MSET2 Streaming Prognostics for IoT Telemetry on **Oracle Roving Edge Infrastructure**

Safe harbor statement

The following is intended to outline our general product direction. It is intended for information purposes only, and may not be incorporated into any contract. It is not a commitment to deliver any material, code, or functionality, and should not be relied upon in making purchasing decisions. The development, release, timing, and pricing of any features or functionality described for Oracle's products may change and remains at the sole discretion of Oracle Corporation.

What We're Going To Cover Today

- Edge Infrastructure and its use for Analytics applications
- Using Multivariate State Estimation Technique with Nvidia GPU acceleration for IoT prognostic anomaly detection

Oracle Hybrid Cloud and Roving Edge Infrastructure

Dan Itkis, Sr. Product Manager, Oracle Cloud Infrastructure

29 Oracle Cloud regions and growing

January 2021: 29 regions live, 9+ planned; 6 Azure Interconnect regions

Fundamentals of hybrid cloud

Single server

Hyperscale public cloud

SMALL — **Deployment size** — LARGE

Lowest — **Cost to build** — Highest

Fundamentals of hybrid cloud

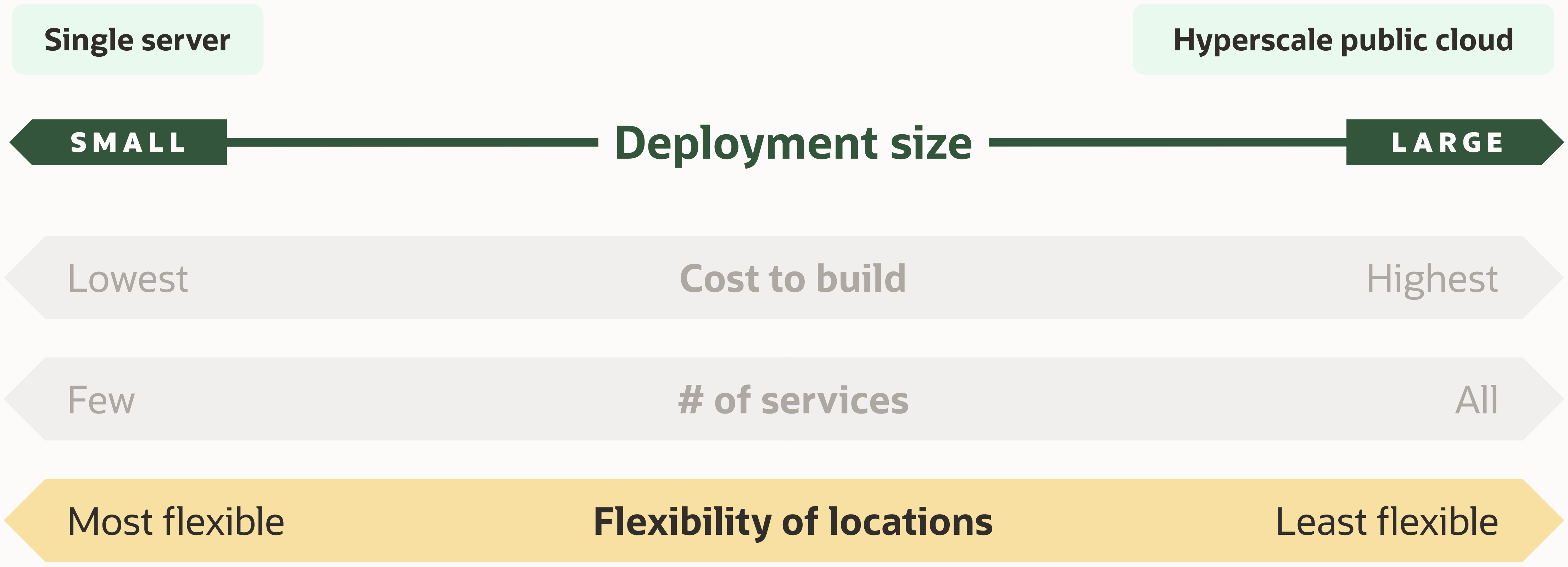
Single server | **Hyperscale public cloud**

SMALL — **Deployment size** — **LARGE**

Lowest — **Cost to build** — Highest

Few — **# of services** — All

Fundamentals of hybrid cloud



Fundamentals of hybrid cloud

Single server

Hyperscale public cloud

SMALL — **Deployment size** — LARGE

Lowest	Cost to build	Highest
Few	# of services	All
Most flexible	Flexibility of locations	Least flexible

Most flexible Flexibility of locations Least flexible

Fundamentals of hybrid cloud

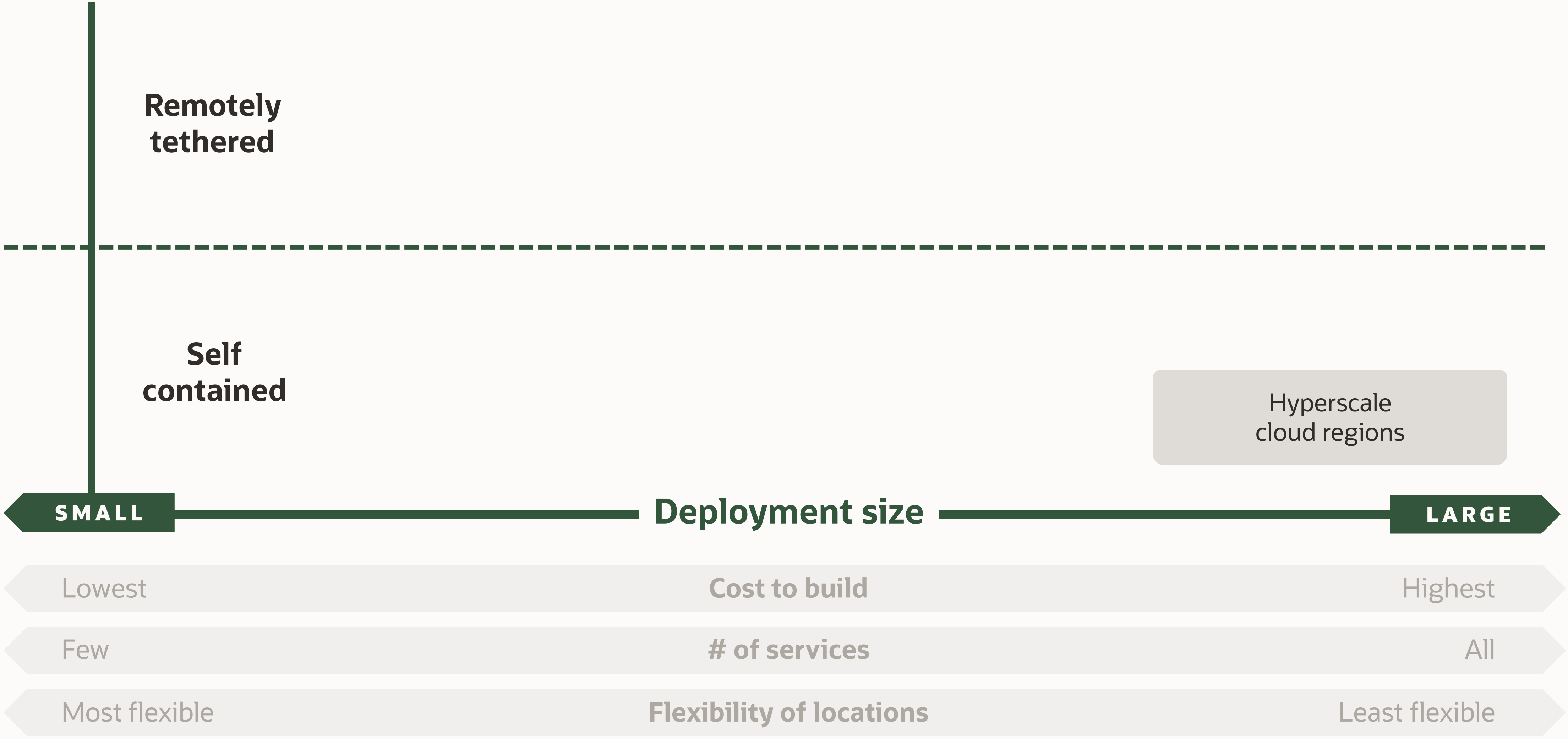
Remotely tethered: Requires connection to public cloud for some or all functionality

