



INTUITION

Driving Scale with Cloud-Native and High-Density Ground Systems

Virtualization revolutionized IT and telecommunications by abstracting software from hardware, introducing unprecedented flexibility, scalability, and efficiency to infrastructure management. Built on the foundation of virtual machines and advanced by cloud-native architectures- with agile, lightweight solutions like containers and microservices- these technologies have been integral to telco and IT operations for years. Today, their adoption is expanding into satellite network architectures, where cloud-native designs paired with high-density configurations are redefining systems to deliver scalable solutions that meet the evolving demands in an increasingly software-defined era on the cusp of integrating 5G NTN. At the heart of cloud-native architectures is the concept of dynamic scalability and exceptional density, where additional compute resources can be packed and expanded dynamically without significant architectural changes. This ability to scale on demand removes the rigid constraints of traditional systems while addressing increasing service loads.

Building on this foundation, cloud-based systems introduce the agility needed to deliver on-demand services that today's users increasingly expect. By decoupling from hardware-bound limitations, operators can accelerate time to market and optimize network costs, all while rolling out new features seamlessly and at scale.

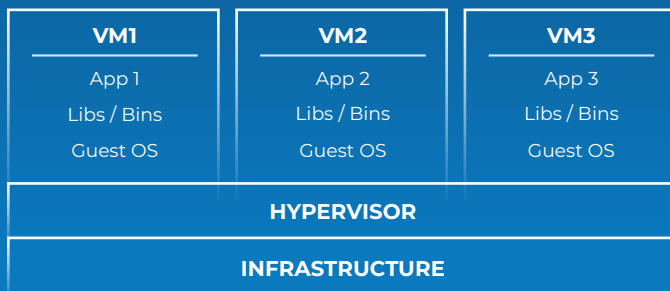
VIRTUALIZATION TECHNIQUES: COMPARING VIRTUAL MACHINES (VM) AND CONTAINERS

VMs and containers are distinct technologies for deploying applications, differing in architecture, resource use, and suitability for tasks.

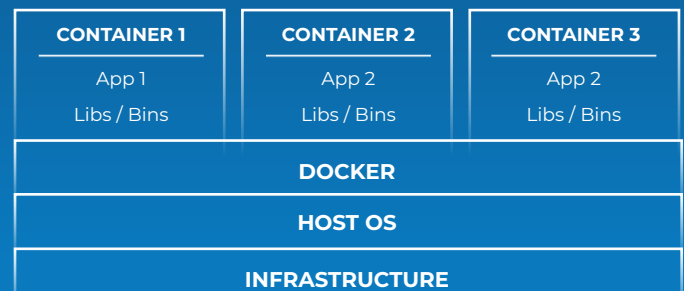
Virtual Machines include the entire operating system (OS), necessary libraries, and the application itself. They operate on a hypervisor that interfaces with the physical hardware, making them highly versatile and capable of running a wide range of applications. However, VMs are larger in size, often running into gigabytes, which can result in slower boot times. This makes them ideal for hosting monolithic applications as they resemble physical servers in structure and functionality. VMs also allow full control over the OS environment, but their reliance on guest OSes adds overhead, leading to higher resource consumption.

Containers, on the other hand, package only the application and its dependencies, relying on a container runtime like Docker to interact with the host OS. This lightweight architecture results in significantly smaller images, often measured in megabytes, enabling faster downloads and near-instant startup times. Containers are highly portable and consistent, performing seamlessly across development, staging, and production environments. They excel in dynamic environments where rapid scaling is necessary and are particularly well-suited for cloud-native, microservice architectures due to their efficiency and platform-agnostic nature.

VIRTUAL MACHINES



CONTAINERS



While VMs are a good fit for traditional, resource-intensive applications requiring isolation and control, containers are ideal for agile development workflows and modern, distributed systems such as used in Intuition.

