2022

Tactical ISR/C2 Integration with AI/ML Augmentation

Maule, Randy W.

Monterey, California: Naval Postgraduate School

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NAVAL RESEARCH PROGRAM

NAVAL POSTGRADUATE SCHOOL

TACTICAL ISR/C2 INTEGRATION WITH AI/ML AUGMENTATION

NPS-22-N215-A

Dr. Randy W. Maule
Department of Information Sciences

December 2022

Prepared for:
Commander, Naval Surface Forces (CNSF)

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Research Topic

- NAVPLAN 2021 and 2022 specify Distributed Maritime Operations (DMO) with a tactical grid to connect distributed nodes for processing at the tactical edge with Artificial Intelligence/Machine Learning (AI/ML) to support:
  - Expeditionary Advanced Base Operations (EABO)
  - Littoral Operations in a Contested Environment (LOCE)
  - Joint All-Domain Command and Control (JADC2)

- Intelligence, Surveillance and Reconnaissance (ISR) and Command and Control (C2) hardware and software have yet to be fully integrated and configurations tested.

Objectives

- Evaluate options for ISR and C2 integration into a universal Common Operational Picture (COP)
  - Hardware Infrastructure: Tactical cloud hardware and deployment options
  - Software Infrastructure: Tactical cloud software and deployment options
  - Application Services: C2/ISR integrated solutions sufficient to support a universal COP from HQ to tactical commands to warfighters at the far edge on mobile devices
- AI/ML for decision and automation support

Questions

- Which cloud hardware infrastructure configurations best support tactical operations for mobile warfighters?
- Which distributed hybrid cloud software architectures best support a universal COP in mobile and disconnected operations?
- Can C2 and ISR software be integrated to provide a universal COP on hybrid tactical cloud architecture?
- How can AI/ML be integrated into hybrid cloud and COP operations to enhance decision support?

Method

- Data Requirements / Systems Review: Tactical cloud hardware, hybrid cloud software, C2 and ISR systems
- Request/Obtain Data from Topic Sponsors: Collect resources to support topic sponsor requirements for a universal COP
- Collect and Analyze Data: Evaluate distributed and converged data processing technologies suitable for DMO/EABO tactical edge nodes
- Provide Empirical Evidence: Determine specifications for a universal COP and determine feasibility for tactical cloud deployment
- Evaluate tactical edge software and signal processing options for D-DIL, EMS, GPS, and cyber challenged operations
- Determine sustainment options for self-contained tactical edge equipment, peer and reachback services, with AI/ML decision support.
- Final Report/ Final Presentation

Guidance

Supported Initiatives

Digital Modernization

DoD DIGITAL MODERNIZATION STRATEGY

DoD Information Resource Management Strategic Plan FY19-23

CLEARED
For Open Publication

Jul 12, 2019

Department of Defense
OFFICE OF PREPUBLICATION AND SECURITY REVIEW

Electromagnetic Spectrum Operations

- ➢ *Resilient, secure, and adaptive tactical*
- ➢ *Contested, congested, and operationally limited EMS environment*

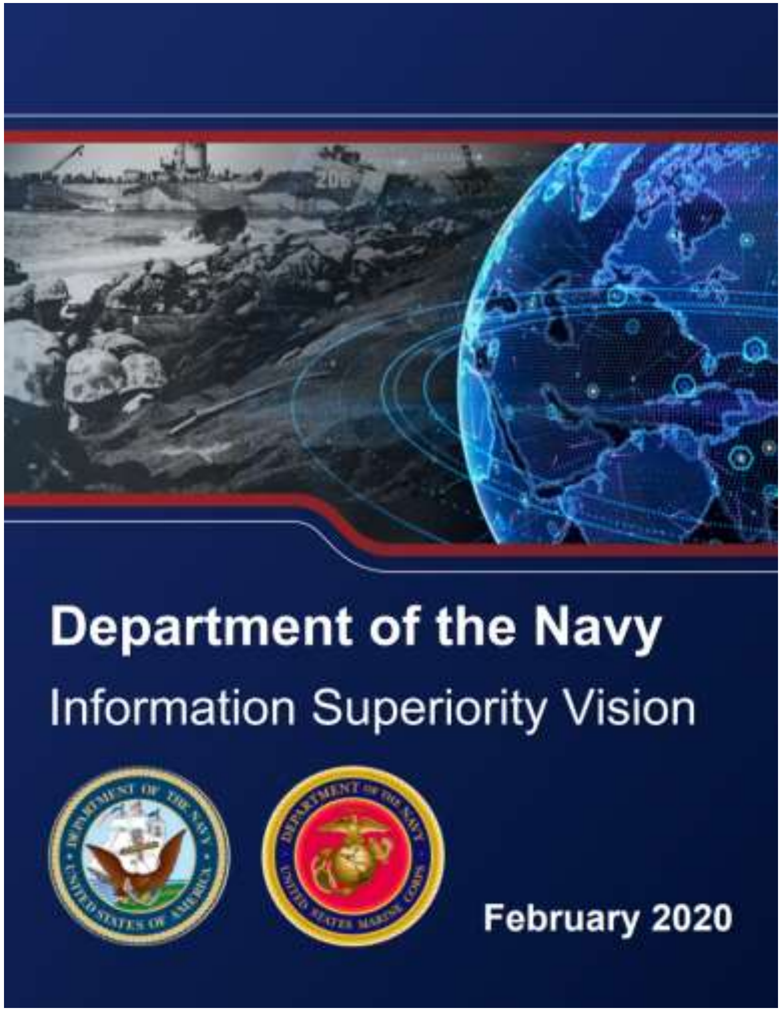
Hyper-Converged Infrastructure (HCI)

- ➢ *Tightly-integrated compute, storage, networking, and virtualization*

DoD CIO Priorities

- ○ Cybersecurity
- ○ Artificial Intelligence (AI)
- ○ Cloud
- ○ Command, Control and Communications (C3)

Information Superiority



Department of the Navy

Information Superiority Vision

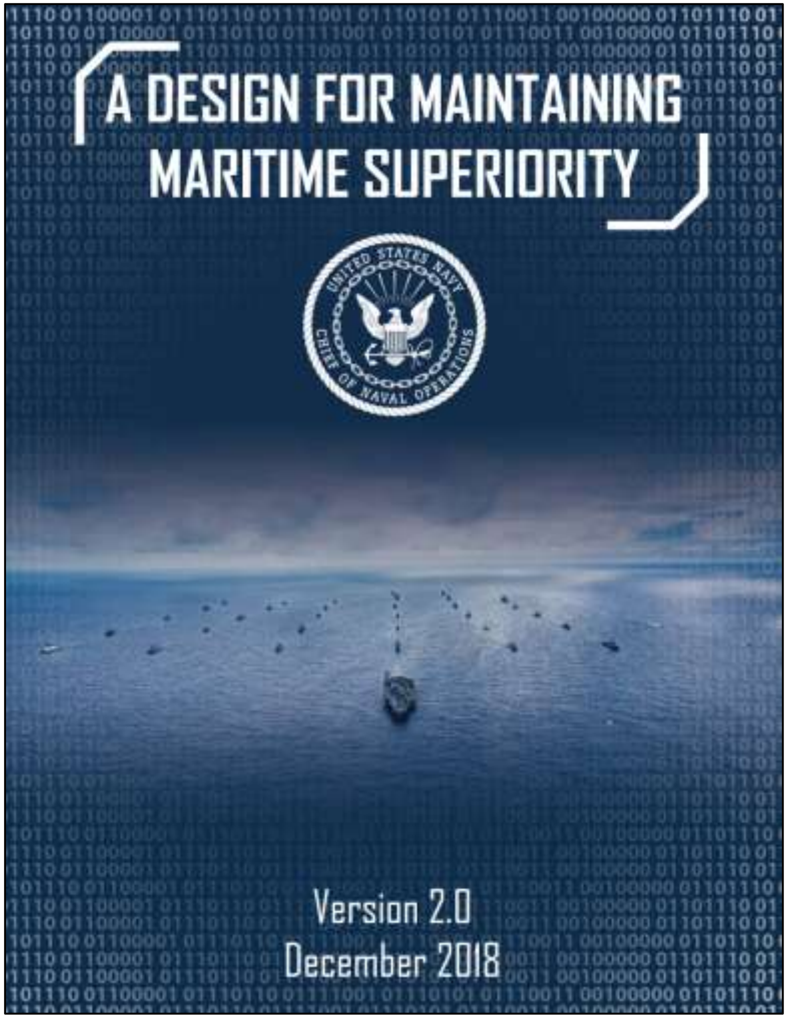
February 2020

Infrastructure – modernize from the current state of fragmented, non-performant, outdated, and indefensible architectures to a unified, logical modern infrastructure capable of delivering information advantage.

Naval Mesh – leverage the existing Naval Tactical Grid (NTG) to create a Naval Mesh Network that extends the DON network and in D-DIL environments can operate cut off from the DON network until connections are reestablished.

Cloud – provide a performant, defendable cloud-enabled network with unified shore and tactical edge processing, storage and networks with identity management across the grid so that tactical edge networks operate as one logical construct.

Maritime Superiority



A DESIGN FOR MAINTAINING MARITIME SUPERIORITY

UNITED STATES NAVY CHIEF OF NAVAL OPERATIONS

Version 2.0

December 2018

- Distributed Maritime Operations (DMO)
- Expeditionary Advanced Base Operations (EABO)
- Littoral Operations in a Contested Environment (LOCE)

Accelerate *Ready, Relevant Learning* (RRL). To retain our competitive advantage.

Instill *continuous learning* behaviors to broaden and deepen warfighting knowledge

Enable adaptation, improvement, and strengthen mission command to out-think and outfight any adversary.

Expeditionary Advanced Based Operations

- We do not collect the data we need systematically, *we lack the processes and technology to make sense of the data we do collect*, and we do not leverage the data we have to identify the decision space in manning, training, and equipping the force.

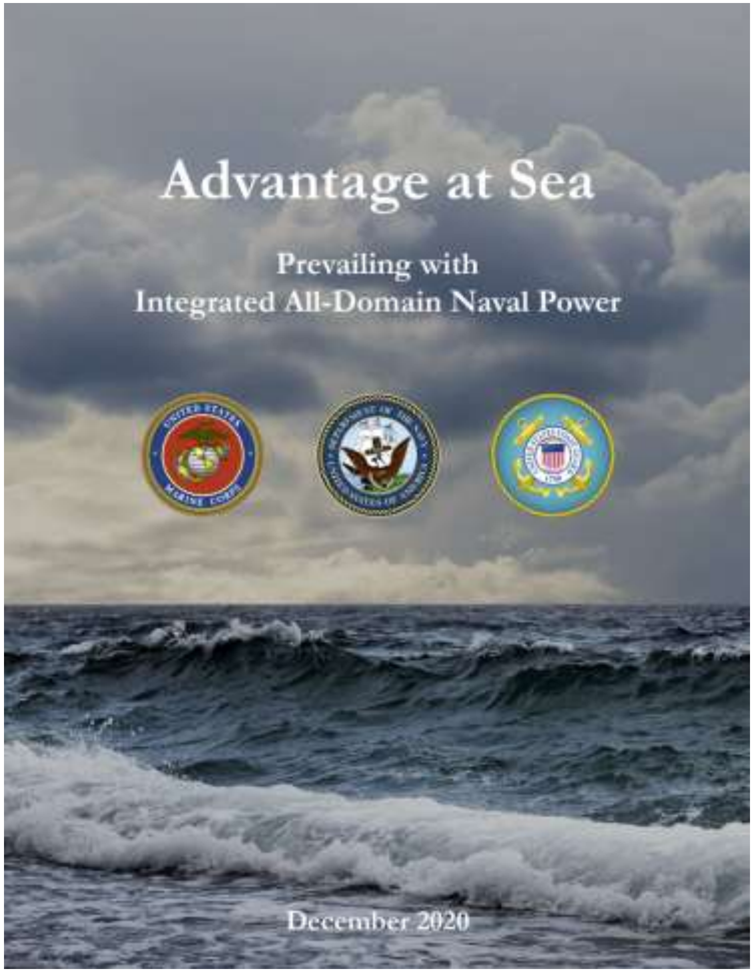
- We will make strategic investments in *data science, machine learning, and artificial intelligence*. Initial investments will be focused on challenges we are confronting in talent management, predictive maintenance, logistics, intelligence, and training.

- We will explore investments in *decision support tools* that leverage data science and artificial intelligence for the *tactical commander*. Success is defined in terms of finding the smallest, lowest signature options that yield the maximum operational utility .

Commandant's Planning Guidance

38th Commandant of the Marine Corps

Tri-Service Maritime Strategy



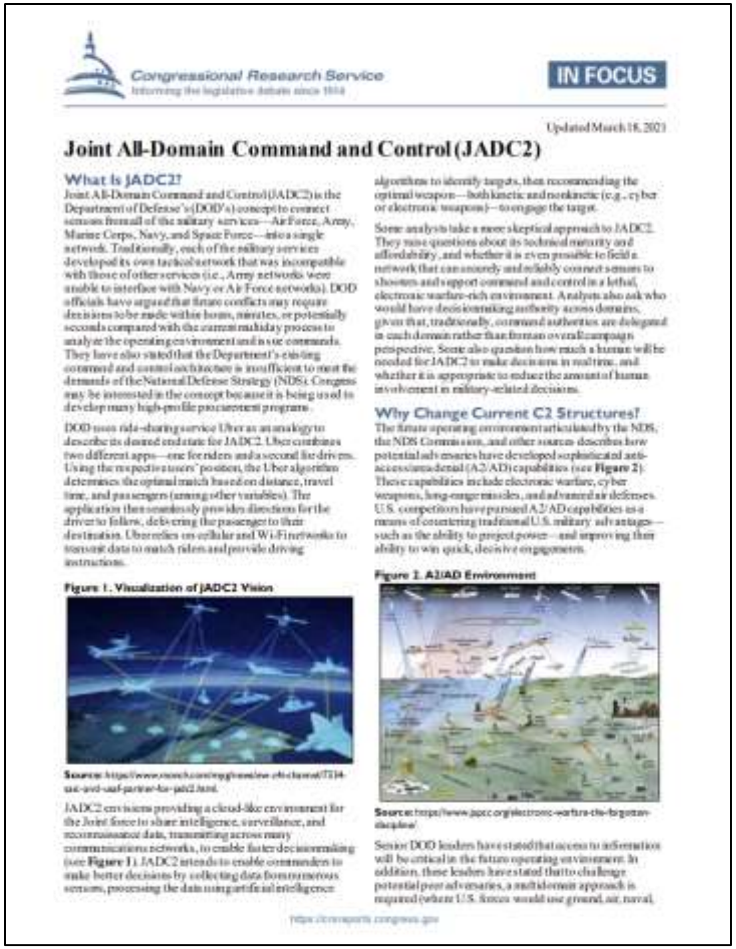
Advantage at Sea

Prevailing with
Integrated All-Domain Naval Power

December 2020

- The Naval Service will accelerate delivery of the next-generation *Naval Operational Architecture*, composed of the *Naval Tactical Grid*, battle management aids, data structures and infrastructure that underpin distributed operations.
- This network will be fully interoperable with *Joint All-Domain Command and Control* systems and will combine inputs into an actionable common operational picture.
- Leveraging *artificial intelligence* and *machine learning*, we will give our warfighters enhanced situational awareness and facilitate decision making at tactically relevant speeds.

Joint All-Domain Command and Control



Congressional Research Service
Informing the legislative debate since 1914

IN FOCUS

Updated March 18, 2021

Joint All-Domain Command and Control (JADC2)

What Is JADC2?

Joint All-Domain Command and Control (JADC2) is the Department of Defense's (DOD's) concept to connect sensors from all of the military services—Air Force, Army, Marine Corps, Navy, and Space Force—into a single network. Traditionally, each of the military services developed its own tactical network that was incompatible with those of other services (i.e., Army networks were unable to interface with Navy or Air Force networks). DOD officials have argued that future conflicts may require decisions to be made within hours, minutes, or potentially seconds compared with the current multiday process to analyze the operating environment and issue commands. They have also stated that the Department's existing command and control architecture is insufficient to meet the demands of the National Defense Strategy (NDS). Congress may be interested in the concept because it is being used to develop many high-profile procurement programs.

DOD uses ride-sharing service Uber as an analogy to describe its desired end state for JADC2. Uber combines two different apps—one for riders and a second for drivers. Using the respective users' position, the Uber algorithm determines the optimal match based on distance, travel time, and passengers (among other variables). The application then seamlessly provides directions for the driver to follow, delivering the passenger to their destination. Uber relies on cellular and Wi-Fi networks to transmit data to match riders and provide driving instructions.

Figure 1. Visualization of JADC2 Vision

Source: https://www.[illegible]/7734-uas-and-uaf-partner-for-jadc2.html.

JADC2 envisions providing a cloud-like environment for the Joint force to share intelligence, surveillance, and reconnaissance data, transmitting across many communications networks, to enable faster decisionmaking (see Figure 1). JADC2 intends to enable commanders to make better decisions by collecting data from numerous sensors, processing the data using artificial intelligence algorithms to identify targets, then recommending the optimal weapon—both kinetic and nonkinetic (e.g., cyber or electronic weapons)—to engage the target.

Some analysts take a more skeptical approach to JADC2. They raise questions about its technical maturity and affordability, and whether it is even possible to field a network that can securely and reliably connect sensors to shooters and support command and control in a lethal, electronic warfare-rich environment. Analysts also ask who would have decisionmaking authority across domains, given that, traditionally, command authorities are delegated in each domain rather than from an overall campaign perspective. Some also question how much a human will be needed for JADC2 to make decisions in real time, and whether it is appropriate to reduce the amount of human involvement in military-related decisions.

Why Change Current C2 Structures?

The future operating environment articulated by the NDS, the NDS Commission, and other sources describes how potential adversaries have developed sophisticated anti-access/area denial (A2/AD) capabilities (see **Figure 2**). These capabilities include electronic warfare, cyber weapons, long-range missiles, and advanced air defenses. U.S. competitors have pursued A2/AD capabilities as a means of countering traditional U.S. military advantages—such as the ability to project power—and improving their ability to win quick, decisive engagements.

Figure 2. A2/AD Environment

Source: https://www.japcc.org/electronic-warfare-the-forgotten-discipline/

Senior DOD leaders have stated that access to information will be critical in the future operating environment. In addition, these leaders have stated that to challenge potential peer adversaries, a multidomain approach is required (where U.S. forces would use ground, air, naval,

https://crsreports.congress.gov

- Joint All-Domain Command and Control (JADC2) is the Department of Defense's (DOD's) concept to *connect sensors from all of the military services*—Air Force, Army, Marine Corps, Navy, and Space Force—into a single network.

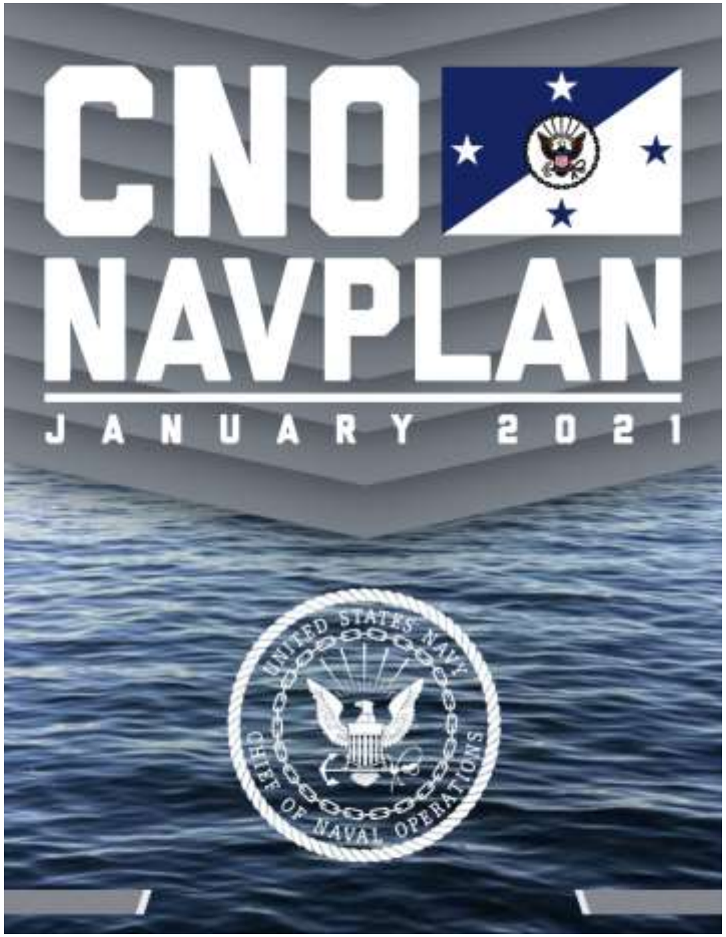
- JADC2 will enable commanders to *make better decisions by collecting data from numerous sensors, processing the data using artificial intelligence algorithms to identify targets*, then recommending the optimal weapon—both kinetic and non-kinetic (e.g., cyber or electronic weapons)—to engage the target.

CNO NAVPLAN

- The Navigation Plan charts the course to execute the *Tri-Service Maritime Strategy* using DMO, LOCE, and EABO for sea and shore-based fires from distributed platforms.

- The *Naval Operational Architecture* provides counter-C5ISRT capabilities; weapons of increasing range and speed; and directed-energy systems capable of defeating anti-ship cruise missiles.

- All connected in the *Naval Operational Architecture* (NOA) that integrates with JADC2; the NOA collection of networks, infrastructure, data, and analytic tools will provide decision advantage.



CNO NAVPLAN

JANUARY 2021

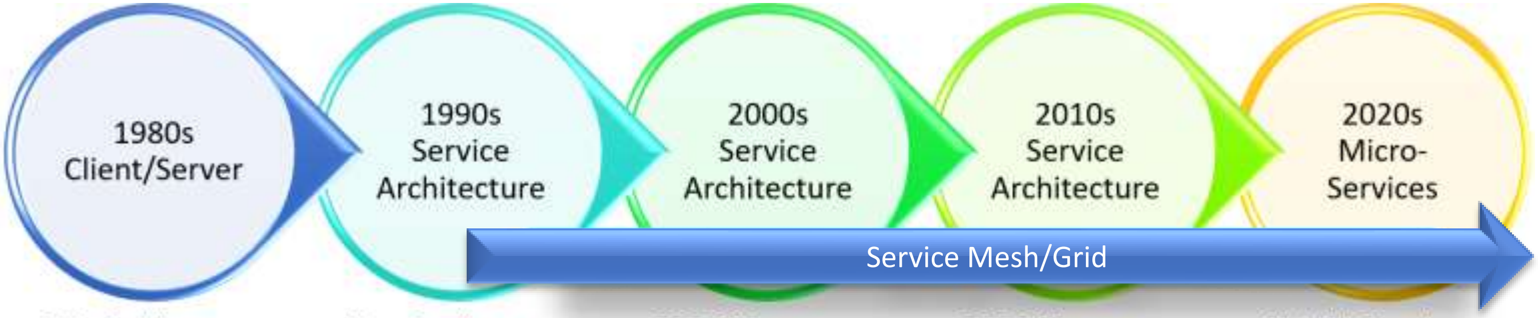
UNITED STATES NAVY

CHIEF OF NAVAL OPERATIONS

Tactical Infrastructure

HQ – Tactical Command – Far Edge

Tactical Cloud Architecture


1980s Client/Server
1990s Service Architecture
2000s Service Architecture
2010s Service Architecture
2020s Micro-Services
Service Mesh/Grid

1980s Client/Server
- Ship Architecture
- Shore Architecture
- Host Servers

1990s Service Architecture
- Host Services
- Communications
- Service Bus

2000s Service Architecture
- FORCENet
- Web Services
- CANES
- Virtual Machines

2010s Service Architecture
- FORCENet
- CANES/ACS
- Cloud Services
- Containers

2020s Micro-Services
- Hybrid Cloud
- ACS/C2C24
- Pod Services
- Service Mesh

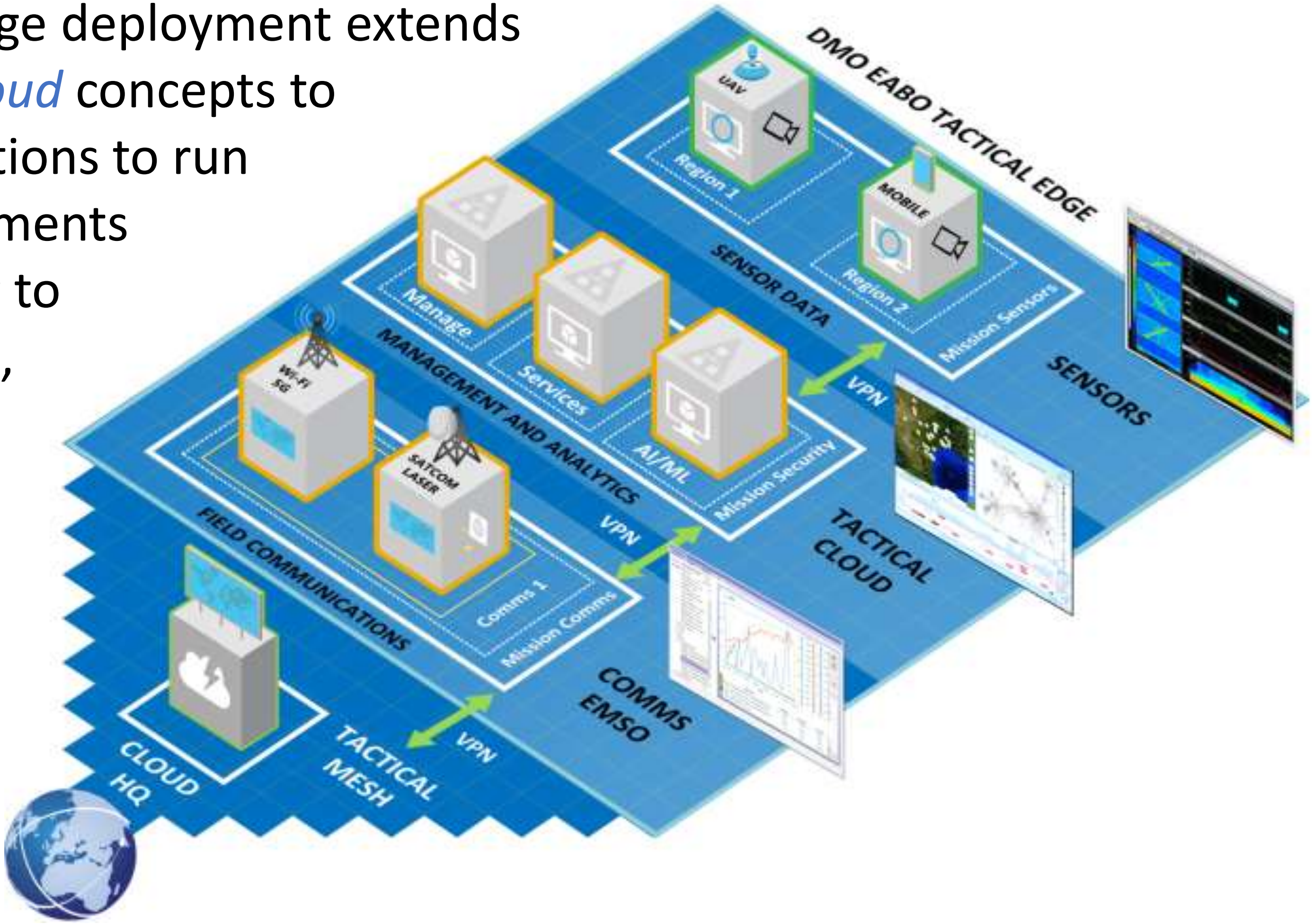
Beacons, sensors and geo-positioning
Mobile users, apps and devices
Reliable performance & experience
Apps
Data
Intelligent Edge
Ubiquitous connectivity
Built-in data analysis
Adaptive trust security

AI /ML at the tactical edge (source: IBM)

- *Distributed platforms* (ship/shore)
- *Converged hardware/software*
- *Hybrid cloud edge* services
- DMO tactical grid:
  - *EABO*
  - *LOCE*

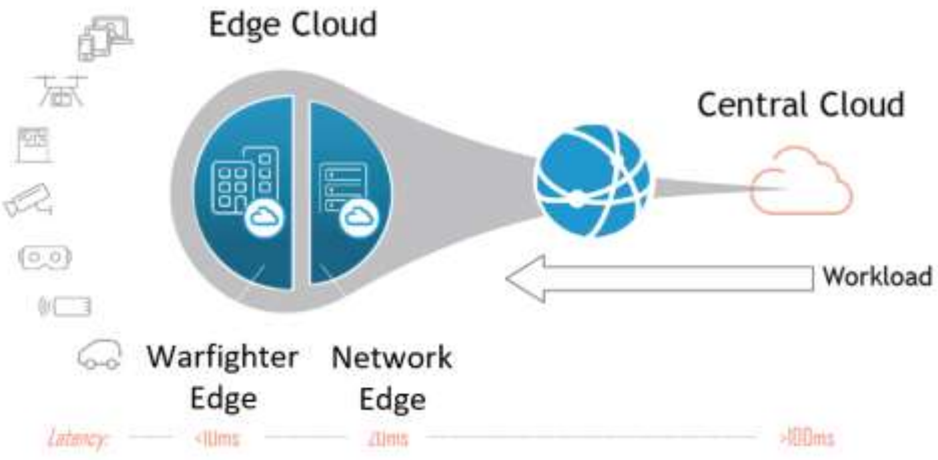
Tactical Edge Node

The Tactical Edge deployment extends *open hybrid cloud* concepts to enable applications to run across environments without having to rebuild, retrain, or maintain separate systems.