Self contained: Control and data planes together, can operate independently

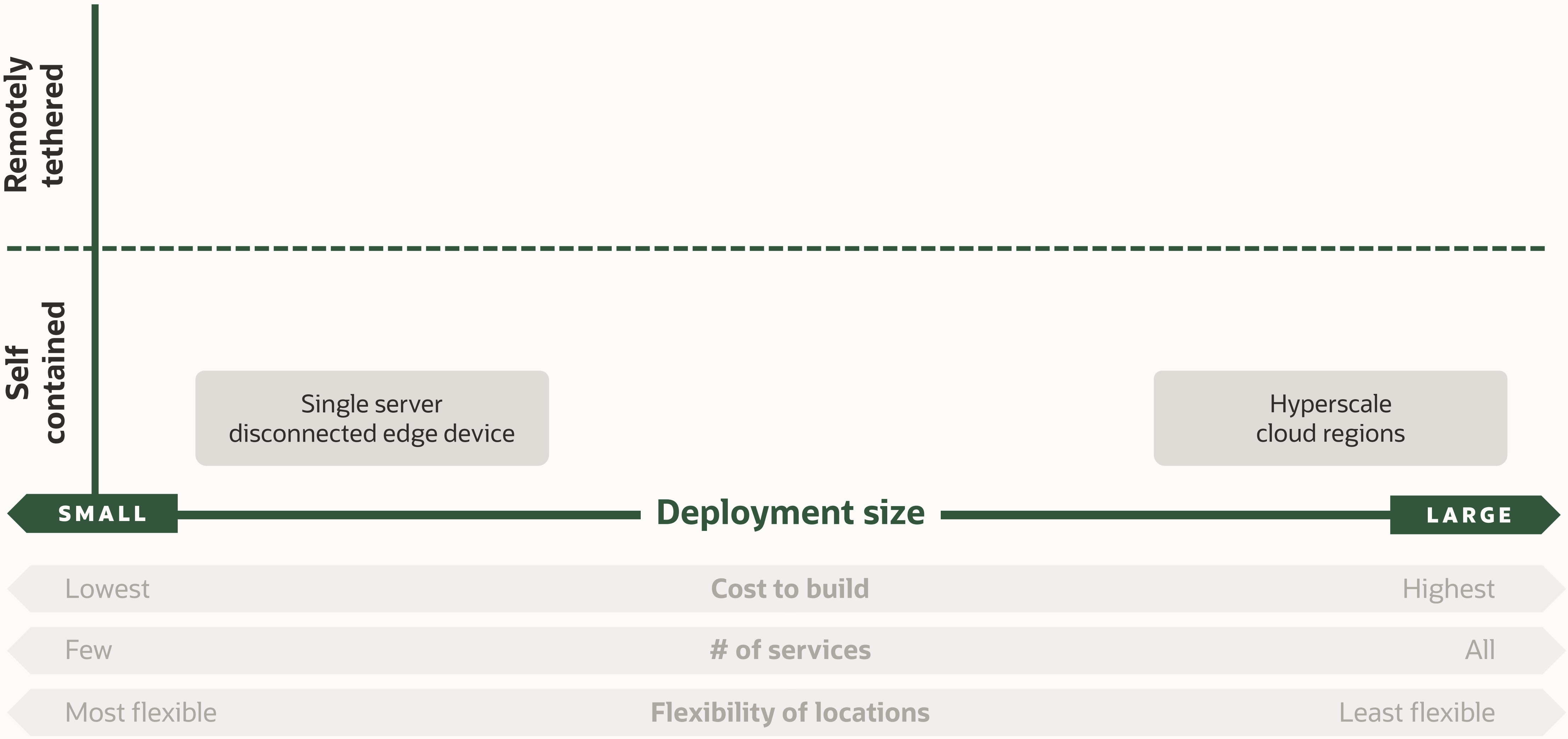
SMALL — **Deployment size** — LARGE

Lowest	**Cost to build**	Highest
Few	**# of services**	All
Most flexible	**Flexibility of locations**	Least flexible

