

# IBM PowerHA System Mirror for i

HA Solutions for the 21<sup>st</sup> Century

April 2015

Steven Finnes



## Session objectives

Understand the basics of the PowerHA on IBM i offering

Understand clustering verses VM restart (full system replication)

Discuss the PowerHA strategic roadmap

Brief discussion on HA for Linux on Power

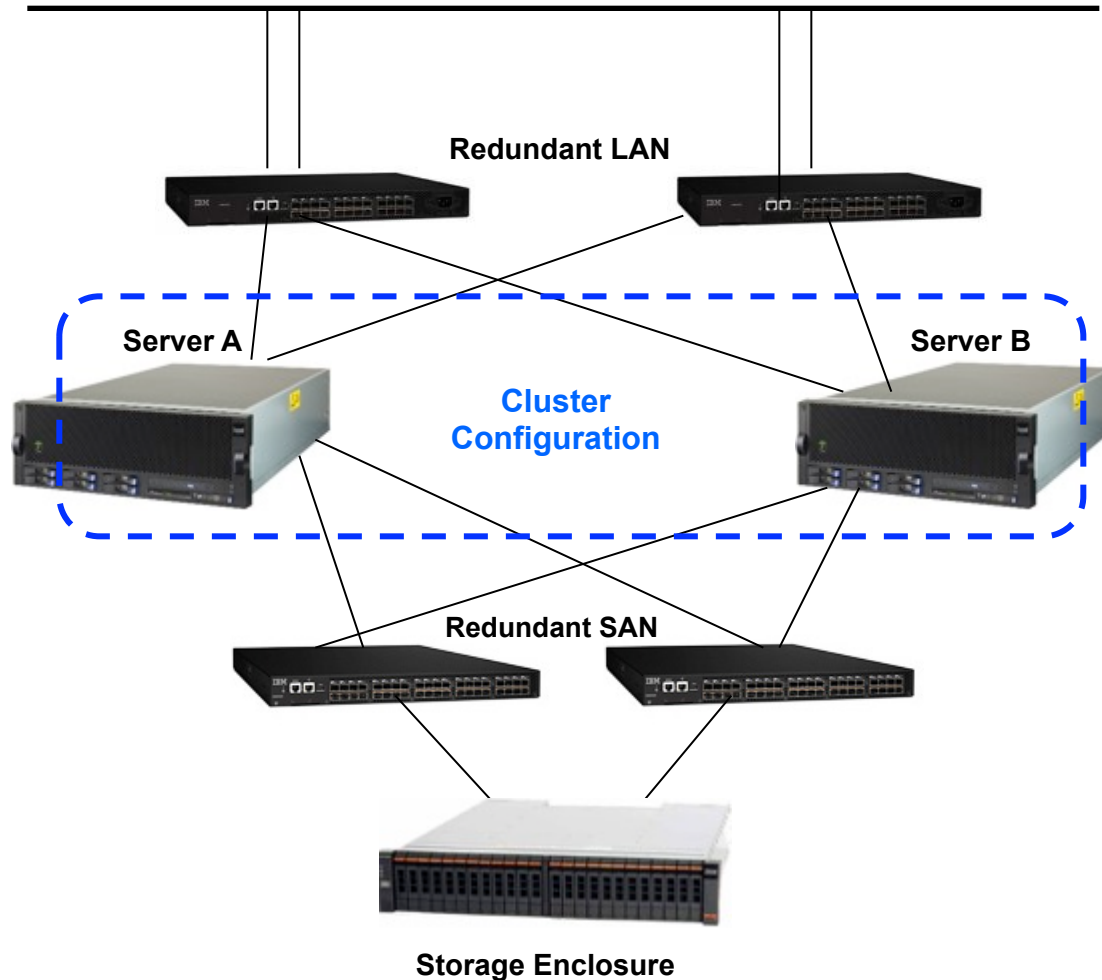
Note that there are topics that I will cover that are not in the handout

## PowerHA for i

- ✓ Comprehensive HA/DR solutions for multi-site or data center
- ✓ Shared storage clustering technology
- ✓ Provides automation for ease of use
- ✓ Implemented in IBM i, SLIC, and storage management
- ✓ Data replication is provided by IBM storage
- ✓ FlashCopy enables off line tape backup
- ✓ Designed for regular role swap operations and automated failovers
- ✓ Developed and supported by IBM



# PowerHA SystemMirror Shared Storage Cluster



## Benefits:

- Automated Fallover
- Non disruptive upgrades PTFs
- Application Monitoring
- Implemented in SLIC
- Event / ERROR Notification
- GUI, CL mgmt

## Different Failure Types:

- IP Loss Detection
- Loss of Storage
- Application Interruption
- Server Crash
- Loss of Power

## Configuration Options

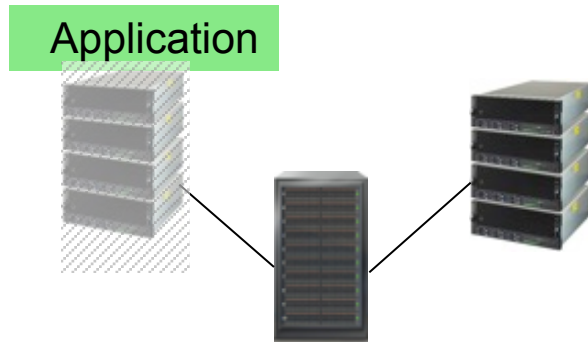
- Active / Passive
- Mutual Takeover

## Solution Approach for High Availability (HA)

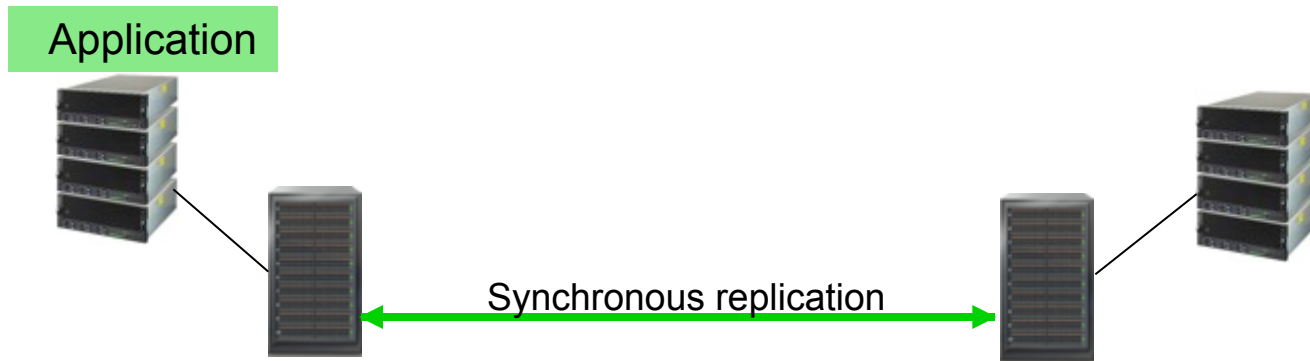
- Requirements
  - Near continuous application service
  - Recovery Time Objective (RTO) measured in minutes
  - Recovery Point Objective (RPO) is zero (no data loss)
  - Eliminate affects of planned outages including hardware and software maintenance (upgrades, PTF apply etc)
- Solution Strategy:
  - PowerHA with switchable LUNs
  - PowerHA with geographic mirroring synchronous mode
  - PowerHA with Metro Mirror (synchronous replication)