THE SCALABILITY BENEFITS OF CLOUD NATIVE ARCHITECTURES

Cloud-native architectures are purpose-built for scalability. They use microservices and container-based architecture to deploy applications as modular, independent components that can scale horizontally based on user demand. Containers deliver application code with its dependencies, allowing consistent deployment across different environments such as on-premises data centers and public or private clouds. Infrastructure orchestration automatically manages compute resources, enabling applications to scale efficiently while maintaining performance and availability. This abstraction separates applications from the underlying infrastructure and supports elasticity, efficient resource use, fault isolation and independent software deployments. These characteristics are essential for building resilient and highly scalable satellite networks.

ST Engineering iDirect's next-generation ground system, Intuition is leveraging the cloud-native architecture as a foundational layer, one built on containerization (no longer just on VMs) and (Kubernetes-type) orchestration to enable dynamic scalability and flexible deployments.

Compared to other platforms the cloud-native and high-density architecture in Intuition marks a fundamental shift from traditional hardware-based, monolithic systems to agile, highly virtualized environments. By embedding smart **resource allocation** and Kubernetes, the architecture allows compute power, memory, and storage to scale up or down horizontally across used compute resources allowing dynamic workload utilization in real-time. This design ensures that the system continues to operate efficiently and without interruption, even if a compute node fails, by dynamically reallocating network functions to other available nodes as needed.

The cloud-native architecture relies on **orchestration**. That's where opensource Kubernetes comes into play, an industry-standard platform for managing containerized services and microservices at large scale. Orchestration facilitates optimized resource allocation and utilization, ensuring that resources are no longer over-provisioned but are right-sized based on actual requirements.

Intuition is built on OpenShift, a Kubernetes-based platform that provides a user-friendly interface, embedded security features, and deployment flexibility. It orchestrates containers and updated VMs using

Kubernetes principles. This architecture abstracts software from the underlying hardware infrastructure, allowing key functions such as Network Management Systems (NMS), Network Processing, and Baseband Processing to be deployed on Commercial Off-The-Shelf (COTS) servers. As a result, operators gain the flexibility of **hybrid deployments** across private and public cloud environments while maintaining the option to use purpose-built hardware if needed.

DOWNLOAD THE WHITEPAPER:
HOW TO OPTIMIZE
CLOUD DEPLOYMENTS.

ST Engineering

USE CASES THAT BENEFIT FROM HYBRID DEPLOYMENT SCENARIOS ARE:

SMART GATEWAY DIVERSITY

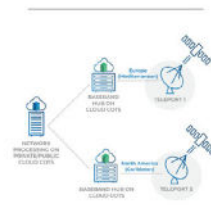
Operators can achieve geographic redundancy and enhance network diversity more cost-effectively by leveraging dynamic and automated deployment of redundant network and baseband processing. This can be done using either public, cloud or shared capacity. In the event of a disruption at the primary location, network traffic can be seamlessly switched to the cloud setup. This approach leads to significant Capex savings, as it eliminates the need to build and maintain a fully redundant geo-diverse system or standby by deploying baseband processing only when needed, and automating resource allocation, operators can optimize resource utilization and reduce operational costs, ensuring a resilient and efficient network infrastructure.



DISASTER RECOVERY

Hybrid cloud solutions can provide a robust disaster recovery strategy. By replicating critical data and applications to the cloud, businesses can ensure continuity in case of on-premises failures. This approach allows for quick recovery times and minimizes downtime, ensuring business operations can continue smoothly.

USE CASE #1: GATEWAY DIVERSITY/ DISASTER RECOVERY



SEASONAL TRAFFIC EXPANSIONS

Service providers can right-size their network for seasonal or event-driven traffic surges by dynamically scaling operations in the cloud. For example, when serving the cruise market with seasonal traffic in the Caribbean and later in the year in the Mediterranean, service providers can avoid the cost of maintaining one fully loaded and one barely loaded network architecture. Instead, they can centralize all network functions in the cloud, paying only for what they need. This automated and flexible approach allows for quick scaling of services during peak periods or special events, ensuring that resources are efficiently allocated to meet customer demands without the need for upfront investment in additional infrastructure.

