Today’s challenges demand innovation

*Full system and stack open innovation required*

*Data holds competitive value*

---

**Moore’s Law**

- Processor Technology
- Firmware / OS
- Accelerators
- Software
- Storage
- Network

**Data Growth**

- 44 zettabytes
- 2010
- 2020
- You are here

**Price/Performance**

- 2000
- 2020

---

© 2017 OpenPOWER Foundation
OpenPOWER, a catalyst for Open Innovation

**Market Shifts**
- Moore’s law no longer satisfies performance gain
- Growing workload demands
- Numerous IT consumption models
- Mature Open software ecosystem

**Open Development**
- Open software, open hardware

**Collaboration of thought leaders**
- Simultaneous innovation, multiple disciplines

**Performance of POWER architecture**
- Amplified capability

**New Open Innovation**
- Rich software ecosystem
- Spectrum of power servers
- Multiple hardware options
- Derivative POWER chips

OpenPOWER is an open development community, using the POWER Architecture to serve the evolving needs of customers

Feeds back … resulting in client choice
OpenPOWER Foundation reach

- **300+ members**
- **100+ OpenPOWER Ready™ products**
- **31 countries**
- **6 continents**
- **20+ System Manufactures**
- **40+ OpenPOWER systems shipping / in development**
- **40+ ISVs**
Growing ecosystem that delivers open innovation across the stack
Cross community engagement drives mutual progress
So what?

What difference does it make?
Evolution to Revolution

Vision
Opening the door, a license to innovate

Execution
Game changing solutions

Adoption
- Hyperscale & Cloud Service Providers
- High Performance Computing & Analytics
- Domestic IT agendas

Incorporated December 2013
OpenPOWER Summit March 2015
OpenPOWER Summit April 2016
Demonstrating rapid progress

INCORPORATION
December, 2013
Incorporation of OpenPOWER Foundation

HIGH PERFORMANCE COMPUTING – U.S.
November, 2014
U.S. Department of Energy chose OpenPOWER design for $325M supercomputing contract

HIGH PERFORMANCE COMPUTING - Europe
June, 2015
UK Government invests £115M in STFC for Watson and OpenPOWER

OPEN COLLABORATION at OpenPOWER Summit
April, 2016
Google & Rackspace announce collaboration on OCP compliant P9 servers optimized for HSDCs

CHINA CLIENT DEPLOYMENT at OpenPOWER China Summit
June, 2016
• Inspur first OpenPOWER servers announced
• Tencent announces deployments on SPARK workloads
• China Mobile deploys Linux OpenPOWER servers

2013  2014  2015  2016

PUBLIC LAUNCH
April, 2014
Public launch of website, members and demonstrations (Tyan & Google planars)

INDUSTRY INNOVATION
March, 2015
Foundation kicks off 1st OpenPOWER Summit
• 50+ member presentations
• 15+ product reveals

SOFTWARE and ACCELERATION at SuperComputing 2015
November, 2015
• 1,900 software apps with support for POWER processors
• 46 OpenPOWER members showcasing at SC15, numerous accelerated computing announcements

OPEN COLLABORATION at OpenCompute Summit
March, 2016
• Cross-industry collaboration with Open Compute Project and HPC Advisory Council
• OpenPOWER Open Compute systems at OCP Summit

IBM PUBLIC LAUNCH – NEW OpenPOWER HPC & COMMERCIAL SERVERS
September, 2016
• NVLink enabled LC server for HPC
• Commercial LC servers for High Density and Big Data/Analytics

5 members  50 members  80 members  115 members  155 members  200 members  260+ members
Accelerates Technology roadmap

**Mellanox Interconnect**
- Connect-IB
  - FDR Infiniband
  - PCIe Gen3
- ConnectX-4
  - EDR Infiniband
  - CAPI over PCIe Gen3
- ConnectX-5
  - Next-Gen Infiniband
  - Enhanced CAPI over PCIe Gen4

**Xilinx FPGAs**
- UltraScale
  - CAPI, PCIe Gen3
- UltraScale +
  - Enhanced CAPI, PCIe Gen3
- UltraScale +
  - CAPI 2.0, PCIe Gen4

