



ArcGIS and the Internet of Things (IoT)

Josh Joyner

Adam Mollenkopf

An abstract 3D architectural graphic on the right side of the slide. It features various geometric shapes in shades of blue, orange, and green, some with topographic contour lines. The shapes are layered and perspective-oriented, creating a sense of depth and complexity.

**GIS
INSPIRING
WHAT'S
NEXT**

Agenda:

- 1 What is the IoT?
 - 2 Decomposing an IoT solution
 - 3 IoT deployment patterns
 - 4 ArcGIS as an IoT platform
 - 5 Applying spatiotemporal analytics to IoT data
 - 6 Handling IoT scale requirements
 - 7 Additional resources
-



1

What is the IoT?

Internet of Things overview

What is the IoT?

The network of physical objects that contain embedded technology to communicate and sense or interact with their internal states or the external environment.

Internet of Things overview

What Things?

Digital
Pipelines

Connected Cars
Connected Health
Connected Home

Precision
Agriculture

Intelligent
Logistics

Smart City
Smart Community



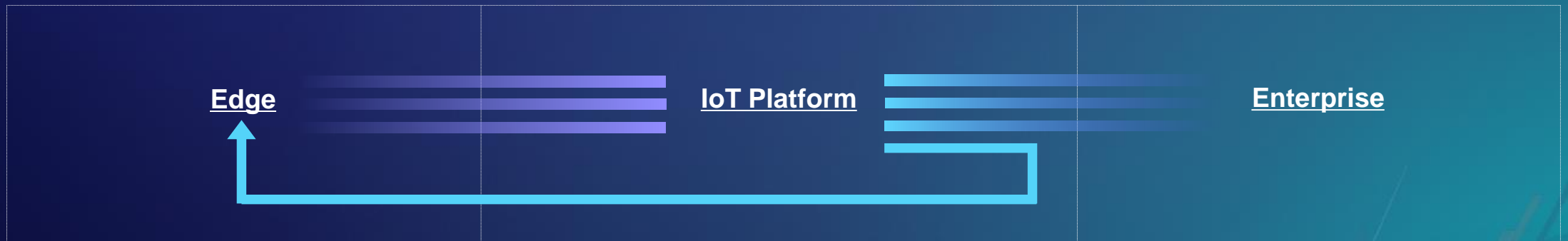
2

Decomposing an IoT Solution

Blueprint

for IoT solutions

- The Internet of Things (IoT) is an integrated solution that senses & collects data from devices at the edge, analyzes that data and takes action to accomplish the business goals of an enterprise.
- An IoT solution consists of the following layers:
 - **Edge:** Embedded technology at the “edge” that senses, acquires & disseminates data.
 - **IoT platform:** Accepts, ingests, stores, analyzes and shares intelligence gleaned from the data.
 - **Enterprise:** Applications & processes that act upon the intelligence as a result of analytic results.

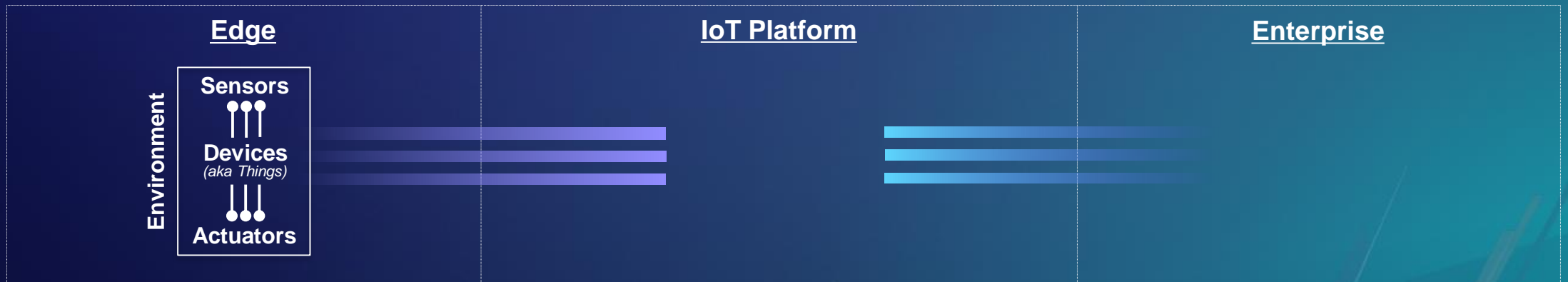


Edge of an IoT solution

environment, sensors, devices & actuators

- The Edge consists of:

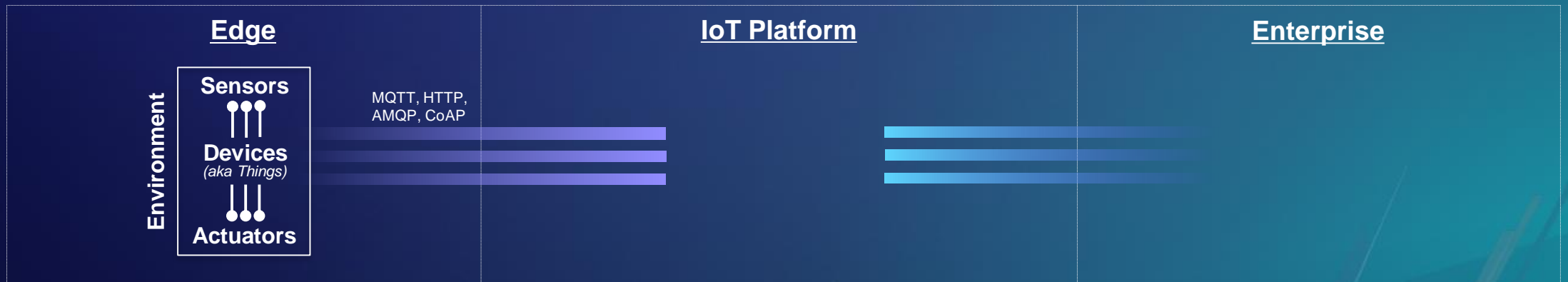
- **Environment:** The “real world” that generates real-time observations which are sampled by sensors and converted to information by devices.
- **Sensors:** Samples & collects data from the environment, typically 1,000 times per second to ensure sampling accuracy.
- **Devices (aka Things):** Applies basic analytics to sensor data to reduce it to a more limited & valuable dataset for transmission. Typically devices emit data on set intervals (once per second), when certain events occur, or when polled.
- **Actuators:** Receive commands to adjust the behavior of devices in our environment.



Edge of an IoT solution

edge to IoT platform communication protocols

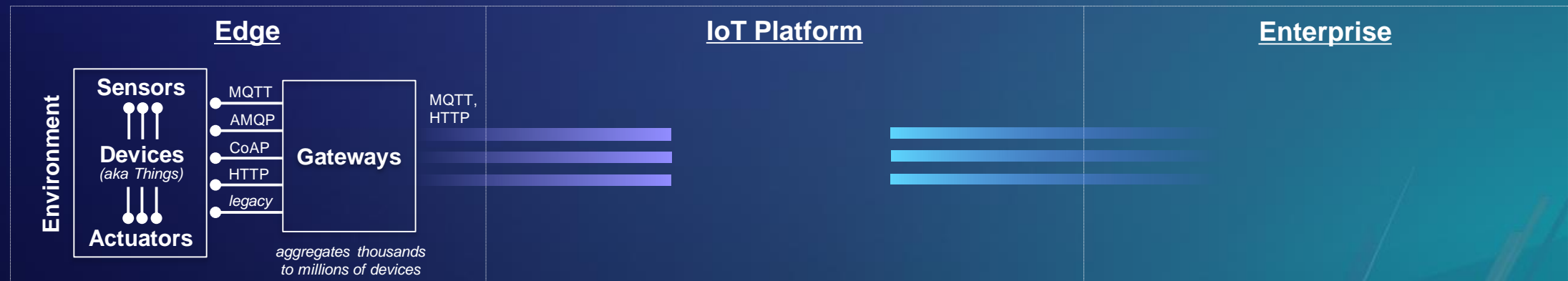
- Edge communication to an IoT platform typically uses one of the following protocols:
 - **MQTT:** Message Queuing Telemetry Transport
 - **HTTP:** Hyper Text Transfer Protocol, pushed or polled
 - **AMQP:** Advanced Message Queuing Protocol
 - **CoAP:** Constrained Application Protocol



Edge of an IoT solution

gateways

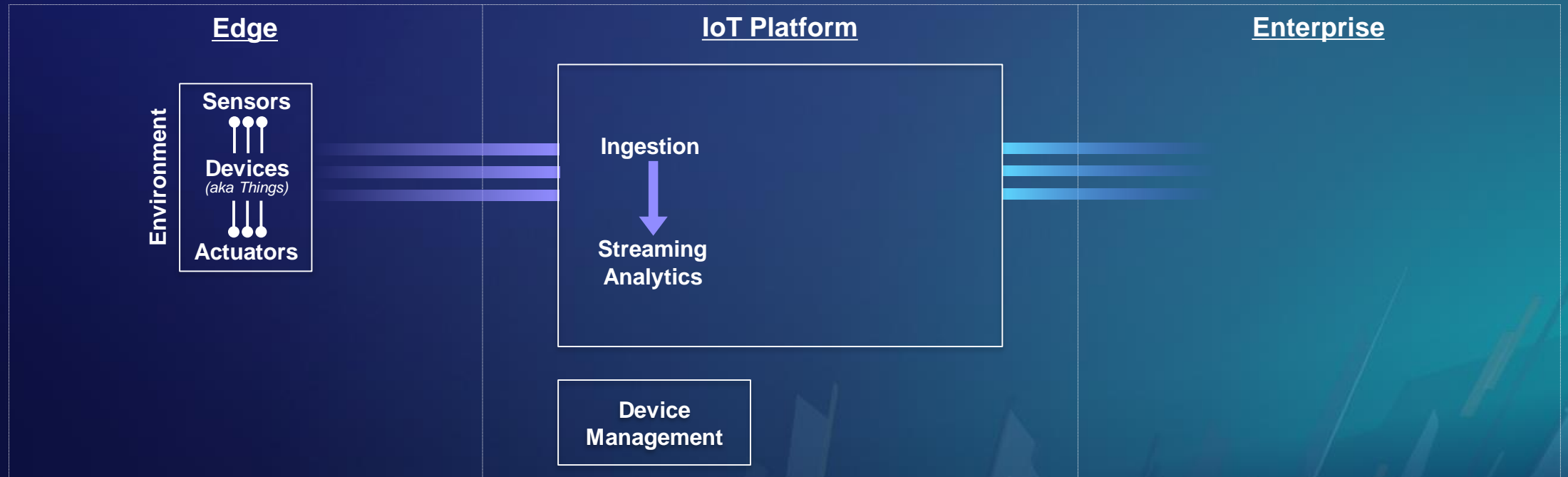
- Optionally, the Edge may consist of one or more:
 - **Gateways (aka Aggregation Points):** Accepts multiple protocols & data models from disparate devices & translates that data into the IoT Platform's protocol, API & data model. Serves as a primary interconnection to the IoT Platform.
- Gateway communication to an IoT platform typically uses one of the following protocols:
 - **MQTT:** Message Queuing Telemetry Transport
 - **HTTP:** Hyper Text Transfer Protocol, pushed or polled



IoT platform

device management & ingestion

- An IoT platform consists of:
 - **Device Management:** Authenticates & establishes secure communications with the Edge devices and/or gateways to ensure incoming data can be trusted. Also, is responsible for keeping devices up to date and provisioning software updates as appropriate.
 - **Ingestion:** Accepts data from the Edge and prepares it to be consumed by one or more Streaming Analytics.

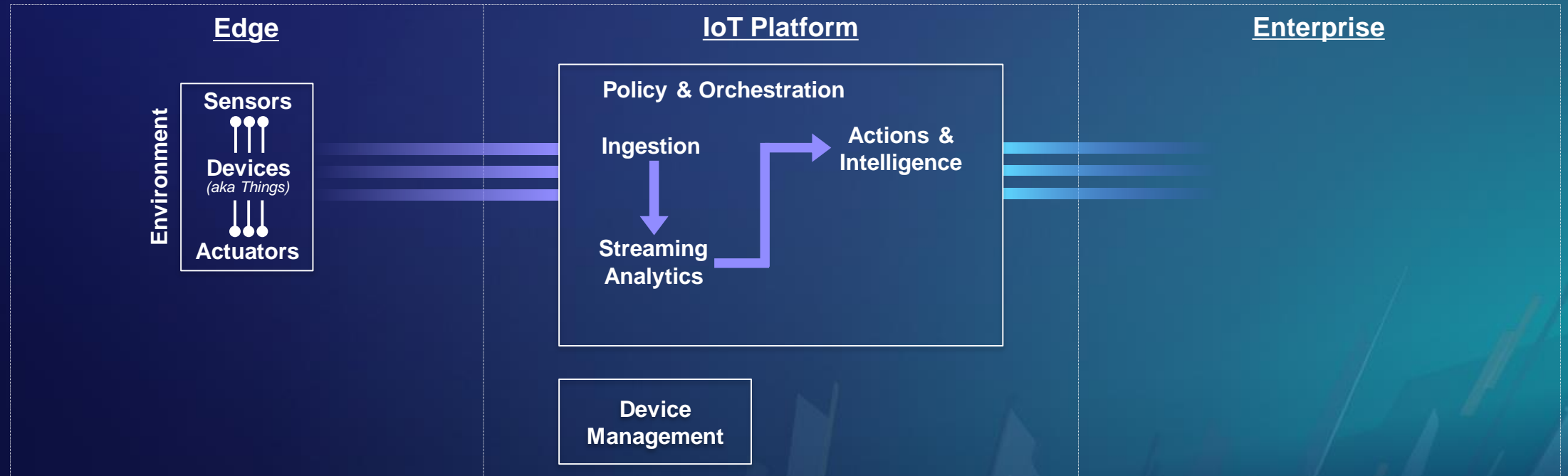


IoT platform

streaming analytics, policy, orchestration, actions & intelligence

- An IoT platform consists of:

- **Streaming Analytics:** consumes a continuous stream of data from the Ingestion layer using Orchestration & a Policy (aka Business Rule) to make decisions about what to do: trigger immediate actions and/or store the data in a Data Store for Visualization and subsequent Analytics.
- **Actions & Intelligence:** takes action via secure access to Actuate Edge Devices and/or Enterprise applications.

