AWS Prescriptive Guidance

Designing and implementing logging and monitoring with Amazon CloudWatch

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This guide helps you design and implement logging and monitoring with Amazon CloudWatch and related Amazon Web Services (AWS) management and governance services for workloads that use Amazon Elastic Compute Cloud (Amazon EC2) instances, Amazon Elastic Container Service (Amazon ECS), Amazon Elastic Kubernetes Service (Amazon EKS), AWS Lambda, and on-premises servers. The guide is intended for operations teams, DevOps engineers, and application engineers that manage workloads on the AWS Cloud.

Your logging and monitoring approach should be based on the five pillars of the AWS Well-Architected Framework. These pillars are operational excellence, security, reliability, performance efficiency, and cost optimization. A well-architected monitoring and alarming solution improves reliability and performance by helping you proactively analyze and adjust your infrastructure.

This guide doesn't extensively discuss logging and monitoring for security or cost-optimization because these are topics that require in-depth evaluation. There are many AWS services that support security logging and monitoring, including AWS CloudTrail, AWS Config, Amazon Inspector, Amazon Detective, Amazon Macie, Amazon GuardDuty, and AWS Security Hub. You can also use AWS Cost Explorer, AWS Budgets, and CloudWatch billing metrics for cost optimization.

The following table outlines the six areas that your logging and monitoring solution should address.

Capturing and ingesting log files and metrics	Identify, configure, and send system and application logs and metrics to AWS services from different sources.
Searching and analyzing logs	Search and analyze logs for operations management, problem identification, troubleshooting, and applications analysis.
Monitoring metrics and alarming	Identify and act on observations and trends in your workloads.
Monitoring application and service availability	Reduce downtime and improve your ability to meet service level targets by continuously monitoring service availability.
Tracing applications	Trace application requests in systems and external dependencies to fine-tune performance, perform root cause analysis, and troubleshoot issues.
Creating dashboards and visualizations	Create dashboards that focus on relevant metrics and observations for your systems and workloads, which helps continuous improvement and proactive discovery of issues.

CloudWatch can meet most logging and monitoring requirements, and provides a reliable, scalable, and flexible solution. Many AWS services automatically provide CloudWatch metrics, in addition to CloudWatch logging integration for monitoring and analysis. CloudWatch also provides agents and log drivers to support a variety of compute options such as servers (both in the cloud and on premises), containers, and serverless computing. This guide also covers the following AWS services that are used with logging and monitoring:

- AWS Systems Manager Distributor, Systems Manager State Manager, and Systems Manager Automation to automate, configure, and update the CloudWatch agent for your EC2 instances and on-premises servers
- Amazon OpenSearch Service (successor to Amazon Elasticsearch Service) for advanced log aggregation, search, and analysis
- Amazon Route 53 health checks and CloudWatch Synthetics to monitor application and service availability
- Amazon Managed Service for Prometheus for monitoring containerized applications at scale
- AWS X-Ray for application tracing and runtime analysis
- Amazon Managed Grafana to visualize and analyze data from multiple sources (for example, CloudWatch, Amazon OpenSearch Service, and Amazon Timestream)

The AWS compute services that you choose also affect the implementation and configuration of your logging and monitoring solution. For example, CloudWatch's implementation and configuration is different for Amazon EC2, Amazon ECS, Amazon EKS, and Lambda.

Application and workload owners can often forget about logging and monitoring or inconsistently configure and implement it. This means that workloads enter production with limited observability, which causes delays in identifying issues and increases the time taken to troubleshoot and resolve them. At a minimum, your logging and monitoring solution must address the systems layer for the operating system (OS)-level logs and metrics, in addition to the application layer for application logs and metrics. The guide provides a recommended approach for addressing these two layers across different compute types, including the three compute types outlined in the following table.

Long-running and immutable EC2 instances	System and application logs and metrics across multiple operating systems (OSs) in multiple AWS Regions or accounts.
Containers	System and application logs and metrics for your Amazon ECS and Amazon EKS clusters, including examples for different configurations.
Serverless	System and application logs and metrics for your Lambda functions and considerations for customization.

This guide provides a logging and monitoring solution that addresses CloudWatch and related AWS services in the following areas:

- Planning your CloudWatch deployment (p. 6) – Considerations for planning your CloudWatch deployment and guidance on centralizing your CloudWatch configuration.
- Configuring the CloudWatch agent for EC2 instances and on-premises servers (p. 11) – CloudWatch configuration details for system-level and application-level logging and metrics.
- CloudWatch agent installation approaches for Amazon EC2 and on-premises servers (p. 20) – Approaches for installing the CloudWatch agent, including automated deployment using Systems Manager across multiple Regions and accounts.

- Logging and monitoring on Amazon ECS (p. 29) – Guidance for configuring CloudWatch for cluster-level and application-level logging and metrics in Amazon ECS.
- Logging and monitoring on Amazon EKS (p. 33) – Guidance for configuring CloudWatch for cluster-level and application-level logging and metrics in Amazon EKS.
- Prometheus monitoring on Amazon EKS (p. 38) – Introduces and compares Amazon Managed Service for Prometheus with CloudWatch Container Insights monitoring for Prometheus.
- Logging and metrics for AWS Lambda (p. 39) – Guidance for configuring CloudWatch for your Lambda functions.
- Searching and analyzing logs in CloudWatch (p. 42) – Methods to analyze your logs using Amazon CloudWatch Application Insights, CloudWatch Logs Insights, and extending log analysis to Amazon OpenSearch Service.
- Alarming options with CloudWatch (p. 47) – Introduces CloudWatch Alarms and CloudWatch Anomaly Detection and provides guidance on alarm creation and setup.
- Monitoring application and service availability (p. 49) – Introduces and compares CloudWatch Synthetics and Route 53 health checks for automated availability monitoring.
- Tracing applications with AWS X-Ray (p. 50) – Introduction and setup for application tracing using X-Ray for Amazon EC2, Amazon ECS, Amazon EKS, and Lambda
- Dashboards and visualizations with CloudWatch (p. 53) – Introduction to CloudWatch Dashboards for improved observability across AWS workloads.
- CloudWatch integration with AWS services (p. 56) – Explains how CloudWatch integrates with various AWS services.
- Amazon Managed Grafana for dashboarding and visualization (p. 57) – Introduces and compares Amazon Managed Grafana with CloudWatch for dashboarding and visualization.

Implementation examples are used throughout this guide across these areas and are also available from the AWS Samples GitHub repository.

Targeted business outcomes

Creating a logging and monitoring solution designed for the AWS Cloud is integral for achieving the six advantages of cloud computing. Your logging and monitoring solution should help your IT organization achieve business outcomes that benefit your business processes, business partners, employees, and customers. You can expect the following four outcomes after implementing a logging and monitoring solution aligned with the AWS Well-Architected Framework:

Accelerate operational readiness

Enabling a logging and monitoring solution is an important component of preparing a workload for production support and use. Operational readiness can quickly become a bottleneck if you rely too heavily on manual processes and can also reduce the time to value (TTV) for your IT investments. An ineffective approach also results in limited observability of your workloads. This can increase the risk of prolonged outages, customer dissatisfaction, and failed business processes.

You can use this guide's approaches to standardize and automate your logging and monitoring on the AWS Cloud. New workloads then require minimal manual preparation and intervention for production logging and monitoring. This also helps reduce the time and steps required to create logging and monitoring standards at scale for different workloads across multiple accounts and Regions.

Improve operational excellence

This guide provides multiple best practices for logging and monitoring that help diverse workloads meet business objectives and operational excellence. This guide also provides detailed examples and open-source, reusable templates that you can use with an infrastructure as code (IaC) approach to implement a well-architected logging and monitoring solution using AWS services. Improving operational excellence is iterative and requires continuous improvement. The guide provides suggestions on how to continuously improve logging and monitoring practices.

Enhance operational visibility

Your business processes and applications might be supported by different IT resources and hosted on different compute types, either on premises or on the AWS Cloud. Your operational visibility can be limited by inconsistent and incomplete implementations of your logging and monitoring strategy. Adopting a comprehensive logging and monitoring approach helps you quickly identify, diagnose, and respond to issues across your workloads. This guide helps you design and implement approaches to improve your complete operational visibility and reduce the mean time to resolve (MTTR) failures. A comprehensive logging and monitoring approach also helps your organization improve service quality, enhance end-user experience, and meet service-level agreements (SLAs).

Scale operations and reduce overhead costs

You can scale the logging and monitoring practices from this guide to support multiple Regions and accounts, short-lived resources, and multiple environments. The guide provides approaches and examples to automate manual steps (for example installing and configuring agents, monitoring metrics,

and notifying or taking action when issues occur). These approaches are helpful when your cloud adoption matures and grows and you need to scale operational capability without increasing cloud management activities or resources.

