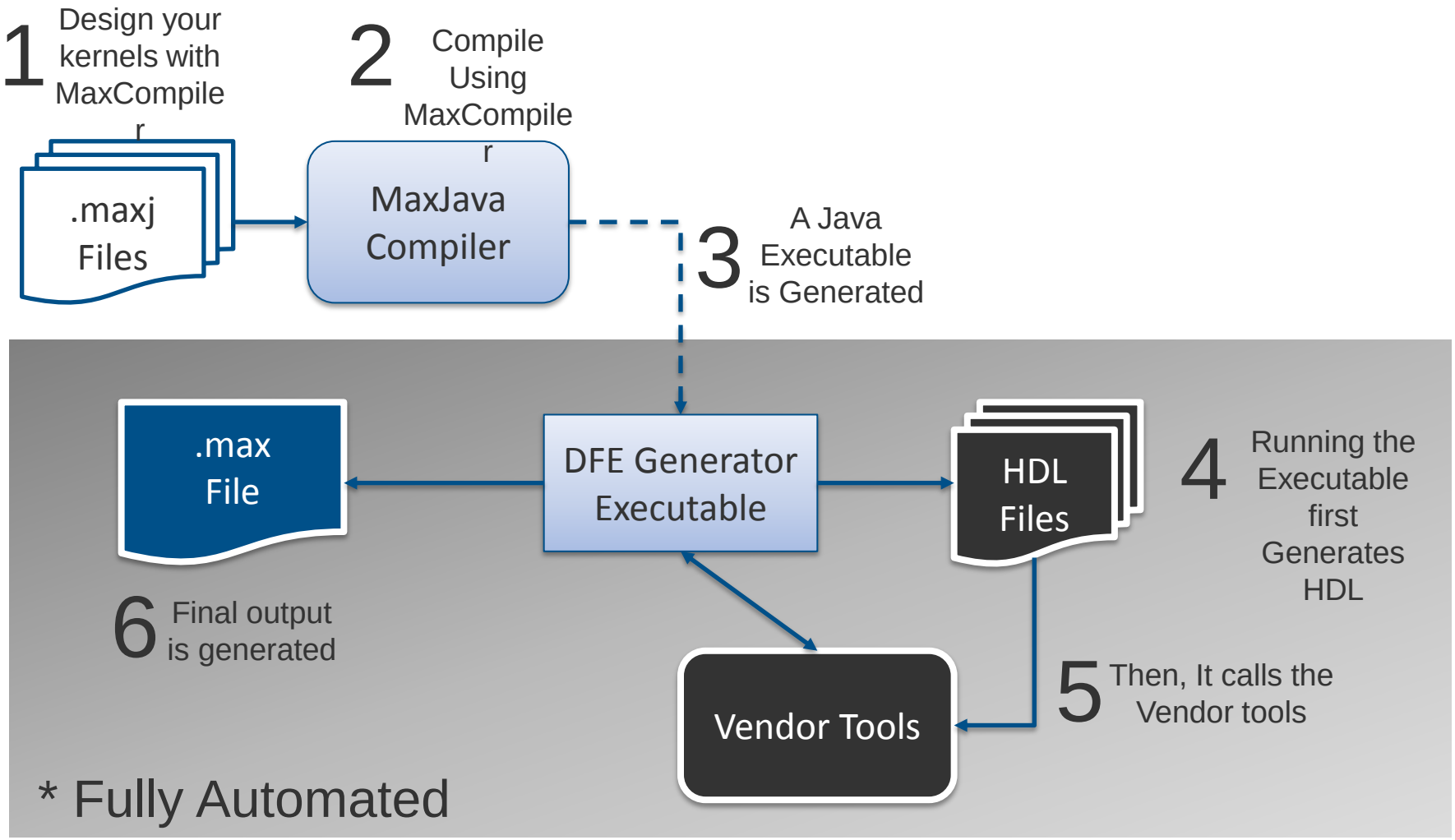