# PowerHA clustering solutions for high availability



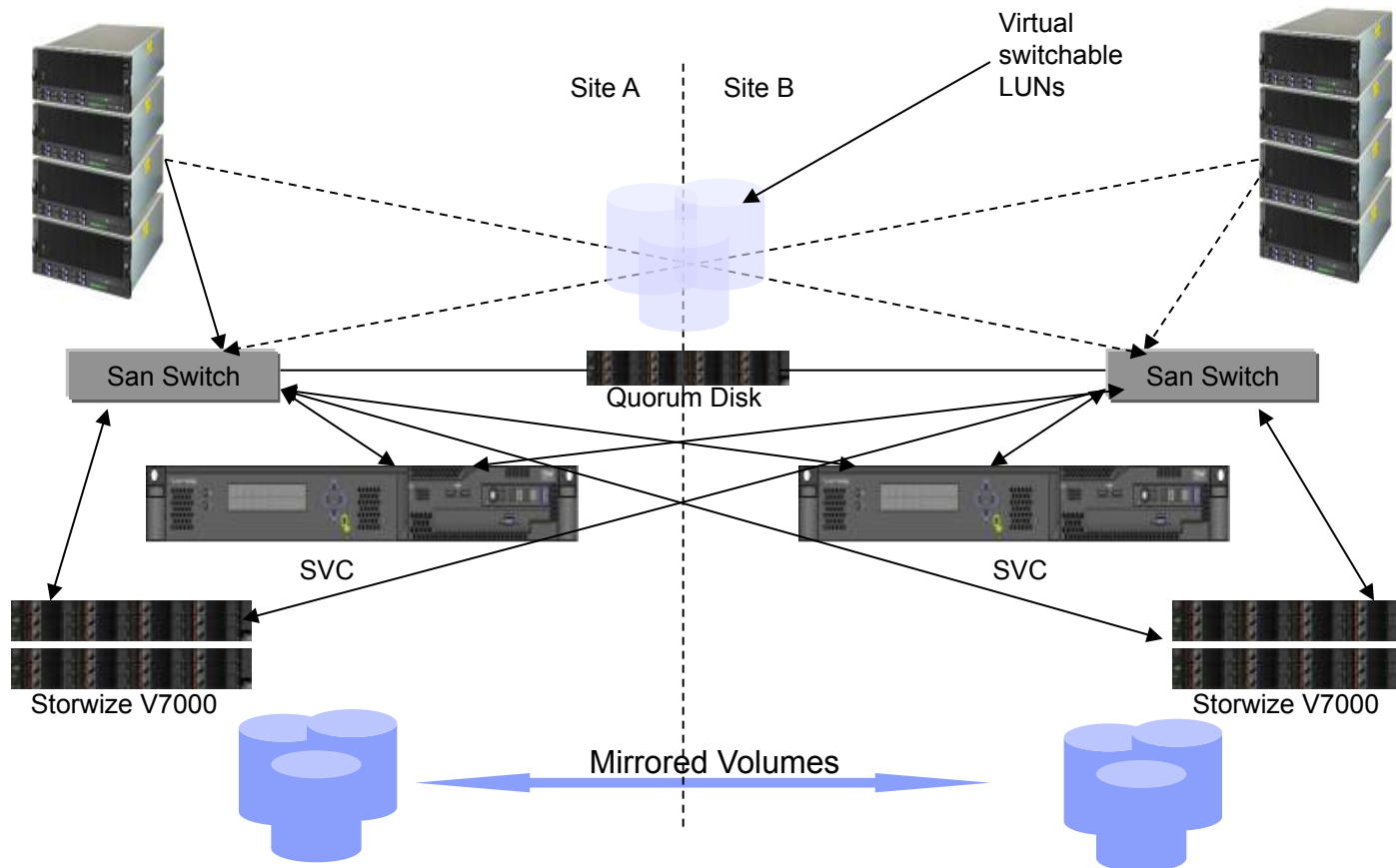
Example: high availability configuration



Example: high availability configuration



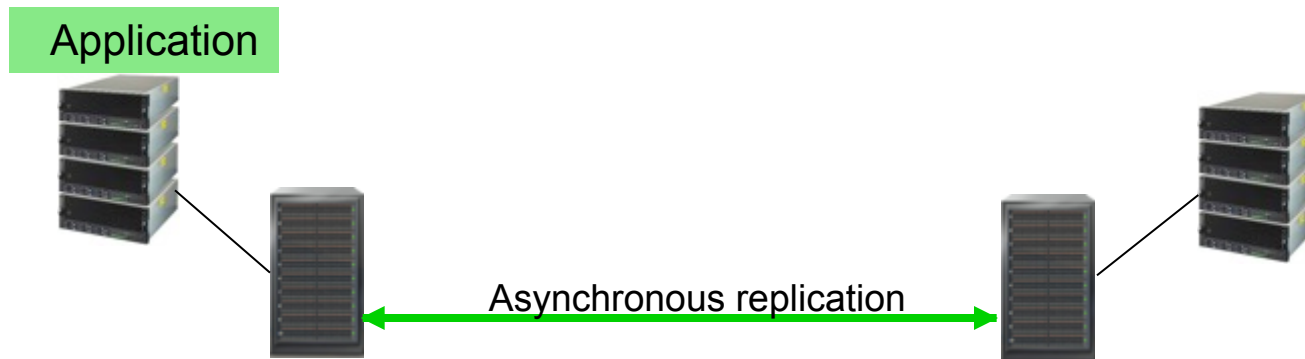
# PowerHA SVC stretch cluster



- PowerHA Standard Edition (appears as a switchable LUN cluster)
- Site A and Site B volumes are mirrored by the SVC (under the covers)
- Solution provides cross-campus continuously available storage in a PowerHA cluster

## Solution Approach for Disaster Recovery (DR)

- Requirements
  - Recover operations at a remote location due to site outage
  - Recovery Time Objective (RTO) measured in hours
  - Recovery Point Objective (RPO)  $\geq$  zero (may be minutes)
  - Simplified disaster recovery compliance testing
  
- Solution Strategy:
  - PowerHA with Geographic Mirroring Async Mode
  - PowerHA with Global Mirroring (asynchronous storage replication)



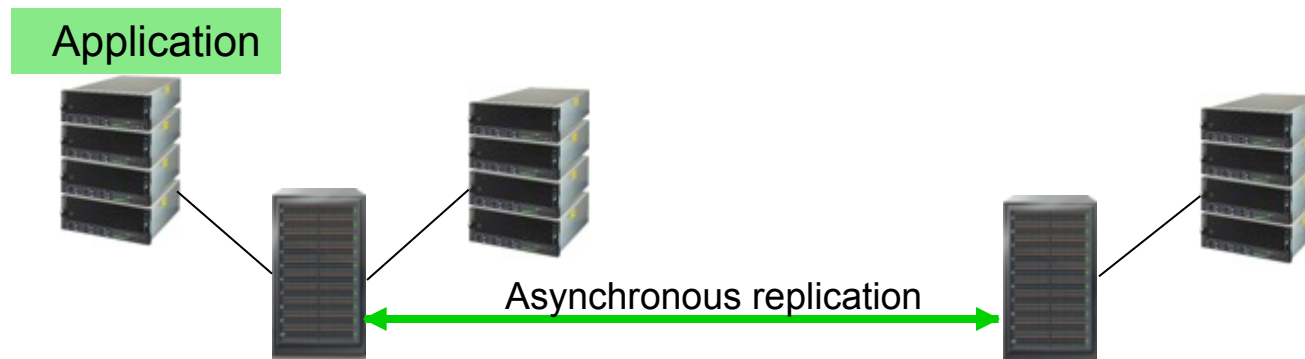
Example: disaster recovery configuration



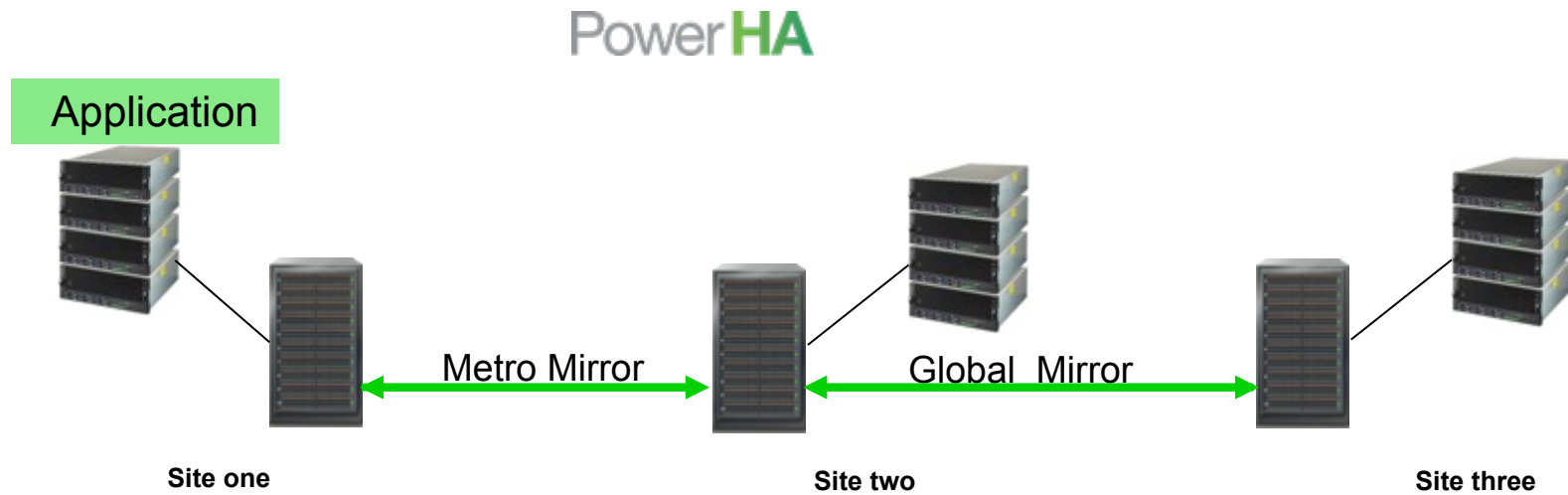
## Unified Multi-Site HA/DR Solution



- Requirements
  - Multi-site configurations
  - Data center/campus component for HA
  - Multiple site configuration for DR
- Solution Strategy:
  - Unified clustering solution for data center & multi-site resiliency
  - PowerHA SystemMirror Enterprise Edition



