ACCELERATING DIGITAL TRANSFORMATION THROUGH CLOUD-NATIVE APPLICATIONS
An Overview of VMware Cloud-Native Solutions
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Summary
Executive Summary

Digital transformation is disrupting business models in every industry and is expected to deliver $100 trillion of value over the next decade. To unlock the potential of digitalization, IT leaders are grappling with a massive transformation that is crucial to driving business growth, competitive advantage, and customer loyalty. The key to this transformation lies in cloud-native solutions that leverage modern application frameworks for rapid innovation, continuous delivery, and superior experiences across any infrastructure, whether on-premises or in a public cloud.

VMware’s cloud-native solutions address a range of digital transformation needs – from modernizing traditional applications to building next-gen, distributed, microservices-based applications. VMware can help enterprises realize the benefits of containerization and modern application architectures today—without compromising operations, security, or compliance—empowering developers to transform their businesses through agility and innovation.

The Drive to Cloud-Native Applications

We live in the business environment Marc Andreessen predicted only a half decade ago: software has indeed “eaten the world.” To survive and thrive, modern enterprises are undergoing rapid digitalization—products and services delivered through software are becoming the major competitive differentiators of the business. The need to increase both the speed and agility with which new applications are developed and deployed is driving organizations to adopt a new breed of cloud-native applications built atop scalable and flexible modern application frameworks.

Cloud-native applications are pieces of software designed to capitalize on cloud functionality. Typically, they are:

- **Composed of Microservices** – cloud-native apps adopt a microservices architecture model, where each application is a collection of small services that can be operated independent of the other services in the application.

- **Packaged in Containers** – containers provide isolation contexts for microservices. Containers are highly accessible, scalable, easily portable from one environment to another, and fast to create or tear down, making them ideal for building and running applications composed of microservices.

- **Rapidly (Re)Deployable in a Continuous Delivery Model** – software developers and IT operations teams collaborate under this model to build, test, and release software updates as soon as they are ready, without affecting customers or developers on other teams.

By embracing cloud-native applications, enterprises can expect to gain not only speed and agility of application delivery, but also increased flexibility in app development and reduced complexity of their IT systems, empowering development teams to do better, more innovative work. When successfully adopted, cloud native systems automate routine tasks, minimize downtime and patching, and, most significantly, free IT to focus on partnering in innovation with the business it serves.
Challenges on the Journey to Cloud-Native
Cloud-native systems offer compelling value propositions to enterprises, however, challenges remain as the industry is still maturing. The journey to cloud-native can be fraught with risk as emerging frameworks and tooling are often overly complex and lack the security, visibility, and stability that enterprises require. However, these risks are increasingly tolerated as the push to become cloud native builds in response to rapidly changing market conditions and rising consumer expectations in a digital economy. Faster time-to-service and market agility are becoming the new norm, and expectations are rising for businesses to compete effectively.

While cloud-native technologies are available today, the vast majority are not fully production-ready. Enterprises engaging in proofs of concept (POCs) are learning the true capabilities of the products being tested, and also discovering unanticipated complexities that must be overcome before moving into production. These challenges encompass people, process, and technology, requiring an overall “cultural shift” across the enterprise. Some of the challenges are:

• Business model changes
• Development model changes
• Technology maturity issues
• Product readiness/feature gaps
• Product integration into existing systems
• Operational tooling, workflow, processes
• Staff expertise and training
• Vendor readiness to provide support, training, and professional services

The industry, meanwhile, is evolving at a daunting pace. As application developers are quickly adopting cloud native solutions for DevTest, IT is struggling to take these solutions into production where high availability, security, compliance, and quality requirements must still be met.

Modernizing Traditional Applications
Modern applications offer a number of operational benefits, including simplified development workflow, ease of automation, simplified application maintenance, improved scalability and more. While best practices dictate that new applications should be developed in a cloud native manner, most enterprises of any scale also run multiple legacy applications. Re-architecting these existing applications can be a daunting task. Fortunately, many of these operational benefits can be achieved by simply containerizing existing applications.

