XDF XILINX DEVELOPER FORUM

Financial Analytics Acceleration

Presented By

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Title Director of Maxeler IoT-Labs
Date Dec 10, 2018

XILINX

FPGA technology is getting traction among Datacenter providers and is expected to grow significantly at 124% yearly to reach $432M in 2023

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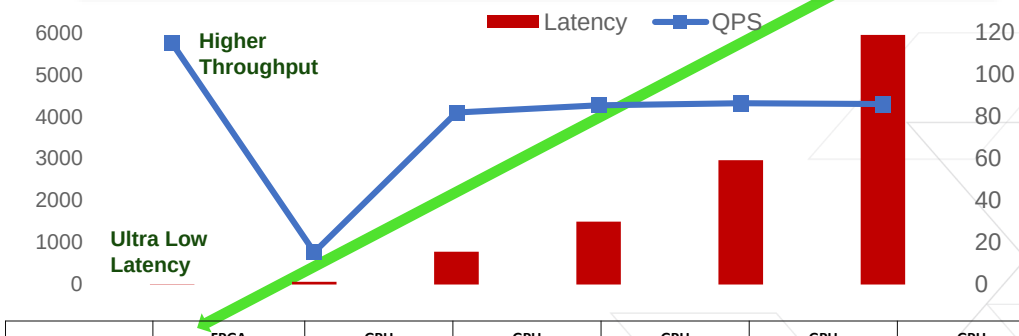
- Alibaba cloud showed FPGAs overperform **GPUs** with **higher throughput** and **ultra low latency**
- FPGAs sales are **expected to grow much faster in HPC Datacenters** than GPUs, CPUs and ASICs in the next 5 years

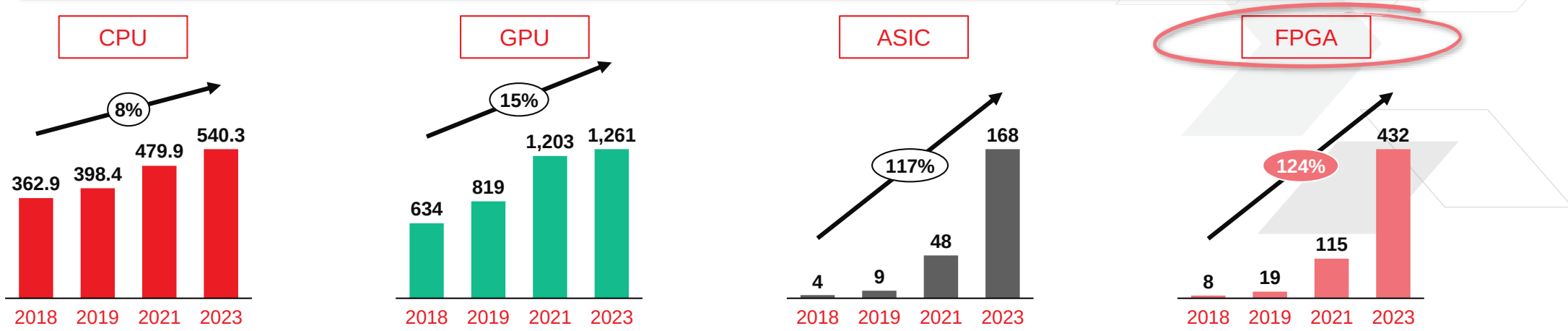
FPGA vs. GPU with Resnet18



	FPGA BS=1	GPU BS=1	GPU BS=64	GPU BS=128	GPU BS=256	GPU BS=512
Latency	0.174	1.29973	15.6022	29.9793	59.2734	118.949
QPS	5747	769	4101	4269	4319	4301

Source: www.alibabacloud.com

Projected HPC Datacenter accelerator market, by processor type 2018-2023 ($M)



Source: Data Center Accelerator Market-MarketsandMarkets (2018)

Finance in Action at Maxeler

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Maximum Performance Computing

MARKET PORTFOLIO COUNTERPARTY DEEP TECH

Spot Sensitivity Settings

Width: 0.01%

Maximum: 0.05%

Base Currency: USD

Expiry Bucket

1 | Day | Add

- 1D
- 2D
- 1W
- 1M
- 3M

Delete

Spot Sens | Time Sens | Bucket Sens

Currency Pair: USD/ARS

0d

#	-0.05%	-0.04%	-0.03%	-0.02%	-0.01%	0.00%	0.01%	0.02%	0.03%
Spot	17.5134	17.5152	17.5170	17.5187	17.5205	17.5222	17.5240	17.5257	17.5275
Diff in PV	(3,160,959)	(3,163,094)	(3,165,227)	(3,167,360)	(3,169,492)	0	(3,173,754)	(3,175,884)	(3,178,013)
Delta	(1,218,169)	(1,217,914)	(1,217,267)	(1,216,969)	(1,216,534)	(1,892,822)	(1,215,792)	(1,215,223)	(1,214,869)
Gamma	466,454	(1,436,911)	3,654,126	123,237	(511,166)	2,813,874	(926,839)	1,196,996	624,249
Vega	6,026,129	6,031,456	6,036,845	6,042,152	6,047,515	13,002,747	6,058,193	6,063,571	6,068,918
Theta	(356,695)	(357,262)	(357,821)	(358,388)	(358,947)	(976,706)	(360,077)	(360,631)	(361,193)