# Three site clustering solutions for DR and/or HA



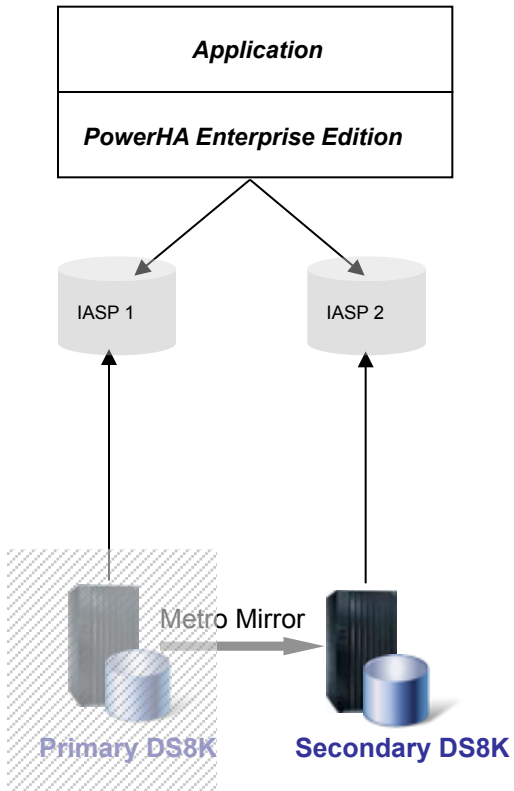
Metro Global Mirror (MGM) cluster



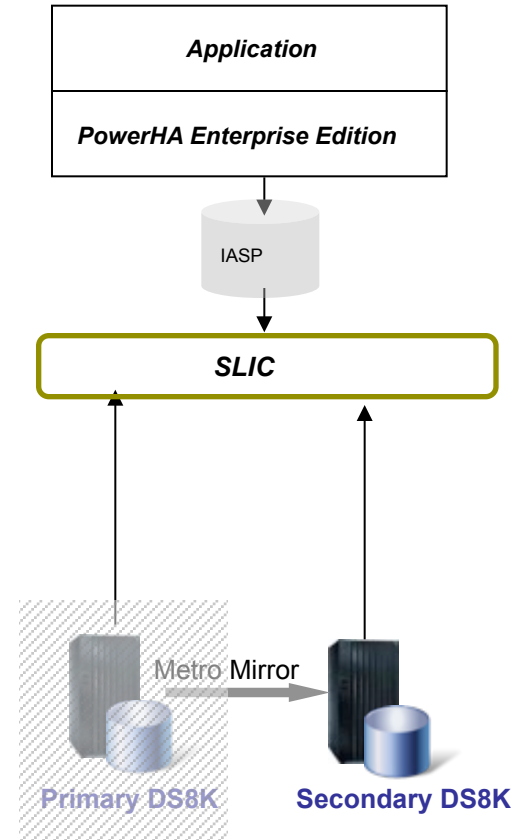
# PowerHA HyperSwap clustering technology (V7.2 plans\*)

Applications halts while cluster switches  
 - Storage resumes after cluster switch

Applications continue to use the IASP  
 - Storage switched via SLIC

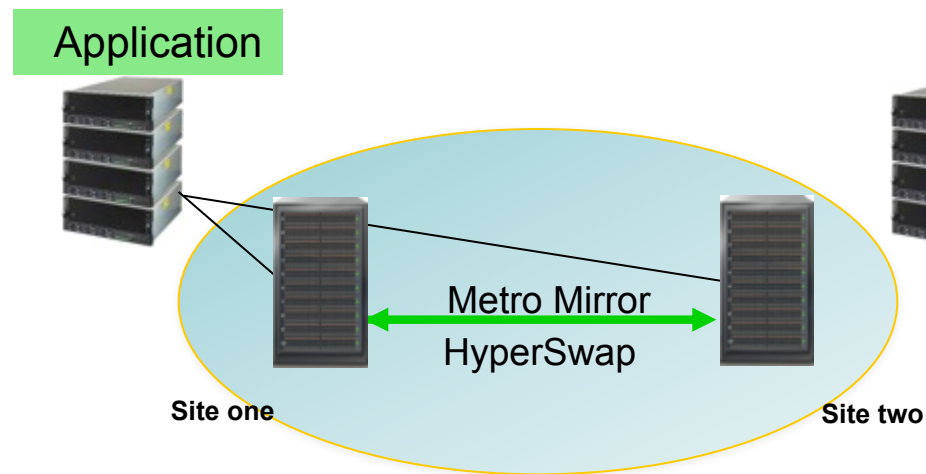


Traditional Metro Mirror Cluster



HyperSwap Cluster

# Two site single system PowerHA solution with HyperSwap

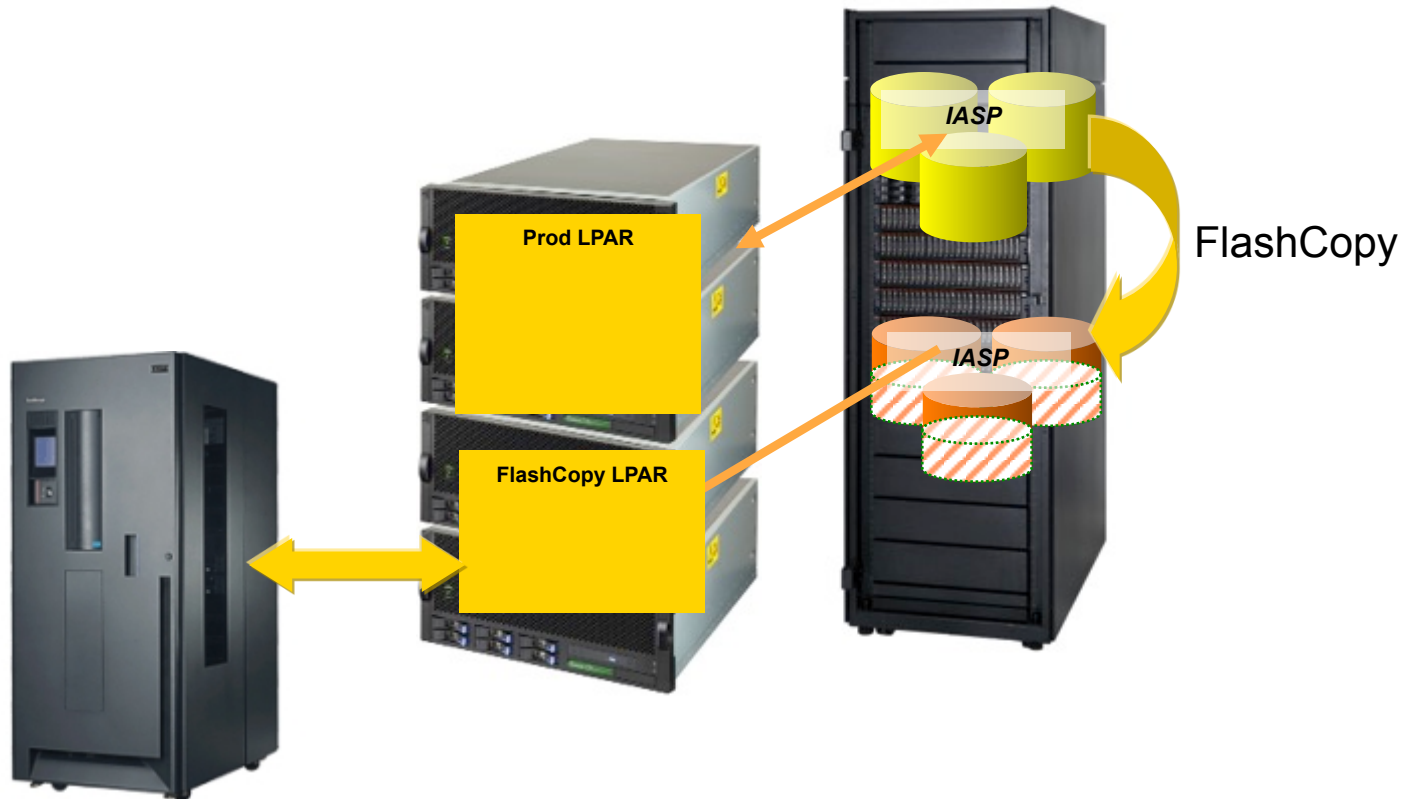


## PowerHA HyperSwap Cluster

- PowerHA Express Edition manages a DS8K HyperSwap config
- Can be used with LPM
- Available now