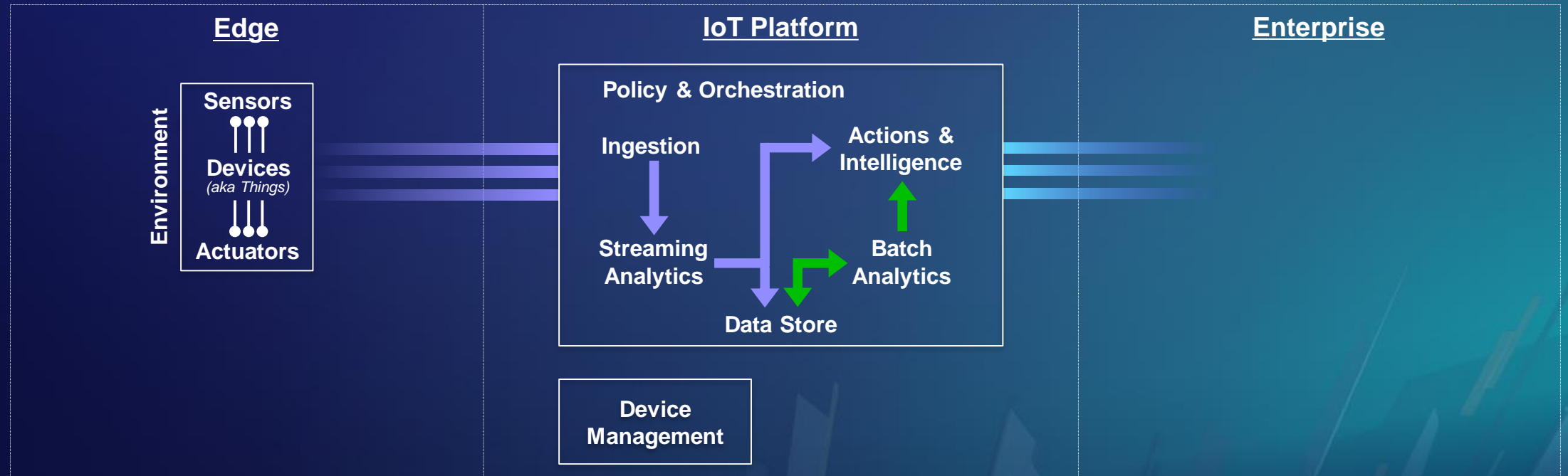


IoT platform

data store & batch analytics

- An IoT platform consists of:

- **Data Store:** provides storage for data that has been Orchestrated for storage. Prepares stored data for efficient visualization, interactive queries & Batch Analytics.
- **Batch Analytics:** performs descriptive, prescriptive and/or predictive analysis on data, processes resulting events & applies policies to determine actions. Typically, can be ad-hoc or scheduled on a recurring basis.

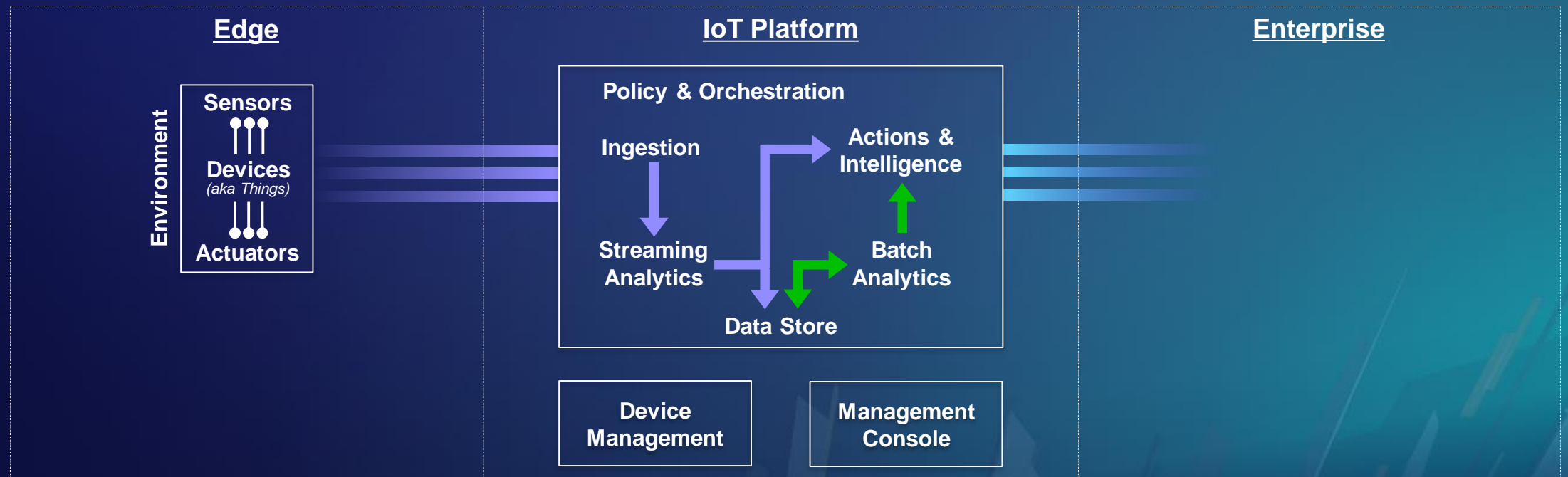


IoT platform

management console, policy & orchestration

- An IoT platform consists of:

- **Management Console:** Handles a range of management tasks for the IoT platform such as managing the flow of data, creating Policies, setting event thresholds & managing Data Stores.
- **Policy (aka Business Rule):** Processes resulting data from Analytics & compares thresholds/triggers configured by data scientists to determine a course of action for the orchestration engine to execute.
- **Orchestration:** Coordinates steps necessary to execute an action.

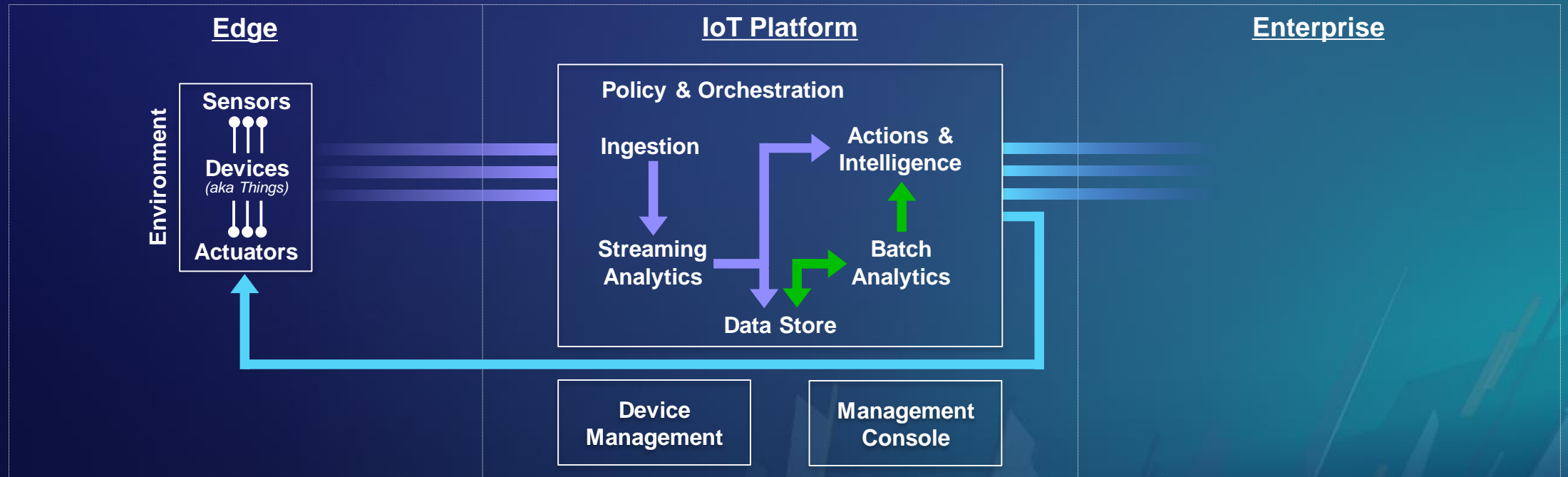


IoT platform

actuating devices

- An IoT platform consists of:

- **Actuation Action:** A special type of action that sends a command to a device to alter the behavior of it's environment.

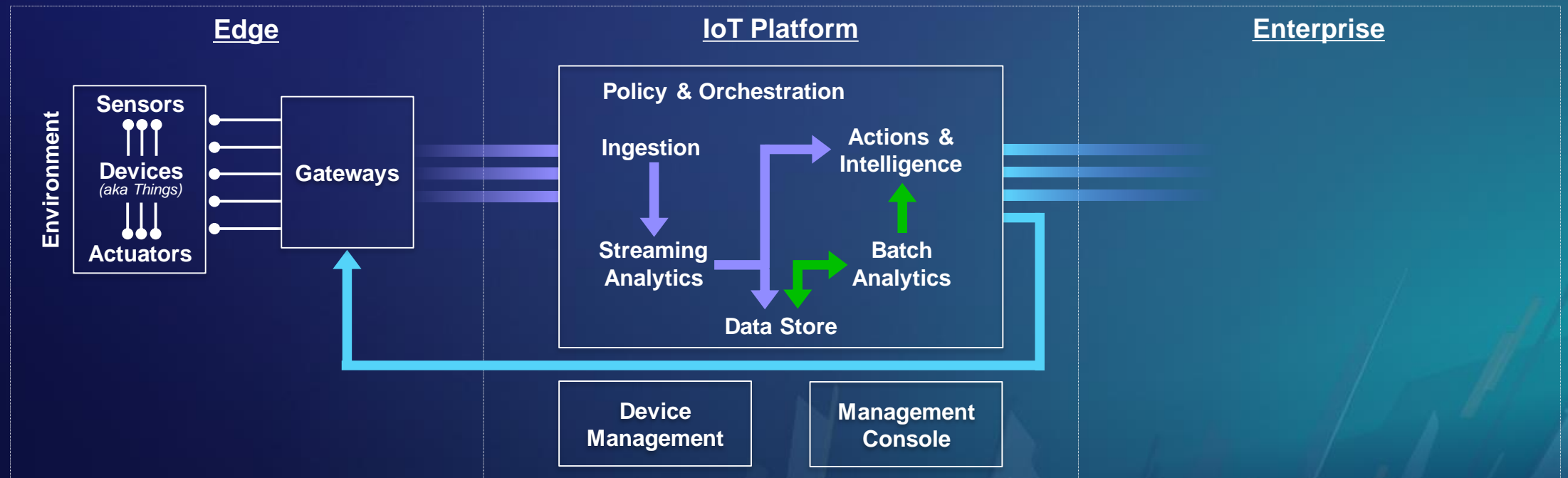


IoT platform

actuating devices with a gateway

- An IoT platform consists of:

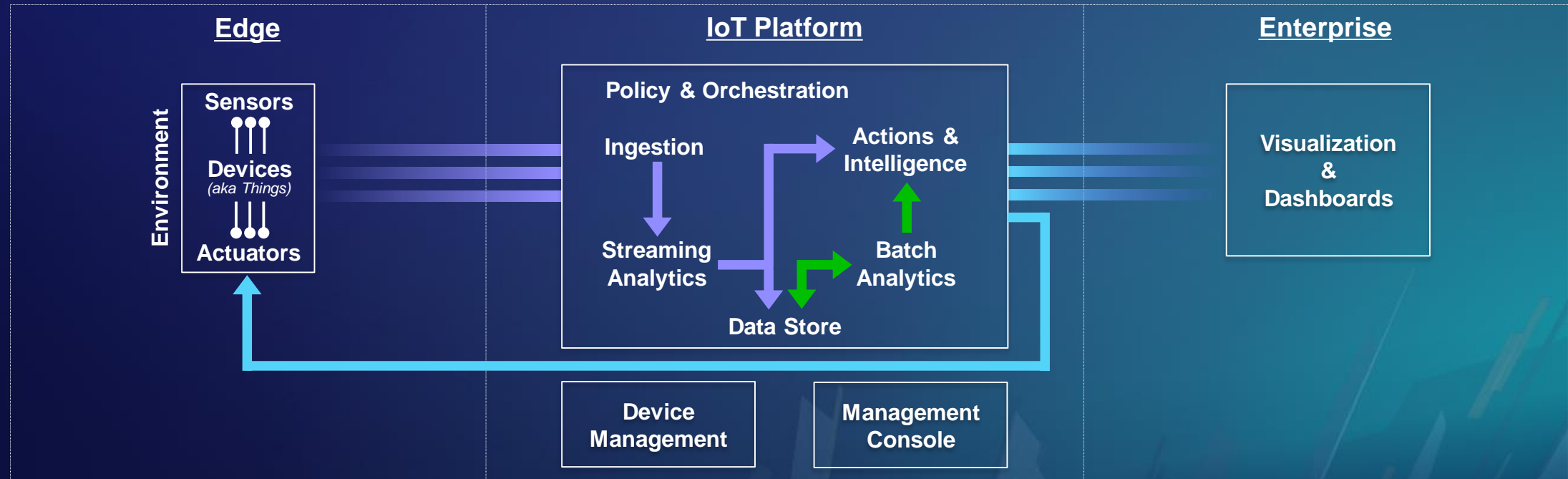
- **Actuation Action:** A special type of action that sends a command to a device to alter the behavior of it's environment. When a gateway is present it is responsible for mediating the actuation command to the appropriate device.



Enterprise

visualization & dashboards

- The Enterprise layer of an IoT consists of:
 - **Visualization:** enables data scientists to spot key trends and patterns using exploratory visual analysis techniques that have the ability to interactively query the data. Once trends are recognized policies can be created to automatically detect the pattern and automatically trigger desired action(s).
 - **Dashboards:** Dashboards can be configured to enable the monitoring of an IoT solution's environment and the behavior of it's Devices/Things.