Planning your CloudWatch deployment

The complexity and scope of a logging and monitoring solution depends on several factors, including:

- How many environments, Regions, and accounts are used and how this number might increase.
- The variety and types of your existing workloads and architectures.
- The compute types and OSs that must be logged and monitored.
- Whether there are both on-premises locations and AWS infrastructure.
- The aggregation and analytic requirements of multiple systems and applications.
- Security requirements that prevent unauthorized exposure of logs and metrics.
- Products and solutions that must integrate with your logging and monitoring solution to support operational processes.

You must regularly review and update your logging and monitoring solution with new or updated workload deployments. Updates to your logging, monitoring, and alarming should be identified and applied when issues are observed. These issues can then be proactively identified and prevented in the future.

You must make sure that you consistently install and configure software and services for capturing and ingesting logs and metrics. An established logging and monitoring approach uses multiple AWS or independent software vendor (ISV) services and solutions for different domains (for example, security, performance, networking, or analytics). Each domain has its own deployment and configuration requirements.

We recommend using CloudWatch to capture and ingest logs and metrics for multiple OSs and compute types. Many AWS services use CloudWatch to log, monitor, and publish logs and metrics, without requiring further configuration. CloudWatch provides a software agent that can be installed and configured for different OSs and environments. The following sections outline how to deploy, install, and configure the CloudWatch agent for multiple accounts, Regions, and configurations:

Topics

Using CloudWatch in centralized or distributed accounts

Although CloudWatch is designed to monitor AWS services or resources in one account and Region, you can use a central account to capture logs and metrics from multiple accounts and Regions. If you use more than one account or Region, you should evaluate whether to use the centralized account approach or an individual account to capture logs and metrics. Typically, a hybrid approach is required for multi-account and multi-Region deployments to support the requirements of security, analytics, operations, and workload owners.

The following table provides areas to consider when choosing to use a centralized, distributed, or hybrid approach.

Account structures	Your organization might have several separate accounts (for example, accounts for non-production and production workloads) or thousands of accounts for single applications in specific environments. We recommend that you maintain application logs and metrics in the account that the workload runs on, which gives workload owners access to the logs and metrics. This enables them to have an active role in logging and monitoring. We also recommend that you use a separate logging account to aggregate all workload logs for analysis, aggregation, trends, and centralized operations. Separate logging accounts can also be used for security, archiving and monitoring, and analytics.
Access requirements	Team members (for example, workload owners or developers) require access to logs and metrics to troubleshoot and make improvements. Logs should be maintained in the workload's account to make access and troubleshooting easier. If logs and metrics are maintained in a separate account from the workload, users might need to regularly alternate between accounts. Using a centralized account provides log information to authorized users without granting access to the workload account. This can simplify access requirements for analytic workloads where aggregation is required from workloads running in multiple accounts. The centralized logging account can also have alternative search and aggregation options, such as an Amazon OpenSearch Service cluster. Amazon OpenSearch Service provides fine-grained access control down to the field level for your logs. Fine-grained access control is important when you have sensitive or confidential data that requires specialized access and permissions.
Operations	Many organizations have a centralized operations and security team or an external organization for operational support that requires access to logs for monitoring. Centralized logging and monitoring can make it easier to identify trends, search, aggregate, and perform analytics across all accounts and workloads. If your organization uses the "you build it, you run it" approach for DevOps, then workload owners require logging and monitoring information in their account. A hybrid approach might be required to satisfy central operations and analytics, in addition to distributed workload ownership.
Environment	You can choose to host logs and metrics in a central location for production accounts and keep logs and metrics for other environments (for example, development or testing) in the same or separate accounts, depending on security requirements and account architecture. This helps prevent sensitive data created during production from being accessed by a broader audience.

CloudWatch provides multiple options to process logs in real time with CloudWatch subscription filters. You can use subscription filters to stream logs in real time to AWS services for custom processing, analysis, and loading to other systems. This can be particularly helpful if you take a hybrid approach

where your logs and metrics are available in individual accounts and Regions, in addition to a centralized account and Region. The following list provides examples of AWS services that can be used for this:

- Amazon Kinesis Data Firehose – Kinesis Data Firehose provides a streaming solution that automatically scales and resizes based on the data volume being produced. You don't need to manage the number of shards in an Amazon Kinesis data stream and you can directly connect to Amazon Simple Storage Service (Amazon S3), Amazon OpenSearch Service, or Amazon Redshift with no additional coding. Kinesis Data Firehose is an effective solution if you want to centralize your logs in those AWS services.
- Amazon Kinesis Data Streams – Kinesis Data Streams is an appropriate solution if you need to integrate with a service that Kinesis Data Firehose doesn't support and implement additional processing logic. You can create an Amazon CloudWatch Logs destination in your accounts and Regions that specifies a Kinesis data stream in a central account and an AWS Identity and Access Management (IAM) role that grants it permission to place records in the stream. Kinesis Data Streams provides a flexible, open-ended landing zone for your log data that can then be consumed by different options. You can read the Kinesis Data Streams log data into your account, perform preprocessing, and send the data to your chosen destination.

  However, you must configure the shards for the stream so that it is appropriately sized for the log data that is produced. Kinesis Data Streams acts as a temporary intermediary or queue for your log data, and you can store the data within the Kinesis stream for between one to 365 days. Kinesis Data Streams also supports replay capability, which means you can replay data that was not consumed.
- Amazon OpenSearch Service (successor to Amazon Elasticsearch Service) – CloudWatch Logs can stream logs in a log group to an OpenSearch cluster in an individual or centralized account. When you configure a log group to stream data to an OpenSearch cluster, a Lambda function is created in the same account and Region as your log group. The Lambda function must have a network connection with the OpenSearch cluster. You can customize the Lambda function to perform additional preprocessing, in addition to customizing the ingestion into Amazon OpenSearch Service. Centralized logging with Amazon OpenSearch Service makes it easier to analyze, search, and troubleshoot issues across multiple components in your cloud architecture.
- Lambda – If you use Kinesis Data Streams, you need to provision and manage compute resources that consume data from your stream. To avoid this, you can stream log data directly to Lambda for processing and send it to a destination based on your logic. This means that you don't need to provision and manage compute resources to process incoming data. If you choose to use Lambda, make sure that your solution is compatible with Lambda quotas.

You might need to process or share log data stored in CloudWatch Logs in file format. You can create an export task to export a log group to Amazon S3 for a specific date or time range. For example, you might choose to export logs on a daily basis to Amazon S3 for analytics and auditing. Lambda can be used to automate this solution. You can also combine this solution with Amazon S3 replication to ship and centralize your logs from multiple accounts and Regions to one centralized account and Region.

The CloudWatch agent configuration can also specify a `credentials` field in the `agent` section. This specifies an IAM role to use when sending metrics and logs to a different account. If specified, this field contains the `role_arn` parameter. This field can be used when you only need centralized logging and monitoring in a specific centralized account and Region.

You can also use AWS SDK to write your own custom processing application in a language of your choice, read logs and metrics from your accounts, and send data to a centralized account or other destination for further processing and monitoring.

Creating and storing standard CloudWatch agent configuration files

We recommend that you create a standard CloudWatch agent configuration file that includes the system logs and metrics that you want to capture across all your EC2 instances and on-premises servers. You can use the CloudWatch agent configuration file wizard to help you create the configuration file. You can run the configuration wizard multiple times to generate unique configurations for different systems and environments. You can also modify the configuration file or create variations by using the configuration file schema. The CloudWatch agent configuration file can be stored in AWS Systems Manager Parameter Store. However, this approach is harder to scale across multiple accounts and Regions because parameter values must be created and synchronized in each account and Region.

The `amazon-cloudwatch-agent-ctl` script included with the CloudWatch agent allows you to specify a configuration file, Parameter Store parameter, or the agent's default configuration. The default configuration aligns to the basic, predefined metric set and configures the agent to report memory and disk space metrics to CloudWatch. However, it doesn't include any log file configurations. The default configuration is also applied if you use Systems Manager Quick Setup for the CloudWatch agent.

Because the default configuration doesn't include logging and isn't customized for your requirements, we recommend that you create and load your configuration files by including them in the CloudWatch configuration file directory. For Linux, the CloudWatch configuration directory is found at `/opt/aws/amazon-cloudwatch-agent/etc/amazon-cloudwatch-agent.d`. For Windows, the configuration directory is found at `C:\ProgramData\Amazon\AmazonCloudWatchAgent\Configs`.

When you start the CloudWatch agent, the agent automatically appends each file found in these directories to create a CloudWatch composite configuration file. The configuration files should be stored in a central location (for example, an S3 bucket) that can be accessed by your required accounts and Regions. They should also be copied to the CloudWatch configuration file directory. For more information about this approach, see the Set up State Manager and Distributor for CloudWatch agent deployment and configuration (p. 21) section of this guide.