**NVIDIA GPUs**
- Kepler
  - PCIe Gen3
- Pascal
  - NVLink
- Volta
  - Enhanced NVLink

**IBM CPUs & Systems**
- POWER8
  - OpenPower CAPI Interface
  - 2015
- POWER8 with NVLink
  - 2016
- POWER9
  - Enhanced CAPI & NVLink
  - 2017
OpenPOWER Technology: 2.5x Faster CPU-GPU Connection via NVLink

GPUs Bottlenecked by PCIe Bandwidth From CPU-System Memory

NVLink Enables Fast Unified Memory Access between CPU & GPU Memories
OpenPOWER Technology: Coherent Accelerator Processor Interface (CAPI)

Typical I/O Model Flow

DD Call → Copy or Pin Source Data → MMIO Notify Accelerator → Acceleration → Poll / Int Completion → Copy or Unpin Result Data → Ret. From DD Completion

Flow with a Coherent Model

Shared Mem. Notify Accelerator → Acceleration → Shared Memory Completion

Easier programming model

Virtual addressing & data Caching

Enables applications not possible on I/O
Hyperscale Data Centers progressing with strong technology underpinnings…

Hosted Customer Offering
Higher workload density means lower cost per workload/customer

Big Data Workloads Running on Spark
2x+ Performance

Multiple Workloads Ported
POWER I/O Subsystem Advantages

Online CRM Systems
Scale and Performance Advantages

Going-Forward Key Elements:
-- Leverage broad set of ODM-developed OpenPOWER Solutions (Co-Sell with IBM):
  - Multitude of potential offerings for HSDCs; Support HSDC preferred supply chain
-- Future Offerings to address key HSDC pain points:
  - High-Density Storage Solutions
  - Machine Learning / Deep Learning
  - Spark / Hadoop
China OpenPOWER ecosystem building…

Fostering partnerships that enable local collaboration

Delivering technologies that meet local needs

China OpenPOWER Summit June 16’ On Stage:

- Tencent – First Internet Data Center to deploy
- China Mobile- First China Telco to deploy
- Inspur- First Tier 1 Server Provider to deliver

First China “local” POWER chip, CP1 Shipping in China local servers

Inspur 2-socket POWER8 Server

Neu Cloud expands Linux local servers

Expanding local software ecosystem
Tencent Smashes Big Data Record with IBM and OpenPOWER

Tencent Cloud, the largest cloud provider in the world, set four world records in the GraySort & MinuteSort categories of the renowned Sort Benchmark Contest, which measures how fast they can sort & organize data, a fundamental Big Data Analytics process – obliterating 2015’s winners at rates of 2x to 5x faster.

• 3.3x & 2.8x greater performance than 2015’s winners in the Indy and Daytona GraySort, respectively.
• 4.8x & 5.0x greater performance than 2015’s winners in the Daytona and Indy MinuteSort, respectively.
• 33x faster performance per node than 2015’s Indy MinuteSort winner.
• 31.6x faster performance per node than 2015’s Daytona MinuteSort winner.

"In the future, the ability to manage big data will be the foundation of successful Internet businesses. Tencent Cloud can provide precise high performance computing to enterprises using minimal time and resources. We will continue to improve the back end technology for our cloud service by optimizing architecture, software and hardware to help global enterprises solve complex business challenges by leveraging hyper-scale computing platforms."

- Zeus Jiang, Vice President of Tencent Cloud and General manager of Tencent's Data Platform Department
HPC demonstrating rapid progress…

- **Complex Design Opportunities**
  - Key Segments: Research Institutes, Commercial and Gov. Enterprises, Universities, Intelligence

- **Commercial Offerings Commencing**
  - Portfolio of GPU-Based Offerings Key to Driving Revenue Acceleration
  - Key Segments: Accelerated DB, Genomics, University Research

**1H16 Results**

- Significant Design Wins: Genomics, Gov Enterprise, University, Research

**2H16 - 2018**

- Accelerating Design Opportunities:
  - 20 Different Countries
  - Commercial and Research

- **Commercial Offerings Gaining Traction**
  - Significant Differentiation in Accelerated DB and Genomics

- **Artificial Intelligence / Machine Learning / Deep Learning**

- NVLink differentiation with GPUs (S822LC for HPC)
What is next?