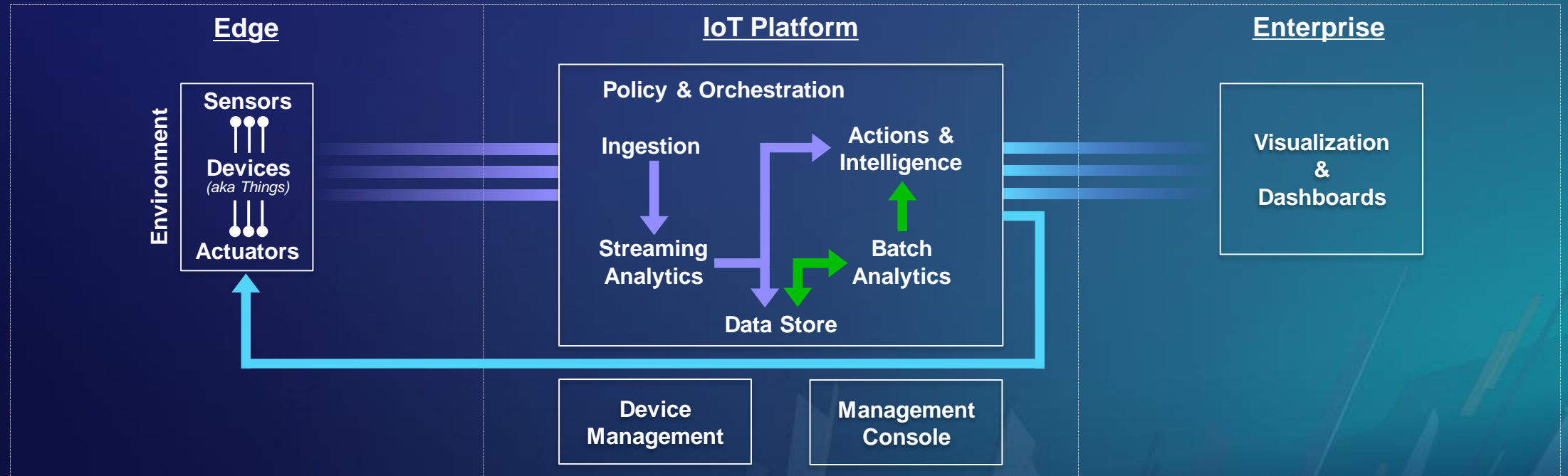
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IoT deployment patterns

Blueprint

for IoT solutions

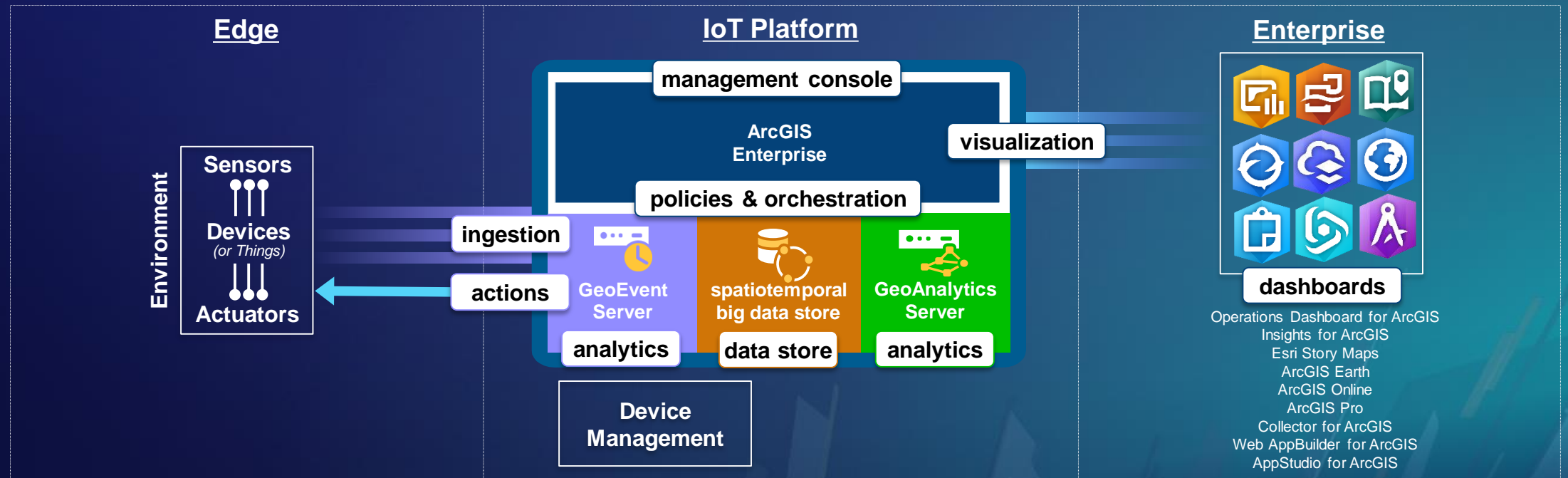
- An IoT Platform & Enterprise consists of the following capabilities:
 - Ingestion
 - Streaming Analytics & Policies
 - Actions (including Actuation)
 - Data Store
 - Device Management
 - Batch Analytics
 - Management Console
 - Visualization
 - Dashboards



ArcGIS as an IoT Platform

enabling geospatial insights with your IoT solution

- An ArcGIS based IoT Platform & Enterprise consists of the following capabilities:
 - **Ingestion:** GeoEvent Server input connectors
 - **Batch Analytics:** GeoAnalytics Server
 - **Streaming Analytics & Policies:** GeoEvent Services
 - **Management Console:** Portal & GeoEvent Manager
 - **Actions (including Actuation):** GeoEvent output connectors
 - **Visualization:** Map & Feature Services
 - **Data Store:** spatiotemporal big data store
 - **Dashboards:** Operations Dashboard, Insights, Story Maps



ArcGIS & the IoT

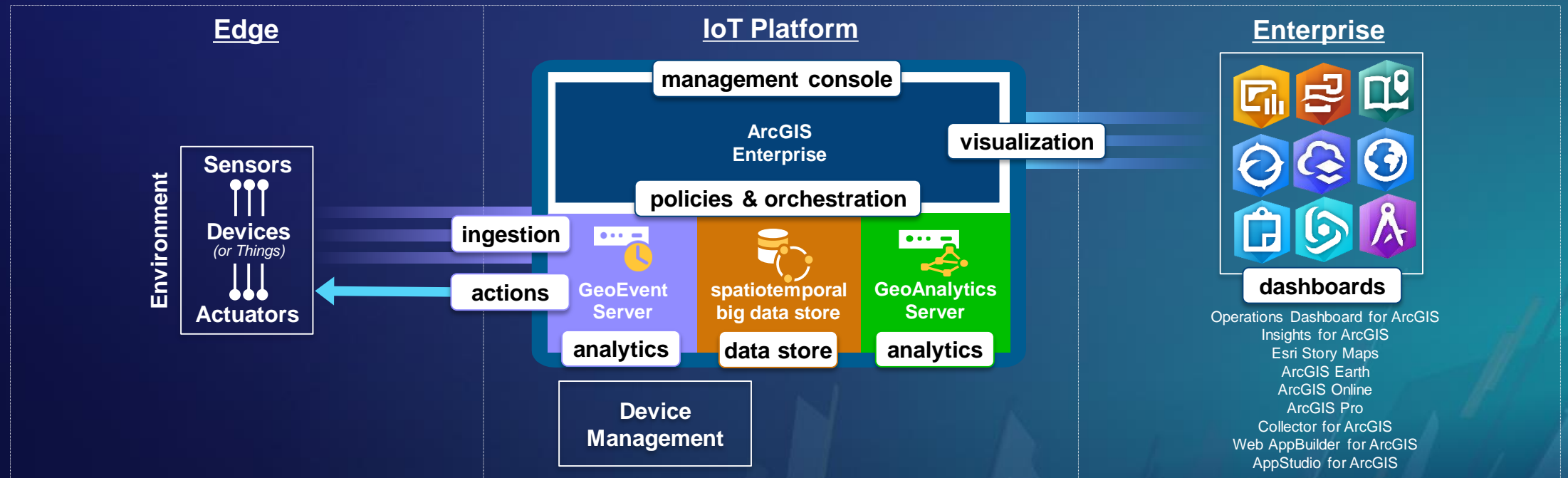
enabling geospatial insights with your IoT



ArcGIS as an IoT Platform

enabling geospatial insights with your IoT solution

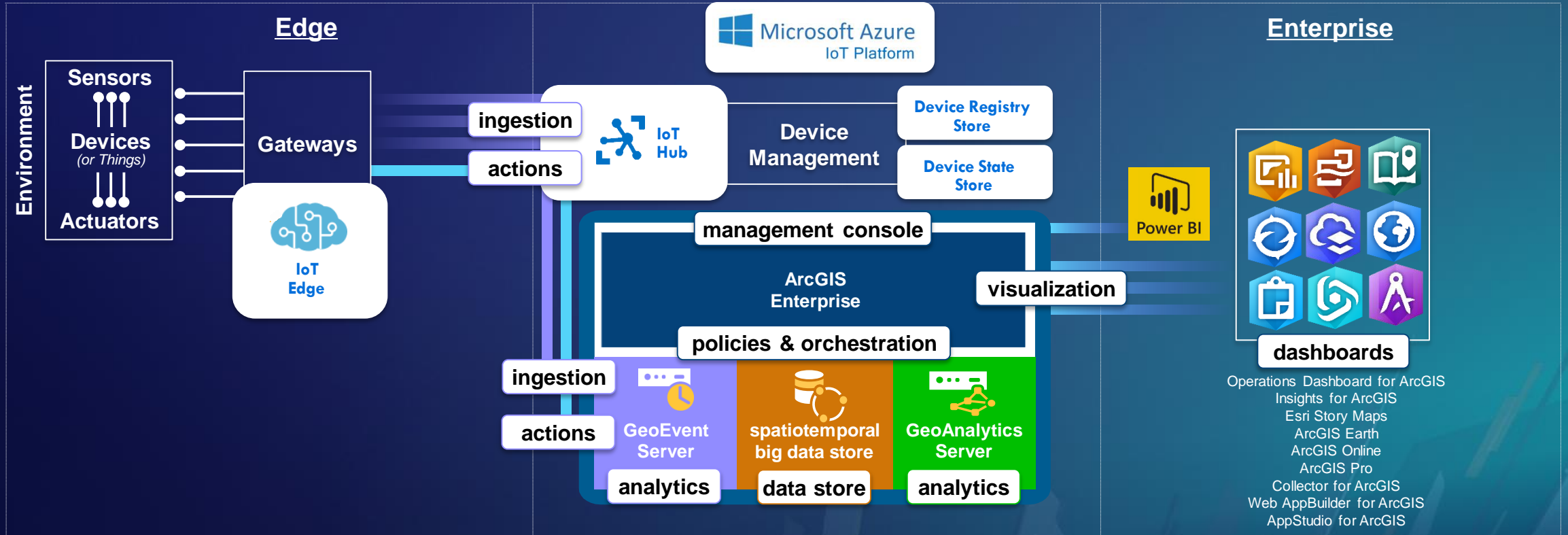
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 - **Data Store:** spatiotemporal big data store
 - **Dashboards:** Operations Dashboard, Insights, Story Maps
 - **Device Management:** for those requiring this functionality another IoT platform can be complemented with ArcGIS.



Complementing an IoT platform with ArcGIS

enabling geospatial insights with your IoT solution

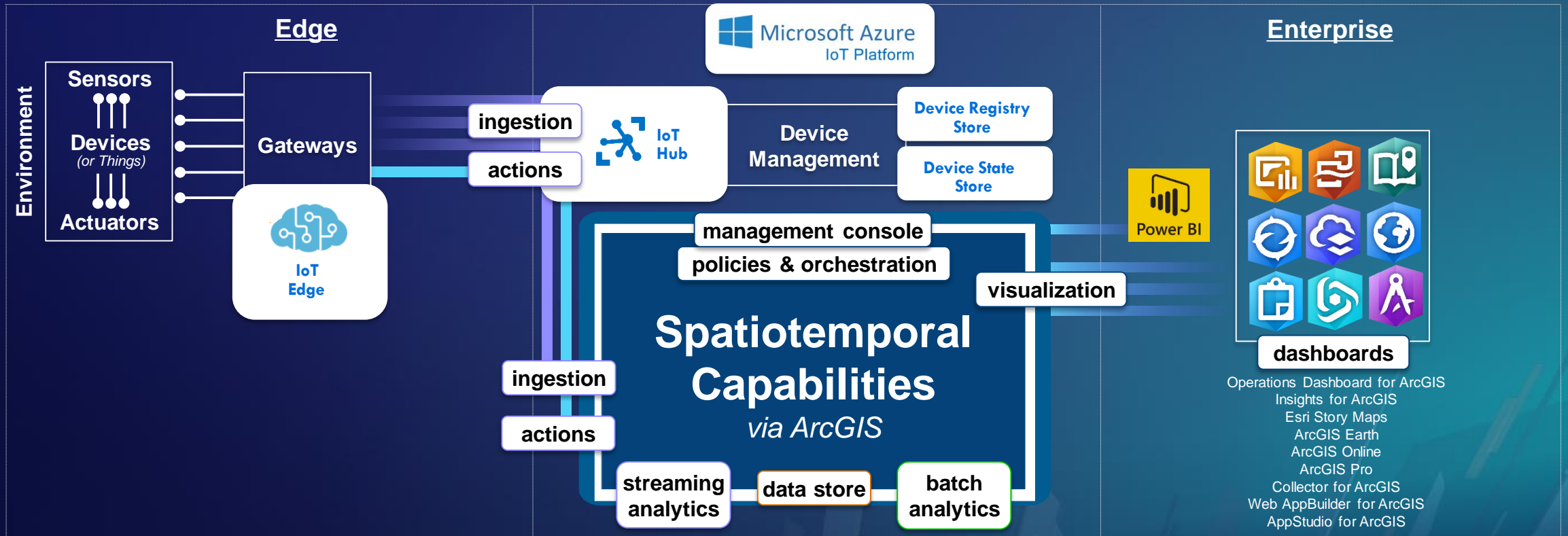
- The Edge of an IoT broadcasts into an IoT platform such as: *Azure IoT, Amazon IoT, Cisco IoT, IBM Bluemix, ...*
- The IoT platform integrates with ArcGIS to expand it's capabilities with spatiotemporal analytics, visualization & dashboards.



Complementing an IoT platform with ArcGIS

enabling geospatial insights with your IoT solution

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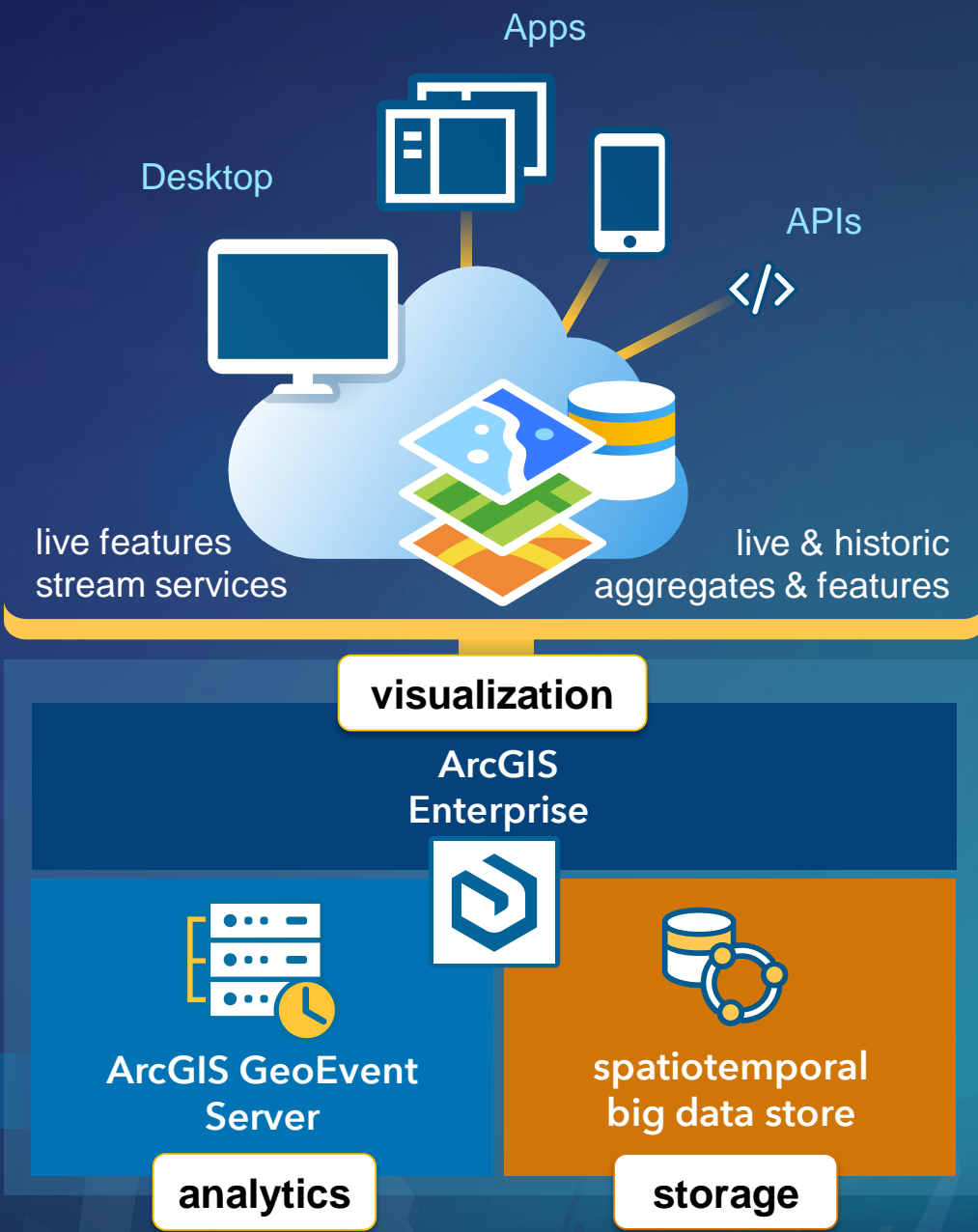