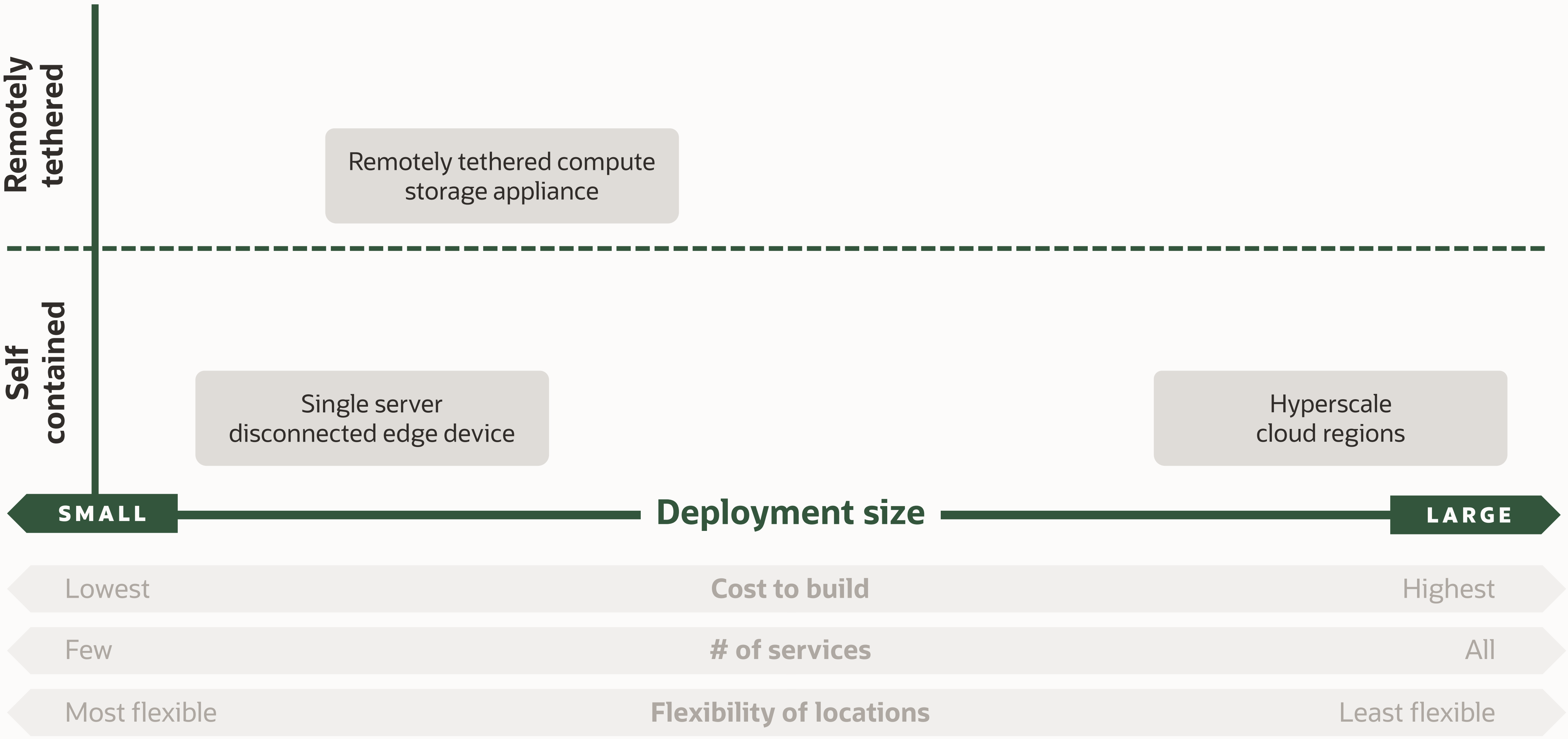
Current industry offerings



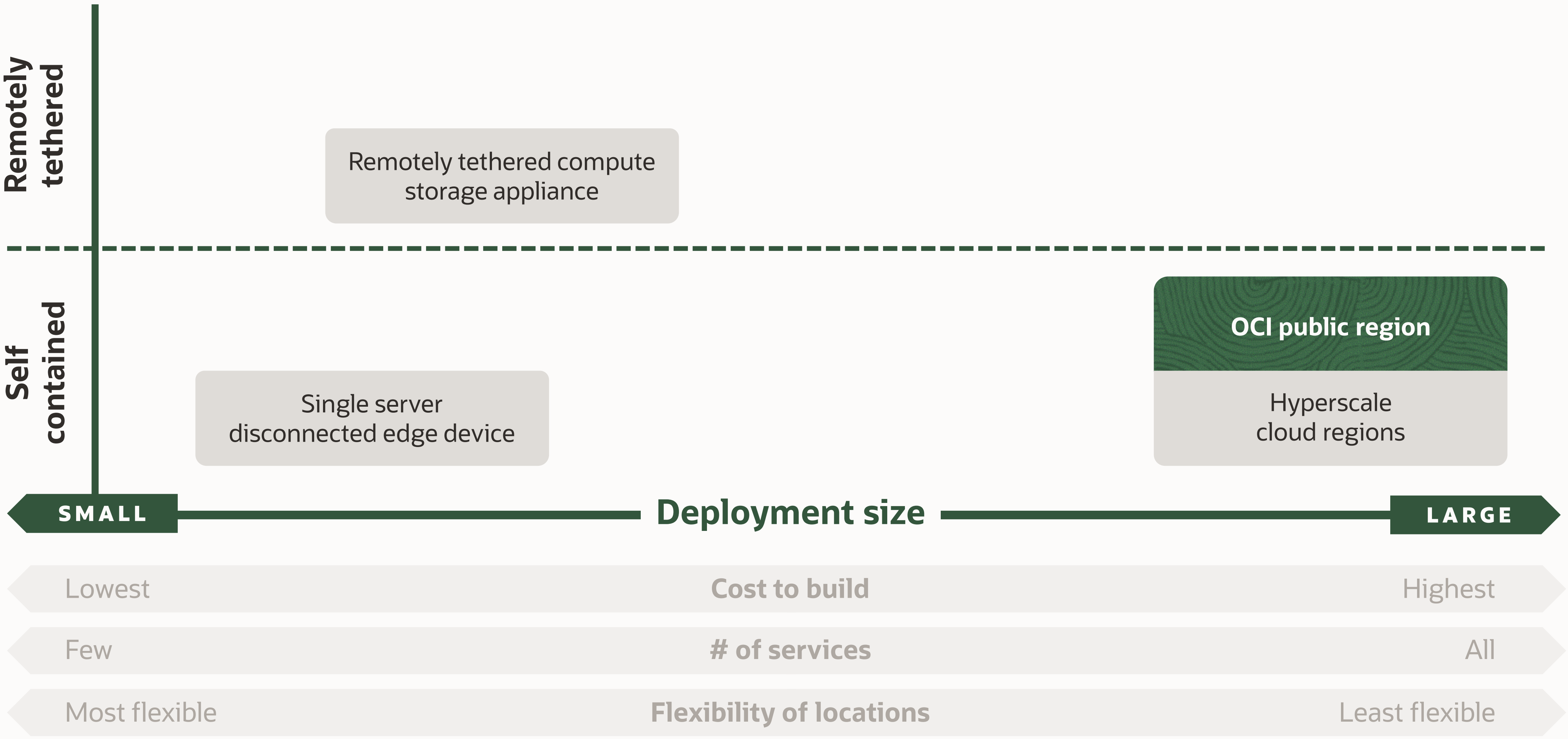
Current industry offerings



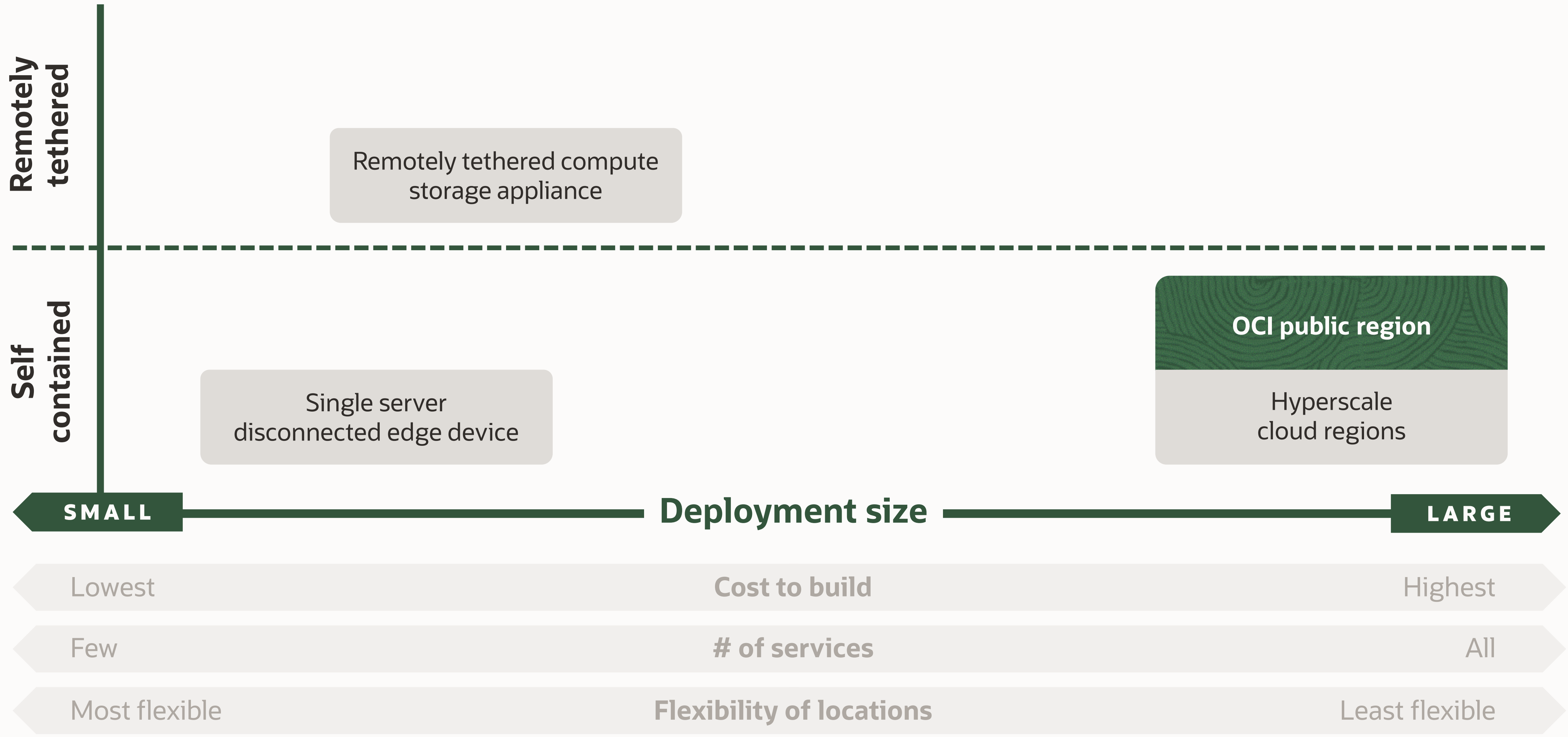
Current industry offerings



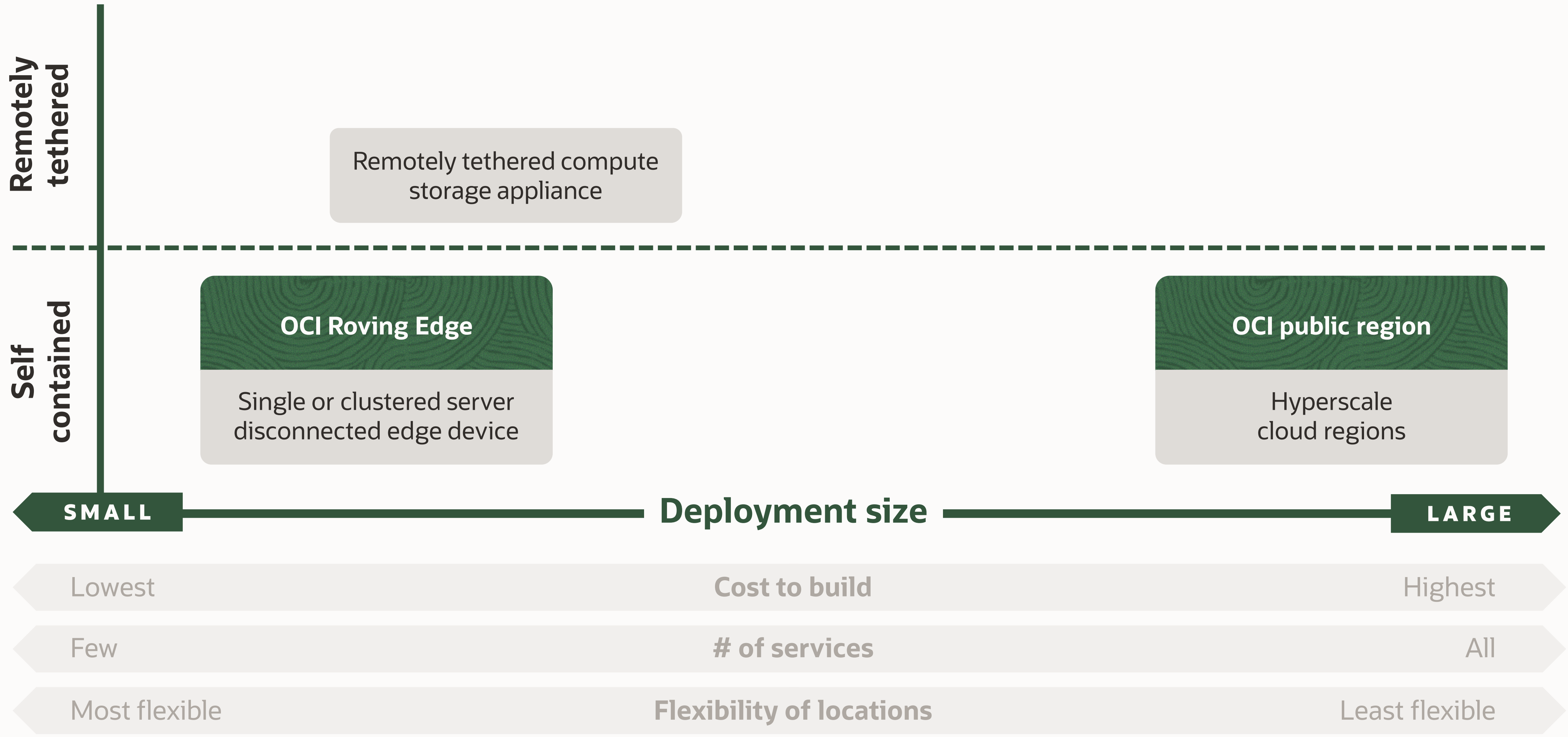
OCI offerings – public region



OCI offerings



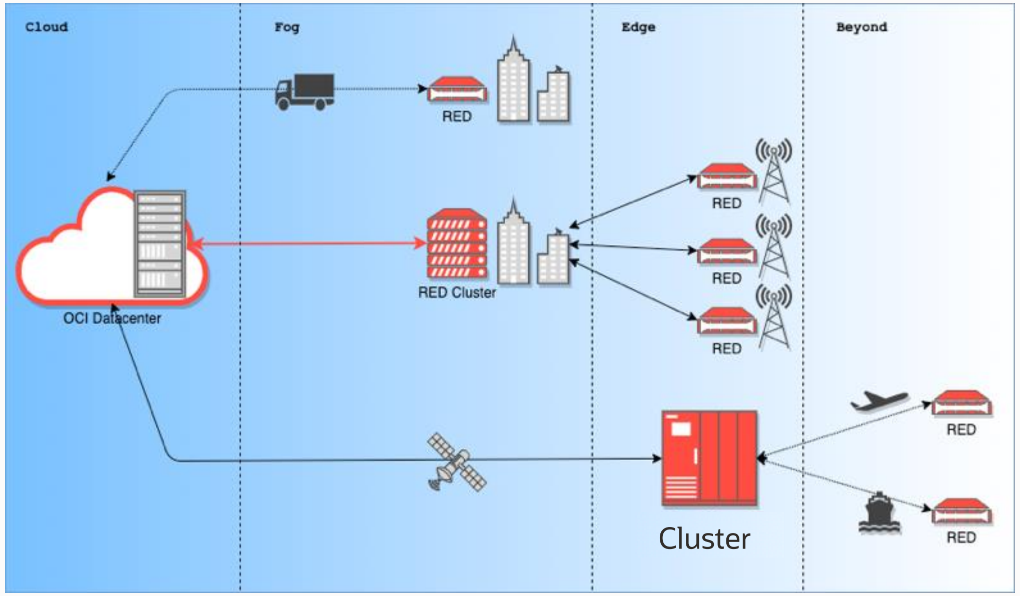
Roving Edge Infrastructure



Oracle Roving Edge Infrastructure: Executive Summary

Oracle Roving Edge Infrastructure allows operating cloud-based workloads outside of the data center