1d

#	-0.05%	-0.04%	-0.03%	-0.02%	-0.01%	0.00%	0.01%	0.02%	0.03%
Spot	17.5134	17.5152	17.5170	17.5187	17.5205	17.5222	17.5240	17.5257	17.5275
Diff in PV	10,671	8,536	6,401	4,266	2,133	0	(2,132)	(4,263)	(6,394)
Delta	(1,219,007)	(1,218,848)	(1,218,194)	(1,217,717)	(1,217,424)	(1,217,142)	(1,216,645)	(1,216,179)	(1,215,748)
Gamma	1,032,853	(3,838,008)	(221,330)	2,287,774	728,779	(2,193,488)	(1,227,074)	427,330	(582,729)
Vega	6,004,985	6,010,276	6,015,610	6,020,934	6,026,274	6,031,570	6,036,901	6,042,249	6,047,544
Theta	(356,419)	(356,986)	(357,537)	(358,093)	(358,650)	(359,215)	(359,769)	(360,329)	(360,889)

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Project: HVaR Monitoring Demo | This demo is using Dataflow Engines | demo-user

89x FPGA speedup box-2-box over CPUs

HVaR Monitoring Demo

Swap Portfolio HVaR Monitoring System

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Market data

Libor | OIS

USD.1M | USD.3M | USD.6M | EUR.1M | EUR.3M | EUR.6M | EUR.1Y

Term	Type	Mid	Timestamp
3 MO	SPREADS	0.063	Tue, 18 Sep 2018 15:45:19
6 MO	SPREADS	0.068	Tue, 18 Sep 2018 15:46:40
1 YR	SPREADS	0.079	Tue, 18 Sep 2018 15:45:19
2 YR	SPREADS	0.084	Tue, 18 Sep 2018 15:45:19
3 YR	SPREADS	0.083	Tue, 18 Sep 2018 15:45:19
4 YR	SPREADS	0.082	Tue, 18 Sep 2018 15:47:58
5 YR	SPREADS	0.081	Tue, 18 Sep 2018 15:45:19
7 YR	SPREADS	0.073	Tue, 18 Sep 2018 15:46:03
10 YR	SPREADS	0.063	Tue, 18 Sep 2018 15:48:22
12 YR	SPREADS	0.056	Tue, 18 Sep 2018 15:47:18
15 YR	SPREADS	0.048	Tue, 18 Sep 2018 15:45:41
20 YR	SPREADS	0.041	Tue, 18 Sep 2018 15:47:43

Incoming Trades

Portfolio size: 250,452 Portfolio PV: $3,179,622 Pending trades: 98

Floating leg	Fixed leg	Maturity	Notional	Timestamp
USD IBOR 3M	PAY 2.52% 6M	6/4/2018	$3,438,500	15:48:24
USD IBOR 3M	RECEIVE 1.30% 6M	5/8/2018	$3,000,000	15:48:24
USD IBOR 3M	RECEIVE 1.35% 6M	3/20/2018	$6,200,000	15:48:24
USD IBOR 3M	RECEIVE 0.89% 6M	3/18/2016	$7,240,000	15:48:23

HVaR

HVaR: $8,469,331,579 Swaps per second: 8,049,623

Maxeler Real-Time Risk Monitor on AWS F1 and XBB

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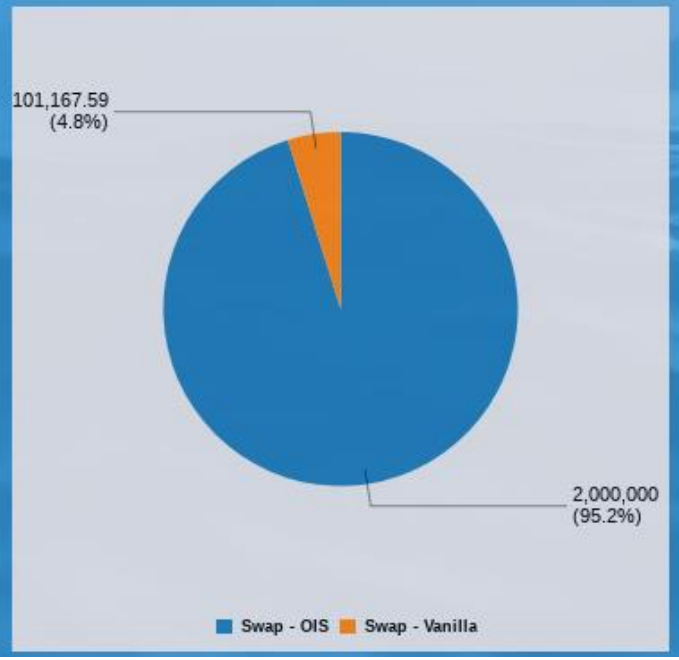
Counterparty Name	Total DV01	Number of Trades	CVA	Gross Exposure	SIMM
BARCLAYS ASSET MANAGEMENT LIMITED	321.50	4	$4.47	$2,101,167.59	15,937