Edge Computing

- Consistent deployment model from the core to the edge
- Dynamic and static caching for lower response time
- Automated provisioning, updating, maintenance
- Flexible connectivity and management options
- On-site aggregation and big data analytics
- Higher resiliency and lower costs
- Highly available applications
- Real-time monitoring
- Local data security
- Low latency

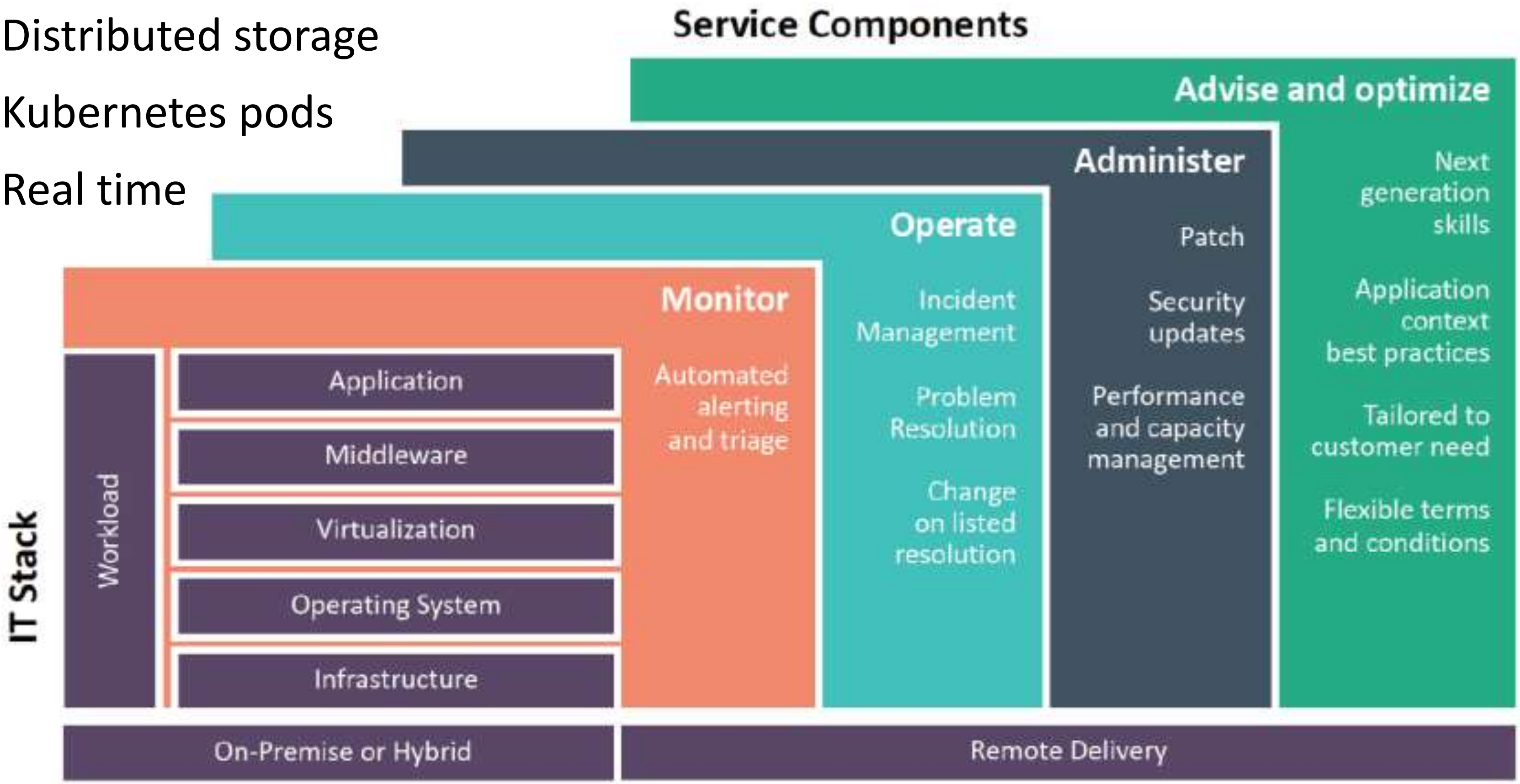


Low-latency edge computing (source: HPE)

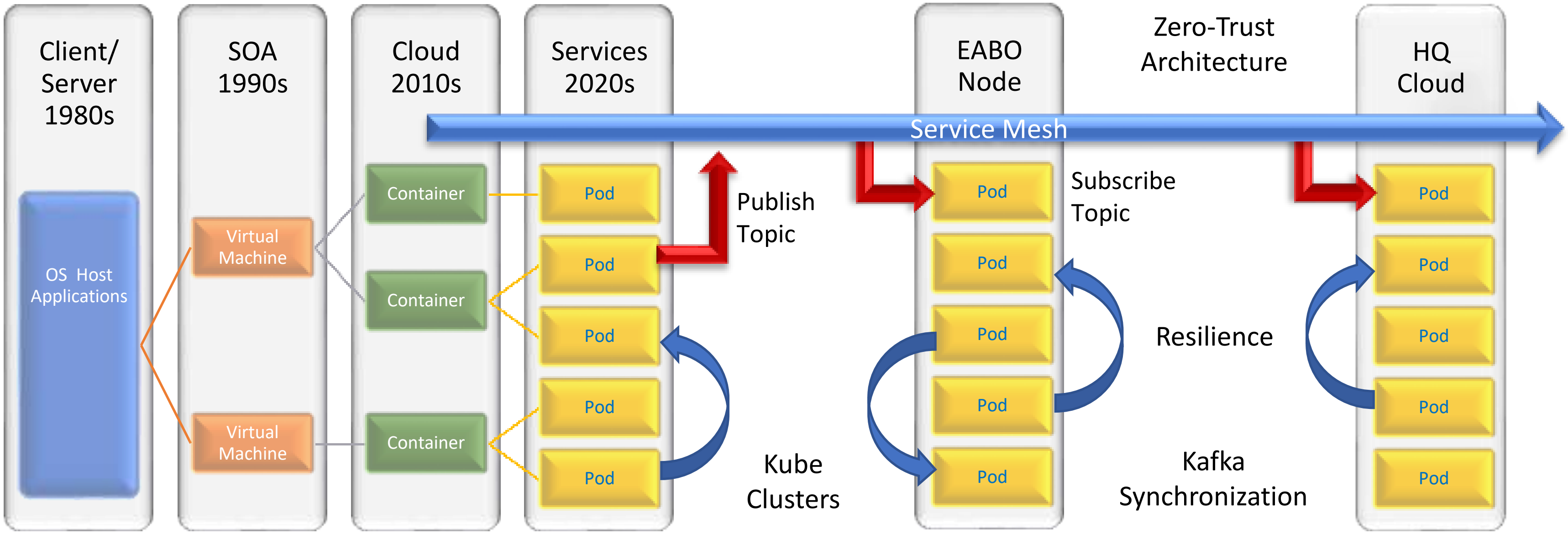
Hyper-Converged Infrastructure

- High availability to operate, regardless of WAN connection state
- Low Space, Weight and Power, Low Cost (SWaP-C)
- Fully autonomous clusters
- Distributed storage
- Kubernetes pods
- Real time

Source: HPE



Service Evolution Zero Trust



- ➢ Event-driven services better mirror real-world events to improve SA
- ➢ Capabilities can be added to services without reprogramming
- ➢ Architecture is better able to manage topology changes, systems failure
- ➢ Operations in D-DIL, EMS, and cyber challenged environments

Cloud Software

DMO/EABO Tactical Grid

DMO/EABO Tactical Edge

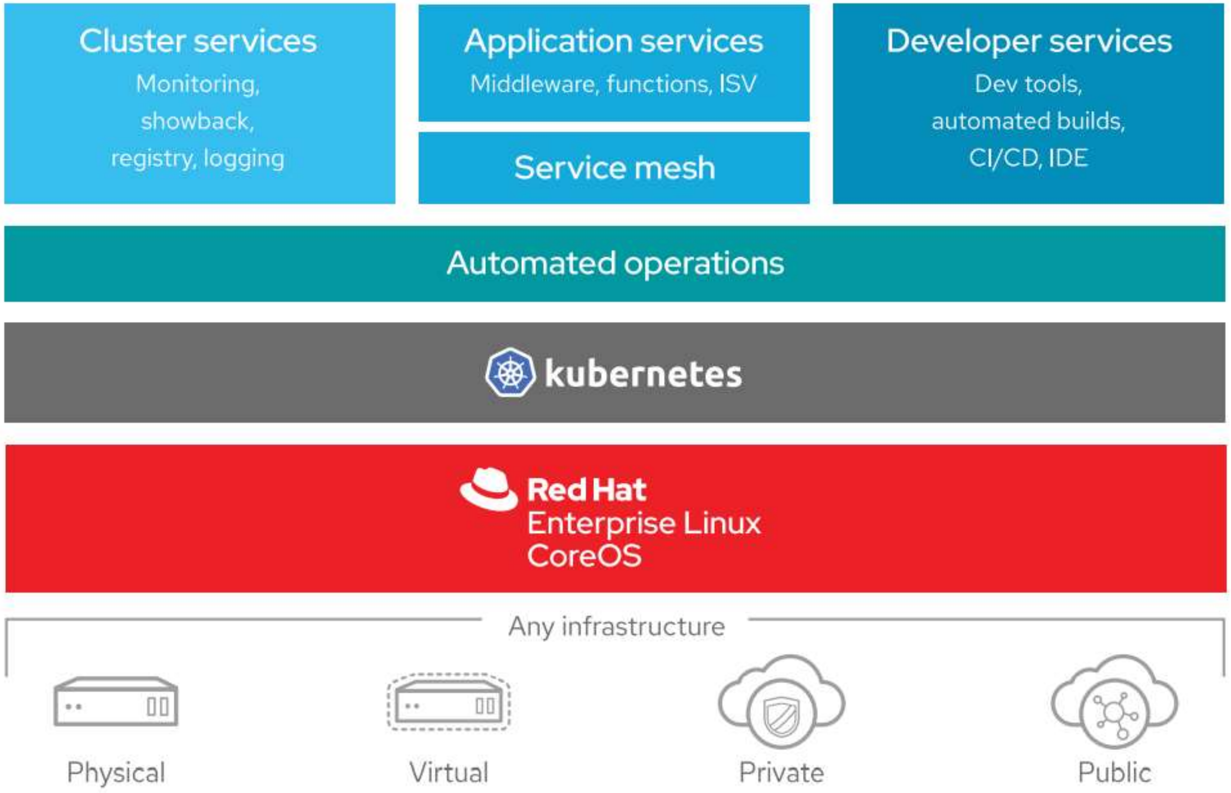
- Hybrid cloud distributed services and storage, data center capabilities at the far tactical edge
- Tolerant of geographically distributed data sources and high-latency/low-bandwidth interconnects
- Limited physical space, restrictive power, heat generation, vibration and shock, restricted and intermittent connections
- Offline operations with regional nodes on the tactical grid, with central synchronization when communications are available
- Scale pods, nodes and clusters with remote out-of-band management agents to synchronize across tactical and regional/HQ clouds
- Integrated artificial intelligence with machine and deep learning for decision support at the tactical edge

Containers

- Extend virtualization to containers to speed app development and deployment, agility, and portability.
- Package and isolate applications that include the entire runtime environment to eliminate physical machines and operating systems.
- Deploy without a kernel with embedded dependencies to enable conflicting software on the same host.
- Eliminate competition for resources such as networking and storage.
- Automatically transition apps between host environments and across systems and geographic areas.
- Micro-services scale to meet demand, scaling only the services, not the entire application.
- Security in the container pipeline to make the containers scalable and trusted.

Orchestration

- Kubernetes de-facto standard for open source container orchestration to automate deployment, scaling, management of containerized applications.
- Containers wrapped into pods with metadata as single deployment entity.
- Controllers determine the number of pods for the workload.
- Devices w/o IPs.
- Secure access.
- Architecture:
  - Micro-services
  - Serverless

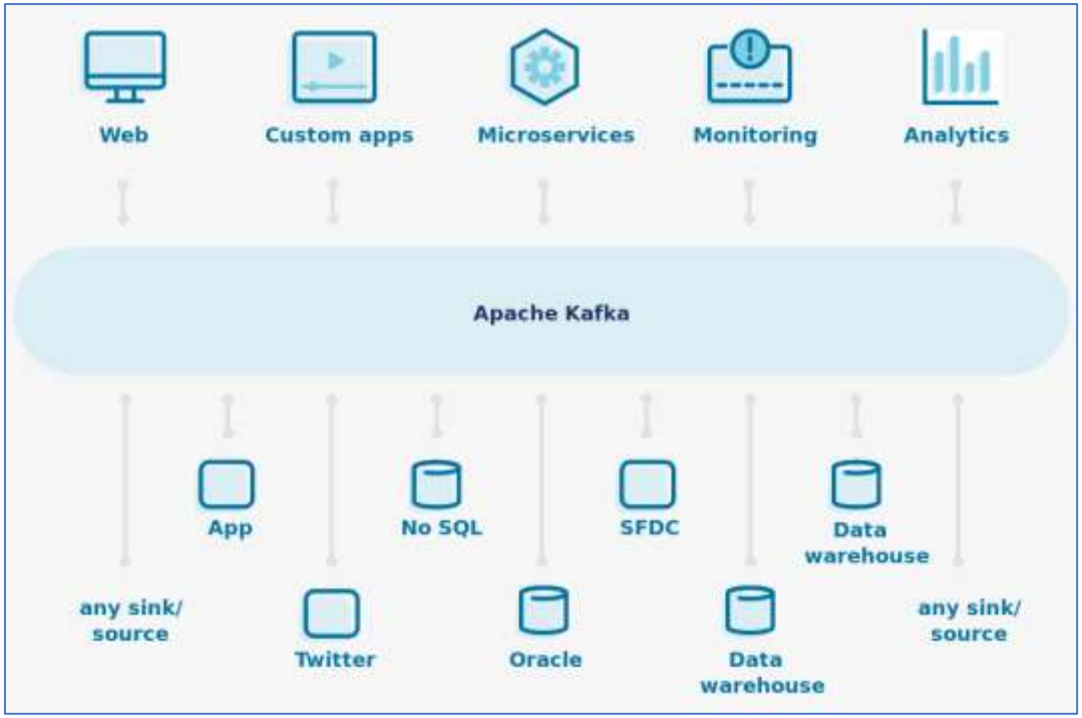


Source: IBM/Red Hat

Real Time Streaming Architecture

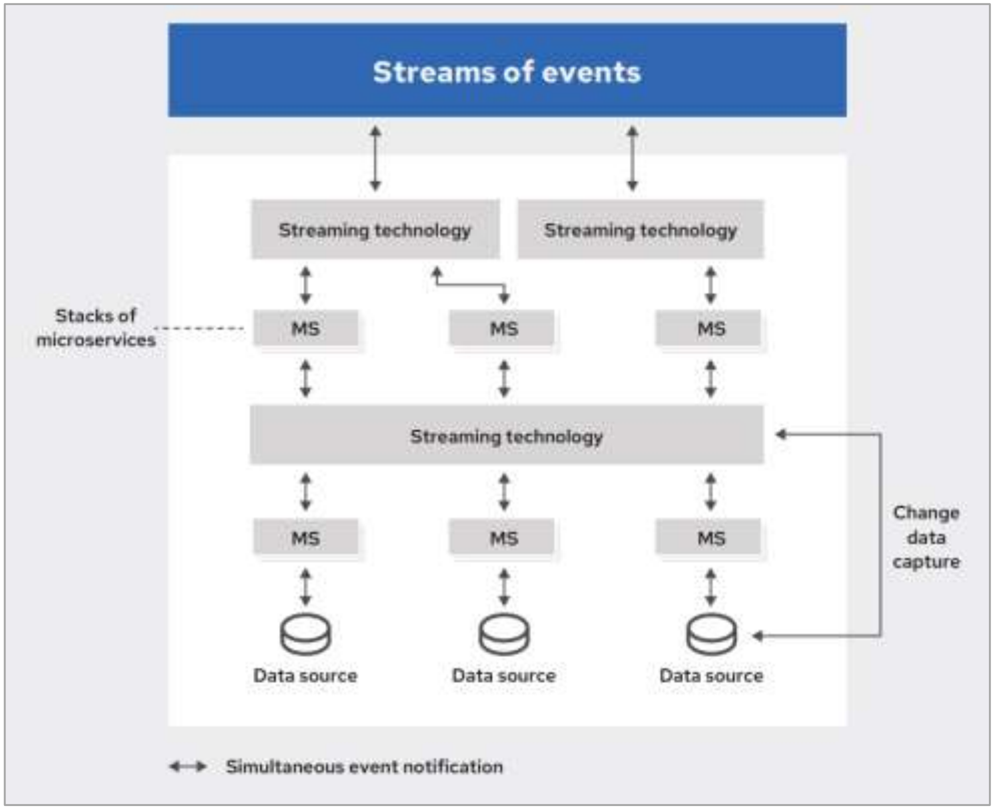
Apache Kafka:

- Distributed system designed for streaming data and media management.
- De-facto communication bus for event-driven and real time architecture.
- Highly resilient, horizontally-scalable, and fault-tolerant.
- High-performance data pipelines, analytics, EDA.
- Topics published as stream of events consumed by subscribers.
- Stream can be consumed within applications and micro-services.
- Optimized for C2/ISR sensor integration



Source: Confluent

Kafka Streams



Source: IBM/Red Hat

Event-Driven Architecture (EDA)

- Asynchronous communication
- Cloud and container development
- Agile, flexible, and scalable
- Distributed microservices
- Stateless microservices
- Loosely coupled
- Sender/publisher objects
- Receiver/subscriber objects
- Users receive events simultaneously
- Low latency, high throughput
- Real time event reaction
- Improved situational awareness

- Kafka EDA is optimized for data in motion in real-time streams. Streams can be captured and replayed, or transformed into new streams and published to subscribers.
- Non-blocking communication releases resources without a response.

Test Cases

Microsoft Azure Stack Hub/HCI

IBM/Red Hat OpenShift

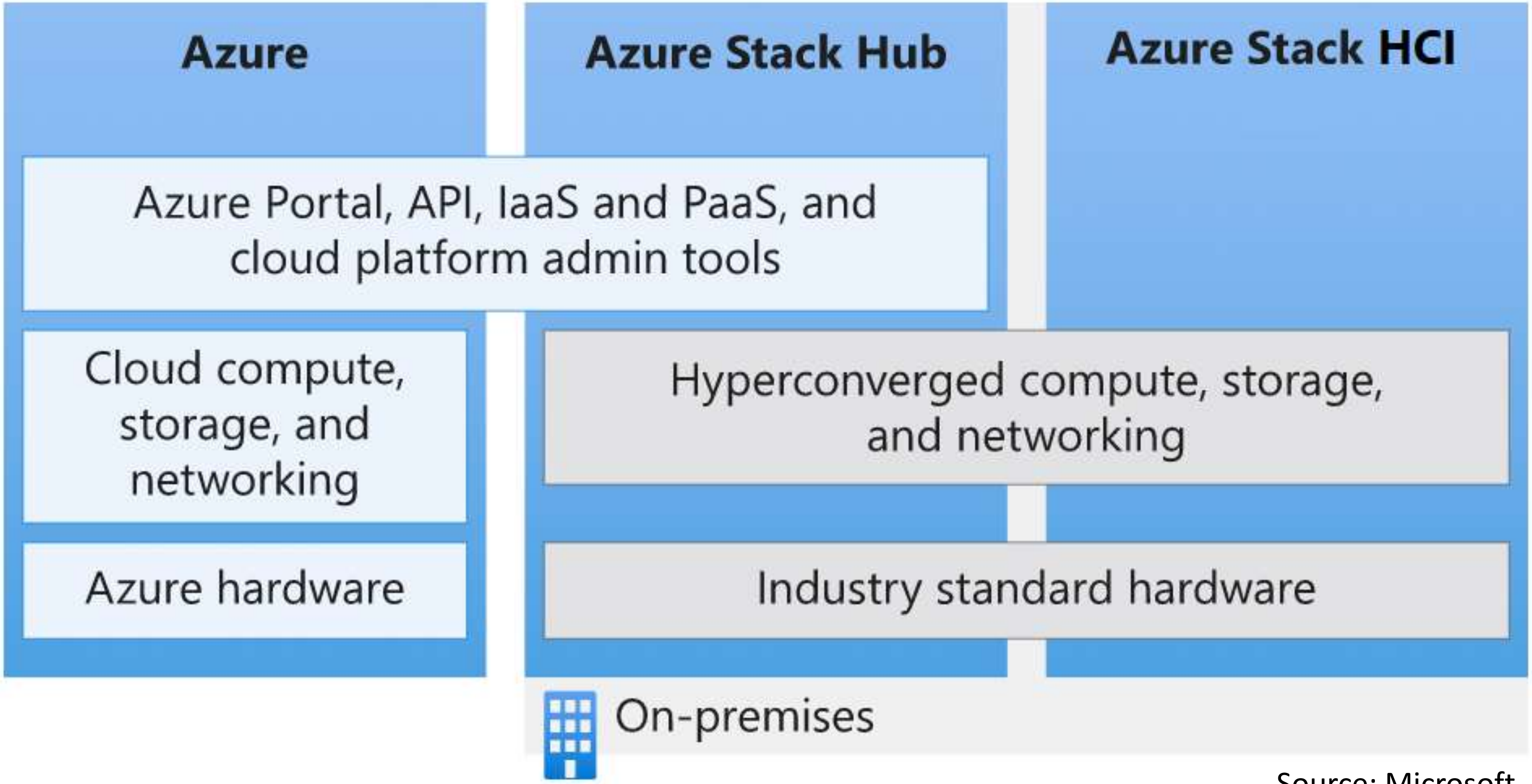
Azure Stack

- Microsoft makes two versions of Azure Stack. Both are premise, hybrid cloud versions of Azure:
  1. *Azure Stack Hub* is a private, autonomous cloud that provides connected or disconnected cloud-native apps for Azure services in premise deployments.
  2. *Azure Stack HCI* is a virtualization host that uses a hybrid solution that integrates with Azure public cloud to provide scalable virtualization and storage for high-performance workloads in edge deployments. Does not currently support disconnected operations.

Microsoft makes an Azure edge appliance that is a subscription service from Azure that was not tested for this project since it cannot be independently deployed.

Source: Microsoft

Azure Stack Comparison



Azure

Azure Stack Hub

Azure Stack HCI

Azure Portal, API, IaaS and PaaS, and cloud platform admin tools

Cloud compute, storage, and networking

Hyperconverged compute, storage, and networking

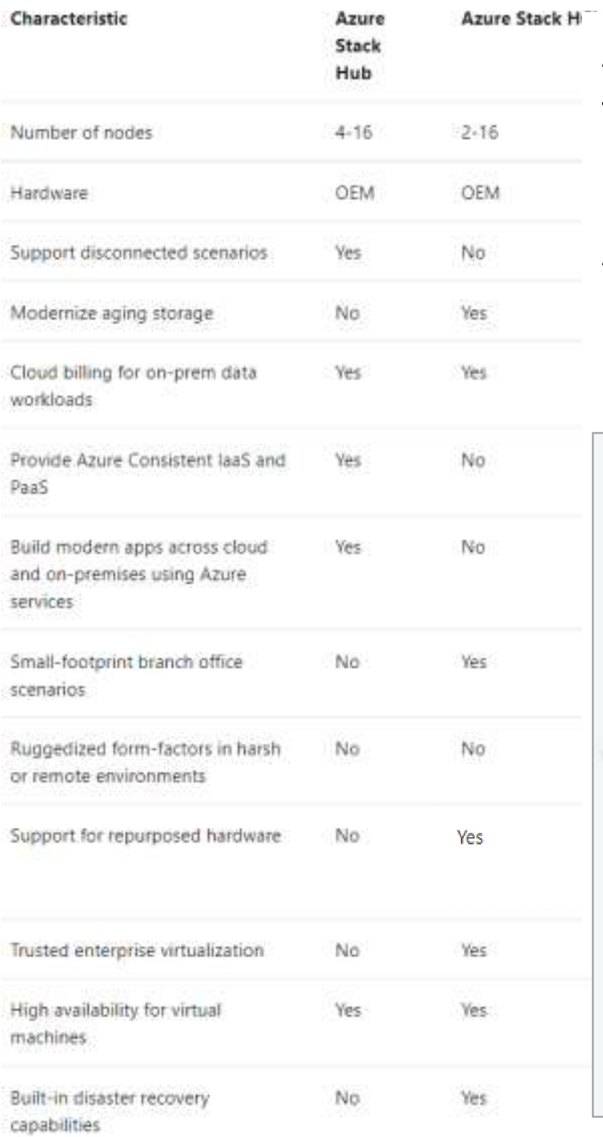
Azure hardware

Industry standard hardware

On-premises

Source: Microsoft

Azure Stack Comparison

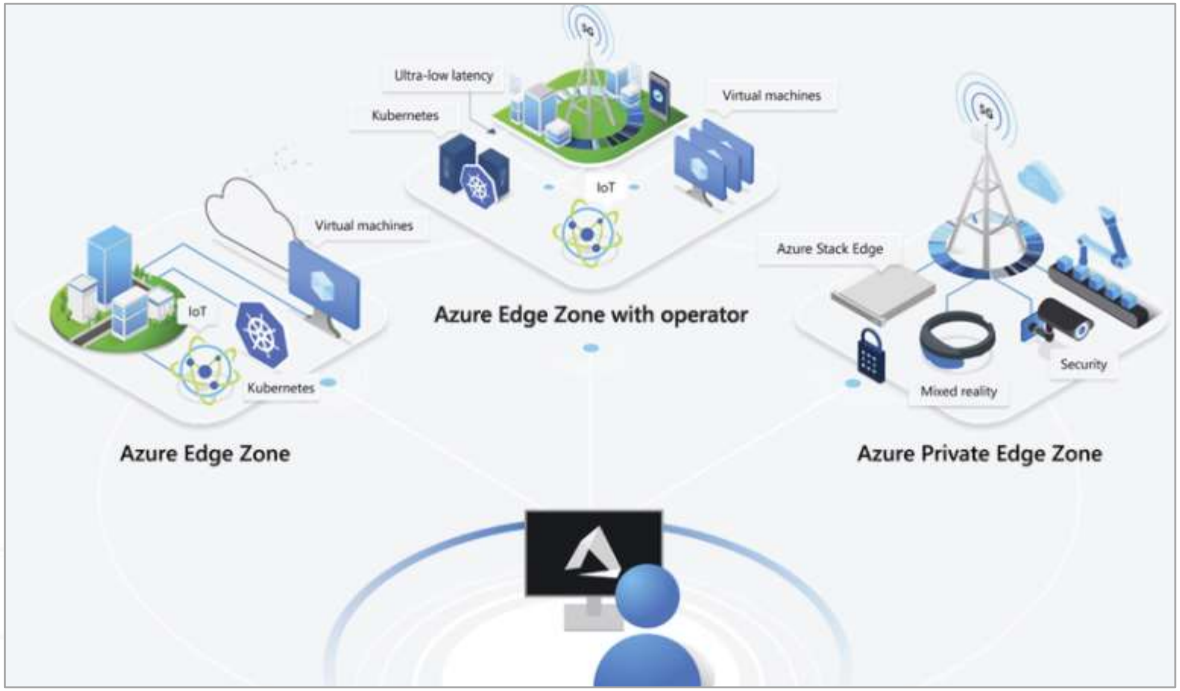


Characteristic	Azure Stack Hub	Azure Stack H
Number of nodes	4-16	2-16
Hardware	OEM	OEM
Support disconnected scenarios	Yes	No
Modernize aging storage	No	Yes
Cloud billing for on-prem data workloads	Yes	Yes
Provide Azure Consistent IaaS and PaaS	Yes	No
Build modern apps across cloud and on-premises using Azure services	Yes	No
Small-footprint branch office scenarios	No	Yes
Ruggedized form-factors in harsh or remote environments	No	No
Support for repurposed hardware	No	Yes
Trusted enterprise virtualization	No	Yes
High availability for virtual machines	Yes	Yes
Built-in disaster recovery capabilities	No	Yes

Source: Microsoft

Azure Stack Hub allows a restricted set of administrative tasks via well-defined, constrained interfaces but is able to run disconnected from the network and Azure cloud.

Azure Stack HCI provides full, direct access to the underlying hardware and the operating system running on cluster nodes but cannot run disconnected from Azure cloud.

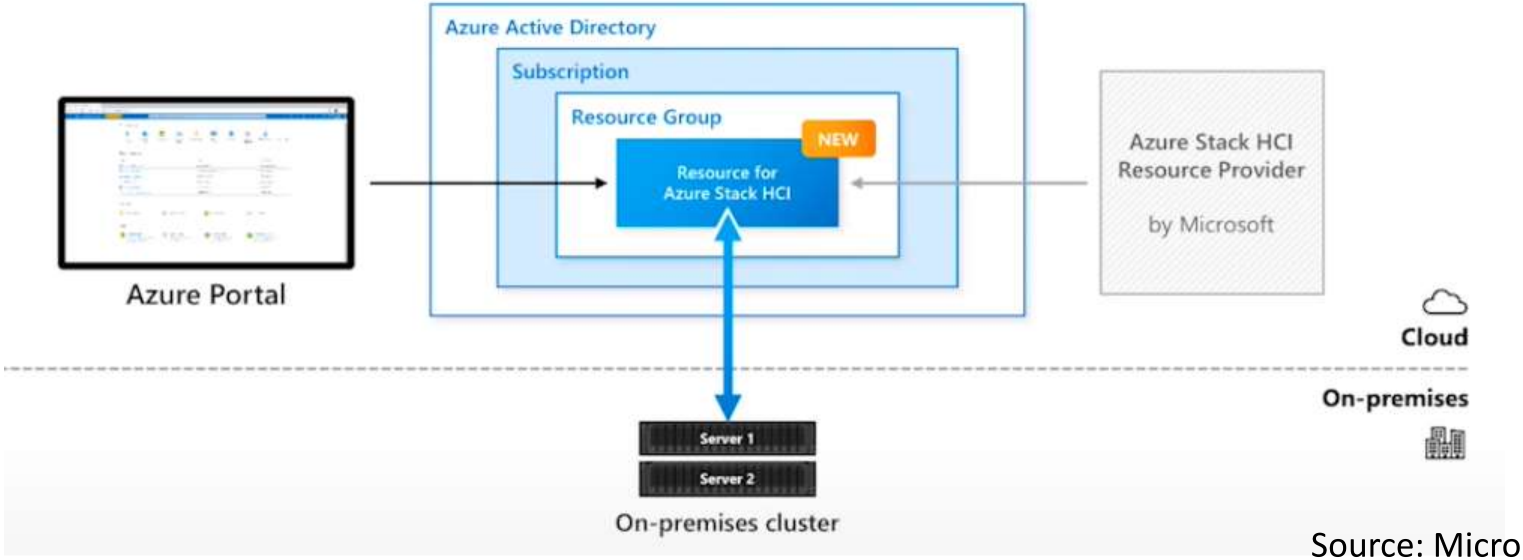


Azure Stack Hub

- Azure Stack Hub is purchased pre-configured from an industry partner (e.g., IBM, Dell, HPE)
- Azure Stack Hub is an extension of Azure for on premise cloud computing.
- Azure Stack Hub can provide Azure services either connected to the internet (and Azure) or in disconnected environments with no internet connectivity.
- Azure Stack Hub uses the same underlying technologies as public Azure, which includes Infrastructure-as-a-Service (IaaS), Software-as-a-Service (SaaS), and optional Platform-as-a-Service (PaaS) capabilities.
- Azure Stack Hub operators can offer PaaS services to users including:
  - Service Fabric
  - Kubernetes Container Service
  - Ethereum Blockchain
  - Cloud Foundry

Azure Stack HCI

- Azure Stack Hyper-Converged infrastructure (HCI) operating system is delivered as an Azure service.
- Azure Stack HCI can be deploy and run Windows and Linux virtual machines (VMs) in premise datacenters or at the tactical edge.
- Azure Stack HCI can integrate back to Azure public cloud for backup, monitoring, and to use Azure Security Center.
- Azure Stack HCI support for disconnected operations TBD.

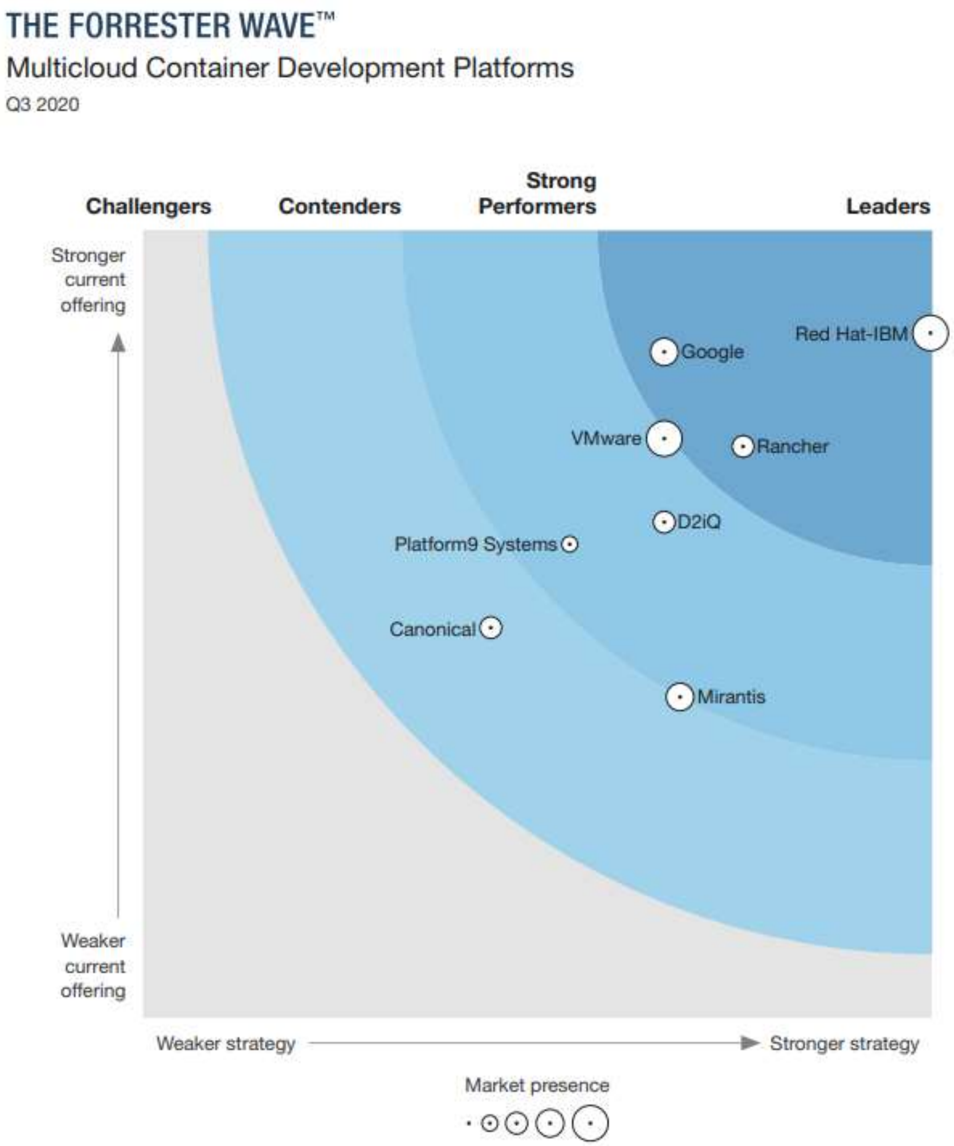


Source: Microsoft

OpenShift

- OpenShift is a platform for developing and running containerized applications that can scale from a few machines and applications to thousands.
- OpenShift Container Platform (OCP) incorporates a Kubernetes foundation to extend containerized applications from a single cloud to multi-cloud environments.
- Our default cluster will consist of four bare metal machines: a bastion node and 3 cluster nodes. Virtualization is available through the Kubernetes API.
- The bastion node will host all of the infrastructure and services required for the cluster to operate using a layer 2 switch to connect all four nodes.
- For added security, the bastion node is the only node to connect to the network and all communications are through the bastion.
- Each node has an out-of-band management interface on the same layer 2 network.
- The bastion node runs Red Hat Enterprise Linux and the nodes run Red Hat CoreOS (RHCOS) that includes:
  - The CRI-O Kubernetes native container runtime that integrates with the OS for running, stopping, and restarting containers.
  - The Kubelet node agent for Kubernetes for launching and monitoring containers.