However, while true cloud-native applications maintain availability at the application layer, traditional applications that are “modernized” rely on highly available infrastructure as the source of their availability. These modernized applications present unique requirements: a container framework that supports modern container constructs while at the same time providing highly available underlying infrastructure.
VMware Cloud-Native Solutions

VMware’s cloud native solutions directly address these concerns, helping customers both build – and then seamlessly manage – next-generation, cloud native applications, and modernize their existing applications.

VMware cloud native solutions:

- Significantly reduce the complexity, and therefore the risk and cost, of setting up cloud native infrastructures.
- Ensure agility, resilience, reliability, interoperability, and security throughout the cloud native application lifecycle.
- Make it possible to address container workloads incrementally by using existing tools, processes, policies, and procedures.
- Serve the needs of both app developers and operations engineers, allowing both to excel at their jobs and make IT a business partner in innovation.
- Support open standards and engage with the open source community.

![Cloud Native Solution Portfolio Diagram](image)

**Figure 1**: VMware Cloud Native Solution Portfolio

Most importantly, VMware cloud-native solutions enable enterprises to reap the benefits of cloud native apps on their own terms. They deliver cutting-edge, cloud-ready infrastructures that are both trusted and tested—leaving customers to focus on adding the value that only they can deliver.

VMware’s cloud native portfolio includes VMware vSphere® Integrated Containers™, for running containerized workloads with existing infrastructure, and VMware Photon™ Platform, for building new cloud-native infrastructure solutions from the ground up. In addition, it embraces VMware solutions that address challenges associated with container networking, storage, and management.

**vSphere Integrated Containers**: Bring containerized workloads into an existing infrastructure, modernize traditional apps

Current VMware vSphere customers looking to run containers alongside existing workloads can start deploying cloud native apps immediately with vSphere Integrated Containers.
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KEY FEATURES OF vSPHERE INTEGRATED CONTAINERS

Run containers alongside existing workloads
By leveraging the existing capabilities of vSphere, IT operations can run containerized apps alongside traditional apps on the same infrastructure without having to build out a separate, specialized container infrastructure stack.

Combine portability with security, visibility, and management
By running containers as VMs, IT teams can leverage the core vSphere capabilities—enterprise-class security, networking, storage, resource management, and compliance—that are essential to running containerized applications in a production environment.

Leverage your existing infrastructure, scale easily
vSphere Integrated Containers helps avoid costly and time-consuming infrastructure re-architecting. vSphere Integrated Containers also scales application deployments instantly.

Deploy container images on highly available infrastructure
An ideal solution for modernized traditional applications that require highly available infrastructure. Leverage core vSphere features such as VMware HA and vMotion®.

Provide developers with a Docker-compatible interface
Developers already familiar with Docker can build applications in containers by using a Docker-compatible management portal for self-service provisioning.

Available with vSphere Enterprise Plus 6.0 or later, or with vSphere with Operations Management™ Enterprise Plus, vSphere Integrated Containers creates an enterprise container infrastructure within vSphere, allowing both traditional and containerized applications to run side-by-side on a common infrastructure.

vSphere Integrated Containers has three main capabilities: portal, registry, and engine. The portal provides a user interface and an API for managing container repositories, images, hosts, and instances. The registry furnishes a user interface and an API so developers can make their own container repositories and images. The engine is a container runtime integrated with vSphere.

These capabilities let VMware customers deliver a production-ready enterprise container solution to their development teams without having to build out a separate, specialized container infrastructure stack. By supporting containers in their vSphere environments, IT teams gain the security, isolation, and management of VMs while developers enjoy the speed and agility of containers. And since it is based on vSphere, vSphere Integrated Containers provides the highly-available infrastructure required to confidently run modernized traditional applications in production.

**Figure 2: vSphere Integrated Containers**

VMware Photon Platform: Build a new API-driven infrastructure stack for cloud native workloads
Photon Platform is a container-optimized cloud platform that delivers on-demand tools and services for developers to build, test, and run cloud native applications. At the same time, it gives IT and DevOps the tools and insights they need to maintain the security, control, and performance of their data center infrastructure.