- Fully integrated with the Oracle Cloud, Oracle Roving Edge Infrastructure makes it easy to migrate your images, applications and data to the edge
- Bringing IaaS and PaaS services to the edge, Oracle Roving Edge Infrastructure enables you to run time-sensitive applications closer to where data is generated
- Capable of functioning in fully disconnected environments, or with intermittent or low-bandwidth communications, Oracle Roving Edge Infrastructure brings tactical decision-making to the field, even in the most remote and austere environments



Oracle Roving Edge Infrastructure

Accelerate Cloud Workloads Outside the Bounds of Your Data Center

Delivers tactical edge compute and storage in remote and austere environments

Perform low-latency data processing at the point of data ingestion

Run time-sensitive apps in disconnected environments, or with intermittent or low-latency connectivity

Unified Customer Experience

Effortless Adoption,
Control and Management

Extension of your Oracle Cloud Infrastructure (OCI) tenancy

Similar look and feel as the OCI console

Data synchronization between Oracle Cloud and the edge

Roving Edge Device

All-Environment Device

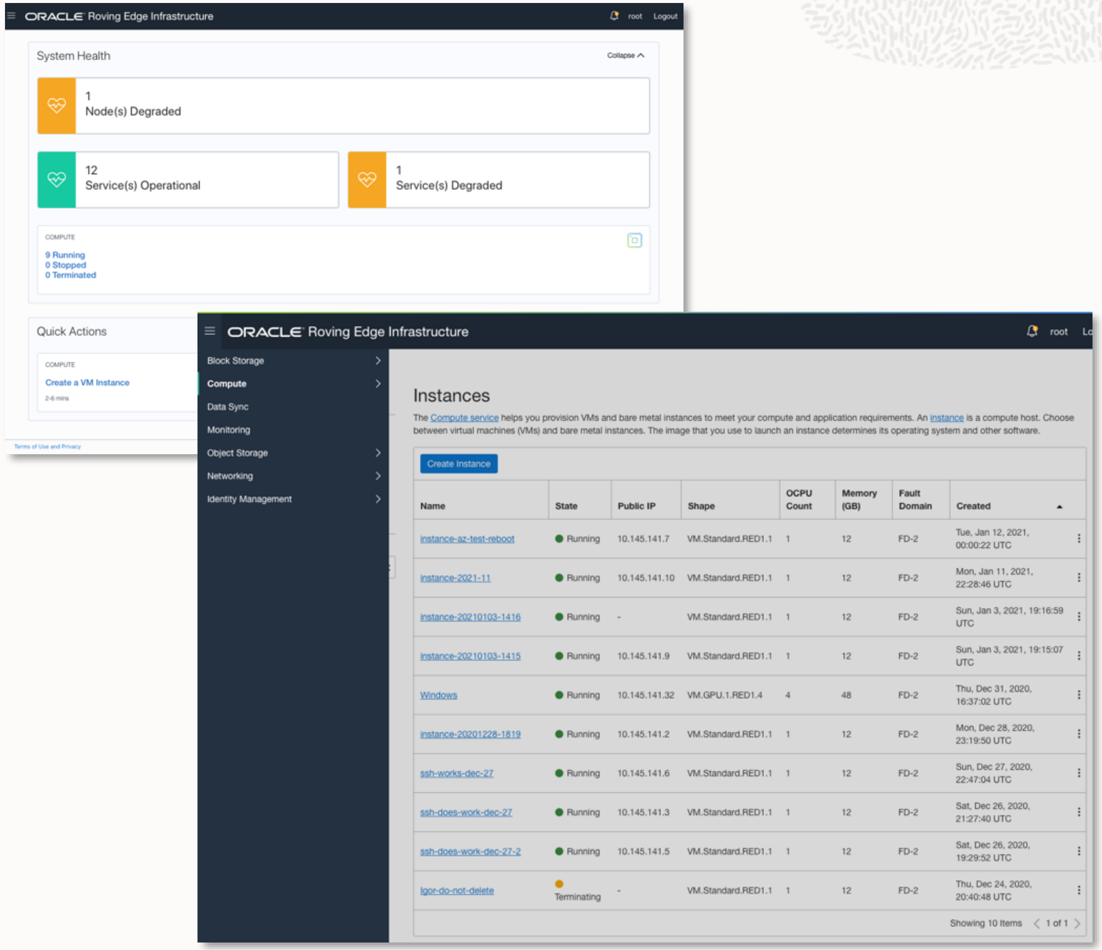
- Balanced mix of compute and storage
- Ruggedized
- Portable
- Scalable – 5 to 15 Nodes (RED Clusters)

- 80 OCPUs, 512 GB RAM, Embedded NVIDIA GPU
- 61 TB NVMe per node
- Tamper-evident seals, Built-in, Trusted Platform Module for security
- Weighs <88 lbs. with ruggedized case, 38lbs without the case

Capabilities

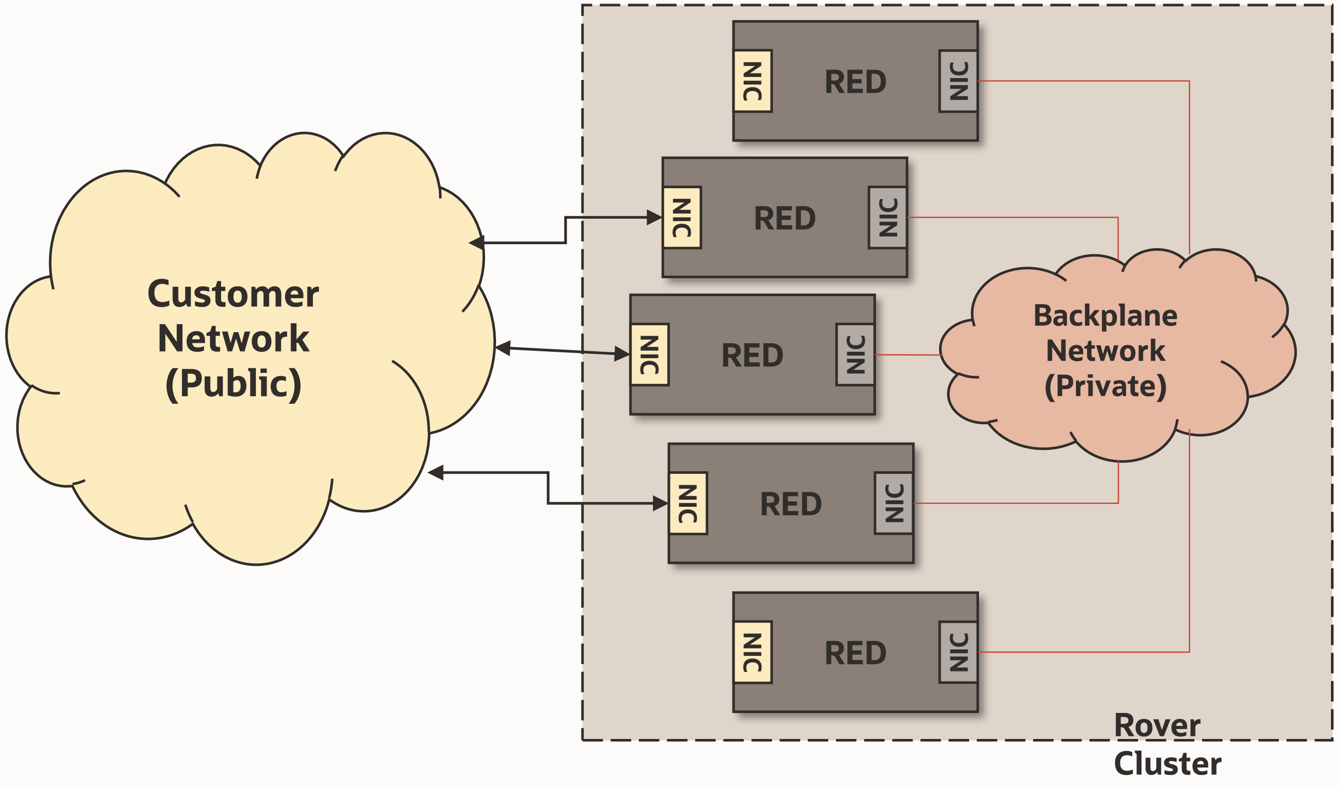
- **Oracle Roving Edge Infrastructure enables customers to run time-sensitive, mission critical cloud applications and services at the edge. It supports IaaS and PaaS workloads, such as:**
  - Compute (virtual machines, containers, Functions)
  - Storage (clustered object store, as well as block volumes and shared file system)
  - Oracle Database and Analytics
  - Data Synchronization with the Oracle Cloud

- **Oracle Roving Edge Infrastructure also includes:**
  - Local web-based GUI console for control and management of the node or cluster
  - An integrated cloud service to provides for configuration and provisioning