OpenShift Hybrid Multi-Cloud



THE FORRESTER WAVE™

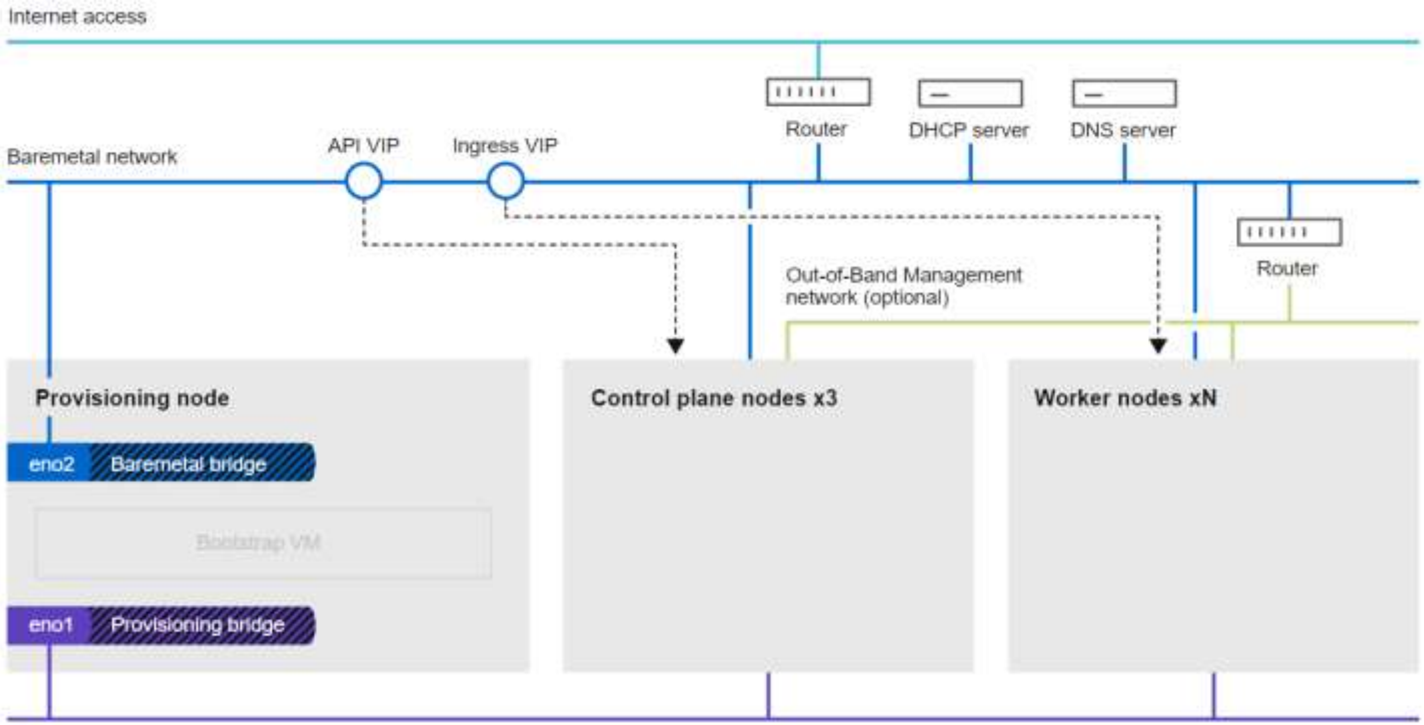
Multicloud Container Development Platforms

Q3 2020

- ➢Most widely deployed multi-cloud container platform
- ➢Integrated development and unified operations across public and on-premises platforms
- ➢Build once, deploy anywhere
- ➢Micro-services application development
- ➢Seamless integration with public and private cloud services.

OpenShift Control Plane

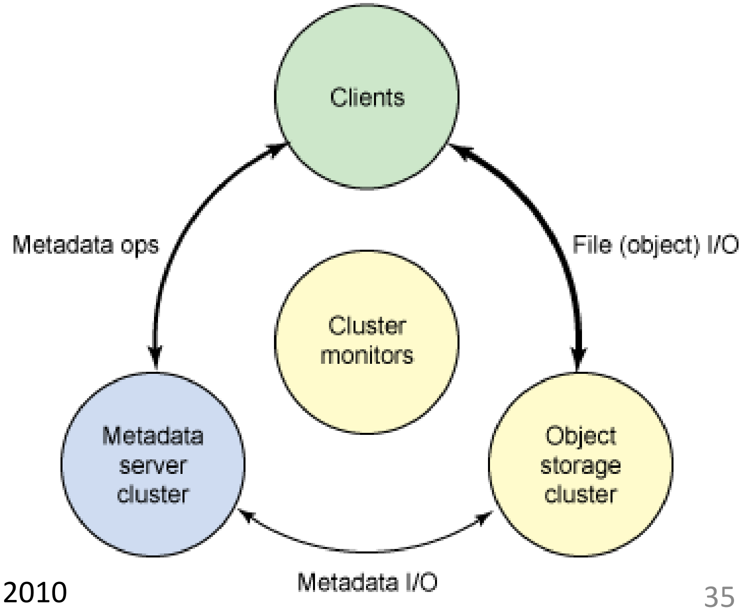
- The control plane is composed of the master machines that manage the cluster and workloads on the compute/worker machines.
- The cluster manages upgrades to the machines by the actions of the cluster version, machine configuration, and individual operators.



Source: IBM/Red Hat

OpenShift Storage

- IBM/Red Hat OpenShift Container Platform (OCP), renamed OpenShift Data Foundation (ODF), provides software-defined storage for containers that support Kubernetes private, hybrid, and multi-cloud deployments.
- Multi-cloud gateways abstract storage infrastructure so data can be stored in many different places but seen as one persistent store.
- Data can be formatted as files, blocks, or objects to support different Kubernetes workloads and help developers deploy applications across multiple tactical clouds.
- ODF is based on the Ceph open source storage standard for unified storage across single and distributed clusters:
  - Distributed operations
  - No single point of failure
  - Scalable to the exabyte level
  - Replicates data for fault-tolerance
  - Self-healing and self-managing



Source: Jones, 2010

Selected Tactical Cloud Hardware

NPS Laboratory Tests

Configuration

- Tactical cloud node configurations from Hewlett Packard Enterprise, IBM, and Dell Computer were evaluated.
- At the time of this writing only the HPE EL8000 provided the required specifications for low SWaP-C, ruggedized, high performance computing for tactical edge deployment.
- “Ruggedized” in this instance refers to water, shock, and vibration per MIL-STD 810G tests.

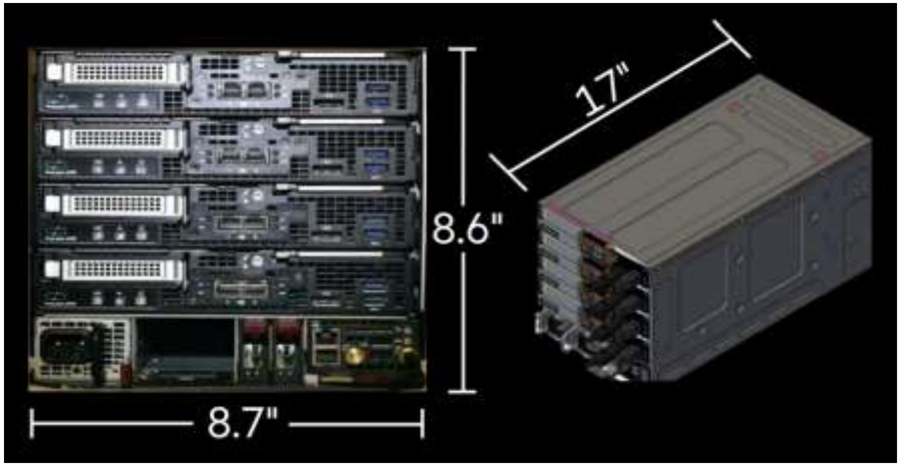
DMO/EABO Tactical Cloud Node

Video Link

HPE EL8000 HCI

Hyper-Converged Infrastructure (HCI):

- Compute and storage components located in the same cluster:
  - 112 Xeon cores (CPU)
  - 6TB memory (RAM)
  - 122TB storage (NVMe)
  - NVIDIA AI/ML (GPU)



Source: HPE

Multi-access Edge Compute (MEC) for C5ISRT, AR/VR, video analytics, AI/ML, AI/DNN

EL8000: Specifications

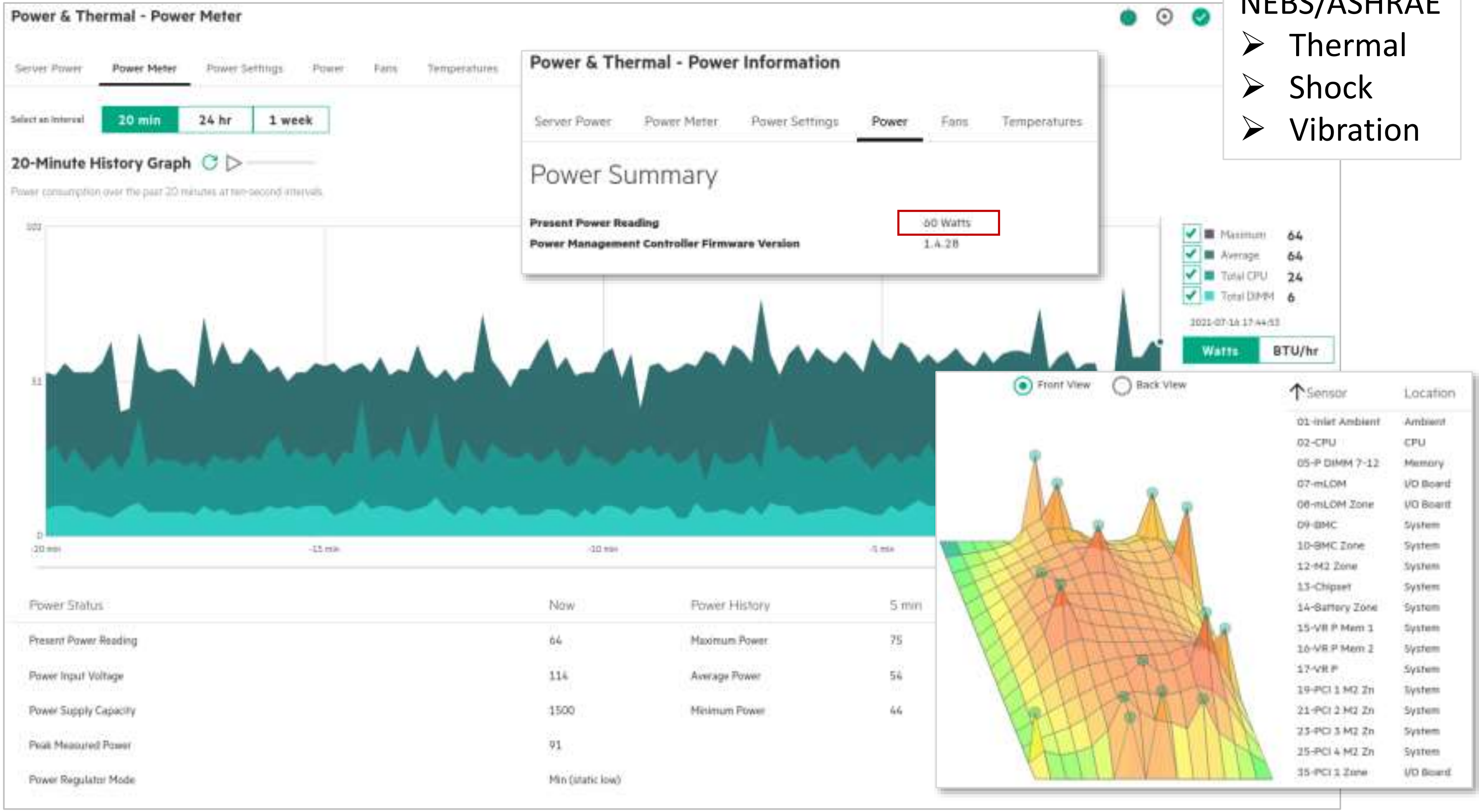
EL8000 HCI tactical cloud edge node:

- Multi-access Edge Compute (MEC), 5G optimization
- Optimized for IoT sensor processing
- Real-time data acquisition and analytics
- Remote management
- Rugged, compact, energy-efficient
- Scalable and modular for real-time AI workloads
- Components can be combined, scaled and hot-swapped
- Intel and Xilinx FPGAs, Intel or Mellanox NICs
- 2TB NVMe internal storage drives per slot
- 6TB memory and 122TB storage per chassis
- 4 PCIe slots per CPU socket, NVIDIA Tesla AI/ML GPUs
- Bare metal to virtualized AI workloads
- Units can be combined for global data center workloads

Power

NEBS/ASHRAE

- ➢ Thermal
- ➢ Shock
- ➢ Vibration



Power & Thermal - Power Meter

20-Minute History Graph

Power consumption over the past 20 minutes at ten-second intervals

☑ ■ Maximum	64
☑ ■ Average	64
☑ ■ Total CPU	24
☑ ■ Total DIMM	6

2021-07-16 17:44:53

Power Status	Now	Power History	5 min
Present Power Reading	64	Maximum Power	75
Power Input Voltage	114	Average Power	54
Power Supply Capacity	1500	Minimum Power	44
Peak Measured Power	91		
Power Regulator Mode	Min (static low)		

Power & Thermal - Power Information

Power Summary

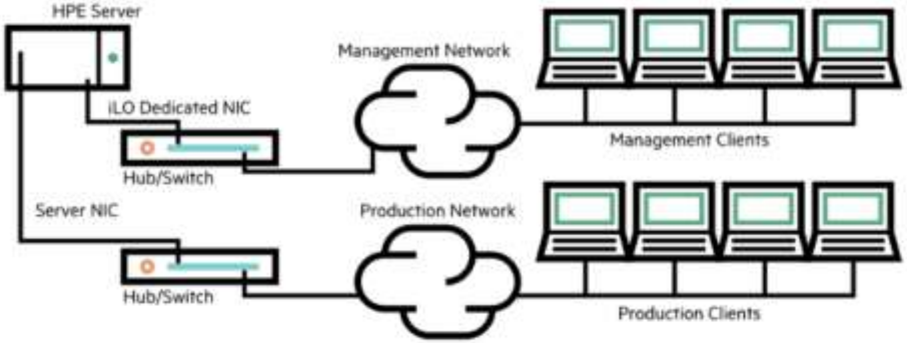
Present Power Reading	60 Watts
Power Management Controller Firmware Version	1.4.28

↑Sensor	Location
01-Inlet Ambient	Ambient
02-CPU	CPU
05-P DIMM 7-12	Memory
07-mLOM	I/O Board
08-mLOM Zone	I/O Board
09-BMC	System
10-BMC Zone	System
12-M2 Zone	System
13-Chipset	System
14-Battery Zone	System
15-VR P Mem 1	System
16-VR P Mem 2	System
17-VR P	System
19-PCI 1 M2 Zn	System
21-PCI 2 M2 Zn	System
23-PCI 3 M2 Zn	System
25-PCI 4 M2 Zn	System
35-PCI 1 Zone	I/O Board

Agentless Management

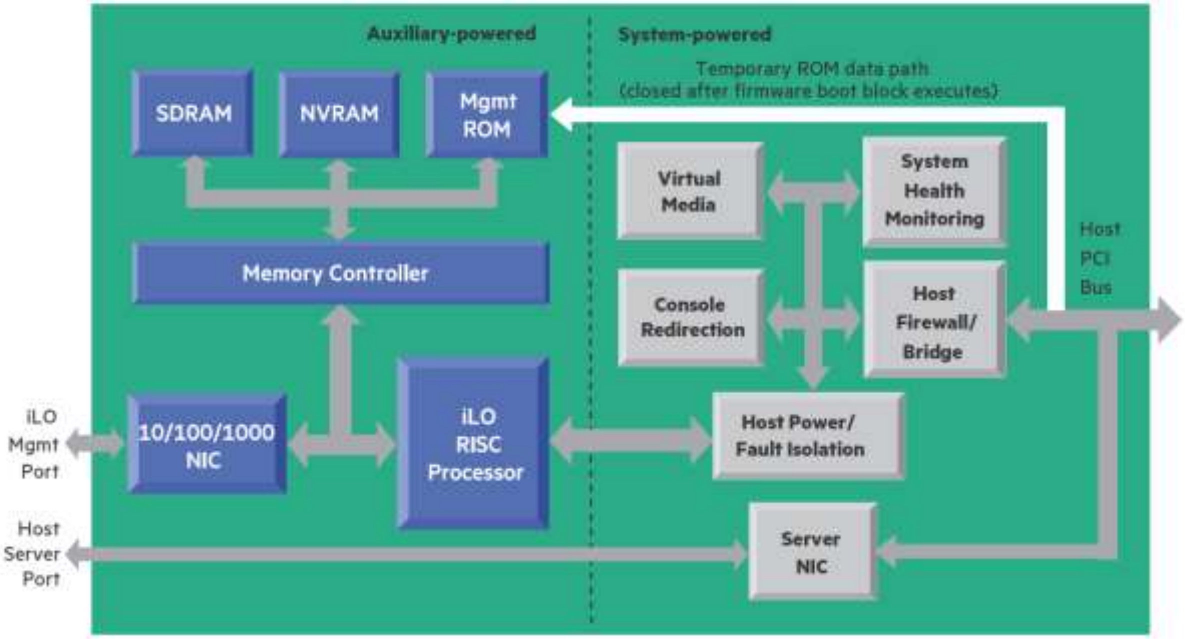
- Agentless Management uses out-of-band communication for increased security and stability.
- Health monitoring and alerting is built into the system and begins when power is connected.
- Runs on the iLO hardware, independent of the operating system and processor.
- The management network provides access to the servers in the event of failure in the production network.
- The management network cannot be accessed from production.

Component	Agentless Management without AMS	Additional information provided when AMS is installed
Server health	• Fans • Temperatures • Power supplies • Memory • CPU • NVDIMM	N/A
Storage	• Smart Array • SMART Drive Monitoring (connected to Smart Array) • Internal and external drives connected to Smart Array • Smart Storage Energy Pack monitoring (supported servers only)	• SMART Drive Monitoring (connected to Smart Array, Smart HBA, and AHCI) • iSCSI (Windows) • NVMe drives
Network	• MAC addresses for embedded NICs that support NC-SI over MCTP • Physical link connectivity and link up/link down traps for NICs that support NC-SI over MCTP • Fibre Channel adapters that support Hewlett Packard Enterprise vendor-defined MCTP commands	• MAC and IP address for standup and embedded NICs • Link up/link down traps • NIC teaming and bridging information (Windows and Linux) • Supported Fibre Channel adapters • VLAN information (Windows and Linux)
	• iLO data • Firmware inventory • Device inventory	• OS information (host SNMP MIB) • Driver/service inventory • Logging events to OS logs [1], [2]
	• Memory • Drives (physical and logical)	N/A



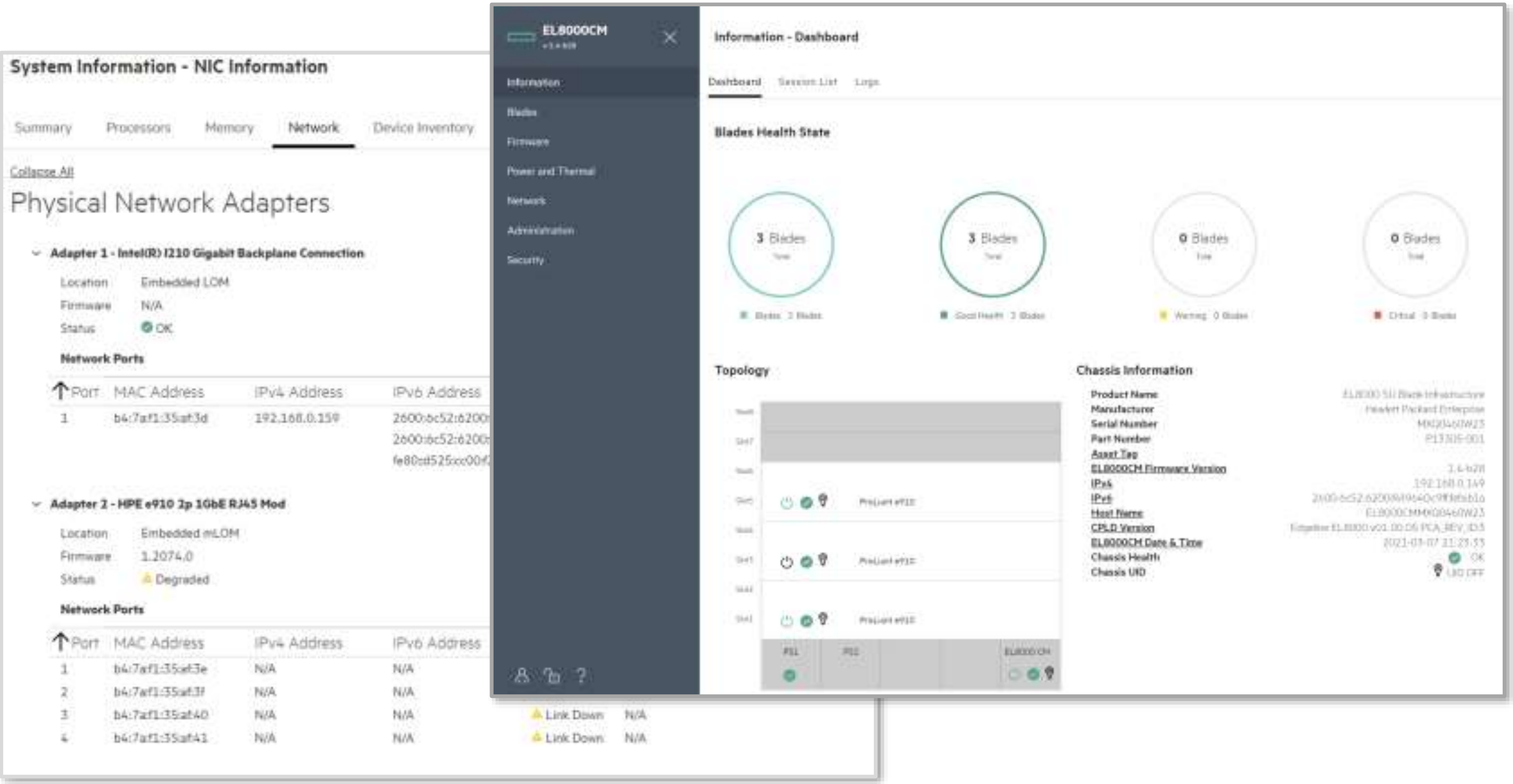
Integrated Lights-Out (iLO)

- Protected PCI bus – iLO shields keys and data stored in memory and firmware, and does not allow direct access to keys via the PCI bus.
- Network and management ports – iLO's firewall and bridge logic prevent any connection between the iLO management port and the server Ethernet port so attacks on the server network cannot compromise iLO and vice-versa.
- Services include:
  - Two-factor authentication
  - One-button secure erase NIST 800-88r1
  - Intelligent OS provisioning
  - Automatic backup, restore, reimage
  - System diagnostics
  - Remote repair
  - Server power
  - Thermal control
  - RESTful API
    - Browser
    - Mobile app
    - SSH client
    - BIOS access



Source: HPE

System Monitor



System Information - NIC Information

Summary | Processors | Memory | Network | Device Inventory

Collapse All

Physical Network Adapters

Adapter 1 - Intel(R) I210 Gigabit Backplane Connection

Location Embedded LOM
Firmware N/A
Status OK

Network Ports

Port	MAC Address	IPv4 Address	IPv6 Address
1	b4:7af1:35:af:3d	192.168.0.159	2600:6c52:6200 2600:6c52:6200 fe80::d525:cc00:f

Adapter 2 - HPE e910 2p 1GbE RJ45 Mod

Location Embedded mLOM
Firmware 1.2074.0
Status Degraded

Network Ports

Port	MAC Address	IPv4 Address	IPv6 Address		
1	b4:7af1:35:af:3e	N/A	N/A		
2	b4:7af1:35:af:3f	N/A	N/A		
3	b4:7af1:35:af:40	N/A	N/A	Link Down	N/A
4	b4:7af1:35:af:41	N/A	N/A	Link Down	N/A

EL8000CM

Information
Blades
Firmware
Power and Thermal
Network
Administration
Security

Information - Dashboard

Dashboard | Session List | Logs

Blades Health State

3 Blades Total — Blades 3 Blades
3 Blades Total — Good Health 3 Blades
0 Blades Total — Warning 0 Blades
0 Blades Total — Critical 0 Blades

Topology

Chassis Information

Product Name	EL8000 5U Blade Infrastructure
Manufacturer	Hewlett Packard Enterprise
Serial Number	MXQ0460W23
Part Number	P13305-001
Asset Tag	
EL8000CM Firmware Version	1.4-b28
IPv4	192.168.0.149
IPv6	2600:6c52:6200:[illegible]
Host Name	EL8000CMMXQ0460W23
CPLD Version	Edgeline EL8000 v01.00.06 PCA_REV_ID3
EL8000CM Date & Time	2021-03-07 11:25:53
Chassis Health	OK
Chassis UID	UID OFF

- ➢ Endpoint tamper detection
- ➢ 2- factor authentication CAC/PIV
- ➢ Global directory/Kerberos authentication
- ➢ iLO federation across servers with HTML 5 interface

Source: SEA Laboratory

Remote Provisioning

Intelligent Provisioning (remote server management) – All needed firmware, drivers, and tools are available on the system so the server is immediately ready for provisioning:

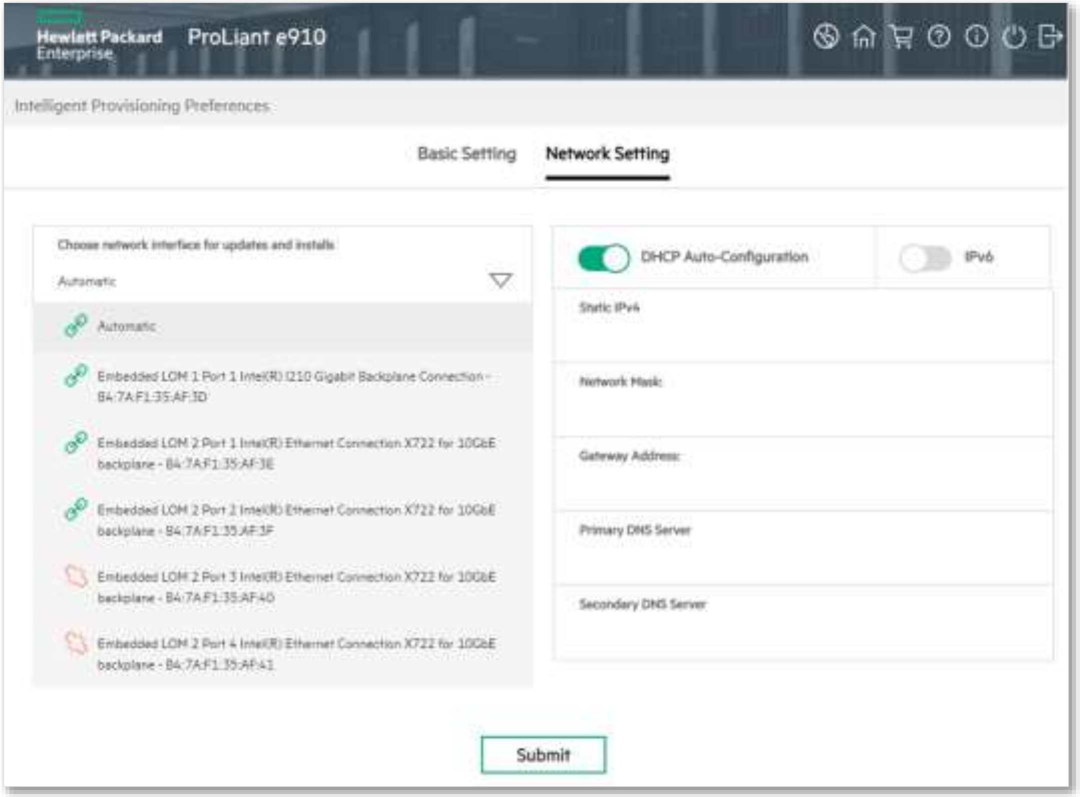
- Perform functions when the server is OFF
- Perform tasks while running an operating system without powering OFF the server.

iLO-dedicated management:

- Secure management firewall
- Out-of-band communication
- Increased security and stability

Monitor internal subsystems:

- Thermal
- Power
- Memory
- Storage
- Machine learning
- Predictive analytics
- Problem recommendations


Hewlett Packard Enterprise
ProLiant e910
Intelligent Provisioning Preferences
Basic Setting
Network Setting
Submit

Choose network interface for updates and installs

Automatic

- Automatic
- Embedded LOM 1 Port 1 Intel(R) I210 Gigabit Backplane Connection - B4:7A:F1:35:AF:3D
- Embedded LOM 2 Port 1 Intel(R) Ethernet Connection X722 for 10GbE backplane - B4:7A:F1:35:AF:3E
- Embedded LOM 2 Port 2 Intel(R) Ethernet Connection X722 for 10GbE backplane - B4:7A:F1:35:AF:3F
- Embedded LOM 2 Port 3 Intel(R) Ethernet Connection X722 for 10GbE backplane - B4:7A:F1:35:AF:40
- Embedded LOM 2 Port 4 Intel(R) Ethernet Connection X722 for 10GbE backplane - B4:7A:F1:35:AF:41

● DHCP Auto-Configuration

○ IPv6

Static IPv4

Network Mask:

Gateway Address:

Primary DNS Server

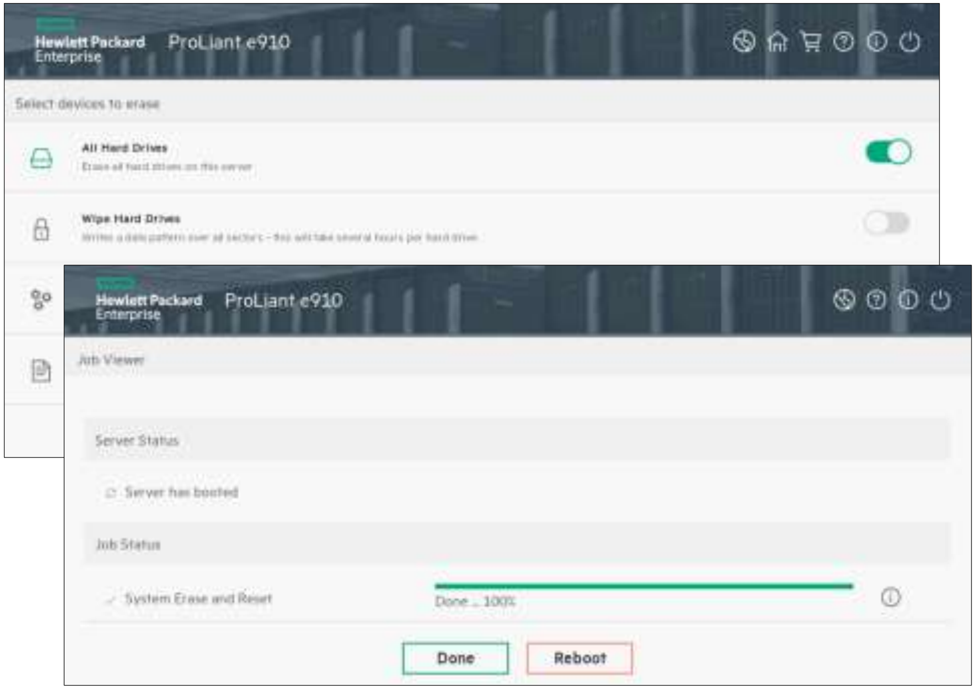
Secondary DNS Server

Source: SEA Laboratory

Erase and Reset

Intelligent Provisioning provides two methods to remotely decommission or repurpose a server :

- **One-button Secure Erase**
  - Automatically returns the server and supported components to the default state following NIST Special Publication 800-88 Revision 1, Guidelines for Media Sanitization.
- **System Erase and Reset**
  - The System Erase and Reset function overwrites data on drives by using the guidelines from DoD 5220.22-M.
  - Software overwrites all block devices attached to the system by applying random patterns.