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ArcGIS as an IoT Platform

ArcGIS Enterprise

with real-time capabilities



Commercial

- Financial Services
- Insurance
- Logistics / Trucking
- Manufacturing
- Media & Entertainment
- Real Estate
- Retail

Defense & Intelligence

- Intelligence
- Military Operations

Public Safety

- Emergency / Disaster Mgmt
- Fire, Rescue, EMS
- Homeland Security
- National Security
- Law Enforcement
- Special Events

Natural Resources

- Agriculture
- Forestry
- Mining
- Oil & Gas
- Pipeline

Health & Human Services

- Hospital & Health Systems
- Pharmaceuticals
- Public Health

Transportation

- Aviation
- DOT
- Railways
- Maritime & Ports
- Public Transit

Government

- National
- State
- Local

Utilities

- Electric & Gas
- Telco / Cable
- Public Works

Water

- Water resources
- Water / wastewater / stormwater

Professional Services

- AEC
- Environmental Mgmt
- GIS & IT

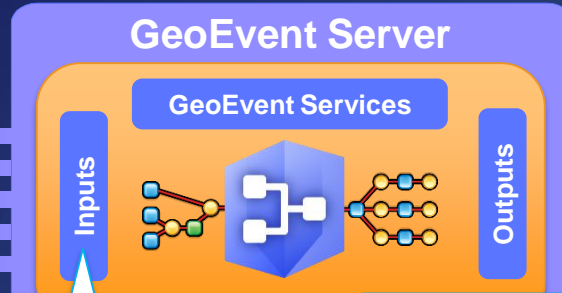
Nonprofits & Education

- Conservation
- Humanitarian
- Sustainable Development
- Higher Ed
- Research/Science Institutions



Ingestion

Configurable Input Connectors



you can create
your own
inputs

Out of the Box

- Poll an ArcGIS Server for Features
- Poll an external website for GeoJSON, JSON, or XML
- Receive Features, GeoJSON, JSON, or XML on a REST endpoint
- Receive GeoJSON or JSON on a WebSocket
- Receive RSS
- Receive Text from a TCP or UDP Socket
- Subscribe to an external WebSocket for GeoJSON or JSON
- Watch a Folder for new CSV, GeoJSON, or JSON Files

Esri Gallery

- ActiveMQ
- AIS
- Common Alerting Protocol
- Cursor-on-Target
- Exploitation Support Data
- GTFS
- Instagram
- Kafka
- KML
- MQTT
- NMEA 0183
- RabbitMQ
- Sierra Wireless (RAP)
- Trimble (TAIP)
- Twitter

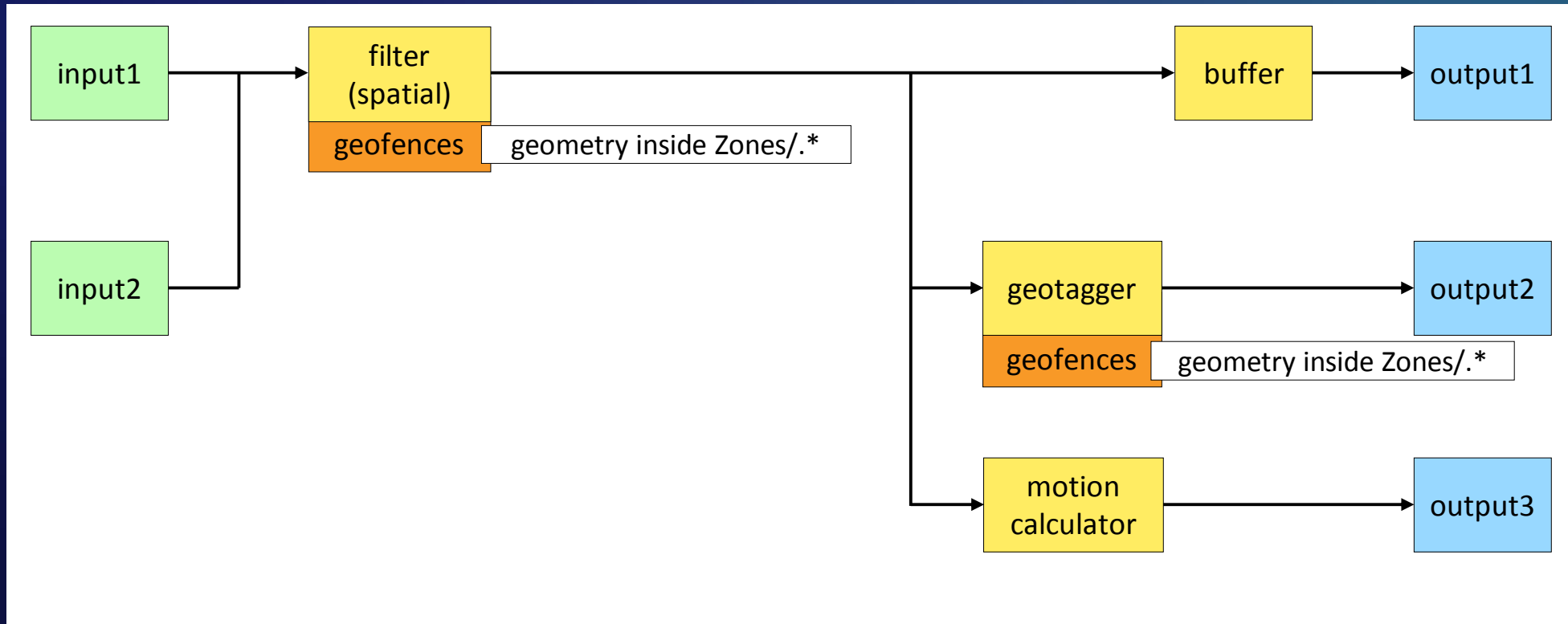
Partner Gallery

- Amazon IoT
- Azure IoT
- CompassLDE
- enviroCar
- exactEarth AIS
- FlightAware
- GNIP
- Networkfleet
- OSISoft
- Valarm
- Waze
- Zonar
- Geotab
- Telogis

Streaming analytics, policies & orchestration

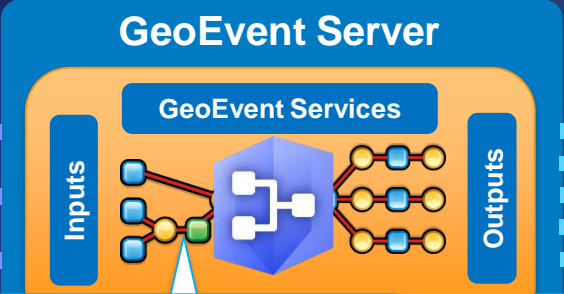
GeoEvent Server: geoevent services

- A **GeoEvent Service** configures the flow of real-time data,
 - the **filtering** and **geoevent processing** steps to perform,
 - the input(s) where data comes from and the output(s) to which results are sent.



Real-Time Analytics

Configurable Processors



you can create your own processors

Out of the Box

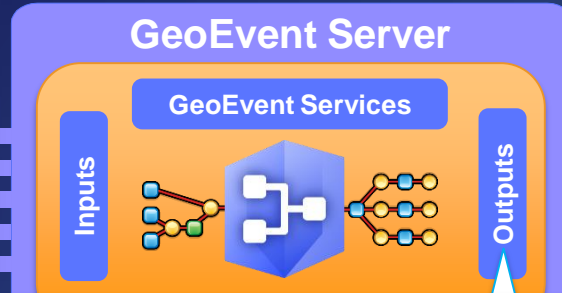
Buffer Creator	Geotagger
Convex Hull Creator	Incident Detector
Difference Creator	Intersector
Envelope Creator	Projector
Field Calculator	Simplifier
Field Enricher	Symmetric Difference
Field Mapper	Track Gap Detector
Field Reducer	Union Creator

Esri Gallery

Add XYZ	Range Fan
Bearing	Reverse Geocoder
Ellipse	Service Area Creator
Event Volume Control	Symbol Lookup
Extent Enricher	Track Idle Detector
Field Grouper	Unit Converter
GeoNames Lookup	Visibility
Motion Calculator	Query Report

Dissemination

Configurable Output Connectors



you can create your own outputs

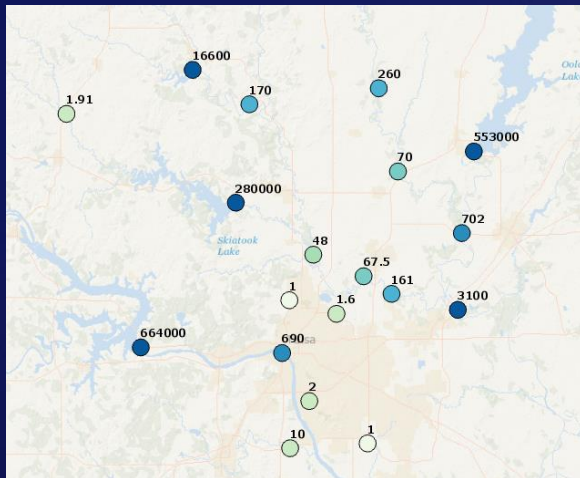
- Out of the Box**
- Add or Update a Feature
 - Publish Text to a UDP Socket
 - Push GeoJSON or JSON to an external Website
 - Push GeoJSON or JSON to an external WebSocket
 - Push Text to an external TCP Socket
 - Send a Text Message
 - Send an Email
 - Send an Instant Message
 - Send Features to a Stream Service
 - Write to a CSV, GeoJSON, or JSON File
 - Add a Feature to a spatiotemporal big data store
 - Update a feature in a spatiotemporal big data store

- Esri Gallery**
- Amazon IoT
 - Azure IoT
 - ActiveMQ
 - Cursor-on-Target
 - Hadoop
 - Kafka
 - MongoDB
 - MQTT
 - RabbitMQ
 - Twitter

Real-Time GIS

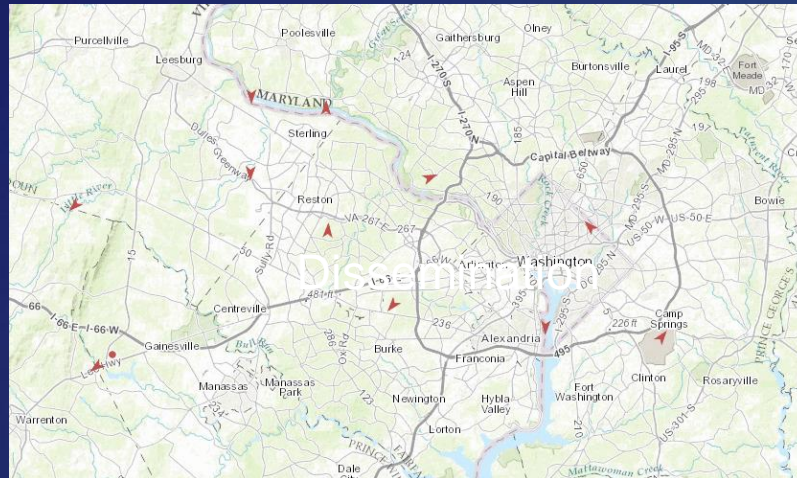
Types of observations and data

stationary sensors...



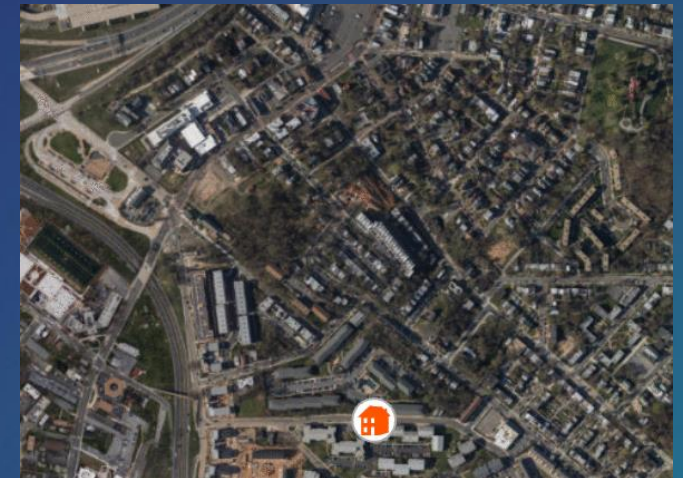
- water gauges
- weather stations
- air quality sensors
- device temperature

things that move...



- airplanes
- vehicles
- animals
- storms
- ships
- satellites
- trains
- people

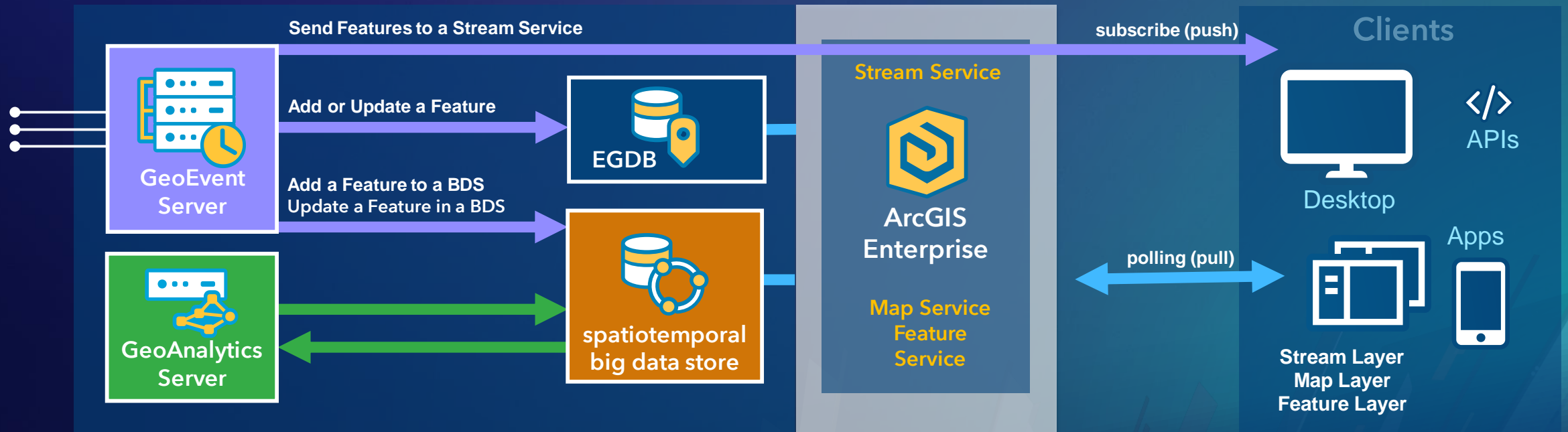
things that “just happen”...