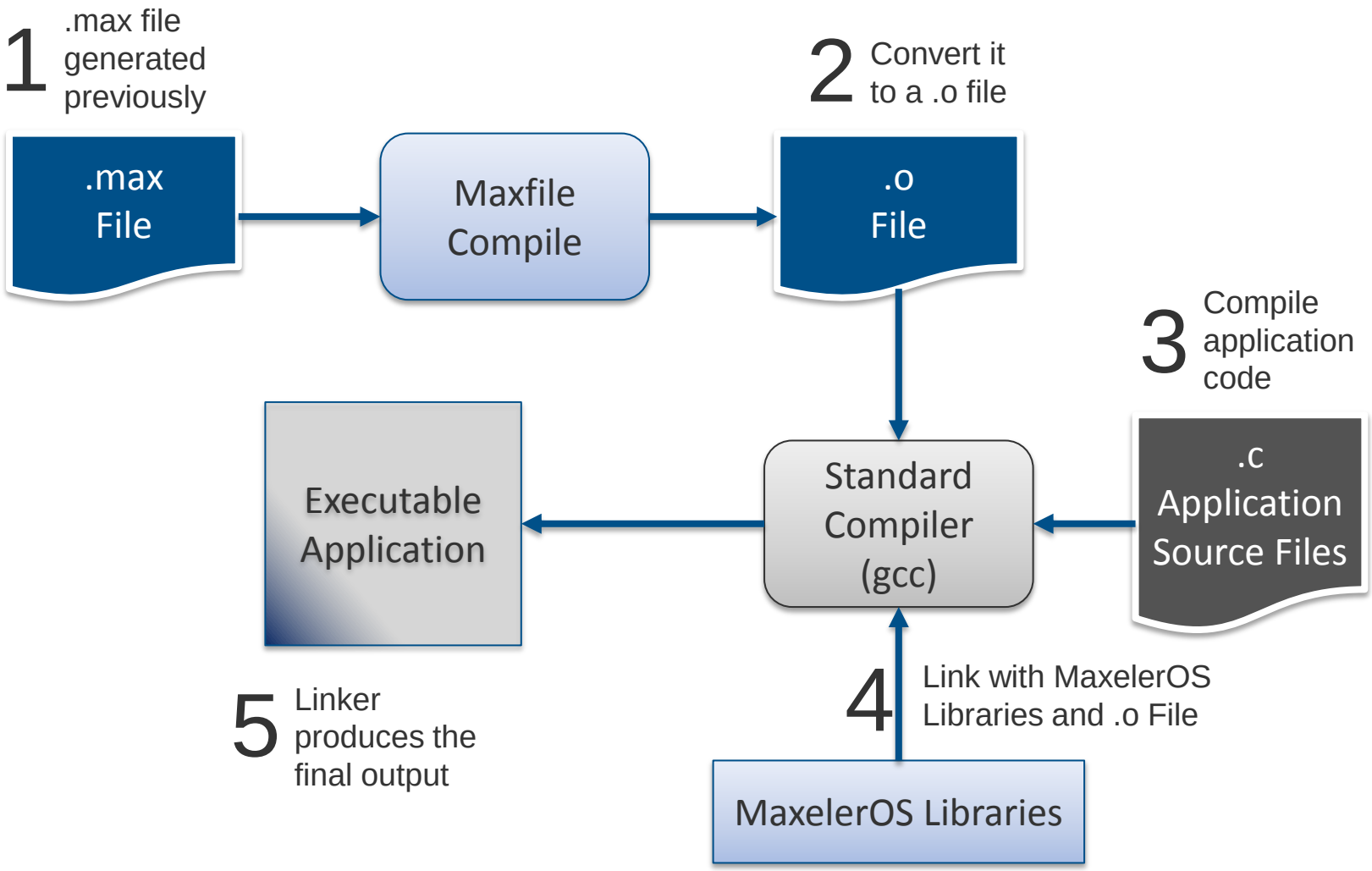
From Graphs to Hardware

