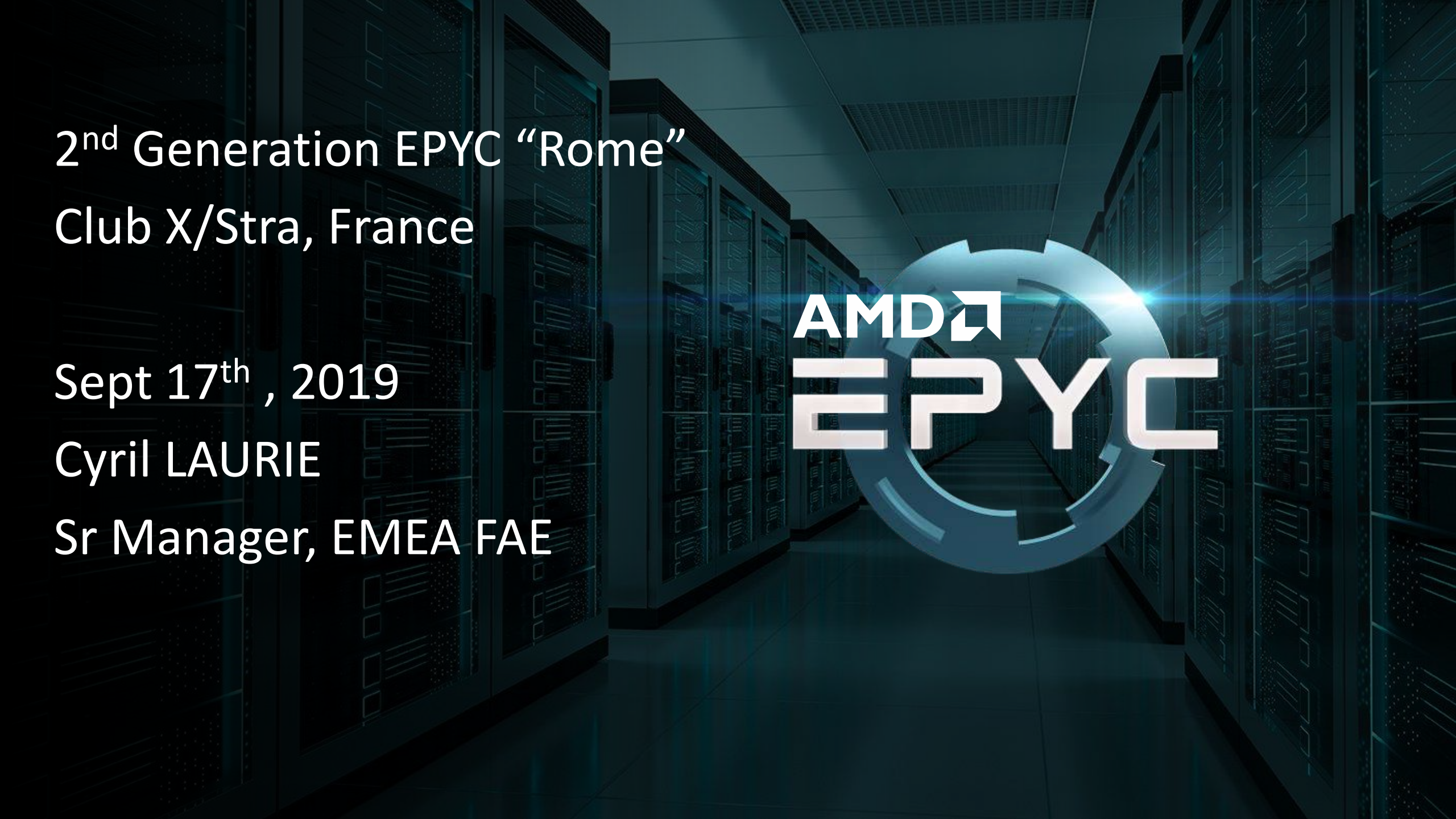
2nd Generation EPYC “Rome”

Club X/Stra, France

Sept 17th , 2019

Cyril LAURIE

Sr Manager, EMEA FAE



OUR MISSION

Build great products that accelerate next-generation computing experiences

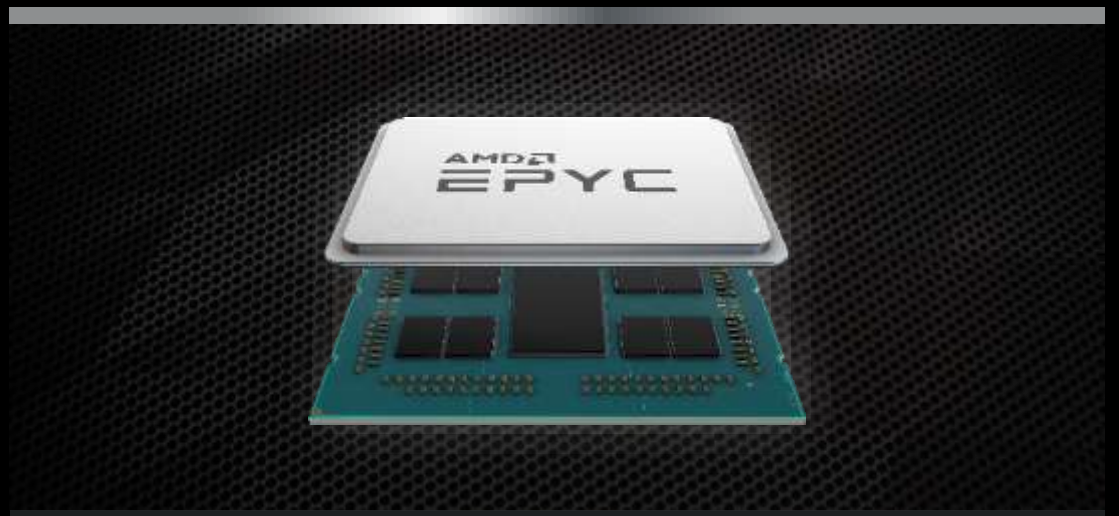

AMD
LEADERSHIP HIGH-PERFORMANCE COMPUTING

2019 AMD EPYC™ LINEUP

A NEW ERA IN THE DATA CENTER

1st Gen EPYC™ Processors

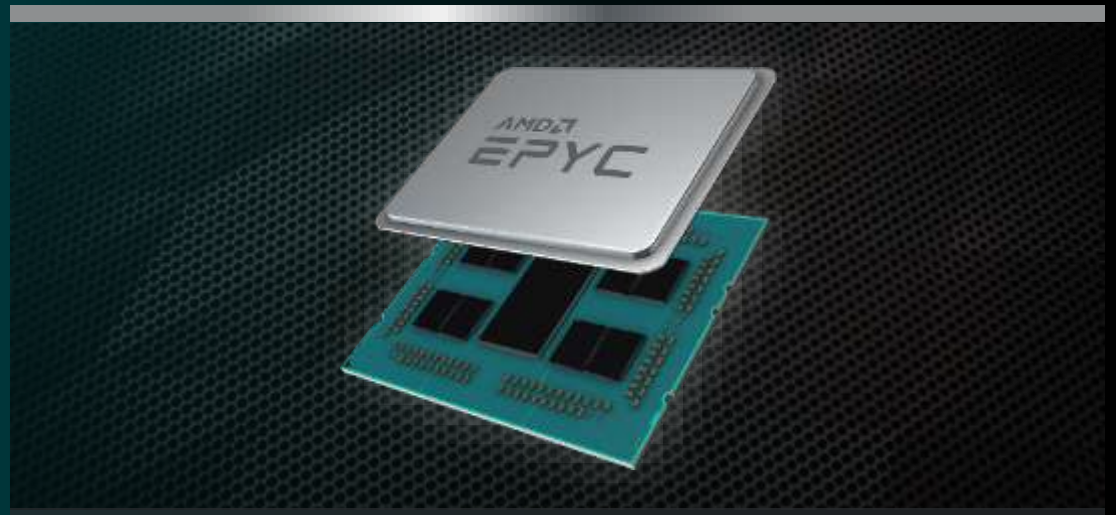
"Zen" Architecture



2nd Gen EPYC™ Processors

"Zen 2" Architecture

AMD DATA CENTER COMPUTE LEADERSHIP



World's 1st 7nm x86 Data Center CPU

World's Highest Performance X86 Server Processor

2ND GEN **AMD EPYC™**

80 WORLD RECORDS AND COUNTING

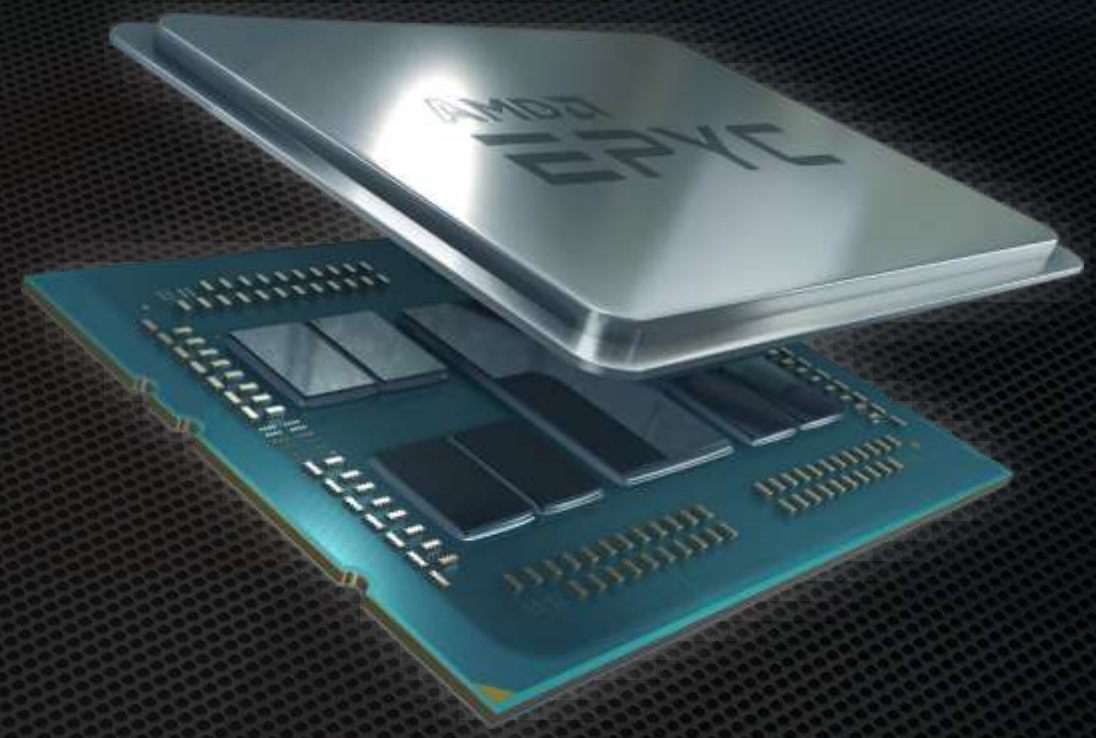
15	HPC
41	SDI/ENTERPRISE
18	BIG DATA
6	CLOUD

See endnotes ROM-169, ROM-114

AMD

THE NEW STANDARD
FOR THE MODERN DATA CENTER

2ND GEN AMD EPYC™ PROCESSOR



RECORD-SHATTERING PERFORMANCE
Highest Performance x86 Server Processor*

BREAKTHROUGH ARCHITECTURE
Chiplet Design, "Zen 2" Core, Infinity Fabric™

DISRUPTIVE TCO
Higher Performance Drives Lower CapEx and OpEx

64 Cores / 128 Threads	128 OR HIGHER PCIe® 4.0 Lanes	Up to 225 Watt TDP	Up to 3.4 GHz Precision Boost

See endnote ROM-169, ROM-06a; *EPYC 7742 - see endnote ROM-114

2ND GEN AMD EPYC™

DAY 1 ECOSYSTEM SUPPORT

Hardware Partners	AMD RADEON INSTINCT, Micron, Western Digital, NVIDIA, BROADCOM, XILINX, Mellanox, SK hynix, SAMSUNG, SEAGATE
OS	Microsoft, CITRIX, vmware, redhat, CANONICAL, ORACLE, SUSE
Apps	Altair, vmware, Microsoft, CLOUDERA, LSTC, simplivity, SIEMENS, Mellanox, docker, ANSYS, SQL Server, Java, Hadoop, MAVENIR, ceph, VERTICA, elastic, BEAMR, ERICSSON, PostgreSQL, NETSCOUT, splunk>, sas, StorMagic, Excelero, ScaleMP, NUTANIX, redislabs, RedHat, SAP, NOKIA, Quobyte, ORACLE, WEKA.io, MEMSQL, MAPR, Couchbase, HORTONWORKS, cadence, TRANSWARP, DATASTAX, SYNOPSYS, mongoDB., Mentor, MarkLogic

AMD SERVER COMPUTE SOLUTIONS

DELIVERING CHOICE AND INNOVATION FOR THE MODERN DATA CENTER

HPC

Enterprise

Cloud

AMD EPYC

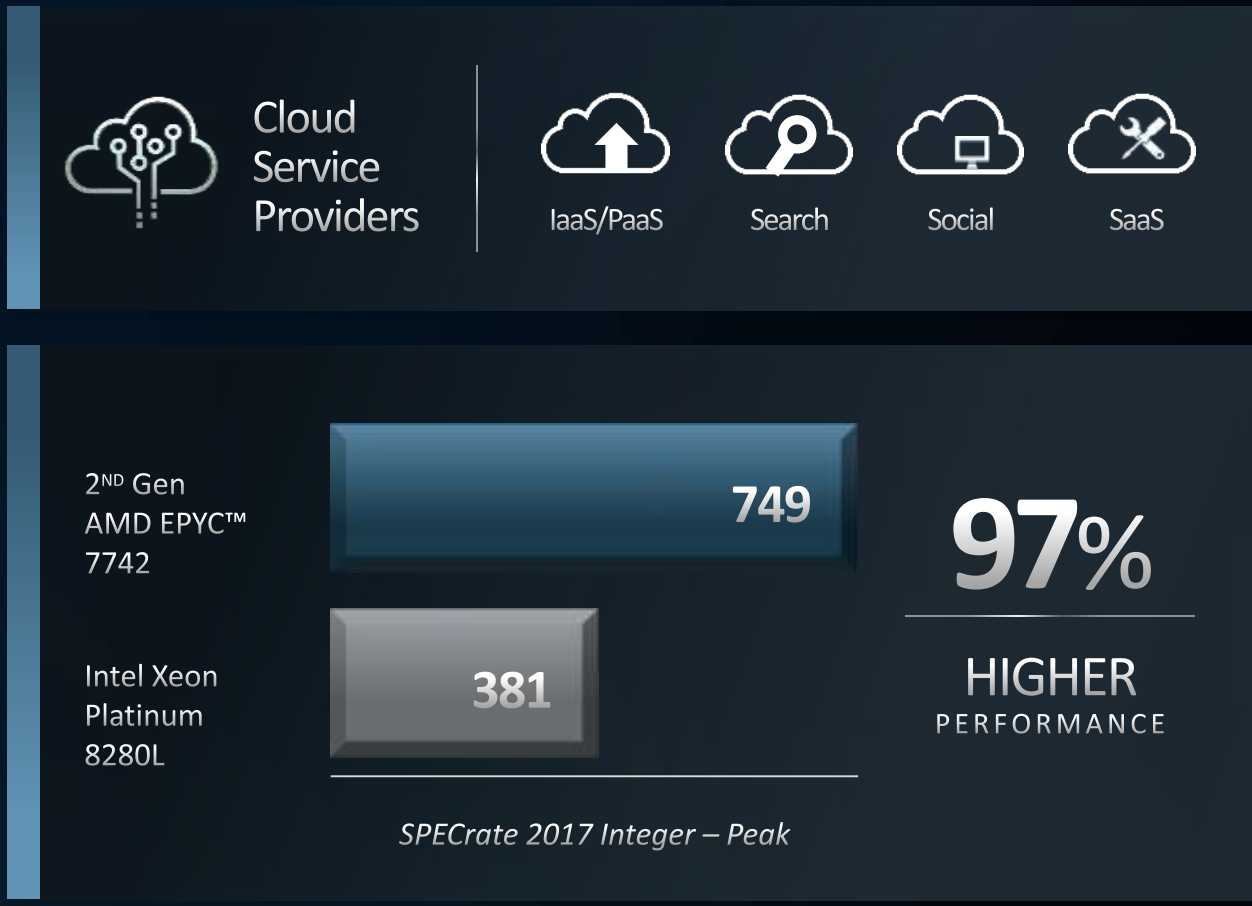
THE MOST DEMANDING CLOUD ENVIRONMENTS RUN EPYC™ PROCESSORS

Google
Microsoft Azure
aws
BAIDU
Tencent Cloud
Dropbox
packet
ORACLE CLOUD
OVH
Scaleway
HETZNER ONLINE