Storing CloudWatch configuration files in an S3 bucket

We recommend that you use CloudWatch configuration files instead of Parameter Store parameters for the following reasons:

- If you use multiple Regions, you must synchronize CloudWatch configuration updates in each Region's Parameter Store. Parameter Store is a Regional service and the same parameter must be updated in each Region that uses the CloudWatch agent.
- If you have multiple CloudWatch configurations, you must initiate the retrieval and application of each Parameter Store configuration. You must individually retrieve each CloudWatch configuration from the Parameter Store and also update the retrieval method whenever you add a new configuration. In contrast, CloudWatch provides a configuration directory for storing configuration files and applies each configuration in the directory, without requiring them to be individually specified.
- If you use multiple accounts, you must ensure that each new account has the required CloudWatch configurations in its Parameter Store. You also need to make sure that any configuration changes are applied to these accounts and their Regions in the future.

You can store CloudWatch configurations in an S3 bucket that is accessible from all your accounts and Regions. You can then copy these configurations from the S3 bucket to the CloudWatch configuration directory by using Systems Manager Automation runbooks and Systems Manager State Manager. You can use the cloudwatch-config-s3-bucket.yaml AWS CloudFormation template to create an S3 bucket that is

accessible from multiple accounts within an organization in AWS Organizations. The template includes an `OrganizationID` parameter that grants read access to all accounts within your organization.

After you create the S3 bucket, you can create a key or folder prefix structure to store your CloudWatch configuration files. The following table outlines a sample folder structure.

/config/standard/windows/ec2	Store standard Windows-specific CloudWatch configuration files for Amazon EC2. You can also further categorize your standard OS configurations for different Windows versions, EC2 instance types, and environments under this folder.
/config/standard/windows/onpremises	Store standard Windows-specific CloudWatch configuration files for on-premises servers. You can also further categorize your standard OS configurations for different Windows versions, server types, and environments under this folder.
/config/standard/linux/ec2	Store your standard Linux-specific CloudWatch configuration files for Amazon EC2. You can also further categorize your standard OS configuration for different Linux distributions, EC2 instance types, and environments under this folder.
/config/standard/linux/onpremises	Store your standard Linux-specific CloudWatch configuration files for on-premises servers. You can also further categorize your standard OS configuration for different Linux distributions, server types, and environments under this folder.
/config/ecs	Store CloudWatch configuration files that are specific to Amazon ECS if you use Amazon ECS container instances. These configurations can be appended to the standard Amazon EC2 configurations for Amazon ECS specific systems-level logging and monitoring.
/config/<application_name>	Store your application-specific CloudWatch configuration files. You can also further categorize your applications with additional folders and prefixes for environments and versions.

The augmented sample Systems Manager runbook, provided in the Set up State Manager and Distributor for CloudWatch agent deployment and configuration (p. 21) section of this guide, is configured to retrieve files using the S3 bucket created by the cloudwatch-config-s3-bucket.yaml AWS CloudFormation template.

Alternatively, you can use a version control system (for example, GitHub or AWS CodeCommit) to store your configuration files. If you want to automatically retrieve configuration files stored in a version control system, you have to manage or centralize the credential storage and update the Systems Manager Automation runbook that is used to retrieve the credentials across your accounts and Regions

Configuring the CloudWatch agent for EC2 instances and on-premises servers

Many organizations run workloads on both physical servers and virtual machines (VMs). These workloads typically run on different OSs that each have unique installation and configuration requirements for capturing and ingesting metrics.

If you choose to use EC2 instances, you can have a high level of control over your instance and OS configuration. However, this higher level of control and responsibility requires you to monitor and adjust configurations to achieve more efficient usage. You can improve your operational effectiveness by establishing standards for logging and monitoring, and applying a standard installation and configuration approach for capturing and ingesting logs and metrics.

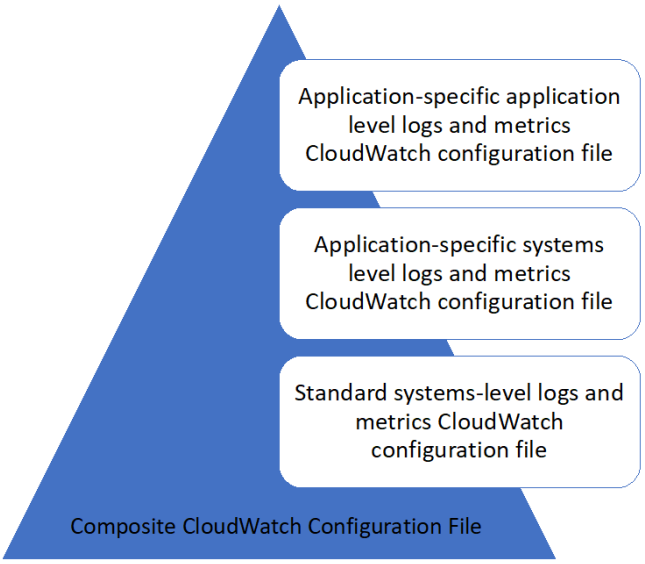
Organizations that migrate or extend their IT investments to the AWS Cloud can leverage CloudWatch to achieve a unified logging and monitoring solution. CloudWatch pricing means that you incrementally pay for the metrics and logs that you want to capture. You can also capture logs and metrics for on-premises servers by using a similar CloudWatch agent installation process as that for Amazon EC2.

Before you begin installing and deploying CloudWatch, make sure that you evaluate the logging and metric configurations for your systems and applications. Ensure that you define the standard logs and metrics that you need to capture for the OSs that you want to use. System logs and metrics are the foundation and standard for a logging and monitoring solution because they are generated by the OS and are different for Linux and Windows. There are important metrics and log files available across Linux distributions, in addition to those that are specific to a Linux version or distribution. This variance also occurs between different Windows versions.

Configuring the CloudWatch agent

CloudWatch captures metrics and logs for Amazon EC2 and on-premises servers by using CloudWatch agents and agent configuration files that are specific to each OS. We recommend that you define your organization's standard metric and log capture configuration before you begin installing the CloudWatch agent at scale in your accounts.

You can combine multiple CloudWatch agent configurations to form a composite CloudWatch agent configuration. One recommended approach is to define and divide configurations for your logs and metrics at the system and application level. The following diagram illustrates how multiple CloudWatch configuration file types for different requirements can be combined to form a composite CloudWatch configuration:



These logs and metrics can also be further classified and configured for specific environments or requirements. For example, you could define a smaller subset of logs and metrics with lower precision for unregulated development environments, and a larger, more complete set with higher precision for regulated production environments.

Configuring log capture for EC2 instances

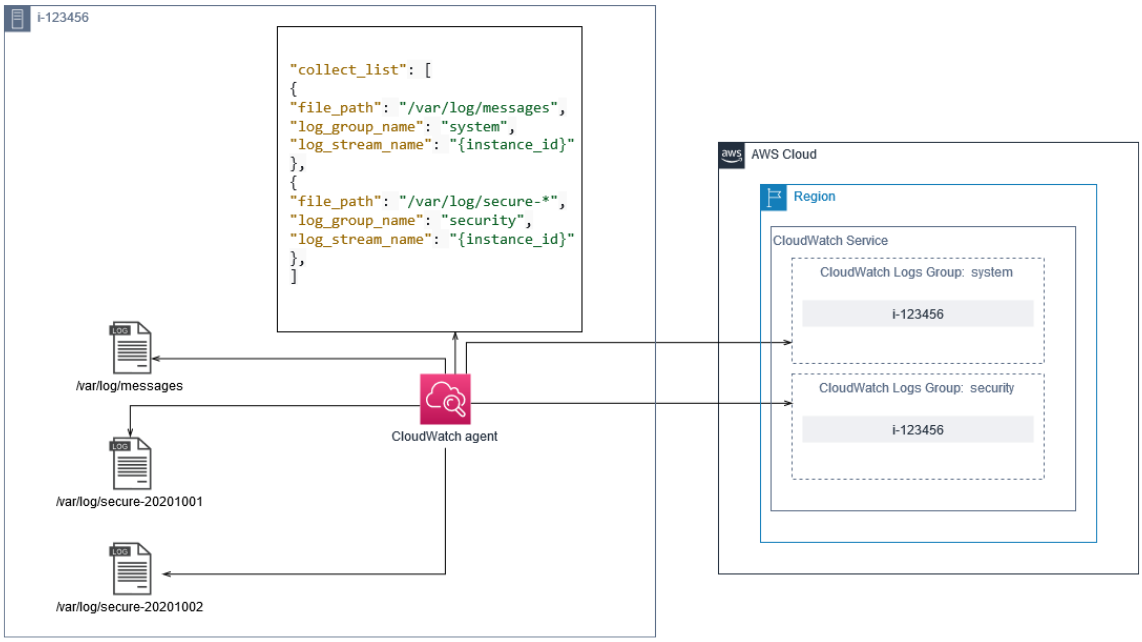
By default, Amazon EC2 doesn't monitor or capture log files. Instead, log files are captured and ingested into CloudWatch Logs by the CloudWatch agent software installed on your EC2 instance, AWS API, or AWS Command Line Interface (AWS CLI). We recommend using the CloudWatch agent to ingest log files into CloudWatch Logs for Amazon EC2 and on-premises servers.