- crimes
- lightning
- accidents
- tweets

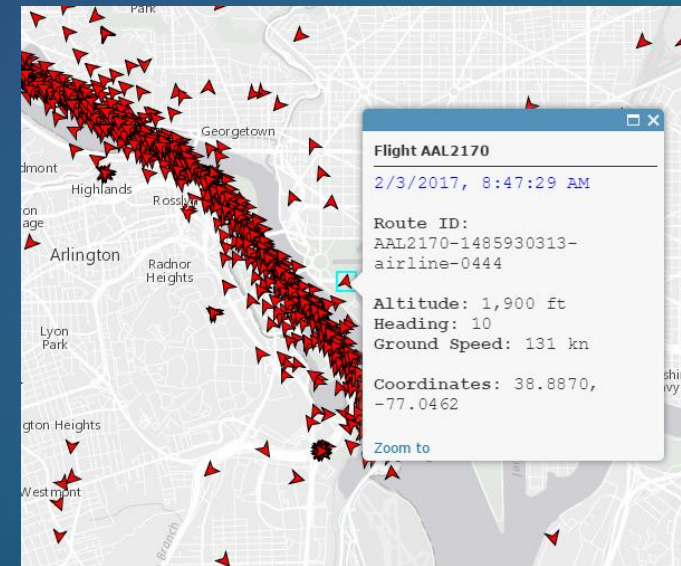
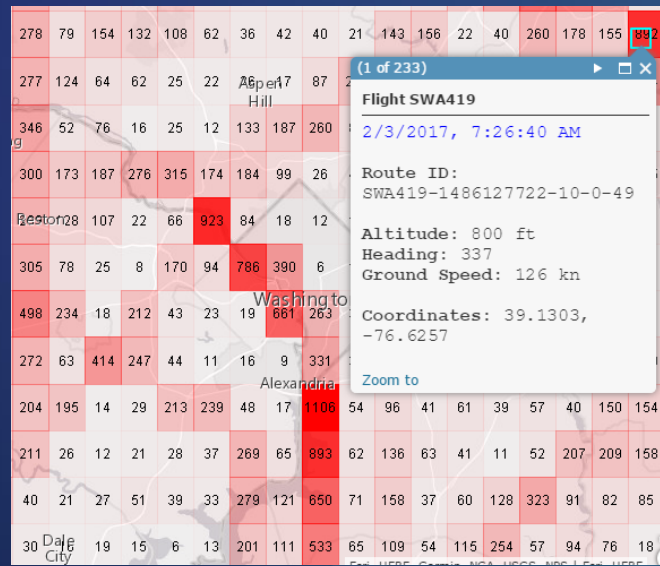
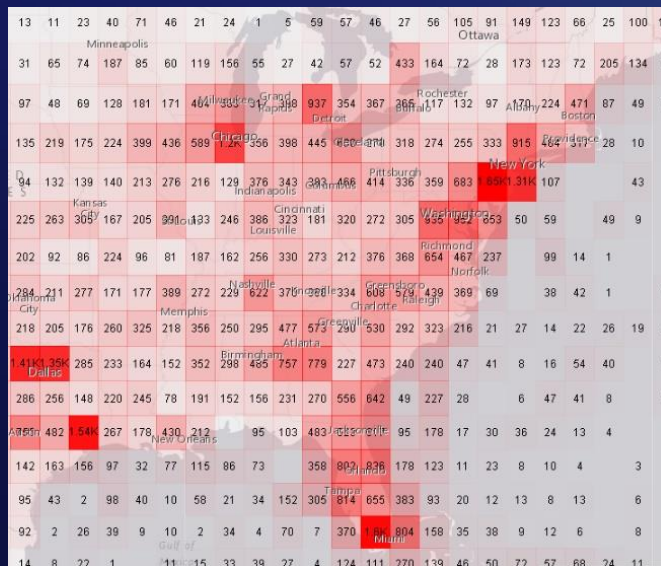
Consuming Real-Time Data

- Stream layers in apps **subscribe** to stream services to immediately visualize observations
 - does not require storage, low latency, no playback
- Map & Features layers in apps periodically **poll** to visualize most current observations
 - backed by an enterprise geodatabase (EGDB) or a spatiotemporal big data store (BDS)
 - history can be retrieved & queried for playback



Visualization of observation data

- Map & Feature Services that make use data in the spatiotemporal store enable you to:
 - visualize on-the-fly aggregations of data
 - perform exploratory queries over any combination of space, time and attributes
 - switch visualization from aggregations to raw features
 - inspect feature level attributes while in aggregation or raw feature views
 - replay via a time-slider historic observations in aggregation or raw feature views

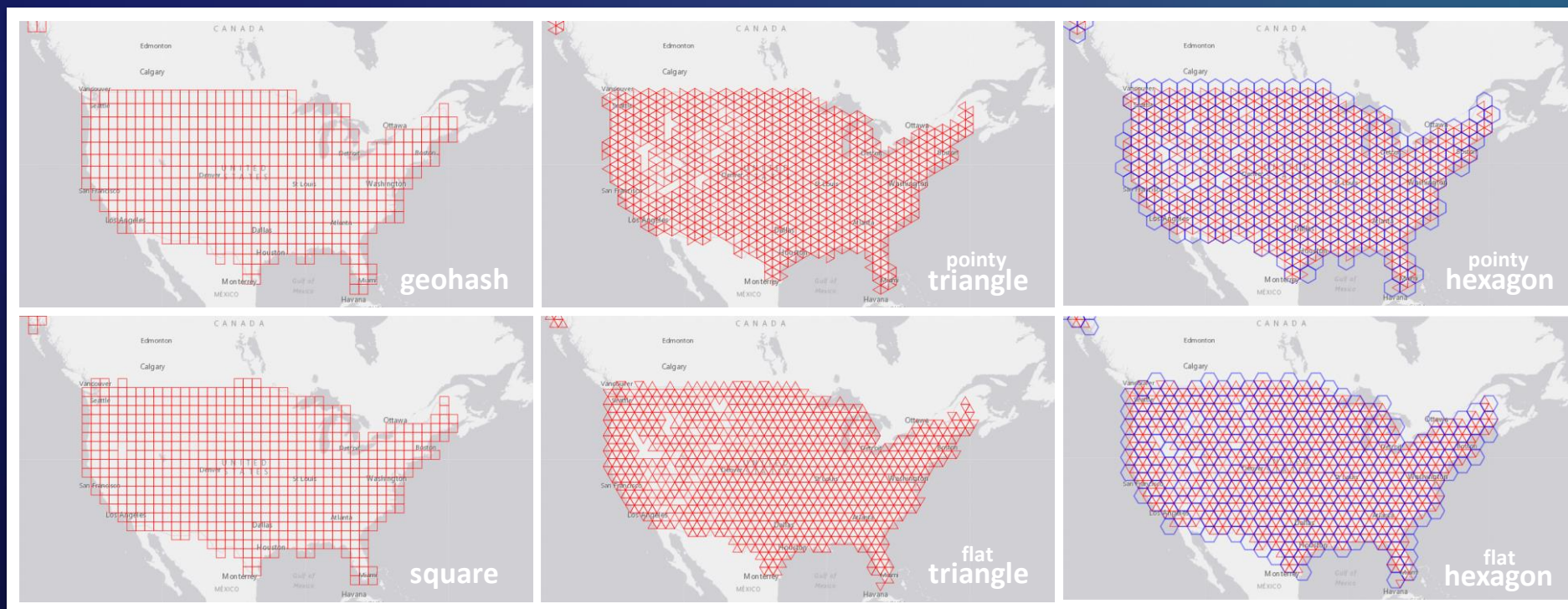


Storage

spatial indexing to support on-the-fly aggregations

10.5

- as data is written to a data source in the data store:
 - up to four types of spatial indices are supported: **geohash**, **square**, **pointy**, & **flat hexagon/triangle**
 - this is in addition to a **temporal index** on the **time field**
 - and an **inverted index** on each of the **attribute fields**





5

Applying spatiotemporal analytics to IoT Data

Batch analysis

GeoAnalytics Server: analytic capabilities

"I want to..."



Summarize Data



Join Features
Aggregate Points
Summarize within
Summarize Attributes
Reconstruct Tracks

Use Proximity



Create Buffers

Find Locations



Detect Incidents
Find Similar Locations
Geocode Locations

Analyze Patterns



Calculate Density
Find Hot Spots
Create Space Time Cube

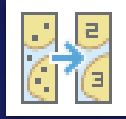
Manage Data



Calculate Field
Copy To Data Store

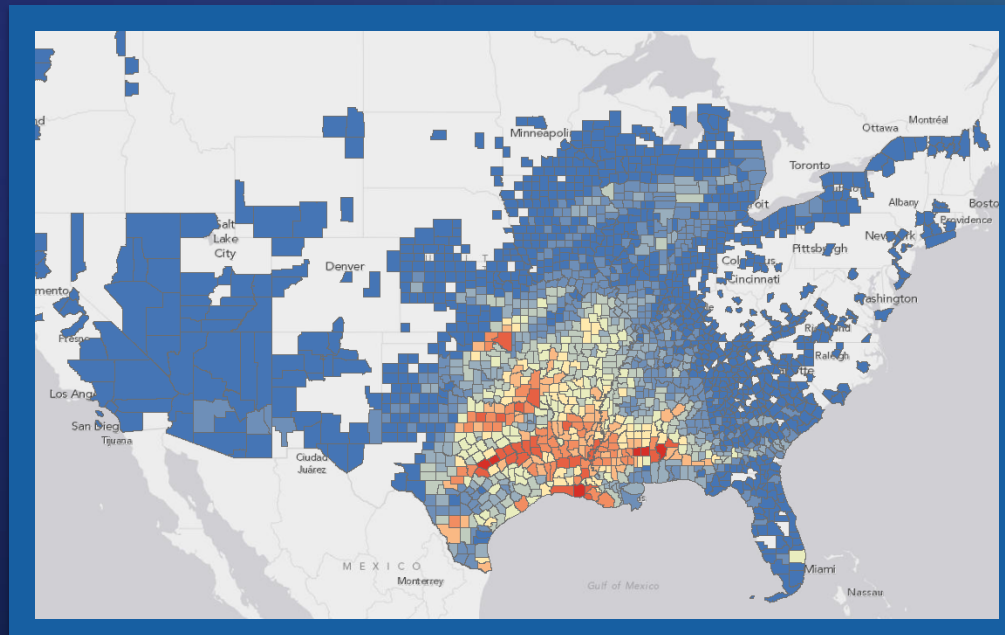
Batch analysis

summarize data



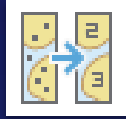
- Aggregate Points:

- *“How does the spatial distribution of vehicle collisions change over time?”*
- *“What zip codes have the highest count of crimes incidents?”*
- *“Where are there the most power outages?”*
- *“What does my data look like?”*



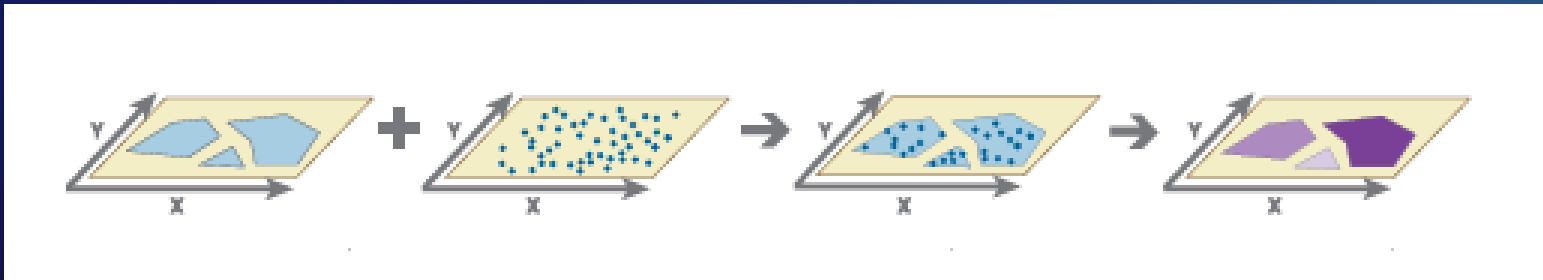
Batch analysis

summarize data



- **Aggregate Points:**

- **Input 1:** *Points*, **Input 2:** *Polygons (or generate bins)*
- **Output:** *Polygons*

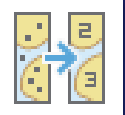


- Aggregates point data into either a square grid, a hexagonal grid, or user-supplied polygon features
- Users can choose to aggregate either spatially or spatiotemporally
- A count of points is returned for each grid cell (*bins*), in addition to optional attribute field statistics

Batch analysis

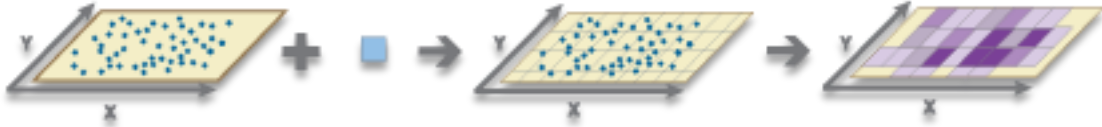
summarize data

- Aggregate Points:



Methods of Aggregation

Spatial, into bins:



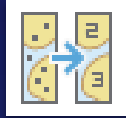
Spatial, into polygons:



Batch analysis

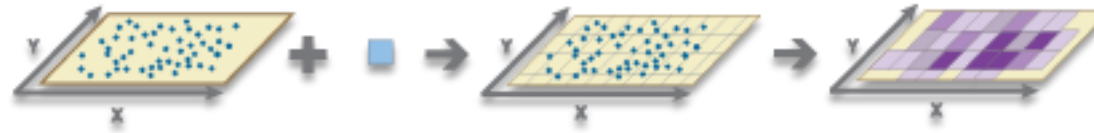
summarize data

- Aggregate Points:



Methods of Aggregation

Spatial, into bins:



Spatial, into polygons:



Spatiotemporal, into bins:



Spatiotemporal, into polygons:



Batch analysis

summarize data



- Join Features:
 - *“Which crime events occurred near sporting events, spatially & temporally?”*
 - *“Which bodies of water intersect cities with populations greater than one million people?”*
 - *“Which traffic jams occurred because of car accidents?”*