The architecture of Photon Platform combines compute, networking, storage, and security into an API-driven system that furnishes infrastructure as a service for cloud native applications. Developers get the flexibility and ease-of-use they’ve found only in the public cloud, but now supplied through a secure, private data center that fulfills the operational and security requirements of IT.
KEY FEATURES OF VMWARE PHOTON PLATFORM

Simple, out-of-box solution covering the entire infrastructure stack
Photon Platform is purpose-built for cloud-native applications. It leverages VMware's proven technologies in compute, networking, and storage to offer a comprehensive infrastructure solution optimized for deploying containers. No need to assemble your cloud native infrastructure stack from multiple, open source tools. Instead, you can get it all from Photon Platform.

Developer-friendly platform
Photon Platform delivers an entire IaaS layer for a secure container runtime environment. Developer and platform services teams can access infrastructure primitives through simple, public-cloud-like APIs, in addition to a command-line interface and a web interface. Architected to deploy entire container frameworks, the platform offers Kubernetes as a Service, enabling deployment of an entire Kubernetes cluster with a single command. Photon Platform also works seamlessly with the leading PaaS platform, Pivotal Cloud Foundry.

Fast, web-scale and secure cloud native deployment
Meeting the demanding needs of today's web-scale cloud native applications, Photon Platform's control plane scales massively, supports a high-churn environment, and is extremely fast. Multitenancy, identity management, and access control provide enterprise-grade security for cloud native workloads.

VMware-backed, enterprise-grade quality
You get tools developed with the speed and creativity unique to open source software, but backed by VMware's expertise in delivering and supporting mission-critical infrastructure. VMware has you covered with a full stack, and its world-class services and support team is ready to get you started today.

Photon Platform brings scale and performance to the data center so that enterprises can cost-effectively fulfill a variety of use cases in house:

- **Kubernetes as a Service**: Developers can deploy, resize, and destroy Kubernetes clusters to develop, test, and automate containerized applications.
- **Platform as a Service**: Photon Platform integrates with Pivotal Cloud Foundry to build and scale applications for the cloud.
- **Continuous integration and delivery**: The simplicity of Photon Platform improves the CI/CD pipeline with uniformity and reusability, especially in environments with high container churn.
- **API-managed on-premises cloud**: IT can deploy a vast amount of resources and automate their management through a RESTful API.
- **Security**: The VMware Lightwave security service protects applications, Kubernetes clusters, and Photon Platform components.

Container Networking
Networking is a major barrier to moving cloud native applications from development to production. Most deployments of containerized apps today do not feature native container networking—i.e. the container network is not reachable by the data center network and each container does not have its own unique IP address. This lack of native container networking creates challenges for both networking and security operations teams:

- **Challenges with Networking Address Translation (NAT)** – Security operations teams are unable to apply security policies to containerized applications. Additionally, network and security teams' operational tooling cannot be used to monitor, debug, and troubleshoot these containerized apps—a problem that is often cited as one of the key challenges in operationalizing containers at scale.
- **Connectivity to apps on VMs and bare metal** – most containerized applications require access to services or apps running on bare metal and VM infrastructure. The lack of native container network integration with the data center network requires implementing ramp nodes or on-ramp, off-ramp nodes to connect the data center network with the container network.
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KEY FEATURES OF VMWARE NSX-T FOR CONTAINERS

- Developer CaaS and PaaS experience remains the same.
- Auto-creation and scaling of networks and routers created when a new namespace or project organization is created.
- Connectivity to data center network with BGP and ECMP.
- Micro-segmentation per container or pod.
- Operational and troubleshooting tools for containers—Counters, Traceflow, IPFIX, SPAN.
- Multi-Tenancy - most IT departments require their compute, network, and storage infrastructure to be multi-tenant so that admins can provision policies for QoS, rate limiting for a particular tenant or class of application. Without native container networking these operations cannot be performed at the container level.

VMware NSX

VMware NSX® successfully tackles these challenges. NSX-T supports native container networking and micro-segmentation for CaaS (Container-as-a-Service ) and PaaS(Platform-as-a-Service), providing tools with which network and security teams can operationalize containerized apps at enterprise scale. NSX-T is part of the architecture of Photon Platform, and NSX for vSphere is part of the architecture for vSphere Integrated Containers.

VMware NSX-T is also being developed to provide a consistent feature set across CaaS and PaaS platforms, such as Kubernetes, Pivotal Cloud Foundry, Docker, and Mesos, as well as across compute platforms, such as vSphere, Photon Platform, bare metal servers, and public cloud VMs.