You can search and filter logs, as well as extract metrics and run automation based on pattern patching from log files in CloudWatch. CloudWatch supports plaintext, space delimited, and JSON-formatted filter and pattern syntax options, with JSON-formatted logs providing the most flexibility. To increase the filtering and analysis options, you should use a formatted log output instead of plain text.

The CloudWatch agent uses a configuration file that defines the logs and metrics to send to CloudWatch. CloudWatch then captures each log file as a log stream and groups these log streams into a log group. This helps you perform operations across logs from your EC2 instances, such as searching for a matching string.

The default log stream name is the same as the EC2 instance ID and the default log group name is the same as the log file path. The log stream's name must be unique within the CloudWatch log group. You can use `instance_id`, `hostname`, `local_hostname`, or `ip_address` for dynamic substitution in the log stream and log group names, which means that you can use the same CloudWatch agent configuration file across multiple EC2 instances.

The following diagram shows a CloudWatch agent configuration for capturing logs. The log group is defined by the captured log files and contains separate log streams for each EC2 instance because the `{instance_id}` variable is used for the log stream name and EC2 instance IDs are unique.



Log groups define the retention, tags, security, metric filters, and search scope for the log streams that they contain. The default grouping behavior based on the log file name helps you search, create metrics, and alarm on data that is specific to a log file across EC2 instances in an account and Region. You should evaluate whether further log group refinement is required. For example, your account might be shared by multiple business units and have different technical or operations owners. This means that you must further refine the log group name to reflect the separation and ownership. This approach allows you to concentrate your analysis and troubleshooting on the relevant EC2 instance.

If multiple environments use one account, you can separate the logging for workloads that run in each environment. The following table shows a log group naming convention that includes the business unit, project or application, and environment.

Log group name	`/<Business unit>/<Project or application name>/<Environment>/<Log file name>`
Log stream name	`<EC2 instance ID>`

You can also group all log files for an EC2 instance into the same log group. This makes it easier to search and analyze across a set of log files for a single EC2 instance. This is useful if most of your EC2 instances service one application or workload and each EC2 instance serves a specific purpose. The following table shows how your log group and log stream naming could be formatted to support this approach.

Log group name	`/<Business unit>/<Project or application name>/<Environment>/<EC2 instance ID>`
Log stream name	`<Log file name>`

Configuring metrics capture for EC2 instances

By default, your EC2 instances are enabled for basic monitoring and a standard set of metrics (for example, CPU, network, or storage-related metrics) is automatically sent to CloudWatch every five minutes. CloudWatch metrics can vary depending on the instance family, for example, burstable performance instances have metrics for CPU credits. Amazon EC2 standard metrics are included in your instance price. If you enable detailed monitoring for your EC2 instances, you can receive data in one-minute periods. The period frequency impacts your CloudWatch costs, so make sure that you evaluate whether detailed monitoring is required for all or only some of your EC2 instances. For example, you could enable detailed monitoring for production workloads but use basic monitoring for non-production workloads.

On-premises servers don't include any default metrics for CloudWatch and must use the CloudWatch agent, AWS CLI, or AWS SDK to capture metrics. This means that you must define the metrics that you want to capture (for example, CPU utilization) in the CloudWatch configuration file. You can create a unique CloudWatch configuration file that includes the standard EC2 instance metrics for your on-premises servers and apply it in addition to your standard CloudWatch configuration.

Metrics in CloudWatch are uniquely defined by metric name and zero or more dimensions, and are uniquely grouped in a metric namespace. Metrics provided by an AWS service have a namespace that begins with `AWS` (for example, `AWS/EC2`), and non-AWS metrics are considered custom metrics. Metrics that you configure and capture with the CloudWatch agent are all considered custom metrics. Because the number of created metrics impacts your CloudWatch costs, you should evaluate whether each metric is required for all or only some of your EC2 instances. For example, you could define a complete set of metrics for production workloads but use a smaller subset of these metrics for non-production workloads.

`CWAgent` is the default namespace for metrics published by the CloudWatch agent. Similar to log groups, the metric namespace organizes a set of metrics so that they can be found together in one place. You should modify the namespace to reflect a business unit, project or application, and environment (for example, `/<Business unit>/<Project or application name>/<Environment>`). This approach is useful if multiple unrelated workloads use the same account. You can also correlate your namespace naming convention to your CloudWatch log group naming convention.

Metrics are also identified by their dimensions, which help you analyze them against a set of conditions and are the properties that observations are recorded against. Amazon EC2 includes separate metrics for EC2 instances with `InstanceId`and `AutoScalingGroupName` dimensions. You also receive metrics with the `ImageId` and `InstanceType` dimensions if you enable detailed monitoring. For example, Amazon EC2 provides a separate EC2 instance metric for the CPU utilization with the `InstanceId` dimensions, in addition to separate CPU utilization metric for the `InstanceType` dimension. This helps you analyze CPU utilization for each unique EC2 instance, in addition to all EC2 instances of a specific instance type.

Adding more dimensions increases your analysis capability but also increases your overall costs, because each metric and unique dimension value combination results in a new metric. For example, if you create a metric for the memory utilization percentage against the `InstanceId` dimension, then this is a new metric for each EC2 instance. If your organization runs thousands of EC2 instances, this causes thousands of metrics and results in higher costs. To control and predict costs, make sure that you determine the metric's cardinality and which dimensions add the most value. For example, you could define a complete set of dimensions for your production workload metrics but a smaller subset of these dimensions for non-production workloads.

You can use the `append_dimensions` property to add dimensions to one or all metrics defined in your CloudWatch configuration. You can also dynamically append the `ImageId`, `InstanceId`, `InstanceType`, and `AutoScalingGroupName` to all metrics in your CloudWatch configuration. Alternatively, you can append an arbitrary dimension name and value for specific metrics by using the `append_dimensions` property on that metric. CloudWatch can also aggregate statistics on metric dimensions that you defined with the `aggregation_dimensions` property.

For example, you could aggregate the memory used against the `InstanceType` dimension to see the average memory used by all EC2 instances for each instance type. If you use `t2.micro` instances running in a Region, you could determine if workloads using the `t2.micro` class are overutilizing or underutilizing the memory provided. Underutilization might be a sign of workloads using EC2 classes with an unrequired memory capacity. In contrast, overutilization might be a sign of workloads using Amazon EC2 classes with insufficient memory.

The following diagram shows a sample CloudWatch metrics configuration that uses a custom namespace, added dimensions, and aggregation by `InstanceType`.

System-level CloudWatch configuration

Systems-level metrics and logs are a central component of a monitoring and logging solution, and the CloudWatch agent has specific configuration options for Windows and Linux.

We recommend that you use the CloudWatch configuration file wizard or configuration file schema to define the CloudWatch agent configuration file for each OS that you plan to support. Additional workload-specific, OS-level logs and metrics can be defined in separate CloudWatch configuration files and appended to the standard configuration. These unique configuration files should be separately stored in an S3 bucket where they can be retrieved by your EC2 instances. An example of an S3 bucket setup for this purpose is described in the Storing CloudWatch configuration files in an S3 bucket (p. 9) section of this guide. You can automatically retrieve and apply these configurations using State Manager and Distributor.

Configuring system-level logs

System-level logs are essential for diagnosing and troubleshooting issues on premises or on the AWS Cloud. Your log capture approach should include any system and security logs generated by the OS. The OS-generated log files might be different depending on the OS version.

The CloudWatch agent supports monitoring Windows event logs by providing the event log name. You can choose which Windows event logs you want to monitor (for example `System`, `Application`, or `Security`).

The system, application, and security logs for Linux systems are typically stored in the `/var/log` directory. The following table defines the common default log files that you should monitor, but you should check the `/etc/rsyslog.conf` or `/etc/syslog.conf` file to determine the specific setup for your system's log files.

Fedora distribution	`/var/log/boot.log*` – Bootup log

(Amazon Linux, CentOS, Red Hat Enterprise Linux)	`/var/log/dmesg` – Kernel log
	`/var/log/secure` – Security and authentication log
	`/var/log/messages` – General system log
	`/var/log/cron*` – Cron Logs
	`/var/log/cloud-init-output.log` – Output from `Userdata` startup scripts
Debian (Ubuntu)	`/var/log/syslog` – Bootup log
	`/var/log/cloud-init-output.log` – Output from `Userdata` startup scripts
	`/var/log/auth.log` – Security and authentication log
	`/var/log/kern.log` – Kernel log

Your organization might also have other agents or system components that generate logs you want to monitor. You should evaluate and decide which log files are generated by these agents or applications, and include them in your configuration by identifying their file location. For example, you should include the Systems Manager and CloudWatch agent logs in your configuration. The following table provides the location of these agent logs for Windows and Linux.