MORE THAN 50 **AMD EPYC™ CLOUD INSTANCES**

AMD EPYC™ CLOUD LEADERSHIP

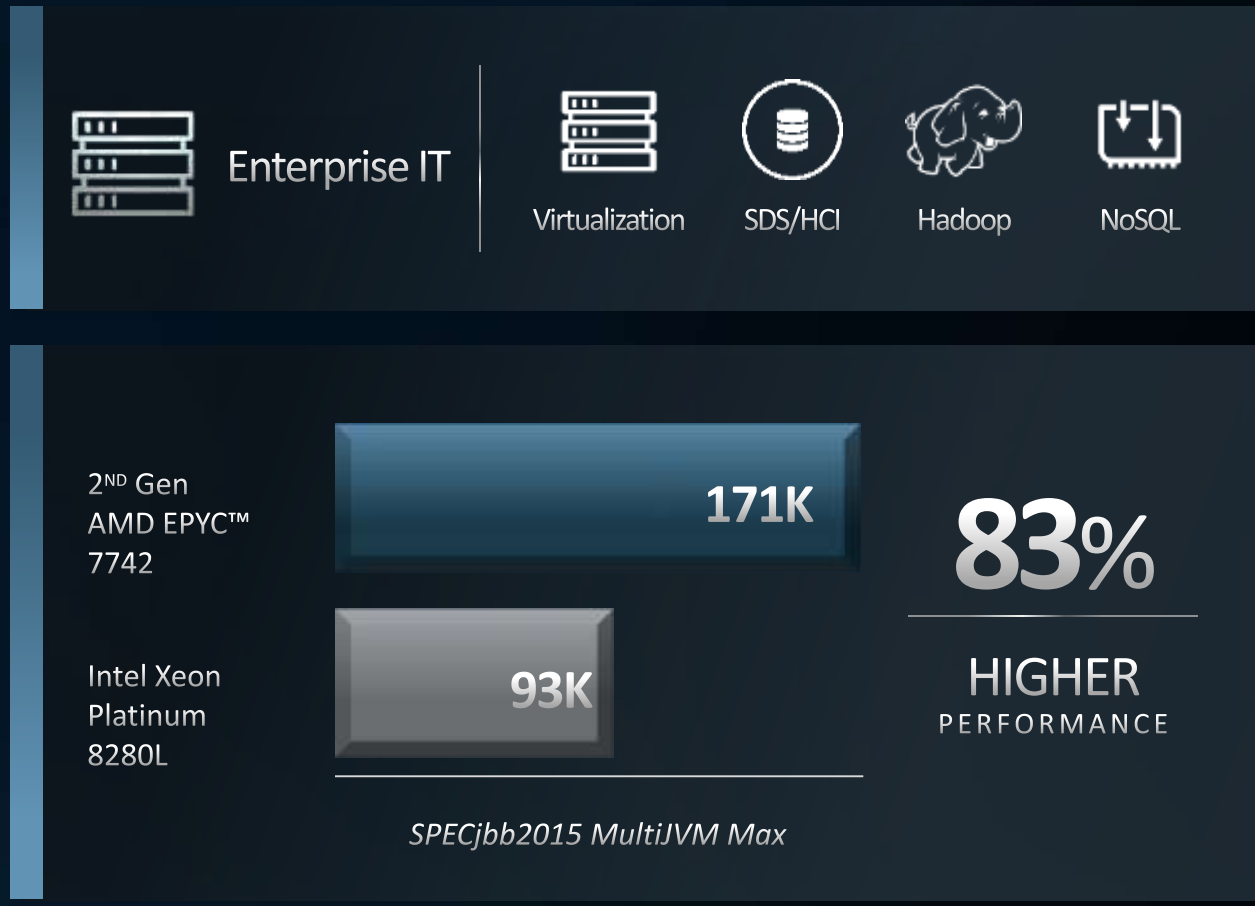
- Greater than 2X Container Density
- Optimized Search and Newsfeed Performance
- Instance TCO Leadership



See endnote ROM-172, TCO-2, ROM-250

AMD EPYC™
ENTERPRISE LEADERSHIP

- Greater than 2X Virtual Machine Density
- World Record Database Performance
- Leadership Data Analytics



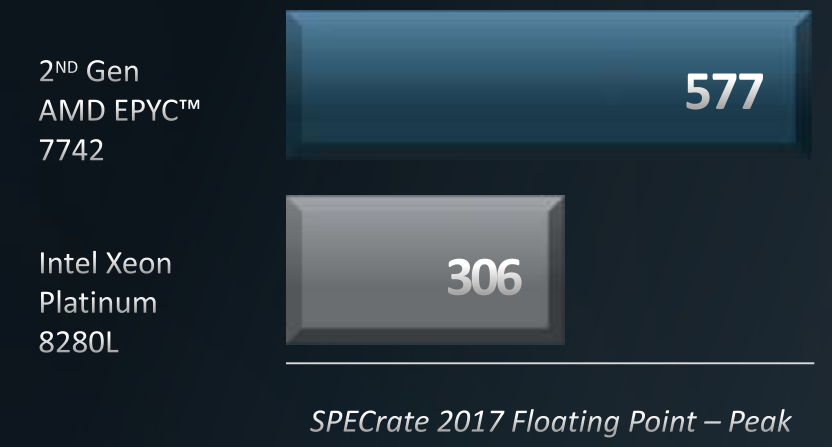
See endnote TCO-2, ROM-139, ROM-115

AMD EPYC™ HPC LEADERSHIP

- Faster Simulations and Discovery
- 45% More Memory Bandwidth
- 2X the I/O performance with PCIe 4.0

High Performance Computing

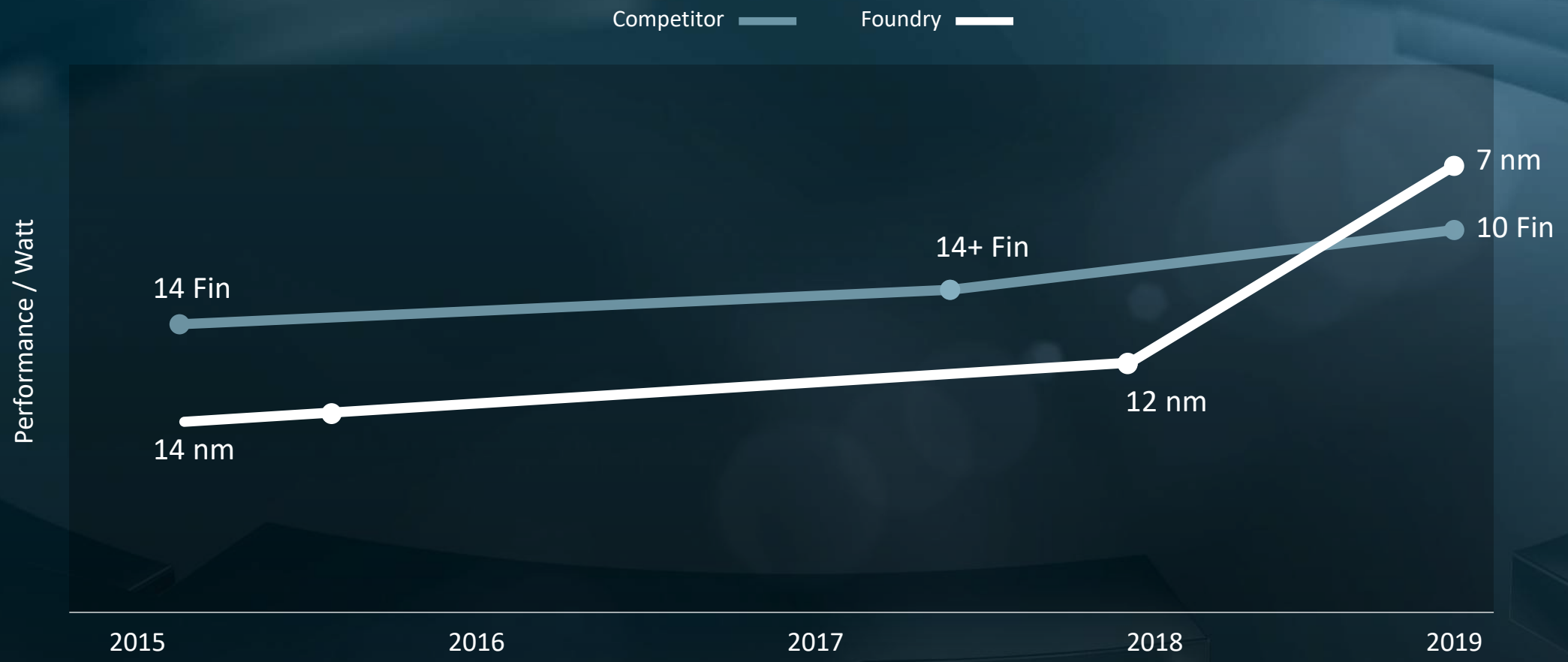
Design & Simulation | Research & Academia | Machine Learning | Supercomputing



88% HIGHER PERFORMANCE

See endnote ROM-11, ROM-251

7NM INVERTS THE PLAYING FIELD



Major Node, Significant Investment	Faster, Smaller, Lower Power Transistors	Multiple Products in Development	Deep Partnerships with TSMC and Design Automation Vendors