USE CASE #2: SEASONAL/ EVENT TRAFFIC

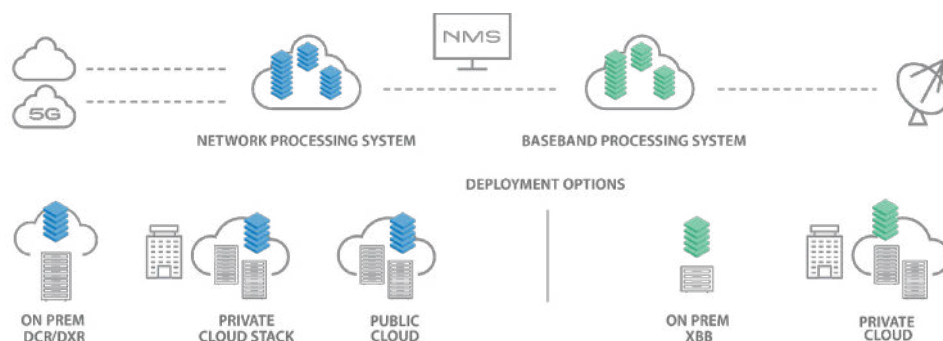


iDIRECT

CASE STUDIES

Intuition's cloud-native, high-density architecture requires less compute infrastructure than traditional platforms. That's because traditional platforms rely on monolithic architectures, where compute resource requirements scale based on the number of networks and total throughput. In contrast, Intuition uses a distributed, cloud-native architecture that scales horizontally based primarily on throughput.

INTUITION GROUND SEGMENT ARCHITECTURE



In terms of **network processing** requirements Intuition delivers efficiency gains ranging from 25% for small and up to 80% for large-scale deployments. Consequently, the reduced need for compute hardware also decreases air conditioning, electricity consumption, rack space, and operational overhead, ultimately lowering the overall TCO.

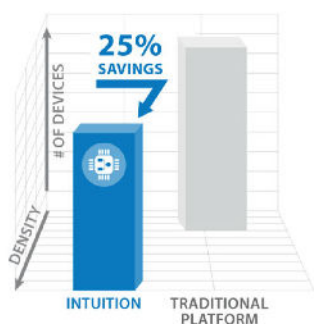
Intuition's high-density **baseband processing** infrastructure, the XBB, supports a larger number of networks and carriers per unit, resulting in baseband processing footprint savings of up to 50% for small networks and up to 90% for very large networks when compared to traditional hub baseband solutions.

The result of these design changes in Intuition are depicted in these four use cases ranging from small scale deployments (< 1.5 Gbps total network throughput, <6 networks) all the way to very large-scale deployments (>100 Gbps, >100 networks).