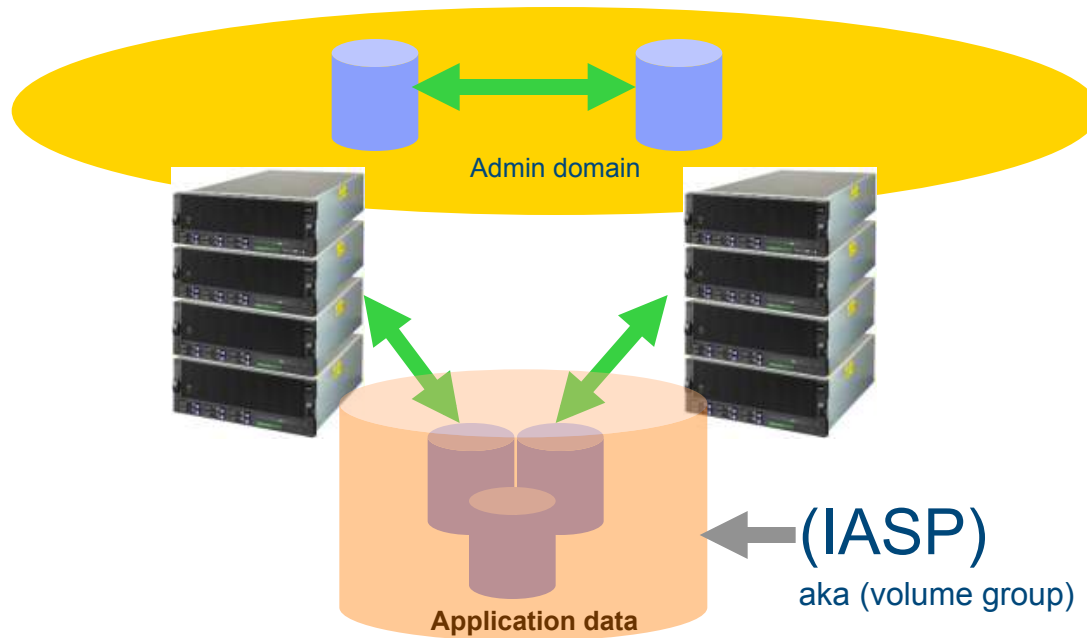


# ELIMINATE the backup window with FlashCopy



- FlashCopy with PowerHA essentially eliminates your backup window
- Full system flash copy is also an option though not as seamless as with IASPs

# PowerHA basic concepts

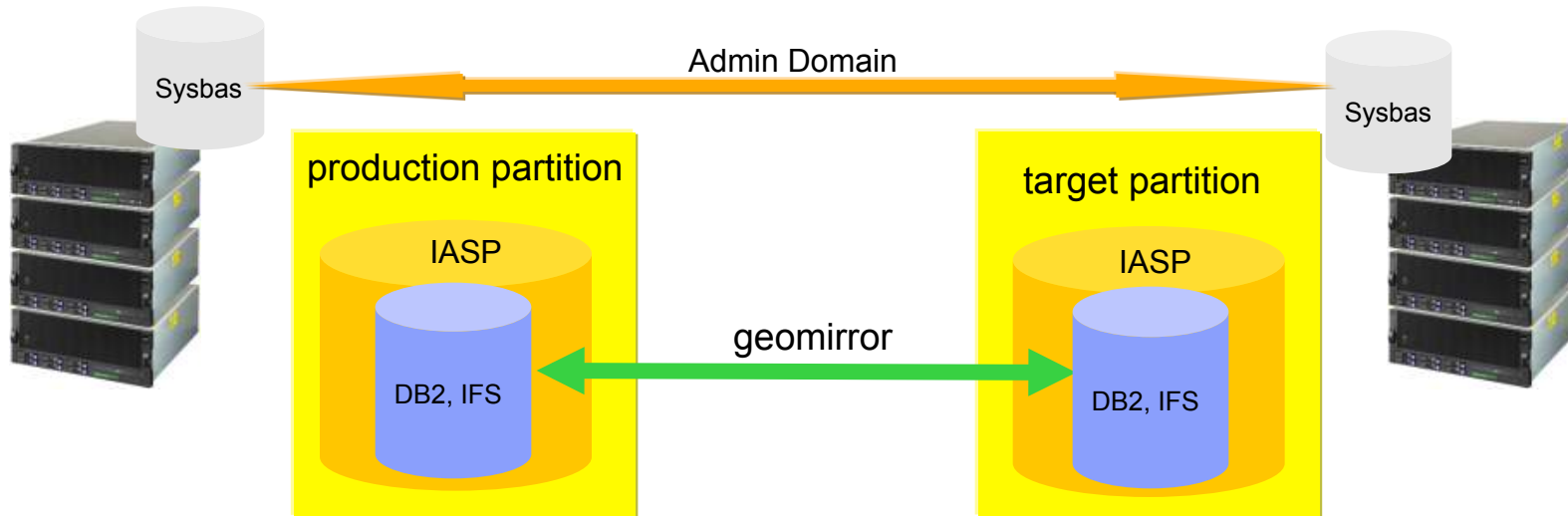


- **PowerHA SystemMirror creates and manages a shared storage cluster topology**
  - IASP volume group hosts the DB, IFS data
  - Admin Domain manages the sysbas data
  - Note that the foundational topology does not involve replication

## What about IT shops with only one or two processors ?

- PowerHA with geographic mirroring is the answer
  - Typically used by shops with under 4 Tbytes and internal disk
  - IASP size driven by resync time requirements
  - After an unplanned outage the target data is replicated back to the source therefore the larger the IASP the longer the resync time
- Geomirroring is IBM i mirroring of the IASP data over IP
  - IBM i storage management sends the memory pages to both the remote and local server either synchronously or asynchronously
  - Synchronous distance is typically under 30 or 40 KM but distance is driven by application response time requirements

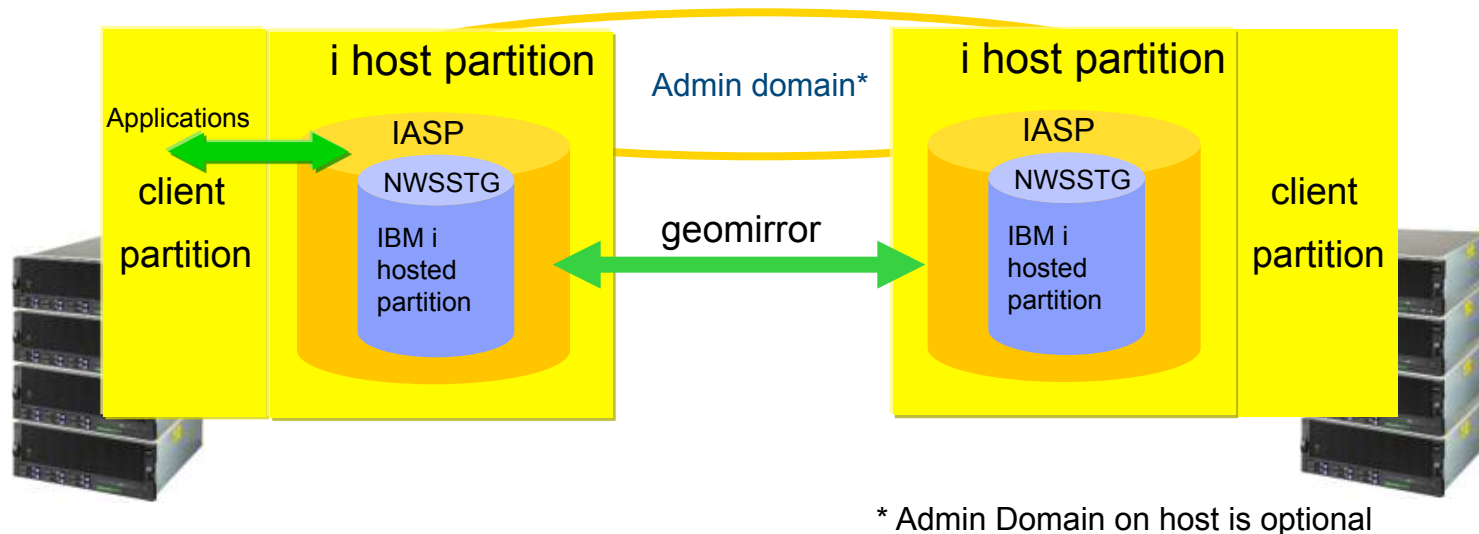
# PowerHA – geomirroring – HA/DR clustering



- PowerHA geomirror cluster (typically with internal disk and < 4 Tbytes )
- Complete HA/DR coverage for all outage types (hardware, middleware, operator error)
- Off line back-up followed by source side /target side tracking change resynchronization
- Synchronous mode up to 40 KM, production and target always identical
- Asynchronous mode unlimited distance, production and target ordered and consistent



# PowerHA – geomirroring – i hosting i remote partition restart for DR



- Non-cluster PowerHA configuration, full system replication
- IBM client placed into a network storage space which is placed into an IASP
- Guest and host partition must be shut down before remote host and client can be restarted
- Benefit: easy to set up (in production world wide today, Express Edition not required)
- Limitation: no heart beating, can't do concurrent OS upgrades
- Unplanned failover requires an abnormal IPL of target

