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Self Service Infrastructure Environment for Next Generation High Performance Test and Evaluation (T&E)

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Self Service Portal for Test and Evaluation Infrastructure Life Cycle Management, Provisioning, and Orchestration of "Layer 0" (PCIe) through Layer 7

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Introduction

Test and Evaluation High Performance Compute Centers are expanding throughout major industries as the need for the computational power across larger data sets and workflows grows exponentially. Lower barriers of entry and higher performing centers are accounting for the bottle neck throttling the adoption of workflows in these Compute Centers. With the advent of technology breakthroughs in the interconnect backplane technology based on industry standard PCIe (*Peripheral Component Interconnect express*) interface, to solve latency and bandwidth limits, and Lab as a Service automation frameworks, Test and Evaluation Compute Centers can solve both of these issues. Test Centers with a focus on "as a Self Service" portals to schedule, reserve, and configure new, faster, and greener network infrastructure will allow more users to adopt and consume resources and deliver solutions to high compute and big data test and evaluation problems at a new pace.

The key to the successful deployment of Test and Evaluation Compute Centers as a Self-Service (TECaaS) is based on Lab as a Service frameworks combined with automation tools to provide a wide range of provisioning and orchestration automation linking the workflow to the infrastructure. The ability to disaggregate and aggregate the network, compute, memory, and storage items (i.e., Layer 0 interconnect) into unique stacks for specific workflows, while being managed as a life cycle



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sandbox will allow users to more efficiently consume the Test and Evaluation Compute resources.

This article will address the problems facing the Test and Evaluation Centers (TEC), solutions to the problems, risks, and an example solution using the latest available set of tools and methodologies to accomplish the goal of delivering Test and Evaluation as a TECaaS.

Test and Evaluation High Performance Computing Center Usage Barriers

Test and Evaluation High Performance Computing (HPC) Center environments encompass a number of different types that share some common characteristics, but also have their own unique requirements.

HPC Is a Changing and Challenging Data-Driven Environment

The remarkable increase in the amount of data being collected that must be analyzed and stored is driving the rapid adoption of advanced data analytics and Artificial Intelligence (AI) that is challenging the fundamental architectures of today's ASC data centers in a way not seen since the 1990s.

AI and the associated Machine Learning (ML) and Deep Learning (DL) applications are fueling demand for fundamental change in the creation of compute and

storage clusters. Faster and larger storage arrays and a rapid proliferation of specialized compute accelerators, like GPUs (Graphic Processor Units), FPGAs (Field Programmable Gate Array), and custom ASICs (Application Specific Integrated Circuit), are creating bottlenecks and configuration problems for the interconnect systems, as the traditional networks were never designed to handle the performance requirements of these workloads and devices.

Further, the rapid pace of change in acceleration technology and AI software fuels the necessity for flexible and easy to upgrade architectures, capable of incorporating new technology without demanding forklift upgrades to expensive equipment. This means disaggregating elements of the traditional server into separate pieces that can be easily shared. But, in order to effectively disaggregate storage and accelerators, the interconnects must support both an exceptionally low latency AND high bandwidth.

And, of course, data center managers want to drive high utilization of expensive new storage and acceleration products to keep both Capex and Opex costs down.

Add all these up and these Advanced Scale Computing, Enterprise, Cloud, and Edge data centers need both scale-up and then scale-out resources across the cluster and require a network technology that will grow in both directions.

Two potential solutions both raise new issues. Scaling-up computing systems into ever-larger “super-servers” is generally cost prohibitive for all but the largest academic or government institutions. Scaling-out computer power by replicating servers introduces overprovisioning and underutilization inefficiencies.

A few IT technology industry efforts, stated below, are aimed at overcoming these issues:

- Numerous companies—from established to startup—are developing a new wave of more efficient, niche accelerators. Rather than general purpose GPUs, these chips work faster and use less power because they are designed for very specific processing tasks.
- Solid State Disk (SSD) storage providers are rapidly improving performance.
- Advanced Scale Computing (ASC) is disaggregating resources into a *composable infrastructure* where compute, storage, and accelerator resources can be accessed on-demand.