AMD

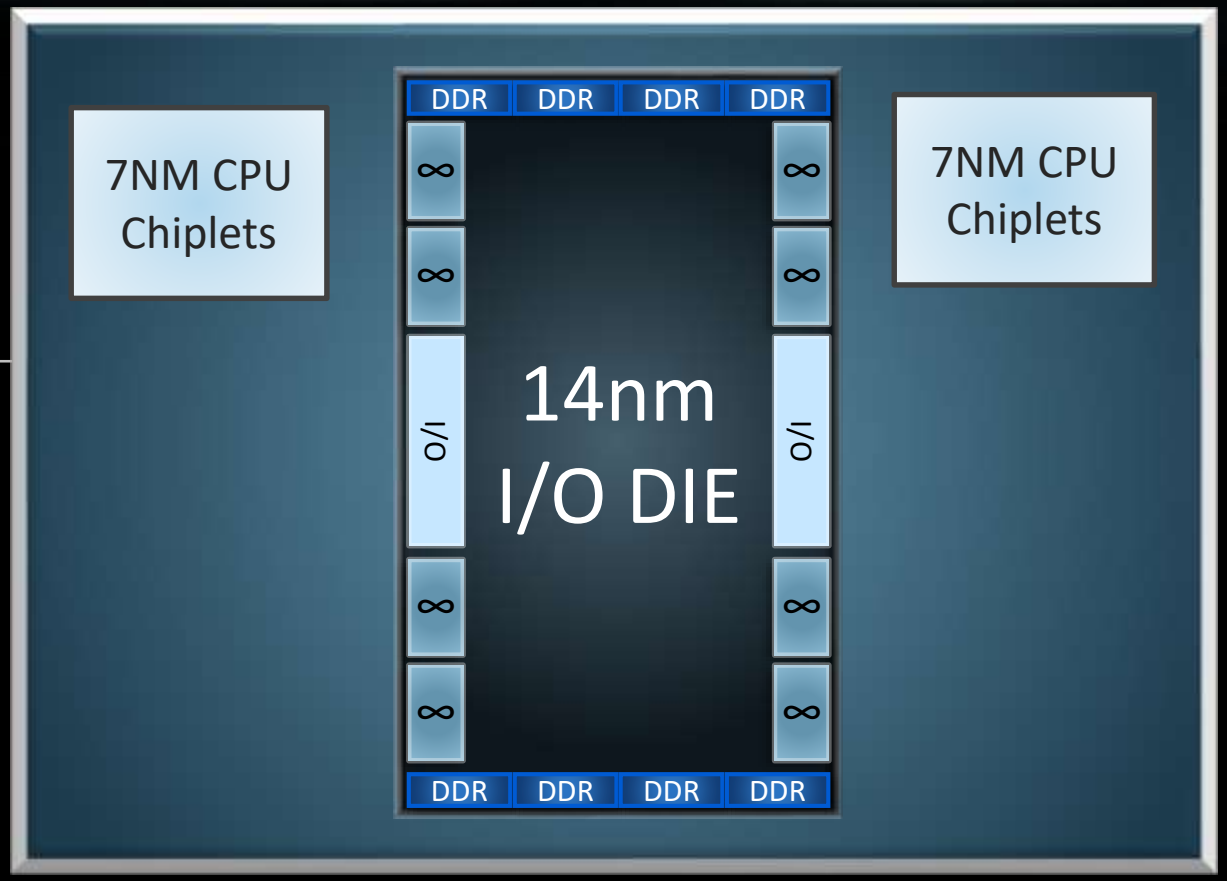
REVOLUTIONARY CHIPLET DESIGN

Each IP in its Optimal Technology

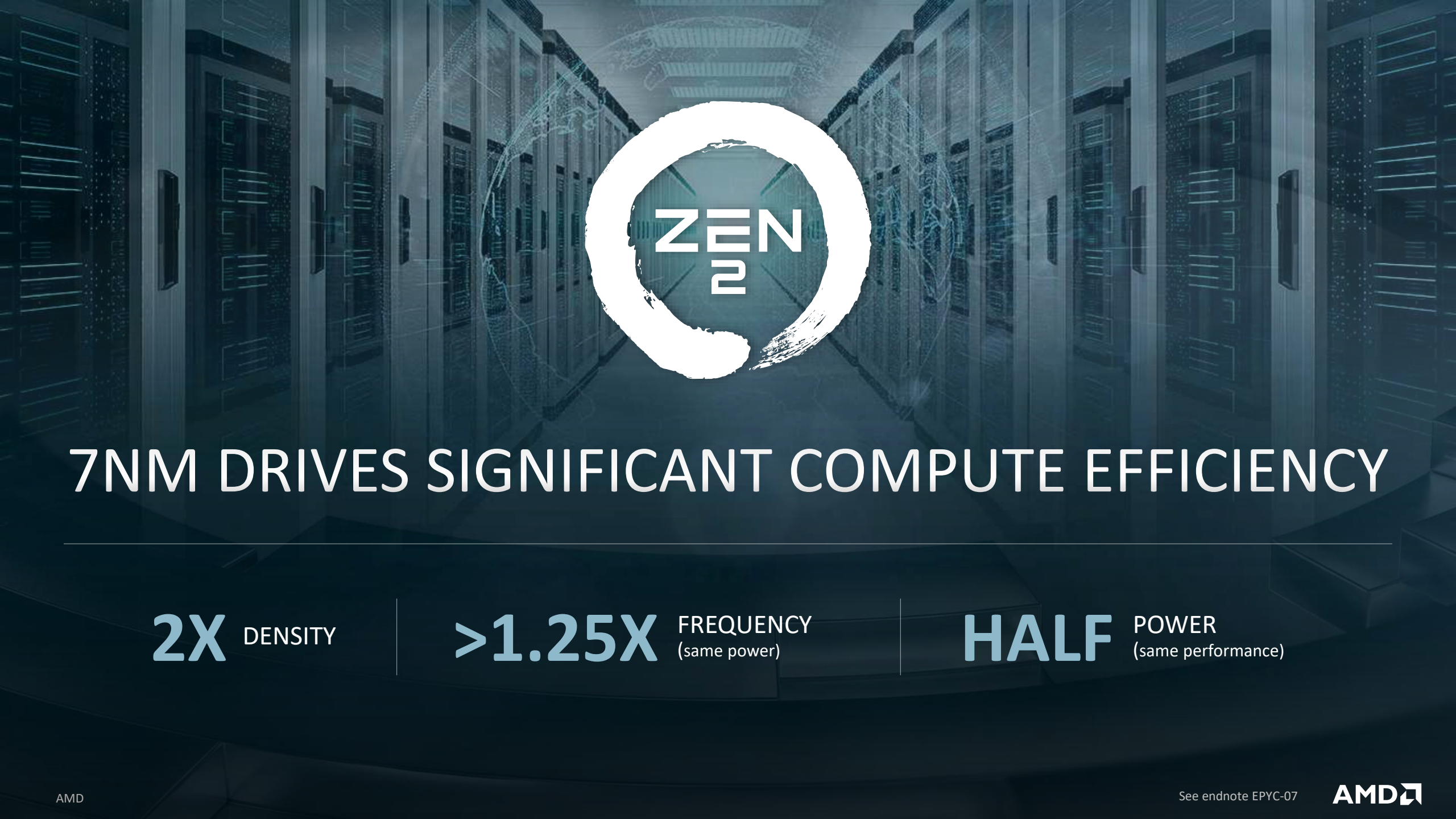
Infinity Fabric Enabled Modularity

Optimized I/O Die Improves Latency and Power

7nm Tech for CPU Performance and Power



"Zen 2" Based EPYC Processors



7NM DRIVES SIGNIFICANT COMPUTE EFFICIENCY

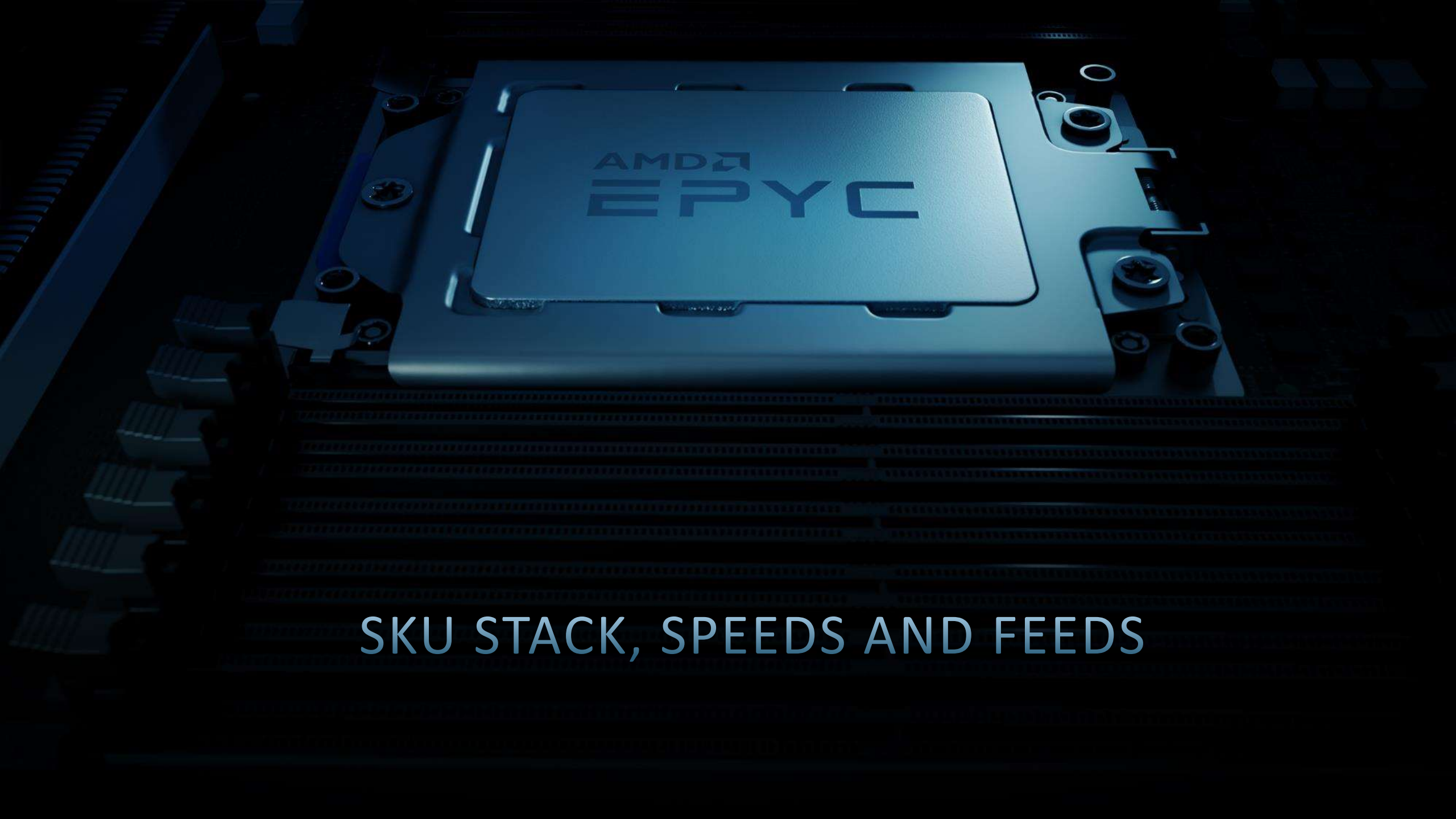
2X DENSITY

>1.25X FREQUENCY
(same power)

HALF POWER
(same performance)

See endnote EPYC-07

AMD



SKU STACK, SPEEDS AND FEEDS

AMD EPYC™ 7002 SERIES PROCESSORS AT A GLANCE

"NAPLES" FOUNDATION WITH INCREASED PERFORMANCE, CAPABILITIES, AND ADVANCED SECURITY

COMPUTE

Up to **2X** AMD "Zen" x86 cores
(up to **64** cores/**128** threads)

Up to **4X** shared L3 cache (256MB)
Up to **2X** L3 cache per core
(16MB per 4 cores)

Reduced System Diameter
(NUMA domain)

TDP range: 120W-**225W**

MEMORY

8 channel DDR4 with ECC
up to **3200** MHz

RDIMM, LRDIMM, 3DS, NVDIMM

2 DIMMs/channel capacity of **4TB**/socket*

PERFORMANCE

~4x+ Peak TFLOPS/Socket
~2X+ Increased perf/socket

INTEGRATED I/O – NO CHIPSET

128 lanes PCIe® Gen3 & **Gen4** **

- Used for PCIe, SATA, and Coherent Interconnect
- Up to 32 SATA or NVMe devices

SECURITY

Dedicated Security Subsystem

Hardware Root-of-Trust

Additional Security Features

* When using 256GB DIMM
** Gen 4 support expected to require motherboard update to support higher data rate.
See endnotes: ROM-04, 23. EPYC projected performance.

AMD

EPYC™ - THE POWER OF SIMPLICITY

Advanced Features Consistent Across Simplified Product Stack

	EPYC 8 CORE	EPYC 12/16 CORE	EPYC 24/32 CORE	EPYC 48/64 CORE
	7262 7252	7302 7282 7272	7542 7502 7452 7402 7352	7742 7702 7642 7552
ONE-SOCKET ONLY	7232P	7302P	7502P 7402P	7702P

- 8 Channels of DDR4-3200
- 4TB memory support
- 128 lanes PCIe®3 and PCIe®4
- SMT & Turbo boost
- 18G AMD Infinity Fabric™
- Secure Memory Encryption
- Secure Encrypted Virtualization

See endnotes ROM-06

AMD

SKU NAMING CONVENTION

AMD EPYC™ 7002 Series (Rome)

Generation

2 = Rome

Product Segment

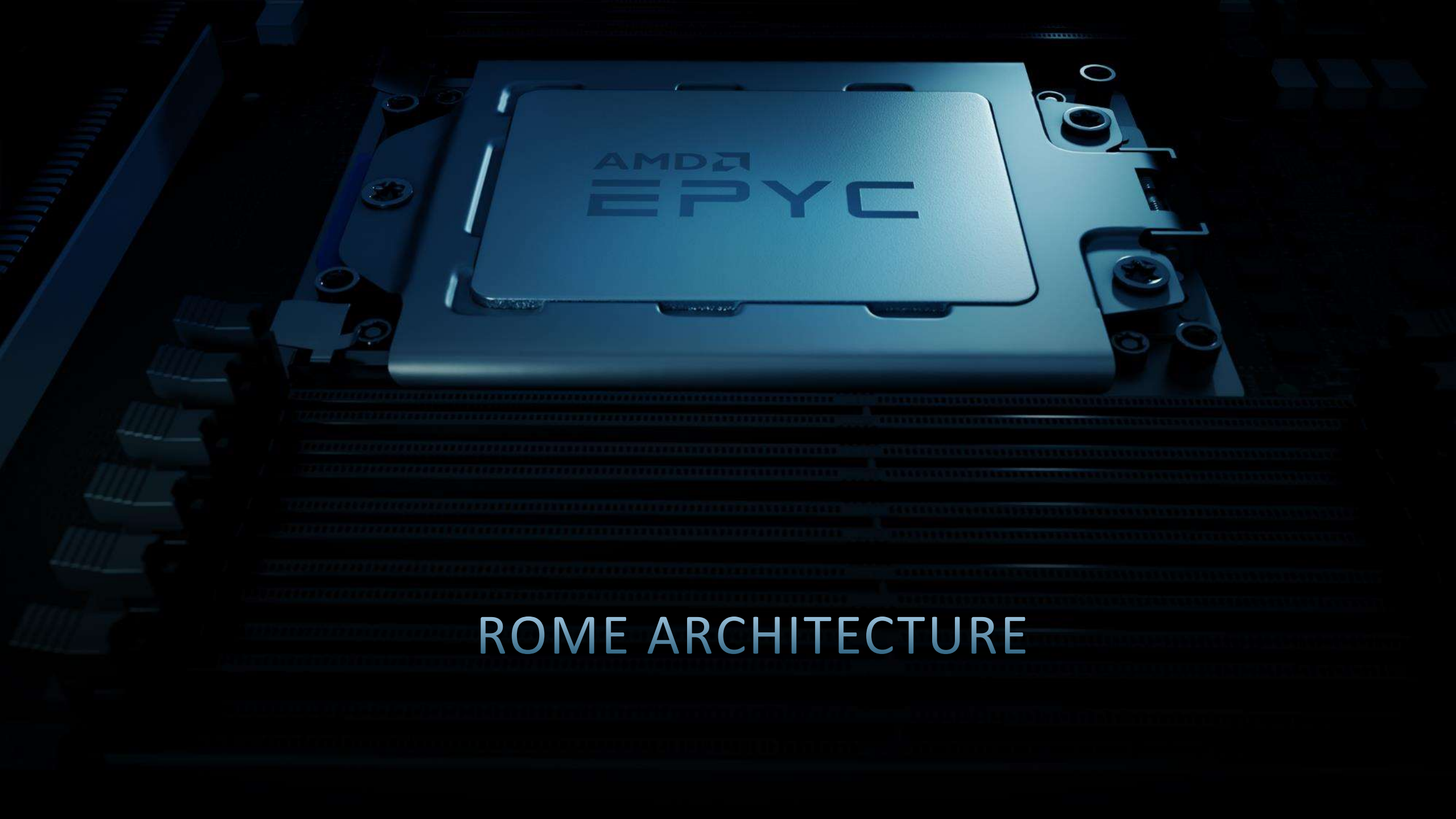
- 7xxx – High performance Server SOC/APU (i.e. Naples, Rome, Milan).

Model Number

- Higher number indicates higher levels of performance
- No direct tie to core counts, power, or frequency
- “X4” indicates group D SKUs

Modifier (Features)

1P Only = “P”



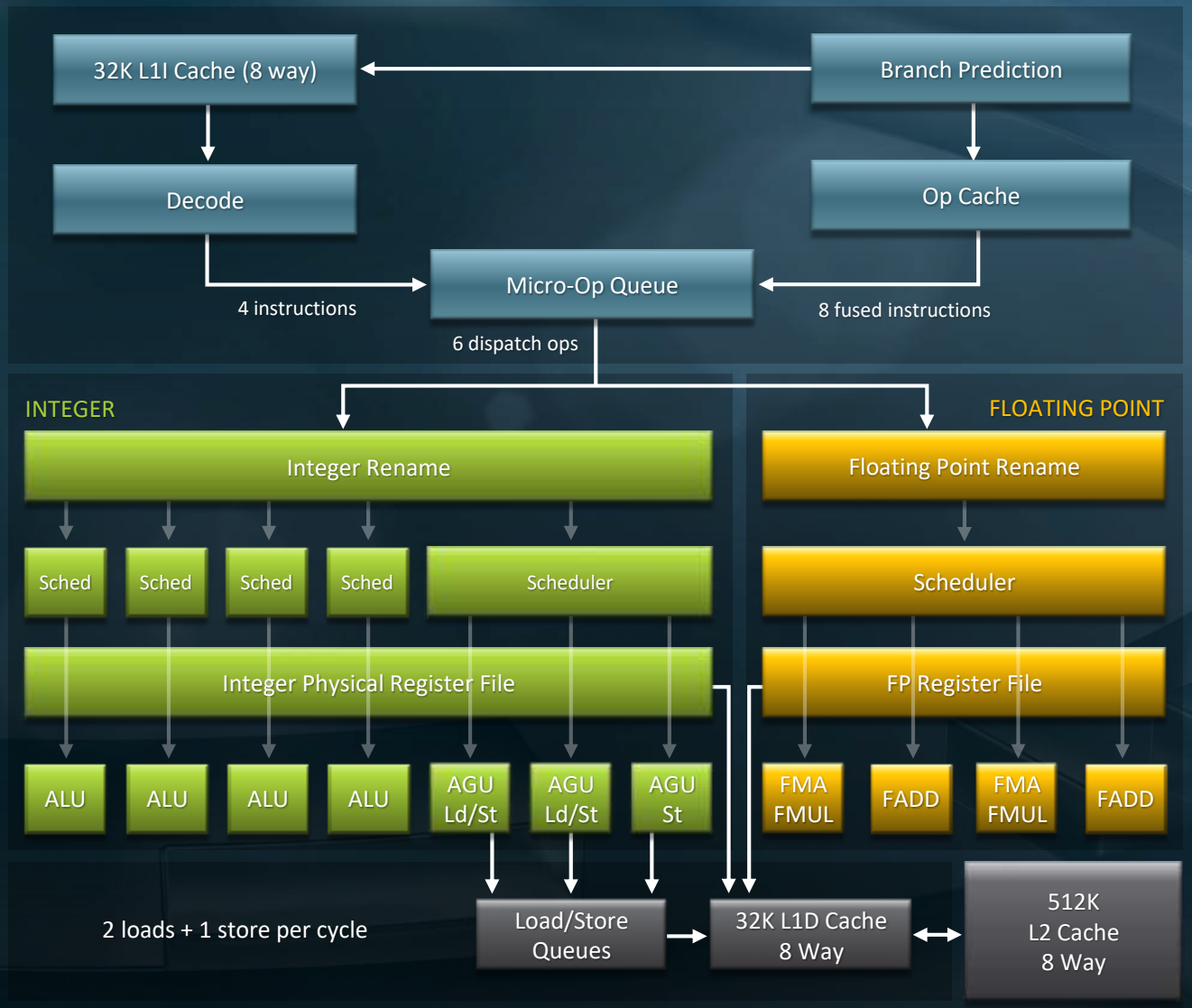
ROME ARCHITECTURE

"ZEN 2" IS A BETTER PERFORMING CORE*

- TAGE branch predictor
- 2x op cache capacity
- Reoptimized L1I cache
- 3rd address generation unit
- 2x FP data path width
- Nearly 2x L1 bandwidth
- 2x L3 capacity
- Improved prefetch throttling

WITH LOWER POWER

- 7nm technology
- Higher op cache hit rate
- Focused clock and data gating improvements
- Low power design methodologies



*vs original “Zen” core

AMD

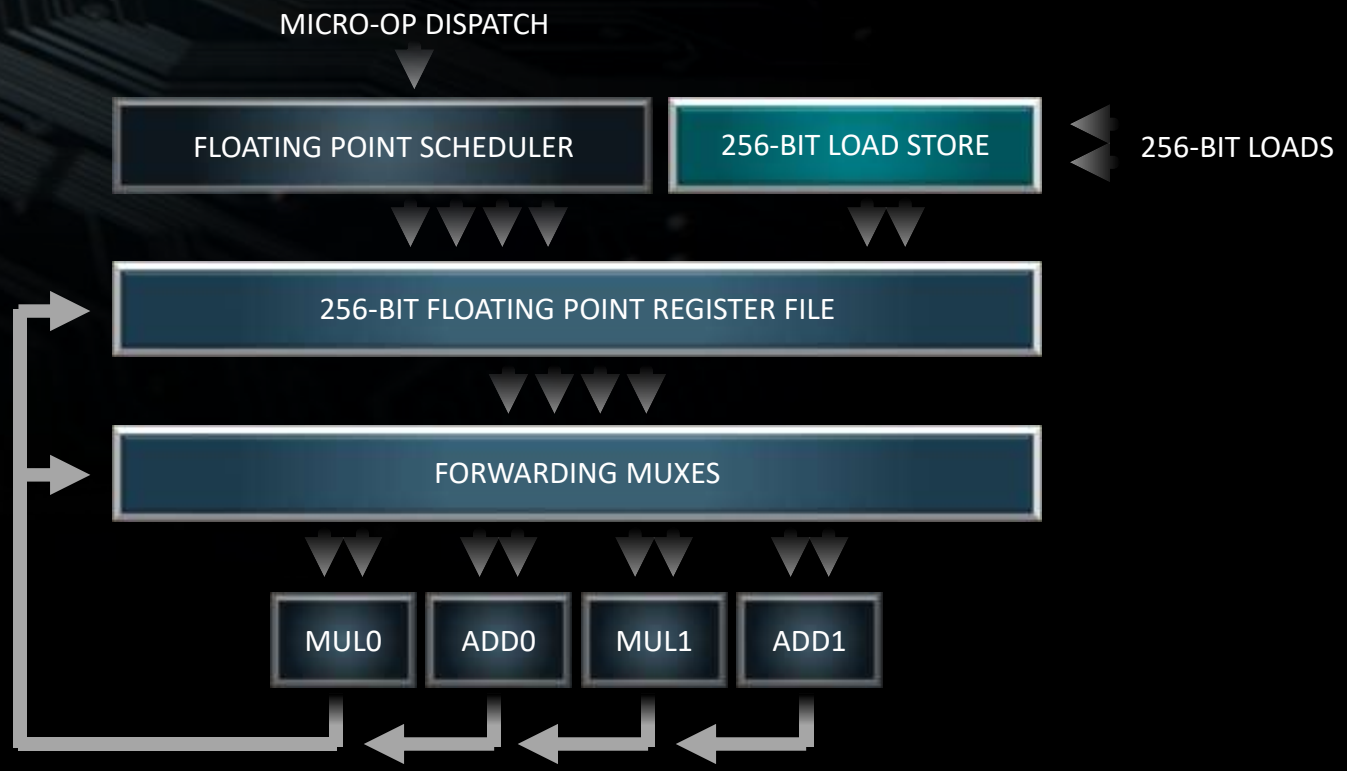
FLOATING POINT ADVANCES

Doubled Floating Point Width to 256-Bit

Doubled Load / Store Bandwidth

Increased Dispatch / Retire Bandwidth

Maintained High Throughput for All Modes



PRIORITY ON SECURITY

HW OPTIMIZED SECURITY FEATURES*		SECURE MICROARCHITECTURE		SECURE MEMORY AND VIRTUALIZATION	
Spectre v2		N/A	Lazy FP state restore	SME	Secure Memory Encryption
IBRS	Restricts indirect branch prediction	N/A	Meltdown	SEV-ES	SEV with encrypted state
IBPB	Flush indirect branch predictor (optimized)	N/A	L1TF / Foreshadow	SEV-2.0	SEV with up to 509 encrypted guests
STIBP	Isolate branch predictor between SMT threads	N/A	TLBleed	SEV-VTE	SEV with virtual transparent encryption
Spectre v4		N/A	ZombieLoad / Fallout / RIDL		
SSB**	Disable speculative store bypass				

*Settings for the security features can be found at https://developer.amd.com/wp-content/resources/Architecture_Guidelines_Update_Indirect_Branch_Control.pdf.