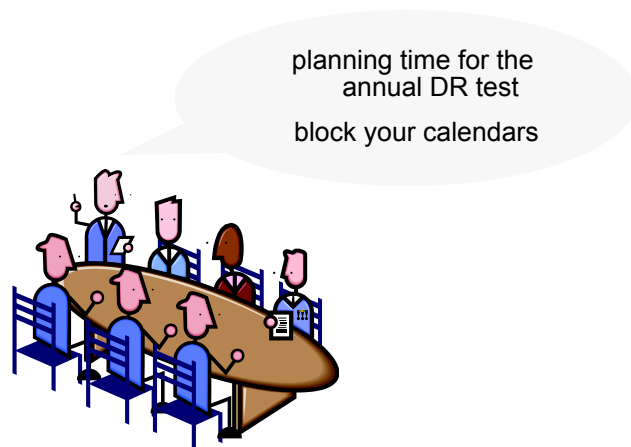
# IBM i HA/DR Customer Profile

## TRADITIONAL

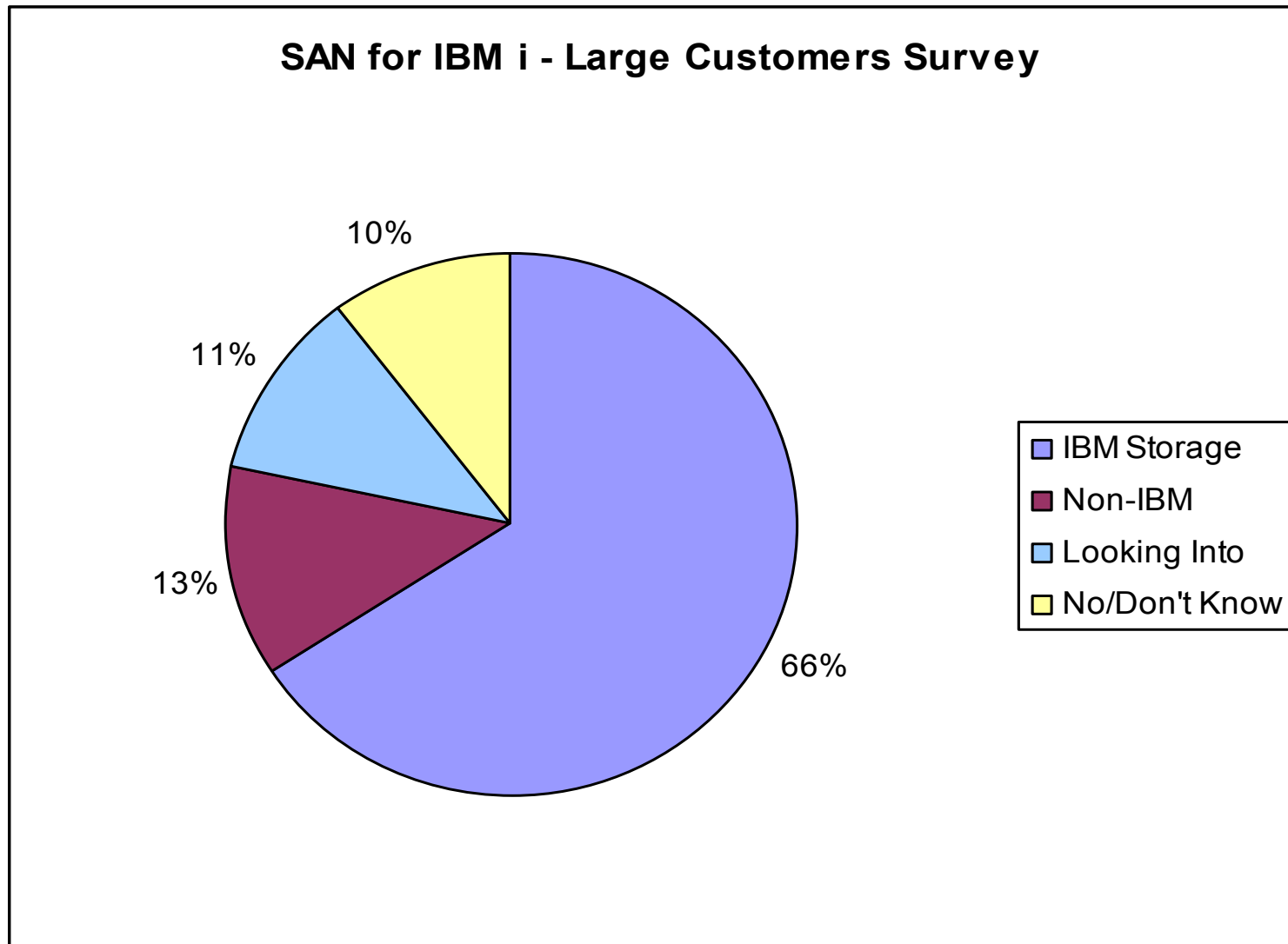
- Internal Disk
- Logical replication
- CBU with multiple cores licensed for replication workload
- Role-swap = seldom if ever
- Backup window = ranges up to a few hours
- TCO = staffing, SWMA, upgrade charges,
- Staffing = dedicated specialist
- Outage management = complex
- Support = vendor

## PowerHA

- IBM Storage or (Internal Disk with geomirroring)
- Switchable LUNs, Metro or Global Mirroring
- CBU with only 1 core licensed
- Role-swap = daily, weekly, monthly, quarterly
- Backup window = minutes
- TCO = minimal staffing, SWMA
- Staffing = minutes/week
- Outage management = simple
- Support = IBM



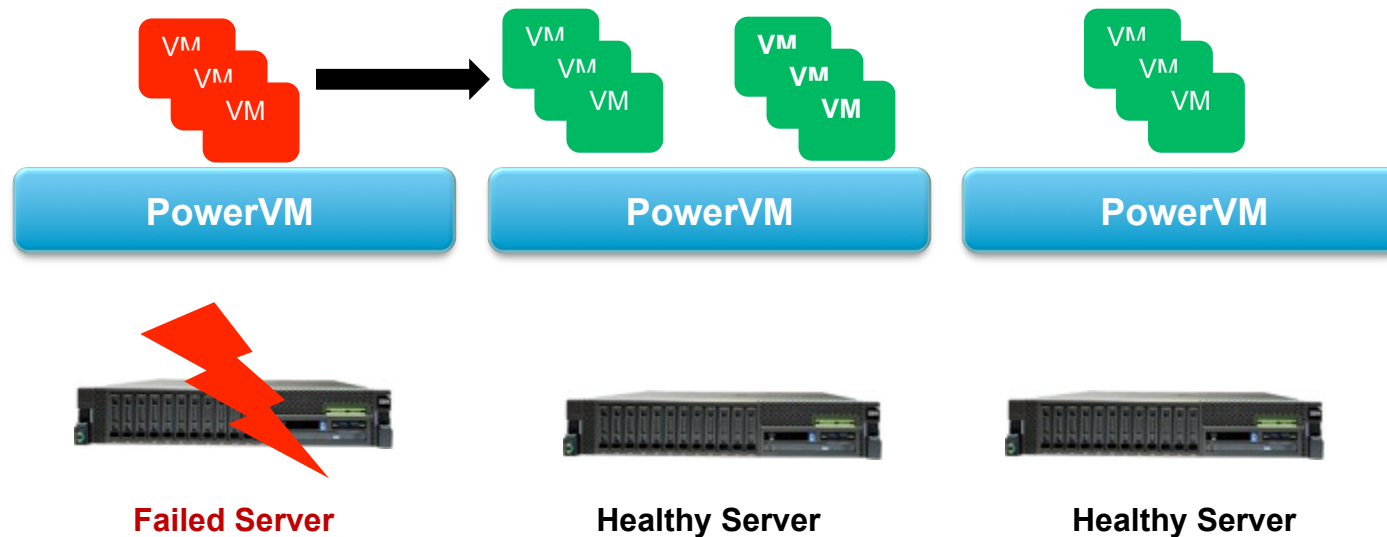
# Large Users Survey: The Move is On



## PowerVC Managing PowerVM Remote VM Restart

PowerVC Remote VM Restart enables starting VMs from a failed host on another server

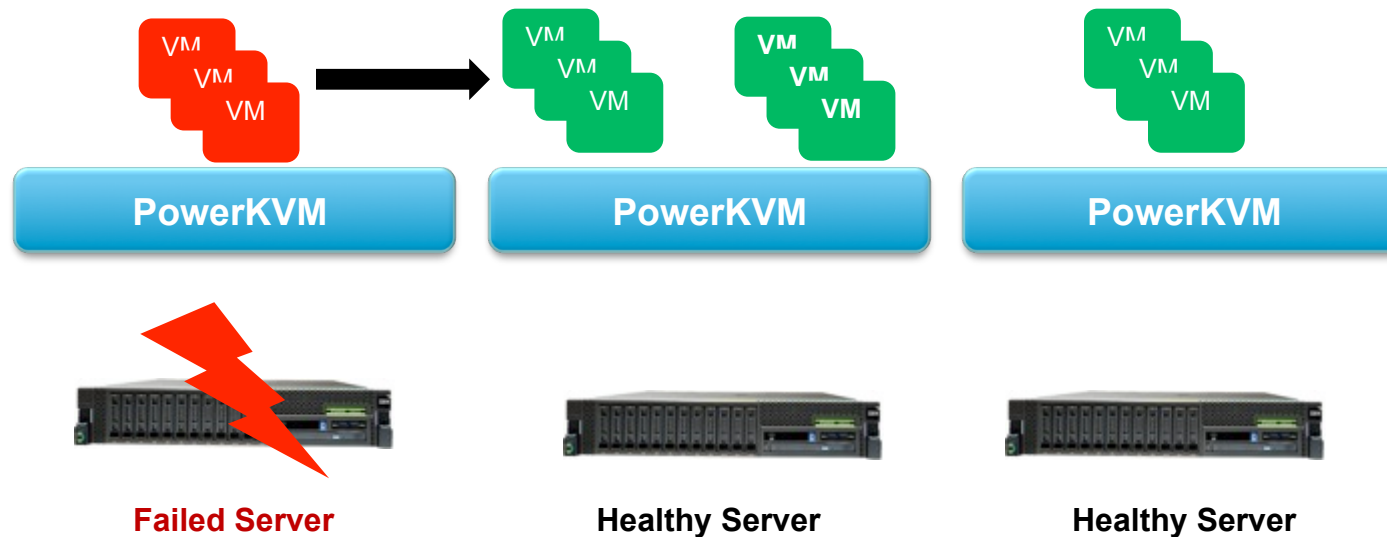
- **Accelerate recovery time** for a failed Power Server
- VMs are automatically rebooted on new servers
- Works with **AIX, IBM i or Linux** VMs
- Requires a human decision to perform restart using PowerVC
- Host Group policy controls VM placement upon restart