Hewlett Packard Enterprise ProLiant e910

Select devices to erase

All Hard Drives
Erase all hard drives on this server

Wipe Hard Drives
Writes a data pattern over all sectors – this will take several hours per hard drive

Hewlett Packard Enterprise ProLiant e910

Job Viewer

Server Status

Server has booted

Job Status

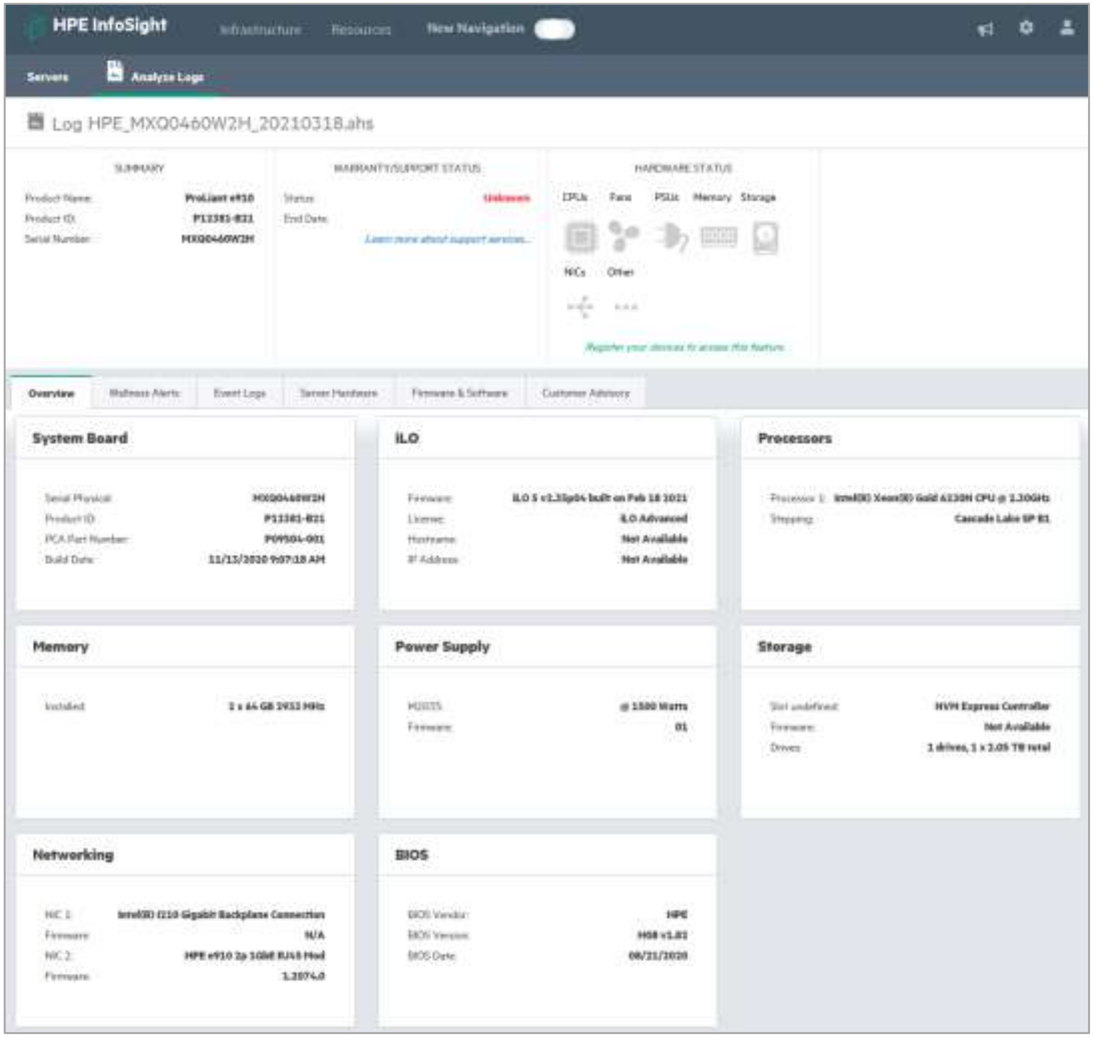
System Erase and Reset — Done ... 100%

Source: SEA Laboratory

Remote Log Analysis

Active Health System Viewer

- Parse File
  - Process and Collate Data
  - Analyze for Faults
  - Generate Output
- Load database
  - Configuration data
  - Build information
  - Fault Analysis data
  - PCI Information
  - USB Information
  - Link Module Information
  - Event data



Log HPE_MXQ0460W2H_20210318.ahs

SUMMARY

Product Name: ProLiant e910
Product ID: P13381-B21
Serial Number: MXQ0460W2H

WARRANTY/SUPPORT STATUS

Status: Unknown
End Date:
Learn more about support services...

HARDWARE STATUS

Register your devices to access this feature.

System Board

Serial Physical: MXQ0460W2H
Product ID: P13381-B21
PCA Part Number: P09504-001
Build Date: 11/13/2020 9:07:18 AM

iLO

Firmware: iLO 5 v2.35p04 built on Feb 18 2021
License: iLO Advanced
Hostname: Not Available
IP Address: Not Available

Processors

Processor 1: Intel(R) Xeon(R) Gold 6230N CPU @ 2.30GHz
Stepping: Cascade Lake SP B1

Memory

Installed: 1 x 64 GB 2933 MHz

Power Supply

HSTNS: @ 1500 Watts
Firmware: 01

Storage

Slot undefined: NVM Express Controller
Firmware: Not Available
Drives: 1 drives, 1 x 2.05 TB total

Networking

NIC 1: Intel(R) I210 Gigabit Backplane Connection
Firmware: N/A
NIC 2: HPE e910 2p 10GbE RJ45 Mod
Firmware: 1.2074.0

BIOS

BIOS Vendor: HPE
BIOS Version: H08 v1.02
BIOS Date: 08/21/2020

Source: SEA Laboratory

Selected Tactical Cloud Software

NPS Laboratory Tests

About

- Azure Stack Hub required 5 servers while the EL8000 provides 4. The HPE team dedicated to an Azure 4-server conversion for the EL8000 conversion for this project was discontinued by HPE. Microsoft did not participate. Azure Stack HCI is an extension of Windows Server Data Center that can run on two servers but at the time of our tests could no operate offline, requiring connection to the Azure public cloud. Tests were discontinued.
- OpenShift also normally requires 5 servers, but an IBM/Red Hat team worked with HPE to make the conversion to 4 servers for the EL8000 configuration used in this project. OpenShift is the software used in Fleet CANES/ACS and C2C24/Project Overmatch.

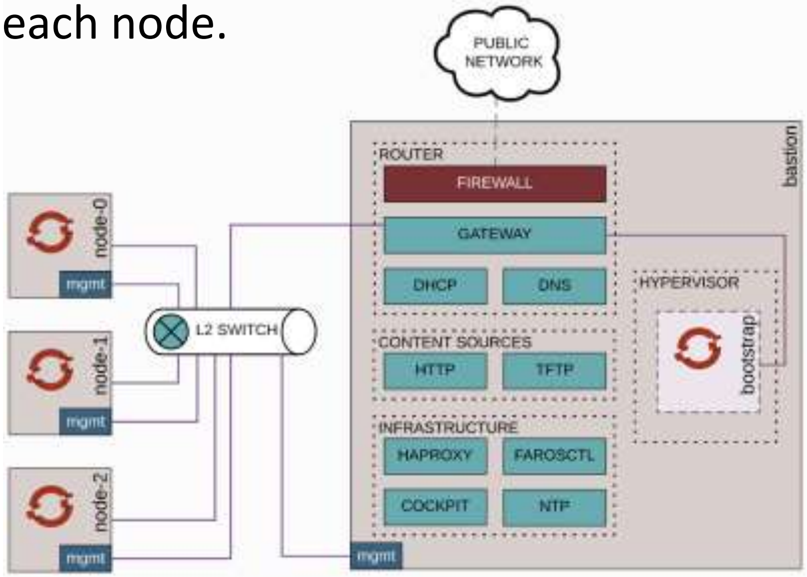
Configuration

This project tested 4 independent compute nodes/servers in a 5U chassis on small footprint, bare-metal clusters:

- Node 1 is the Bastion/Management Node: The bastion node runs Red Hat Enterprise Linux and hosts the scripts, files, and tools to provision the bootstrap, control-plane, and compute nodes. After deployment the bastion node serves as the administrative node for the cluster.
- Nodes 2, 3 and 4 are the OpenShift Cluster Nodes: The "worker-nodes" run OpenShift Kubernetes and OpenShift Container Storage (OCS) across nodes with management agents on each node.

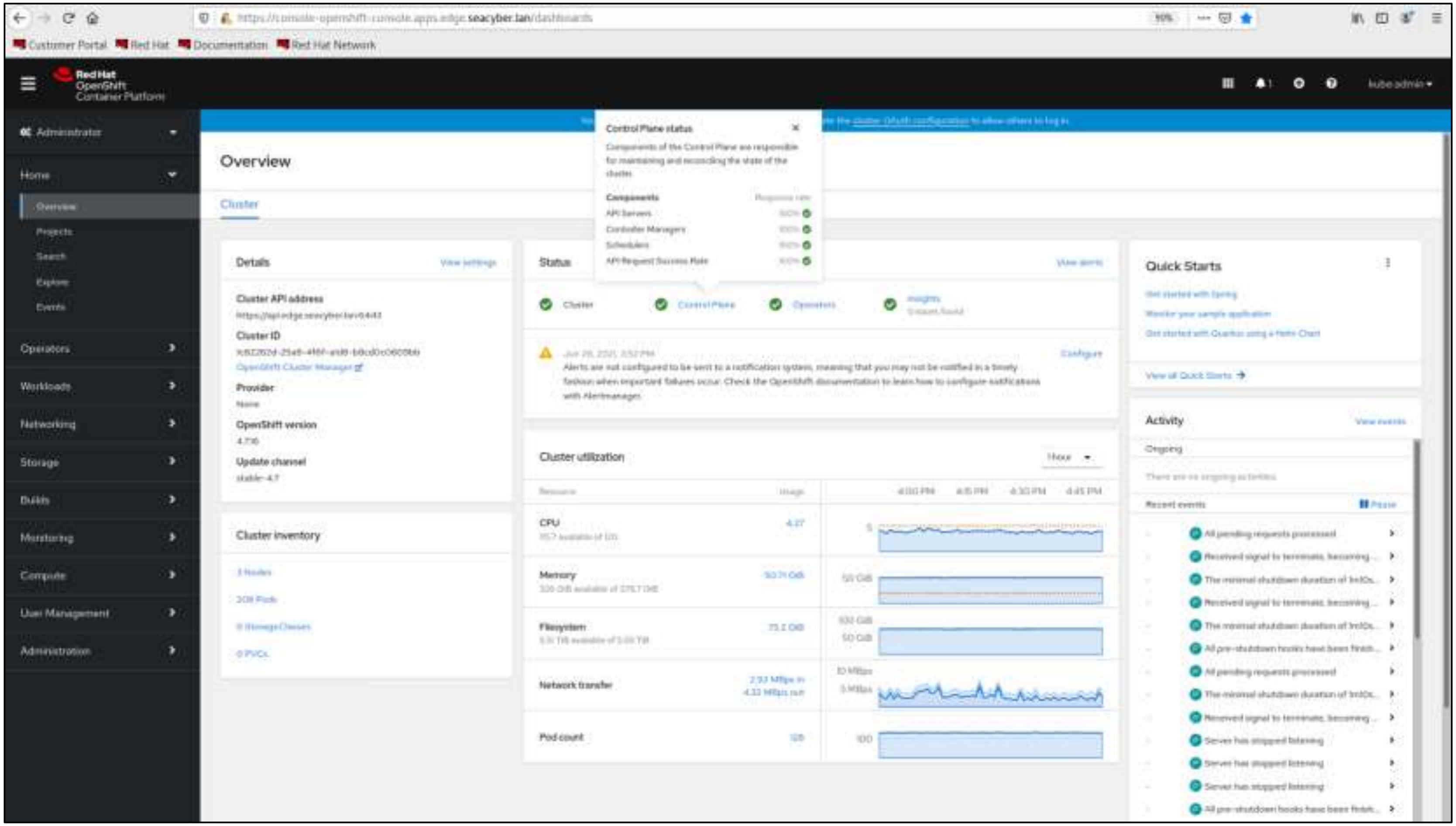
The architecture is specifically designed for far edge environments with minimal power draw and minimal heat production – to be self-sustaining without dependence on other infrastructure.

The Red Hat OpenShift Container Storage applies Federal Information Processing Standard (FIPS) 140-2 (FIPS-140-2) security requirements for cryptographic modules.



Source: HPE and RedHat

Cluster



Control Plane status

Components of the Control Plane are responsible for maintaining and reconciling the state of the cluster.

Components	Response rate
API Servers	100% ✓
Controller Managers	100% ✓
Schedulers	100% ✓
API Request Success Rate	100% ✓

Details

Cluster API address: https://api.edge.seacyber.lan:6443

Cluster ID: [illegible]

Provider: None

OpenShift version: 4.7.16

Update channel: stable-4.7

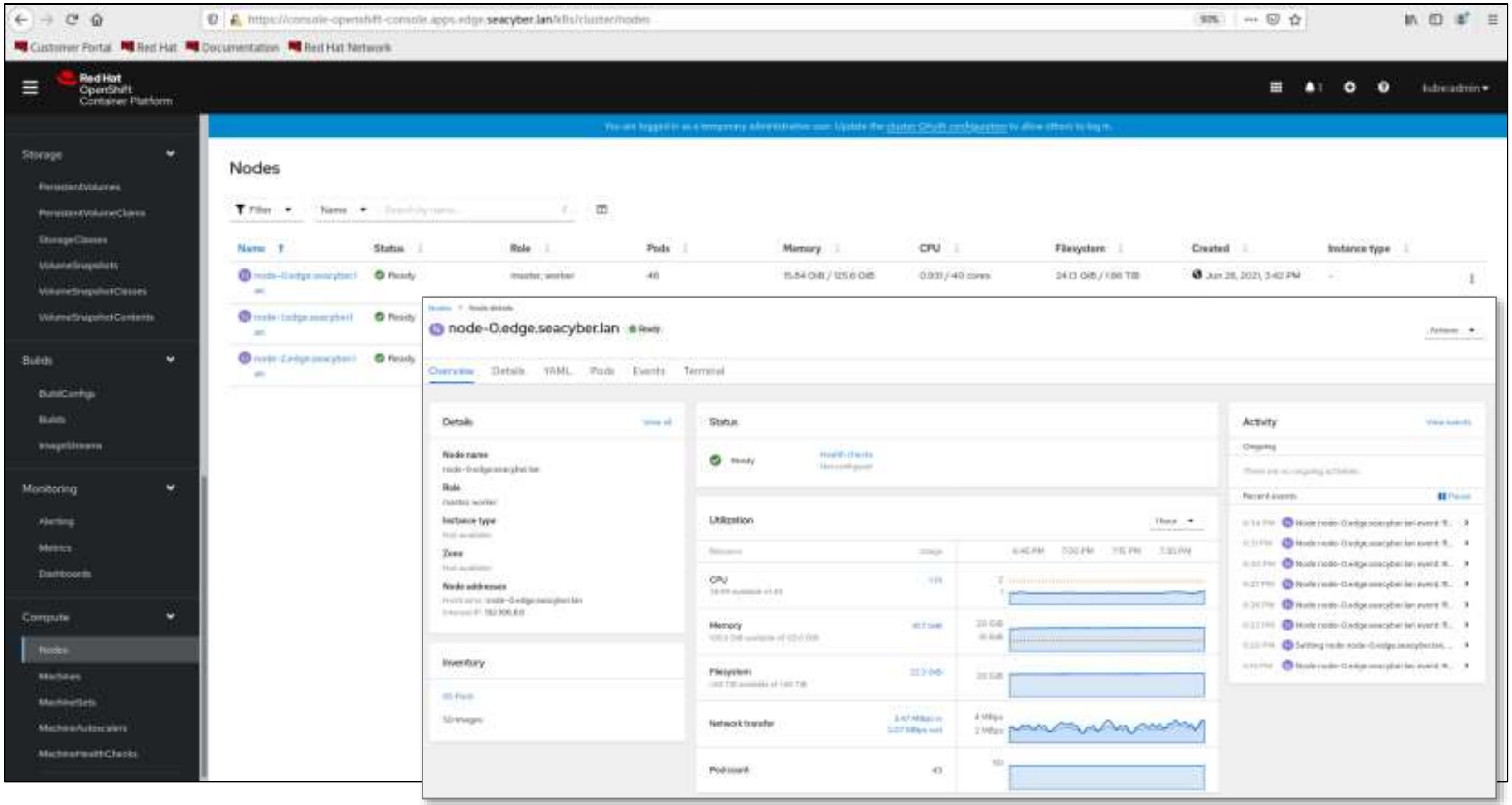
Jun 28, 2021, 3:52 PM
Alerts are not configured to be sent to a notification system, meaning that you may not be notified in a timely fashion when important failures occur. Check the OpenShift documentation to learn how to configure notifications with Alertmanager.

Resource	Usage
CPU [illegible] available of [illegible]	4.27
Memory 326 GiB available of 376.7 GiB	50.71 GiB
Filesystem 5.31 TiB available of 5.09 TiB	73.2 GiB
Network transfer	2.93 MBps in 4.33 MBps out
Pod count	128

There are no ongoing activities.

- All pending requests processed
- Received signal to terminate, becoming ...
- The minimal shutdown duration of 1m10s...
- Received signal to terminate, becoming ...
- The minimal shutdown duration of 1m10s...
- All pre-shutdown hooks have been finish...
- All pending requests processed
- The minimal shutdown duration of 1m10s...
- Received signal to terminate, becoming ...
- Server has stopped listening
- Server has stopped listening
- Server has stopped listening
- All pre-shutdown hooks have been finish...

Nodes



https://console-openshift-console.apps.edge.seacyber.lan/k8s/cluster/nodes

Nodes

Name	Status	Role	Pods	Memory	CPU	Filesystem	Created	Instance type
node-0.edge.seacyber.lan	Ready	master, worker	46	15.84 GiB / 125.6 GiB	0.931 / 40 cores	24.13 GiB / 1.86 TB	Jun 28, 2021, 3:42 PM	-
node-1.edge.seacyber.lan	Ready							
node-2.edge.seacyber.lan	Ready							

node-0.edge.seacyber.lan Ready

Details

Node name
node-0.edge.seacyber.lan

Role
master, worker

Instance type
Not available

Zone
Not available

Node addresses

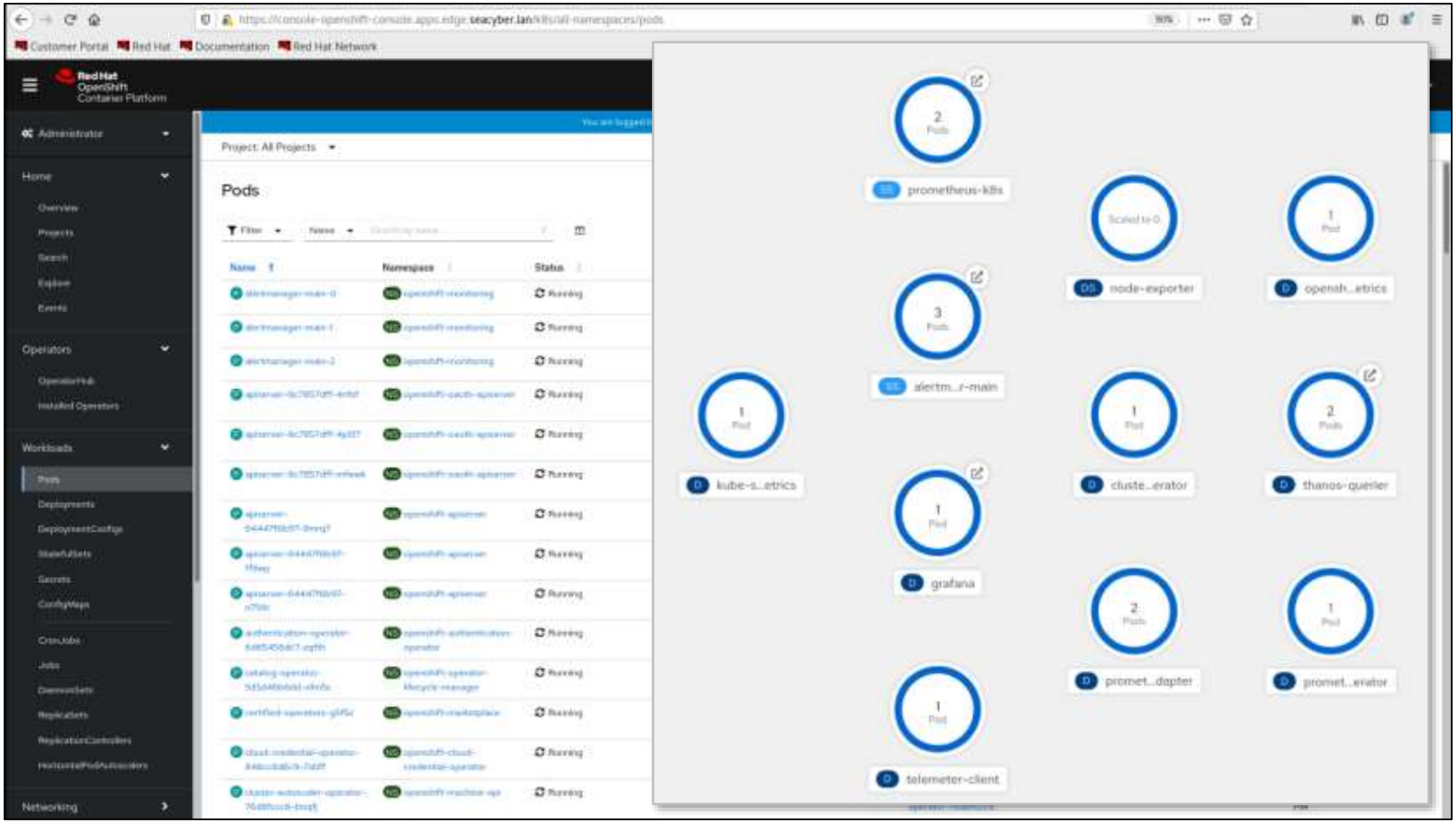
Status: Ready

Utilization

Resource	Usage
CPU	
Memory	
Filesystem	
Network transfer	
Pod count	43

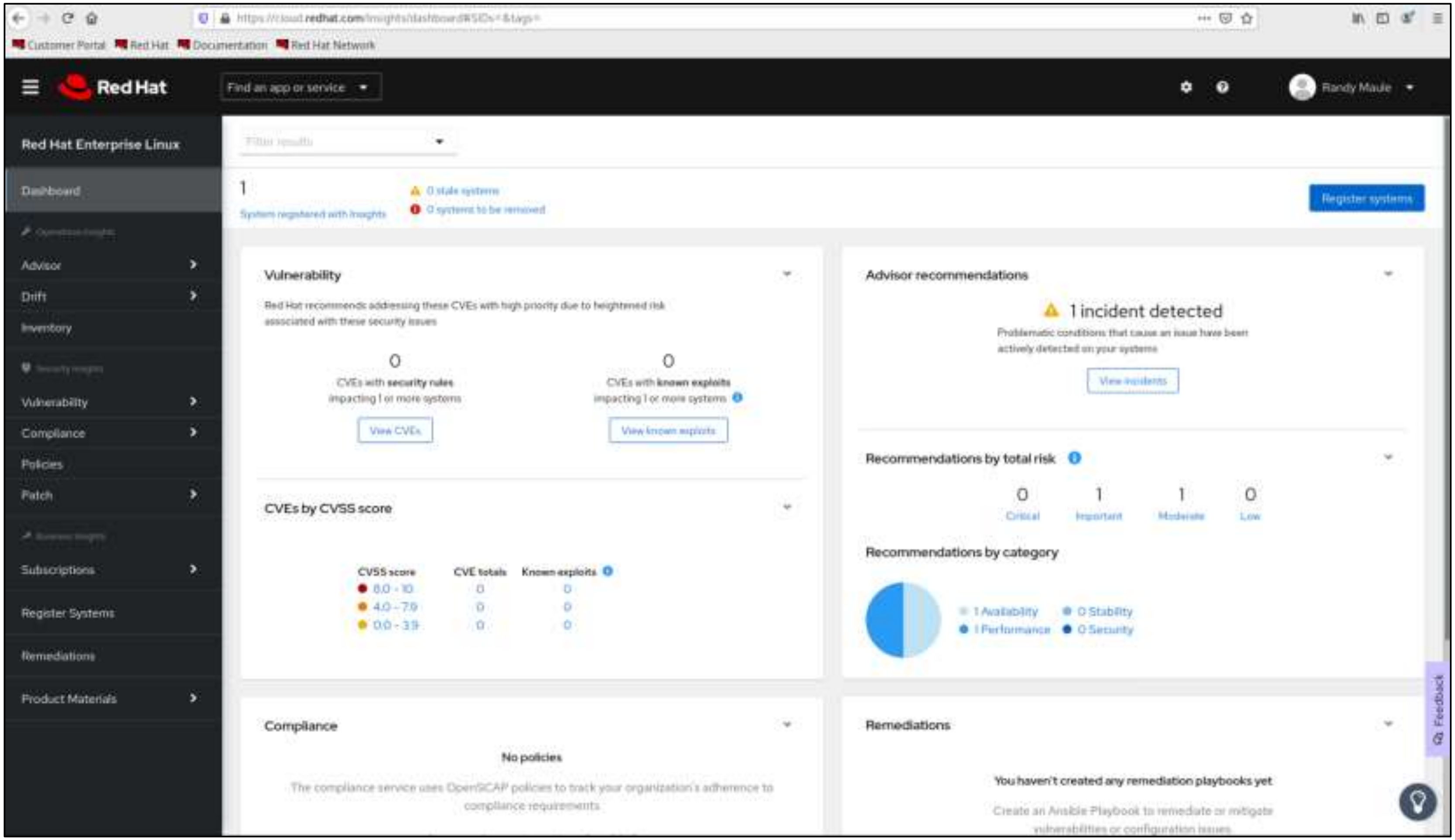
Inventory

Pods



Name	Namespace	Status
alertmanager-main-0	NS openshift-monitoring	Running
alertmanager-main-1	NS openshift-monitoring	Running
alertmanager-main-2	NS openshift-monitoring	Running
apiserver-8c7857dff-4nfxf	NS openshift-oauth-apiserver	Running
apiserver-8c7857dff-4g[illegible]	NS openshift-oauth-apiserver	Running
apiserver-8c7857dff-[illegible]	NS openshift-oauth-apiserver	Running
apiserver-54447f68d97-8mnj[illegible]	NS openshift-apiserver	Running
apiserver-6444?f66d97-ff9wq	NS openshift-apiserver	Running
apiserver-6444?f66d97-n79[illegible]	NS openshift-apiserver	Running
authentication-operator-6d65458dc7-xqfth	NS openshift-authentication-operator	Running
catalog-operator-5d56466b6d-[illegible]	NS openshift-operator-lifecycle-manager	Running
certified-operators-g5f5c	NS openshift-marketplace	Running
cloud-credential-operator-848cc8d69-7ddff	NS openshift-cloud-credential-operator	Running
cluster-autoscaler-operator-76[illegible]-bnqf	NS openshift-machine-api	Running

Auditors



1
System registered with Insights

⚠ 0 stale systems

❗ 0 systems to be removed

Vulnerability

Red Hat recommends addressing these CVEs with high priority due to heightened risk associated with these security issues

0
CVEs with **security rules** impacting 1 or more systems

0
CVEs with **known exploits** impacting 1 or more systems

CVEs by CVSS score

CVSS score	CVE totals	Known exploits
● 8.0 - 10	0	0
● 4.0 - 7.9	0	0
● 0.0 - 3.9	0	0

Compliance

No policies

The compliance service uses OpenSCAP policies to track your organization's adherence to compliance requirements

Advisor recommendations

⚠ 1 incident detected

Problematic conditions that cause an issue have been actively detected on your systems

Recommendations by total risk

Critical	Important	Moderate	Low
0	1	1	0

Recommendations by category

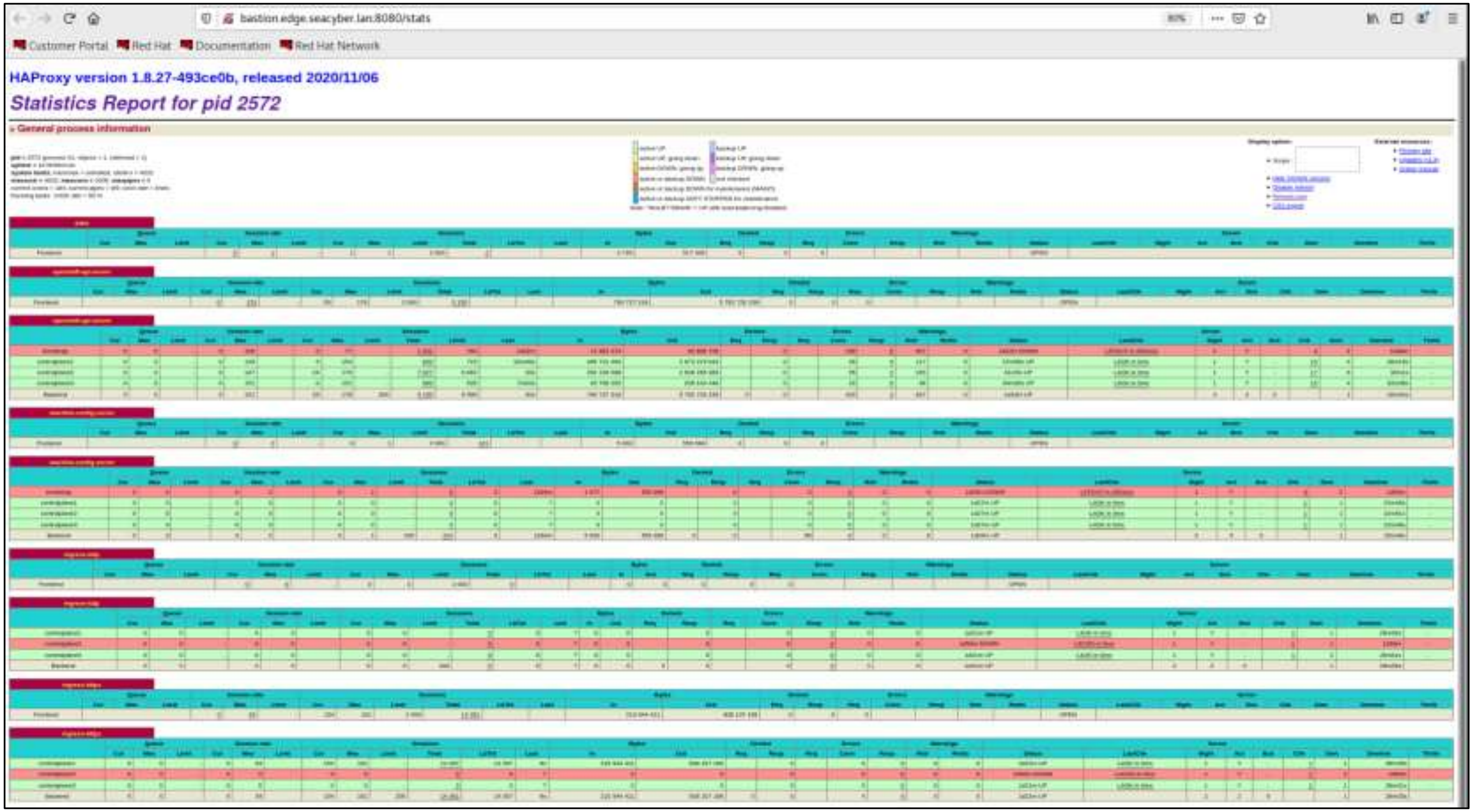
- 1 Availability
- 1 Performance
- 0 Stability
- 0 Security

Remediations

You haven't created any remediation playbooks yet

Create an Ansible Playbook to remediate or mitigate vulnerabilities or configuration issues.