**See whitepaper: https://developer.amd.com/wp-content/resources/124441_AMD64_SpeculativeStoreBypassDisable_Whitepaper_final.pdf

MEMORY SPEED AND BANDWIDTH IMPROVEMENTS

AMD EPYC™ 7002 Series

DDR4 speeds in a 1-of-1 DIMM per Channel Server*

DR RDIMM: 3200 MHz | LRDIMM: 3200 MHz

	Intel® Xeon® 2nd Gen Scalable ("Cascade Lake SP")	AMD EPYC™ 7001 Series	AMD EPYC™ 7002 Series
Max Theoretical Memory BW per 2P server (1 DR DPC)	12 x DDR4-2933 = 282GB/s	16 x DDR4-2666 = 340GB/s	16 x DDR4-3200* = 410GB/s
AMD EPYC™ Advantage		**+21%**	**+45%**

Provisioned Bandwidth for Performance Scaling

Not supported on all motherboards – see endnotes ROM-06 for details.

*AMD POR memory speeds in a one DIMM per channel system implementation

CHIPLETS EVOLVED – HYBRID MULTI-DIE ARCHITECTURE

Use the Most Advanced Technology Where it is Needed Most

Each IP in its Optimal Technology, 2nd Gen Infinity Fabric™ Connected

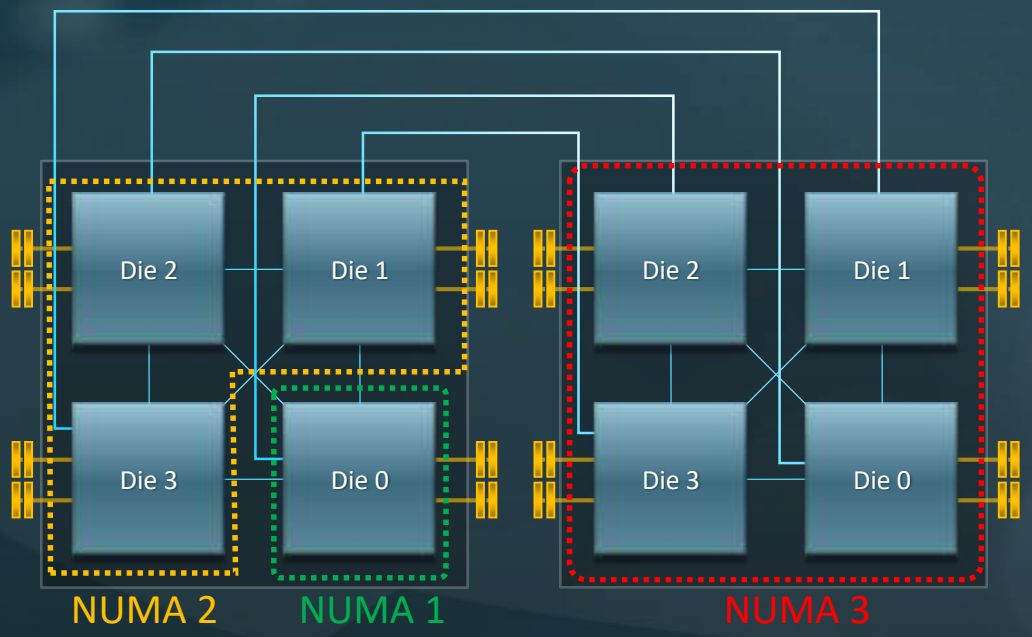
Centralized I/O Die Improves NUMA

Superior Technology for CPU Performance and Power

AMD

EPYC™ 7002 SERIES NUMA ADVANCEMENTS

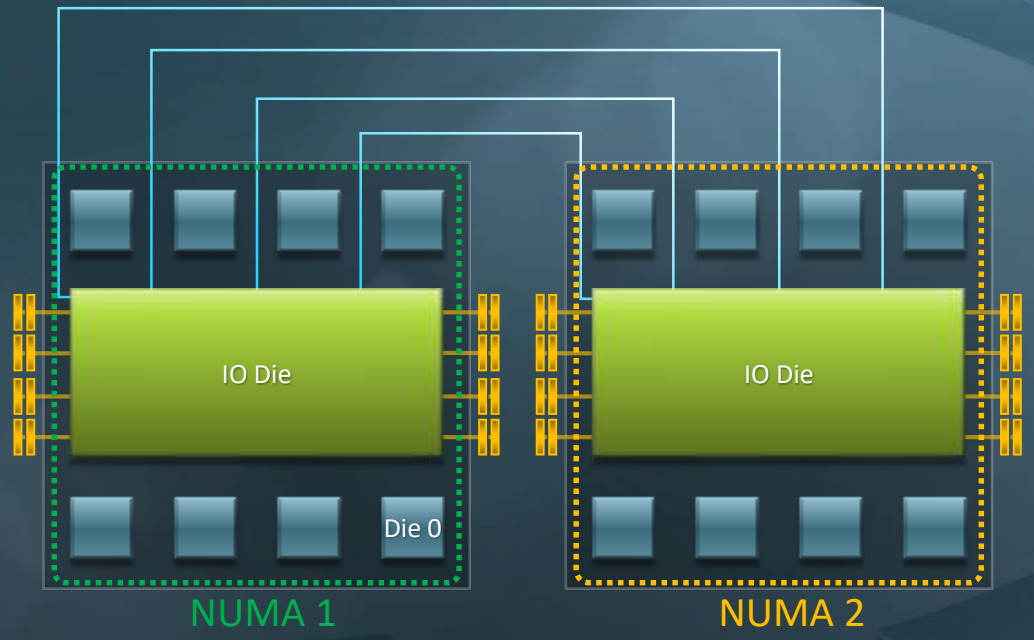
EPYC™ 7001 Series Processors



Domain	Latency[4] (ns)
NUMA1	90
NUMA2	141
NUMA3	234
Avg. Local[2]	128

3 NUMA Distances
8 NUMA Domains

EPYC™ 7002 Series Processors



Domain	Latency[4] (ns)
NUMA1[3]	104
NUMA2	201
Latency Reduction[1]	19%/14%

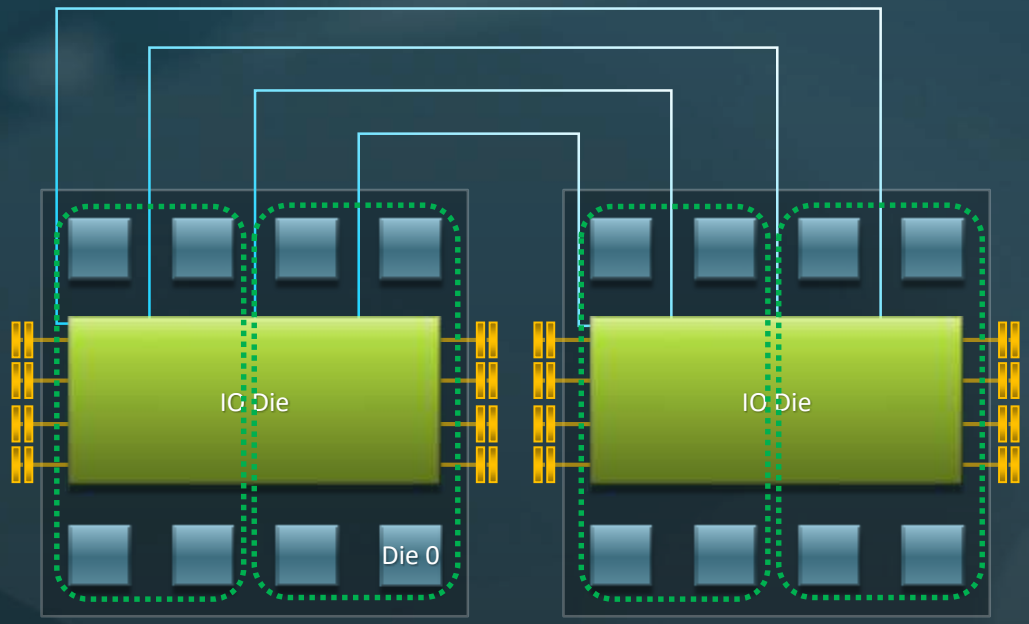
2 NUMA Distances
2 NUMA Domains

Reduced Number of NUMA Domains and Distances: Improved NUMA Attributes for General Workloads

1: EPYC 7002 Series NUMA 1 vs EPYC 7001 Series Avg. Local; EPYC 7002 Series NUMA2 vs EPYC 7001 Series NUMA 3
2: 75% NUMA 2 + 25% NUMA 1 traffic mix; 3: NPS=1 Default Setting; 4: DRAM Page Miss

EPYC™ 7002 SERIES NUMA TUNING OPTIONS

EPYC™ 7002 SERIES PROCESSORS



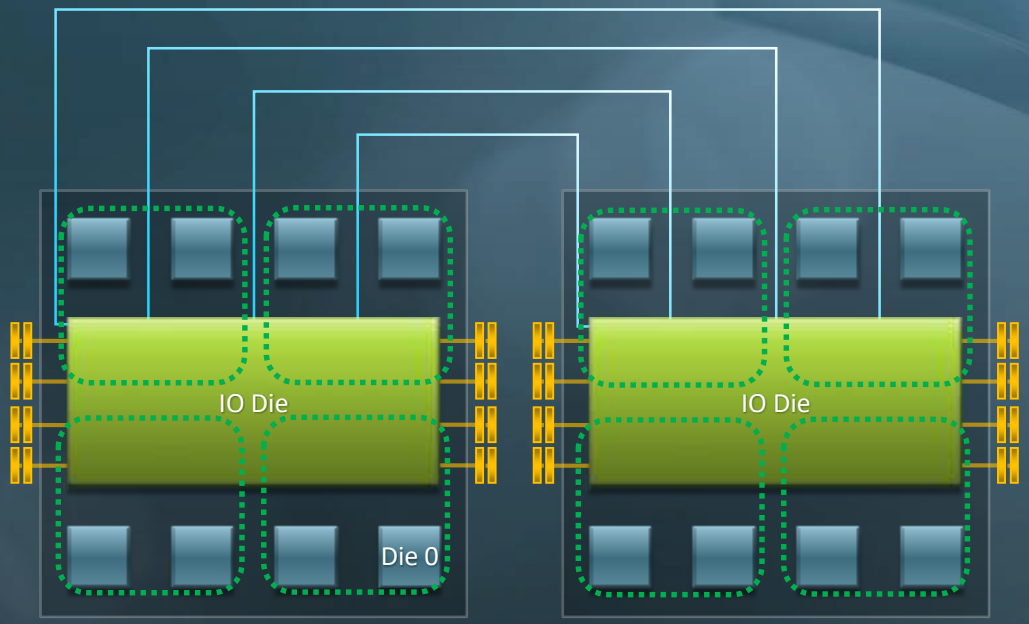
NPS=2 NUMA Configuration[1]

NPS = NUMA Nodes Per Socket

Affinitize ½ cores to ½ DRAM/socket

3 NUMA Distances; 4 NUMA Domains

EPYC™ 7002 SERIES PROCESSORS



NPS=4 NUMA Configuration[1]

NPS = NUMA Nodes Per Socket

Affinitize ¼ cores to ¼ DRAM/socket

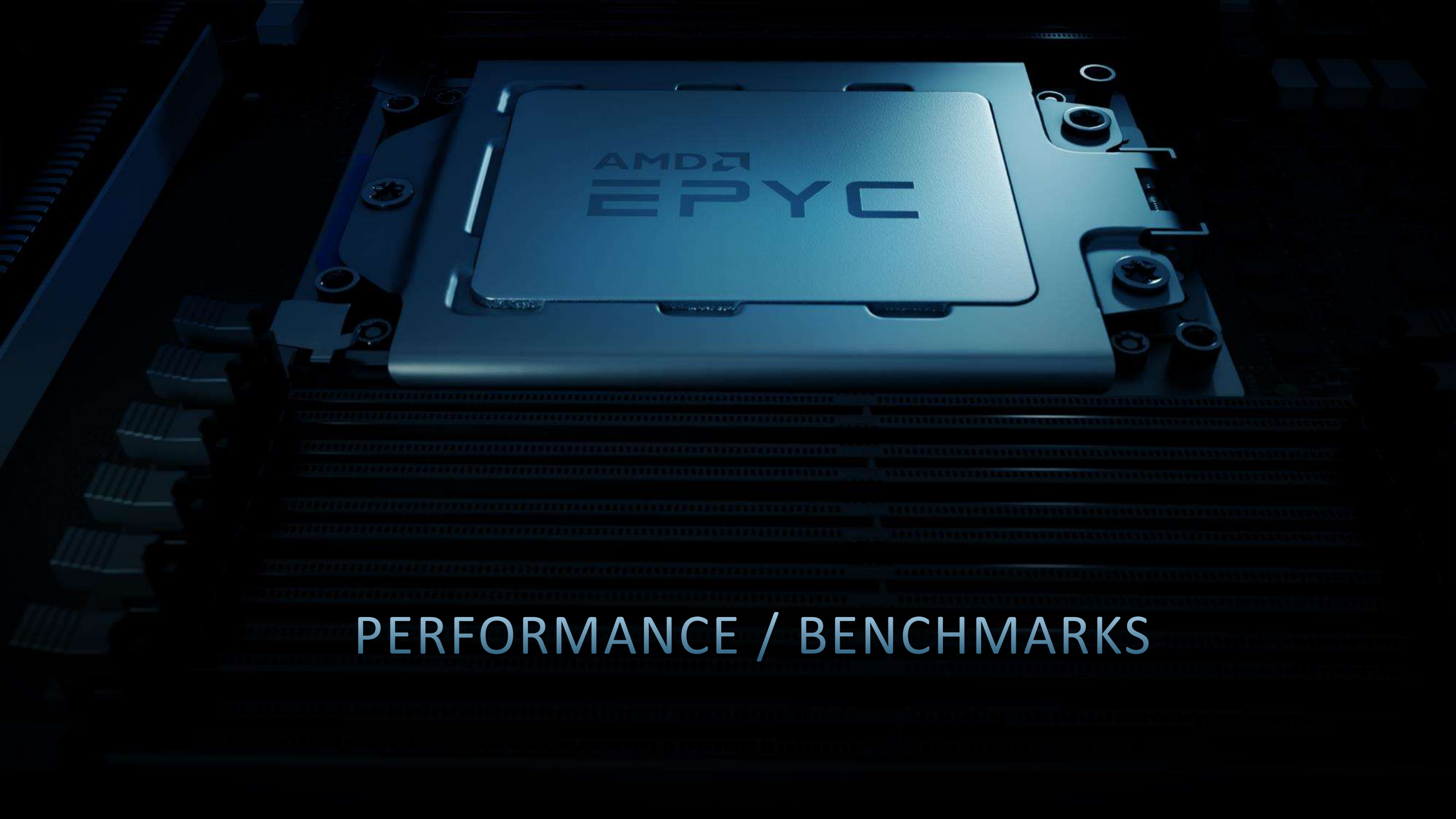
3 NUMA Distances; 8 NUMA Domains

Boot-Time-Configurable for NUMA-aware Applications Enabling Additional Performance Tuning