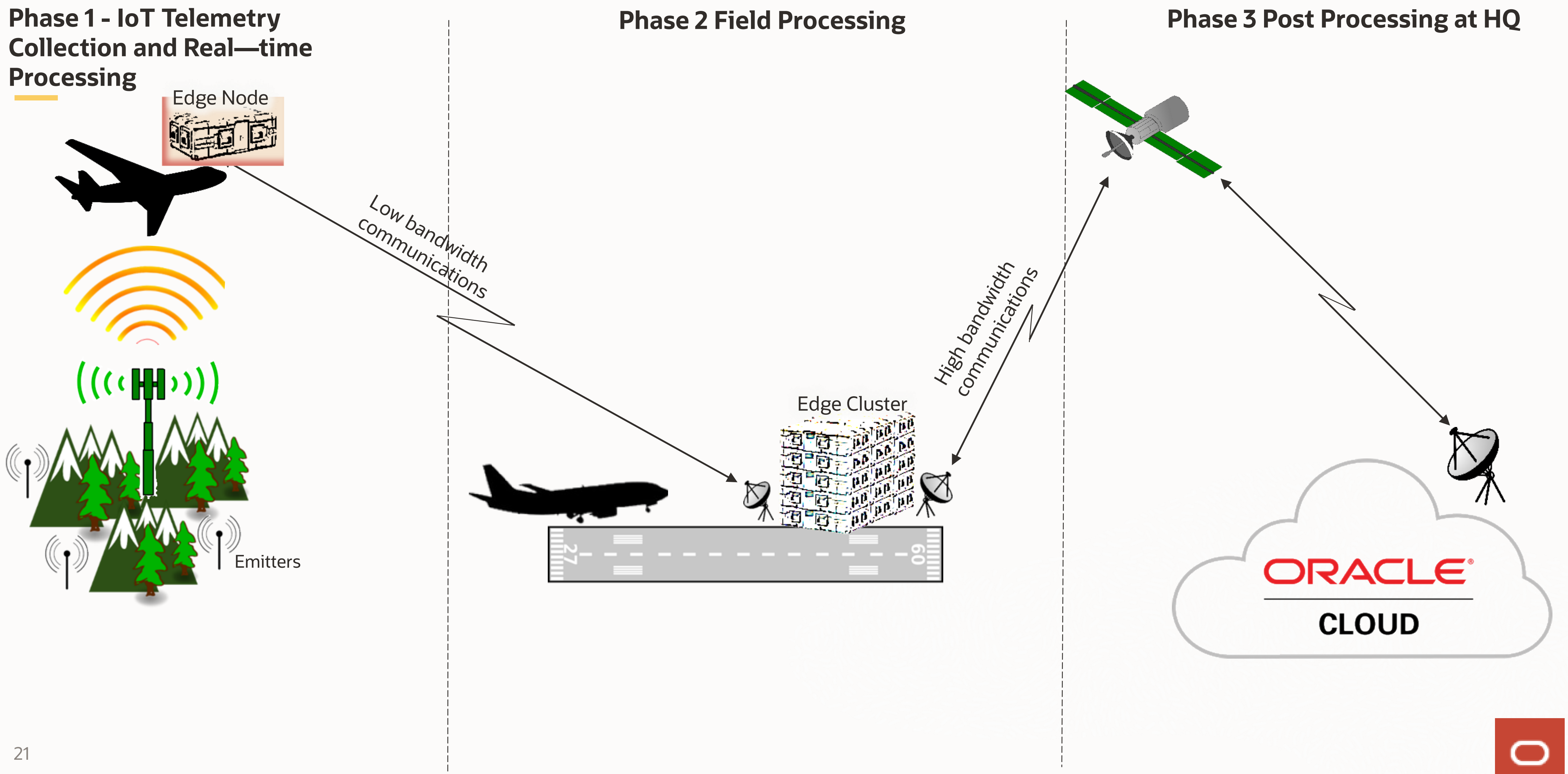


Clusters

- **RED nodes can be clustered to increase capacity and durability**
  - 5 to 15 nodes per cluster
  - 160 – 480 OCPU's
  - 230 to 690 TB of raw storage
  - Clusters automatically include a separate "Cluster Kit" which provides a high-speed switch and cabling



Use Case: Field Telemetry



Roving Edge's Hyper Scale Computing Power Enabling Digital Twins

MSET2-Based Digital Twins Solutions Deliver Science and Innovation Breakthroughs in Avionic IoT Prognostics

Let’s talk about MSET2 on Roving Edge

Guang Wang, Machine Learning Researcher, Oracle Labs
Kenny Gross, AI Architect, Oracle Labs

Multivariate State Estimation Technique

Advanced Statistical Machine Learning for IoT Prognostic Applications

- Nonlinear, nonparametric machine learning method for prognostic anomaly detection
- Originally developed at the USDOE’s Argonne Natn’l Laboratory in the 1990's
- Nuclear plants, NASA, commercial aviation, and business-critical industrial applications
- High sensitivity for detecting subtle anomalies in noisy or even chaotic time series metrics
- Ultra-low false-alarm and missed-alarm probabilities
- Ideal candidate ML algorithm for dense-sensor IoT applications

MSET History

MSET, funded by the DoE and developed by Argonne National Laboratories.

Approved by the US NRC. Today, in use by 100% of US Reactors and most of the 450 Commercial Reactors world-wide.

MSET History

MSET, funded by the DoE and developed by Argonne National Laboratories.

Approved by the US NRC. Today, in use by 100% of US Reactors and most of the 450 Commercial Reactors world-wide.

Big Data ML Prognostics? Oracle was the pioneer of "massive data" streaming ML prognostics long before any other industry.

The reason:

MSET1 was originally developed for commercial nuclear plants. One $10B nuke plant has 3400 sensors. One Oracle M6 Server has 3400 sensors inside!

There are 96 Commercial Nuclear Reactors in the US. However, there are a thousand racks of servers in a data center these days. A medium sized Cloud Data Center has >1 Million sensors.

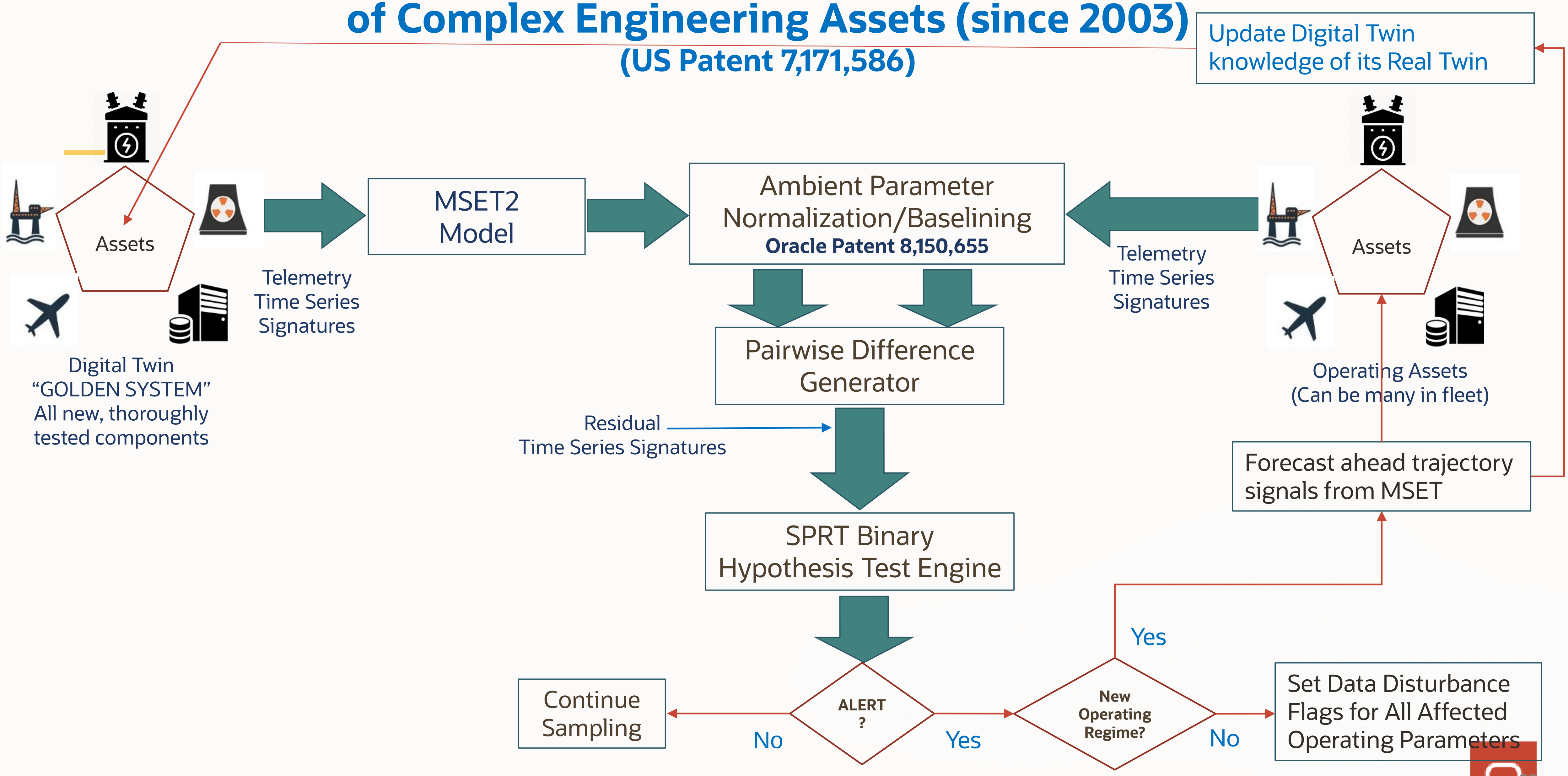
Oracle started developing Big Data ML Prognostics 20 years ago, well before the IoT "explosion in sensors" in other industries in the last few years.