Windows	CloudWatch agent	`$Env:ProgramData\Amazon\AmazonCloudWatchAgent\Logs\amazon-cloudwatch-agent.log`

	Systems Manager agent	`%PROGRAMDATA%\Amazon\SSM\Logs\amazon-ssm-agent.log`
		
		`%PROGRAMDATA%\Amazon\SSM\Logs\errors.log`
		
		`%PROGRAMDATA%\Amazon\SSM\Logs\audits\amazon-ssm-agent-audit-YYYY-MM-DD`

Linux	CloudWatch agent	`/opt/aws/amazon-cloudwatch-agent/logs/amazon-cloudwatch-agent.log`

	Systems Manager agent	`/var/log/amazon/ssm/amazon-ssm-agent.log`
		
		`/var/log/amazon/ssm/errors.log`
		
		`/var/log/amazon/ssm/audits/amazon-ssm-agent-audit-YYYY-MM-DD`

CloudWatch ignores a log file if the log file is defined in the CloudWatch agent configuration but isn't found. This is useful when you want to maintain a single log configuration for Linux, instead of separate configurations for each distribution. It is also useful when a log file doesn't exist until the agent or software application starts running.

Configuring system-level metrics

Memory and disk space utilization aren't included in standard metrics provided by Amazon EC2. To include these metrics, you must install and configure the CloudWatch agent on your EC2 instances. The CloudWatch agent configuration wizard creates a CloudWatch configuration with predefined metrics and you can add or remove metrics as required. Make sure that you review the predefined metric sets to determine the appropriate level that you require.

End users and workload owners should publish additional system metrics based on specific requirements for a server or EC2 instance. These metric definitions should be stored, versioned, and maintained in a separate CloudWatch agent configuration file, and shared in a central location (for example, Amazon S3) for reuse and automation.

Standard Amazon EC2 metrics are not automatically captured in on-premises servers. These metrics must be defined in a CloudWatch agent configuration file used by the on-premises instances. You can create a separate metric configuration file for on-premises instances with metrics such as CPU utilization, and have these metrics appended to the standard metrics configuration file.

Application-level CloudWatch configuration

Application logs and metrics are generated by running applications and are application specific. Make sure that you define the logs and metrics required to adequately monitor applications that are regularly used by your organization. For example, your organization might have standardized on Microsoft Internet Information Server (IIS) for web-based applications. You can create a standard log and metric CloudWatch configuration for IIS that can also be used across your organization. Application-specific configuration files can be stored in a centralized location (for example, an S3 bucket) and are accessed by workload owners or through automated retrieval, and copied to the CloudWatch configuration directory. The CloudWatch agent automatically combines CloudWatch configuration files found in the configuration file directory of each EC2 instance or server into a composite CloudWatch configuration. The end result is a CloudWatch configuration that includes your organization's standard system-level configuration, as well as all relevant application-level CloudWatch configurations.

Workload owners should identify and configure log files and metrics for all critical applications and components.

Configuring application-level logs

Application-level logging varies depending on whether the application is a commercial off-the-shelf (COTS) or custom developed application. COTS applications and their components might provide several options for log configuration and output, such as log detail level, log file format, and log file location. However, most COTS or third-party applications don't allow you to fundamentally change the logging (for example, updating the application's code to include additional log statements or formats that are not configurable). At a minimum, you should configure logging options for COTS or third-party applications to log warning and error-level information, preferably in JSON format.

You can integrate custom-developed applications with CloudWatch Logs by including the application's log files in your CloudWatch configuration. Custom applications provide better log quality and control because you can customize the log output format, categorize and separate component output to separate log files, in addition to including any additional required details. Make sure that you review

and standardize on logging libraries and the required data and formatting for your organization so that analytics and processing become easier.

You can also write to a CloudWatch log stream with the CloudWatch Logs `PutLogEvents` API call or by using the AWS SDK. You can use the API or SDK for custom logging requirements, such as coordinating logging to a single log stream across a distributed set of components and servers. However, the easiest to maintain and most widely applicable solution is to configure your applications to write to log files and then use the CloudWatch agent to read and stream the log files to CloudWatch.

You should also consider the kind of metrics that you want to measure from your application log files. You can use metric filters to measure, graph, and alarm on this data in a CloudWatch log group. For example, you can use a metric filter to count failed login attempts by identifying them in your logs.

You can also create custom metrics for your custom-developed applications by using the CloudWatch embedded metric format in your application log files.

Configuring application-level metrics

Custom metrics are metrics that aren't directly provided by AWS services to CloudWatch and they are published in a custom namespace in CloudWatch metrics. All application metrics are considered custom CloudWatch metrics. Application metrics might align to an EC2 instance, application component, API call, or even a business function. You must also consider the importance and cardinality of the dimensions that you choose for your metrics. Dimensions with high cardinality generate a large number of custom metrics and could increase your CloudWatch costs.

CloudWatch helps you capture application-level metrics in multiple ways, including the following:

- Capture process-level metrics by defining the individual processes that you want to capture from the procstat plugin.
- An application publishes a metric to Windows Performance Monitor and this metric is defined in the CloudWatch configuration.
- Metric filters and patterns are applied against an application's logs in CloudWatch.
- An application writes to a CloudWatch log by using the CloudWatch embedded metric format.
- An application sends a metric to CloudWatch through the API or AWS SDK.
- An application sends a metric to a collectd or StatsD daemon with a configured CloudWatch agent.

You can use procstat to monitor and measure critical application processes with the CloudWatch agent. This helps you to raise an alarm and take action (for example, a notification or restart process) if a critical process is no longer running for your application. You can also measure the performance characteristics of your application processes and raise an alarm if a particular process is acting abnormally.

Procstat monitoring is also useful if you can't update your COTS applications with additional custom metrics. For example, you can create a `my_process` metric that measures the `cpu_time` and includes a custom `application_version` dimension. You can also use multiple CloudWatch agent configuration files for an application if you have different dimensions for different metrics.

If your application runs on Windows, you should evaluate if it already publishes metrics to Windows Performance Monitor. Many COTS applications integrate with Windows Performance Monitor, which helps you easily monitor application metrics. CloudWatch also integrates with Windows Performance Monitor and you can capture any metrics that are already available in it.

Make sure that you review the logging format and log information provided by your applications to determine which metrics can be extracted with metric filters. You could review historical logs for the application to determine how error messages and abnormal shutdowns are represented. You should also review previously reported issues to determine if a metric could be captured to prevent the issue from

recurring. You should also review the application's documentation and ask the application developers to confirm how error messages can be identified.

For custom-developed applications, work with the application's developers to define important metrics that can be implemented by using the CloudWatch embedded metric format, AWS SDK, or AWS API. The recommended approach is to use the embedded metric format. You can use the AWS provided open-source embedded metric format libraries to help you write your statements in the required format. You would also need to update your application-specific CloudWatch configuration to include the embedded metric format agent. This causes the agent running on the EC2 instance to act as a local embedded metric format endpoint that sends embedded metric format metrics to CloudWatch.

If your applications already support publishing metrics to collectd or statsd, you can leverage them to ingest metrics into CloudWatch.

CloudWatch agent installation approaches for Amazon EC2 and on-premises servers

Automating the CloudWatch agent's installation process helps you quickly and consistently deploy it and capture the required logs and metrics. There are several approaches for automating the CloudWatch agent installation, including multi-account and multi-Region support. The following automated installation approaches are discussed:

- **Installing the CloudWatch agent using Systems Manager Distributor and Systems Manager State Manager (p. 20)** – We recommend using this approach if your EC2 instances and on-premises servers are running the Systems Manager agent. This ensures that the CloudWatch agent is kept updated and you can report on and remediate servers that don't have the CloudWatch agent. This approach also scales to support multiple accounts and Regions.
- **Deploying the CloudWatch agent as a part of the user data script during EC2 instance provisioning (p. 27)** – Amazon EC2 allows you to define a startup script that is run when you first boot or reboot. You can define a script to automate the agent's download and installation process. This can also be included in AWS CloudFormation scripts and AWS Service Catalog products. This approach might be appropriate on an as-needed basis if there is a customized agent installation and configuration approach for a specific workload that deviates from your standards.
- **Including the CloudWatch agent in Amazon Machine Images (AMIs) (p. 27)** – You can install the CloudWatch agent in your custom AMIs for Amazon EC2. The EC2 instances that use the AMI will automatically have the agent installed and started. However, you must ensure the agent and its configuration are regularly updated.

Installing the CloudWatch agent using Systems Manager Distributor and State Manager

You can use Systems Manager State Manager with Systems Manager Distributor to automatically install and update the CloudWatch agent on servers and EC2 instances. Distributor includes the `AmazonCloudWatchAgent` AWS managed package that installs the most recent CloudWatch agent version.