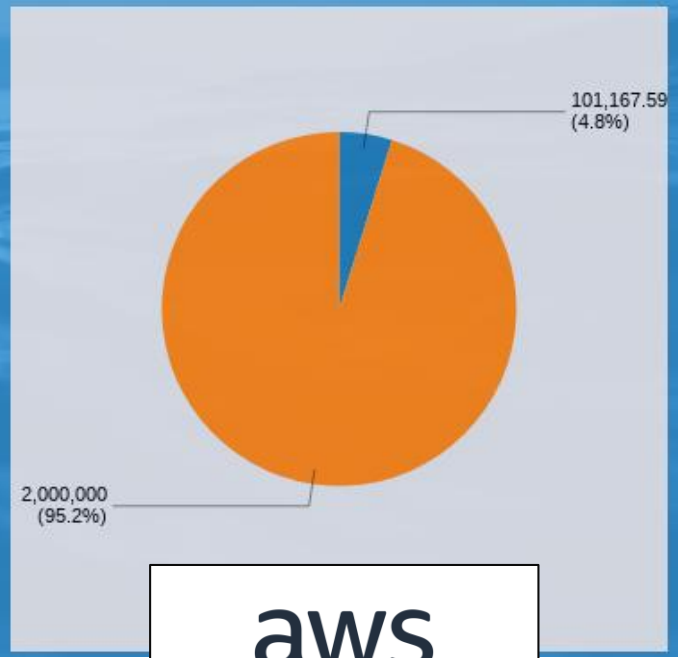
Values without new trades	$15,937.38	$-1,999,996.00	$4.47	$2,101,167.59	15,937
Marginal contribution of new trades	$15,615.89	$2,000,000.00	$4.47	$2,101,167.59	15,937

"BARCLAYS ASSET MANAGEMENT LIMITED" Drill Down

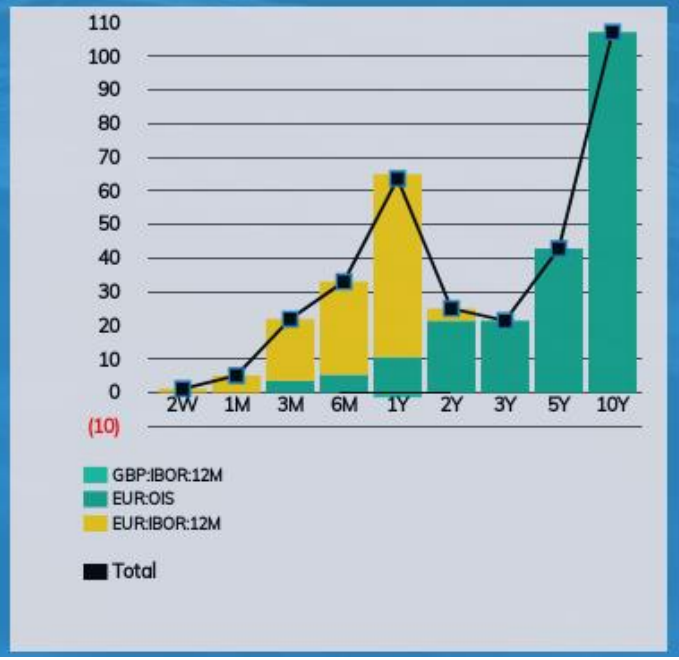
Pie chart of exposure by asset type



Pie chart of exposure by currency



DV01 by tenor/subcurve chart (from SIMM)