Oracle Advanced Prognostics (MSET2) Utility Use Cases

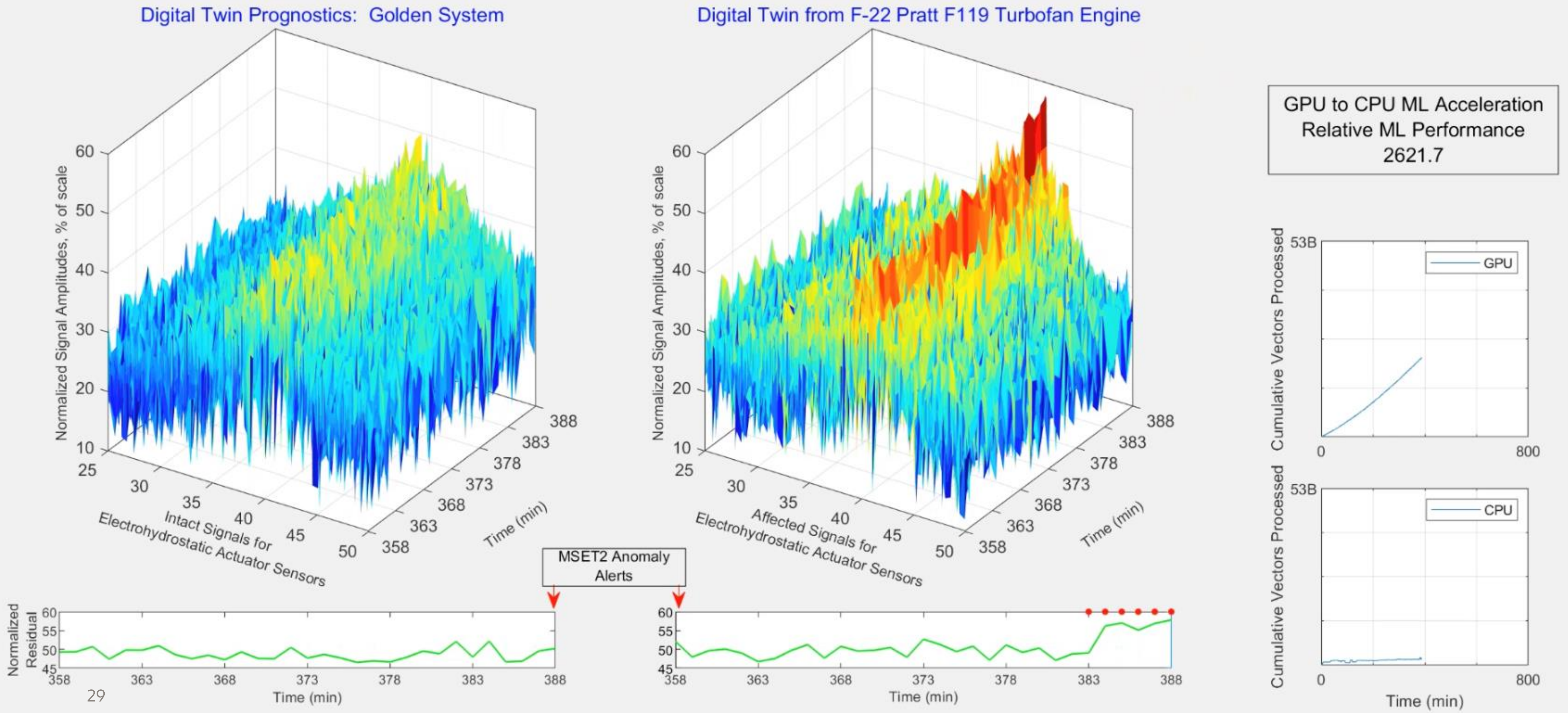
- Smart Meter and Grid Operations
- Energy Efficiency and Demand Response
- Strategic Asset Management & Capital Planning
- Underground (UG) primary voltage cables
- UG cable components
- UG GIL, in-line Splices & Terminations
- OH Connectors & Splices
- Wind Turbines
- Batteries
- Load Shape Forecasting / AMI Data
- Switch Gear
- Breakers/Recolsures
- Reactive Load Forecasting
- Transformer Load Management
- High Speed Relays
- Substation & SCADA Monitoring
- Conservation Voltage Regulation
- Customer Experience
- Cyber Security
- Supply Chain Counterfeit Electronics
- Solar Panels

Oracle's Pioneering "Digital Twin" Innovation for Advanced Prognostics of Complex Engineering Assets (since 2003)

(US Patent 7,171,586)

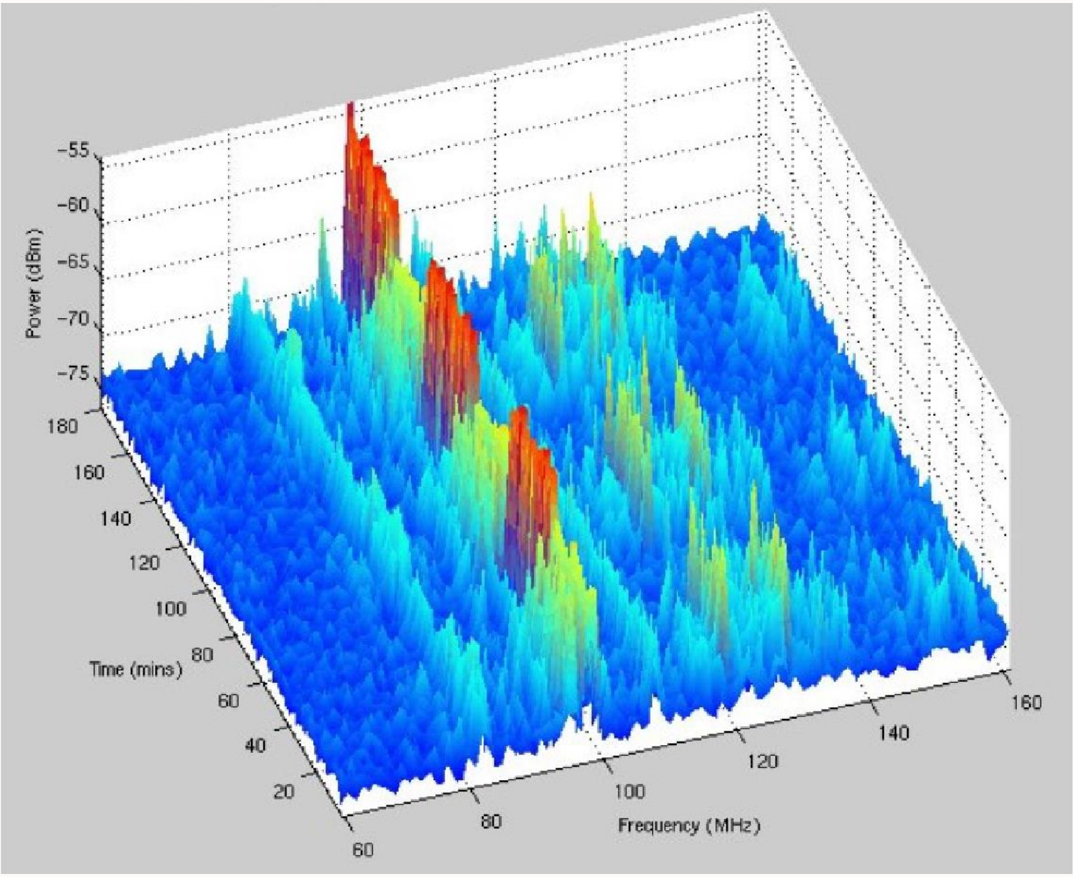


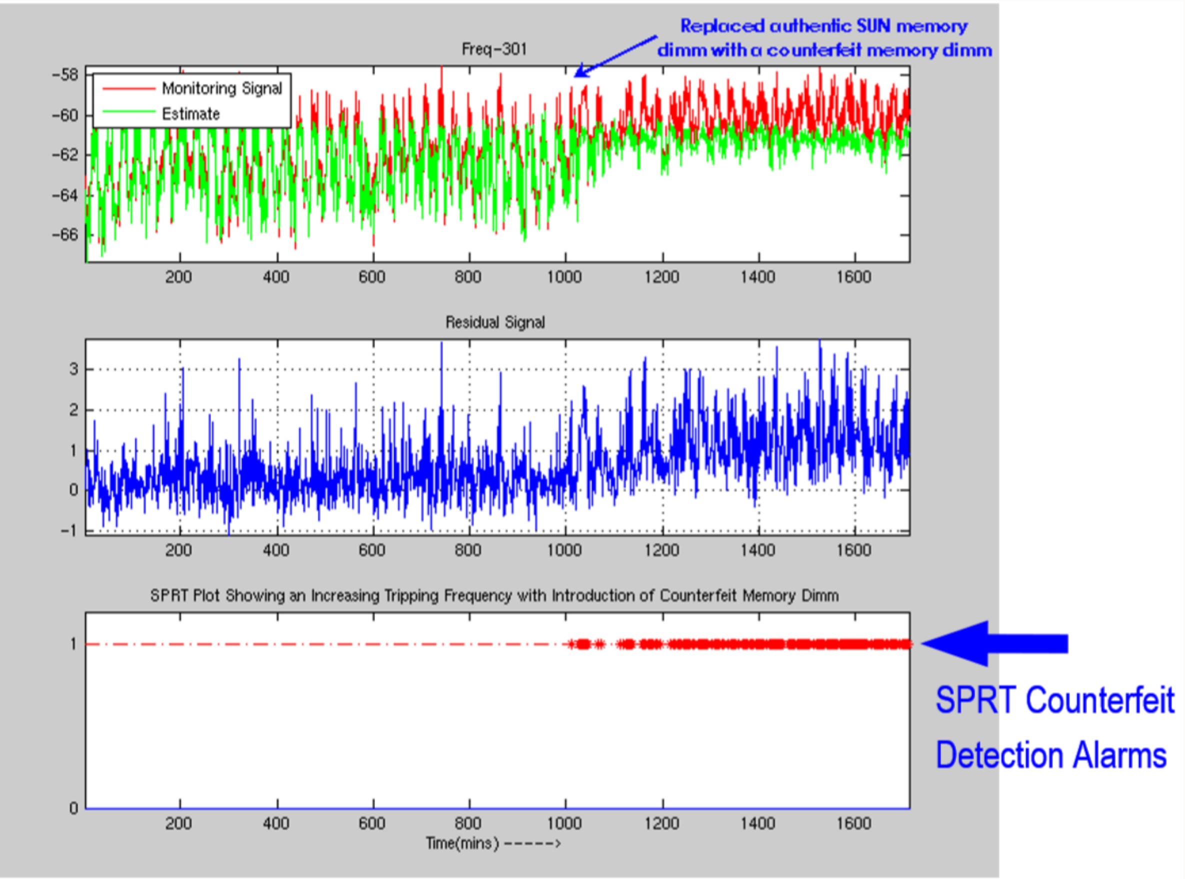
Example: MSET2 Streaming Prognostics Use Case for USAF F-22 IoT Telemetry Signals on Roving Edge