The era of Cognitive Computing
Introducing PowerAI: Get Started Fast with Deep Learning

Package of Pre-Compiled Major Deep Learning Frameworks

Easy to install & get started with Deep Learning with Enterprise-Class Support

Optimized for Performance To Take Advantage of NVLink

Enterprise Deep Learning Distribution Enabled by High Performance Computing Infrastructure
S822LC for HPC: Artificial Intelligence Differentiation!

- First to market by 3 months with new NVIDIA Pascal GPU
- NVLink between CPU & GPU is POWER-only feature; Not available on Intel CPUs

IBM “S822LC” NVLink Server GA: September 2016

4x P100 GPUs with NVLink to 2x Power8 CPUs

No NVLink between CPU & GPU for x86 Servers

NVLink 2.5x Faster Communication between CPU & GPU Memories

Application Bottleneck due to PCIe between CPU & GPU

NVLink 80 GB/s

PCIe 32 GB/s
PowerAI Deep Learning Software Distribution

Deep Learning Frameworks
- Caffe
- NVCaffe
- IBMCaffe
- Torch
- TensorFlow
- DL4J
- Theano
- Chainer

Supporting Libraries
- OpenBLAS
- Bazel
- Distributed Frameworks
- NCCL
- DIGITS

Accelerated Servers and Infrastructure for Scaling

Cluster of NVLink Servers

Spectrum Scale: High-Speed Parallel File System

Scale to Cloud

Coming Soon
PowerAI on Power8 Minsky Server:
2.2x Faster than Previous Generation x86 Servers

IBM S822LC (Minsky) 20-cores 2.86GHz 512GB memory / 4 NVIDIA Tesla P100 GPUs / Ubuntu 16.04 / CUDA 8.0.44 / cuDNN 5.1 / IBM Caffe 1.0.0-rc3 / Imagenet Data

Intel Broadwell E5-2640v4 20-core 2.6 GHz 512GB memory / 8 NVIDIA TeslaM40 GPUs / Ubuntu 16.04 / CUDA 8.0.44 / cuDNN 5.1 / BVLC Caffe 1.0.0-rc3 / Imagenet Data
TensorFlow on Tesla P100: PowerAI is 30% faster (larger is better)

IBM S822LC 20-cores 2.86GHz 512GB memory / 4 NVIDIA Tesla P100 GPUs / Ubuntu 16.04 / CUDA 8.0.44 / cuDNN 5.1 / TensorFlow 0.12.0 / Inception v3 Benchmark (64 image minibatch)

Intel Broadwell E5-2640v4 20-core 2.6 GHz 512GB memory / 4 NVIDIA Tesla P100 GPUs / Ubuntu 16.04 / CUDA 8.0.44 / cuDNN 5.1 / TensorFlow 0.12.0 / Inception v3 Benchmark (64 image minibatch)
Getting Started with PowerAI

• Install PowerAI on your existing S822LC for HPC server

http://ibm.biz/powerai

• Don’t have an S822LC for HPC?
  • Reference architecture / system requirements are available for the first system shipping with POWER8, NVLink, and Tesla P100 (next slide)
  • Visit IBM POWER HPC Cloud partners to test drive these frameworks on POWER8/P100 today
    • https://power.jarvice.com/ (Nimbix HPC Cloud)
OPF Memberships
Membership Options

Anyone may participate in OpenPOWER. Membership levels are designed for those that are investing to grow and enhance the OpenPOWER community and its proliferation within the industry.

- The OpenPOWER Foundation is a Not-for-profit entity with a Board of Directors and a Technical Steering Committee.
  - Membership levels provide either a default Board of Director position (Platinum) or an opportunity to be elected to the Board (Gold, Silver, and Associate/Academic members). The Bylaws include additional governance detail.
  - Technical Steering Committee is formed from Work group Leads and Platinum members.