Cluster Metrics



bastion.edge.seacyber.lan:8080/stats

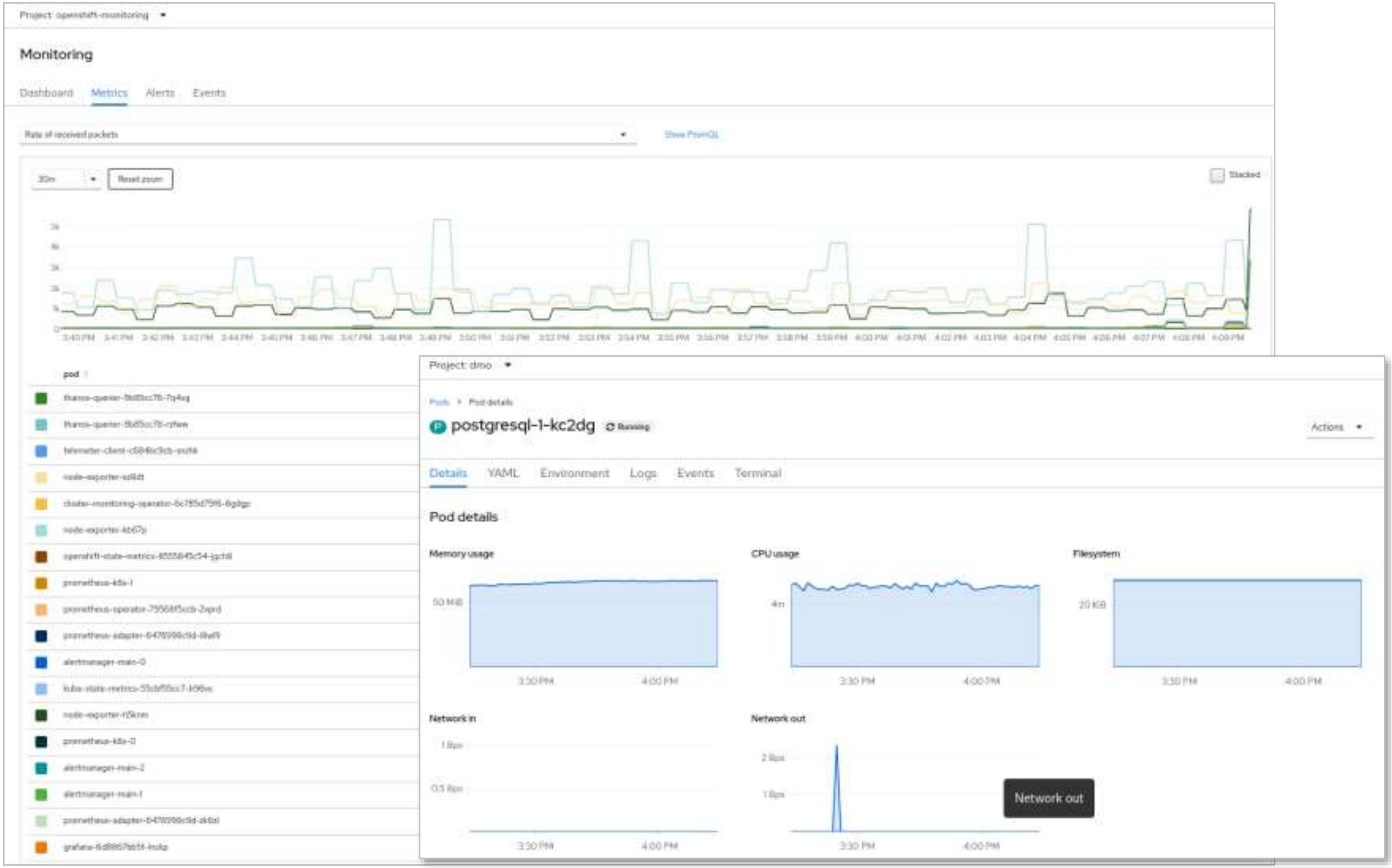
Customer Portal · Red Hat · Documentation · Red Hat Network

HAProxy version 1.8.27-493ce0b, released 2020/11/06

Statistics Report for pid 2572

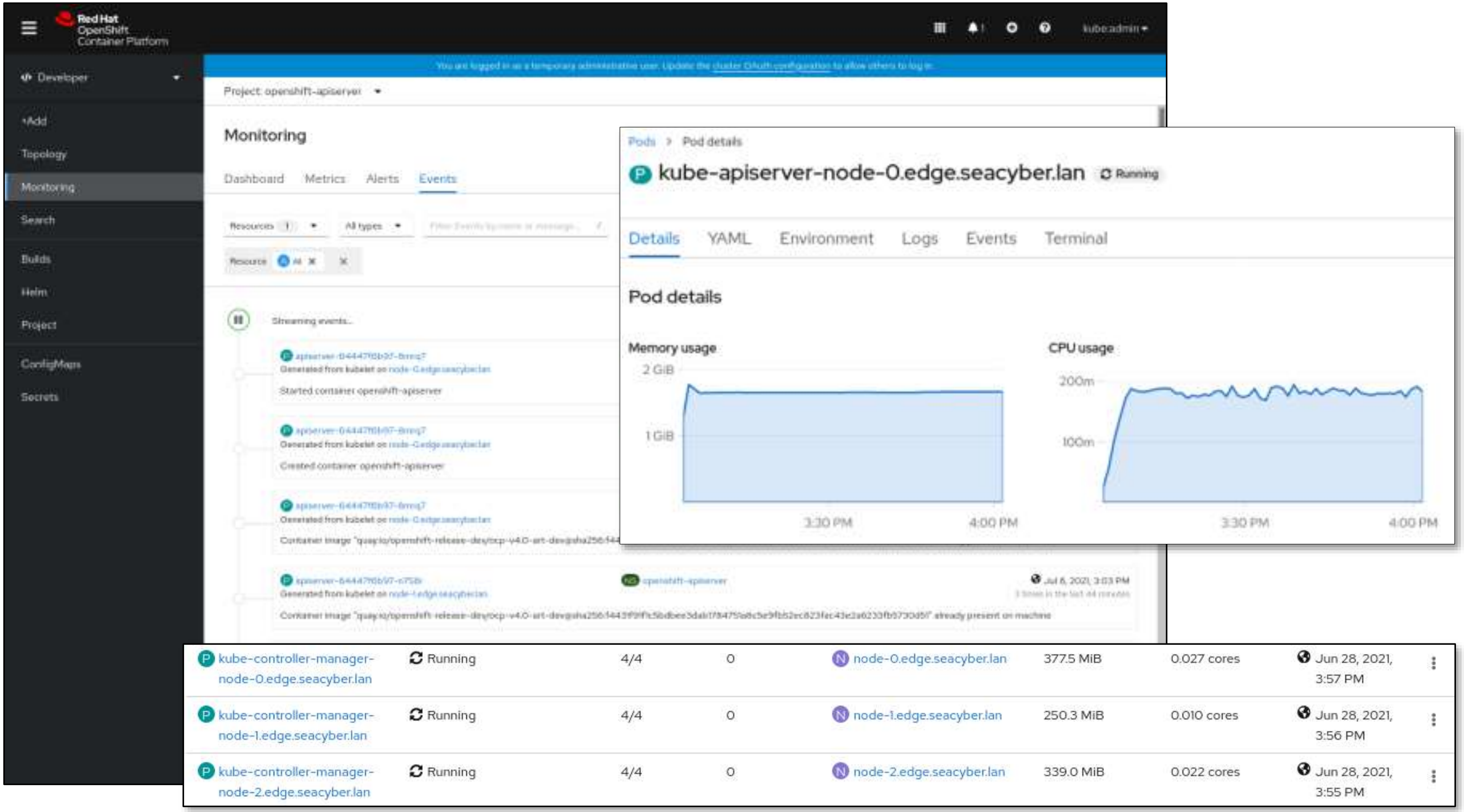
» General process information

Node Metrics



	pod
🟩	thanos-querier-9b85cc78-7q4wg
🟦	thanos-querier-9b85cc78-rjfww
🟦	telemeter-client-c684bc9cb-wufsk
🟨	node-exporter-sz8dt
🟨	cluster-monitoring-operator-6c785d7596-6gdgp
🟦	node-exporter-kb67p
🟫	openshift-state-metrics-8555845c54-jgch8
🟧	prometheus-k8s-1
🟧	prometheus-operator-79568f5ccb-2xprd
🟦	prometheus-adapter-6478998c9d-l8wl9
🟦	alertmanager-main-0
🟦	kube-state-metrics-55cbf55cc7-k96vs
🟩	node-exporter-n5knm
🟩	prometheus-k8s-0
🟦	alertmanager-main-2
🟩	alertmanager-main-1
🟩	prometheus-adapter-6478998c9d-zk6xl
🟧	grafana-6d8867bb5f-lnckp

Pod Metrics



You are logged in as a temporary administrative user. Update the cluster OAuth configuration to allow others to log in.

Project: openshift-apiserver

Monitoring

Dashboard Metrics Alerts Events

Resources 1 · All types · Filter Events by name or message...

Resource: All

Streaming events...

apiserver-6444716b97-8mrq7
Generated from kubelet on node-0.edge.seacyber.lan
Started container openshift-apiserver

apiserver-6444716b97-8mrq7
Generated from kubelet on node-0.edge.seacyber.lan
Created container openshift-apiserver

apiserver-6444716b97-8mrq7
Generated from kubelet on node-0.edge.seacyber.lan
Container image "quay.io/openshift-release-dev/ocp-v4.0-art-dev@sha256:f44

apiserver-6444716b97-n758r · NS openshift-apiserver · Jul 6, 2021, 3:03 PM
Generated from kubelet on node-1.edge.seacyber.lan · 3 times in the last 44 minutes
Container image "quay.io/openshift-release-dev/ocp-v4.0-art-dev@sha256:f443f9ffc5bdbee3dab178475a8c5e9fb52ec823fec43e2a6233fb5730d51" already present on machine

Pods > Pod details

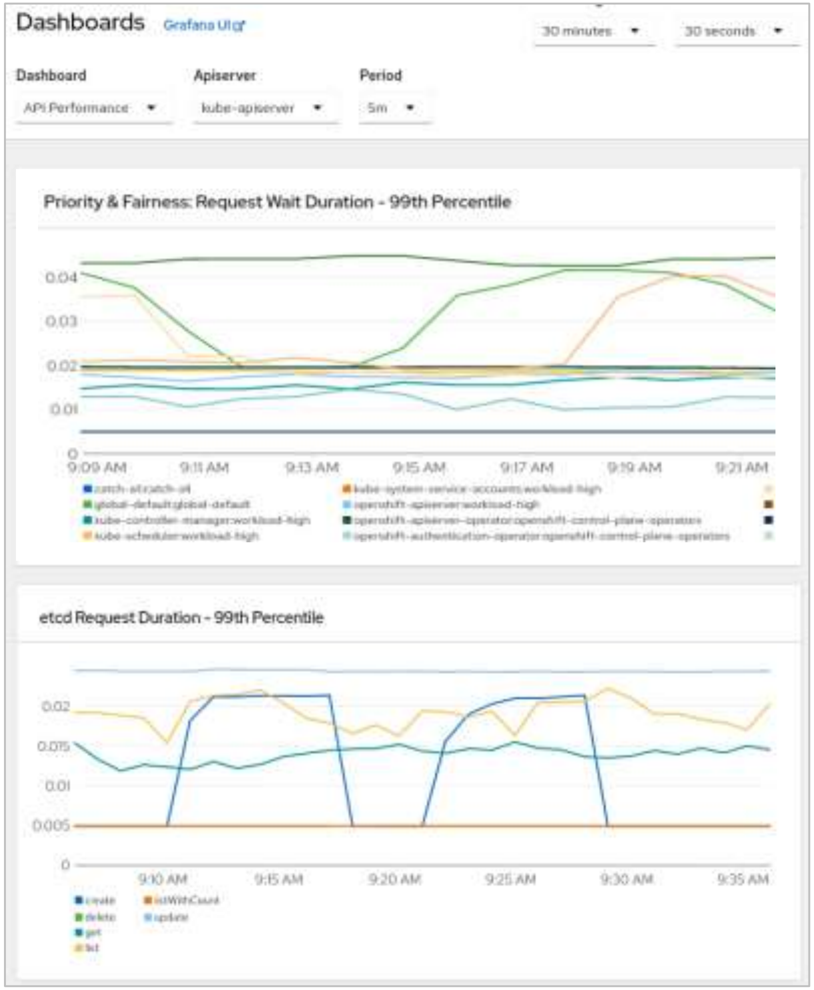
P kube-apiserver-node-0.edge.seacyber.lan Running

Details YAML Environment Logs Events Terminal

Pod details

P kube-controller-manager-node-0.edge.seacyber.lan	Running	4/4	0	N node-0.edge.seacyber.lan	377.5 MiB	0.027 cores	Jun 28, 2021, 3:57 PM	⋮
P kube-controller-manager-node-1.edge.seacyber.lan	Running	4/4	0	N node-1.edge.seacyber.lan	250.3 MiB	0.010 cores	Jun 28, 2021, 3:56 PM	⋮
P kube-controller-manager-node-2.edge.seacyber.lan	Running	4/4	0	N node-2.edge.seacyber.lan	339.0 MiB	0.022 cores	Jun 28, 2021, 3:55 PM	⋮

Grafana



Dashboards Grafana UI

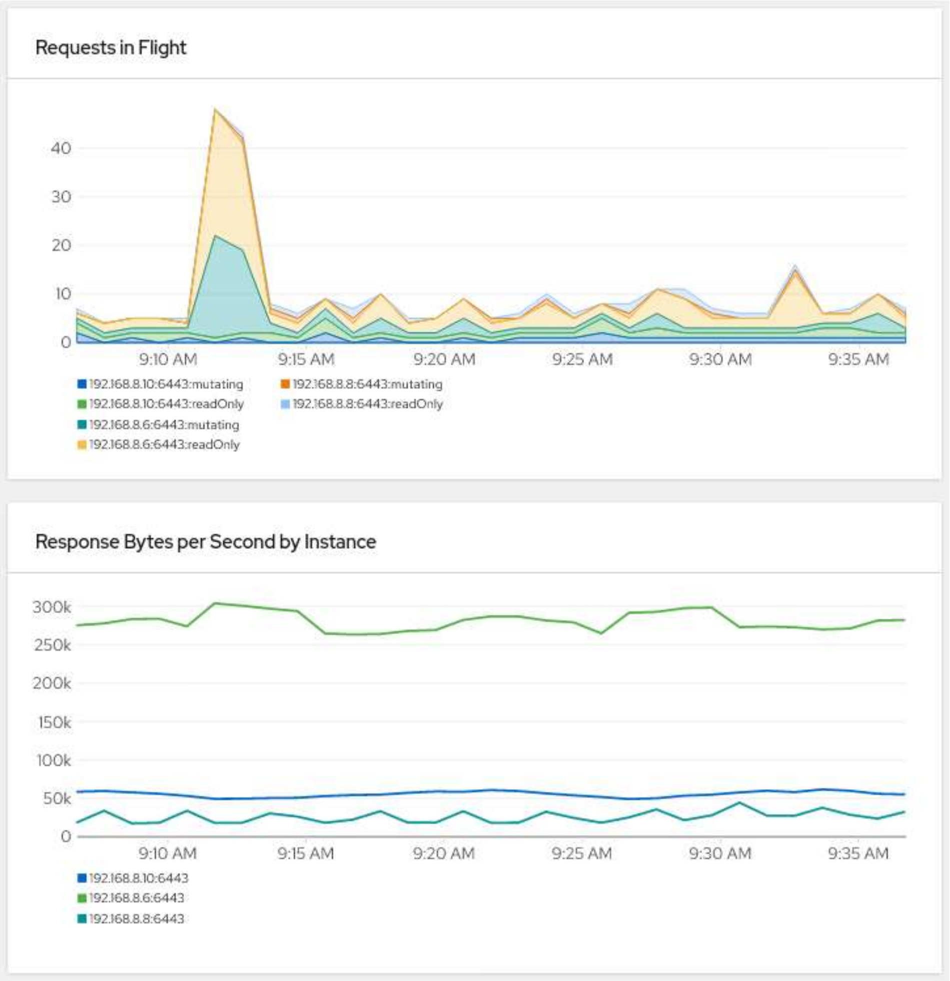
30 minutes ▾ 30 seconds ▾

Dashboard: API Performance ▾

Apiserver: kube-apiserver ▾

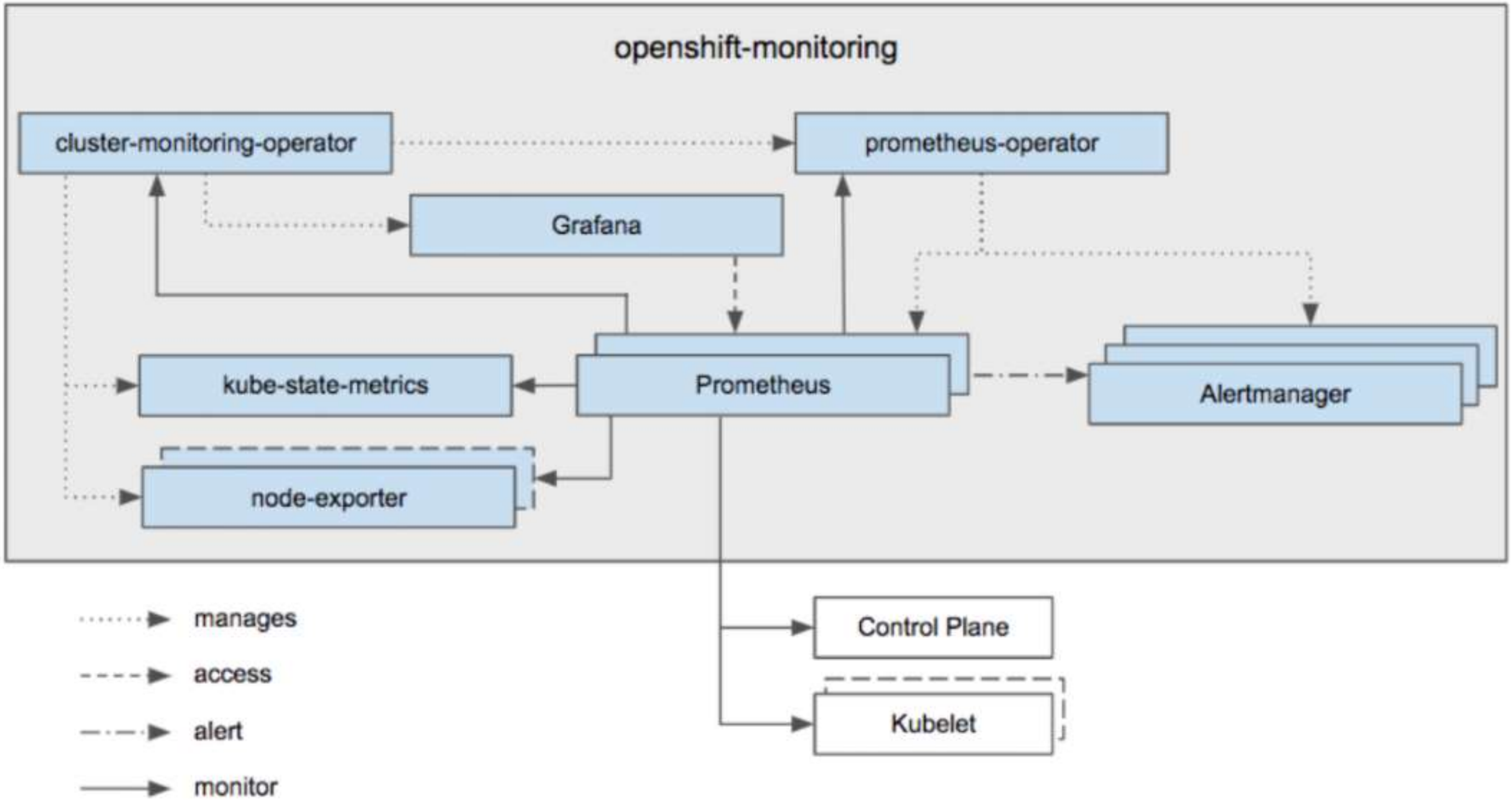
Period: 5m ▾

Priority & Fairness: Request Wait Duration - 99th Percentile
0.04
0.03
0.02
0.01
0
9:09 AM
9:11 AM
9:13 AM
9:15 AM
9:17 AM
9:19 AM
9:21 AM
catch-all:catch-all
global-default:global-default
kube-controller-manager:workload-high
kube-scheduler:workload-high
kube-system-service-accounts:workload-high
openshift-apiserver:workload-high
openshift-apiserver-operator:openshift-control-plane-operators
openshift-authentication-operator:openshift-control-plane-operators
etcd Request Duration - 99th Percentile
0.02
0.015
0.01
0.005
0
9:10 AM
9:15 AM
9:20 AM
9:25 AM
9:30 AM
9:35 AM
create
delete
get
list
listWithCount
update

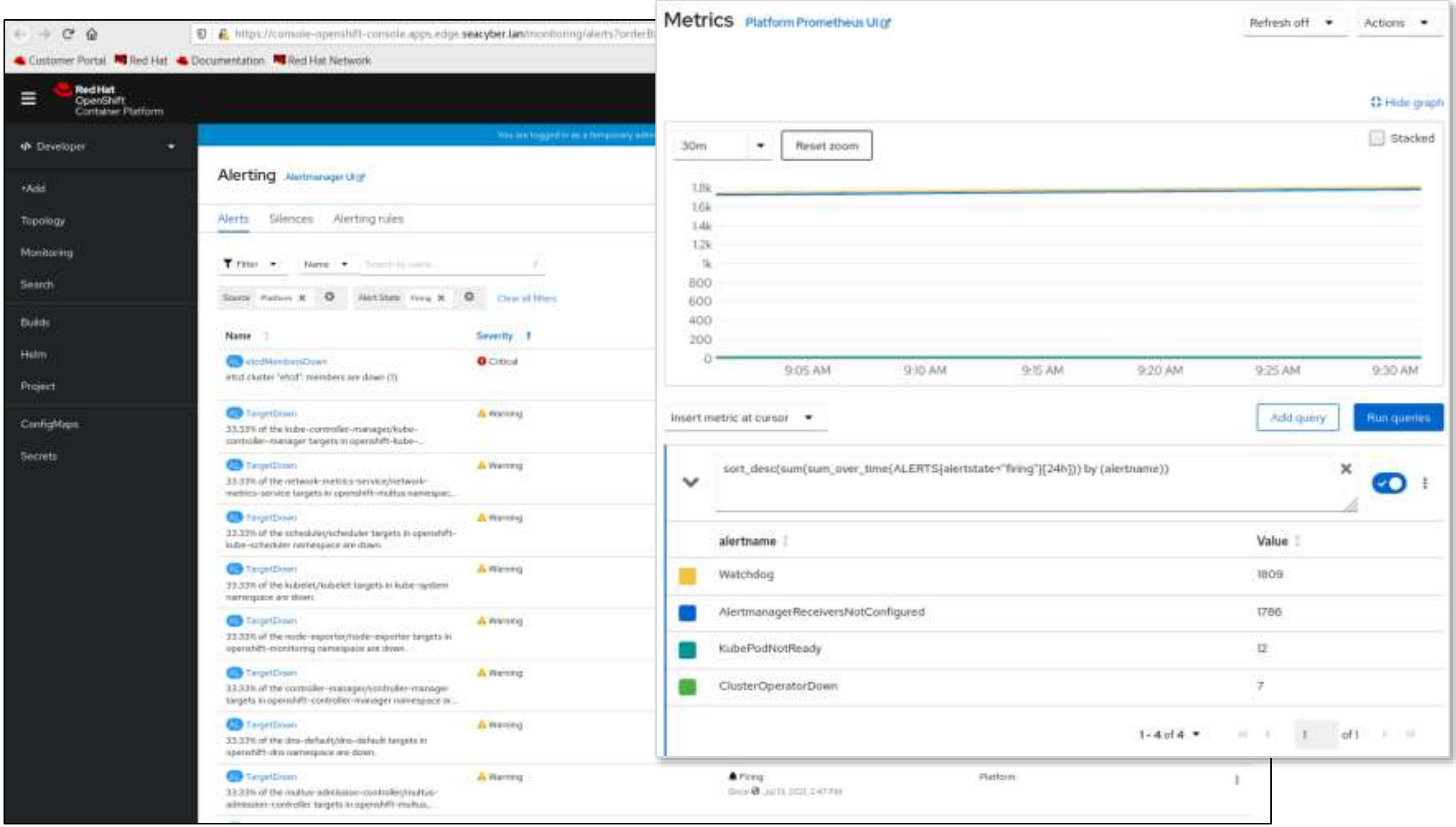


Requests in Flight
40
30
20
10
0
9:10 AM
9:15 AM
9:20 AM
9:25 AM
9:30 AM
9:35 AM
192.168.8.10:6443:mutating
192.168.8.10:6443:readOnly
192.168.8.6:6443:mutating
192.168.8.6:6443:readOnly
192.168.8.8:6443:mutating
192.168.8.8:6443:readOnly
Response Bytes per Second by Instance
300k
250k
200k
150k
100k
50k
0
9:10 AM
9:15 AM
9:20 AM
9:25 AM
9:30 AM
9:35 AM
192.168.8.10:6443
192.168.8.6:6443
192.168.8.8:6443

Prometheus


openshift-monitoring
cluster-monitoring-operator
prometheus-operator
Grafana
kube-state-metrics
Prometheus
Alertmanager
node-exporter
Control Plane
Kubelet
manages
access
alert
monitor

Prometheus



https://console-openshift-console.apps.edge.seacyber.lan/monitoring/alerts?orderB

Alerting Alertmanager UI

Name	Severity
AL etcdMembersDown etcd cluster "etcd": members are down (1).	Critical
AL TargetDown 33.33% of the kube-controller-manager/kube-controller-manager targets in openshift-kube-...	Warning
AL TargetDown 33.33% of the network-metrics-service/network-metrics-service targets in openshift-multus namespac...	Warning
AL TargetDown 33.33% of the scheduler/scheduler targets in openshift-kube-scheduler namespace are down.	Warning
AL TargetDown 33.33% of the kubelet/kubelet targets in kube-system namespace are down.	Warning
AL TargetDown 33.33% of the node-exporter/node-exporter targets in openshift-monitoring namespace are down.	Warning
AL TargetDown 33.33% of the controller-manager/controller-manager targets in openshift-controller-manager namespace ar...	Warning
AL TargetDown 33.33% of the dns-default/dns-default targets in openshift-dns namespace are down.	Warning
AL TargetDown 33.33% of the multus-admission-controller/multus-admission-controller targets in openshift-multus...	Warning

Firing
Since Jul 13, 2021, 2:47 PM
Platform

Metrics Platform Prometheus UI

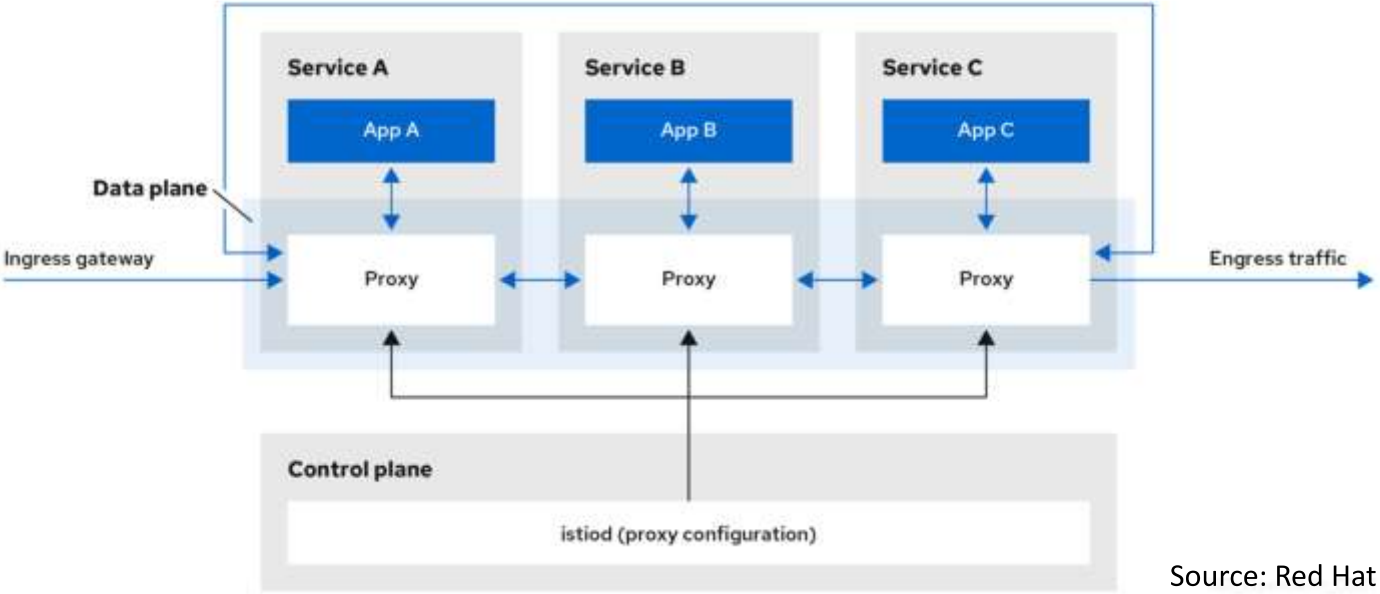
```
sort_desc(sum(sum_over_time(ALERTS{alertstate="firing"}[24h])) by (alertname))
```

	alertname	Value
🟨	Watchdog	1809
🟦	AlertmanagerReceiversNotConfigured	1786
🟩	KubePodNotReady	12
🟩	ClusterOperatorDown	7

1 - 4 of 4 1 of 1

Service Mesh

- The service mesh (Istio open source) consists of a data plane and a control plane
- Intelligent proxies run alongside pod application containers to intercept, control and modify inbound and outbound communication
- Benefits include:
  - Centralized point of control in an application
  - Enterprise applications split into modular services to ease scaling and maintenance
  - Load balancing
  - Authentication
  - Failover
  - Monitoring
  - Rate limiting
  - Access control.



Source: Red Hat

Selected C2/ISR Services

ESRI - Industry

NPS Laboratory Tests

Enterprise Suite

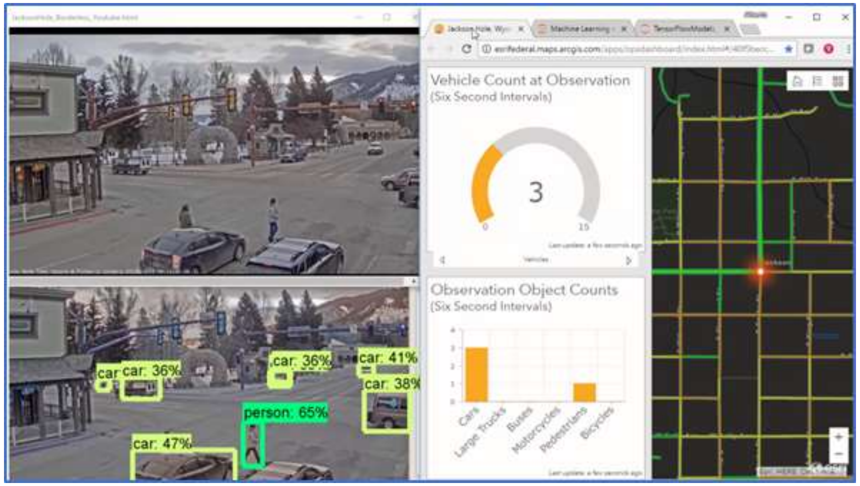
		TCPED					AI/ML		Hybrid Cloud					
	Asset	Task	Collect	Process	Exploit	Disseminate	Data Science	Automation	Collaborate	Containers	Microservices	Kubernetes	Kafka/Stream	Tactical Cloud
Enterprise	ArcGIS Enterprise	X	X	X	X	X	X	X	X	X	X	X	X	X
	ArcGIS Enterprise Portal		X	X	X	X	X		X	X	X	X		X
	ArcGIS Data Store									X	X	X		X
	ArcGIS Web Adaptor									X	X	X		X
	ArcGIS Server [Advanced]		X	X	X	X	X	X	X	X	X	X	X	X

- Enterprise Portal serves as the central hub and common user interface for C2/ISR services.
- Data Store is the data storage server; Web Adaptor to integrate with existing servers and security infrastructure.
- Server is the primary enterprise geodatabase with feature and geodata services, including advanced raster analysis and surface generation, and integrated analysis of raster and vector data.