## PowerVC Managing PowerKVM Remote VM Restart

PowerVC Remote VM Restart enables starting VMs from a failed host on another server

- **Accelerate recovery time** for a failed Power Server
- VMs are automatically rebooted on new servers
- **Works with any Linux VM type**
- Requires a human decision to perform restart using PowerVC
- Host Group policy controls VM placement upon restart

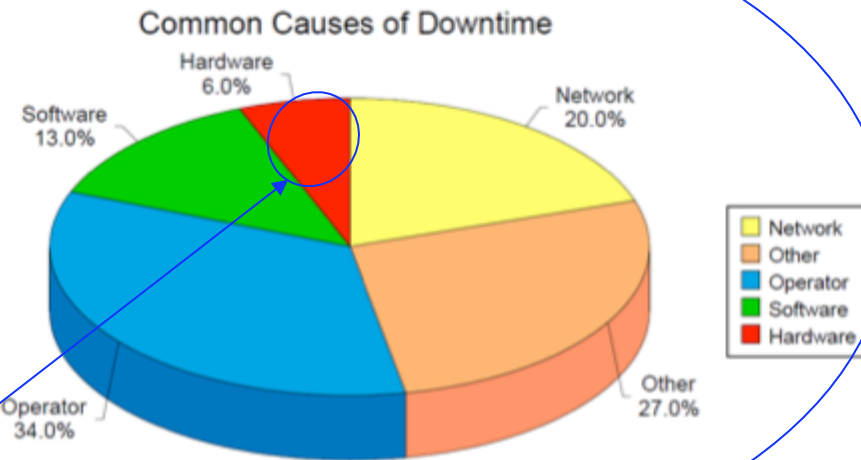


## PowerVC Restart vs PowerHA Comparison

| Capability                                   | PowerVC          | PowerHA          |
|--|------------------|------------------|
| PowerVM                                      | ✓                | ✓                |
| PowerKVM                                     | ✓                | ✗                |
| Source & Target System can be separate HMC s | ✗                | ✓                |
| Graphical Management UI                      | ✓                | ✗                |
| Local or Remote Recovery                     | Local only       | Local and Remote |
| AIX, IBM i, Linux                            | ✓, ✓, ✓          | AIX, IBM i       |
| Hardware support                             | POWER8, fw 8.20↑ | POWER 6,7,8      |
| Complexity                                   | Low              | Medium           |
| PowerVM EE Required                          | Yes              | No               |
| Pricing                                      | Per core         | Per core         |

# Common Causes of Downtime and Classification

|         |   |
|---------|---|
| Group 1 | Predictive + failures of hardware.<br>Eg: (CPU & Memory)  |
| Group 2 | <ul style="list-style-type: none"> <li>▪ Network/Storage Adapter failures</li> <li>▪ External Errors<br/>(Eg: Storage errors, Switch errors etc)</li> </ul> |
| Group 3 | Critical OS events (Eg: Volume failures, Critical File system failures, etc)  |
| Group 4 | Software/Middleware failures and Operator Errors  |
| Group 5 | Site Outages  |



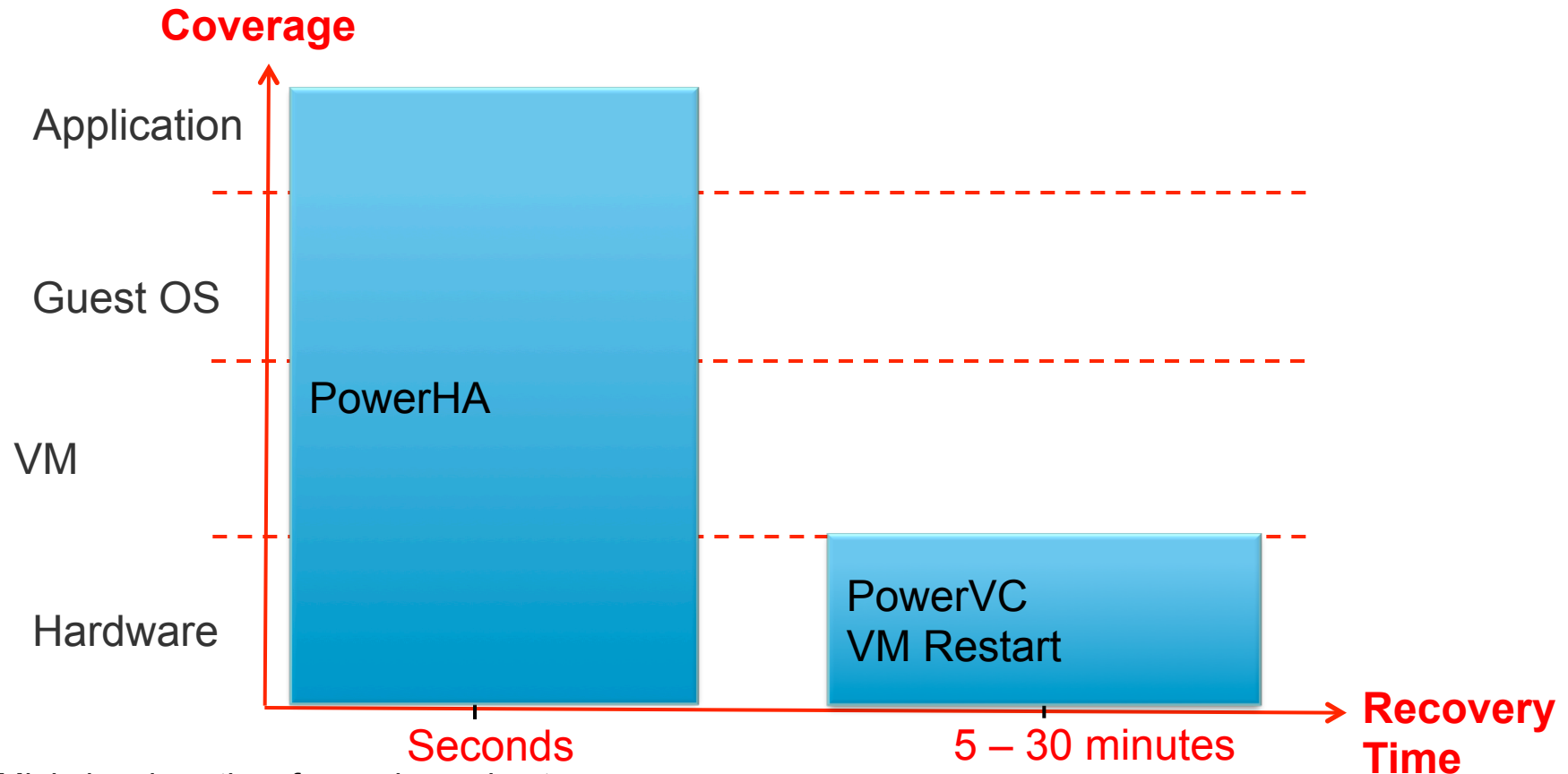
Source: The Standish Group International, Inc.

Hypervisor HA Technology Coverage

- Remote VM Restart
- Active Memory Mirroring

Clustering Coverage

# Clustering and Power Virtualization Technology HA Coverage



Minimize downtime for unplanned outages

- PowerHA provides complete coverage and lowest recovery times
- PowerVC Remote VM Restart provides additional coverage for Server Hardware Issues.