This installation approach has the following prerequisites:

- The Systems Manager agent must be installed and running on your servers or EC2 instances. The Systems Manager agent is preinstalled on Amazon Linux, Amazon Linux 2, and some AMIs. The agent must also be installed and configured on other images or on-premises VMs and servers.
- An IAM role or credentials that have the required CloudWatch and Systems Manager permissions must be attached to the EC2 instance or defined in the credentials file for an on-premises server. For example, you can create an IAM role that includes the AWS managed policies: `AmazonSSMManagedInstanceCore` for Systems Manager and `CloudWatchAgentServerPolicy` for CloudWatch. You can use the ssm-cloudwatch-instance-role.yaml AWS CloudFormation template to deploy an IAM role and instance profile that includes both of these policies. This template can also be modified to include other standard IAM permissions for your EC2 instances. For on-premises servers or VMs, should configure the CloudWatch agent to use the Systems Manager service role that

was configured for the on-premises server. For more information about this, see How can I configure on-premises servers that use Systems Manager Agent and the unified CloudWatch agent to use only temporary credentials? in the AWS Knowledge Center.

The following list provides several advantages for using the Systems Manager Distributor and State Manager approach to install and maintain the CloudWatch agent:

- **Automated installation for multiple OSs** – You don't need to write and maintain a script for each OS to download and install the CloudWatch agent.
- **Automatic update checks** – State Manager automatically and regularly checks that each EC2 instance has the most recent CloudWatch version.
- **Compliance reporting** – The Systems Manager compliance dashboard shows which EC2 instances failed to successfully install the Distributor package.
- **Automated installation for newly launched EC2 instances** – New EC2 instances that are launched into your account automatically receive the CloudWatch agent.

However, you should also consider the following three areas before you choose this approach:

- **Collision with an existing association** – If another association already installs or configures the CloudWatch agent, then the two associations might interfere with each other and potentially cause issues. When using this approach, you should remove any existing associations that install or update the CloudWatch agent and configuration.
- **Updating custom agent configuration files** – Distributor performs an installation by using the default configuration file. If you use a custom configuration file or multiple CloudWatch configuration files, you must update the configuration after the installation.
- **Multi-Region or multi-account setup** – The State Manager association must be set up in each account and Region. New accounts in a multi-account environment must be updated to include the State Manager association. You need to centralize or synchronize the CloudWatch configuration so that multiple accounts and Regions can retrieve and apply your required standards.

Set up State Manager and Distributor for CloudWatch agent deployment and configuration

You can use Systems Manager Quick Setup to quickly configure Systems Manager features, including automatically installing and updating the CloudWatch agent on your EC2 instances. The Quick Setup deploys an AWS CloudFormation stack that deploys and configures Systems Manager resources based on your choices.

The following list provides two important actions that are performed by Quick Setup for automated CloudWatch agent installation and update:

1. **Create Systems Manager custom documents** – Quick Setup creates the following Systems Manager documents for use with State Manager. The document names might vary but the content remains the same:
   - `CreateAndAttachIAMToInstance` – Creates the `AmazonSSMRoleForInstancesQuickSetup` role and instance profile if they don't exist and attaches the `AmazonSSMManagedInstanceCore` policy to the role. This doesn't include the required `CloudWatchAgentServerPolicy` IAM policy. You must update this policy and update this Systems Manager document to include this policy as described in the following section.
   - `InstallAndManageCloudWatchDocument` – Installs the CloudWatch agent with Distributor and configures each EC2 instance one time with a default CloudWatch agent configuration using the `AWS-ConfigureAWSPackage` Systems Manager document.

- `UpdateCloudWatchDocument` – Updates the CloudWatch agent by installing the latest CloudWatch agent using the `AWS-ConfigureAWSPackage` Systems Manager document. Updating or uninstalling the agent doesn't remove the existing CloudWatch configuration files from the EC2 instance.

2. **Create State Manager associations** – State Manager associations are created and configured to use the custom created Systems Manager documents. The State Manager association names might vary but the configuration remains the same:
   - `ManageCloudWatchAgent` – Runs the `InstallAndManageCloudWatchDocument` Systems Manager document one time for each EC2 instance.
   - `UpdateCloudWatchAgent` – Runs the `UpdateCloudWatchDocument` Systems Manager document every 30 days for each EC2 instance.
   - Runs the `CreateAndAttachIAMToInstance` Systems Manager document one time for each EC2 instance.

You must augment and customize the completed Quick Setup configuration to include CloudWatch permissions and support custom CloudWatch configurations. In particular, the `CreateAndAttachIAMToInstance` and the `InstallAndManageCloudWatchDocument` document will need to be updated. You can manually update the Systems Manager documents created by Quick Setup. Alternatively, you can use your own CloudFormation template to provision the same resources with the necessary updates as well as configure and deploy other Systems Manager resources and not use Quick Setup.

> **Important**
> Quick Setup creates an AWS CloudFormation stack to deploy and configure Systems Manager resources based on your choices. If you update your Quick Setup choices, you might need to manually re-update the Systems Manager documents.

The following sections describe how to manually update the Systems Manager resources created by Quick Setup, as well as use your own AWS CloudFormation template to perform an updated Quick Setup. We recommend that you use your own AWS CloudFormation template to avoid manually updating resources created by Quick Setup and AWS CloudFormation.

Use Systems Manager Quick Setup and manually update the created Systems Manager resources

The Systems Manager resources created by the Quick Setup approach must be updated to include the required CloudWatch agent permissions and support multiple CloudWatch configuration files. This section describes how to update the IAM role and Systems Manager documents to use a centralized S3 bucket containing CloudWatch configurations that is accessible from multiple accounts. Creating an S3 bucket to store the CloudWatch configuration files is discussed in the Storing CloudWatch configuration files in an S3 bucket (p. 9) section of this guide.

Update the `CreateAndAttachIAMToInstance` Systems Manager document

This Systems Manager document created by Quick Setup checks whether an EC2 instance has an existing IAM instance profile attached to it. If it does, it attaches the `AmazonSSMManagedInstanceCore` policy to the existing role. This protects your existing EC2 instances from losing AWS permissions that might be assigned through existing instance profiles. You need to add a step in this document to attach the `CloudWatchAgentServerPolicy` IAM policy to EC2 instances that already have an instance profile attached. The Systems Manager document also creates the IAM role if it doesn't exist and an EC2 instance doesn't have an instance profile attached to it. You must update this section of the document to also include the `CloudWatchAgentServerPolicy` IAM policy.

Review the completed CreateAndAttachIAMToInstance.yaml sample document and compare it to the document created by Quick Setup. Edit the existing document to include the required steps and changes. Based on your Quick Setup choices the document created by Quick Setup might be different than the provided sample document, so ensure that you make the required adjustments. The sample document includes the Quick Setup option choice to scan instances for missing patches daily and therefore includes a policy for Systems Manager Patch Manager.

Update the `InstallAndManageCloudWatchDocument` Systems Manager document

This Systems Manager document created by Quick Setup installs the CloudWatch agent and configures it with the default CloudWatch agent configuration. The default CloudWatch configuration aligns to the basic, predefined metric set. You must replace the default configuration step and add steps to download your CloudWatch configuration files from your CloudWatch configuration S3 bucket.

Review the completed InstallAndManageCloudWatchDocument.yaml updated document and compare it to the document created by Quick Setup. The document created by your Quick Setup might be different, so make sure that you have made the required adjustments. Edit your existing document to include the necessary steps and changes.

Use AWS CloudFormation instead of Quick Setup

Instead of using Quick Setup, you can use AWS CloudFormation to configure Systems Manager. This approach allows you to customize your Systems Manager configuration according to your specific requirements. This approach also avoids manual updates to the configured Systems Manager resources created by Quick Setup to support custom CloudWatch configurations.

The Quick Setup feature also uses AWS CloudFormation and creates a AWS CloudFormation stack set to deploy and configure Systems Manager resources based on your choices. Before you can use AWS CloudFormation stack sets, you must create the IAM roles used by AWS CloudFormation StackSets to support deployments across multiple accounts or Regions. Quick Setup creates the roles it requires to support multi-Region or multi-account deployments with AWS CloudFormation StackSets. You must complete the prerequisites for AWS CloudFormation StackSets if you want to configure and deploy Systems Manager resources in multiple Regions or multiple accounts from a single account and Region. For more information about this, see Prerequisites for stack set operations in the AWS CloudFormation documentation.

Review the AWS-QuickSetup-SSMHostMgmt.yaml AWS CloudFormation template for customized Quick Setup.

You should review the resources and capabilities in the AWS CloudFormation template and make adjustments according to your requirements. You should version control the AWS CloudFormation template that you use and incrementally test changes to confirm the required result. Additionally, you should perform cloud security reviews to determine if there are any policy adjustments that are required based on your organization's requirements.

You should deploy the AWS CloudFormation stack in a single test account and Region, and perform any necessary test cases to customize and confirm the desired result. You can then graduate your deployment to multiple Regions in a single account, and then to multiple accounts and multiple regions.