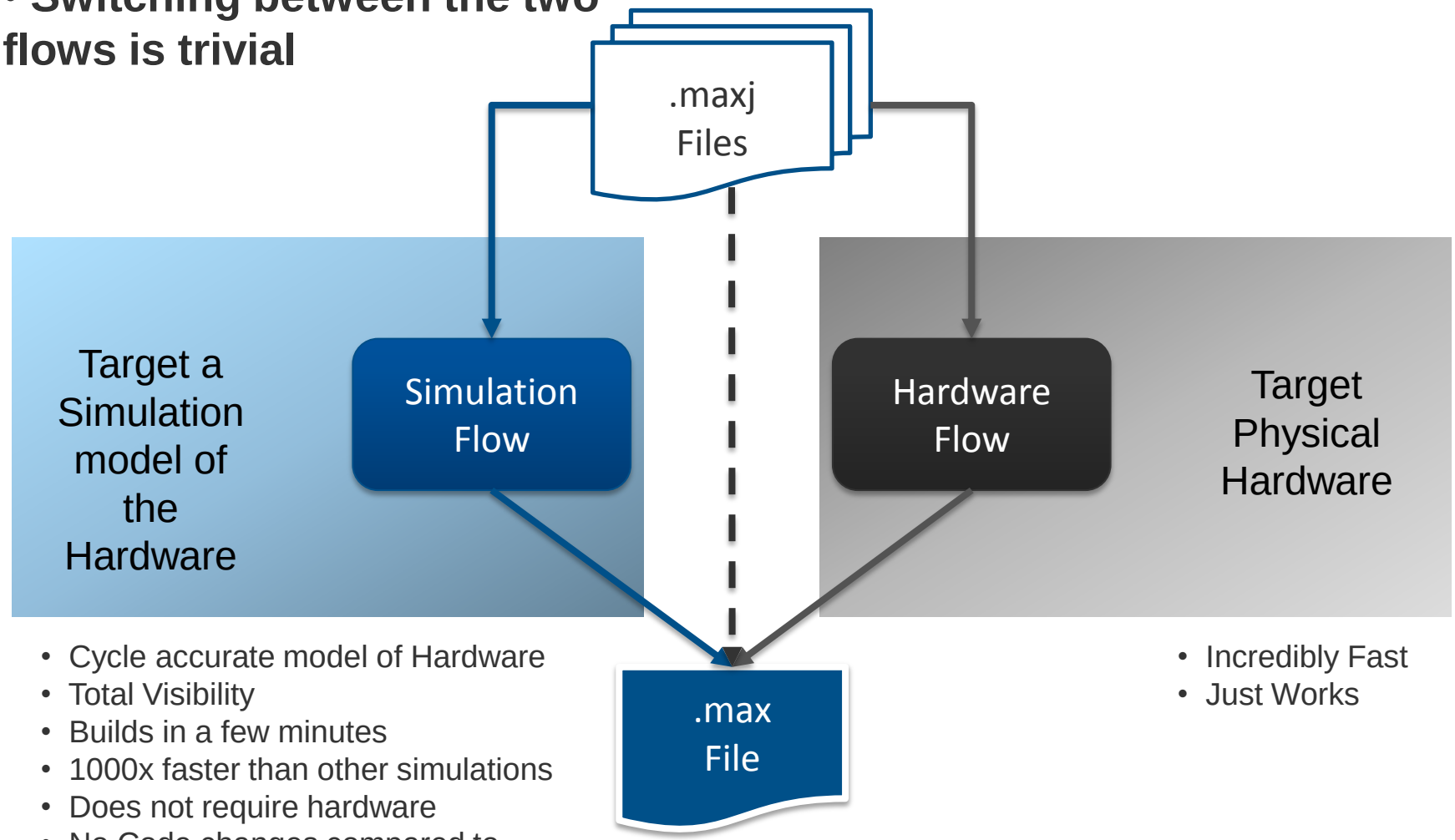


From .max to Application



Simulation

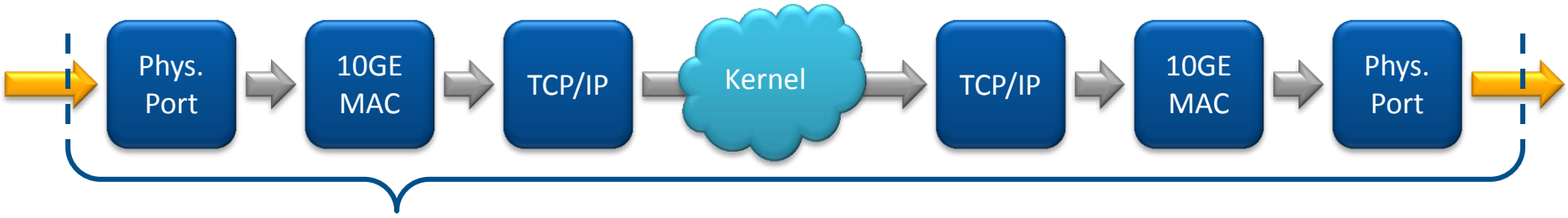
- **Switching between the two flows is trivial**