Although disaggregating resources is the right solution, now the system interconnect that enables composable becomes critically important. Insufficient speed and high latency in the interconnect networks create a

bottleneck in scaling-up and scaling-out with ASC. The underlying question for customers then becomes: How can I best manage all these new compute, storage, and network resources to break the constraints of prepacked servers and scale my computing to meet changing requirements, while getting the best bang for my computing buck?

Addressing the Issues – Solutions for a High-Performance Test and Evaluation Center Service

PCIe Based Interconnect Network

Starting with a fundamentally different architecture, a PCIe (Peripheral Component Interconnect express) interconnect network eliminates the bottleneck. This architecture can construct a multi-rack, composable infrastructure that performs as if every storage and compute element was inside a single box, providing many benefits:

- Native PCI Express (PCIe) communication between hundreds of mixed processing units, cutting latency by eliminating the entire translation layer required by other interconnect network options.
- True Direct Memory Access and sharing of *all* connected processors and memory with point-to-point connections between any two devices, reducing customer investment in these resources.
- Dynamically disaggregation and composable, scalable, and elastic infrastructure.
- A roadmap for end-to-end data speed improvements across the entire interconnect network.
- Legacy support for Test and Evaluation Compute resources.

Self Service Portal for TECaaS

Many entities today are struggling with how to efficiently manage their infrastructure with the continuous pressure to reduce cost while increasing performance, capacity, and ease of use for their consumers. These entities have identified the following infrastructure management needs:

- Support of new technologies
 - New Interconnect for networking based on PCIe resources
- Scheduling, reserving, managing, deploying (life cycle) environments
- Auto provisioning of resources (physical and virtual)
- Supporting converged infrastructure and legacy hardware

- Support of cross domains (public and private clouds)
- Automation Framework to control provisioning from PCIe thru Layer 7
- IT admin activities
 - Auto-discovery, lab resets, resource health-checks
 - Powering down devices when not in use
 - Support for maintenance modes on resources
 - Integrating Help Desk applications into the workflow of administration of the HPPC
 - Spinning up new resources on demand, etc.
 - Adding workload provisioning on top of the compute stack optimization of the provisioning and orchestration specific to the stack and the workload
- Supporting multiple tenancies and domains
- Configuration management of HPC resources
- Enabling user automation (configuring and deploying workloads, Virtual machines, containers, DevOps flows, sandboxing, etc.)
- Sharing of intellectual property
 - Support processes, automation, configurations, resources, use cases, etc.
 - Community based and open source focused
- Integration with other tools such Help Desk, Ticketing systems, and Simulators
- Metrics on the processes/activities, resources, usage, and users, to manage the life cycle of the environment.

This list is by no means complete but it does address the majority of the problems seen by these entities. All of the above actions need to be handled in a standardized and centralized approach in order to be effective and consumable by the different roles involving the use of the Test and Evaluation infrastructure. The actions need to be managed with a life cycle approach for both the management of the Test and Evaluation infrastructure and the activities within the Compute Center. The maintenance of resources, the roll back of configurations, and the validation testing of an environment before releasing it to the consumers are all examples of actions that are repeatable yet highly configurable and complex.

Management needs to understand how well the compute infrastructure is functioning so that decisions about the maintenance and life cycle of the T&E infrastructure can be made from the data analytics available. The infrastructure needs to have tools in place to support not only these actions, but the life cycle management of these actions as well. Most importantly, the environment needs to support new tools and processes

as well as share intellectual property (IP) developed across all levels and users of the environment (administrators, developers, end users, etc.).

The Risk of Not Implementing TECaaS

Given the financial cost of a Compute Center and its importance to the rest of the organization, it doesn't pay to make the significant capital and operational investments while neglecting the life cycle management of the infrastructure. The highly manual processes associated with life cycle management typically used in large Infrastructure labs are the enemy of reliability, repeatability, and auditability. Manual or non-managed processes are often visible in a number of ways:

- *Absence of live inventory visibility.* In most T&E environments, equipment inventory is not tracked in a way that provides live visibility to engineers. While most IT organizations perform asset tracking for financial purposes, what passes for the inventory management used by engineers is a spreadsheet that is often ill-maintained. As a result, it can be difficult to tell without exhaustive work what resources or equipment exists, is being used by whom, and what is truly available.
- *Offline topology design.* Since there is no usable inventory visibility, it follows that topology design is done completely offline without regard for resource availability. Visio or other diagramming tools are most common, and basically produce the electronic version of a paper drawing, which is usually then printed to aid in a time-consuming manual hunt for relevant equipment.
- *Chaotic connectivity management and costly errors.* Once inventory is found that is apparently available, engineers must manually re-cable connections between the equipment. With multiple engineers making adds, moves and changes, typically without up-to-date documentation, errors such as disconnecting someone else's infrastructure inevitably occur.
- *Underutilized resources wasted resources.* Often servers, memory, storage, and networking resources are locked into a particular set of virtualization tools or stacks, greatly limiting the sharing and balancing of these resources for different workloads.
- *Use of custom environments instead of COTS (Commercial Off The Shelf) tools.* Using these custom tools to manage the environment leads to excessive cost, limited use within different groups, and limited industry expertise to lower maintenance costs for the management environment. Different custom tools and environments without a common

control interface across different user roles can cause limits in adoption of the environment due to increased training and expertise needed to support multiple management environment tools and processes.

- *Lack of device/stack configuration baselining.* Engineers using the infrastructure must often change OS images, apply patches, and create new configurations on devices. Unfortunately, it's all too easy to forget to set devices or environments back to a baseline state, which means that when the next engineer uses the resource, they may wrongly assume that it is configured at a known baseline state and execute a series of test protocols on an incorrect configuration.
- *Legacy resource support.* HPC leaders must constantly be aware of obsolescence support when adopting new HPC resources to ensure compatibility and extend the life cycle of very costly resources.

The result of these manual processes is inaccuracy, inefficiency, and waste, evident through a number of indicators:

- *Lack of process integrity and repeatability.* Manual processes tend to experience operator errors that compromise process integrity. The lack of repeatability that results means that it is very hard to offer sufficient verification of processes.
- *Poor process documentation.* Manual processes are by nature difficult and time-consuming to capture in documentation for auditing purposes. When changes occur in procedures or processes, it is too easy to miss documentation steps, which can impact the audit trail.
- *Incomplete process reporting.* Process methodologies can generate voluminous results of data. Manual analysis processes struggle to digest these data and provide sufficient reporting for auditing purposes.
- *Imbalanced ratio of setup to actual usage.* Infrastructure engineers can easily spend days in the setup process for a procedure that takes less than an hour to run.
- *Very low asset utilization.* Millions of dollars in capital equipment are typically only 15% to 20% utilized. This represents a huge waste of annual capital depreciation costs and wasted capability.

There are significant implications of the inaccuracy and waste created by manual operating processes in T&E labs:

- *Risk of errors and non-optimized T&E infrastructure due to process integrity, repeatability, and documentation issues.* Even if the processes are painstakingly

performed in an accurate fashion most of the time, the inefficiency and slow pace of manual or separate custom processes may make it nearly impossible for allocated personnel to achieve fast T&E infrastructure delivery, which causes a reduced utilization of the infrastructure.

- *T&E lab asset utilization under 20% represents a significant waste of capital depreciation costs.* Low asset utilization also means that as demands for infrastructure deployment grow, the pace of investment in infrastructure lab capacity will rise at a rapid rate. With large infrastructures costing anywhere from \$1K to \$3K per square foot inclusive of equipment costs, this can lead to huge, unnecessary CAPEX outlays over time.

TECaaS Implementation

PCIe based Interconnect Network

Starting with a fundamentally different architecture, *PCIe interconnect network* eliminates the bottleneck. This architecture can construct a multi-rack, composable infrastructure that performs as if every storage and compute element was inside a single box, providing many benefits:

- *PCIe interconnect network* provides wider lanes and faster data throughput (256Gbps full duplex). *PCIe interconnect network* is administered using APIs (Application Programming Interface) that provides a simple interface for configuring computing clusters on-the-fly.
- *PCIe interconnect network* is 100% compliant with the industry's leading standard, PCI Express, ensuring high levels of support and compatibility from an enormous selection of vendors and technologies. Every new storage, acceleration, and compute technology fully supports the latest PCIe standards ensuring full access to the latest and most capable technologies.
- And as IT experts begin to use new architectures for moving compute to the data at the edge of your networks, *PCIe interconnect network* is a natural choice, offering the greatest depth of support in storage, compute and acceleration technology, the highest density, lowest power, and best performance.