Persistent Storage

Because containers are ephemeral, managing their state is one of the biggest challenges in container adoption since it requires building a robust, elastic, and programmable storage infrastructure. Containers on their own do not provide a storage solution for effortlessly running data intensive applications and persistent states. They lack the security, data integrity, data protection, and storage services that are expected in a modern IT infrastructure.

vSphere environments address this gap by offering storage infrastructure choices for container environments, from hyper-converged infrastructure (HCI) powered by VMware vSAN™ to traditional SAN and NAS storage. These approaches support both vSphere and Photon Platform.
For Photon Platform, vSAN offers tighter integration specifically engineered to meet the needs of the DevOps community—the integration promotes the developer to self-service administrator for agile storage operations. It enables Photon Platform to deliver persistent, server-based storage for next-generation applications that are managed solely through APIs.

Another key storage hurdles center around deploying data intensive, stateful applications, which are among the most popular images on Docker Hub. Deploying stateless applications is relatively easy and any supported vSphere storage solution can be used, including vSAN, VMFS, and NFS. For stateful applications, however, multiple factors need to be considered when building a container environment, including the ability to survive a restart and handle a container being restarted on a different host.

VMware offers two persistent volume offerings for situations like these, one for Docker and one for Kubernetes. With both offerings, container storage is carved out of proven VM storage, providing all of the enterprise capabilities and storage services already available for VM storage. This combination of container schedulers and vSphere storage delivers a complete solution for stateful applications.

**Figure 5: Persistent Storage for Containers**

- **Persistent Storage for Docker**: This Docker plug-in abstracts the underlying enterprise-class storage of the vSphere environment and makes it available as Docker volumes. It is easy to install and use from a developer perspective yet leaves storage visibility and control in the hands of a vSphere administrator. It supports data services such as cloning and snapshots, ensuring that data is both resilient and highly available. Additionally, when using vSAN as the underlying storage layer, storage based policies are fully supported to take full advantage of using hyper-converged infrastructure with containers on vSphere.
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KEY FEATURES OF STORAGE FOR CONTAINERS

• **Proven persistent shared storage:** Use proven enterprise class technologies such as VMware vSAN, VMFS, and NFS.

• **Multitenancy, security and access control:** Empower the vSphere administrator to manage security and access controls on the underlying hosts or data centers.

• **Infrastructure as code:** Simple, programmable, and self-service policy based provisioning of storage that scales with application without disruption.

• **Single HCL:** Use the same vSphere storage for VMs and containers, and run them concurrently.

• **Persistent Storage for Kubernetes:** Stateful containers orchestrated by Kubernetes can also leverage persistent vSphere Storage (vSAN, VMFS, and NFS) with Kubernetes persistent volume, dynamic provisioning and StatefulSet primitives. It offers high availability to stateful applications, delivering resiliency and availability characteristics to cloud native applications.

Storage policy-based provisioning of persistent volumes enables applications to specify SLAs and quality of service at the granularity of container volumes. Database workloads scale on demand as a result of the tight integration with Kubernetes scheduler and features like StatefulSet. vSphere administrators can continue to use the VMware vCenter Server® console to monitor storage consumption and compliance.

**Container Management**

Operationalizing container-based applications remains a daunting challenge to enterprises while they are adopting cloud native technologies. VMware vRealize® Automation™ cross-cloud container management solution, however, provides a clear separation of concerns across IT Ops and development teams.

To better address the needs of both developers and IT, vRealize Automation release 7.2 offers out-of-the box container management capabilities that allow developers and application teams to accelerate application delivery. It leverages open source Project Admiral, a highly scalable and very lightweight container management platform, to deploy and manage containers through virtual container hosts on VMware vSphere Integrated Containers. Developers can provision container hosts from the vRealize Automation service catalog as well as model containerized applications using unified service blueprints or Docker Compose.