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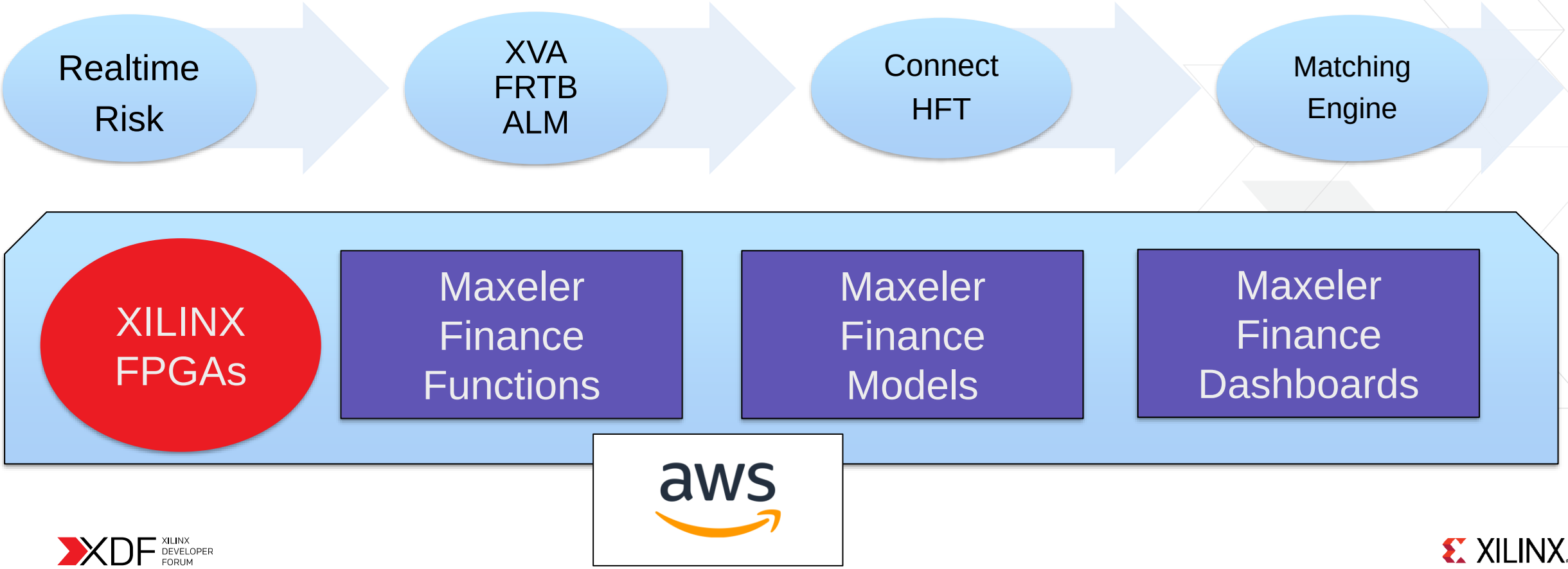
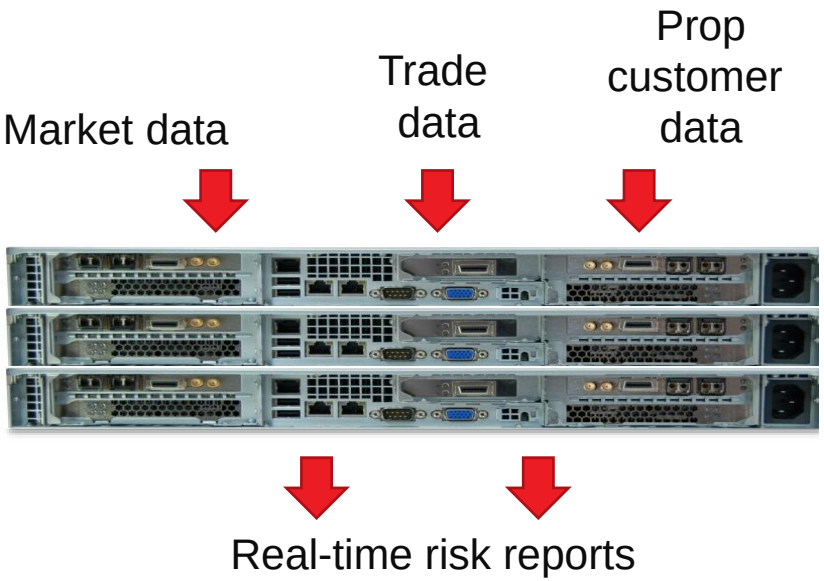
Solving Risk for Banks

By adapting the computer to the problem,
we are helping our clients to solve the previously unsolvable.



CME Group deployed Maxeler FPGA solution

- **Maxeler Risk analytics library with FPGA support, deployed by CME Group see www.hotchips.org, 2013 at Stanford, and live CME webpage at http://www.cmegroup.com/trading/interest-rates/dsf-analytics.html**

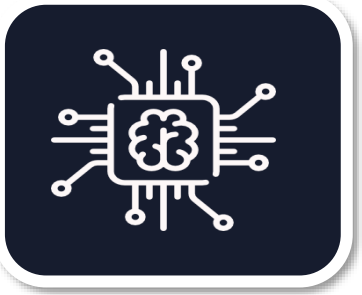


Price calculations per second

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 and Forbes Magazine**, Maxeler Makes Waves With Dataflow Design, 2011*