NOTE: Additional CCX-as-NUMA/L3-as-NUMA Option available for to-sensitive workloads

Preferred approach: OS/HV uses CPUID reporting ($ topology); but CCX-as-NUMA may leverage existing SW more easily

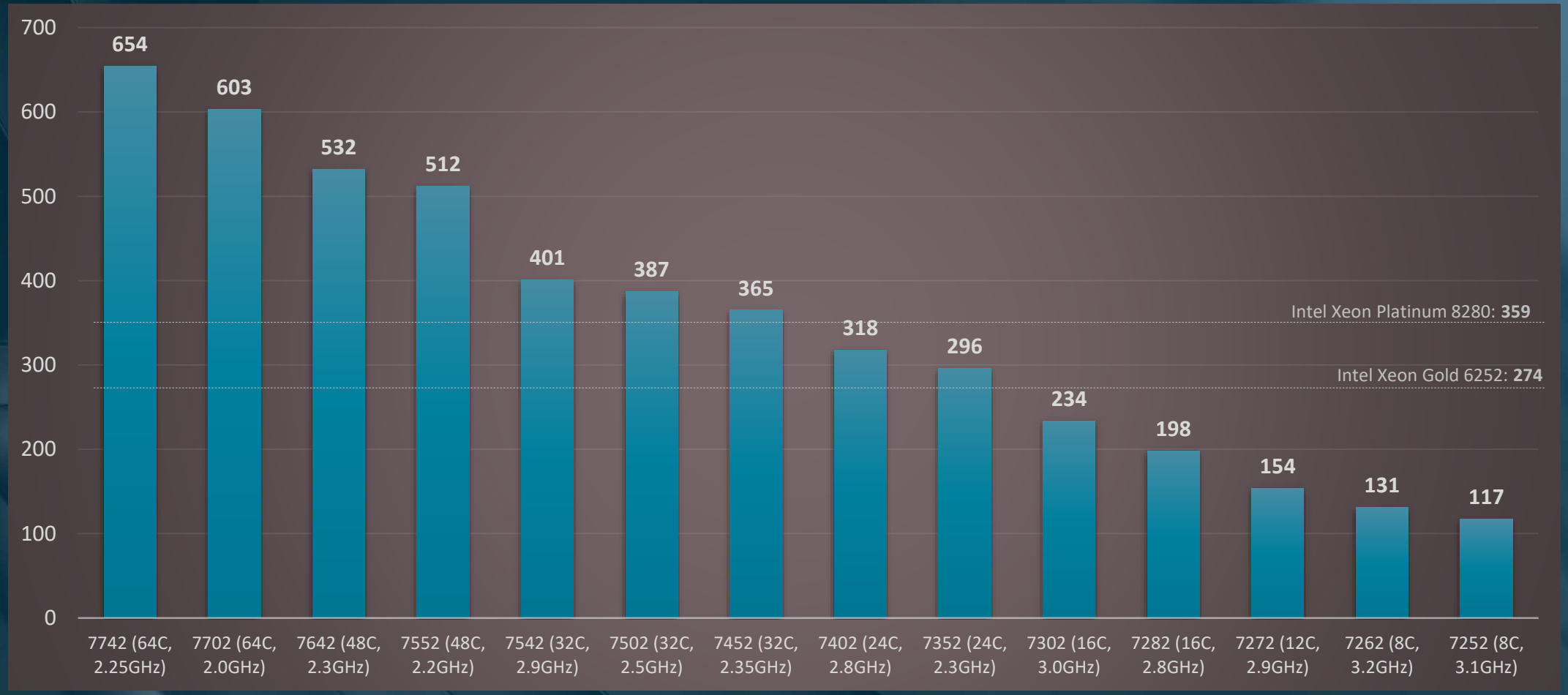
1: NPS=2 and NPS=4 may be restricted on some OPNs or DRAM populations



PERFORMANCE / BENCHMARKS

ROME 2P PERFORMANCE ESTIMATES

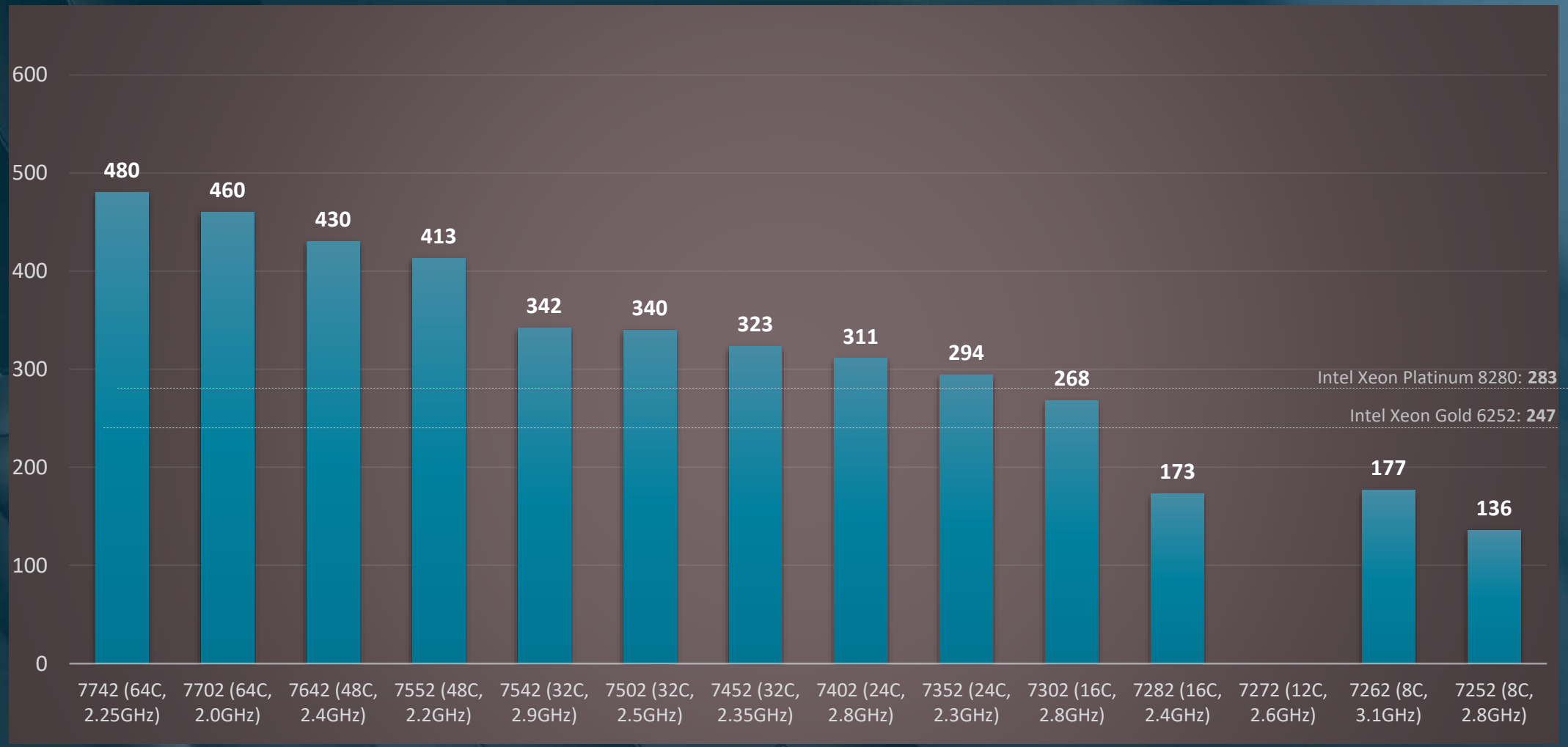
SPECINTRATE_2017_RATE_BASE



- Estimates shown as on the high end of range of scores shown in backup
- For all except EPYC 7282, 7272 and 7252, AMD SPEC CPU® 2017 estimates configured with 2xEPYC SOCs with 8 Channels of memory with DDR3200 using AOCC compiler.
- For EPYC 7282,7272 and 7252 AMD SPEC CPU® 2017 estimates configured with 2xEPYC SOCs with 4 Channels of memory with DDR2666 using AOCC compiler
- Intel Xeon scores represent highest reported 2-socket system score published at www.spec.org as of 10 May 2019
- More information about SPEC CPU® 2017 is available at http://www.spec.org

ROME 2P PERFORMANCE ESTIMATES

SPECFPRATE_2017_RATE_BASE



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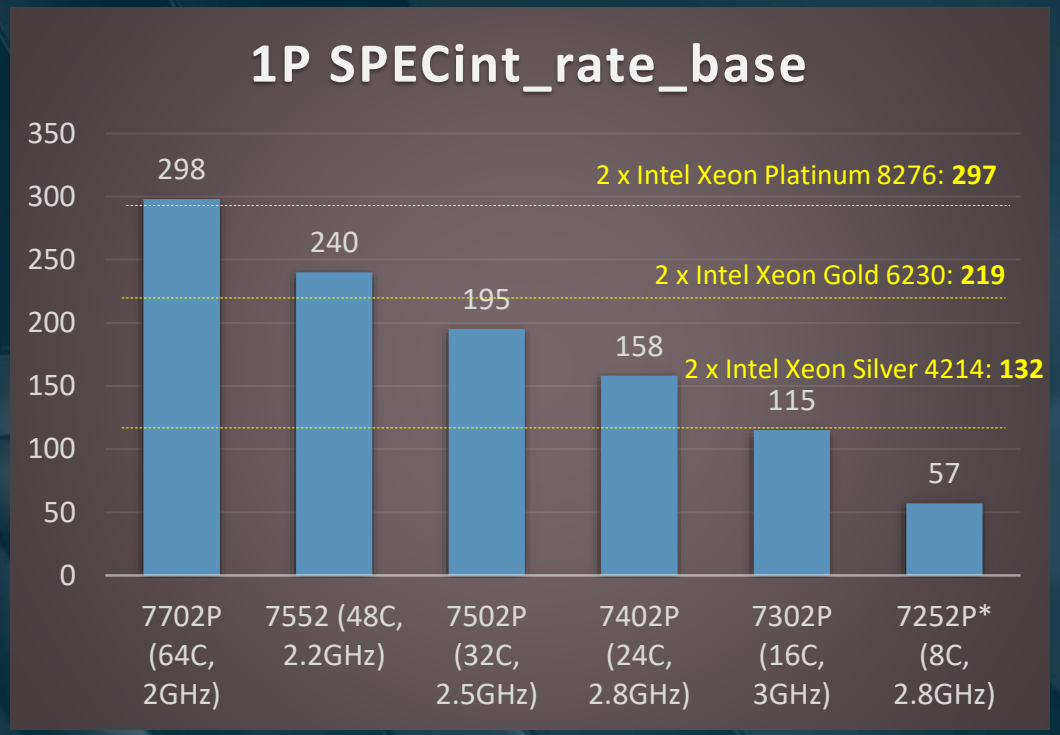
PERFORMANCE AND EFFICIENCY FOR PRIVATE CLOUD

1P "ROME" SETTING A NEW STANDARD OF EXPECTATION



1P EPYC vs 2P Xeon

- 1P EPYC can compete with the entire Xeon stack on raw performance
- 50-150W lower silicon power for ***greater rack density or lower power bills***
- Huge perf/$ advantage for ***CapEx savings***
- Potential SW license cost savings (i.e. VMWare)
- Stronger feature set—freq, core density, PCIe4, DDR4-3200

- Estimates shown as on the high end of range of scores shown in backup
- For all except EPYC 7252P, AMD SPEC CPU® 2017 estimates configured with 1xEPYC SOCs with 8 Channels of memory with DDR3200 using AOCC compiler.
- For EPYC 7252P, AMD SPEC CPU® 2017 estimates configured with 1xEPYC SOCs with 4 Channels of memory with DDR2666 using AOCC compiler
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STREAM

2x 7742, DDR4-3200 dual rank		
Run configuration	**Threads**	**TRIAD, MB/s**
1 core / L3	32	353984.6
2 cores / L3	64	339448.9
3 cores / L3	96	331390.9
4 cores / L3	128	324819.6
Single socket	64	162851.4

Set:

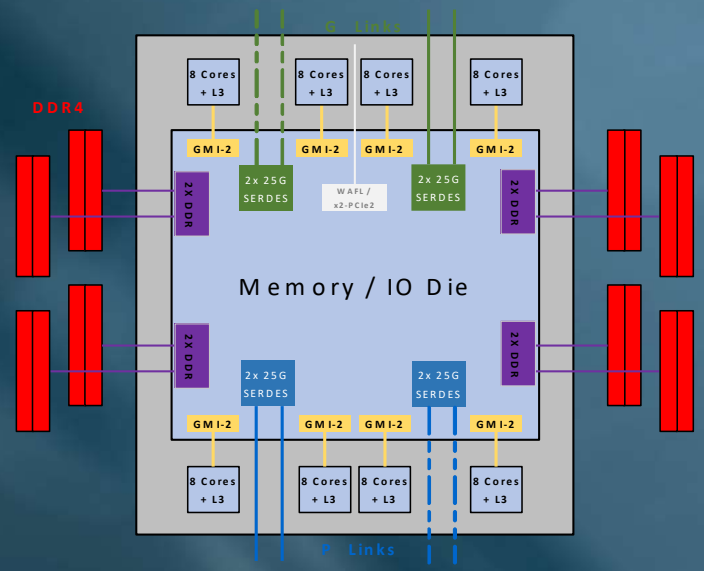
```
#!/bin/bash
echo 0 > /proc/sys/kernel/randomize_va_space
echo 0 > /proc/sys/vm/nr_hugepages
echo 0 > /proc/sys/kernel/numa_balancing
echo 'never' > /sys/kernel/mm/transparent_hugepage/enabled
echo 'never' > /sys/kernel/mm/transparent_hugepage/defrag
```

Compile:

```
icc -o stream.bin stream.c -DSTATIC -DNTIMES=10 DSTREAM_ARRAY_SIZE=2500000000
-mcmodel=large -shared-intel -Ofast -qopenmp -ffreestanding -qopt-streaming-stores always
```

Run: (e.g. 1 core per L3)

```
export OMP_PROC_BIND=true
export OMP_NUM_THREADS=32
export OMP_PLACES="{1},{5},{9},{13},{17},{21},{25},{29},{33},{37},{41},{45},{49},{53},{57},{61},
{65},{69},{73},{77},{81},{85},{89},{93},{97},{101},{105},{109},{113},{117},{121},{125}“
./stream.bin
```