Enterprise Extensions

		TCPED					AI/ML		Hybrid Cloud					
	Asset	Task	Collect	Process	Exploit	Disseminate	Data Science	Automation	Collaborate	Containers	Microservices	Kubernetes	Kafka/Stream	Tactical Cloud
Extensions	ArcGIS GeoAI Toolbox			X	X		X	X						X
	ArcGIS GeoAnalytics Server			X	X		X	X						X
	ArcGIS GeoEvent Server		X	X	X		X	X					X	X
	ArcGIS Image Server		X	X	X	X	X	X	X					X
	ArcGIS Knowledge Server		X	X	X	X	X	X	X					X
	ArcGIS Mission Server	X	X	X	X	X			X				X	X
	ArcGIS Notebook Server	X	X	X	X	X	X	X		X	X	X		X
	ArcGIS Workflow Manager Server	X	X	X	X	X	X	X	X					X

- ➢GeoAnalytics Server: Workflows.
- ➢GeoAI Toolbox: Geospatial AI/ML.
- ➢GeoEvent Server: Sensor streams.
- ➢Mission Server: Tactical SA.
- ➢Notebook Server: Mobile AI/ML.
- ➢Workflow Manager: Scheduling.



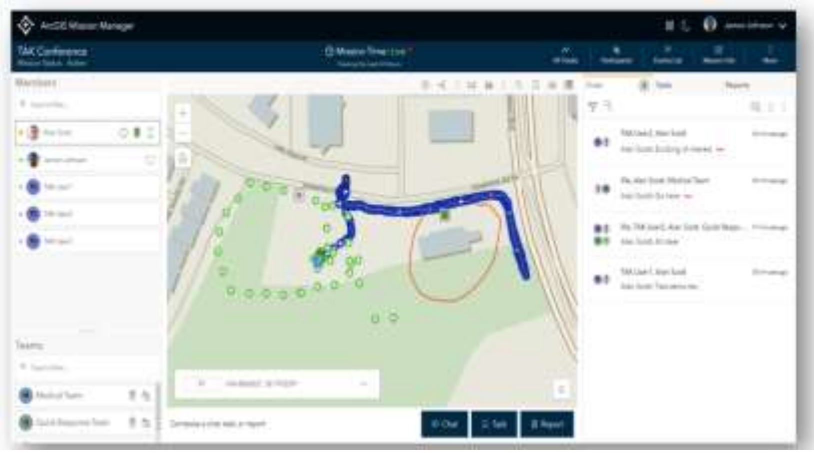
(Source: ESRI)

Applications

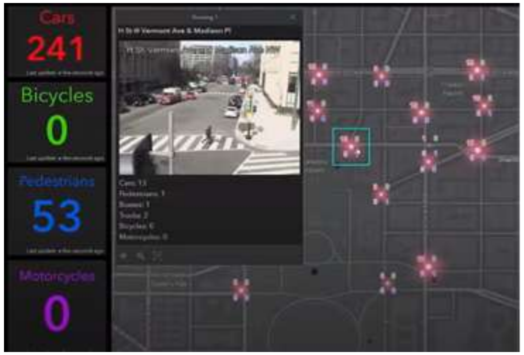
		TCPED					AI/ML		Hybrid Cloud					
	Asset	Task	Collect	Process	Exploit	Disseminate	Data Science	Automation	Collaborate	Containers	Microservices	Kubernetes	Kafka/Stream	Tactical Cloud
Applications	ArcGIS ATAK/iTAK	X	X			X			X				X	X
	ArcGIS Dashboards					X								X
	ArcGIS Data Reviewer			X			X	X						
	ArcGIS Defense Mapping		X	X	X									X
	ArcGIS Drone2Map	X	X	X	X		X						X	X
	ArcGIS Excalibur			X	X	X								X
	ArcGIS Experience Builder			X	X	X	X	X						X
	ArcGIS Insights						X	X						X
	ArcGIS Intelligence Toolbox		X	X	X		X	X						X
	ArcGIS LocateXT		X	X	X	X	X	X						X
	ArcGIS Mission Manager	X	X	X	X	X			X				X	X
	ArcGIS Pro Intelligence			X	X	X	X	X						X
	ArcGIS Production Mapping			X	X	X								X
	ArcGIS Publisher					X								X
	ArcGIS Workflow Manager	X				X		X	X					X

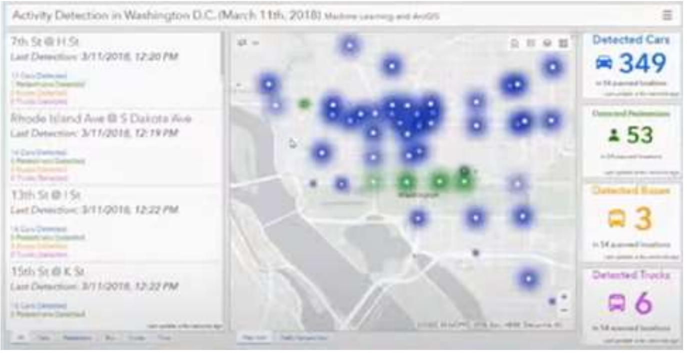
Applications

ArcGIS TAK Integration (Source: ESRI)

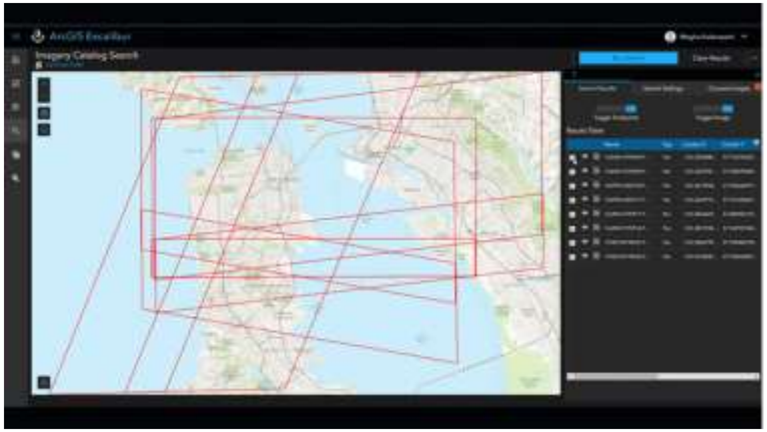


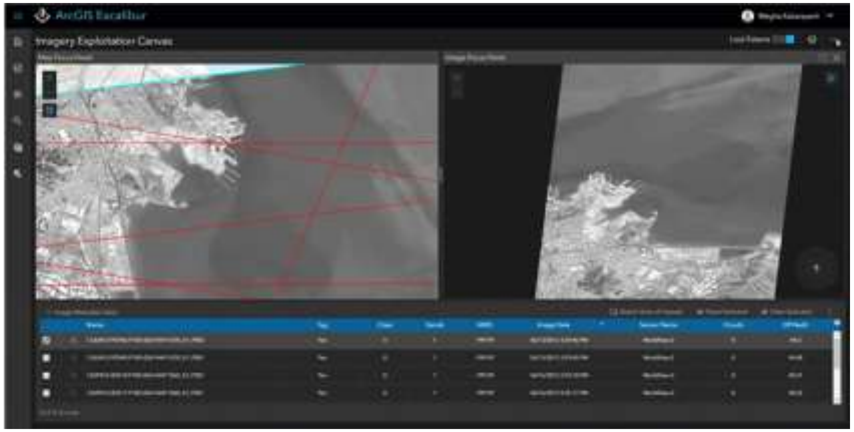
Command Operations Dashboards (Source: ESRI)



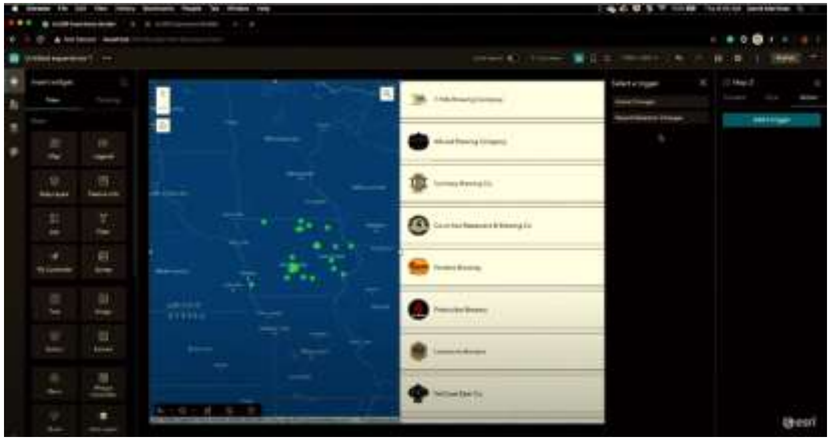

Activity Detection in Washington D.C. (March 11th, 2018)
7th St @ H St
Last Detection: 3/11/2018, 12:20 PM
Rhode Island Ave @ S Dakota Ave
Last Detection: 3/11/2018, 12:19 PM
13th St @ I St
Last Detection: 3/11/2018, 12:22 PM
15th St @ K St
Last Detection: 3/11/2018, 12:22 PM
Detected Cars
349
53
Detected Buses
3
Detected Trucks
6

Applications





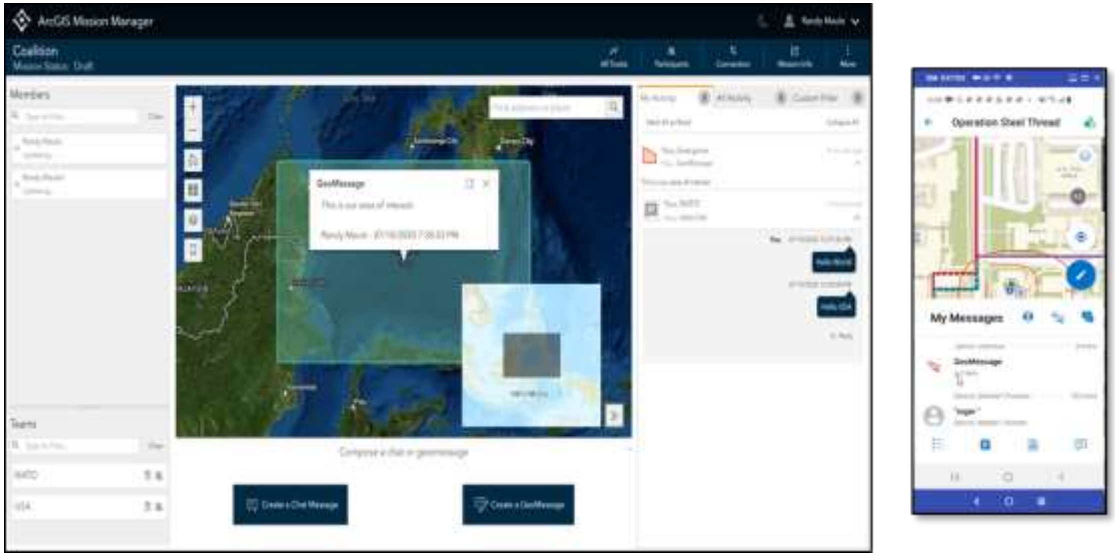
Excalibur Tactical Exploitation (Source: ESRI)



Mission Dashboard (Source: ESRI)

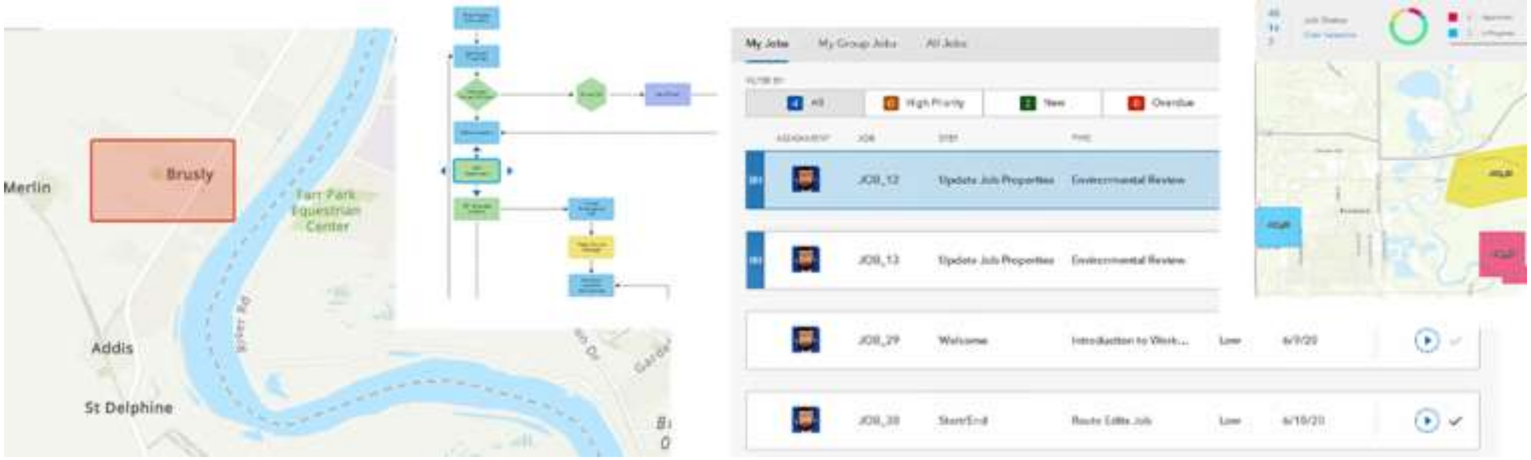
ArcGIS Drone2Map (Source: ESRI)

Applications



Mission Portal
(Source: ESRI)

Workflow Manager
(Source: ESRI)



Field Apps

		TCPED					AI/ML		Hybrid Cloud					
	Asset	Task	Collect	Process	Exploit	Disseminate	Data Science	Automation	Collaborate	Containers	Microservices	Kubernetes	Kafka/Stream	Tactical Cloud
Field Apps	ArcGIS Collector		X											X
	ArcGIS Field Maps		X	X	X	X		X	X				X	X
	ArcGIS Mission Responder	X	X	X	X	X			X				X	X
	ArcGIS Navigator			X		X			X				X	X
	ArcGIS QuickCapture		X										X	X
	ArcGIS Survey123		X	X	X	X		X	X				X	X
	ArcGIS Workforce	X	X	X	X	X			X				X	X

- ➢Collector: Mobile iOS/ Android.
- ➢Navigator: Turn-by-turn mobile navigation.
- ➢Survey123: Field collection audio, images, and questions.
- ➢Workforce: CTP field to HQ.

Selected C2/ISR Services

TAK – Government

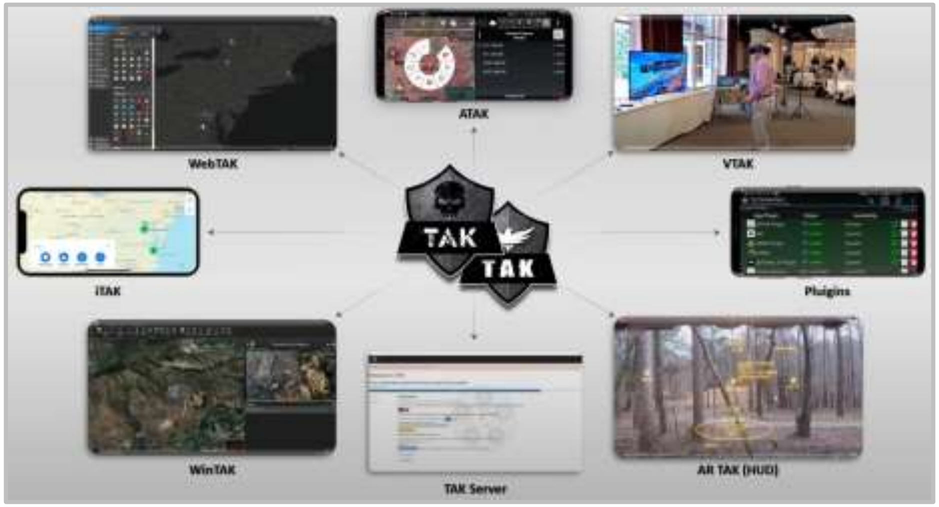
NPS Laboratory Tests

Tactical Assault Kit (TAK)

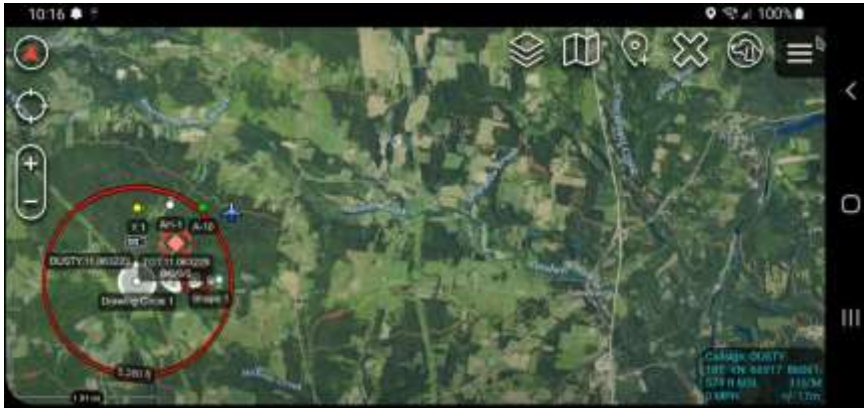
		TCPED					AI/ML		Hybrid Cloud					
	Asset	Task	Collect	Process	Exploit	Disseminate	Data Science	Automation	Collaborate	Containers	Microservices	Kubernetes	Kafka	Tactical Cloud
Core	TAK Server	X	X	X	X	X			X	X	X	X	X	X
	ATAK/iTAK	X	X						X					X
	WebTAK	X				X								X
	VTAK	X												X

Servers, containers, and mobile apps with versions for military forces, law enforcement, and emergency responders:

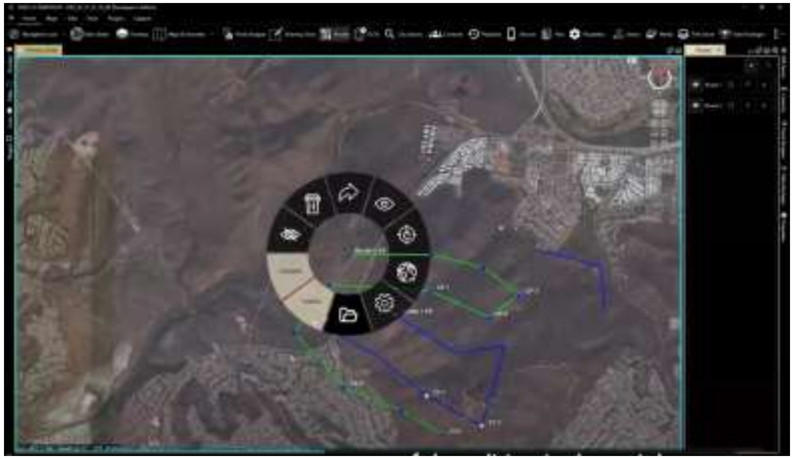
- ➢ATAK/iTAK: Android/iPhone
- ➢WebTAK: Browser
- ➢VTAK: Virtual Reality



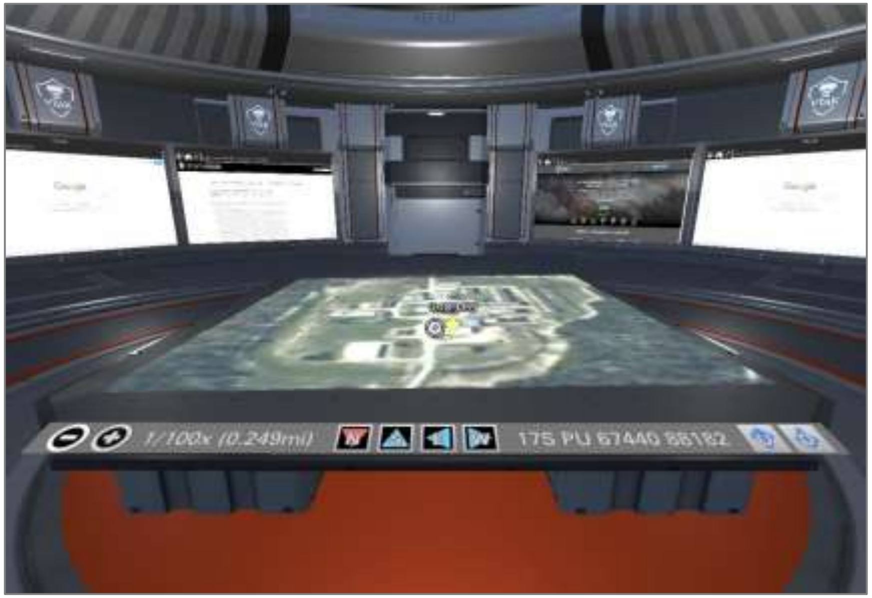
Tactical Assault Kit (TAK)



ATAK map interface (Source: TAK)

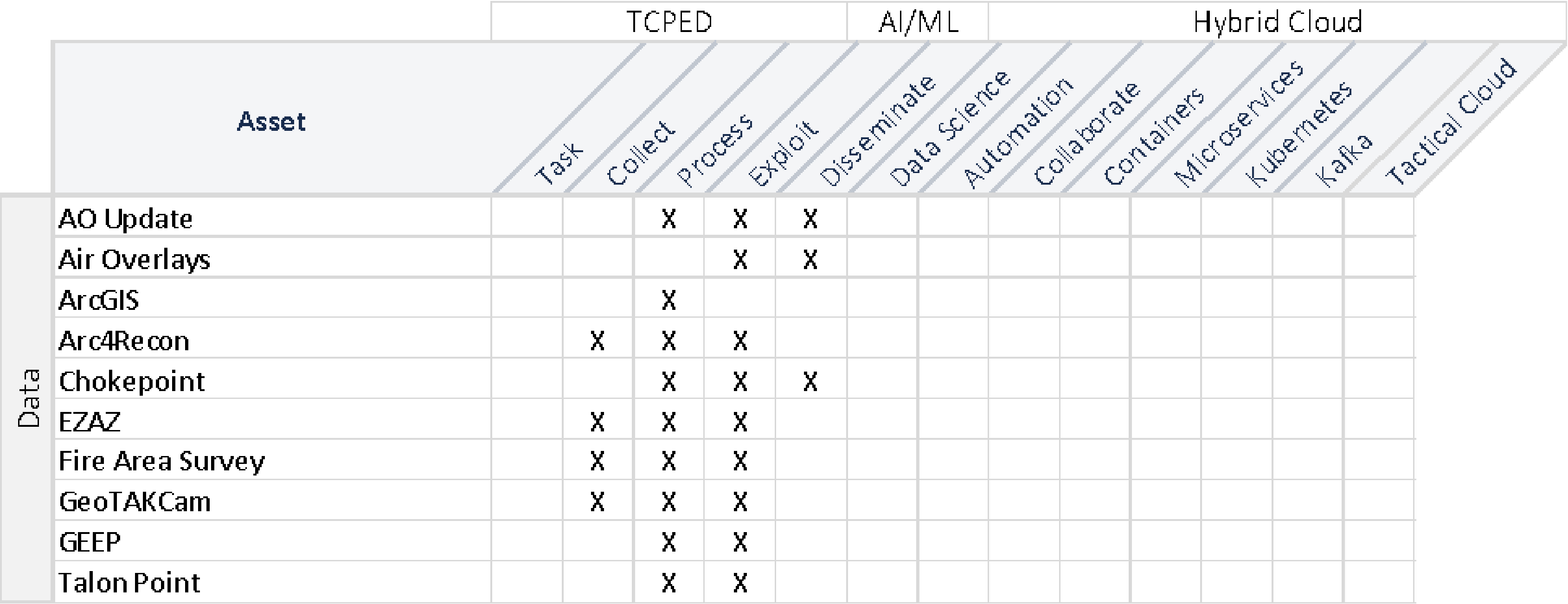


TACX map tools (Source: TAK)



VTAK TOC (Source: TAK)

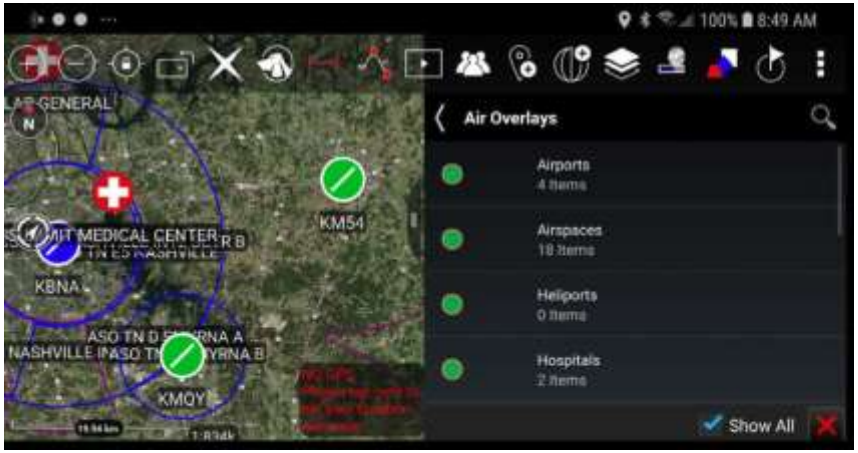
TAK Data Plugins



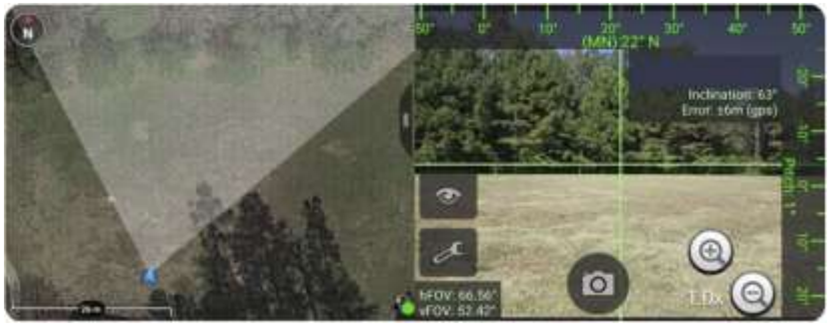
		TCPED					AI/ML		Hybrid Cloud					
	Asset	Task	Collect	Process	Exploit	Disseminate	Data Science	Automation	Collaborate	Containers	Microservices	Kubernetes	Kafka	Tactical Cloud
Data	AO Update			X	X	X								
	Air Overlays				X	X								
	ArcGIS			X										
	Arc4Recon		X	X	X									
	Chokepoint			X	X	X								
	EZAZ		X	X	X									
	Fire Area Survey		X	X	X									
	GeoTAKCam		X	X	X									
	GEEP			X	X									
	Talon Point			X	X									

- ➢Add data and functions to the TAK family of devices.
- ➢Open API and SDK facilitate plugin development to enhance the core mapping application with tools for mission requirements.

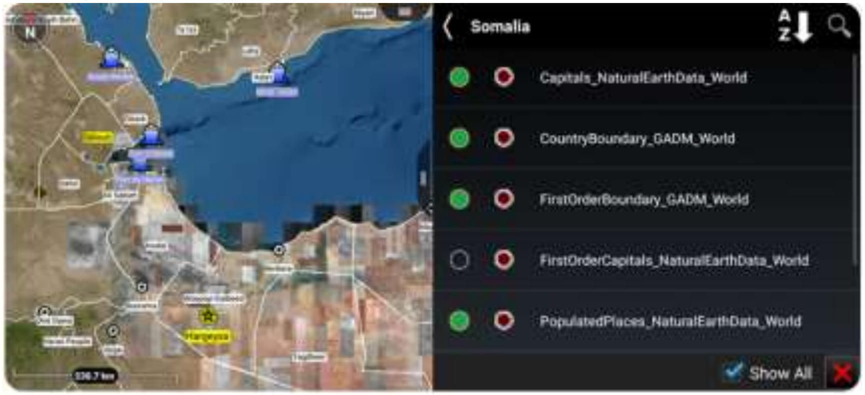
TAK Data Plugins



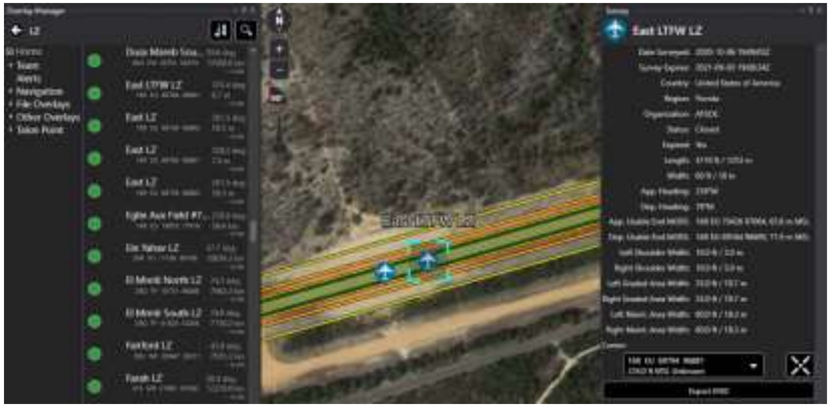
Air Overlay (Source: TAK)



GeoTAKCam (Source: TAK)


Somalia
Capitals_NaturalEarthData_World
CountryBoundary_GADM_World
FirstOrderBoundary_GADM_World
FirstOrderCapitals_NaturalEarthData_World
PopulatedPlaces_NaturalEarthData_World
Show All

Google Streaming Services (Source: TAK)



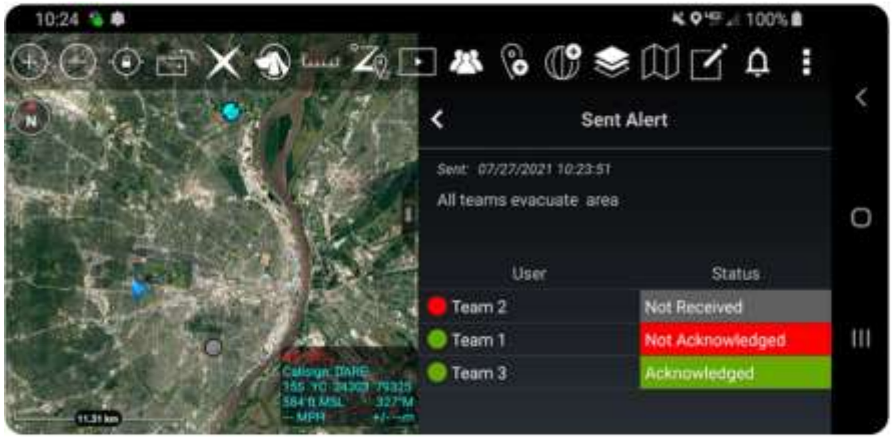
Assault Zone DB (Source: TAK)

TAK Communication Plugins

		TCPED					AI/ML		Hybrid Cloud					
	Asset	Task	Collect	Process	Exploit	Disseminate	Data Science	Automation	Collaborate	Containers	Microservices	Kubernetes	Kafka	Tactical Cloud
Communication	Alert			X		X			X					
	ESChat								X					
	Hammer								X					
	HUD					X								
	ICE Voice								X					
	ICOM								X					
	MobileJECL								X					
	RF Propogation		X	X	X									
	SPR								X					
	SIP								X					
	TAK Chat		X	X		X			X					
	TAK ICU		X			X			X					
	Wave								X					

- ➢ Enhancements range from team communication, to external device integration, to alerts and notifications.