USE CASE #1

SMALL-SCALE DEPLOYMENT

Network Processing



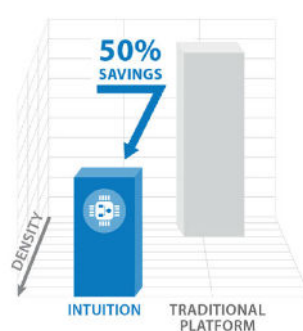
Baseband Processing



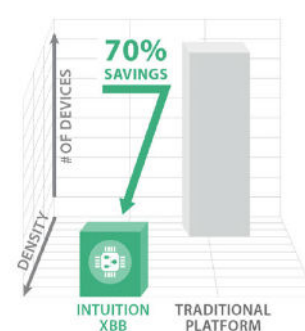
USE CASE #2

MEDIUM-SCALE DEPLOYMENT

Network Processing



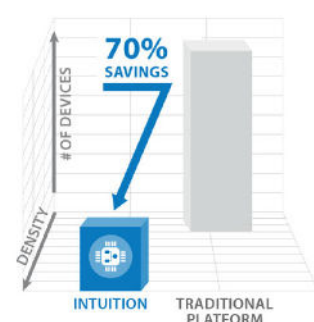
Baseband Processing



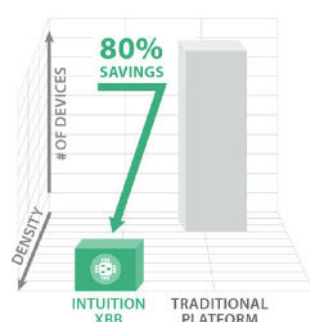
USE CASE #3

LARGE-SCALE DEPLOYMENT

Network Processing



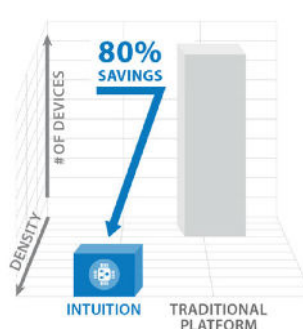
Baseband Processing



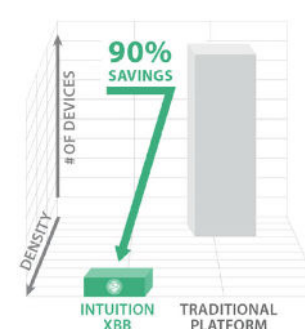
USE CASE #4

VERY LARGE-SCALE DEPLOYMENT

Network Processing



Baseband Processing



These are not the only advantages cloud-native and high-density designs bring. When grouped as cloud-native **microservices**, they become independently deployable services, each designed to fulfill a distinct business function or capability. They represent a paradigm of breaking down monolithic solutions into smaller, independent functional units that work cohesively to achieve the end goal. Unlike traditional system architectures, these smaller units can be deployed, scaled, and managed independently of one another. In the context of an NMS, microservices eliminate the need for the system to shut down entirely in order to implement changes. Like building blocks, these services come together to form robust and adaptable architectures. As independent components microservices also align seamlessly with continuous advancements in software deployment and iteration processes, enabling low-risk updates and rapid feature enhancements, fostering flexibility, quick issue resolution, and improved customer experiences.

A modular, microservice architecture also has advantages for **software upgrades**. Traditional architectures demand extensive testing and often disruptive processes for system-wide updates, which frequently result in service outages or the need for extensive traffic rerouting. By contrast, Intuition's cloud-native design and use of microservices enables incremental enhancements and upgrades based on our **CI/CD approach**. These enhancements would be added on an iterative basis as they are confined to the specific components that require changes and thus are much smaller in scope. With rolling updates, digital twin and green/blue staging individual microservices can be tested or upgraded avoiding system-wide testing and lengthy downtimes when upgrading to the new software releases.

ACCELERATING INNOVATION WITH MODERN CI/CD PRACTICES

Continuous Integration and Continuous Deployment (CI/CD) streamline software development by automating the integration of code changes (CI) and the deployment of updates (CD). CI/CD is a critical practice in modern software development, enabling development teams to detect issues early, ensure consistent builds, and deploy updates with minimal manual effort. Automated pipelines streamline the integration of changes, run tests, and can deploy updates within minutes, compared to the lengthy cycles of traditional approaches.