- Membership options include Platinum, Gold, Silver, and Associate / Academic memberships
  - Annual fee and dedicated full-time equivalent (FTEs) - verification of FTEs on honor system
  - Contributors, committee, Work group leads and project leads influence Technical Steering Committee
  - Associate / Academic level is not available to corporations

<table>
<thead>
<tr>
<th>Membership Level</th>
<th>Annual Fee $ USD</th>
<th>FTEs</th>
<th>Technical Steering Committee</th>
<th>Board / Voting position</th>
</tr>
</thead>
<tbody>
<tr>
<td>Platinum</td>
<td>$100k</td>
<td>10</td>
<td>One seat per member not otherwise represented</td>
<td>Includes board position Includes TSC position</td>
</tr>
<tr>
<td>Gold</td>
<td>$60k</td>
<td>3</td>
<td>May be on TSC if Work group lead</td>
<td>Gold members may elect one board representative per three gold members</td>
</tr>
<tr>
<td>Silver</td>
<td>$20k</td>
<td>0</td>
<td>May be on TSC if Work group lead</td>
<td>Silver members may elect one board representative for all silver members</td>
</tr>
<tr>
<td>Silver ISV</td>
<td>$0 if ISV is &lt;300 employees</td>
<td>0</td>
<td>May be on TSC if Work group lead</td>
<td>Silver members may elect one board representative for all silver members</td>
</tr>
<tr>
<td>Associate &amp; Academic</td>
<td>$0</td>
<td>0</td>
<td>May be on TSC if Work group lead</td>
<td>May be elected to one community observer, non-voting Board seat</td>
</tr>
</tbody>
</table>

Membership agreement, Bylaws, and IP Rights Policy available for review
<table>
<thead>
<tr>
<th>13 OpenPOWER Work Groups</th>
<th>Collaboration</th>
<th>Work Product</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Application and Domain Focused</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Integrated Solutions WG</td>
<td><strong>Unique needs for specific applications / Solutions</strong></td>
<td>Solution frameworks and optimization guidance</td>
</tr>
<tr>
<td>Personalized Medicine WG</td>
<td></td>
<td></td>
</tr>
<tr>
<td>WG for Physical Sciences</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Machine Learning WG</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Interoperability and Inclusion</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OpenPOWER Ready WG</td>
<td><strong>Ensure ecosystems solutions work together</strong></td>
<td>Ready Definition and Criteria</td>
</tr>
<tr>
<td>Compliance WG</td>
<td></td>
<td>Compliance Specs</td>
</tr>
<tr>
<td><strong>System Interfaces for Innovation</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Memory WG</td>
<td><strong>Defining standards for developing and integrating innovative hardware</strong></td>
<td>OpenPOWER Memory Bus Spec</td>
</tr>
<tr>
<td>Accelerator WG</td>
<td>subsystems**</td>
<td>PSL/AFU Interface Spec, CAPI SNAP</td>
</tr>
<tr>
<td>FRU Service Interface Spec WG</td>
<td></td>
<td>FSI Specification</td>
</tr>
<tr>
<td>Input/Output WG</td>
<td></td>
<td>Porting guide, testing guides, etc.</td>
</tr>
<tr>
<td>25GIO Interoperability Mode WG</td>
<td></td>
<td>25GIO Interoperability Spec</td>
</tr>
<tr>
<td><strong>Fundamental System Architecture</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>System Software WG</td>
<td><strong>HW and SW Stack for System Architecture and Interoperability</strong></td>
<td>ELFv2 ABI, LoPAPR</td>
</tr>
<tr>
<td>HW Architecture WG</td>
<td></td>
<td>ISA Profile, IODA, CAIA</td>
</tr>
</tbody>
</table>

SP010 – Tyan OpenPOWER Customer Reference System
CAPI – Coherent Accelerator Processor Interface
AFU – Accelerator Function Unit
FSI – Field Replaceable Unit (FRU) Service Interface
OPMB – OpenPOWER Memory Bus
ABI – Application Binary Interface
SDK – Software Developer Kit