TAK Communication Plugins



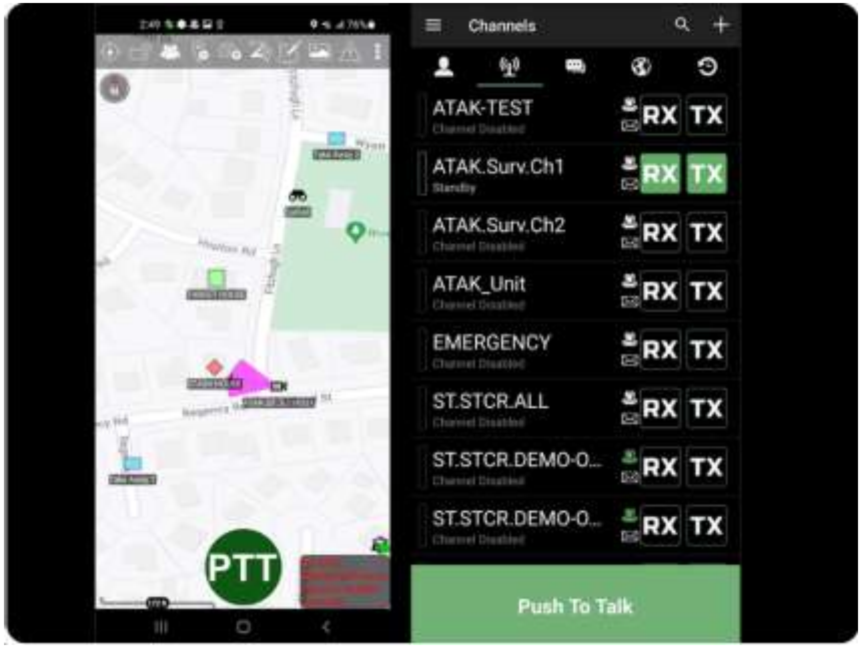
Sent Alert

Sent: 07/27/2021 10:23:51

All teams evacuate area

User	Status
🟥 Team 2	Not Received
🟩 Team 1	Not Acknowledged
🟩 Team 3	Acknowledged

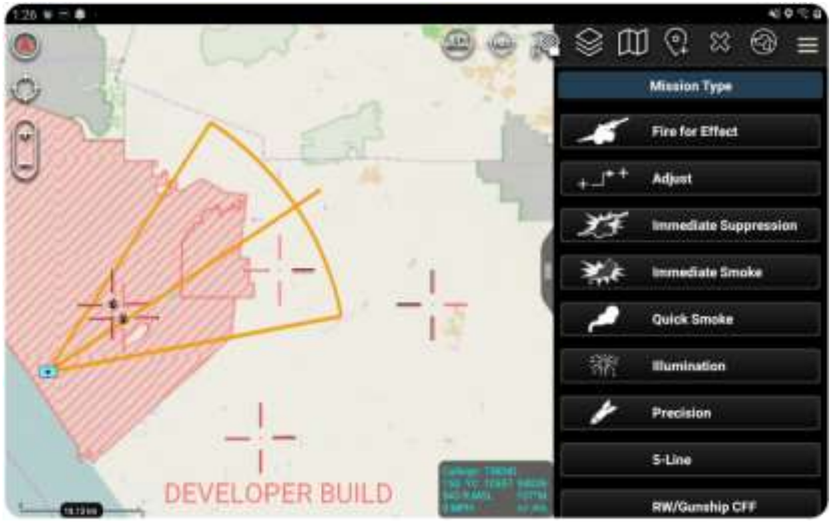
Alert Status Messages (Source: TAK)



Channels

ATAK-TEST Channel Disabled	RX	TX
ATAK.Surv.Ch1 Standby	RX	TX
ATAK.Surv.Ch2 Channel Disabled	RX	TX
ATAK_Unit Channel Disabled	RX	TX
EMERGENCY Channel Disabled	RX	TX
ST.STCR.ALL Channel Disabled	RX	TX
ST.STCR.DEMO-O... Channel Disabled	RX	TX
ST.STCR.DEMO-O... Channel Disabled	RX	TX

Push to Talk (Source: TAK)



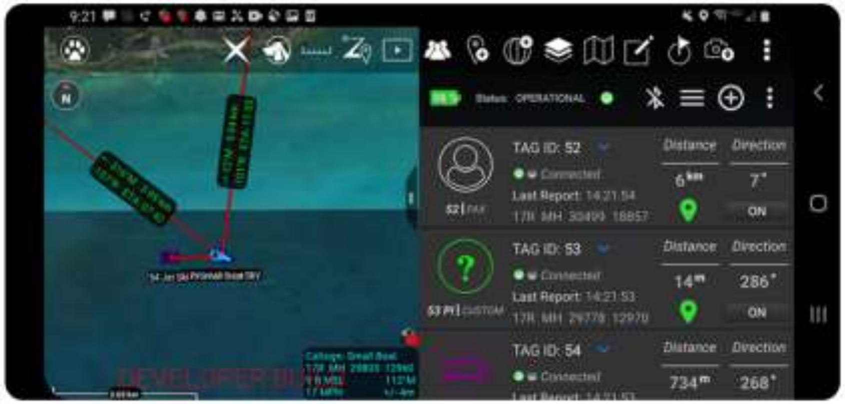
Joint Effects Coordination Link
(Source: TAK)

TAK GPS Plugins

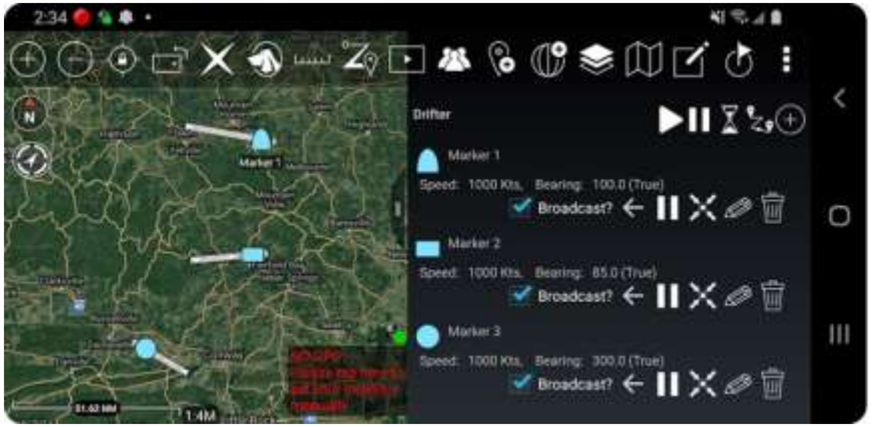
		TCPED					AI/ML		Hybrid Cloud					
	Asset	Task	Collect	Process	Exploit	Disseminate	Data Science	Automation	Collaborate	Containers	Microservices	Kubernetes	Kafka	Tactical Cloud
GPS	AR Repeater		X	X										
	ATOS		X	X										
	AuSS		X	X	X									
	Compass Nav			X										
	DFT Sensors		X	X	X									
	Drifter				X									
	EMAPS		X	X	X									
	Intercep			X	X									
	Last Known Location		X	X										
	Munter				X									
	Neon		X	X	X									
	Stack Manager		X	X	X									
	Tetra		X	X	X	X								
	VNS			X										

- ➢Enhancements range from user navigation, to Augmented Reality (AR), to tracking and targeting.

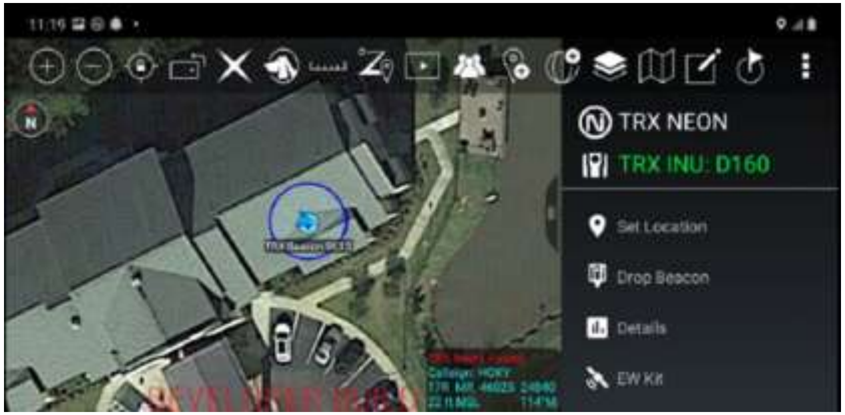
TAK GPS Plugins



ATOS LOS Tracker (Source: TAK)

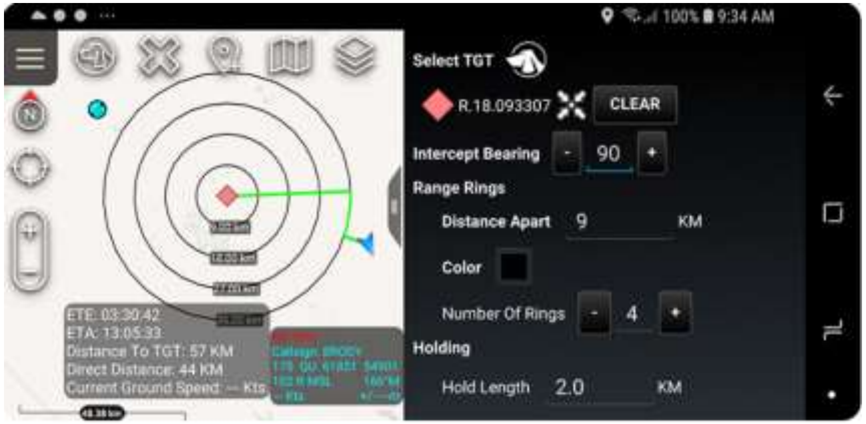

Drifter
Marker 1
Speed: 1000 Kts, Bearing: 100.0 (True)
Broadcast?
Marker 2
Speed: 1000 Kts, Bearing: 85.0 (True)
Broadcast?
Marker 3
Speed: 1000 Kts, Bearing: 300.0 (True)
Broadcast?
1.4M

Drifter Dead Reckoning (Source: TAK)



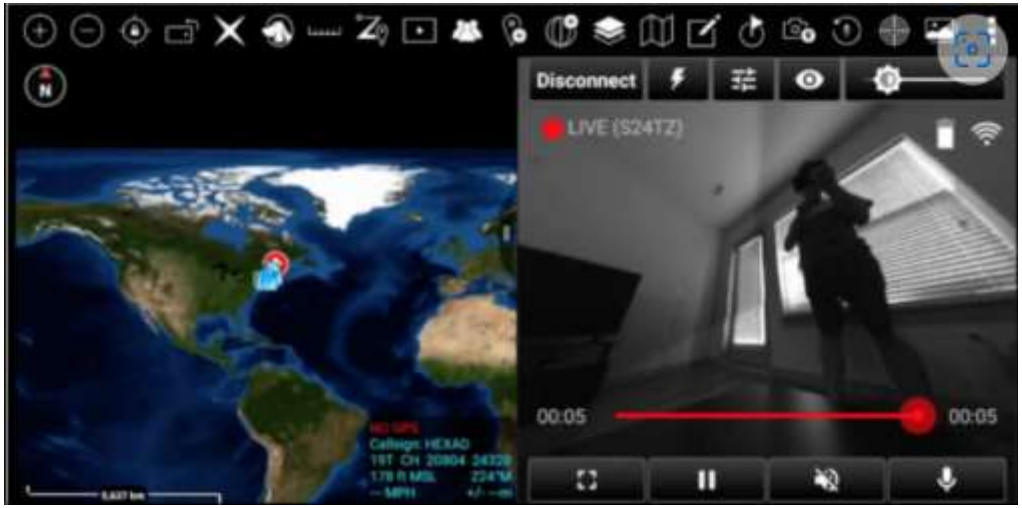
GPS Denied Tracking (Source: TAK)

Intercept Bearing Calculation
(Source: TAK)



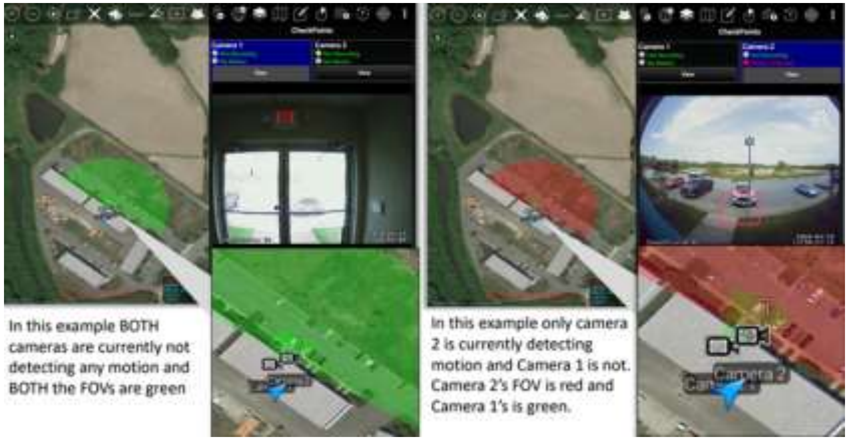
TAK Image Plugins

	Asset	TCPED					AI/ML		Hybrid Cloud					
		Task	Collect	Process	Exploit	Disseminate	Data Science	Automation	Collaborate	Containers	Microservices	Kubernetes	Kafka	Tactical Cloud
Images	Bounce Viewer		X	X										
	Checkpoints		X	X	X									
	Milestone		X	X										
	SSE Tool		X			X								
	Vulcane		X											



Bounce Omnidirectional Tactical Camera (Source: TAK)

TAK Image Plugins



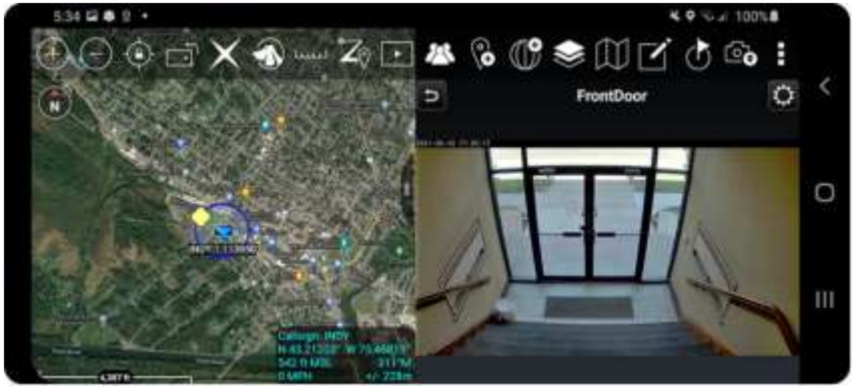
In this example BOTH cameras are currently not detecting any motion and BOTH the FOVs are green

In this example only camera 2 is currently detecting motion and Camera 1 is not. Camera 2's FOV is red and Camera 1's is green.

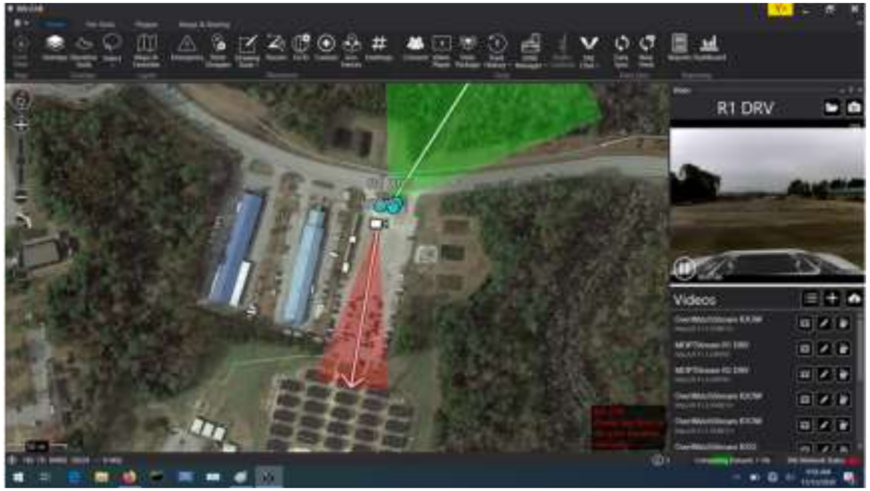
Checkpoints Video Detection and Alert

(Source: TAK)

Milestone Location Stream



(Source: TAK)



Vulcane Vehicle Camera System

(Source: TAK)

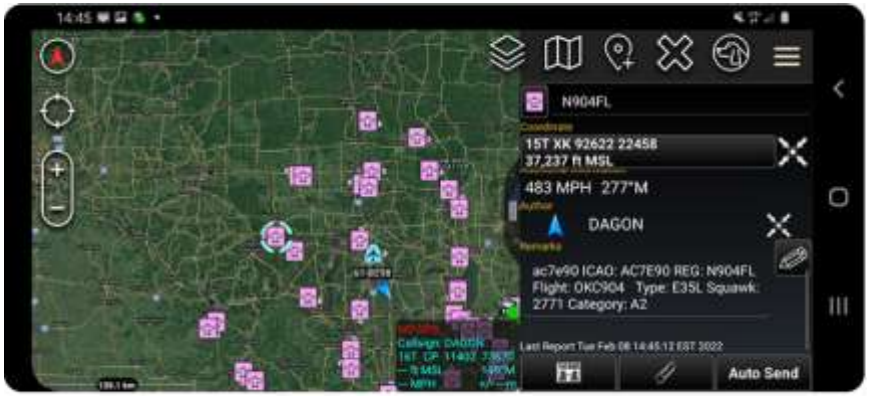
TAK Sensor Fusion Plugins

		TCPED					AI/ML		Hybrid Cloud					
	Asset	Task	Collect	Process	Exploit	Disseminate	Data Science	Automation	Collaborate	Containers	Microservices	Kubernetes	Kafka	Tactical Cloud
Sensor	ADS-B		X	X	X									
	AVO		X	X	X									
	Building Manager		X	X	X									
	CBRN		X	X	X									
	Deep Purple		X	X	X									
	Effects		X	X	X									
	FoCUS		X											
	Ninja		X	X	X									
	Point Mensuration Tool		X	X	X									
	Prowl		X	X	X									
	Somewhere		X	X					X					
	UAS Tool		X	X										
	UGV Tool		X	X										
	Wx Report		X	X	X									

- ➢ To increase the number of sensed entities available on the platform, the sophistication of the fusion, and the processing capabilities.

TAK Sensor Fusion Plugins

ADS-B Service Integration (Source: TAK)



N904FL

15T XK 92622 22458
37,237 ft MSL

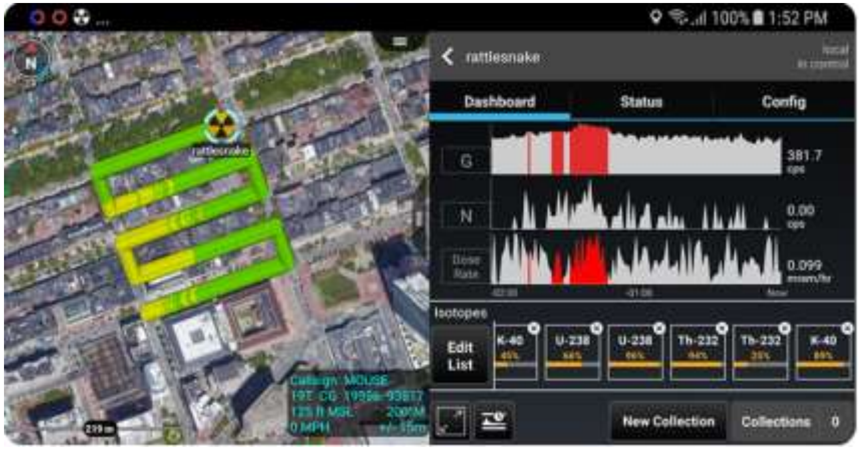
483 MPH 277°M

DAGON

ac7e90 ICAO: AC7E90 REG: N904FL Flight: OKC904 Type: E35L Squawk: 2771 Category: A2

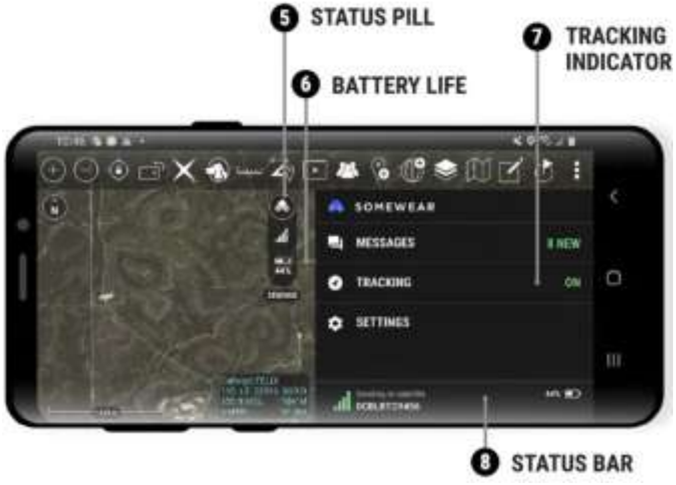
Last Report Tue Feb 08 14:45:12 EST 2022

CBRN Sensor Integration (Source: TAK)



Somewhere Satellite Hotspot

(Source: TAK)



TAK Operations Plugins

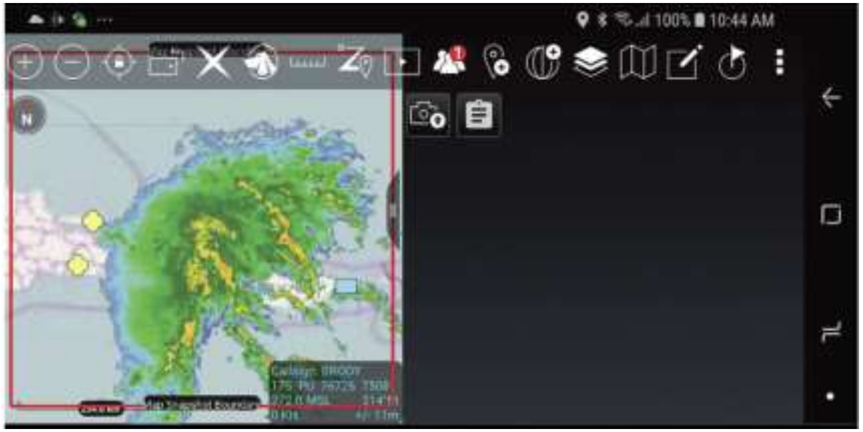
		TCPED					AI/ML		Hybrid Cloud					
	Asset	Task	Collect	Process	Exploit	Disseminate	Data Science	Automation	Collaborate	Containers	Microservices	Kubernetes	Kafka	Tactical Cloud
Operations	CMP	X	X	X	X	X			X					
	Data Sync		X	X	X	X			X					
	ExCheck		X	X		X			X					
	Mission Workflow	X		X		X			X					
	Pager		X	X	X		X							
	Reports		X	X										
	TAK-ML		X	X	X		X	X						
	TAK Replay				X									
	TRAX		X	X	X	X								
	WASP		X	X	X	X			X					

Assessment, reporting and decision support functions:

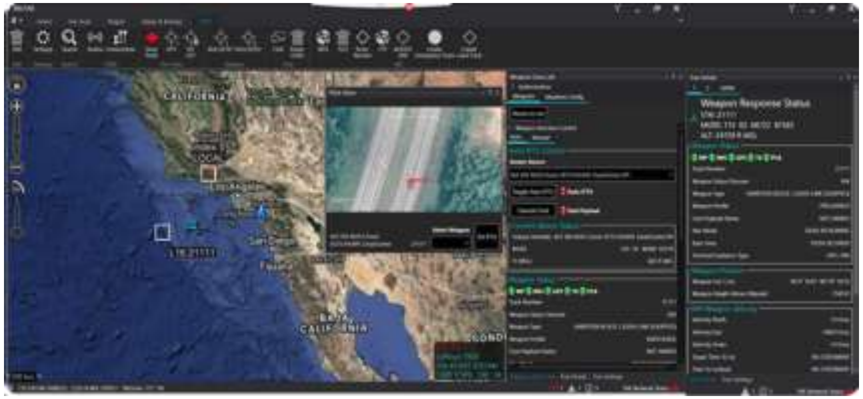
- Calculations for conflict management
- Tactical guidance
- Libraries for the development of AI/ML for decision support

TAK Operations Plugins

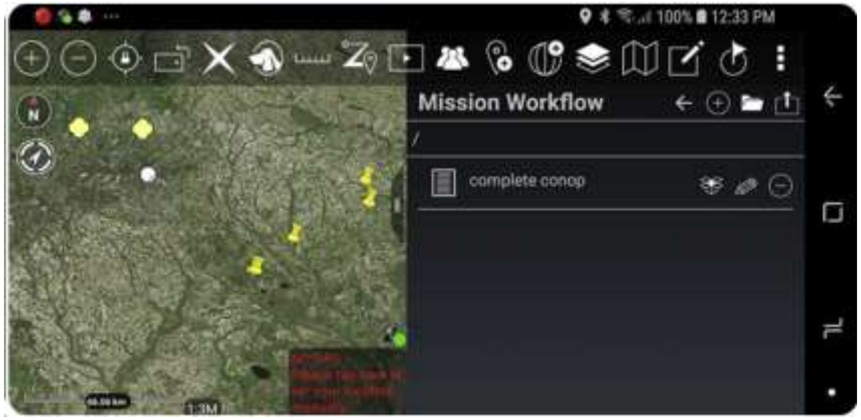
Mission Planner (Source: TAK)



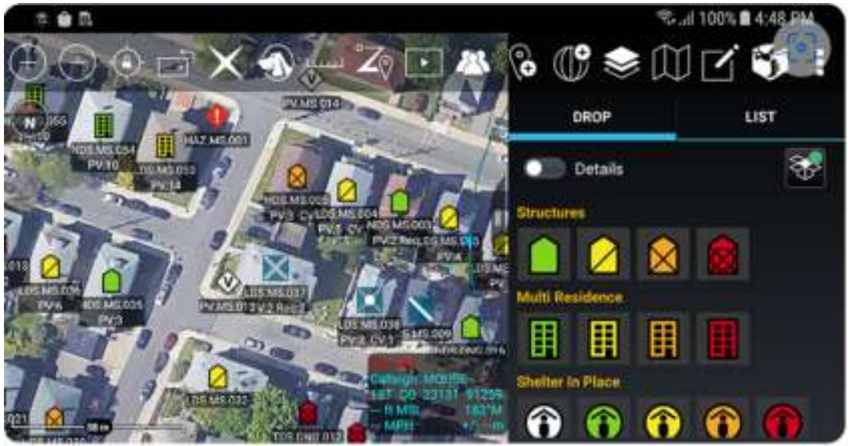
Air-Maritime-Ground COP (Source: TAK)



Mission Workflow (Source: TAK)



Search and Rescue (Source: TAK)



Edge AI/ML

NPS Laboratory Tests

About

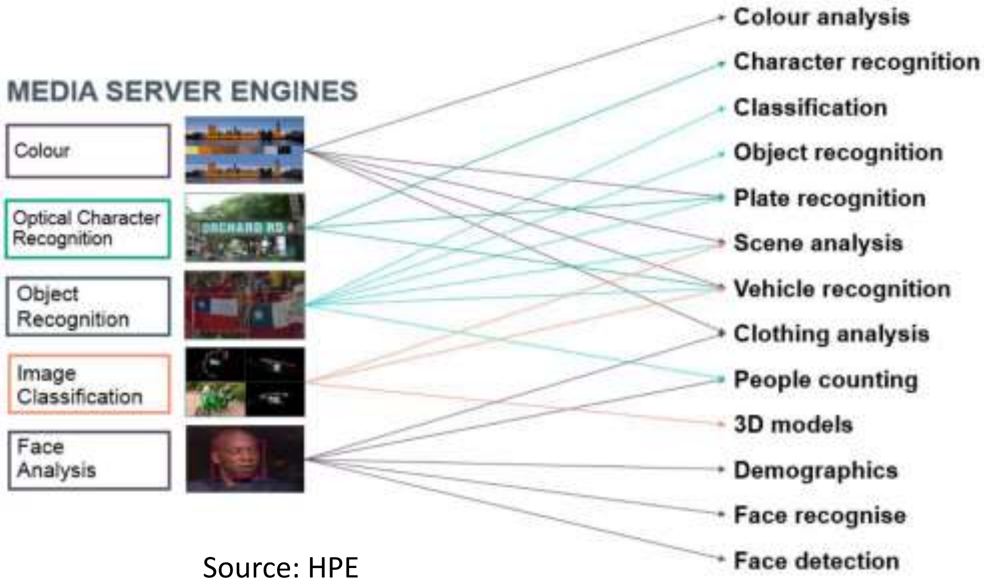
- ➢ This section discusses AI/ML for the EL8000 tactical node:
  - o AI/ML is available for the EL8000 tactical node chassis and servers
  - o AI/ML is available for the OpenShift tactical node operating software.
- ➢ Sensor Open Systems Architecture (SOSA) standards are implemented for hardware, software, functions and behaviors; and for electrical-mechanical interfaces for communications, EO/IR, EW, radar and SIGINT interoperability.
- ➢ AI/ML and AI deep neural network (AI/DNN) algorithms provide context-aware applications that can track and identify objects, analyze motion for events, and extract intelligence from analog or digital streams using an open, low-latency streaming web interface and control API to:
  - o Learn the spectrum instantly and automatically with contextual analysis
  - o Detect and classify RF emissions across bandwidths to report anomalies and threats in near real-time
  - o Assess wide-band and narrow-band signals, analog single carrier modulations, multi-carrier modulation schemes, cellular and infrastructure signals, ISM-band signals (e.g., Wi-Fi, Bluetooth) and mobile radio services
  - o Apply AI/DNN in real-time for signal identification and re-train the neural network as needed for new signals/anomalies.

Embedded AI/ML

EL8000 Software Capabilities	EL8000 Hardware
AI/ML	NVIDIA Tesla T4
Anomaly Detection	NVIDIA Tesla T4
Body Recognition	NVIDIA Tesla T4
Facial Attributes (gender, age, etc.)	NVIDIA Tesla T4
Facial Recognition	NVIDIA Tesla T4
Facial Expression Analysis	NVIDIA Tesla T4
License Plate Recognition	NVIDIA Tesla T4
Object Detection and Classification	NVIDIA Tesla T4
Object Tracking and Pathing	NVIDIA Tesla T4

- EL8000 integrates hardware and software to optimize the platform for sensor collection and processing at the tactical edge
- Embedded AI/ML for situational awareness and GPU-accelerated data visualization for tactical decision support

- AI/ML enables the tactical node to learn from examples.
- AI deep neural network (AI/DNN) algorithms automate that training.