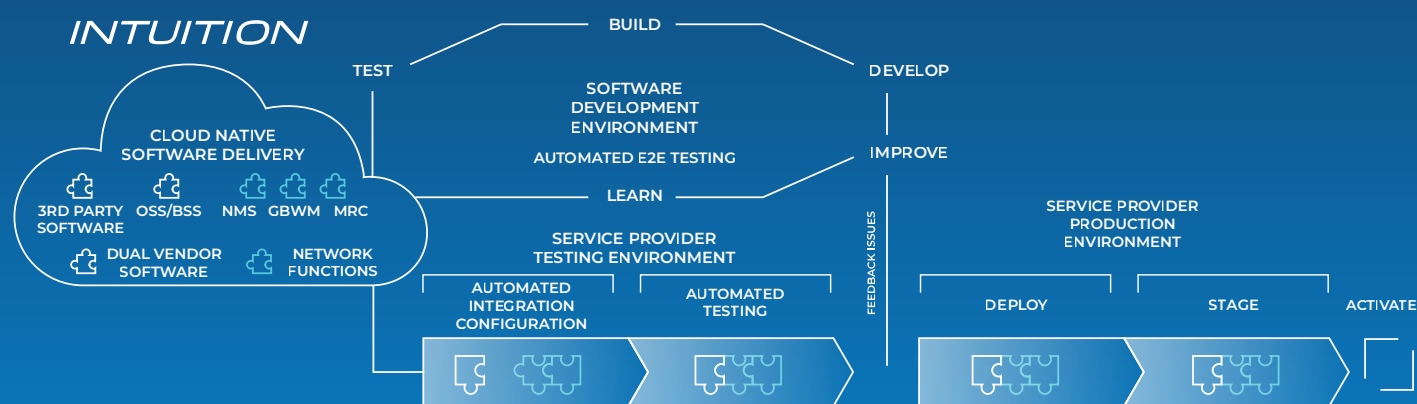


Diagram of Intuition's Scalable Dev and Test Environments based on CI/CD

For cloud-native systems and microservices, CI/CD is critical. Microservices, as independently deployable components, align seamlessly with CI/CD workflows. This ensures that updates to one service don't affect others, enabling low-risk, incremental deployments. Teams can quickly add features, resolve issues, and adapt to user feedback, enhancing customer experiences.

Cloud-native architecture significantly enhances system **resiliency** by decoupling application functionality from the underlying hardware. This abstraction reduces the risk of single points of failure due to physical infrastructure. For example, in a server cluster, the failure of a single node does not disrupt overall operations. Kubernetes orchestration dynamically redistributes workloads across healthy nodes, using resource balancing, self-healing, and automated recovery mechanisms to maintain service continuity. If a compute node fails, containers and virtual machines are automatically rescheduled to available nodes. When the failed node returns, workloads are only rebalanced if needed, avoiding unnecessary disruption. This behavior ensures stability and optimizes resource utilization. Intuition is designed to support geographically distributed deployments, enabling workloads to operate across multiple regions and diverse network topologies. This architecture is particularly effective in environments with geographic redundancy, where a secondary site can immediately assume operations if the primary location becomes unavailable.

Intuition's centralized data center architecture combines built-in redundancy with a cloud-native microservices

design to deliver telco-grade system **availability**—targeting 99.999%. Unlike traditional VSAT platforms that rely on tightly coupled, location-bound infrastructure, Intuition enables flexible deployment by centralizing compute resources within one or more Data Centers. This approach enhances scalability, simplifies management, and significantly improves operational efficiency.

With the move to cloud-native architectures, **security** becomes a core requirement across all systems. That's where a zero-trust architecture is critical. The cloud-native architecture within Intuition has been built with security in mind from the ground up. By embedding security into continuous integration and deployment pipelines and using the latest security practices such as Software Composition Analysis (SCA), Static and Dynamic Application Security Testing (SAST/DAST), and Runtime Application Self-Protection (RASP), Intuition identifies and mitigates vulnerabilities early. Leveraging Kubernetes for dynamic resource allocation and failover, alongside container hardening with trusted base images and automated threat detection, Intuition ensures every element is designed and built on the latest embedded security principles for operation in complex cloud-native environments.

THE STRATEGIC EDGE OF CLOUD-NATIVE SOLUTIONS

The adoption of cloud-native architectures marks a groundbreaking step in modern system design, deployment, and management. By harnessing dynamic scalability, efficient orchestration, and modular microservices, these architectures not only enable unparalleled flexibility, efficiency, and resilience but also redefine operational cost structures.

The cloud-native and high-density design of the Intuition system architecture unlocks significant efficiency gains resulting in lower total cost of ownership (TCO) through minimized compute and baseband processing needs, reduced space and energy consumption, and substantial cuts in operational overhead.

Additionally, cloud-native systems drive innovation with streamlined CI/CD processes, enabling faster feature rollouts, heightened responsiveness, and sustained competitive agility. With built-in zero-trust security frameworks and resilience to hardware failures or geographically distributed workloads, cloud-native architectures deliver a robust, future-proof foundation for achieving business goals.

For operators aiming to future-proof their operations and drive value in a digital era that is moving to 5G NTN and software-designed satellites and networking, adopting cloud-native approaches is not just an opportunity but a strategic imperative.