Zen2/Rome CCD x 8 for 64 cores

HPL

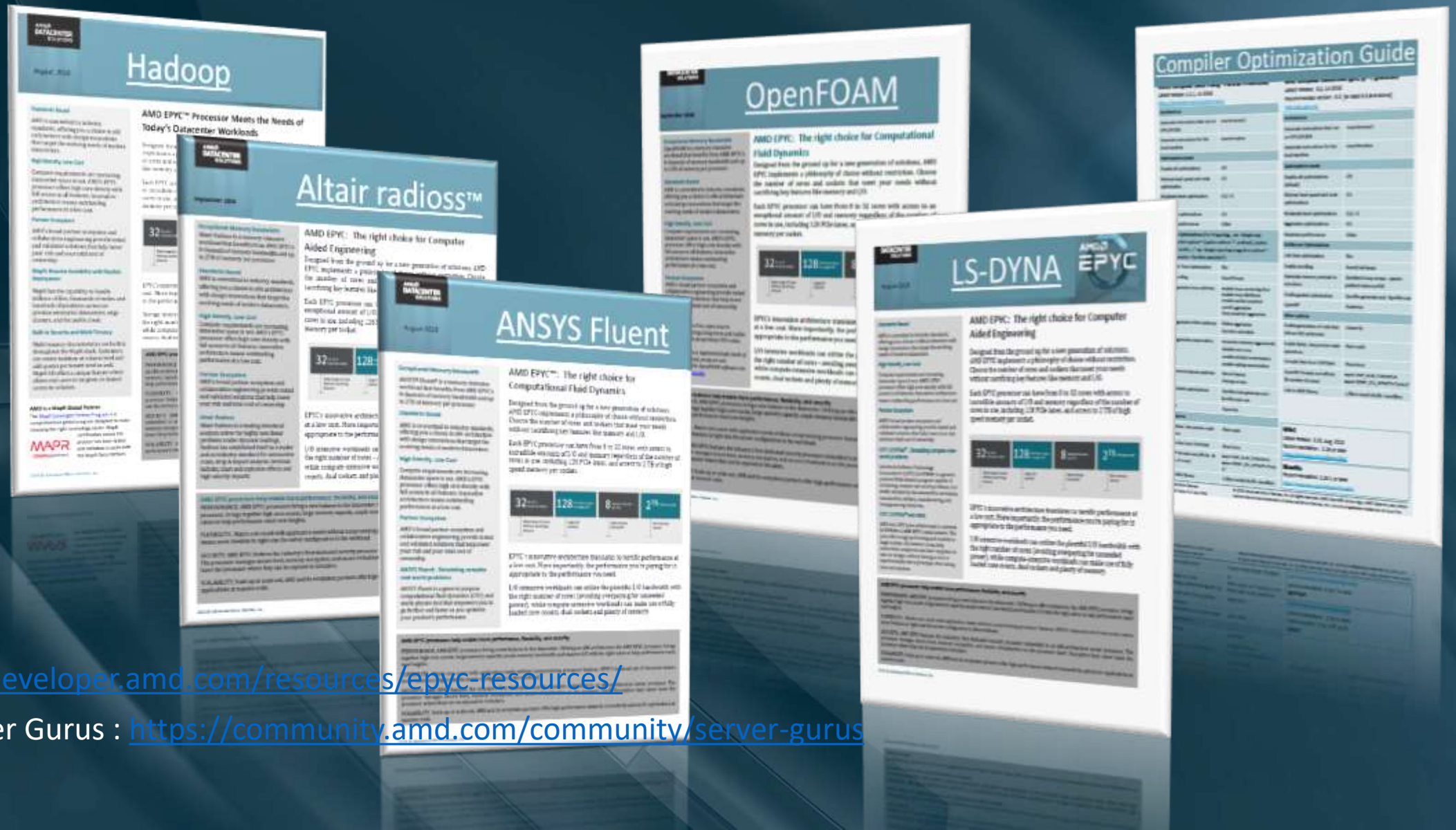
AMD

N	Determinism Slider	TFLOPs per node (2x 7742)
242190 (fit in 512GB)	Power (240W)	3.987
242190 (fit in 512GB)	Performance (225W)	3.833
171776 (fit in 256GB)	Performance (225W)	3.781

Compiled with Intel and MKL

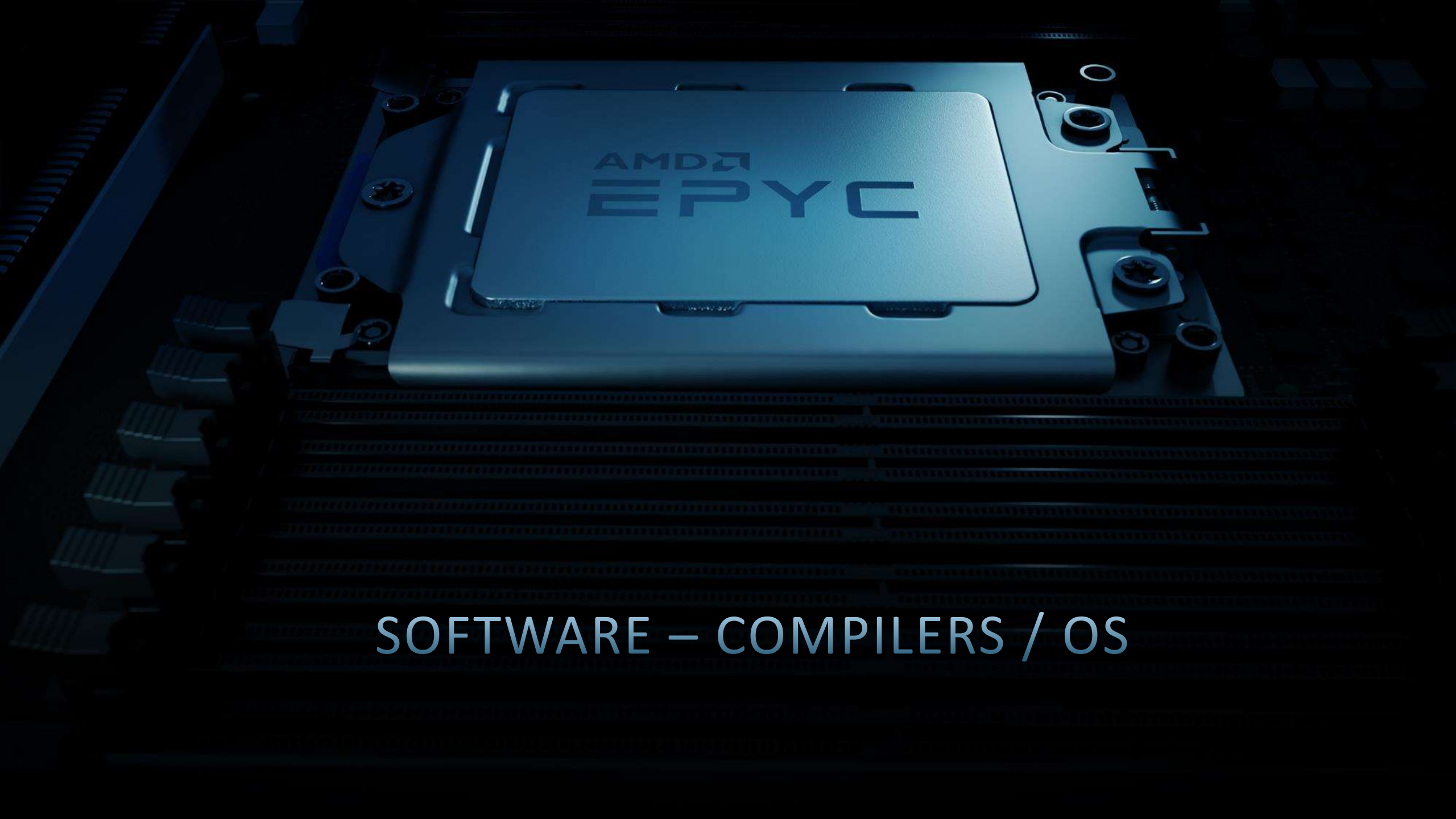
Rune with 32 MPI ranks (1 rank per L3) + OMP_NUM_THREADS=4 on each L3

ENABLING THE HPC ISV ECOSYSTEM



https://developer.amd.com/resources/epyc-resources/

- Server Gurus : https://community.amd.com/community/server-gurus



SOFTWARE – COMPILERS / OS

SOFTWARE DEVELOPMENT ENVIRONMENT

AOCC COMPILER

AOCL LIBRARIES

UPROF PROFILER

HTTP://DEVELOPER.AMD.COM

AOCC: AMD OPTIMIZING C/C++ COMPILER

AMD

Open Sourced – AMD EPYC™ Optimized

C/C++ Support	• Clang
Fortran Support	• AOCC 2.0 ships Flang as its Fortran compiler . Its is improvised AOCC-Flang

AOCL – AMD OPTIMIZING CPU LIBRARIES

AMD

Library	Open/Closed Source	Description
Basic Linear Algebra (**BLIS**)	Open	Portable open-source software framework for instantiating high-performance Basic Linear Algebra Subprograms (BLAS) – like dense linear algebra libraries
Linear Algebra (**libFLAME**)	Open	Portable library for dense matrix computations providing much of the functionality present in Linear Algebra Package (LAPACK)
Fast Fourier Transforms (**FFTW**)	Open	Collection of fast C routines for computing Discrete Fourier Transform (DFT) – open source implementation of Fast Fourier Transform algorithm
Core Math (**LibM**)	Closed	Collection of routines from the list of standard C99 math functions optimized for x86-64 processor based machines; can be used for better accuracy & performance than compiler's math functions
Random Number Generator (**RNG**)	Closed	Both Single and Double Precision Pseudo Random Number Generator library
Secure Random Number Generator (**RNG**)	Open	Both Single and Double Precision Secure Random Number Generator library

AMD MICRO PROFILER (UPROF) - OVERVIEW

System Level Analysis – AMDuProfPcm	Application Level Analysis – AMDuProf/AMDuProfCLI
◢ Basic processor monitoring utility using Core/L3 PMC, UMC Events and Metrics Core metrics: IPC, CPI, Effective Frequency (w, w/o halt), L2 Request, L2 DC Request, L2 DC Miss (PTI) CCX level: L3 Access, L3 Hit, L3 Miss, L3 CCX Miss (PTI) UMC / Memory Bandwidth: Umc0RdBW, Umc0WrBW, Umc1RdBW, Umc1WrBW (GB/s) Multiplexing support by AMD uProf 2.0 release Command line Interface . Generates CSV report OS:- Linux (no dependency on Linux PERF) and FreeBSD	◢ CPU Performance profiling Core PMC (sampling mode) IBS, OS Timer Power Profiling SMU PM data, RAPL, APERF, MPERF, IRPERF Profile data attribution Process, Modules, Functions, Source and Instructions No changes required to application source code. Debug info required. C, C++, Fortran, Java Windows and Linux (Ubuntu and RHEL) On Linux, uses PERF kernel subsystem for CPU profile data collection Command Line Interface (CLI) and GUI CLI generates CSV report

AMD MICRO PROFILER (UPROF)

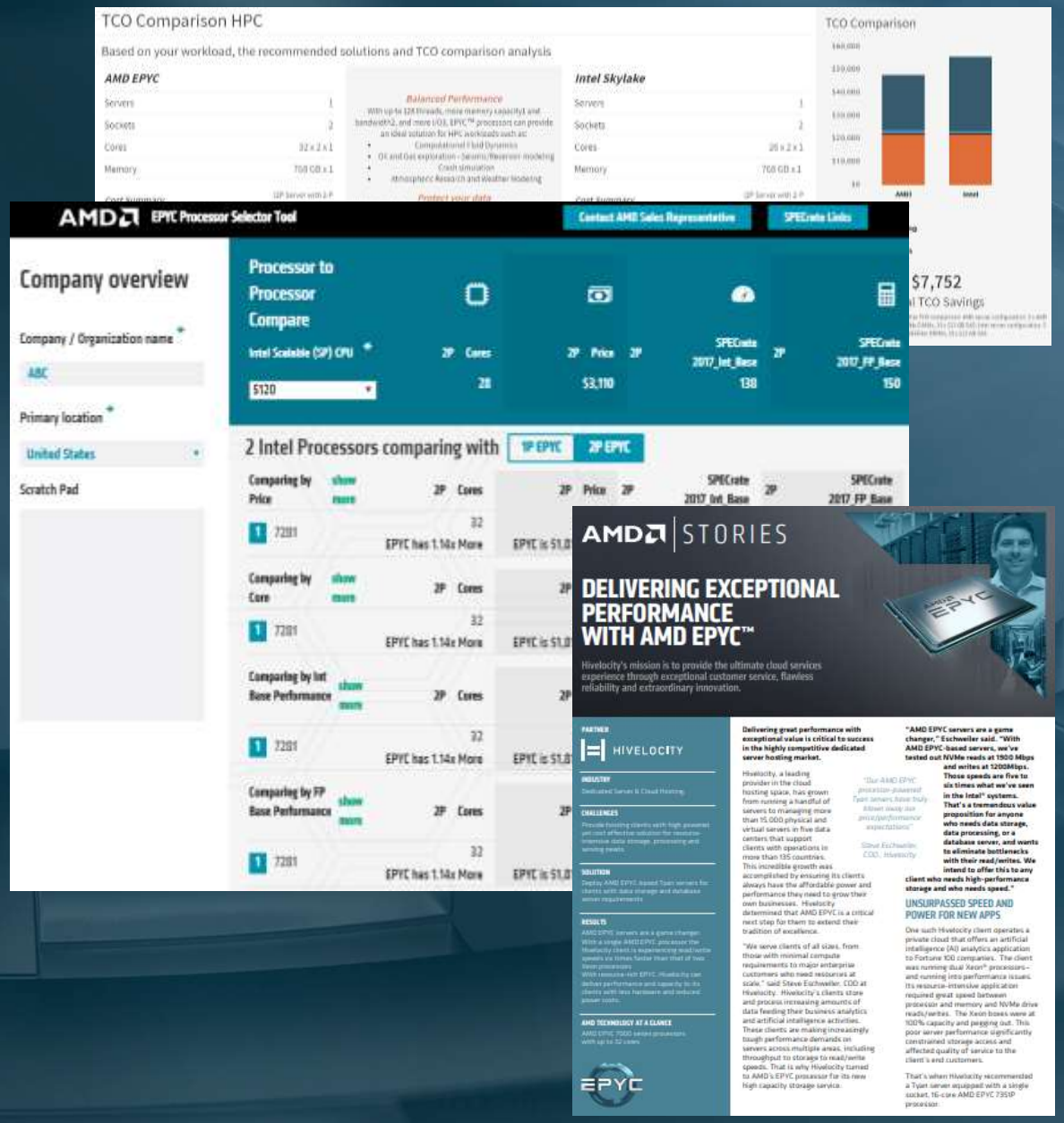
- Remote profiling support
- Top-down analysis capabilities
  - Ability to analyze interesting L3, DF, UMC events on Linux
  - Memory Bandwidth Analysis (built on L3, DF, UMC)
- Tool improvements
  - UI upgrades
  - Performance improvements
  - Overall infrastructure
- Support for Zen2 core based products (Rome etc)

TOOLS & RESOURCES

- EPYC TCO Comparison Tool
- Processor Selector Tool

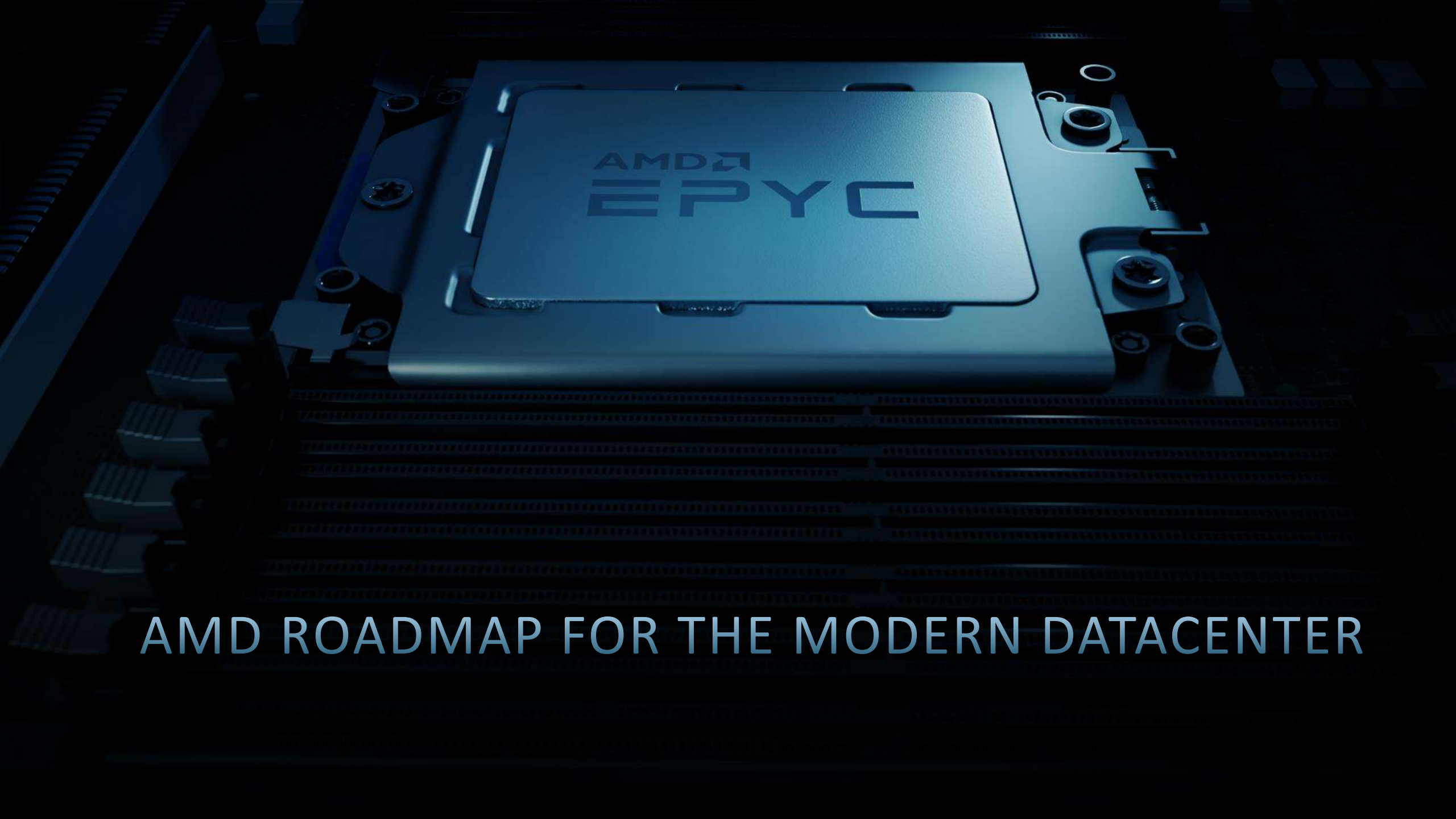
https://www.amd.com/en/processors/epyc-cpu-selector