The Extension of Digital Twins Concept: MSET2-based EMI Fingerprints

- Train on One Golden Asset (certified to have no counterfeits)
- Scan any number of assets in the field, or at loading docs, or ports of entry



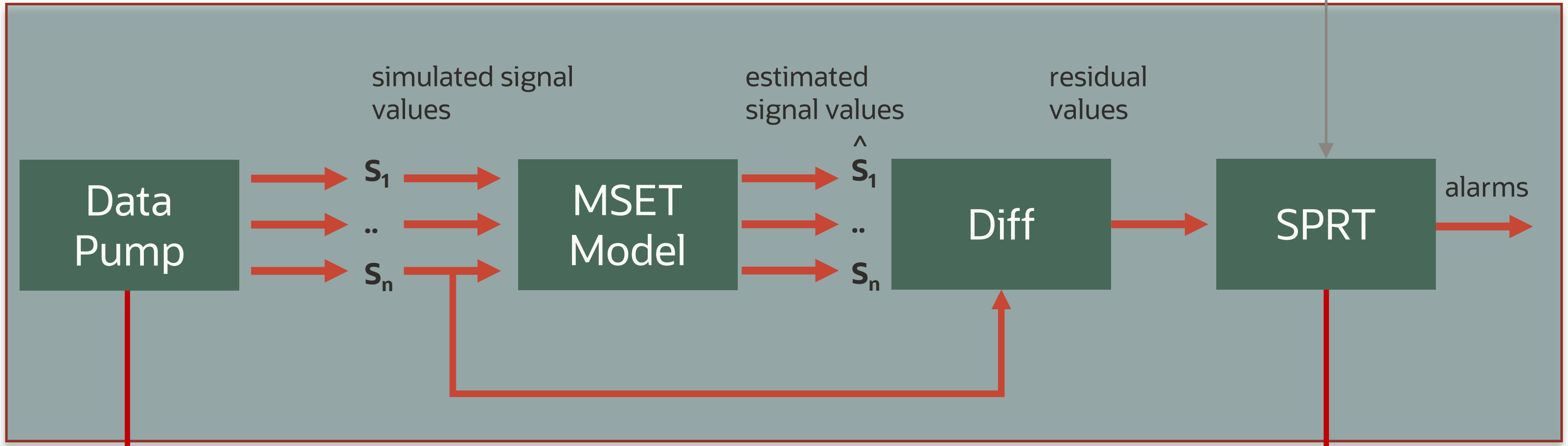


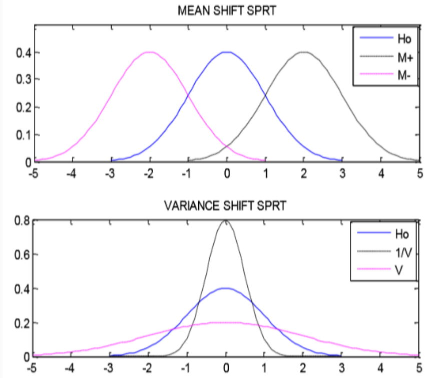
Other Roving Edge Powered IoT Prognostic Applications with MSET2

MSET2 Data-Flow Framework

Prognostic research prototyping with perfect telemetry data

Abraham Wald, (June 1943).
- Oracle developed enhanced SPRT





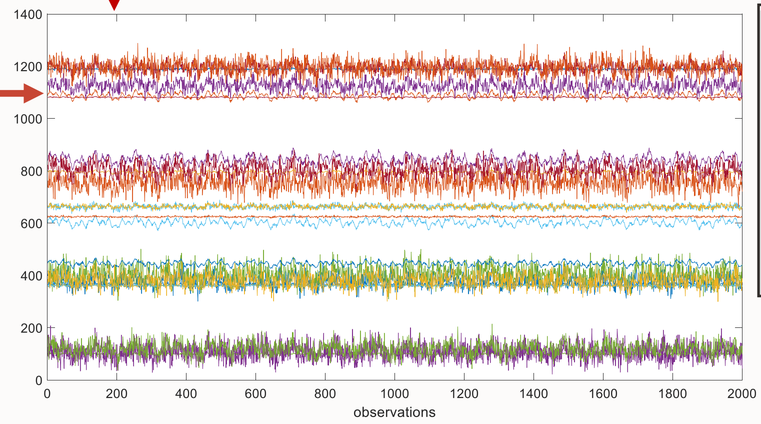
Sequential test for residual signals is based upon two hypotheses:

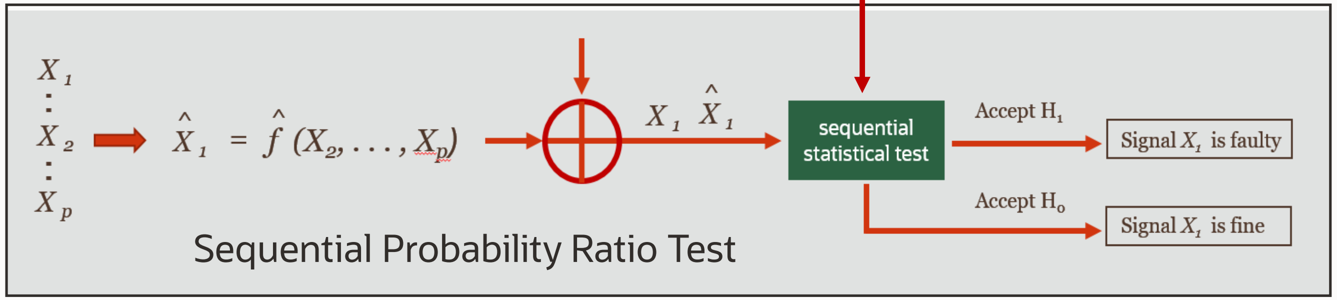
$H_0 : \mu = \mu_0 = 0$

$H_1 : \mu = \mu_1 = M$

Data Historian Database

Telemetry Data Sensor Farm(s)





- High sensitivity for subtle anomaly detection without increasing false alarm probability.
- Can accommodate any measurement noise, work with non-Gaussian noise signals.
- Sequential-binary hypothesis test compares reference distribution (H_0) vs degraded distribution (H_1)

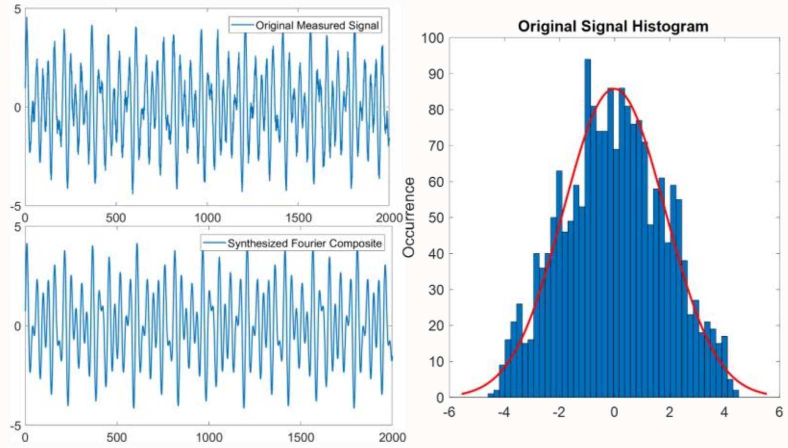
Signal Synthesizer Data Pump for Machine Learning