JP Morgan deployed intra-day Credit risk analytics developed by Maxeler

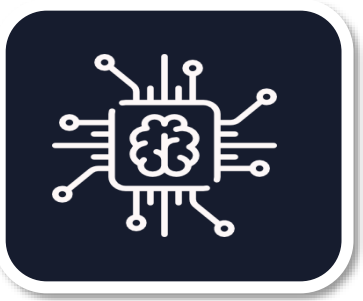


In 2011 JP Morgan implemented **High Performance Computing (HPC) capabilities** developed by Maxeler Technologies based on **FPGA technology** to run **intra-day risk analytics and price its global credit portfolio in near real-time**

Maxeler's solution allowed JP Morgan to run risk calculations up to **200x faster than CPU based solutions** and it **reduced JP Morgan's credit derivatives portfolio calculations from 8 hours to 2 minutes**

The solution was recognized by the American Finance Technology Awards in New York in 2011 as the "Most Cutting Edge IT Initiative"

Citi deployed Maxeler FPGA solution for world-wide real time FX Risk Analytics



In 2017 Citi implemented **High Performance Computing (HPC) capabilities** developed by Maxeler Technologies based on **FPGA technology** to run **real-time FX risk analytics and deliver real-time event risk to traders desks around the world**

Maxeler's solution allowed Citi to show their traders the risk for key future events in real time, as opposed to customary risk reports from overnight batch jobs.

The solution was presented at the Citi client conference in St Petersburg, Florida in 2017.

Real Time Risk for the FX Desk at Citi

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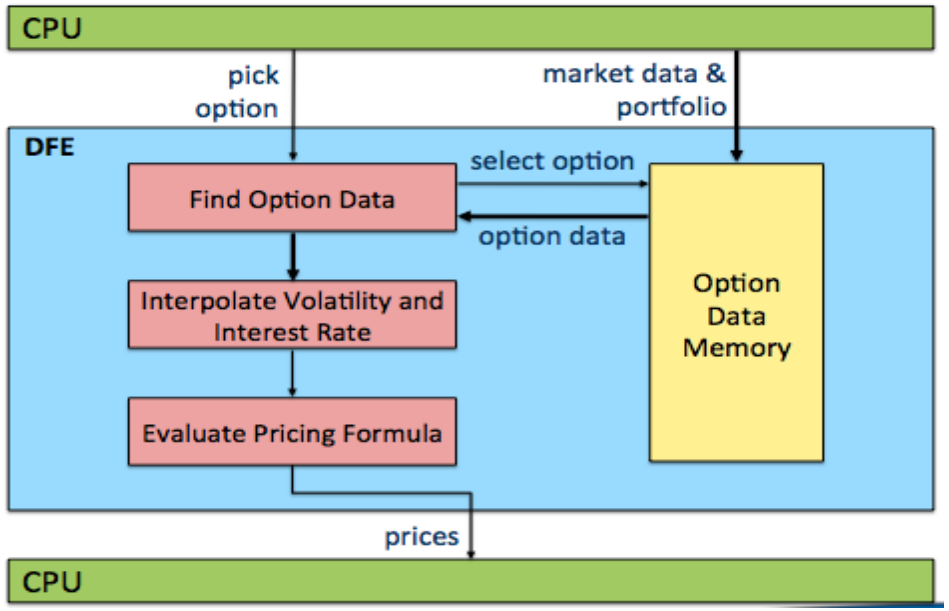
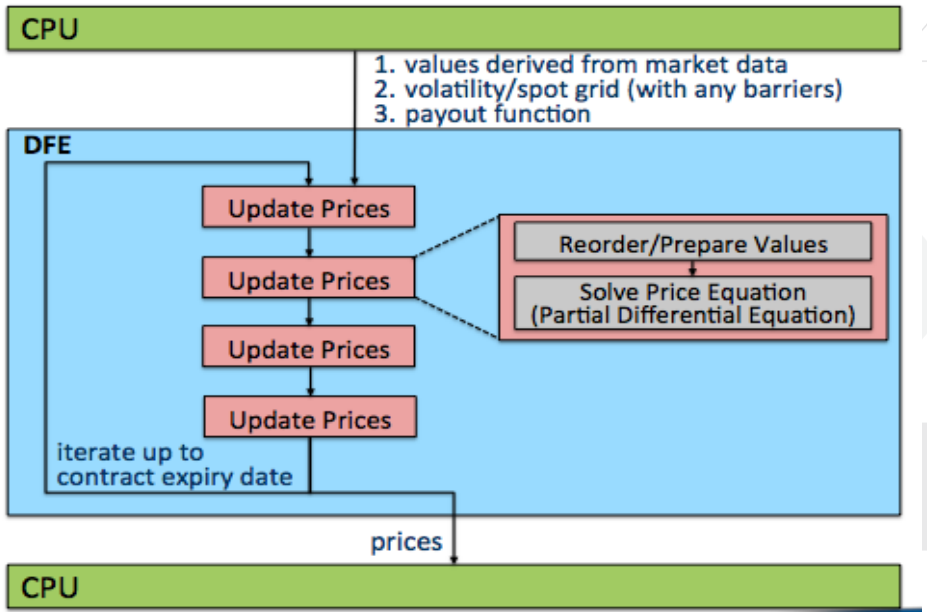
Spot Sense