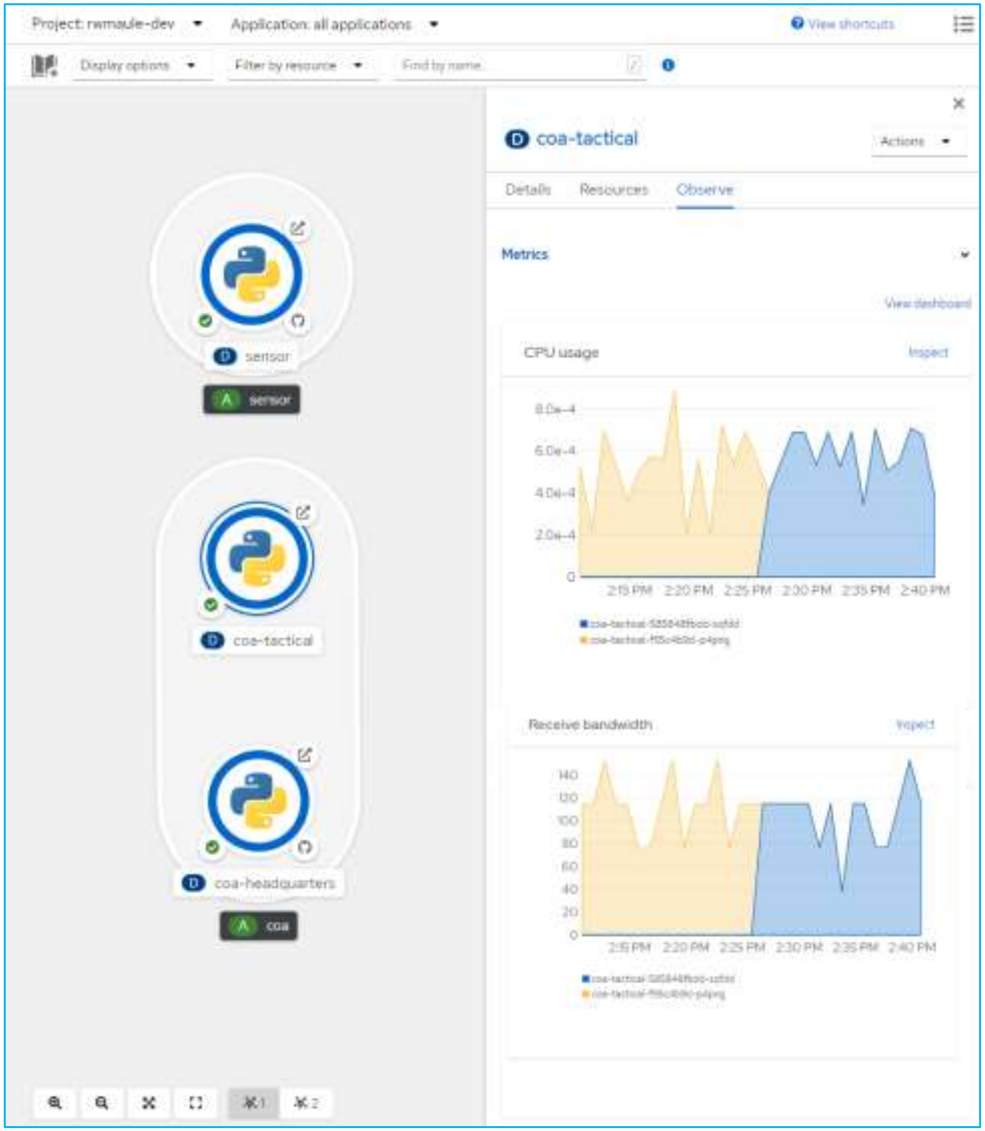
Source: HPE

AI as a Service (AaaS)

Open Data Hub for AI as a Service (AaaS) on Kubernetes:

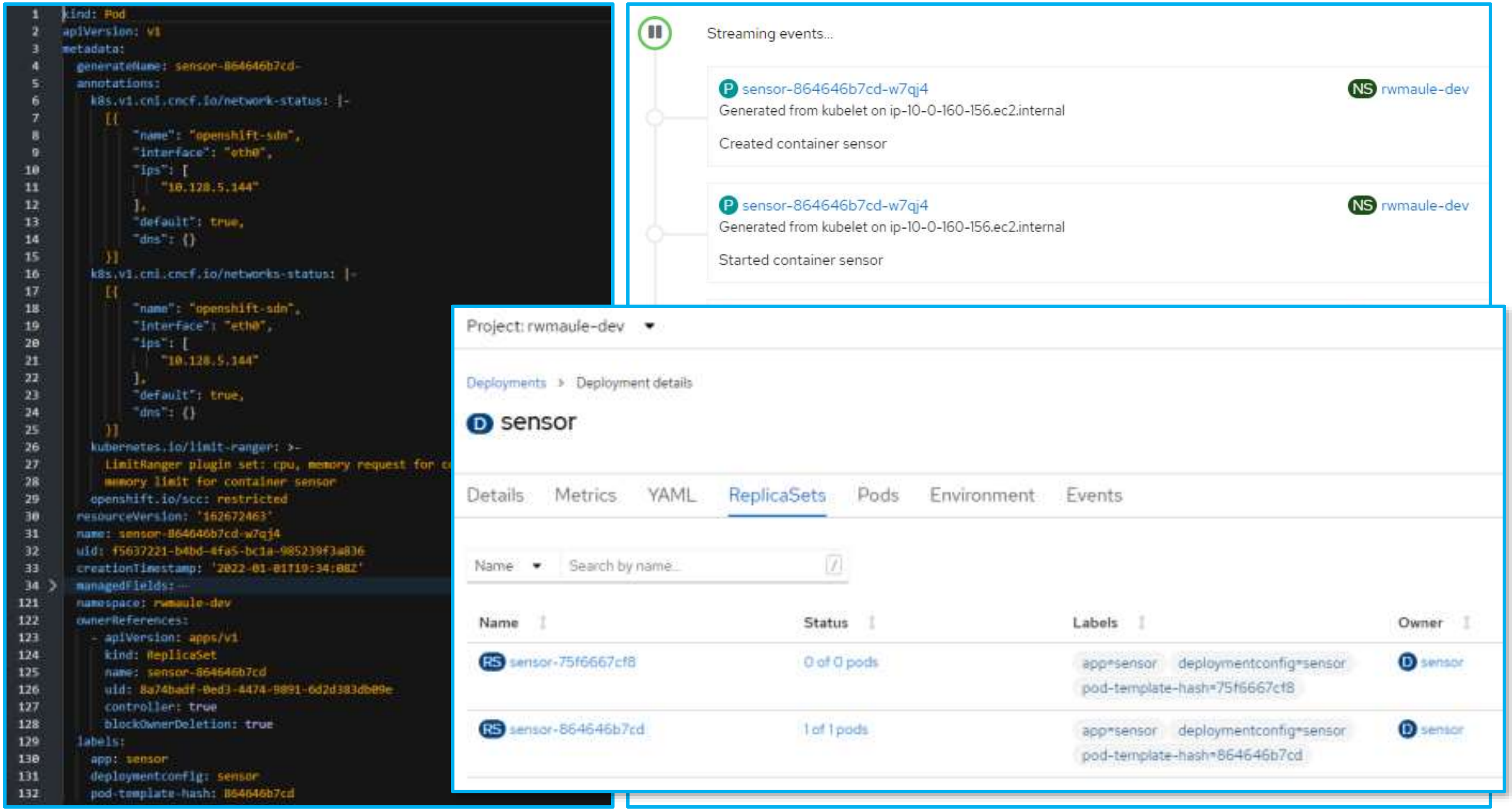
- Ceph Object Storage for analytics at the tactical edge
- Inherits upstream from Kafka/Strimzi and Kubeflow
- Jupyter supports interactive data science and scientific computing
- Scikit-learn ML libraries for Python
- Numpy, Scipy, and Matplotlib for predictive analysis
- TensorFlow end-to-end AI/ML to build/deploy ML-powered apps
- PyTorch open source ML framework for computer vision and NLP
- Jupyter notebooks with integrated TensorFlow, PyTorch, and Apache Spark model development frameworks
- IBM Watson Studio for building and managing models at scale
- OpenVINO and oneAPI analytics toolkits for optimizing and tuning models
- Seldon for deploying, managing, and monitoring models
- Starburst Galaxy for data integration

Tactical Edge AaaS Topology



- ➢ The Topology view provides a visual representation of the applications within a project, their build status, and the components and services associated with them.
- ➢ Pods can be packaged as a container image to run AaaS that can be called from other applications.
- ➢ The number of pods for a service can be scaled up or down to increase or decrease the number of instances of the application.
- ➢ For serverless applications, the Pods are automatically scaled down to zero when idle and scaled up depending on the channel traffic.
- ➢ In this instance we have Sensor Pods, and Course of Action (COA) Pods for the tactical edge and Headquarters.

Node Replica Sets



```yaml
kind: Pod
apiVersion: v1
metadata:
  generateName: sensor-864646b7cd-
  annotations:
    k8s.v1.cni.cncf.io/network-status: |-
      [{
          "name": "openshift-sdn",
          "interface": "eth0",
          "ips": [
              "10.128.5.144"
          ],
          "default": true,
          "dns": {}
      }]
    k8s.v1.cni.cncf.io/networks-status: |-
      [{
          "name": "openshift-sdn",
          "interface": "eth0",
          "ips": [
              "10.128.5.144"
          ],
          "default": true,
          "dns": {}
      }]
    kubernetes.io/limit-ranger: >-
      LimitRanger plugin set: cpu, memory request for c
      memory limit for container sensor
    openshift.io/scc: restricted
  resourceVersion: '162672463'
  name: sensor-864646b7cd-w7qj4
  uid: f5637221-b4bd-4fa5-bc1a-985239f3a836
  creationTimestamp: '2022-01-01T19:34:08Z'
  managedFields: ···
  namespace: rwmaule-dev
  ownerReferences:
    - apiVersion: apps/v1
      kind: ReplicaSet
      name: sensor-864646b7cd
      uid: 8a74badf-0ed3-4474-9891-6d2d383db09e
      controller: true
      blockOwnerDeletion: true
  labels:
    app: sensor
    deploymentconfig: sensor
    pod-template-hash: 864646b7cd
```

Streaming events...

P sensor-864646b7cd-w7qj4 — NS rwmaule-dev
Generated from kubelet on ip-10-0-160-156.ec2.internal
Created container sensor

P sensor-864646b7cd-w7qj4 — NS rwmaule-dev
Generated from kubelet on ip-10-0-160-156.ec2.internal
Started container sensor

Project: rwmaule-dev

Deployments > Deployment details

D sensor

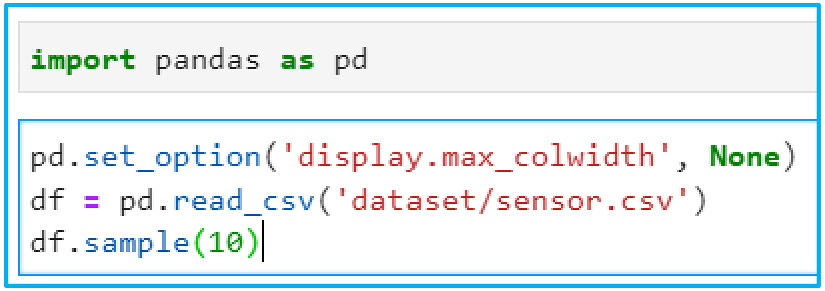
Name	Status	Labels	Owner

RS sensor-75f6667cf8	0 of 0 pods	app=sensor
		deploymentconfig=sensor
		pod-template-hash=75f6667cf8
			D sensor

RS sensor-864646b7cd	1 of 1 pods	app=sensor
		deploymentconfig=sensor
		pod-template-hash=864646b7cd
			D sensor

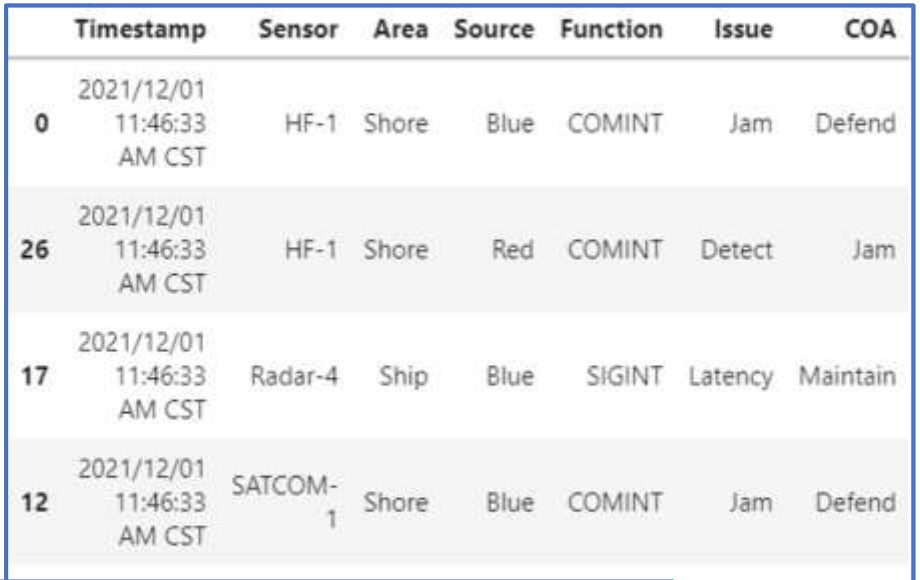
Far Edge Data Collection

In the Jupyter notebook we take a small data set of 52 samples and use the Markovify algorithm to simulate a data set of 1000 derived from the original 52 samples.

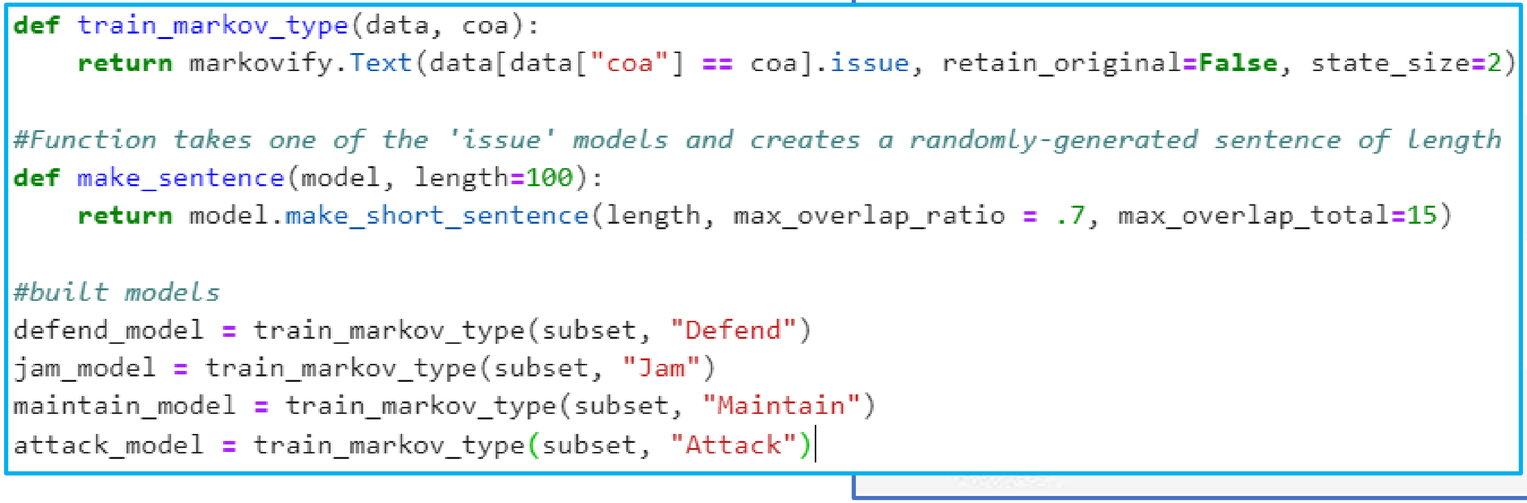


```
import pandas as pd
```

```
pd.set_option('display.max_colwidth', None)
df = pd.read_csv('dataset/sensor.csv')
df.sample(10)
```



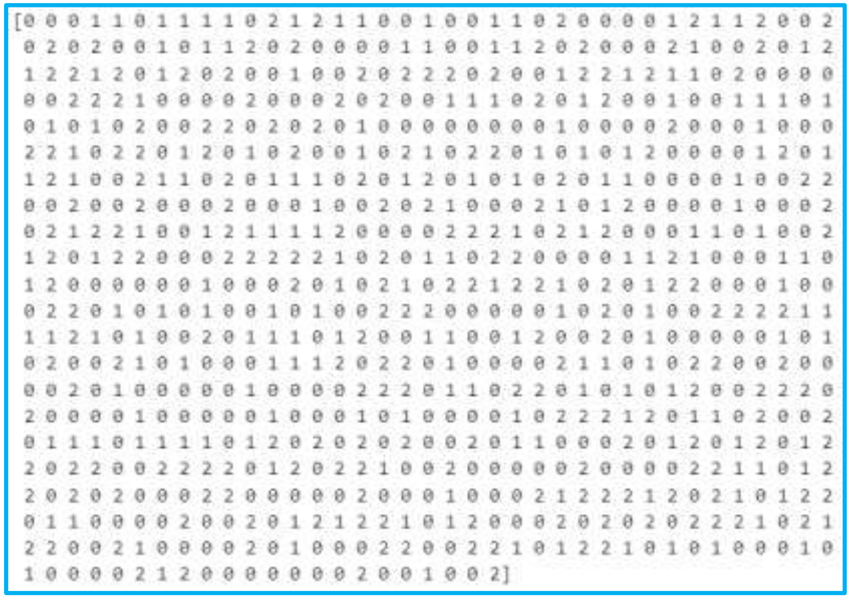
	Timestamp	Sensor	Area	Source	Function	Issue	COA
0	2021/12/01 11:46:33 AM CST	HF-1	Shore	Blue	COMINT	Jam	Defend
26	2021/12/01 11:46:33 AM CST	HF-1	Shore	Red	COMINT	Detect	Jam
17	2021/12/01 11:46:33 AM CST	Radar-4	Ship	Blue	SIGINT	Latency	Maintain
12	2021/12/01 11:46:33 AM CST	SATCOM-1	Shore	Blue	COMINT	Jam	Defend
						Latency	Maintain
						Detect	Attack
						Jam	Defend
						Latency	Maintain



```
def train_markov_type(data, coa):
    return markovify.Text(data[data["coa"] == coa].issue, retain_original=False, state_size=2)

#Function takes one of the 'issue' models and creates a randomly-generated sentence of length
def make_sentence(model, length=100):
    return model.make_short_sentence(length, max_overlap_ratio = .7, max_overlap_total=15)

#built models
defend_model = train_markov_type(subset, "Defend")
jam_model = train_markov_type(subset, "Jam")
maintain_model = train_markov_type(subset, "Maintain")
attack_model = train_markov_type(subset, "Attack")
```

AI/ML Model

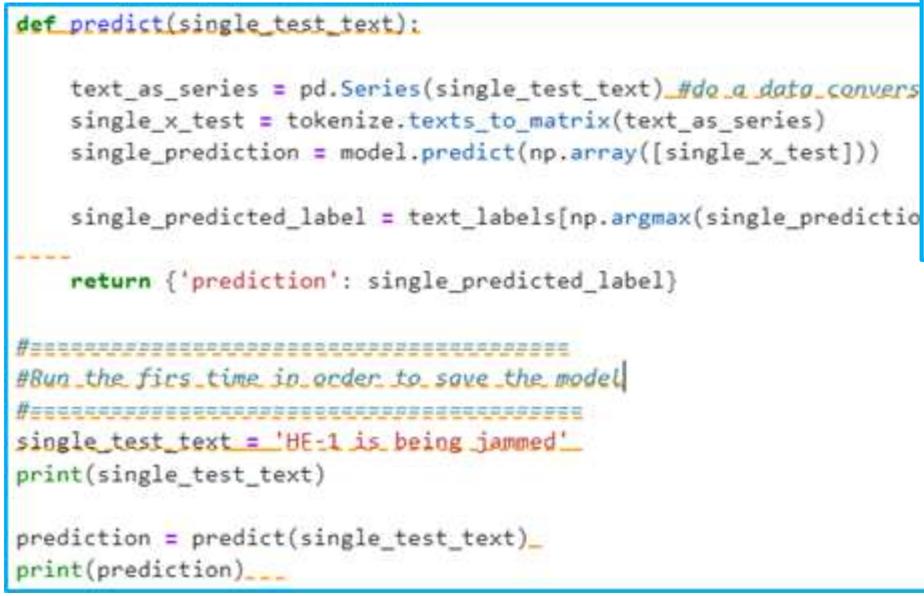
- ➢ Characterize sensor status from free text descriptions entered by users through Natural Language Processing (NLP).
- ➢ Package the code to create a service that can be queried from an application.
- ➢ Train the model on the simulated data, and once trained, enter sensor issues to see if the model has correctly categorized the status.
- ➢ Use the TensorFlow AI/ML libraries to run and share the code:
  - o 80% training, 20% testing.
- ➢ Text entered by warfighters is converted into contextual vectors with numeric representations to form an index.
- ➢ Scikit-learn is used to convert label strings into a numbered index to enable the AI/ML algorithms to work with categorical data.



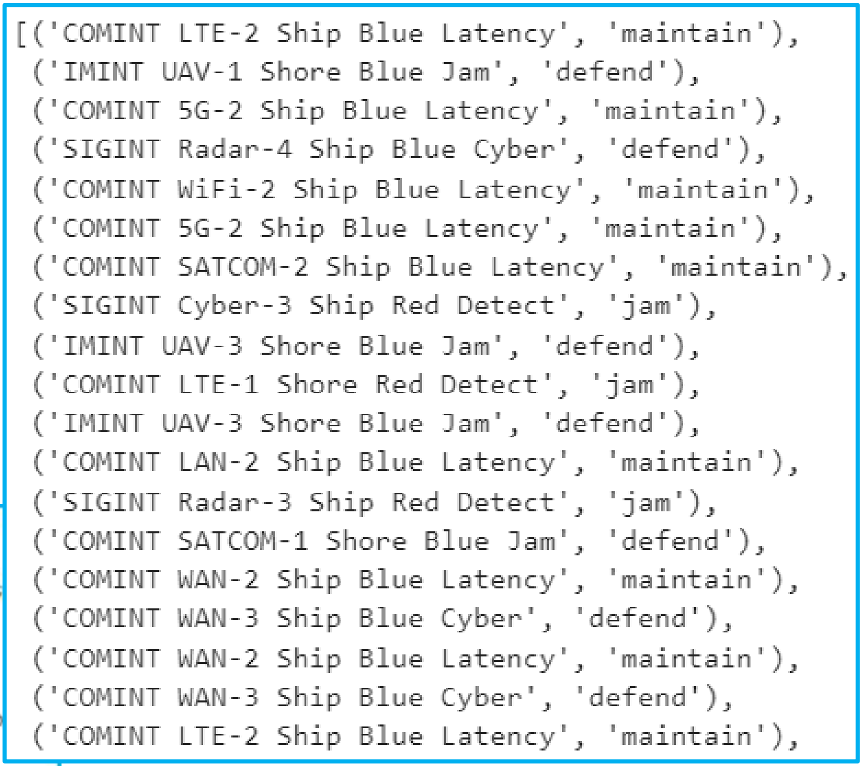
```
[0 0 0 1 1 0 1 1 1 1 0 2 1 2 1 1 0 0 1 0 0 1 1 0 2 0 0 0 0 1 2 1 1 2 0 0 2
 0 2 0 2 0 0 1 0 1 1 2 0 2 0 0 0 0 1 1 0 0 1 1 2 0 2 0 0 0 2 1 0 0 2 0 1 2
 1 2 2 1 2 0 1 2 0 2 0 0 1 0 0 2 0 2 2 2 0 2 0 0 1 2 2 1 2 1 1 0 2 0 0 0 0
 0 0 2 2 2 1 0 0 0 0 2 0 0 0 2 0 2 0 0 1 1 1 0 2 0 1 2 0 0 1 0 0 1 1 1 0 1
 0 1 0 1 0 2 0 0 2 2 0 2 0 2 0 1 0 0 0 0 0 0 0 0 1 0 0 0 0 2 0 0 0 1 0 0 0
 2 2 1 0 2 2 0 1 2 0 1 0 2 0 0 1 0 2 1 0 2 2 0 1 0 1 0 1 2 0 0 0 0 1 2 0 1
 1 2 1 0 0 2 1 1 0 2 0 1 1 1 0 2 0 1 2 0 1 0 1 0 2 0 1 1 0 0 0 0 1 0 0 2 2
 0 0 2 0 0 2 0 0 0 2 0 0 0 1 0 0 2 0 2 1 0 0 0 2 1 0 1 2 0 0 0 0 1 0 0 0 2
 0 2 1 2 2 1 0 0 1 2 1 1 1 1 2 0 0 0 0 2 2 2 1 0 2 1 2 0 0 0 1 1 0 1 0 0 2
 1 2 0 1 2 2 0 0 0 2 2 2 2 2 1 0 2 0 1 1 0 2 2 0 0 0 0 1 1 2 1 0 0 0 1 1 0
 1 2 0 0 0 0 0 0 1 0 0 0 2 0 1 0 2 1 0 2 2 1 2 2 1 0 2 0 1 2 2 0 0 0 1 0 0
 0 2 2 0 1 0 1 0 1 0 0 1 0 1 0 0 2 2 2 0 0 0 0 0 1 0 2 0 1 0 0 2 2 2 2 1 1
 1 1 2 1 0 1 0 0 2 0 1 1 1 0 1 2 0 0 1 1 0 0 1 2 0 0 2 0 1 0 0 0 0 0 1 0 1
 0 2 0 0 2 1 0 1 0 0 0 1 1 1 2 0 2 2 0 1 0 0 0 0 2 1 1 0 1 0 2 2 0 0 2 0 0
 0 0 2 0 1 0 0 0 0 0 1 0 0 0 0 2 2 2 0 1 1 0 2 2 0 1 0 1 0 1 2 0 0 2 2 2 0
 2 0 0 0 0 1 0 0 0 0 0 1 0 0 0 1 0 1 0 0 0 0 1 0 2 2 2 1 2 0 1 1 0 2 0 0 2
 0 1 1 1 0 1 1 1 1 0 1 2 0 2 0 2 0 2 0 0 2 0 1 1 0 0 0 2 0 1 2 0 1 2 0 1 2
 2 0 2 2 0 0 2 2 2 2 0 1 2 0 2 2 1 0 0 2 0 0 0 0 0 2 0 0 0 0 2 2 1 1 0 1 2
 2 0 2 0 2 0 0 0 2 2 0 0 0 0 0 2 0 0 0 1 0 0 0 2 1 2 2 2 1 2 0 2 1 0 1 2 2
 0 1 1 0 0 0 0 2 0 0 2 0 1 2 1 2 2 1 0 1 2 0 0 0 2 0 2 0 2 0 2 2 2 1 0 2 1
 2 2 0 0 2 1 0 0 0 0 2 0 1 0 0 0 2 2 0 0 2 2 1 0 1 2 2 1 0 1 0 1 0 0 0 1 0
 1 0 0 0 0 2 1 2 0 0 0 0 0 0 0 2 0 0 1 0 0 2]
```

Train and Test

- Softmax calculates probabilities for each category in each document.
- Epochs represent the number of times model calculations pass through the data.
- TensorFlow binary is optimized with oneAPI AI/DNN library.



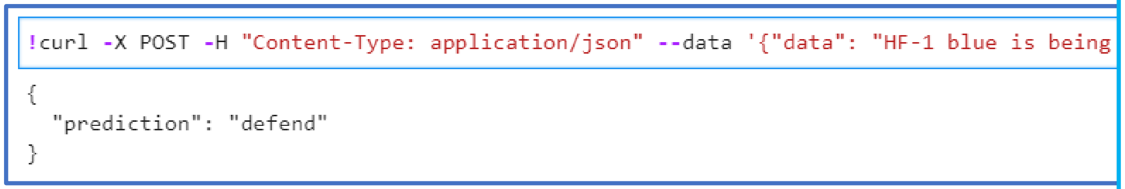
```
def predict(single_test_text):

    text_as_series = pd.Series(single_test_text) #do a data convers
    single_x_test = tokenize.texts_to_matrix(text_as_series)
    single_prediction = model.predict(np.array([single_x_test]))

    single_predicted_label = text_labels[np.argmax(single_predictio

    return {'prediction': single_predicted_label}

#========================================
#Run the firs time in order to save the model
#=========================================
single_test_text = 'HE-1 is being jammed'
print(single_test_text)

prediction = predict(single_test_text)
print(prediction)
```



```
[('COMINT LTE-2 Ship Blue Latency', 'maintain'),
 ('IMINT UAV-1 Shore Blue Jam', 'defend'),
 ('COMINT 5G-2 Ship Blue Latency', 'maintain'),
 ('SIGINT Radar-4 Ship Blue Cyber', 'defend'),
 ('COMINT WiFi-2 Ship Blue Latency', 'maintain'),
 ('COMINT 5G-2 Ship Blue Latency', 'maintain'),
 ('COMINT SATCOM-2 Ship Blue Latency', 'maintain'),
 ('SIGINT Cyber-3 Ship Red Detect', 'jam'),
 ('IMINT UAV-3 Shore Blue Jam', 'defend'),
 ('COMINT LTE-1 Shore Red Detect', 'jam'),
 ('IMINT UAV-3 Shore Blue Jam', 'defend'),
 ('COMINT LAN-2 Ship Blue Latency', 'maintain'),
 ('SIGINT Radar-3 Ship Red Detect', 'jam'),
 ('COMINT SATCOM-1 Shore Blue Jam', 'defend'),
 ('COMINT WAN-2 Ship Blue Latency', 'maintain'),
 ('COMINT WAN-3 Ship Blue Cyber', 'defend'),
 ('COMINT WAN-2 Ship Blue Latency', 'maintain'),
 ('COMINT WAN-3 Ship Blue Cyber', 'defend'),
 ('COMINT LTE-2 Ship Blue Latency', 'maintain'),
```

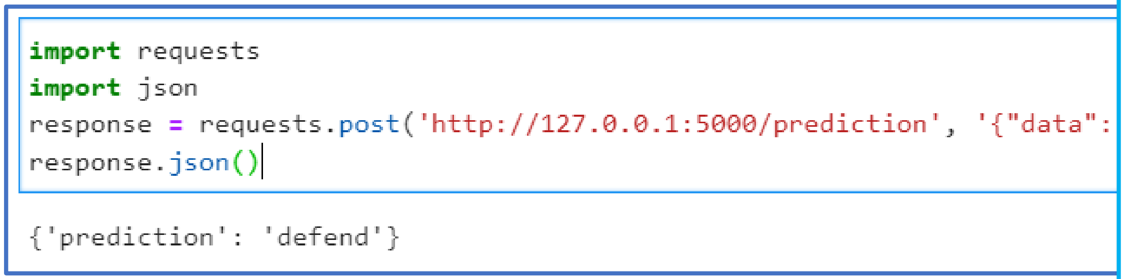
Recommend/Predict

Inline Curl recommendation



```
!curl -X POST -H "Content-Type: application/json" --data '{"data": "HF-1 blue is being
{
  "prediction": "defend"
}
```

Embedded Python recommendation



```
import requests
import json
response = requests.post('http://127.0.0.1:5000/prediction', '{"data":
response.json()

{'prediction': 'defend'}
```

HF-1 is being jammed
{'prediction': 'defend'}

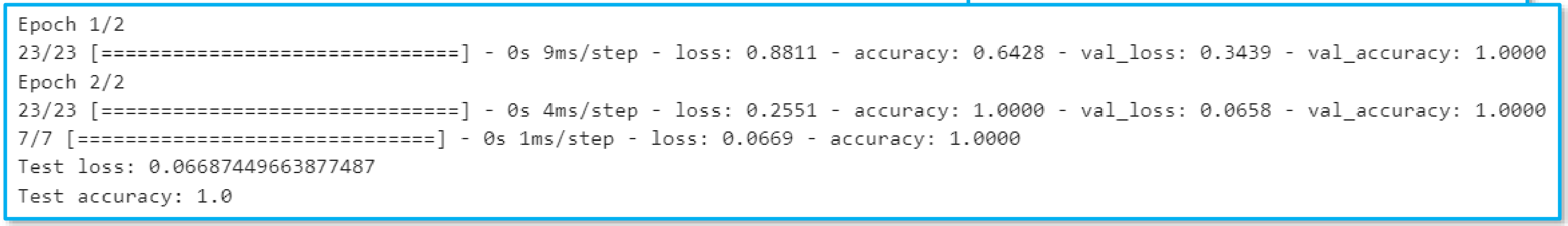
latency issue on HF-2
{'prediction': 'maintain'}

COMINT latency on blue ship SATCOM-2
{'prediction': 'maintain'}

detect COMINT red ship HF-2
{'prediction': ‘jam'}

red shore LAN-1 detect
{'prediction': ‘jam'}

SIGINT jam radar-1 shore blue
{'prediction': 'defend'}



```
Epoch 1/2
23/23 [==============================] - 0s 9ms/step - loss: 0.8811 - accuracy: 0.6428 - val_loss: 0.3439 - val_accuracy: 1.0000
Epoch 2/2
23/23 [==============================] - 0s 4ms/step - loss: 0.2551 - accuracy: 1.0000 - val_loss: 0.0658 - val_accuracy: 1.0000
7/7 [==============================] - 0s 1ms/step - loss: 0.0669 - accuracy: 1.0000
Test loss: 0.066874496638774887
Test accuracy: 1.0
```

Test Cases

Function	Component	Supported	Tested	Result
Orchestration	Kubernetes	Yes	Yes	Recommend
Streams	Kafka	Yes	Yes	Recommend
AI/ML	Jupyter	Yes	Yes	Recommend
AI/ML	TensorFlow	Yes	Yes	Recommend
AI/ML	NLP	Yes	Yes	Recommend
AI/ML	PyTorch	Yes	No	Viable
AI/ML	Spark	Yes	No	Viable
AI/ML	Watson	Yes	No	Viable
AI/ML	Scikit-learn	Yes	Yes	Recommend
AI/DNN	TensorFlow	Yes	No	Viable
AI/DNN	OpenVINO	Yes	No	TBD
AI/ML	Seldon	Yes	No	TBD

Conclusion

Summary and Recommendations

Conclusion

- This project informs DMO, EABO, LOCE, and JADC2 objectives with technical designs for hardware, software, processing, and AI/ML at the tactical edge.
- Hardware was selected to support tactical cloud edge nodes, and software to support hybrid multi-cloud distributed tactical computing in high security architecture suitable for forward deployed forces in D-DIL and challenged EMS and cyber environments.
- Best-of-class industry and government software offering the potential to support an integrated C2/ISR universal COP with legacy and next generation JADC2 sensors and services were evaluated.
- Micro-service mesh/grid, real time streaming architecture, and AI/ML were evaluated for integrated C2/ISR universal COP tactical edge decision support and process automation.
- Future research may continue to refine hardware/software for mobile tactical clouds for extreme edge deployments in challenged environments to support an integrated C2/ISR universal COP with AI/ML services including analytics for enhanced SA, automation, and prediction.