© 2017 OpenPOWER Foundation
Backup
OpenPOWER Open Software and University Cloud Environments

- UNICAMP Brazil, SA
  http://openpower.ic.unicamp.br/mini
  cloud/index.html

- Oregon State
  North America
  http://osuosl.org/services/powerdev

- Brno University / RedHat, Czech Republic
  https://fit-rhlab.rhcloud.com

- SuperVessel
  USA and China
  www.ptopenlab.com

- HPC Center
  University of Texas - TACC
  3Q, 2015

- IIT Bombay, India
  3Q, 2015

- OpenPOWER Platforms
- Open Stack Software
- University research
- Open Development & Ecosystem Support
Engage in the OpenPOWER community

**Technology and Software Innovators**
- Discuss areas of collaboration and synergy in OpenPOWER.
- Sign up for membership and join a work group.
- Build technical and business relationships.

**Innovators, Integrators, and Partners**
- Deep understanding of workload demands and consumption preferences of end users.
- Team with innovators and end users to drive requirements, engage in specific projects.

**End Users**
- Strategic imperatives and workload demands for performance and cost optimization.
- Require open software and systems with choice and flexibility.
- Engage directly on system design options.

**Develop**
- Collaborative innovations with compelling value

**Deliver**
- Collaborative innovations with compelling value

**Deploy**
- Collaborative innovations with compelling value
According to results shared at the STAC Summit on June 4, an IBM Power8-based system server delivered more than twice the performance of the best-in-class x86 counterpart when running a set of standard financial industry benchmarks. - HPC Wire

We estimate that a physical Power Systems server can support twice as many virtual environments – and therefore double the number of client systems – as a physical x86 server. - Ubuntu

The architectures of the last fifteen or more years are clearly not going to take us past the next several years, so there needs to be a step change and there are lots of options but for the workloads we’re looking at ahead, we are confident about this architecture. - Cliff Brereton, STFC

I still see the POWER8 processor as one of the most powerful processors in the industry – and with the accelerators being developed in the OpenPOWER ecosystem, it is going to be hard for other processors (including Intel and ARM silicon) to match some of the acceleration speeds that will be achieved by POWER8 and successive generations. - Clabby Analytics

Both the current results and future potential are so promising that we are preparing to build an OpenPOWER-based, Open Compute platform. And it will run OpenStack services. - Aaron Sullivan, Senior Director & Distinguished Engineer, Rackspace

"People ask me if we would switch to Power, and the answer is absolutely," Urs Hölzle, Google, said emphatically and unequivocally. “Even for a single generation.” - The Platform

The $320 million deal [U.S. Department of Energy's Sierra and Summit supercomputers] is a validation of sorts of IBM’s recent strategic shift to open up its POWER computing architecture for license and use by other companies looking for alternatives to an Intel-controlled world. - Forbes

While other vendors are struggling to establish themselves in China, IBM seems to have found the secret with OpenPOWER. Not only does this seem to be cementing IBM inside the tough Chinese technology market but the benefits, such as SuperVessel, are now starting to be felt across the whole of IBM. - Enterprise Times
With 50+ Hardware reveals on display, laid out across 6 tables, it was challenging getting all in one picture:
28 Systems
19 I/O adapters
6 Switches
5 I/O Expansion drawers
1 Watercooling solution
1 CPU (CP1)

"The search giant [Google] said on Wednesday that, along with cloud computing company Rackspace, it’s co-developing new server designs that are based on IBM chip technology." –Fortune

"'The Power architecture is now fully supported across our toolchain,' said Maire Mahony, a hardware engineering manager at Google and director of the OpenPower Foundation.” –Seeking Alpha

"Google also said it’s developing a data center server with cloud-computing company Rackspace Hosting Inc. that runs on a new IBM OpenPower chip called Power9, rather than Intel processors that go into most servers. The final design will be given away through Facebook Inc.’s Open Compute Project, so other companies can build their data center servers this way, too." –Bloomberg