Demo						Width	0.5%					
EURUSD		-2.50%	-2.00%	-1.50%	-1.00%	-0.50%	0.00%	0.50%	1.00%	1.50%	2.00%	2.50%
$ 3,574,352	Spot	1.0481	1.0535	1.0589	1.0643	1.0696	1.0750	1.0804	1.0858	1.0911	1.0965	1.1019
VaR	PnL	($311,426)	($252,084)	($195,863)	($145,281)	($97,102)	$0	$82,352	$18,174	$207,105	$261,207	$317,135
	$ Delta	($56,212)	($350,495)	($1,257,185)	($4,198,281)	($13,982,850)	($24,857,894)	($8,082,877)	$21,223,144	($2,756,095)	($1,262,855)	($512,937)
	Gamma	$1,081	$7,385	$13,688	$14,441	$15,193	$15,946	($331,453)	($178,974)	($23,906)	($13,530)	($6,489)
	dDelta/dVol	$49,391	$175,372	$301,352	($1,182,173)	($2,665,699)	($4,149,224)	($3,712,182)	$4,733,363	$194,695	$219,753	$151,446
	Vega	$674	$5,362	$10,050	$11,473	$12,896	$14,319	($149,937)	($126,143)	($15,161)	($9,546)	($4,937)
	Theta	($1,202)	($1,609)	($2,015)	($2,369)	($2,722)	($3,076)	$30,442	$27,715	$3,594	$2,449	$1,320
	VaR	$507,042	$2,118,630	$1,267,902	$1,757,108	$4,251,380	$3,574,352	$545,437	$3,830,147	$399,429	$4,421,705	$4,585,151

FX Vanilla Real-time Risk



FX Exotics Real-time Risk



Consistent & stable performance through volatile markets (Brexit, Trump election, etc)

Maxeler Real-Time Risk on Xilinx Alveo and Amazon EC2 F1

- **Real-time risk enables pre-trade computations**
- **Tool suite including:**
  - Credit Value Adjustment (CVA)
  - Initial Margin (IM)
  - Derivatives pricing library enabling custom solutions for FRTB, CCR, and scenario analysis
- **Driven by Bloomberg market data**
- **Dashboard for portfolio and trade-level analysis**
- **Processing done in real-time on Xilinx Alveo and Amazon EC2 F1**

Maxeler Risk and Derivatives Pricing on Xilinx FPGAs

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The first Finance library running on FPGAs

Use Case 1: Swap, Forward Rate Agreements, and Interest Rate Derivatives Pricing
Use Case 2: US Treasury Bond Pricing
Use Case 3: European, American and Asian Option Pricing and Greeks Calculation
Use Case 4: ISDA CDS Pricing and Bootstrapping of Hazard Curves
Use Case 5: Calculating Delta Ladders to get Risk from Changes in Interest Rate Curves
Use Case 6: Bootstrapping Interest Rate Curves
Use Case 7: Historical Value-at-Risk (VaR) for Interest Rate Swaps
Use Case 8: Portfolio Compression for Interest Rate Swaps
Use Case 9: Risk Neutralisation by Replacing an OTC Swaps Portfolio with risk similar standard products (EDF, DSF)
Use Case 10: Implied Volatility Calculator

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Maxeler Applications on Xilinx Alveo and AWS F1