## Basic DR Characteristics Clustering verses DR VM Restart

|                                   | Cluster technology (in band)                 | DR Remote VM Restart (out of band)     |
|-----------------------------------|--|--|
| Error coverage                    | Comprehensive<br>(Monitoring inside the VM ) | Limited<br>(Monitoring external to VM) |
| Workload failover/startup time    | Failover + workload startup (mins)           | Reboot of VM (15 Minutes or more)      |
| Administration                    | Network, Storage, Security, etc              | Minimal                                |
| Deployment Effort                 | Inside the VM (requires skill)               | Outside the VM (simple)                |
| Cost of acquisition               | Redundant cores and LPPs                     | Redundant cores                        |
| Outage Types Covered              | All  | Primarily CEC                          |
| Application/Middleware Resiliency | Independent OS per LPAR                      | Single OS image                        |
| Workload type suitability         | Mission Critical                             | Mission Critical                       |

- General Characteristics
  - Cluster technology monitors events inside of the VM
  - Cluster technology requires redundant licensing for the DR site
  - VM restart technology is generally relatively easy to set up and use
  - DR remote VM restart enables simple compliance testing and minimal redundant licensing

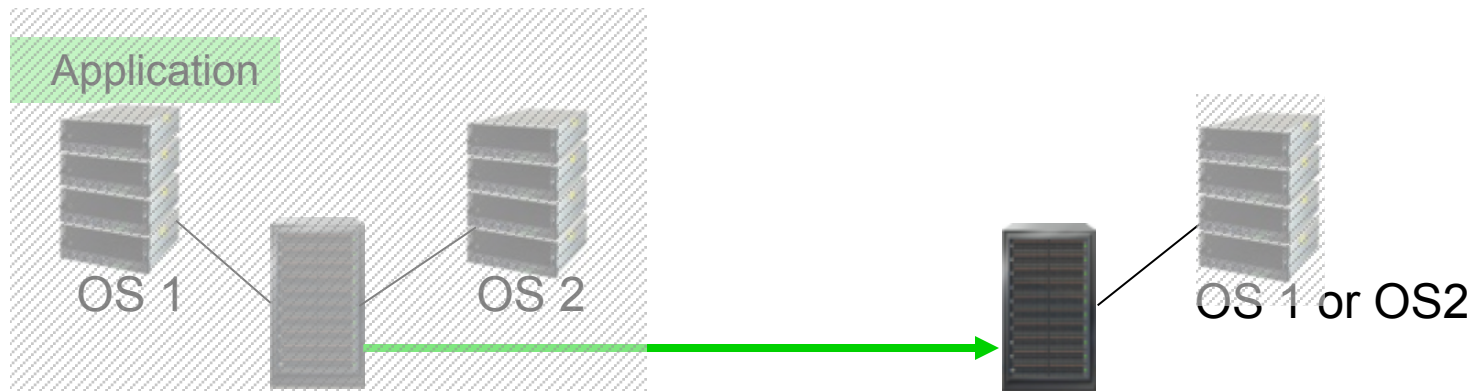
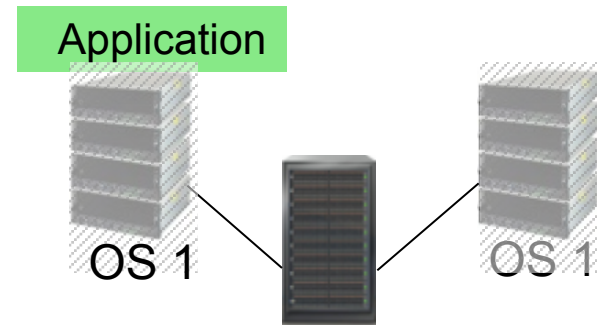
# VM Restart (out-of-band) HA/DR

## VM restart for the data center example

- Single image of OS and application
- External Ksys (out of band) provides automation

## Two-Site VM restart example

- In-band cluster management for the data center
- Out of band VM restart to DR site



---

# PowerLinux Solutions for HA Overview

- IBM
  - Tivoli System Automation for Mutiplatform (TSA-MP)
    - Supports Red Hat and SUSE
  - DB2 HADR
    - Supports Red Hat and SUSE
  
- SUSE
  - Linux Enterprise High Availability Extension
    - <https://www.suse.com/products/highavailability/>
  
- NEC
  - Express Cluster
    - Supports Red Hat and SUSE
  - <http://www.nec.com/en/global/prod/expresscluster/en/overview/index.html>
  
- Ubuntu
  - High Availability Cluster Solutions for Ubuntu 14.04 on Power
    - Supports Red Hat and SUSE
  - [https://www.ibm.com/developerworks/community/wikis/home?lang=en#!/wiki/W51a7ffc4dfd\\_4b40\\_9d82\\_446ebc23c550/page/High%20Availability%20Cluster%20Solutions%20for%20Ubuntu%2014.04%20on%20Power](https://www.ibm.com/developerworks/community/wikis/home?lang=en#!/wiki/W51a7ffc4dfd_4b40_9d82_446ebc23c550/page/High%20Availability%20Cluster%20Solutions%20for%20Ubuntu%2014.04%20on%20Power)

---

## PowerLinux Solutions for HA Overview

- Linbit
  - High availability and disaster recovery (official support pending)
    - Supports RedHat and SUSE
  
- Storeix
  - System Backup for IBM PowerLinux
  - supports Red Hat and SUSE

<http://www-304.ibm.com/partnerworld/gsd/solutiondetails.do?&solution=17057&lc=en>
  
- HAO **for** RHEL on p Systems. Developed and supported by Sine Nomine ... the High-Availability Option (HAO) **for** Red Hat Enterprise **Linux** on p Systems provides software and support tooling to implement ... requirements. SNA engineers can assist with implementing **HA** support **for** many products as part of separate services engagements. ...  

[HAO for RHEL on p Systems \(POWER\)](#)

## IBM i CBU with PowerHA Voucher

- CBU + PowerHA SystemMirror 7.1 for IBM i
  - Sell them together
  - Three days of services included
  - Fast start to better business continuity



Don't forget about PowerCare



# PowerHA SystemMirror 7.2 for i

| PowerHA SystemMirror for IBM i    |       | Express Edition               | Standard Edition              | Enterprise Edition          |
|-----------------------------------|-------|-------------------------------|-------------------------------|-----------------------------|
| Offering Focus                    |       | Data Center CEC HA (per core) | Data Center App HA (per core) | Multi Site HA/DR (per core) |
| Small Tier<br>Blade & Entry Power | Scale | \$2,000                       | \$2,500                       | \$3,250                     |
| Medium Tier<br>Mid-range Power    |       | \$2,800                       | \$3,500                       | \$5,000                     |
| Large Tier<br>Enterprise Servers  |       | \$3,600                       | \$4,500                       | \$6,500                     |

US list prices for example only, prices vary by geo

- **5770 HAS Base PID – no keys, no function**
- **Express Edition data simple center solution**
  - PID 57770 HAS
  - Option 3
- **Standard Edition data center solution**
  - PID 5770 HAS
  - Option 2
- **Enterprise Edition multi-site solution**
  - PID 5770 HAS
  - Option 1



## PowerHA Tools for IBM i – Lab Services

| PowerHA Tools for IBM i   | Capability  | Benefit   | DS8000 | Storwize | Internal |
|---|---|---|--------|----------|----------|
| <b>Smart Assist for PowerHA on IBM i</b>  | Provides operator commands and scripts to supplement PowerHA installation and ongoing operations for IASP enabled applications.   | Simplifies deployment and ongoing management of high availability for critical IBM i applications.  | Yes    | Yes      | Yes      |
| <b>IASP Copy Services Manager</b><br>(Automated recovery with faster IASP-level vary on, no system IPL) |   |   |        |          |          |
| <b>Flashcopy</b>  | Automates Flashcopy of IASP for daily off-line backup with seamless BRMS integration.   | Increases application availability by reducing or eliminating backup window for routine daily backups.  | Yes    | Yes      |          |
| <b>LUN-level Switching</b>  | Simplifies deployment and automates switching of an IASP between IBM i cluster nodes in one data center.  | Enables a business continuity manager to provide a simple, single site HA solution.   | Yes*   | **       |          |
| <b>Metro Mirror or Global Mirror</b>  | Simplifies initial deployment and automates ongoing server and storage management of two-site Metro Mirror or Global Mirror HA or DR solutions. Requires IASP enabled applications..  | Enables a business continuity manager to provide seamless operation of integrated server and storage operations for two-site high availability or disaster recovery.                      | Yes    |          |          |
| <b>Metro Global Mirror (MGM)</b>  | Extends PowerHA functionality to provide three-site server/storage replication solution combining Metro Mirror for HA with Global Mirror for DR. Requires IASP enabled applications and IBM Tivoli Productivity Center – Replication (TPC-R). | Enables a business continuity manager to further lower business risk and maximize business resilience for highly critical business applications that require three-site HA/DR protection. | Yes    |          |          |
| <b>Full System Copy Services Manager</b><br>(Automated recovery, requires full system IPL)              |   |   |        |          | XIV      |
| <b>Flashcopy</b>  | Automates full system Flashcopy for daily off-line backup with integrated support for BRMS without IASP-enabled applications.   | Increases application availability by reducing or eliminating backup window for routine daily backups. Enables an entry solution while planning IASP enablement.                          | Yes    | Yes      | Yes      |
| <b>Metro Mirror or Global Mirror</b>  | Simplifies initial deployment and automates ongoing server and storage management of two-site Metro Mirror or Global Mirror HA or DR solutions. without IASP-enabled applications.  | Enables a business continuity manager to provide seamless operation of integrated server and storage operations for HA or DR. Enables an entry solution while planning IASP enablement.   | Yes    |          |          |

\*DS8000 support available with PowerHA Tools for IBM i 6.1 or earlier, included in PowerHA SystemMirror 7.1 \*\*V7000 support included with PowerHA 7.1 TR6