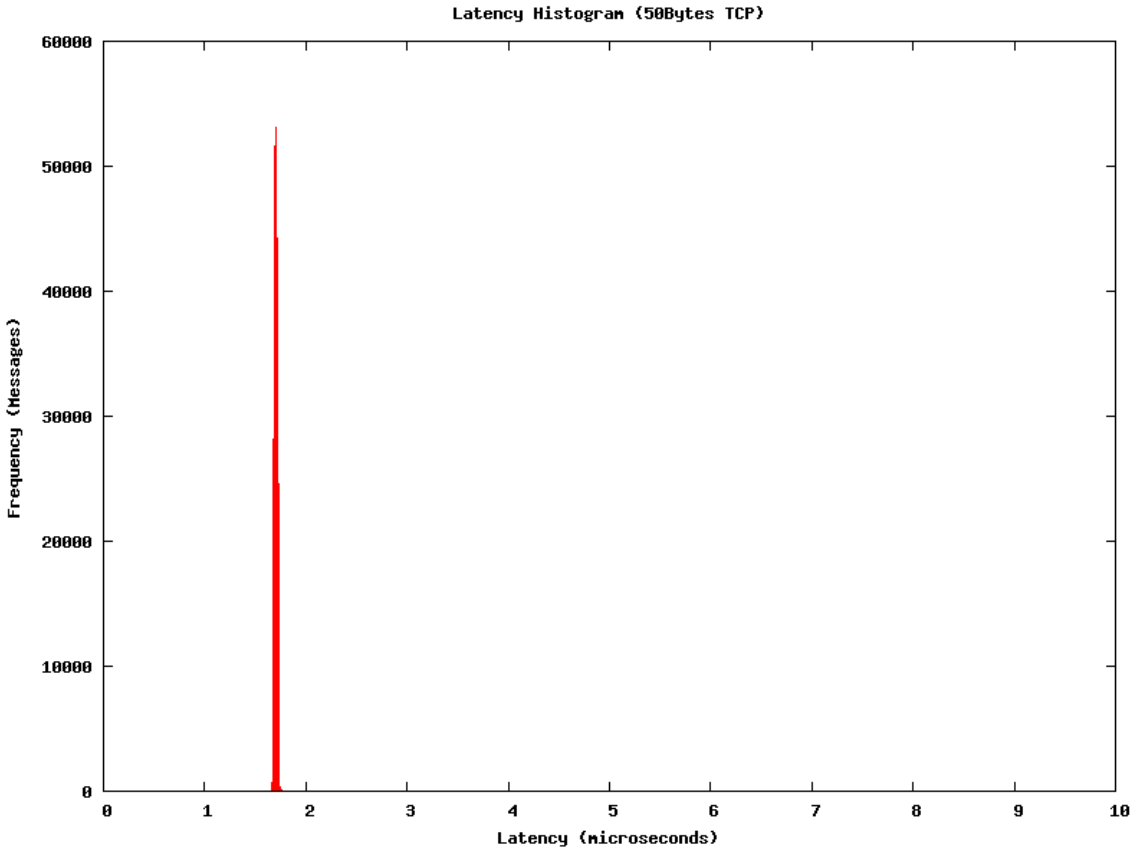


- Cycle accurate model of Hardware
- Total Visibility
- Builds in a few minutes
- 1000x faster than other simulations
- Does not require hardware
- No Code changes compared to hardware
- Software engineering methodologies

- Incredibly Fast
- Just Works

Predictable and Consistent Processing





Measurement Details:
- Dual passive-optical fiber taps, 50/50 – 50um
- Timestamping card on RX and TX fibers
- 50B payload in standard TCP/IP packets
- Timestamps measured after last bit of frame received
- TCP, IP and Ethernet checksums calculated and checked
- Measurements valid up to line rate

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Maxeler Hardware Solutions

MPC C Series

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

MPC X Series

DFEs shared over Infiniband
Up to 8 DFEs with 768GB of RAM and dynamic allocation of DFEs to CPU servers

MPC N Series

Low latency connectivity
Intel Xeon CPUs and 1-2 DFEs with up to six 10Gbit Ethernet connections

MaxWorkstation
Desktop development systems

MaxCloud
On-demand scalable accelerated compute resource, hosted in London