Middleware Automation Framework for TECaaS

Using a TECaaS solution to manage the life cycle of a Compute Center infrastructure environments can help users achieve dramatically higher accuracy, utilization, and productivity. This will lead to significant CAPEX

and OPEX savings, faster infrastructure cycle completion, and sustainably documented processes and reporting for metrics and auditing of the Compute Center Infrastructure's performance. A sound automation and provisioning solution that delivers a fully integrated, object-oriented software framework for automating development, administration, and end user operations on the Compute Center infrastructure controlling from PCIe (Layer 0) through Layer 7 orchestration and provisioning includes:

- Centralized live infrastructure and resource inventory
- Inventory-aware stack/topology design
- Shared calendar based resource and topology reservation
- Connectivity mapping and automated connectivity control
- Easy to create automated provisioning tasks
- Non-programmer friendly automation workflow creation based on a library of highly reusable, template-based objects that can be created from a wide variety of sources and leveraged to create:
 - Auto-discovery, auto base-lining, and other automated maintenance routines
 - Full test automation workflows
- Community sharable IP for automation and management of HPC infrastructures and processes
- Powerful automated reporting that provides a verifiable and sustainable audit trail
- Resource agnostic (any device, any cloud, any hypervisor) to support new technologies
- Ownership of all logs and data sets produced by the toolset

If designed properly, the TECaaS architecture avoids the pitfalls of script-based approaches to automation, which cannot scale due to their high maintenance costs. Best of breed commercial solutions deployed by industry leading organizations worldwide provide them with the fastest path to successfully and sustainably automated framework environments. This is the path which leading power utilities, enterprises, government and military agencies, telecom service providers, and technology manufacturers have chosen to transform chaotic manually driven environments into highly efficient infrastructure operations. These organizations have the ability to perform the following:

- Manage infrastructure inventory including Servers, GPUs/Accelerators, Flash/Storage, L1/L2/L3 switches, and virtual resources such as virtual machines, virtual switches, and containers in a live, searchable database of resource objects

tagged with searchable attributes. This capability eliminates manual searching for equipment in racks, and allows engineers to interface with the datacenter infrastructure efficiently via software. An inventory and resource management tool with object support and hierarchies can represent relatively simple nested resources such as chassis, blades, and ports, or complex, pre-integrated resources stacks such as converged infrastructure and workflow based, stack solutions

- Create variable or abstract topologies via a software GUI that allows drag and drop of resource objects onto a canvas, visually ascertain availability, design, and sanity check connectivity. Save the entire topology as a high-level object in the resource library, so that it can be reused later by other engineers.
- Schedule resources and entire topologies through a common calendaring system, preventing use case disruptions.
- Manage connectivity remotely by generating patching or cabling requests to lab administrators, or if PCIe/Layer 1 switches are in use, to automatically connect and build topologies.
- Make device and service provisioning error free by building automation objects for common provisioning tasks, and execute them from a graphical test topology view. Device/VM provisioning can include uploading OS images, resetting device configurations to baselines, or creating routing adjacencies between virtual switches.
- Create auto-discovery and auto-baselining processes that leverage an extensive array of control interfaces, GUI automation and scripting capabilities to streamline the management of inventory and device states to a compliant baseline.
- Automate complex provisioning and configuration management tasks in a fully documentable and repeatable fashion. Automation can be created through integration of existing automation scripts as objects, as well as creation of new automation objects through screen, GUI, and other capture processes.
- Support for including open source tools, APIs, and existing scripts into the environment and managing them as objects to facilitate reuse, centralization, and standardization of IP.
- Build, configure, and rapidly deploy virtual networked environments through an easy to use, multi-tenancy web portal GUI. Embed other tools to allow integrated workflow applications and other tools into a single pane of glass environment

for easy to consume interfaces for end users.

- Use compute, storage, and networking resources in an optimal and hyper-converged deployment for shared resource pools to meet on-demand needs of users.
- Support Rack Scale Design (RSD) for aggregation/disaggregation of HPC resources.

Support virtual resources from any hypervisor and any physical resource vendor, allowing for a universal user interface for all consumers of the infrastructure.