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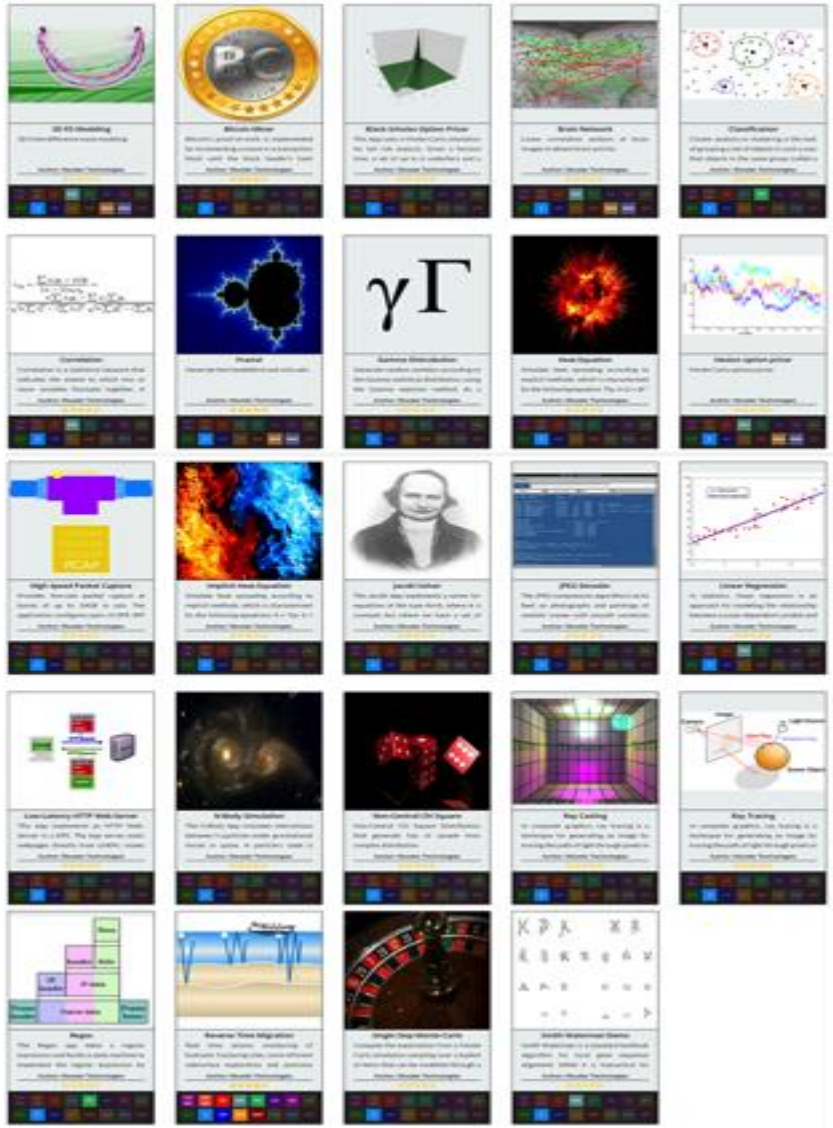

Maxeler FPGA Apps Ecosystem

- **With over 150 universities in our university program, we decided to create an app gallery to enable the community to share applications, examples, demos, …**
- **The App Gallery is complemented by a teaching program, with the first successful course taught at Imperial College in 2014. see http://cc.doc.ic.ac.uk/openspl14**
- **Top 10 APPS:**
  - Correlation: in real-time, pairwise, on 6,000 streams
  - 100% Guaranteed Packet Capture
  - Webserver, cache and load balancing
  - HESTON Option pricer
  - N-body simulation
  - Regex matching (e.g. for Security)
  - Brain network simulation
  - Quantum Chromo-Dynamics kernel
  - Seismic Imaging
  - Realtime Classification

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> **http://appgallery.maxeler.com/**