Database

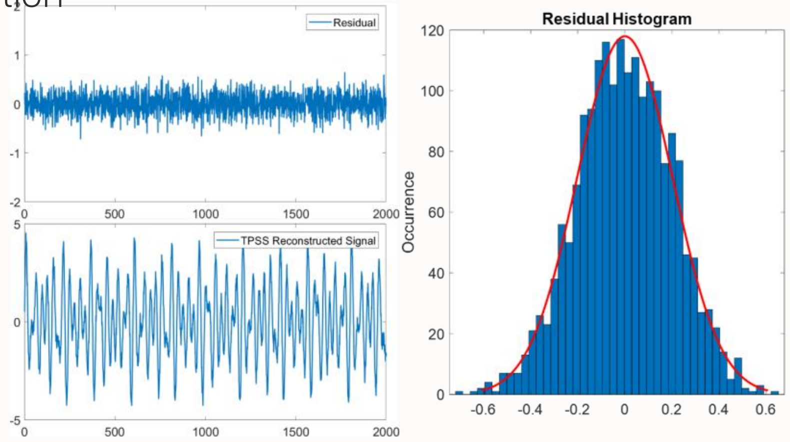
Telemetry Data

Signal Dynamic Extraction

Obtain Signal Dynamics



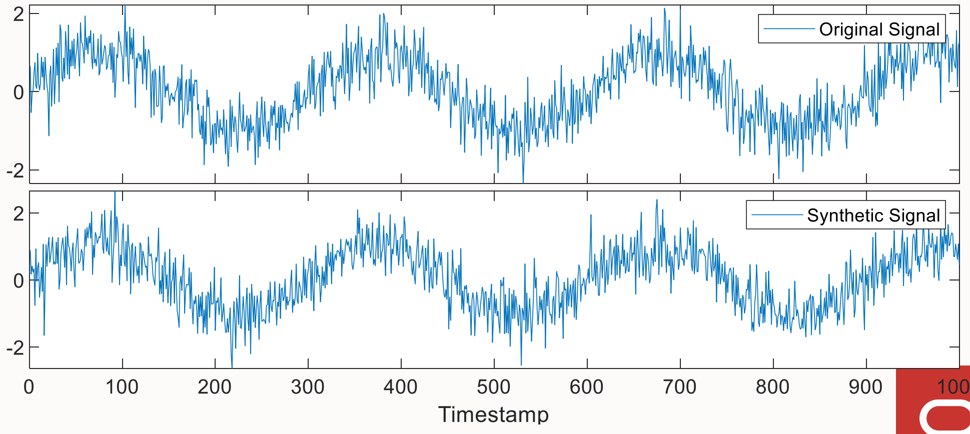
Extract Noise STD



Fourier Composites

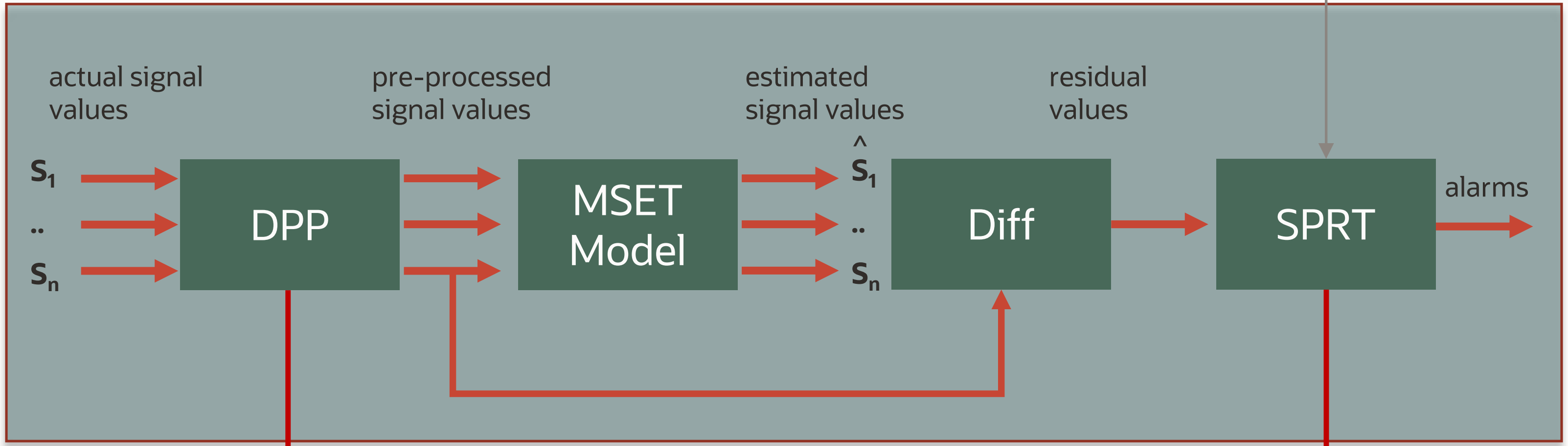
Dispersing Noise STD	Dispersing Mean
Dispersing Amplitude	User-defined Dispersion

Statistically Indistinguishable Synthetic Signals

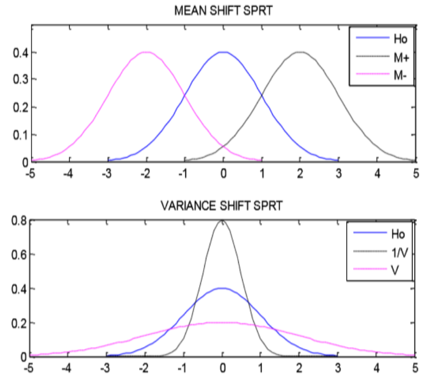


MSET2 Data-Flow Framework

Real world prognostic applications with suboptimal telemetry data



Abraham Wald, (June 1943).
- Oracle uses modified SPRT



Sequential test for residual signals is based upon two hypotheses:

$H_0 : \mu = \mu_0 = 0$

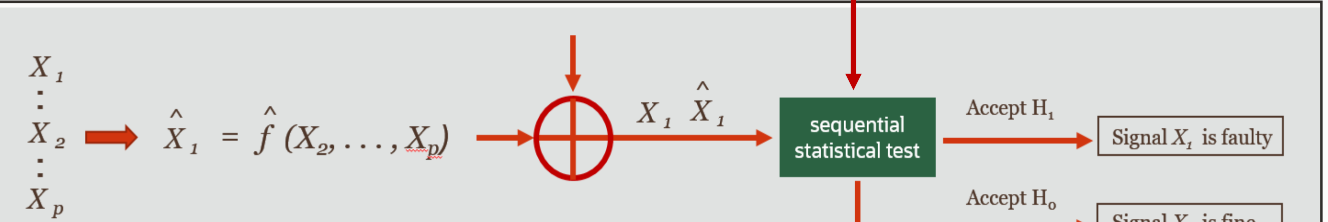
$H_1 : \mu = \mu_1 = M$

Data Historian Database

Telemetry Data Sensor Farm(s)

Intelligent Data Preprocessing

- UnQuantize
- Analytical Resampling Process
- Missing Value Imputation
- Inferential Sensing
- Provenance Certification & Auditability
- TriPoint Clustering (TPC)
- Telemetry Parameter Synthesis System



Sequential Probability Ratio Test

- High sensitivity for subtle anomaly detection without increasing false alarm probability.
- Can accommodate any measurement noise, work with non-Gaussian noise signals.
- Sequential-binary hypothesis test compares reference distribution (H_0) vs degraded distribution (H_1)

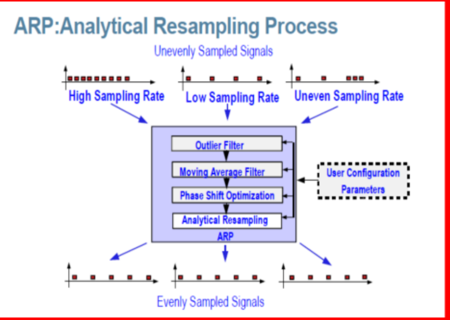
MSET2 for IoT-Centric Industry 4.0 Use Cases

IoT Issues

- Missing values in IoT sensor data
- Variable sampling rates of IoT data
- Asynchronous signals (Clock mismatch)
- Low resolution sensor signals
- Sensor drifting out of calibration

Oracle's Innovations

MVI
Optimal Missing Value Imputation

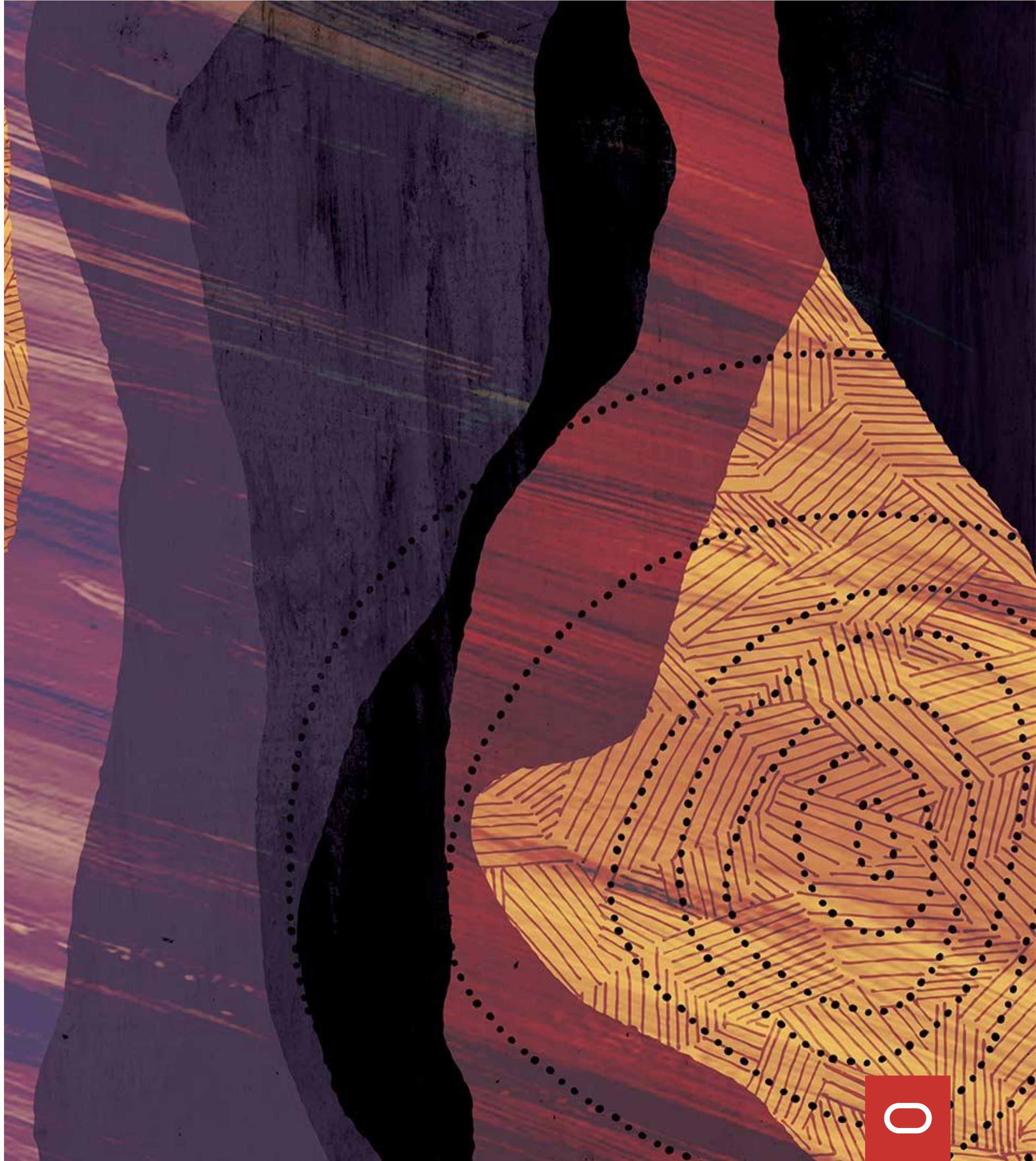


UnQuantize
Low resolution input signals into high accuracy output signals upstream

Inferential Sensing

- Condition Based Predictive Maintenance
- Digital Twin for Prognostics
- Scrap Reduction
- Improve QA/QC Testing
- Remaining Useful Life (RUL)

Thank You



ORACLE