Customized Quick Setup in a single account and Region with an AWS CloudFormation stack

If you are only use a single account and Region, you can deploy the complete example as a AWS CloudFormation stack instead of an AWS CloudFormation stack set. However if possible, we recommend that you use the multi-account, multi-Region stack set approach even if only use a single account and

Region. Using AWS CloudFormation StackSets makes it easier to expand to additional accounts and Regions in the future.

Use the following steps to deploy the AWS-QuickSetup-SSMHostMgmt.yaml AWS CloudFormation template as an AWS CloudFormation stack in a single account and Region:

1. Download the template and check it into your preferred version control system (for example, AWS CodeCommit).
2. Customize the default AWS CloudFormation parameter values based on your organization's requirements.
3. Customize the State Manager association schedules.
4. Customize the Systems Manager document with the `InstallAndManageCloudWatchDocument` logical ID. Confirm that the S3 bucket prefixes align to the prefixes for the S3 bucket containing your CloudWatch configuration.
5. Retrieve and record the Amazon Resource Name (ARN) for the S3 bucket containing your CloudWatch configurations. For more information about this, see the Storing CloudWatch configuration files in an S3 bucket (p. 9) section of this guide. A sample cloudwatch-config-s3-bucket.yaml AWS CloudFormation template is available that includes a bucket policy to provide read access to AWS Organizations accounts.
6. Deploy the customized Quick Setup AWS CloudFormation template to the same account as your S3 bucket:
   - For the `CloudWatchConfigBucketARN` parameter, enter the S3 bucket's ARN.
   - Make adjustments to the parameter options depending on the capabilities that you want to enable for Systems Manager.

7. Deploy a test EC2 instance with and without an IAM role to confirm that the EC2 instance works with CloudWatch.

- Apply the `AttachIAMToInstance` State Manager association. This is a Systems Manager runbook that is configured to run on a schedule. State Manager associations that use runbooks are not automatically applied to new EC2 instances and can be configured to run on a scheduled basis. For more information, see Running automations with triggers using State Manager in the Systems Manager documentation.
- Confirm that the EC2 instance has the required IAM role attached.
- Confirm that the Systems Manager agent is working correctly by confirming that the EC2 instance is visible in Systems Manager.
- Confirm that the CloudWatch agent is working correctly by viewing CloudWatch logs and metrics based on the CloudWatch configurations from your S3 bucket.

Customized Quick Setup in multiple Regions and multiple accounts with AWS CloudFormation StackSets

If you are using multiple accounts and Regions, then you can deploy the AWS-QuickSetup-SSMHostMgmt.yaml AWS CloudFormation template as a stack set. You must complete the AWS CloudFormation StackSet prerequisites before using stack sets. The requirements vary depending on whether you are deploying stack sets with **self-managed** or **service-managed** permissions.

We recommend that you deploy stack sets with service-managed permissions so that new accounts automatically receive the customized Quick Setup. You must deploy a service-managed stack set from the AWS Organizations management account or delegated administrator account. You should deploy the

stack set from a centralized account used for automation that has delegated administrator privileges, rather than the AWS Organizations management account. We also recommend that you test your stack set deployment by targeting a test organizational unit (OU) with a single or small number of accounts in one Region.

1. Complete steps 1 to 5 from the Customized Quick Setup in a single account and Region with an AWS CloudFormation stack (p. 23) section of this guide.
2. Sign in to the AWS Management Console, open the AWS CloudFormation consoler and choose **Create StackSet**:
   - Choose **Template is ready** and **Upload a template file**. Upload the AWS CloudFormation template that you customized to your requirements.
   - Specify the stack set details:
     - Enter a stack set name, for example, `StackSet-SSM-QuickSetup`.
     - Make adjustments to the parameter options depending on the capabilities that you want to enable for Systems Manager.
     - For the `CloudWatchConfigBucketARN` parameter, enter the ARN for your CloudWatch configuration's S3 bucket.
     - Specify the stack set options, choose whether you will use service-managed permissions with AWS Organizations or self-managed permissions.
       - If you choose self-managed permissions, enter the **AWSCloudFormationStackSetAdministrationRole** and **AWSCloudFormationStackSetExecutionRole** IAM role details. The administrator role must exist in the account and the execution role must exist in each target account
     - For **service-managed** permissions with AWS Organizations, we recommend that you first deploy to a test OU instead of the entire organization.
       - Choose whether you want to enable automatic deployments. We recommend that you choose **Enabled**. For account removal behavior, the recommended setting is **Delete stacks**.
     - For **self-managed** permissions, enter the AWS account IDs for the accounts that you want to set up. You must repeat this process for each new account if you use self-managed permissions.
     - Enter the Regions where you will be using CloudWatch and Systems Manager.
     - Confirm that the deployment is successful by viewing the status in the **Operations and Stack instances** tab for the stack set.
     - Test that Systems Manager and CloudWatch are correctly working in the deployed accounts by following step 7 from the Customized Quick Setup in a single account and Region with an AWS CloudFormation stack (p. 23) section of this guide.

Considerations for configuring on-premises servers

The CloudWatch agent for on-premises servers and VMs is installed and configured by using a similar approach to that for EC2 instances. However, the following table provides considerations that you must evaluate when installing and configuring the CloudWatch agent on on-premises servers and VMs.

Point the CloudWatch agent to the same temporary credentials used for Systems Manager.	When you set up Systems Manager in a hybrid environment that includes on-premises servers, you can activate Systems Manager with an IAM role. You should use the role created for your EC2 instances that includes the `CloudWatchAgentServerPolicy` and `AmazonSSMManagedInstanceCore` policies. This results in the Systems Manager agent retrieving and writing temporary credentials

	to a local credentials file. You can point your CloudWatch agent configuration to the same file. You can use the process from Configure on-premises servers that use Systems Manager agent and the unified CloudWatch agent to use only temporary credentials in the AWS Knowledge Center. You can also automate this process by defining a separate Systems Manager Automation runbook and State Manager association, and targeting your on-premises instances with tags. When you create an Systems Manager activation for your on-premises instances, you should include a tag that identifies the instances as on-premises instances.
Consider using accounts and Regions that have VPN or AWS Direct Connect access and AWS PrivateLink.	You can use AWS Direct Connect or AWS Virtual Private Network (AWS VPN) to establish private connections between on-premises networks and your virtual private cloud (VPC). AWS PrivateLink establishes a private connection to CloudWatch Logs with an interface VPC endpoint. This approach is useful if you have restrictions that prevent data being sent over the public internet to a public service endpoint.
All metrics must be included in the CloudWatch configuration file.	Amazon EC2 includes standard metrics (for example, CPU utilization) but these metrics must be defined for on-premises instances. You can use a separate platform configuration file to define these metrics for on-premises servers and then append the configuration to the standard CloudWatch metrics configuration for the platform.

Considerations for ephemeral EC2 instances

EC2 instances are temporary, or *ephemeral*, if they are provisioned by Amazon EC2 Auto Scaling, Amazon EMR, Amazon EC2 Spot Instances, or AWS Batch. Ephemeral EC2 instances can cause a very large number of CloudWatch streams under a common log group without additional information on their runtime origin.

If you use ephemeral EC2 instances, consider adding additional dynamic contextual information in the log group and log stream names. For example, you can include the Spot Instance request ID, Amazon EMR cluster name, or Auto Scaling group name. This information can vary for newly launched EC2 instances and you might have to retrieve and configure it at runtime. You can do this by writing a CloudWatch agent configuration file at boot and restarting the agent to include the updated configuration file. This enables delivery of logs and metrics to CloudWatch using dynamic runtime information.

You should also make sure that your metrics and logs are sent by the CloudWatch agent before your ephemeral EC2 instances are terminated. The CloudWatch agent includes a `flush_interval` parameter that can be configured to define the time interval for flushing log and metric buffers. You can lower this value based on your workload and stop the CloudWatch agent and force the buffers to flush before the EC2 instance is terminated.

Using an automated solution to deploy the CloudWatch agent

If you use an automation solution (for example, Ansible or Chef), you can leverage it to automatically install and update the CloudWatch agent. If you use this approach, you must evaluate the following considerations:

- **Validate that the automation covers the OSs and the OS versions that you support.** If the automation script doesn't support all your organization's OSs, you should define alternative solutions for the unsupported OSs.
- **Validate that the automation solution regularly checks for CloudWatch agent updates and upgrades**. Your automation solution should regularly check for updates to the CloudWatch agent, or regularly uninstall and reinstall the agent. You can use a scheduler or automation solution functionality to regularly check and update the agent.
- **Validate that you can confirm agent installation and configuration compliance**. Your automation solution should enable you to determine when a system doesn't have the agent installed or when the agent isn't working. You can implement a notification or alarm into your automation solution so that failed installations and configurations are tracked.