Table: Business Mobility

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<td>Any Cloud</td>
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Cloud Management Platform
- vRealize Automation
- Admiral (Container Management)
- Harbor (Container Repo)
- VIC

Virtual Cloud Infrastructure
- Compute
- Networking & Security
- Storage
- Hybrid Cloud

DevOps
- vRealize Code Stream

Extensibility

1 vRealize Suite components
2 Included with vSphere Ent+

Figure 6: Container Management by vRealize Automation
At the same time, vRealize Automation supports active collaboration between cloud admins and dev teams for traditional, containerized, and hybrid applications, offering a balance between the operational control of traditional apps and the flexibility that containers offer. Application teams can build hybrid deployments consisting of VMs and containers while Cloud administrators can manage container hosts and apply governance to their usage, including capacity quotas and approval workflows. vRealize Automation 7.2 is thus well suited for organizations looking to modernize existing apps via the adoption of microservices and a cloud-native architecture.

Developer-Ready Infrastructure

The ultimate driver underlying cloud native framework adoption is the need to optimize the application development/delivery processes while minimizing time-to-value. IT teams are under pressure to deliver a platform that offers an “on-demand” and “frictionless” experience for developers while ensuring that their infrastructure also provides enterprise-grade security, compliance, and scale.

VMware and Pivotal partner to present Developer-Ready Infrastructure by integrating Pivotal Cloud Foundry (PCF) with VMware SDDC infrastructure solutions. Developer-Ready Infrastructure provides enterprises with secure, highly available, and automated software-defined compute, storage, and networking resources for modern app development. Running Pivotal Cloud Foundry with Developer-Ready Infrastructure is a powerful combination for businesses, enabling them to meet requirements for faster time-to-market with control and flexibility.

Pivotal Cloud Foundry provides a modern app-centric environment that lets developers focus on delivering applications with speed and frequency of delivery. By abstracting the underlying infrastructure layer, PCF grants developers access to a modern self-service application development environment with an automated infrastructure that responds to their needs. Throughout the application lifecycle, infrastructure resources such as networking are automatically commissioned and de-commissioned as needed.
In this new model, where responsiveness and value drive technologies, developers find new productivity by increasing feature velocity while decreasing costs. IT operators, meanwhile, raise their service levels while supporting more systems and applications in a scalable, secure manner.

Our Open Source Commitment

Open source projects deliver valuable new technologies with wide applicability at unprecedented speed. VMware invests in the open source community in a variety of ways: through project contributions, foundation support, and industry leadership. Our engineers both contribute code to existing projects as well as create and lead new open source projects. Cloud Foundry, Spring, Open vSwitch can all trace their roots to VMware technical leadership. VMware participates in the leading open source foundations and collaborative projects such as the Linux Foundation, Cloud Foundry Foundation, Cloud Native Computing Foundation, Open Container Initiative, OpenStack Foundation, Open Network Automation Project and the newly launched EdgeX Foundation (IoT focused). The company is constantly growing its practice, exploring new projects, and finding new ways to engage open source communities.

In the cloud-native space, VMware has open sourced multiple projects and engaged with the community through developer channels and events. The main elements of vSphere Integrated Containers and the core components of Photon Platform are all available as open source downloads on GitHub.

Current VMware-led cloud native related open source projects include:

**vSphere Integrated Container (VIC) Engine**, the key element of vSphere Integrated Containers, is a container runtime for vSphere that allows developers familiar with Docker to develop in containers and deploy them alongside VM-based workloads on vSphere clusters. It provides a production-grade environment for these workloads that can be managed through the vSphere UI and leverages existing processes to operationalize container apps quickly. The VIC Engine provides lifecycle operations, vCenter support, logs, basic client authentication, volume, and basic networking support.

**Harbor**, embedded in both vSphere Integrated Containers and Photon Platform, is an enterprise-class registry server with advanced security, identity, role based access control, auditing, and management services for Docker images. With Harbor, enterprises can deploy a private registry, keeping their data compliant behind the company firewall. In addition, Harbor supports AD/LDAP integration and the setup of multiple registries with images replicated between registries for high availability. Harbor is already localized in Chinese, English, German, Japanese, and Russian.

**Admiral** is a container management platform providing automated deployment and lifecycle management of container-based applications for developers and cloud ops teams. It manages Docker hosts, policies, multi-container templates, and applications to simplify and automate resource utilization and application delivery. Developers can use Docker Compose, Admiral Templates, or Admiral UI.
to compose their app and deploy it using the Admiral provisioning and orchestration engine. Cloud administrators can manage container host infrastructure and apply governance to its usage, including resource grouping, policy based placement, quotas and reservations, and elastic placement zones. Admiral is a key component of vSphere Integrated Containers.