## IBM Lab Services Offerings for PowerHA for IBM i

| PowerHA Service Offering                                 | Description   |
|--|---|
| IBM i High Availability Architecture and Design Workshop | An experienced IBM i consultant will conduct a planning and design workshop to review solutions and alternatives to meet HA/DR and backup/recovery requirements. The consultant will provide an architecture and implementation plan to meet these requirements.  |
| PowerHA for IBM i Bandwidth Analysis                     | An experienced IBM i consultant will review network bandwidth requirements for implementing storage data replication. IBM will review I/O data patterns and provide a bandwidth estimate to build into the business and project plan for clients deploying PowerHA for IBM i.   |
| IBM i Independent Auxiliary Storage Pool (IASP) Workshop | An experienced IBM i consultant will provide jumpstart services for migrating applications into an IASP. Training includes enabling applications for IASPs, clustering techniques, plus managing PowerHA and HA/DR solution options with IASPs.   |
| PowerHA for IBM i Implementation Services                | An experienced IBM consultant will provide services to implement an HA/DR solution for IBM Power Systems servers with IBM Storage. Depending on specific business requirements, the end-to-end solution implementation may include a combination of PowerHA for IBM i and/or PowerHA Tools for IBM i, plus appropriate storage software such as Metro Mirror, Global Mirror and/or Flashcopy. |

**For more information on PowerHA Tools for IBM i offerings and services, contact: Mark Even [even@us.ibm.com](mailto:even@us.ibm.com) 507-253-1313**

[www.ibm.com/systems/services/labservices](http://www.ibm.com/systems/services/labservices)

[stgls@us.ibm.com](mailto:stgls@us.ibm.com)





## Additional resources for PowerHA IBM i

- PowerHA Wiki
  - [www.ibm.com/developerworks/ibmi/ha/](http://www.ibm.com/developerworks/ibmi/ha/)
- Lab Services
  - <http://www-03.ibm.com/systems/services/labservices>
- PowerCare
  - <http://www-03.ibm.com/systems/power/support/powercare/>
- Redbooks at [www.redbooks.ibm.com](http://www.redbooks.ibm.com)
  - Implementing PowerHA for IBM i - SG24-7405-00 (Nov 2008)
  - IBM i 6.1 Independent ASPs - SG24-7811-00
  - PowerHA SystemMirror for IBM i Cookbook – SG24-7994-00 (Jan 2012)
  - **'IBM i and IBM Storwize Family: A Practical Guide to Usage Scenarios'. SG248197**<http://www.redbooks.ibm.com/redpieces/pdfs/sg248197.pdf>
- IBM System Storage Solutions for IBM i
  - Course code: AS930
  - Duration: 4.0 days
  - [www-304.ibm.com/jct03001c/services/learning/ites.wss/us/en?pageType=course\\_description&courseCode=AS930](http://www-304.ibm.com/jct03001c/services/learning/ites.wss/us/en?pageType=course_description&courseCode=AS930)
- High Availability Clusters (Power HA) and Independent Disk Pools for IBM i
  - Course code: AS541
  - Duration: 4.0 days
  - [www-304.ibm.com/jct03001c/services/learning/ites.wss/us/en?pageType=course\\_description&courseCode=AS541](http://www-304.ibm.com/jct03001c/services/learning/ites.wss/us/en?pageType=course_description&courseCode=AS541)

# Power Systems



Open innovation to put data to  
work across the enterprise

## Special notices

This document was developed for IBM offerings in the United States as of the date of publication. IBM may not make these offerings available in other countries, and the information is subject to change without notice. Consult your local IBM business contact for information on the IBM offerings available in your area.

Information in this document concerning non-IBM products was obtained from the suppliers of these products or other public sources. Questions on the capabilities of non-IBM products should be addressed to the suppliers of those products.

IBM may have patents or pending patent applications covering subject matter in this document. The furnishing of this document does not give you any license to these patents. Send license inquires, in writing, to IBM Director of Licensing, IBM Corporation, New Castle Drive, Armonk, NY 10504-1785 USA.

All statements regarding IBM future direction and intent are subject to change or withdrawal without notice, and represent goals and objectives only.

The information contained in this document has not been submitted to any formal IBM test and is provided "AS IS" with no warranties or guarantees either expressed or implied.

All examples cited or described in this document are presented as illustrations of the manner in which some IBM products can be used and the results that may be achieved. Actual environmental costs and performance characteristics will vary depending on individual client configurations and conditions.

IBM Global Financing offerings are provided through IBM Credit Corporation in the United States and other IBM subsidiaries and divisions worldwide to qualified commercial and government clients. Rates are based on a client's credit rating, financing terms, offering type, equipment type and options, and may vary by country. Other restrictions may apply. Rates and offerings are subject to change, extension or withdrawal without notice.

IBM is not responsible for printing errors in this document that result in pricing or information inaccuracies.

All prices shown are IBM's United States suggested list prices and are subject to change without notice; reseller prices may vary.

IBM hardware products are manufactured from new parts, or new and serviceable used parts. Regardless, our warranty terms apply.

Any performance data contained in this document was determined in a controlled environment. Actual results may vary significantly and are dependent on many factors including system hardware configuration and software design and configuration. Some measurements quoted in this document may have been made on development-level systems. There is no guarantee these measurements will be the same on generally-available systems. Some measurements quoted in this document may have been estimated through extrapolation. Users of this document should verify the applicable data for their specific environment.

Revised September 26, 2006

## Special notices (cont.)

IBM, the IBM logo, ibm.com AIX, AIX (logo), AIX 3L, AIX 6T (logo), AS/400, BladeCenter, Blue Gene, ClusterProven, DB2, ESCON, i5/OS, i5/OS (logo), IBM Business Partner (logo), IntelliStation, LoadLeveler, Lotus, Lotus Notes, Notes, Operating System/400, OS/400, PartnerLink, PartnerWorld, PowerPC, pSeries, Rational, RISC System/6000, RS/6000, THINK, Tivoli, Tivoli (logo), Tivoli Management Environment, WebSphere, xSeries, z/OS, zSeries, Active Memory, Balanced Warehouse, CacheFlow, Cool Blue, IBM Watson, IBM Systems Director VMControl, pureScale, TurboCore, Chiphopper, Cloudscape, DB2 Universal Database, DS4000, DS6000, DS8000, EnergyScale, Enterprise Workload Manager, General Parallel File System, GPFS, HACMP, HACMP/6000, HASM, IBM Systems Director Active Energy Manager, iSeries, Micro-Partitioning, POWER, PowerLinux, PowerExecutive, PowerVM, PowerVM (logo), PowerHA, Power Architecture, Power Everywhere, Power Family, POWER Hypervisor, Power Systems, Power Systems (logo), Power Systems Software, Power Systems Software (logo), POWER2, POWER3, POWER4, POWER4+, POWER5, POWER5+, POWER6, POWER6+, POWER7, POWER7+, Systems, System i, System p, System p5, System Storage, System z, TME 10, Workload Partitions Manager and X-Architecture are trademarks or registered trademarks of International Business Machines Corporation in the United States, other countries, or both. If these and other IBM trademarked terms are marked on their first occurrence in this information with a trademark symbol (® or ™), these symbols indicate U.S. registered or common law trademarks owned by IBM at the time this information was published. Such trademarks may also be registered or common law trademarks in other countries.

A full list of U.S. trademarks owned by IBM may be found at: <http://www.ibm.com/legal/copytrade.shtml>.

Adobe, the Adobe logo, PostScript, and the PostScript logo are either registered trademarks or trademarks of Adobe Systems Incorporated in the United States, and/or other countries.

AltiVec is a trademark of Freescale Semiconductor, Inc.

AMD Opteron is a trademark of Advanced Micro Devices, Inc.

InfiniBand, InfiniBand Trade Association and the InfiniBand design marks are trademarks and/or service marks of the InfiniBand Trade Association.

Intel, Intel logo, Intel Inside, Intel Inside logo, Intel Centrino, Intel Centrino logo, Celeron, Intel Xeon, Intel SpeedStep, Itanium, and Pentium are trademarks or registered trademarks of Intel Corporation or its subsidiaries in the United States and other countries.

IT Infrastructure Library is a registered trademark of the Central Computer and Telecommunications Agency which is now part of the Office of Government Commerce.

Java and all Java-based trademarks and logos are trademarks or registered trademarks of Oracle and/or its affiliates.

Linear Tape-Open, LTO, the LTO Logo, Ultrium, and the Ultrium logo are trademarks of HP, IBM Corp. and Quantum in the U.S. and other countries.

Linux is a registered trademark of Linus Torvalds in the United States, other countries or both.

PowerLinux™ uses the registered trademark Linux® pursuant to a sublicense from LMI, the exclusive licensee of Linus Torvalds, owner of the Linux® mark on a world-wide basis.

Microsoft, Windows and the Windows logo are registered trademarks of Microsoft Corporation in the United States, other countries or both.

NetBench is a registered trademark of Ziff Davis Media in the United States, other countries or both.

SPECint, SPECfp, SPECjbb, SPECweb, SPECjAppServer, SPEC OMP, SPECviewperf, SPECapc, SPECchpc, SPECjvm, SPECmail, SPECimap and SPECsfs are trademarks of the Standard Performance Evaluation Corp (SPEC).

The Power Architecture and Power.org wordmarks and the Power and Power.org logos and related marks are trademarks and service marks licensed by Power.org.

TPC-C and TPC-H are trademarks of the Transaction Performance Processing Council (TPPC).

UNIX is a registered trademark of The Open Group in the United States, other countries or both.

Other company, product and service names may be trademarks or service marks of others.

Revised November 28, 2012