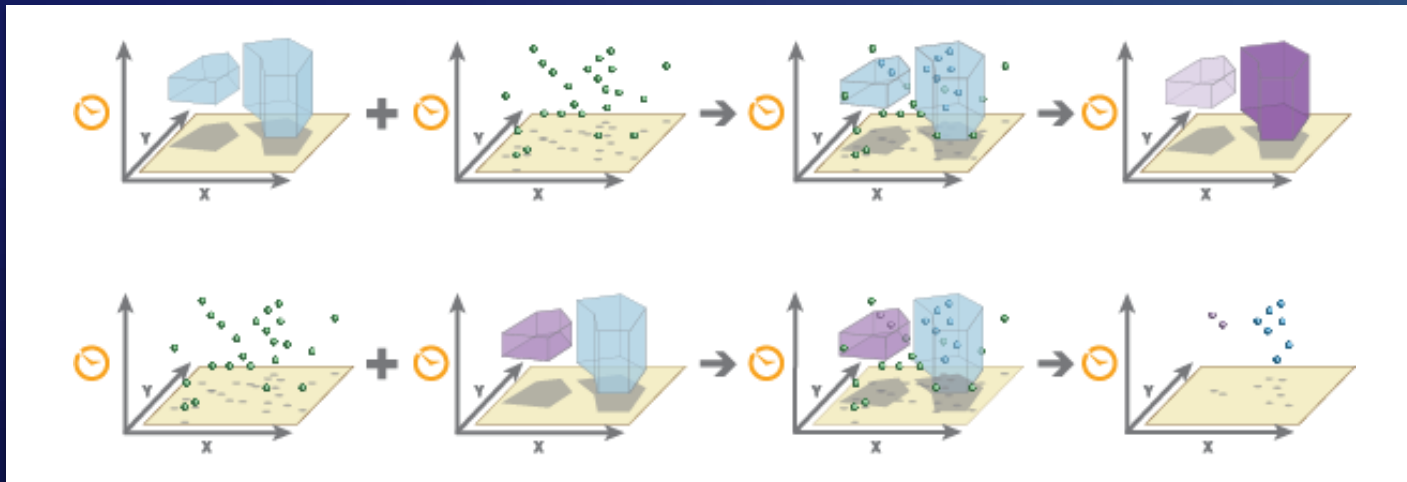
Batch analysis

summarize data



- **Join Features:**

- **Input 1:** *Points, Polygons or Lines*, **Input 2:** *Points, Polygons or Lines*
- **Output:** *Points, Polygons or Lines*



- Joins attributes from one layer to another based on spatial, temporal & attribute relationships, or any combination of those relationships.

Batch analysis

summarize data



- Join Features:

Joins in GeoAnalytics Server

Spatial

- Intersects
- Equals
- Near
- Contains
- Within
- Touches
- Crosses
- Overlaps

Temporal

- Meets
- Met by
- Overlaps
- Overlapped by
- During
- Contains
- Equals
- Finishes
- Finished by
- Starts
- Started by
- Intersects
- Near

Attribute

Features are matched when the field values in the join layer are equal to field values in the target layer.

Near spatial and temporal relationships require a distance/length of time to be specified. For more information see:

<https://pro.arcgis.com/en/pro-app/tool-reference/big-data-analytics/spatial-relationships-with-big-data.htm>

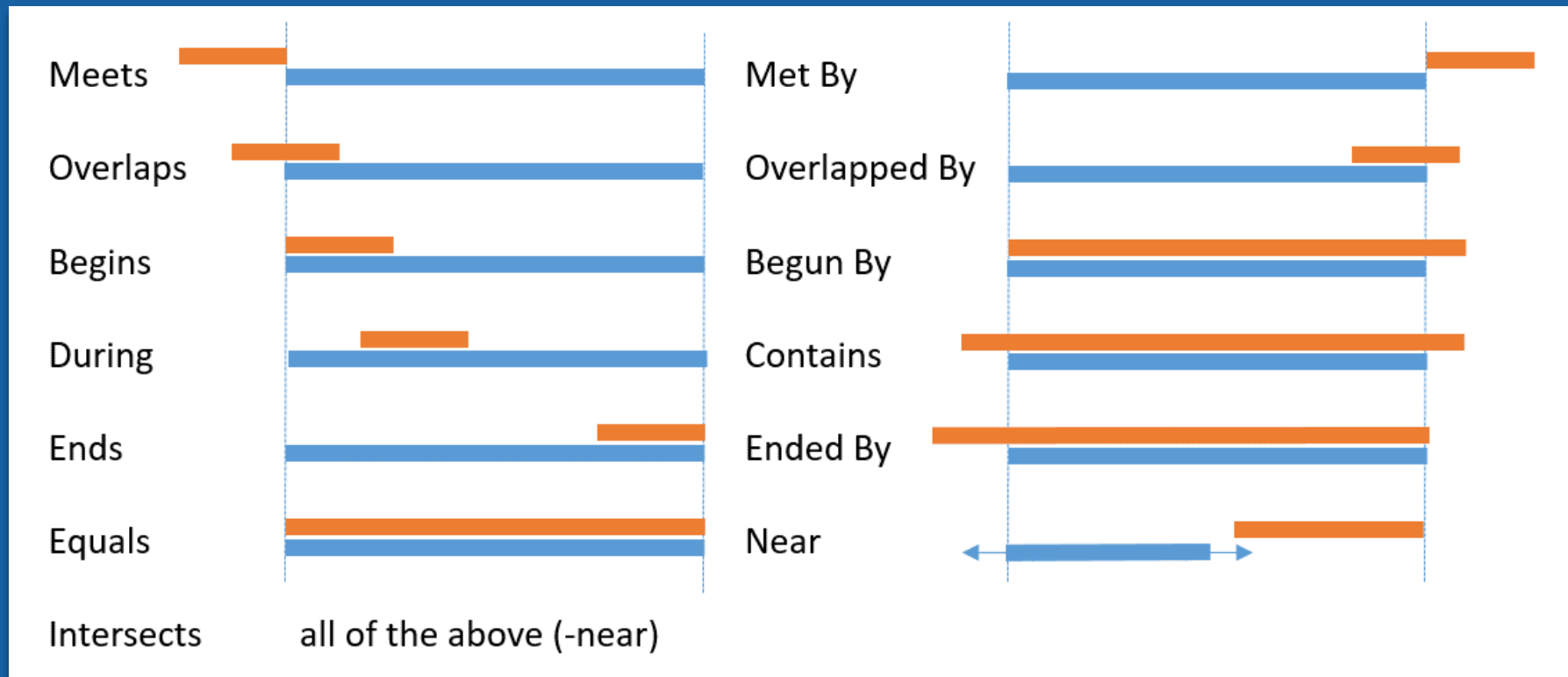
Batch analysis

summarize data



- Join Features:

Temporal Operators





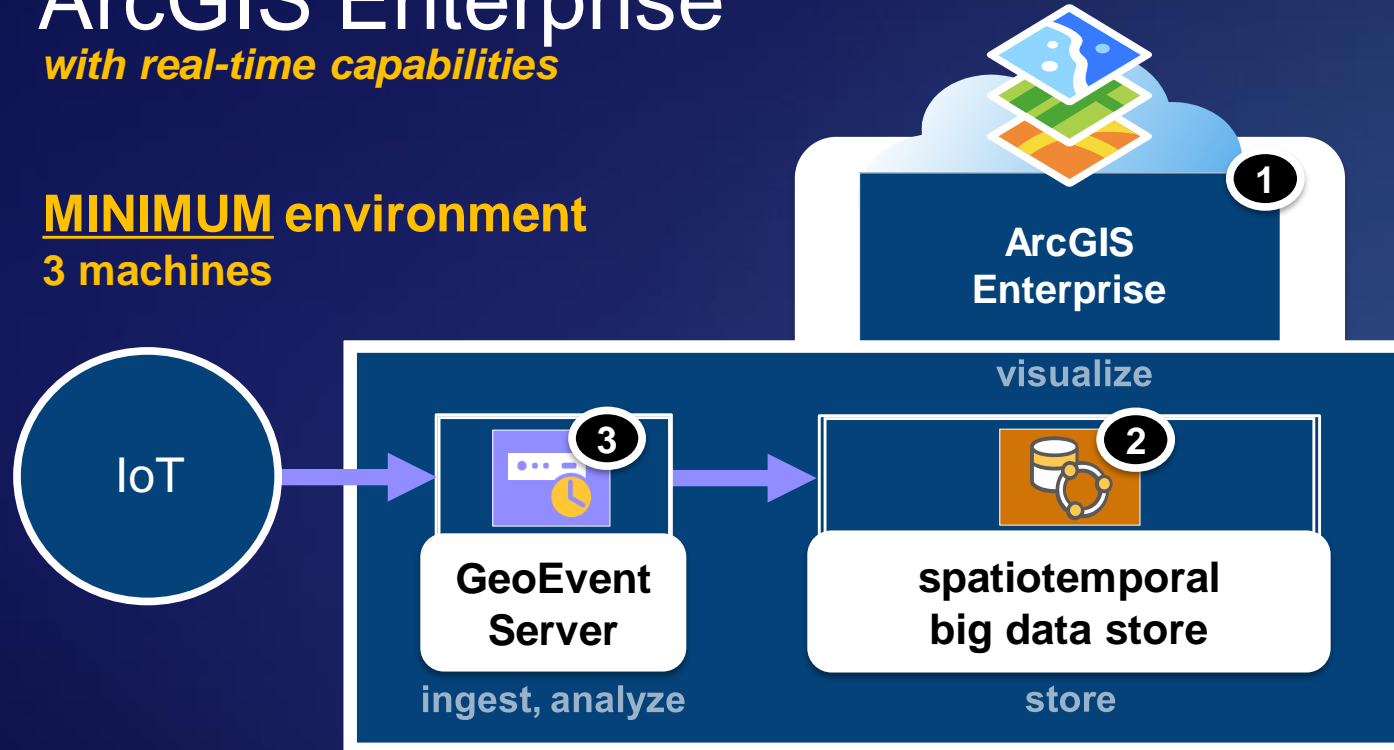
6

Handling IoT scale requirements

ArcGIS Enterprise

with real-time capabilities

MINIMUM environment
3 machines

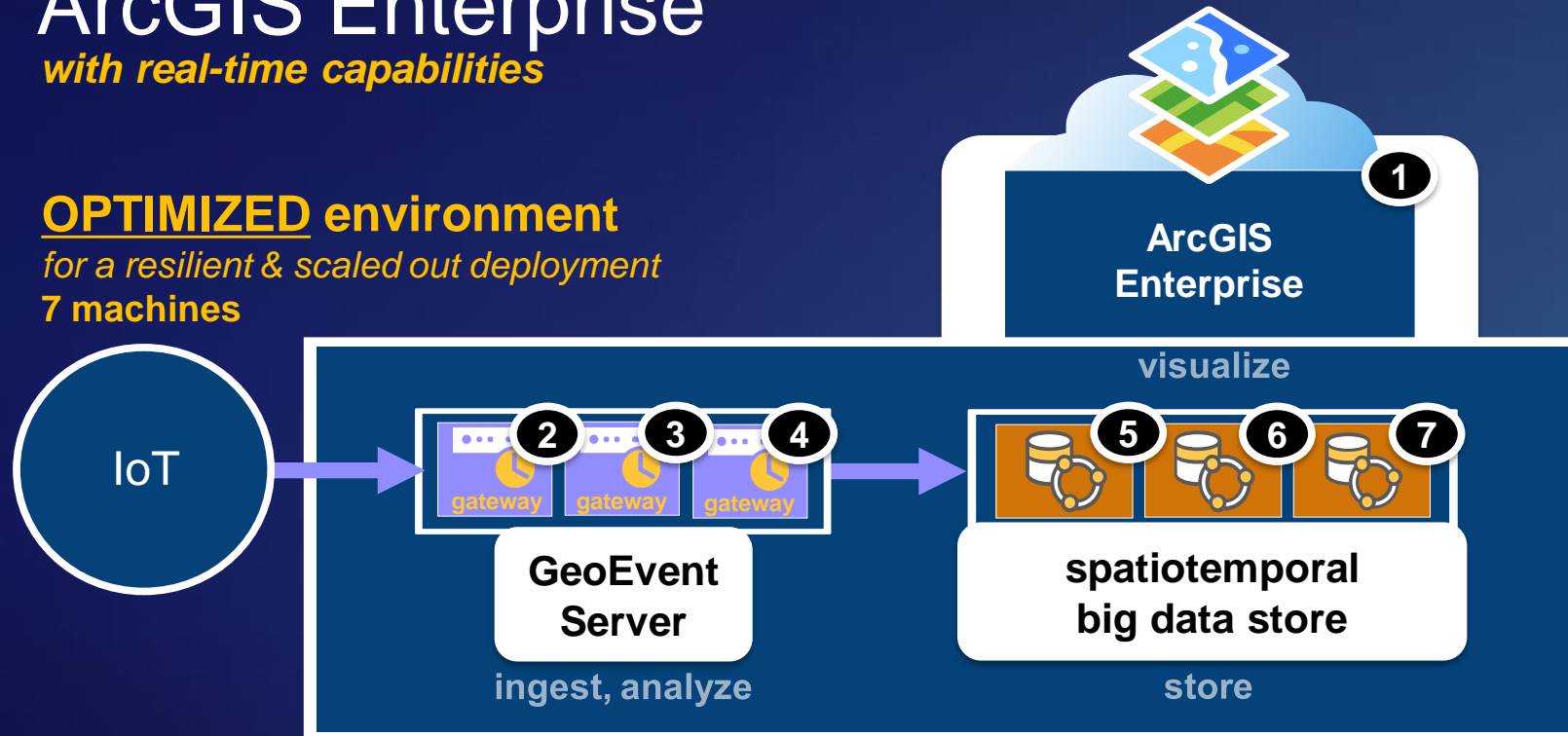


ArcGIS GeoEvent Server	10.2	10.3	10.4	10.5	10.6	10.6.1
Velocity throughput measured in events per second (e/s)	up to 500 e/s	up to 2,000 e/s	up to 3,000 e/s	up to 4,000 e/s	up to 6,000 e/s	up to 10,000 e/s