- EPYC Compiler Guide
- Developer Central (Technical Docs)
- Server Guru Community Portal



EPYC™ TECHNICAL RESOURCES

- **EPYC™ Developer central:** One-place for all the EPYC™ public technical content (*https://developer.amd.com/*)
  - *Tools, SDKs, and Libraries*
  - *Reference Architectures*
  - *Solution Briefs*
  - *Specifications and Manuals*
  - *Naples Tuning Guide*
  - *Rome Tuning Guide [end of 2019 Q4]*
  - *Ecosystem (OS and Hypervisor)*
- **EPYC Server Community "AMD Server Gurus" :** Community forum for Q&As/discussions etc. (*https://community.amd.com/community/server-gurus*)
  - *Important configurations*
  - *Tuning recommendations*
  - *Troubleshooting information*
- **EPYC Compiler Options Quick Ref Guide**



AMD ROADMAP FOR THE MODERN DATACENTER

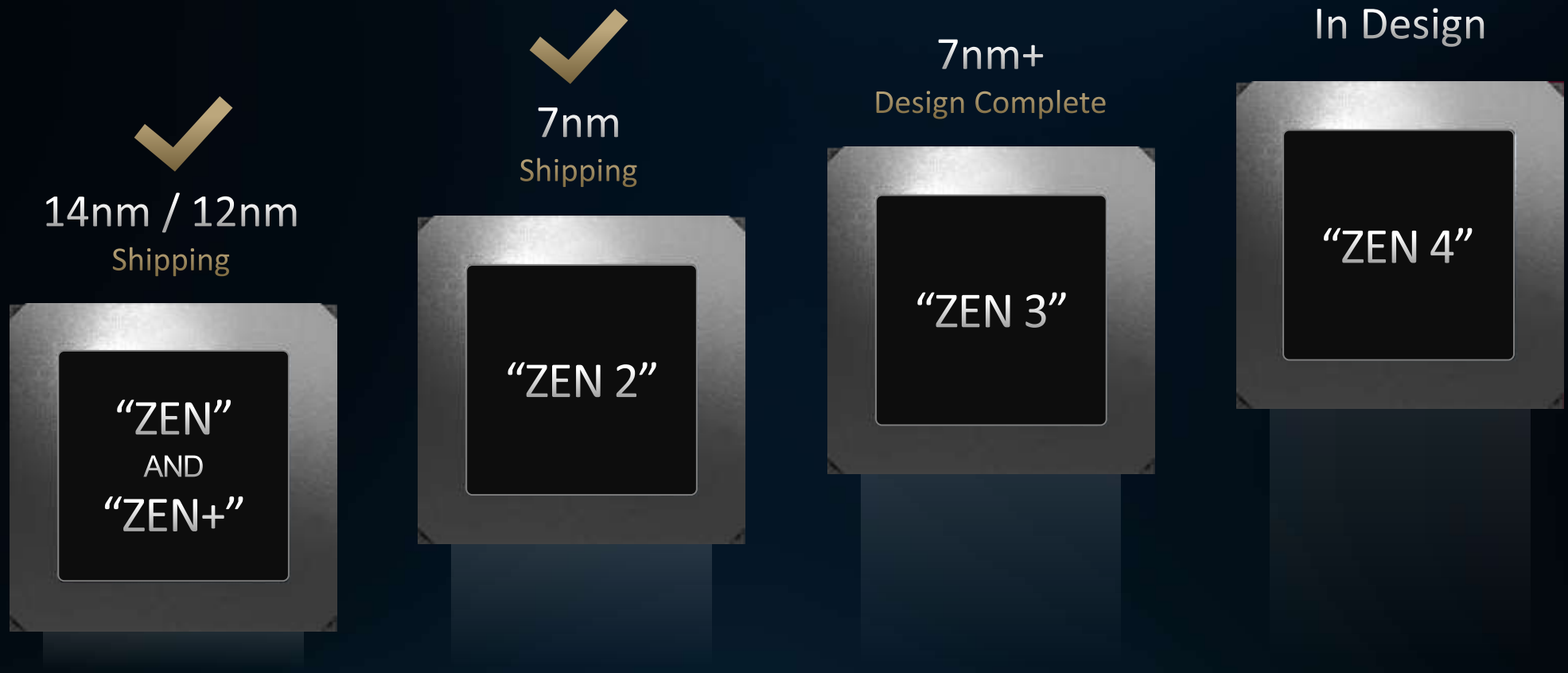
AMD DATA CENTER ROADMAP

LEADERSHIP LONG-TERM COMMITMENT

Roadmaps subject to change

COMPUTE ARCHITECTURE ROADMAP

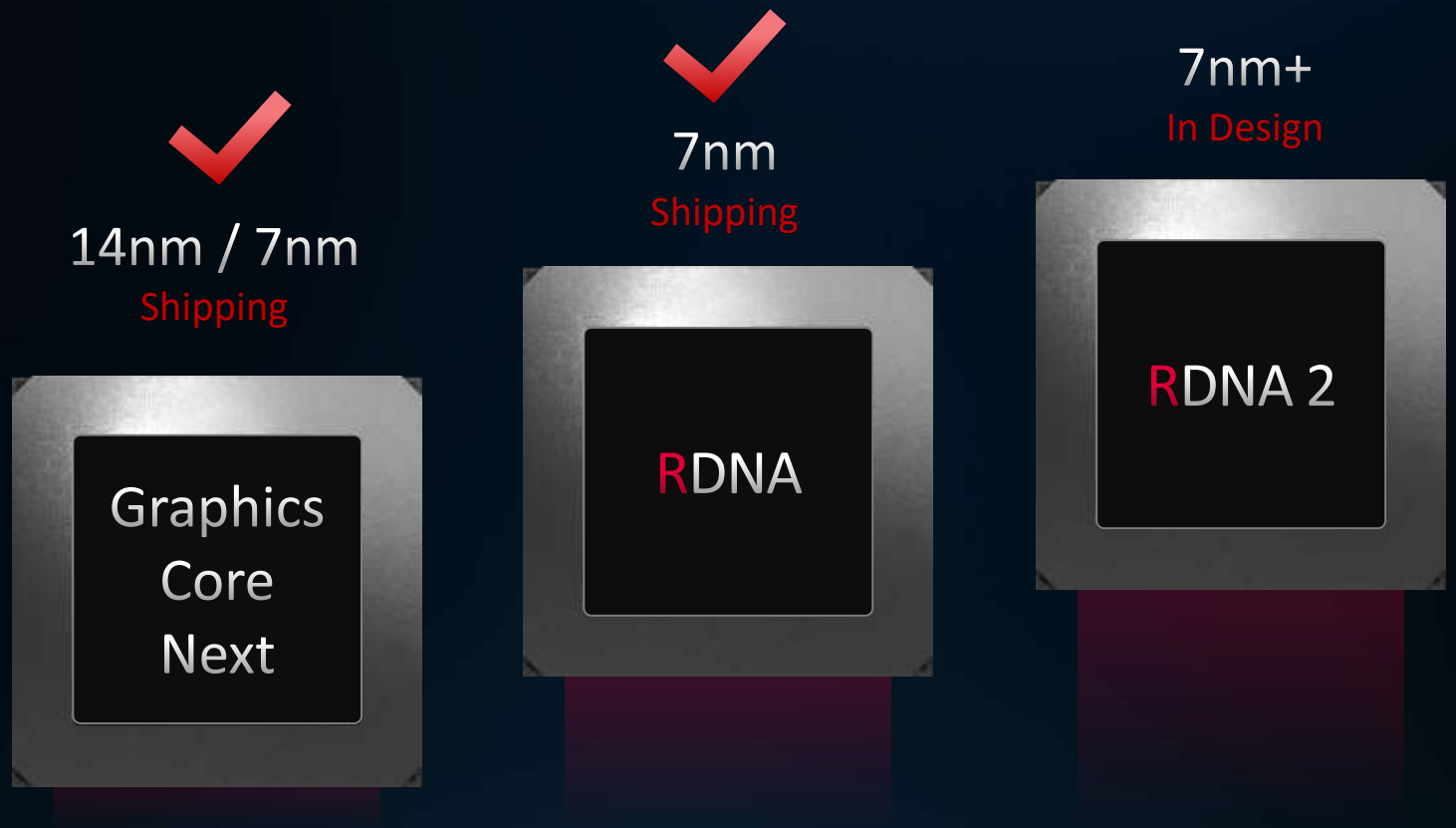
SUSTAINED HIGH-PERFORMANCE LEADERSHIP



Roadmaps subject to change

RADEON GRAPHICS ARCHITECTURE ROADMAP

CONTINUOUS PERFORMANCE, INNOVATION AND EFFICIENCY GAINS



Roadmaps subject to change

THE BIGGEST AND BEST YEAR IN AMD HISTORY

DISCLAIMER AND ATTRIBUTIONS

DISCLAIMER

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AMD

DESIGNED FOR PERFORMANCE

Optimized Process | Hybrid Multi-Die Design | System on Chip

AMD

EPYC


AMD

ENDNOTES

- ROM-06 - Some supported features and functionality of 2nd Gen AMD EPYC™ processors require a BIOS update from your server manufacturer when used with a motherboard designed for the 1st Gen AMD EPYC series processor. A motherboard designed for 2nd Gen EPYC processors is required to enable all available functionality.
- ROM-09 - AMD EPYC 7742 has 64 cores vs. Intel Platinum 8280 with 28 cores. 64 / 28 = 2.287 - 1.0 = 1.3 times (or 130% more). EPYC 7742 has 1.3x more cores.
- ROM-11 - EPYC™ 7002 series has 8 memory channels, supporting 3200 MHz DIMMs yielding 204.8 GB/s of bandwidth vs. the same class of Intel Scalable Gen 2 processors with only 6 memory channels and supporting 2933 MHz DIMMs yielding 140.8 GB/s of bandwidth. 204.8 / 140.8 = 1.454545 - 1.0 = .45 or 45% more. AMD EPYC has 45% more bandwidth. Class based on industry-standard pin-based (LGA) X86 processors.
- ROM-42 - Based on AMD internal testing of ANSYS FLUENT 19.1, lm6000_16m benchmark, as of July 17, 2019 of a 2P EPYC 7742 powered reference server versus a 2P Intel Xeon Platinum 8280 powered server. Results may vary.
- ROM-49 - Based on AMD internal testing of LSTC LS-DYNA R9.3.0, neon benchmark, as of July 17, 2019 of a 2P EPYC 7742 powered reference server versus a 2P Xeon Platinum 8280 powered server. Results may vary.
- ROM-56 - Based on AMD internal testing of Altair RADIOSS 2018, T10M benchmark, as of July 17, 2019 using a 2P EPYC 7742 powered reference server versus a 2P Xeon Platinum 8280 powered server. Results may vary.
- ROM-63 - Based on AMD internal testing of ESI VPS 2018.0, NEON4m benchmark, as of July 17, 2019 using a 2P EPYC 7742 powered reference server versus a 2P Xeon Platinum 8280 powered server. Results may vary.
- ROM-70 - Based on AMD internal testing of Siemens PLM STAR-CCM+ 14.02.009, kcs_with_physics benchmark, as of July 17, 2019 using a 2P EPYC 7742 powered reference server versus a 2P Xeon Platinum 8280 powered server. Results may vary.
- ROM-95 - A 1P EPYC 7742 powered server has SPECrate®2017_int_peak score of 385, int_base score 349 http://spec.org/cpu2017/results/res2019q3/cpu2017-20190722-16290.html as of August 7, 2019. The next highest int_peak score is a 1P Intel Platinum 8280L server with a score of 180, http://spec.org/cpu2017/results/res2019q2/cpu2017-20190319-11289.pdf, and a int-base score of 181 with the 8280, http://spec.org/cpu2017/results/res2019q2/cpu2017-20190318-11230.pdf, as of July 28, 2019. SPEC®, SPECrate® and SPEC CPU® are registered trademarks of the Standard Performance Evaluation Corporation. See www.spec.org for more information.
- ROM-99 - A 2P EPYC 7702 powered server has SPECvirt_sc2013 score of 5451.2 and 305 VMs, https://www.spec.org/virt_sc2013/results/res2019q3/virt_sc2013-20190716-00120-perf.html as of August 7, 2019. The next highest score is a 2P Intel Platinum 8180 server with a score of 3376 and 189 VMs, https://www.spec.org/virt_sc2013/results/res2017q4/virt_sc2013-20171017-00098-perf.html as of July 28, 2019. SPEC® and SPECvirt® are registered trademarks of the Standard Performance Evaluation Corporation. See www.spec.org for more information.
- ROM-128 - An EPYC™ 7702 powered server has a World Record x86 2P SAP SD® 2 tier with Windows® Server score of 45,600 on Aug 7, 2019, https://www.sap.com/dmc/benchmark/2019/Cert19044, that is 43% (45600/ 31900 = 1.429) higher than the previous #1, an Intel Platinum 8180 powered server with a score of 31,900, https://www.sap.com/dmc/benchmark/2017/Cert17028.pdf. SAP® SD scores can be found at https://www.sap.com/dmc/exp/2018-benchmark-directory/#/sd July 31, 2019. More information on SAP Standard Application Benchmarks go to https://www.sap.com/about/benchmark.html. ROM-128

ENDNOTES

- ROM-128 - An EPYC™ 7702 powered server has a World Record x86 2P SAP SD® 2 tier with Windows® Server score of 45,600 on Aug 7, 2019, https://www.sap.com/dmc/benchmark/2019/Cert19044, that is 43% (45600/ 31900 = 1.429) higher than the previous #1, an Intel Platinum 8180 powered server with a score of 31,900, https://www.sap.com/dmc/benchmark/2017/Cert17028.pdf. SAP® SD scores can be found at https://www.sap.com/dmc/exp/2018-benchmark-directory/#/sd, July 31, 2019. More information on SAP Standard Application Benchmarks go to https://www.sap.com/about/benchmark.html. ROM-128
- ROM-144 - A 2P EPYC 7742 powered server has a World Record 2P SPECjbb2015-MultiJVM Max max-jOPS score of 355,121 (SPECjbb2015-MultiJVM Critical scored 151,270 critical-jOPS), http://www.spec.org/jbb2015/results/res2019q3/jbb2015-20190717-00460.html as of August 7, 2019. The highest previous 2P max-jOPS score is 194,068 (SPECjbb2015-MultiJVM Critical scored 53,616 critical-jOPS) by an Intel 8280 server, https://www.spec.org/jbb2015/results/res2019q2/jbb2015-20190313-00374.html. SPEC® and SPECjbb® are registered trademarks of the Standard Performance Evaluation Corporation. See www.spec.org for more information. ROM-144
- ROM-145 - A 2P EPYC 7742 powered server has a World Record 2P SPECjbb2015-MultiJVM Critical critical jOPS score of 233,669 (SPECjbb2015-MultiJVM Max scored 319,609 max-jOPS), http://www.spec.org/jbb2015/results/res2019q3/jbb2015-20190717-00462.html as of August 7, 2019. The highest previous 2P critical-jOPS score is 138,942 (SPECjbb2015-MultiJVM Max scored 169,598 max-jOPS) by an Intel 8280 server, https://www.spec.org/jbb2015/results/res2019q2/jbb2015-20190314-00428.html. SPEC® and SPECjbb® are registered trademarks of the Standard Performance Evaluation Corporation. See www.spec.org for more information. ROM-145
- ROM-149 - A 2P 2U AMD EPYC™ 7702 server scored 18,294 overall ssj_ops/watt on SPEC Power® 2008 with the SUSE® Linux Enterprise Server 12 SP4 OS, as published at https://www.spec.org/power_ssj2008/results/res2019q3/power_ssj2008-20190716-00980.html, which is higher than all other 2-socket publications on the SPEC® website as of 7/27/2019. SPEC® and SPEC Power® are registered trademarks of the Standard Performance Evaluation Corporation. See www.spec.org for more information. ROM-149
- ROM-161 - Results as of 8/7/2019. EPYC™ 7502P result published at TPC website, http://www.tpc.org/5533. Previous best published result on the TPC website at http://www.tpc.org/tpcx-hs/results/tpcxhs_advanced_sort.asp?version=2. TPC and TPC Benchmark are registered trademarks of the Transaction Processing Performance Council. ROM-161
- ROM-169 - For a complete list of world records see http://amd.com/worldrecords. ROM-169