Our persistent storage for Docker plug-in enables running stateful containers backed by storage technologies of choice in a vSphere environment. It is 100% Docker compatible and integrates with Docker Swarm to extend Swarm’s high availability features. It is as easy for end users to install as other Docker APIs, requires no additional configuration by end users, and retains visibility and control in hands of vSphere administrators. This plug-in also brings vSphere’s advanced storage feature-like policy management to the Docker ecosystem and lets vSphere admins manage underlying host security and access controls on a set of hosts or data centers.

Photon OS, a key component of Photon Platform, is a minimal Linux container host, optimized to run on VMware and third-party cloud platforms. Photon OS is compatible with container runtimes such as Docker and container scheduling framework Kubernetes. It contains a yum-compatible package manager that makes the system as small as possible while preserving robust yum package management capabilities. Photon OS supports vSphere installations and is offered in different pre-packaged binary formats available in ISO, OVA, Amazon AMI, and Google GCE images.

Photon Controller is a distributed, multi-tenant host controller optimized for containers. The Photon Controller delivers an API-driven developer experience by exposing RESTful APIs, SDKs, and CLI tooling to automate infrastructure resources easily. It is custom-built for massive scale and speed with support for open container orchestration frameworks such as Kubernetes and Pivotal Cloud Foundry as well virtualized environments allowing the creating of 1,000s of new VM-isolated workloads per minute. Photon Controller functions as the brain of Photon Platform.

Project Lightwave offers enterprise-grade, identity and access management services such as single sign-on, authentication, authorization, and certificate authority, as well as certificate key management for container workloads that need to meet security, governance, and compliance requirements. Project Lightwave is designed for environments that need multi-tenant, multi-master, highly scalable LDAP v3 directory service. It includes directory-integrated certificate authority and store functionality that simplify certificate-based operations and key management across the infrastructure. Lightwave authentication services support Kerberos, OAuth 2.0/OpenID Connect, SAML and WSTrust which enable interoperability with other standards-based technologies in the datacenter.
LEARN MORE ABOUT VMWARE CLOUD-NATIVE SOLUTIONS
To learn how VMware helps customers build, run, and manage cloud-native applications, visit: www.vmware.com/solutions/cloudnative.html

TRY vSPHERE INTEGRATED CONTAINERS
vSphere Integrated Containers is available for immediate download to customers with current licenses for vSphere Enterprise Plus 6.0 and above or vSphere Operations Management Enterprise Plus at www.vmware.com/go/download-vic.

For more information on vSphere Integrated Containers, visit: www.vmware.com/products/vsphere/integrated-containers.html

GET TO KNOW PHOTON PLATFORM
To learn about VMware’s container-optimized Photon Platform, visit: www.vmware.com/products/photon-platform.html

Summary
VMware’s cloud-native solutions empower enterprises to launch their digital transformation today and confidently plan for future growth. Designed to enable strategic, long-term success, they ensure production-grade functionality across VMware’s software-defined data center portfolio, meeting its mission to serve enterprises wherever they are on their transformation journey. Supported container frameworks encompass the industry’s most deployed technologies, such as Docker, Kubernetes, and Pivotal Cloud Foundry. Developer-Ready Infrastructure adds further integration to enhance the developer experience by optimizing feature velocity and code maintenance.

• For enterprises – VMware offers multiple pathways to cloud-scale enterprise container infrastructure instantiated through out-of-the-box, end-to-end solutions that are both reliable and production-ready. VMware’s Cloud-Native solutions provide the advantages of open source technologies with production-grade quality for IT and developers, enabling continuous app delivery to fuel innovation for the modern enterprise.

• For app developers – VMware’s Cloud-Native solutions offer the access to containers and app frameworks that developers need. Developers gain speed, agility, and portability in app development, giving them more freedom to support their business in new and more innovative ways.

• For infrastructure and operations teams – IT teams gain access to solutions for running and managing cloud native workloads in production with enterprise-grade security and performance while retaining the ability to leverage existing tools and technologies.