- Allow multi-tenancy in a secure virtual and physical environment to meet security compliance validation. (Encryption of passwords, Single Sign On, single file virtual network containers.)
- Generate comprehensive audit compliant result reports.
- Produce custom business intelligence dashboards to allow for managers to collect and analyze data from the testing activities and metrics for input into planning initiatives.

The TECaaS's Beneficial Impact on the Infrastructure

Adoption and deployment of a TECaaS methodology supporting *PCIe interconnect network* interconnect technology on your Compute Center leads to significant, positive impacts:

- **Sustainable auditability.** With automation comes built-in documentation of automation processes since the object-oriented method of creating, modifying, and maintaining template elements creates an ongoing and live documentation for process composition and methodology. Automated equipment maintenance processes with documented schedules provide proof of the compliance of the testing environment. Automated results analysis offers robust reporting that offer solid proof of compliance and compliance efforts. Complete control of all data sets produced by the framework allows for control and ownership of all metrics and outputs produced by the toolset.
- **A dramatic increase in the velocity of infrastructure delivery.** Organizations routinely report time savings upwards of 70% in their deployment cycles once they have automated the process of allocating devices, device/VM provisioning, running automation processes, and generating reports.

○ Performance

- *PCIe interconnect network* delivers the industry's lowest latency AND the highest effective

bandwidth. Latency from system memory of one server to system memory of any other is less than 200ns – true PCIe performance across the entire cluster. The current Gen 3 implementation delivers 256Gbits/sec bandwidth, soon to scale up to 512Gbits/sec with PCIe Gen 4.

○ Flexibility

- *PCIe interconnect network* can unite an unprecedented variety of resources, connecting accelerators of all types including GPUs, TPUs, FPGAs, and SoCs to other compute elements or storage devices such as Non-Volatile Memory Express (NVMe), PCIe native storage, and other I/O resources. *PCIe interconnect network* can span multiple servers and multiple racks to scale up single-host systems and scale out multi-host systems, all unified via the *PCIe interconnect network* software.

○ Efficiency

- Featuring 100% PCI-SIG compliance, the *PCIe interconnect network* switch can integrate heterogeneous computing, storage, and accelerators into one symmetrical system-area cluster fabric, so you can do more with less. Patented technology strips away unnecessary conversion, software layers and overheads that add latency to legacy interconnects.

- **Significant savings in infrastructure CAPEX and OPEX.** Organizations deploying infrastructure automation software report increases of 50% to 200% in device utilization, leading to capital budget savings, less depreciation waste, as well as accompanying savings in space, power, and cooling costs.

○ Open Platform, Standards-Based

- *PCIe interconnect network* is built on, and is 100% compliant with, the industry's most widely adopted standard, PCI Express, ensuring low risk, easy integration, and long life. Further, the *PCIe interconnect network* operating system easily integrates third-party applications with its open-source design, including the open-source Redfish® APIs to provide unprecedented integration with a range of third-party applications for fabric automation, orchestration, resource allocation, and job management.

○ Memory-Centric Fabric

- *PCIe interconnect network* is the next generation, memory-centric fabric for a changing compute world. Effortlessly connects new

memory / storage products, the multitude of new accelerators and your choice of processors either directly attached or via server configs like NVMe-oF (Non Volatile Memory Express over Fabric).

○ Driving Down Cost

- The result is lower Capex and Opex through less hardware, higher utilization of resources, lower power consumption, reduced power, and less cooling. Avoid overprovisioning and add just the elements you need. Maximize utilization of the footprint of your data center and contribute to your bottom line.

Conclusion

Test and Evaluation Compute Centers are under tremendous pressure to maintain a sustainable compliance regimen for continuously evolving and increasing the usage and optimization of the deployment of services and resources to their user community. Deploying a TECaaS set of tools and services to automate the life cycle management activities of the Compute Center can dramatically increase the usage and optimization of the resources within the Compute Center, allowing entities to deliver the optimized Compute Center infrastructure faster, less expensive, and with greater performance to their user community. Using this approach to managing the infrastructure ensures that the Compute Center is reliable, efficient, repeatable, and highly auditable. Entities using a TECaaS approach can build a sustainable platform for delivering infrastructure that leverages their users' performance and capability to ensure that their bottom lines are maximized.

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