ArcGIS Enterprise

with real-time capabilities

OPTIMIZED environment
for a resilient & scaled out deployment
7 machines



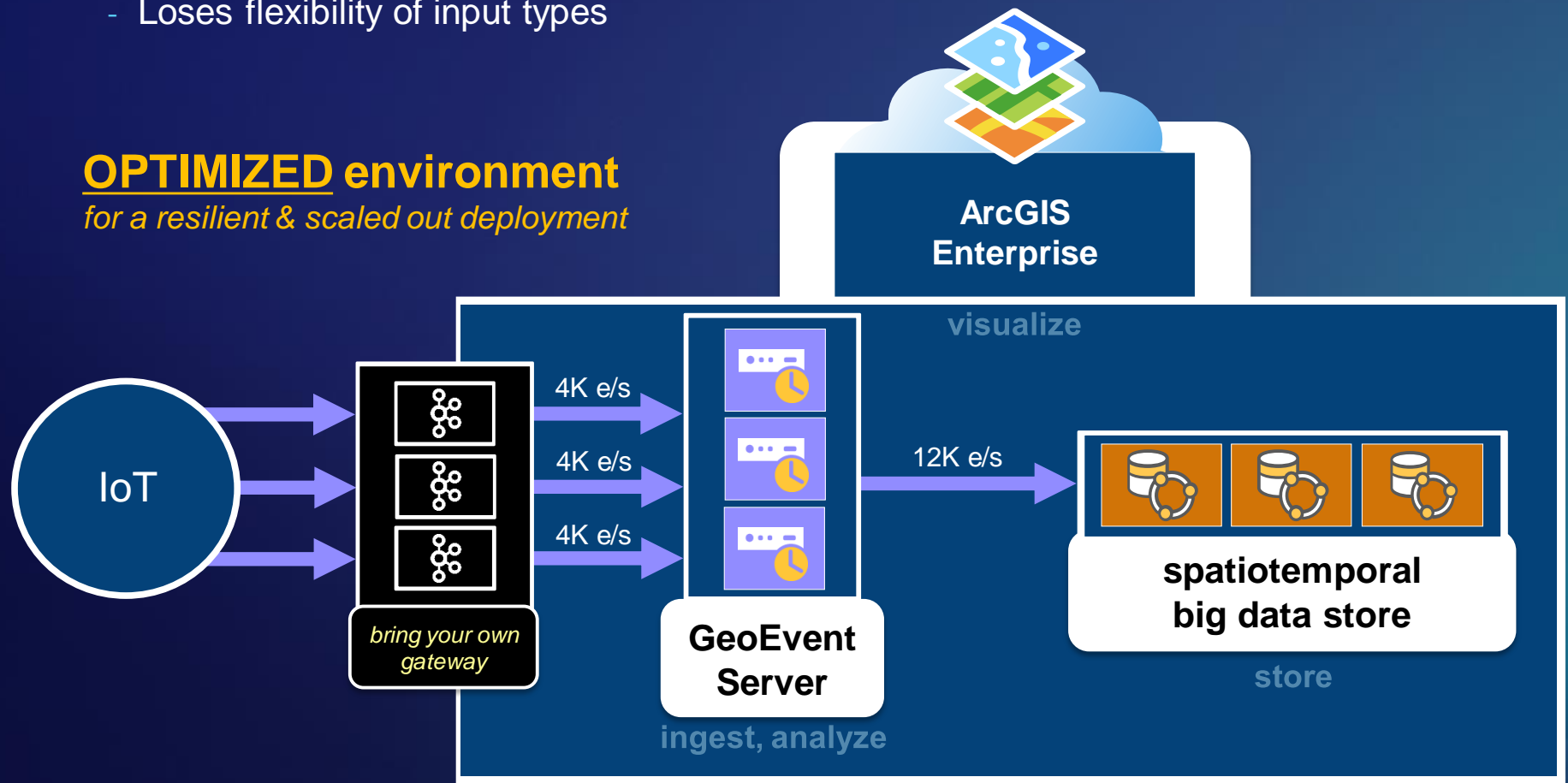
ArcGIS GeoEvent Server	10.2	10.3	10.4	10.5	10.6	10.6.1
Velocity throughput <i>measured in events per second (e/s)</i>	<i>up to 500 e/s</i>	<i>up to 2,000 e/s</i>	<i>up to 3,000 e/s</i>	<i>up to 4,000 e/s</i>	<i>up to 6,000 e/s</i>	<i>up to 10,000 e/s</i>
Resiliency & Scalability <i>via multi-machine site</i>	no	no	no	no	yes	yes

GeoEvent Server

resiliency, scalability, & performance

- ArcGIS 10.5
 - Resiliency (high availability) & scalability is only possible if users “bring their own gateway”
 - Barrier to entry is HIGH & typically requires a professional services engagement for success
 - Loses flexibility of input types

OPTIMIZED environment
for a resilient & scaled out deployment

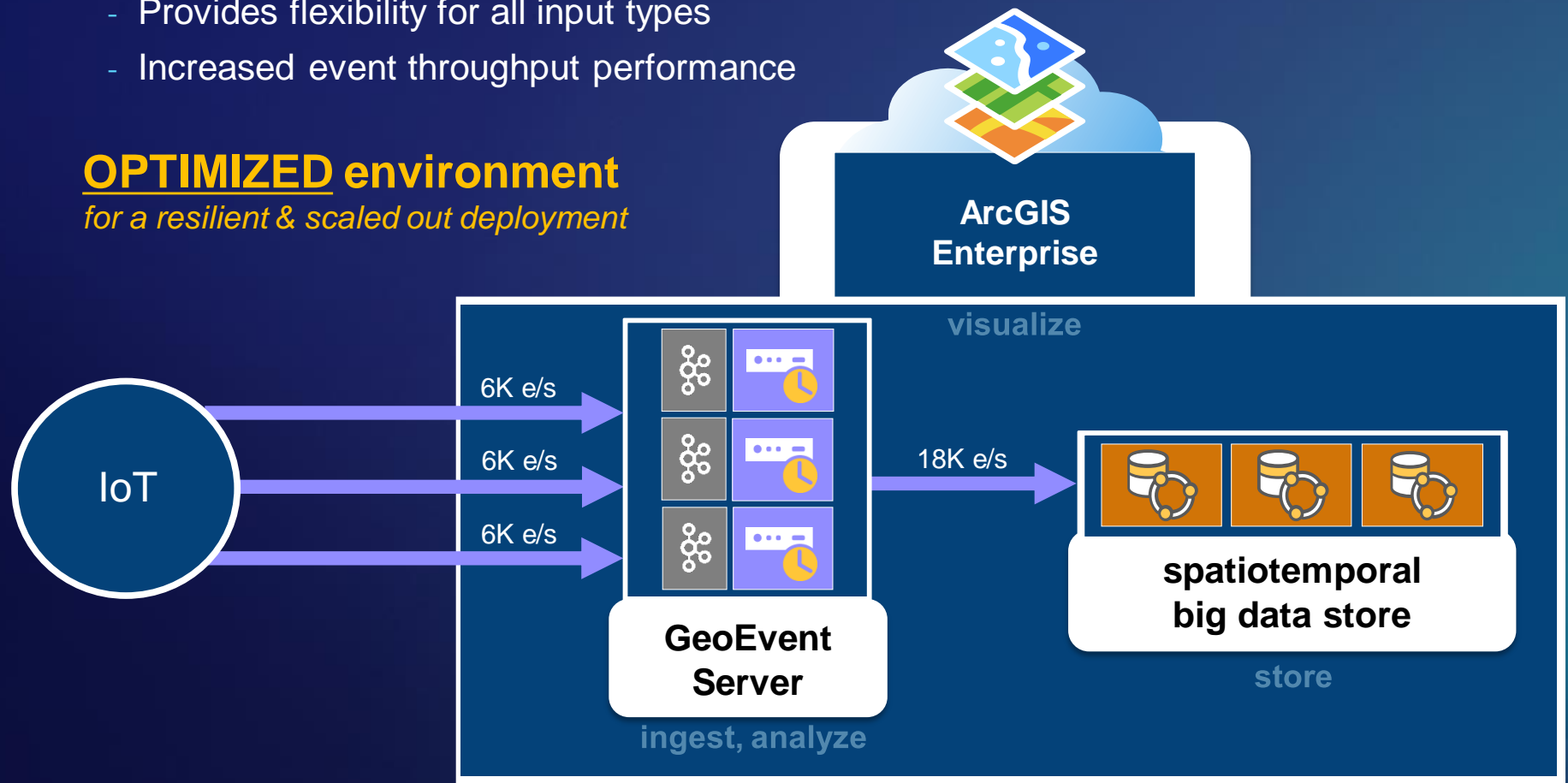


GeoEvent Server

resiliency, scalability, & performance

- ArcGIS 10.6
 - Provides users with a resilient & scalable Real-Time GIS deployment OUT-OF-THE-BOX
 - Introduces a gateway process that is automatically configured as part of GeoEvent Server installation
 - Provides flexibility for all input types
 - Increased event throughput performance

OPTIMIZED environment
for a resilient & scaled out deployment

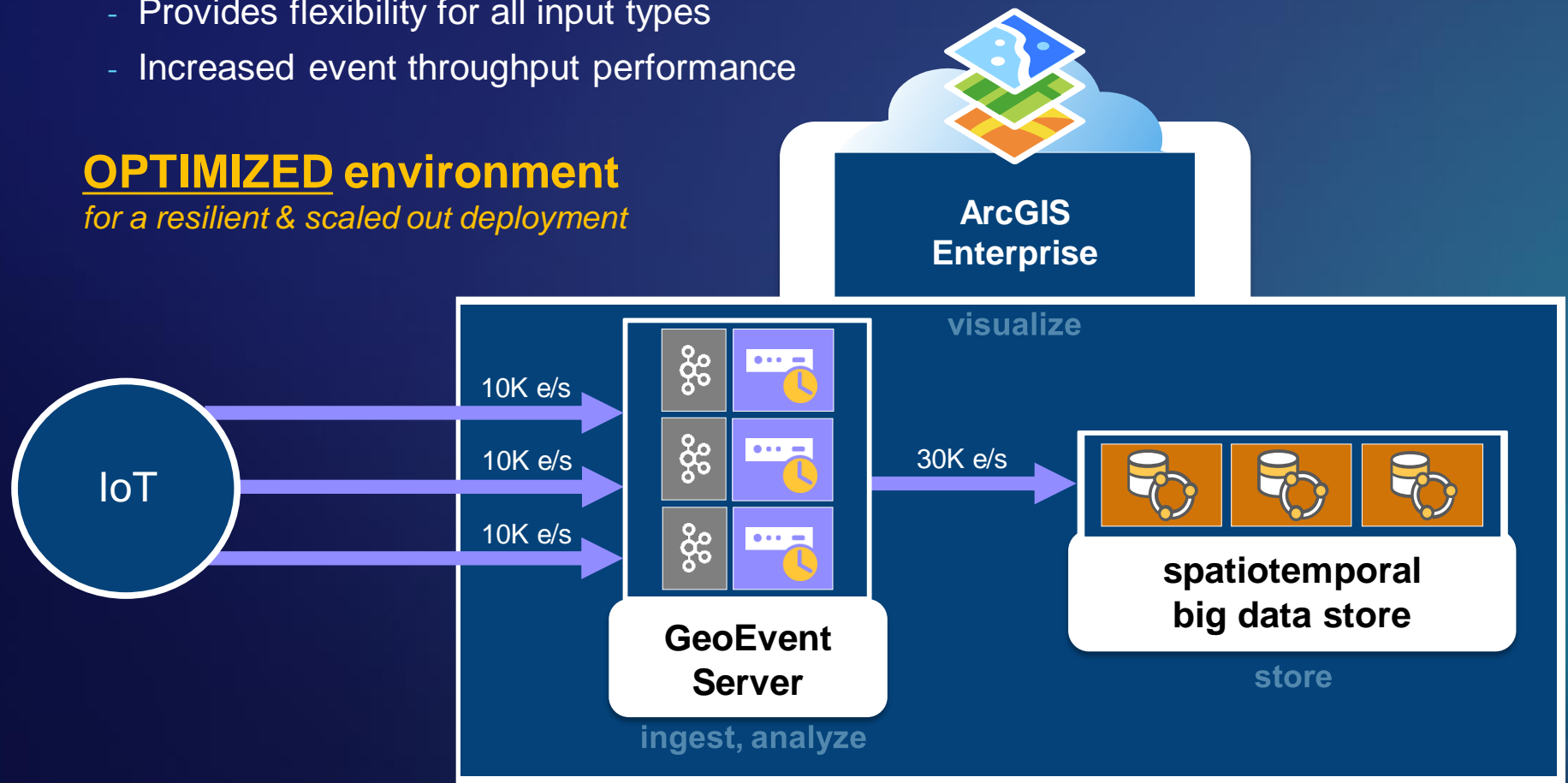


GeoEvent Server

resiliency, scalability, & performance

- ArcGIS 10.6
 - Provides users with a resilient & scalable Real-Time GIS deployment OUT-OF-THE-BOX
 - Introduces a gateway process that is automatically configured as part of GeoEvent Server installation
 - Provides flexibility for all input types
 - Increased event throughput performance

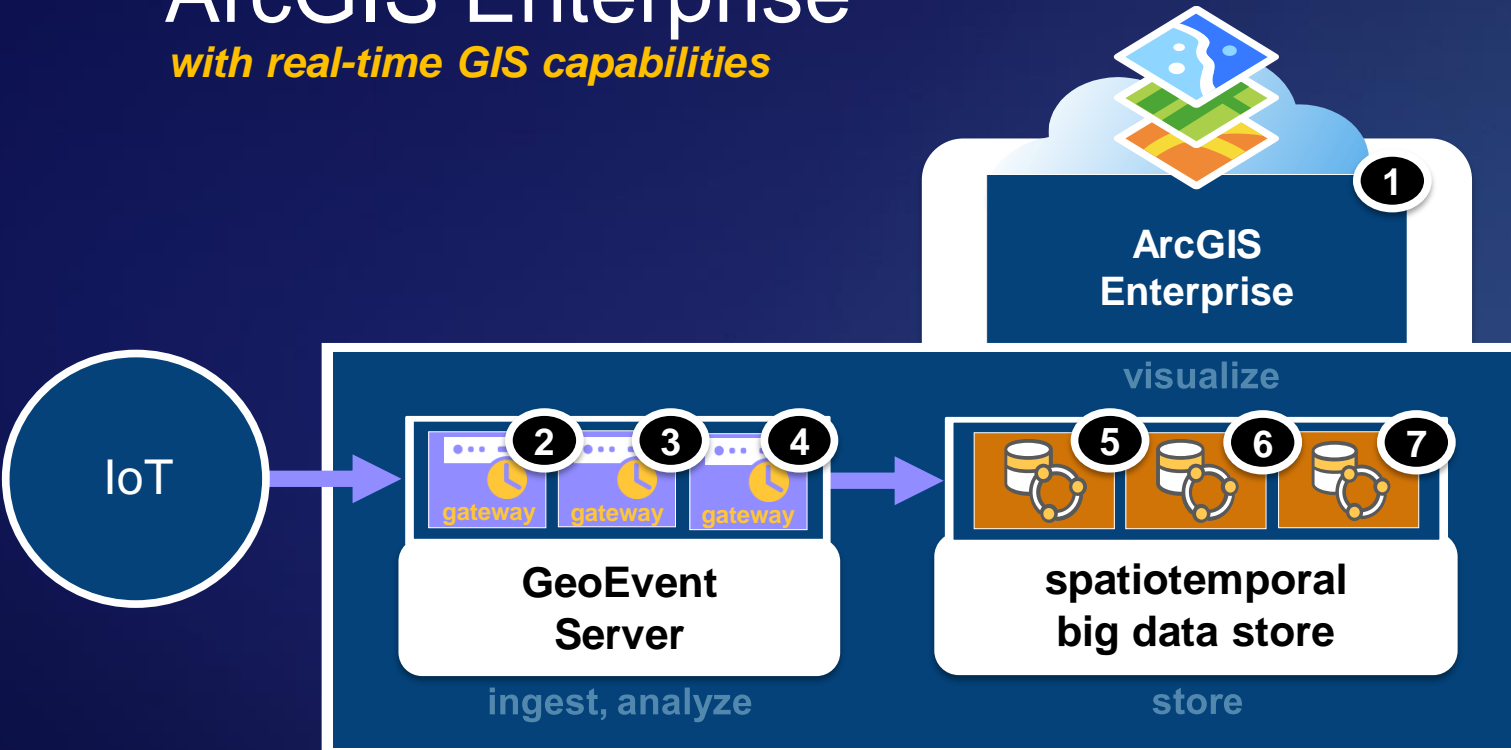
OPTIMIZED environment
for a resilient & scaled out deployment



ArcGIS Enterprise

with real-time GIS capabilities

10.6



OPTIMIZED environment
for a resilient & scaled out deployment
7 machines

ArcGIS GeoEvent Server	10.2	10.3	10.4	10.5	10.6	10.6.1
Velocity throughput measured in events per second (e/s)	up to 500 e/s	up to 2,000 e/s	up to 3,000 e/s	up to 4,000 e/s	up to 6,000 e/s	up to 10,000 e/s
Resiliency & Scalability via multi-machine site	no	no	no	no	yes up to 5 practically, so can scale to up to 30,000 e/s	yes up to 5 practically, so can scale to up to 50,000 e/s

GeoEvent Server


best practices tutorial for multi-machine site deployment

10.6

- Available Now: <http://links.esri.com/geoevent-multiplemachine>

Tutorial - GeoEvent Server 10.6.x Multiple-Machine Site

Overview



ArcGIS GeoEvent Server 10.6.x now supports the creation of multiple-machine sites.