ENDNOTES

- ROM-241 - Projections as of August 2, 2019. The AMD EPYC 7272, $625 per processor, has a projected SPECrate®2017_int_peak of 160 (base of 160) which is 2X the performance / dollar of the Intel Silver 4215, $794 per processor, with peak score of 101, http://spec.org/cpu2017/results/res2019q2/cpu2017-20190428-12685.pdf, (base of 98.5, http://spec.org/cpu2017/results/res2019q2/cpu2017-20190430-13552.pdf on Aug 7, 2019. (160 / $650) / (101 / $794) = 2.01 = 2.0X the performance/dollar. AMD 1kU prices as of Aug 7, 2019; Intel prices as of Aug 7, 20019 from https://ark.intel.com/. SPEC®, SPECrate® and SPEC CPU® are registered trademarks of the Standard Performance Evaluation Corporation. See www.spec.org for more information. ROM-241
- ROM-243 - Projections as of August 2, 2019. The AMD EPYC 7352, $1,350 per processor, has a projected SPECrate®2017_int_peak of 312 (base of 303) which is 2.3X the performance / dollar of the Intel Gold 6226, $1,776 per processor, with peak score of 181 (base of 175) http://spec.org/cpu2017/results/res2019q3/cpu2017-20190709-16044.pdf on Aug 7, 2019 . (312 / $1,350) / (181 / $1,776) = 2.27 = 2.3X the performance/dollar. AMD 1kU prices as of Aug 7, 2019; Intel prices as of Aug 7, 20019 from https://ark.intel.com/. SPEC®, SPECrate® and SPEC CPU® are registered trademarks of the Standard Performance Evaluation Corporation. See www.spec.org for more information. ROM-243.
- ROM-245 - Projections as of August 2, 2019. The AMD EPYC 7502, $2,600 per processor, has a projected SPECrate®2017_int_peak of 416 (base of 380 which is 2.0X the performance / dollar of the Intel Gold 6252, $3,655 per processor, with peak score of 285 (base of 274) http://spec.org/cpu2017/results/res2019q3/cpu2017-20190709-16044.pdf on Aug 7, 2019 . (416 / $2,600) / (285 / $3,655) = 2.05 = 2.0X the performance/dollar. AMD 1kU prices as of Aug 7, 2019; Intel prices as of Aug 7, 20019 from https://ark.intel.com/. SPEC®, SPECrate® and SPEC CPU® are registered trademarks of the Standard Performance Evaluation Corporation. See www.spec.org for more information. ROM-245
- ROM-247 - Projections as of August 2, 2019. The AMD EPYC 7642, $4,775 per processor, has a projected SPECrate®2017_int_peak of 550 (base of 493 which is 1.8X the performance / dollar of the Intel Platinum 8260, $4,702 per processor, with peak score of 297 (base of 274) http://spec.org/cpu2017/results/res2019q2/cpu2017-20190513-13593.pdf on Aug 7, 2019 . (550 / $4,775) / (297 / $4,702) = 1.82 = 2.8X the performance/dollar. AMD 1kU prices as of Aug 7, 2019; Intel prices as of Aug 7, 20019 from https://ark.intel.com/. SPEC®, SPECrate® and SPEC CPU® are registered trademarks of the Standard Performance Evaluation Corporation. See www.spec.org for more information. ROM-247
- ROM-249 - Results as of August 7, 2019. The AMD EPYC 7742, $6,950 per processor, has SPECrate®2017_int_peak of 749 (base of 682) http://spec.org/cpu2017/results/res2019q3/cpu2017-20190722-16242.html which is 4X the performance / dollar than an Intel Platinum 8280M, $13,012 per processor, with peak score of 354 (base of 337) http://spec.org/cpu2017/results/res2019q3/cpu2017-20190625-15893.pdf on Aug 7, 2019 . (749 / $6,950) / (354 / $13,012) = 3.96 = 4.0X the performance/dollar. AMD 1kU prices as of Aug 7, 2019; Intel prices as of Aug 7, 20019 from https://ark.intel.com/. SPEC®, SPECrate® and SPEC CPU® are registered trademarks of the Standard Performance Evaluation Corporation. See www.spec.org for more information. ROM-249

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- ROM-253 - A 1P AMD EPYC 7742, $6950 per processor, has a SPECrate®2017_int_peak of 385 (base of 349) which is 4x the estimated performance / dollar of a 1P Intel Platinum 8280M, $13,012 per processor, with peak score of 181 (base of 181). In the absense of published 1P SPECint scores for the 8280M, the highest of the peak and base scores of the 8280 and the 8280L were use for the 8280M, http://spec.org/cpu2017/results/res2019q2/cpu2017-20190318-11230.pdf, on Aug 2, 2019. (385 / $6950) = (181 / $13,012) = 4.00. AMD 1kU prices as of Aug 7, 2019; Intel prices as of Aug 7, 20019 from https://ark.intel.com/. SPEC®, SPECrate® and SPEC CPU® are registered trademarks of the Standard Performance Evaluation Corporation. See www.spec.org for more information. ROM-253
- ROM-255 - A 1P AMD EPYC 7452, $2025 per processor, has a projected SPECrate®2017_int_peak of 208 (base of 203) which is 2x the estimated performance / dollar of a 1P Intel Gold 6226, $1776 per processor, with peak score of 91 (base of 88). In the absense of published 1P SPECint scores for the 6226, the 2P scores were used and divided by 2, http://spec.org/cpu2017/results/res2019q3/cpu2017-20190709-16044.pdf, on Aug 2, 2019. (208 / $2025) = (91 / $1776) = 2.0. AMD 1kU prices as of Aug 7, 2019; Intel prices as of Aug 7, 20019 from https://ark.intel.com/. SPEC®, SPECrate® and SPEC CPU® are registered trademarks of the Standard Performance Evaluation Corporation. See www.spec.org for more information. ROM-255
- ROM-257 - A 1P AMD EPYC 7282, $6950 per processor, has a projected SPECrate®2017_int_peak of 102 (base of 94) which is 2x the performance / dollar of a 1P Intel Silver 4215 , $794 per processor, with peak score of 49.2 (base of 49.2). In the absense of a published peak score, the base score of 49.2 was used, http://spec.org/cpu2017/results/res2019q2/cpu2017-20190524-14358.pdf, Aug 2,2019. (102 / $6950) = (49.2 / $1776) = 2.53. AMD 1kU prices as of Aug 7, 2019; Intel prices as of Aug 7, 20019 from https://ark.intel.com/. SPEC®, SPECrate® and SPEC CPU® are registered trademarks of the Standard Performance Evaluation Corporation. See www.spec.org for more information. ROM-257
- ROM-258 - Slide represents both published and estimated SPECrate®2017_int_peak performance. Estimates as of July 3, 2019 for AMD EPYC 48C, 32C and 8C processors using computer modeling of preproduction parts and SPECrate®2017_int_peak internal testing results. Results may vary with production silicon testing. Published results for EPYC 64C processor as of August 7, 2019: https://spec.org/cpu2017/results/res2019q3/cpu2017-20190722-16242.html. Intel results as of June 2019: Xeon Platinum: http://spec.org/cpu2017/results/res2019q2/cpu2017-20190429-12779.pdf Xeon Gold: http://spec.org/cpu2017/results/res2019q2/cpu2017-20190404-11744.pdf Xeon Silver: http://spec.org/cpu2017/results/res2019q2/cpu2017-20190430-13444.pdf; Xeon Bronze: http://spec.org/cpu2017/results/res2019q3/cpu2017-20190624-15468.pdf. SPEC®, SPECrate® and SPEC CPU® are registered trademarks of the Standard Performance Evaluation Corporation. See www.spec.org for more information. ROM-258
- ROM-259 - Slide represents both published and estimated 1P SPECrate®2017_int_peak performance. Estimates as of July 3, 2019 for AMD EPYC 48C, 32C and 8C processors using computer modeling of preproduction parts and 1P SPECrate®2017_int_peak internal testing results. Results may vary with production silicon testing. Published results for 1P EPYC 64C processor as of August 7, 2019: http://spec.org/cpu2017/results/res2019q2/cpu2017-20190318-11230.pdf. Intel results as of June 2019: Xeon Platinum: http://spec.org/cpu2017/results/res2019q2/cpu2017-20190318-11230.pdf Xeon Gold: http://spec.org/cpu2017/results/res2019q2/cpu2017-20190611-15301.pdf and http://spec.org/cpu2017/results/res2019q2/cpu2017-20190611-15308.pdf. SPEC®, SPECrate® and SPEC CPU® are registered trademarks of the Standard Performance Evaluation Corporation. See www.spec.org for more information. ROM-259

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- ROM-260 - Slide represents both published and estimated 1P and 2P SPECrate®2017_d: int_peak performance. Estimates as of July 3, 2019 for AMD EPYC 48C, 32C and 8C processors using computer modeling of preproduction parts and 1P SPECrate®2017_int_peak internal testing results. Results may vary with production silicon testing. Published results for 1P EPYC 64C processor as of August 7, 2019: https://spec.org/cpu2017/results/res2019q3/cpu2017-20190722-16242.html. Intel 1P results as of June 2019: Xeon Platinum: http://spec.org/cpu2017/results/res2019q2/cpu2017-20190429-12779.pdf Xeon Gold: http://spec.org/cpu2017/results/res2019q2/cpu2017-20190404-11744.pdf Xeon Silver: http://spec.org/cpu2017/results/res2019q2/cpu2017-20190430-13444.pdf; Xeon Bronze: http://spec.org/cpu2017/results/res2019q3/cpu2017-20190624-15468.pdf. 2P SPECrate®2017_int_peak scores for Intel published June 2019: Xeon Platinum: http://spec.org/cpu2017/results/res2019q2/cpu2017-20190318-11230.pdf Xeon Gold: http://spec.org/cpu2017/results/res2019q2/cpu2017-20190611-15301.pdf and http://spec.org/cpu2017/results/res2019q2/cpu2017-20190611-15308.pdf. SPEC®, SPECrate® and SPEC CPU® are registered trademarks of the Standard Performance Evaluation Corporation. See www.spec.org for more information. ROM-260
- TCO-01 Compares delivering 11,550,120 jOPS as measured by SPECjbb2015-MultiJVM Max-jOPS benchmark utilizing 2 socket Intel 8280 servers versus 2 socket AMD EPYC™ 7742 servers. Intel-based server tested to achieve 192,502 jOPS. AMD EPYC server tested to achieve 355,121jOPS. As a result, an estimated 60 Intel based servers versus 33 AMD EPYC™ based servers are needed to meet a jOPS performance of 11,550,120. System Configurations: Intel Xeon based servers include 2U Rack Mount chassis, with (2) Intel® Xeon® Platinum 8280 2.7GHz base frequency, 28 cores/56 threads, (24) 16GB RDIMM DDR4 2933MT/s, Dual Rank DIMMs, (1) 960GB SATA SSD, (1) dual port 10GbE ethernet adapter dual hot swap power supplies w/cables, and OEM standard warranty with a price of $57,156 each for a total hardware acquisition price of $3,429,360. AMD EPYC™ servers include Dual Socket 2U Rack Mount chassis, with (2) AMD EPYC™ 7742, 2.25GHz base frequency, 64 cores/128 threads, (32) 32GB RDIMM DDR4 2933MT/s, Dual Rank DIMMs, (1) 1.92TB SSD SAS Mix Use drive, (1) dual port 1GbE ethernet adapter, dual hot swap power supplies w/cables, and OEM standard warranty with estimated price of $58,553 each for a total hardware acquisition price of $1,931,589. Estimated System Pricing: Estimated Pricing for Intel Xeon Based Systems based on select OEM system pricing as of 8/5/2019. Estimated Pricing for AMD EPYC™ Based Systems based on projected OEM list price for the most comparable system. Pricing is an AMD estimate only – actual pricing will vary by system and seller. Power cost is an internal AMD estimate based each server consuming 762 watts each input power - electricity cost estimate of $1,610/server calculated at $0.12/kw/hr with an assumed PUE of 2.0, resulting in an estimated 3 yr power cost of $289,800 for Intel-based systems and $159,390 for AMD EPYC™ systems. Datacenter space costs are based on AMD internal estimate of Data Center space cost of $19,053 per cabinet per year results in $171,477 (3 Rack Cabinets) and $94,312 (1.6 Rack Cabinets) over three years for Intel-based and AMD EPYC-based systems respectively. Server Administration cost is calculated with an estimate of $85,795 per server administrator with a ratio of one server administrator per 30 servers resulting in $514,770 (for 60 servers) and $283,124 (for 33 servers) 3 yr server administration costs for Intel-based and AMD EPYC- based systems respectively. Total estimated 3 Year TCO as a result is $4,405,407 for Intel-based Systems and $2,468,415 for AMD EPYC-based systems. As a result, AMD EPYC based systems are estimated to deliver a lower TCO (excluding software costs) of up to 44%. This scenario contains many assumptions and estimates and, while based on AMD internal research and best approximations, should be considered an example for information purposes only, and not used as a basis for decision making over actual testing. See https://www.spec.org/jbb2015/results/res2019q2/jbb2015-20190314-00414.html for Intel Xeon Platinum 8280 score, and see http://spec.org/jbb2015/results/res2019q3/jbb2015-20190717-00463.html for the AMD EPYC 7772 score. SPEC® and SPECjbb® are registered trademarks of the Standard Performance Evaluation Corporation. See www.spec.org for more information. TCO-1

ENDNOTES

- TCO-02 - Comparison results calculated by AMD based on a hypothetical scenario hosting 2,560 virtual machines on 2-socket Intel Xeon 6242 (32 total cores) based systems versus AMD EPYC™ 7702P (64 total cores) based No Compromise Single Socket Systems, excluding software application costs. Each virtual machine is allocated one core and 8GB of DRAM, resulting in 80 Intel based systems (2,560/32) and 40 AMD EPYC based systems (2,560/64). System Configurations: Intel Xeon based servers in 2U Rack Mount chassis, with (2) Intel® Xeon® Gold 6242 2.8GHz base frequency, 16 cores/32 threads, (16) 16GB RDIMM DDR4 2933MT/s, Dual Rank DIMMs, (1) 480GB SSD SAS Mix Use drive, one dual port 10GbE ethernet adapter, dual hot swap power supplies w/cables, and OEM standard warranty with estimated price of $21,196 each for a total hardware acquisition price of $1,695,680. AMD EPYC based servers include - (40) 1U Rack Mount chassis with (1) AMD EPYC 7702P 2.0GHz base frequency, 64 cores/128 threads, (16) 32GB RDIMM DDR4 2933MT/s, Dual Rank DIMMs, (1) 480GB SSD SAS Mix Use drive, one dual port 10GbE ethernet adapter, dual hot swap power supplies w/cables, and OEM standard warranty with estimated price of $23,696 each for a total hardware acquisition price of $947,840. Estimated System Pricing: AMD Estimated Pricing based on select OEM list pricing as of 7/30/2019 for Intel based systems and AMD projected OEM list pricing as of 8/7/2019 for AMD EPYC based systems. Pricing is an AMD estimate only – actual system pricing will varyby system and by seller. Power cost estimate is an internal AMD estimate based on Intel Xeon based system input power - 498 watts, AMD EPYC-based system input power - 389 watts electricity cost calculated at $0.12/kw/hr with an assumed PUE of 2.0. Intel Xeon power cost/server/year is estimated at $1,047, AMD EPYC power cost/server/year is estimated at $818 for a three year total power cost of $251,280 and $98,040 for an estimated total power savings of 61%. Datacenter space costs include 160 U's for Intel Xeon-based Systems or 4 Rack Cabinets and 40 U's for AMD EPYC-based Systems or 1 Rack Cabinet – AMD internal estimate of Data Center space cost of $19,053 per cabinet per year results in 3 year space costs of $228,636 and $57,159 respectively – a 75% savings. Server Administration cost is calculated with an estimate of $85,795 per server administrator with a ratio of one server administrator per 30 servers resulting in 3 year estimated administration costs of $686,360 for 80 Intel Xeon-based Systems and $343,180 for 40 AMD EPYC-based systems – 50% savings. Licensing costs are calculated using VMware vSphere Enterprise Plus licensed per socket and priced as of 7/28/2019 on www.cdw.com at $3,612 each for a total 3-year cost of $577,920 for (80) Intel Xeon-based 2 socket systems and $144,480 for (40) AMD EPYC No Compromise Single Socket-based Systems. Total estimated 3 Year TCO as a result is $3,439,876 for Intel-based Systems and $1,590,699 for AMD EPYC-based systems resulting in an estimated TCO/VM/YR of $448 and $207 respectively – a 54% savings including virtualization management software licenses but excluding other software costs. This scenario contains many assumptions and estimates and, while based on AMD internal research and best approximations, should be considered an example for information purposes only, and not used as a basis for decision making over actual testing. TCO-2
- TCO-03 - Based on 25% TCO improvement claimed by Twitter in EPYC Horizon presentation 8.7.2019; and AMD estimated TCO improvement of up to and 50% TCO in virtualized infrastructure. TCO-3