Maxeler for HPC: QCD on Xilinx Alveo and AWS F1

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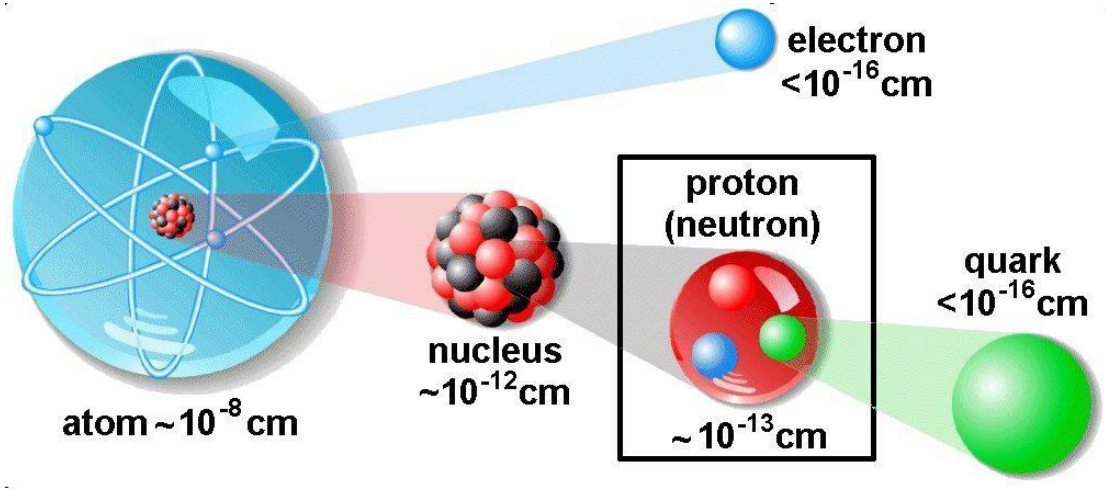
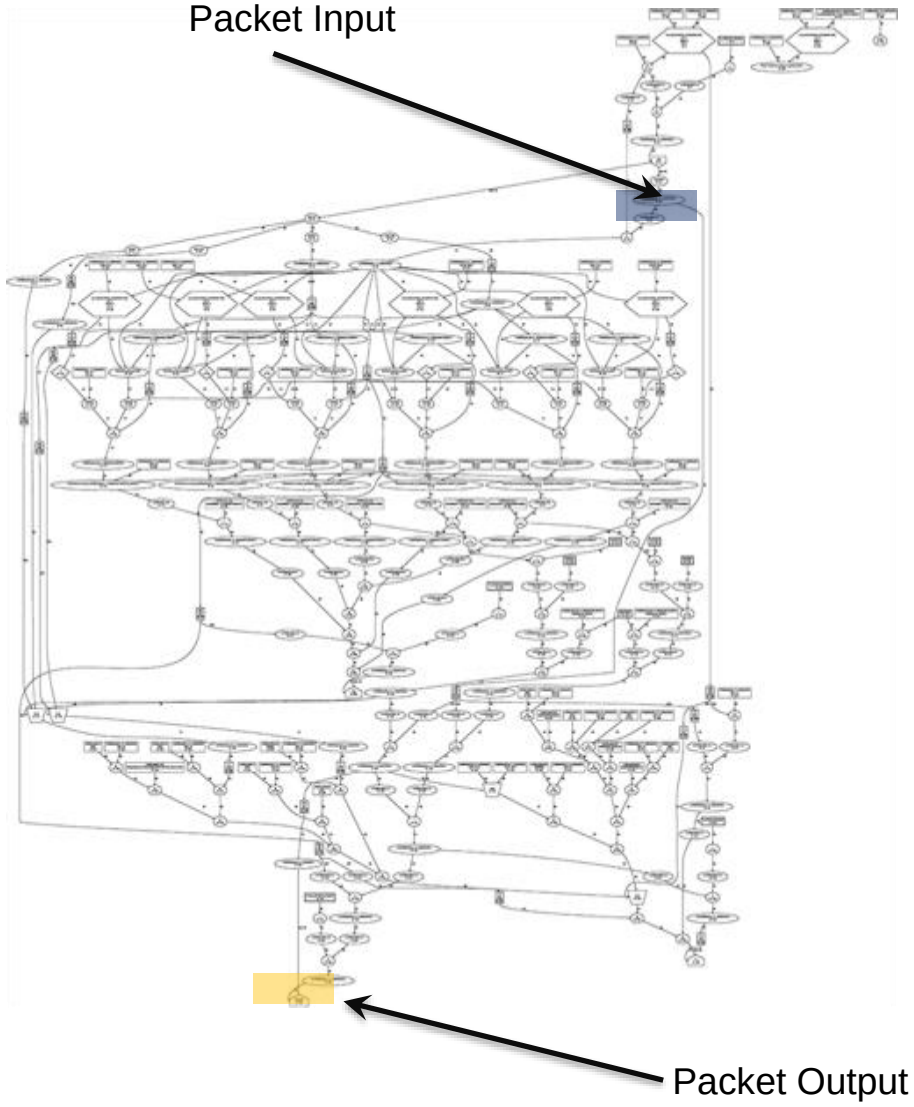
- Quantum Chromodynamics (QCD) is the theory of the strong interaction between quarks and gluons
- Maxeler Dataflow computing for QCD pushes the limits of what can be explored with computational modeling
- Combined with the massive compute available on AWS F1 this is a showcase of the future of High-Performance Computing



Maxeler High Frequency Trading Platform



Example HFT Trading Strategy

- 382 parallel operations
- Simple algorithm
- Calculates average price over a time-window
- Software controlled decision parameters
- Order decision and construction
- 390.4ns Latency
- 10Gbps sustained throughput
- No Jitter

Maxeler Industry Awards and Recognitions based on delivering Xilinx FPGAs to the Datacenter

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CIO Review, **20 Most Promising HPC Companies**, March 2015

CIO Review, **20 Most Promising Networking Companies**, March 2014

Frost and Sullivan **"Most innovative IT vendor "** Dec 2013

Gartner **"Cool Vendor of the Year"** March 2012.

Golden Arrow, "...for **revolutionizing Computers**, "
COM-SULT, January 2012.

American Finance Technology Awards, New York, winner,
"Most Cutting Edge IT Initiative" December 2011

HPCwire Editors Choice Award, November 2011.

Maxeler brings Applications to FPGAs in the Datacenter

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Finance running on Xilinx FPGAs

> delivering market data, processed via pricing models, to dashboards on the traders desk
> delivering low latency, competitive advantage to trading, matching and order execution

Defense running on Xilinx FPGAs

> delivering complex simulations, prediction and identification
> delivering automatically compiled firewalls rules in hardware

IoT running on Xilinx FPGAs

> enabling high end sensor data processing at the edge
> reducing cost of processing vast amounts of sensor data in the datacenter

Smaller.
Faster.

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