Document Link by [GeoEventTeam](#)

Created: Mar 3, 2018 Updated: Mar 3, 2018
View Count: 0

Open

Description

ArcGIS GeoEvent Server 10.6.x now supports the creation of multiple-machine sites. In a multiple-machine site, two or more GeoEvent Server machines can be administered and used as a single logical unit, providing GeoEvent Server administrators with great flexibility to easily adjust the computing power of the site by adding or removing GeoEvent Server machines.


This tutorial will walk you through how to plan, setup, and work with a GeoEvent Server 10.6.x multiple-machine site. Also included is an appendix for administrators to learn how to monitor an existing GeoEvent Server multiple-machine site.

Details

Size: 1 KB
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[f](#) [t](#) [s](#)

Owner


 GeoEventTeam

Tags

[arcgis](#), [geoevent](#), [server](#), [real-time](#), [realtime](#), [multiple](#), [machine](#), [site](#), [tutorial](#), [scale](#), [scaling](#),



ArcGIS® GeoEvent Server Multiple-Machine Site Tutorial



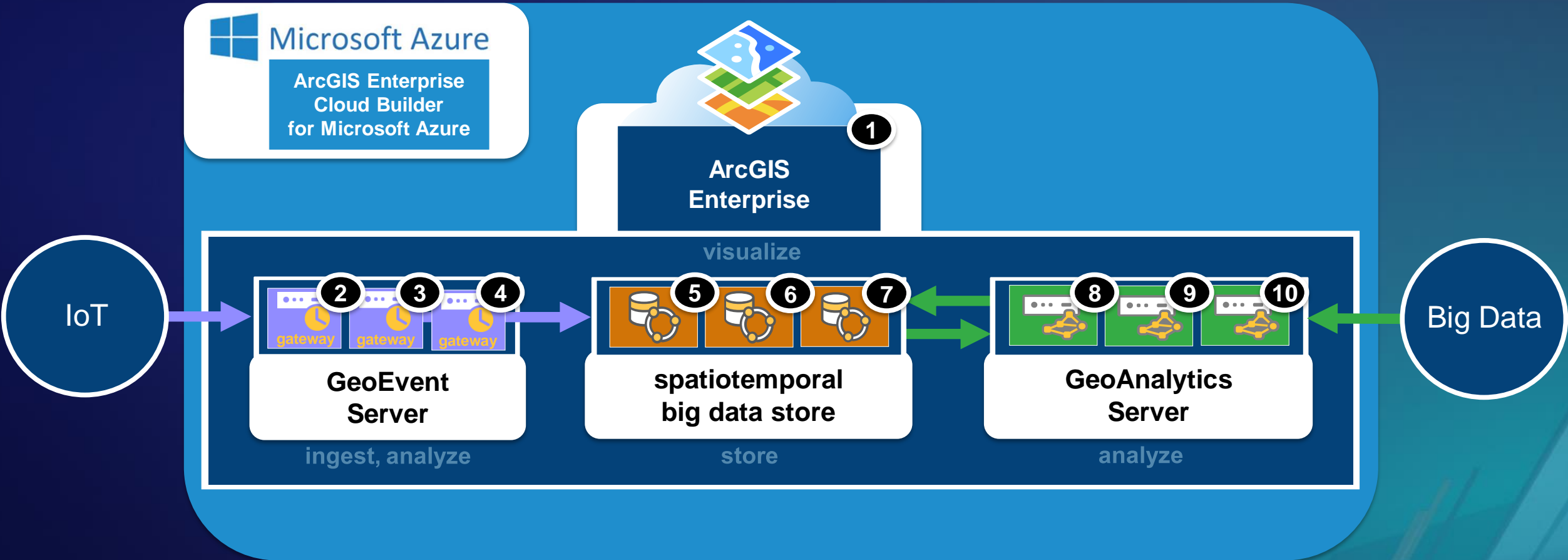
NOTE: The GeoEvent Server Team strives to update product tutorials to reflect the latest release. Depending on the version of GeoEvent Server you are using, there may be inconsistencies between your environment and the illustrations and/or specific steps in exercises or videos bundled with the tutorial. The concepts outlined, however, should be applicable across different versions of GeoEvent Server.

Tutorial - GeoEvent Server Multiple-Machine Site 10.6.x / r1

ArcGIS Enterprise

with real-time & big data GIS capabilities on Microsoft Azure

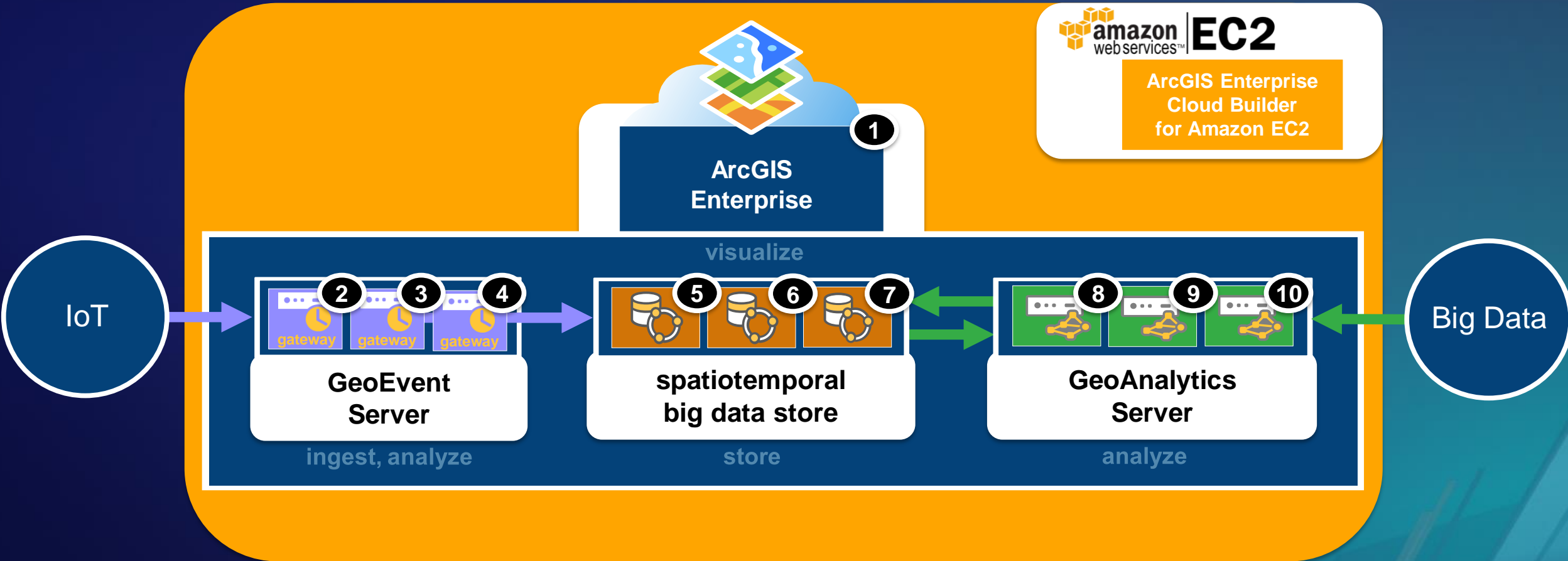
10.6.1



ArcGIS Enterprise

with real-time & big data GIS capabilities on Amazon EC2

10.6.1





Additional Resources

ArcGIS & the Internet of Things

Additional Resources

Esri User Conference 2018 pre-conference seminar on 'Integrating IoT & ArcGIS':

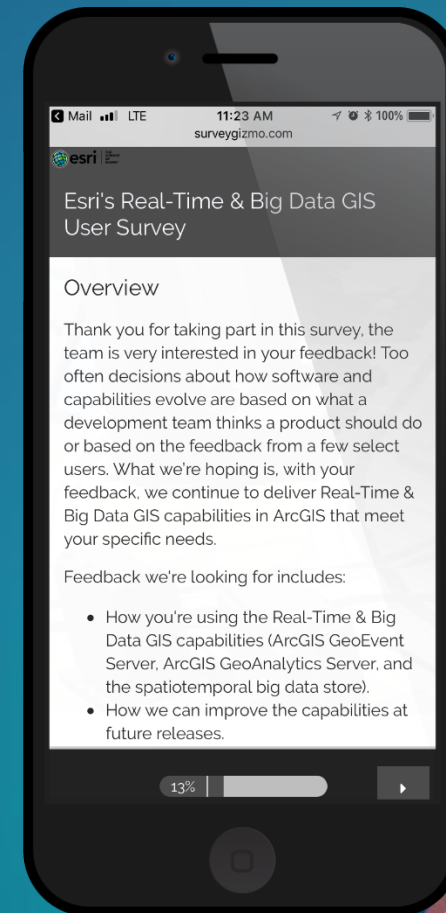
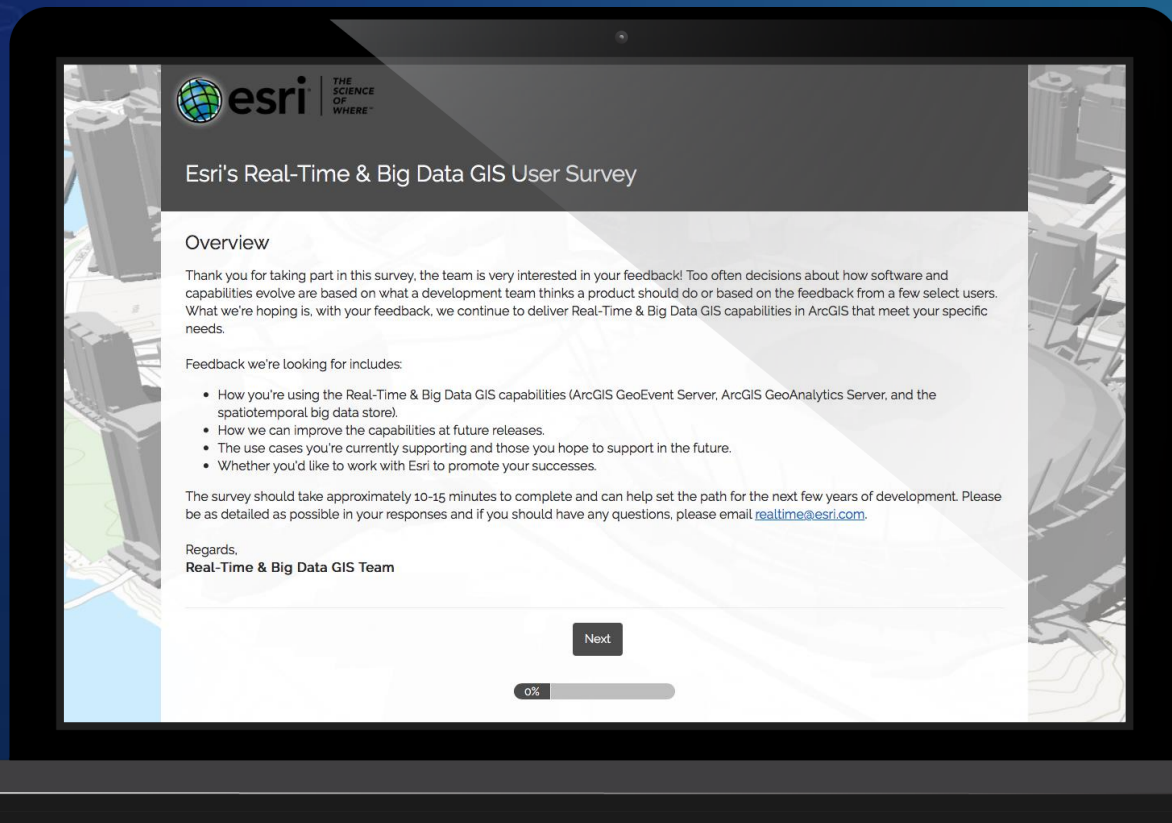
<https://github.com/Esri/integrating-iot-arccgis>

Integrating IoT & ArcGIS

- Agenda [[slides](#), [video](#)]
- What is the IoT? [[slides](#), [video](#)]
- Decomposing an IoT Solution [[slides](#), [video](#)]
- ArcGIS as an IoT Platform [[slides](#), [video](#)]
 - visualization of moving observations (map service) [[video](#)]
 - visualization of stationary observations (map service) [[video](#)]
 - visualization of discrete observations (map service) [[video](#)]
 - visualization of observations (feature service) [[video](#)]
- Deployment patterns [[slides](#), [video](#)]
 - Edge to ArcGIS as an IoT Platform demonstration [[video](#)]
 - Complementing an IoT platform with ArcGIS demonstration [[video](#)]
- Spatiotemporal analytic capabilities [[slides](#), [video](#)]
 - Real-Time spatiotemporal analytics demonstration [[video](#)]
 - Actuation demonstration [[video](#)]
 - Big Data spatiotemporal analytics demonstration [[video](#)]
- Handling IoT scale requirements [[slides](#), [video](#)]
 - Ingestion, streaming analytics, storage & visualization at scale demonstration [[video](#)]
 - Batch analytics at scale demonstration [[video](#)]

Help us improve the Real-Time & Big Data GIS Capabilities

<http://esriurl.com/RealTimeSurvey>



Questions / Feedback?



Josh Joyner

ArcGIS GeoEvent Server, Product Manager
jjoyner@esri.com



Adam Mollenkopf

Real-Time & Big Data GIS Capability Lead
amollenkopf@esri.com
@amollenkopf



esri

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