Deploying the CloudWatch agent during instance provisioning with the user data script

You can use this approach if you don't plan to use Systems Manager and want to selectively use CloudWatch for your EC2 instances. Typically, this approach is used on a one-time basis or when a specialized configuration is required. AWS provides direct links for the CloudWatch agent that can be downloaded in your start-up or user data scripts. The agent installation packages can be silently run without user interaction, which means that you can use them in automated deployments. If you use this approach, you should evaluate the following considerations:

- **Increased risk that users won't install the agent or configure standard metrics**. Users might provision instances without including the necessary steps to install the CloudWatch agent. They could also misconfigure the agent, which might cause logging and monitoring inconsistencies.
- **The installation scripts must be OS specific and suitable for different OS versions**. You require separate scripts if you intended to use both Windows and Linux. The Linux script should also have different installation steps based on the distribution.
- **You must regularly update the CloudWatch agent with new versions when available**. This can be automated if you use Systems Manager with State Manager, but you can also configure the user data script to rerun on instance startup. The CloudWatch agent is then updated and reinstalled on every reboot.
- **You must automate the retrieval and application of standard CloudWatch configurations**. This can be automated if you use Systems Manager with State Manager, but you can also configure a user data script to retrieve the configuration files on boot and restart the CloudWatch agent.

Including the CloudWatch agent in your AMIs

The advantage of using this approach is that you don't have to wait for the CloudWatch agent to be installed and configured, and you can immediately begin logging and monitoring. This helps you better monitor your instance provisioning and startup steps in case instances fail to start. This approach is also appropriate if you don't plan to use the Systems Manager agent. If you use this approach, you should evaluate the following considerations:

- **An update process must exist because AMIs might not include the most recent CloudWatch agent version**. The CloudWatch agent installed in an AMI is only current to the last time the AMI was created. You should include an additional method for updating the agent on a regular basis and when the EC2 instance is provisioned. If you use Systems Manager, you can use the Installing the CloudWatch agent using Systems Manager Distributor and State Manager (p. 20) solution provided in this guide for this. If you don't use Systems Manager, you can use a user data script to update the agent on instance startup and reboot.
- **Your CloudWatch agent configuration file must be retrieved on instance startup**. If you don't use Systems Manager, you can configure a user data script to retrieve the configuration files on boot and then restart the CloudWatch agent.
- **The CloudWatch agent must be restarted after your CloudWatch configuration is updated**.
- **AWS credentials must not be saved in the AMI**. Make sure that no local AWS credentials are stored in the AMI. If you use Amazon EC2, you can apply the necessary IAM role to your instance and avoid local credentials. If you use on-premises instances, you should automate or manually update the instance credentials before starting the CloudWatch agent.

Logging and monitoring on Amazon ECS

Amazon Elastic Container Service (Amazon ECS) provides two launch types for running containers and that determine the type of infrastructure that host tasks and services; these launch types are AWS Fargate and Amazon EC2. Both launch types integrate with CloudWatch but configurations and support vary.

The following sections help you understand how to use CloudWatch for logging and monitoring on Amazon ECS.

Topics

Configuring CloudWatch with an EC2 launch type

With an EC2 launch type, you provision an Amazon ECS cluster of EC2 instances that use the CloudWatch agent for logging and monitoring. An Amazon ECS optimized AMI comes pre-installed with the Amazon ECS container agent and provides CloudWatch metrics for the Amazon ECS cluster.

These default metrics are included in the cost of Amazon ECS, but the default configuration for Amazon ECS doesn't monitor log files or additional metrics (for example, free disk space). You can use the AWS Management Console to provision an Amazon ECS cluster with the EC2 launch type, this creates an AWS CloudFormation stack that deploys an Amazon EC2 Auto Scaling group with a launch configuration. However, this approach means that you can't choose a custom AMI or customize the launch configuration with different settings or additional boot up scripts.

To monitor additional logs and metrics, you must install the CloudWatch agent on your Amazon ECS container instances. You can use the installation approach for EC2 instances from the Installing the CloudWatch agent using Systems Manager Distributor and State Manager (p. 20) section of this guide. However, the Amazon ECS AMI doesn't include the required Systems Manager agent. You should use a custom launch configuration with a user data script that installs the Systems Manager agent when you create your Amazon ECS cluster. This allows your container instances to register with Systems Manager and apply the State Manager associations to install, configure, and update the CloudWatch agent. When State Manager runs and updates your CloudWatch agent configuration, it also applies your standardized systems-level CloudWatch configuration for Amazon EC2. You can also store standardized CloudWatch configurations for Amazon ECS in the S3 bucket for your CloudWatch configuration and automatically apply them with State Manager.

You should make sure that the IAM role or instance profile applied to your Amazon ECS container instances includes the required `CloudWatchAgentServerPolicy` and `AmazonSSMManagedInstanceCore` policies. You can use the ecs_cluster_with_cloudwatch_linux.yaml AWS CloudFormation template to provision Linux-based Amazon ECS clusters. This template creates an Amazon ECS cluster with a custom launch configuration that installs Systems Manager and deploys a custom CloudWatch configuration to monitor log files specific to Amazon ECS.

You should capture the following logs for your Amazon ECS container instances, as well as your standard EC2 instance logs:

- **Amazon ECS agent startup output** – `/var/log/ecs/ecs-init.log`
- **Amazon ECS agent output** – `/var/log/ecs/ecs-agent.log`
- **IAM credential provider requests log** – `/var/log/ecs/audit.log`

For more information about output level, formatting, and additional configuration options, see Amazon ECS log file locations in the Amazon ECS documentation.

> **Important**
> Agent installation or configuration is not required for the Fargate launch type because you don't run or manage EC2 container instances.

Amazon ECS container instances should use the latest Amazon ECS optimized AMIs and container agent. AWS stores public Systems Manager Parameter Store parameters with Amazon ECS optimized AMI information, including the AMI ID. You can retrieve the latest most recently optimized AMI from the Parameter Store by using the Parameter Store parameter format for Amazon ECS optimized AMIs. You can refer to the public Parameter Store parameter that references the most recent AMI or a specific AMI release in your AWS CloudFormation templates.

AWS provides the same Parameter Store parameters in each supported Region. This means that AWS CloudFormation templates referencing these parameters can be reused across Regions and accounts without the AMI to be updated. You can control the deployment of newer Amazon ECS AMIs to your organization by referring to a specific release, which helps you prevent the use of a new Amazon ECS optimized AMI until you test it.

Amazon ECS container logs for EC2 and Fargate launch types

Amazon ECS uses a task definition to deploys and manage containers as tasks and services. You configure the containers that you want to launch into your Amazon ECS cluster within a task definition. Logging is configured with a log driver at the container level. Multiple log driver options provide your containers with different logging systems (for example, `awslogs`,`fluentd`,`gelf`,`json-file`,`journald`,`logentries`,`splunk`,`syslog`, or `awsfirelens`) depending on whether you use the EC2 or Fargate launch type. The Fargate launch type provides a subset of the following log driver options: `awslogs`, `splunk`, and `awsfirelens`. AWS provides the `awslogs` log driver to capture and transmit container output to CloudWatch Logs. Log driver settings enable you to customize the log group, Region, and log stream prefix along with many other options.

The default naming for log groups and the option used by the **Auto-configure CloudWatch Logs** option on the AWS Management Console is `/ecs/<task_name>`. The log stream name used by Amazon ECS has the `<awslogs-stream-prefix>/<container_name>/<task_id>` format. We recommend that you use a group name that groups your logs based on your organization's requirements. In the following table, the `image_name` and `image_tag` are included in the log stream's name.

Log group name	`/<Business unit>/<Project or application name>/<Environment>/<Cluster name>/<Task name>`
Log stream name prefix	`/<image_name>/<image_tag>`

This information is also available in the task definition. However, tasks are regularly updated with new revisions, which means that the task definition might have used a different `image_name` and `image_tag` than those that the task definition is currently using. For more information and naming suggestions, see the Planning your CloudWatch deployment (p. 6) section of this guide.

If you use a continuous integration and continuous delivery (CI/CD) pipeline or automated process, you can create a new task definition revision for your application with each new Docker image build. For example, you can include the Docker image name, image tag, GitHub revision, or other important information in your task definition revision and logging configuration as a part of your CI/CD process.

Using custom log routing with FireLens for Amazon ECS

FireLens for Amazon ECS helps you route logs to Fluentd or Fluent Bit so that you can directly send container logs to AWS services and AWS Partner Network (APN) destinations as well as support log shipping to CloudWatch Logs.

AWS provides a Docker image for Fluent Bit with pre-installed plugins for Amazon Kinesis Data Streams, Amazon Kinesis Data Firehose, and CloudWatch Logs. You can use the FireLens log driver instead of the `awslogs` log driver for more customization and control over logs sent to CloudWatch Logs.

For example, you can use the FireLens log driver to control the log format output. This means that an Amazon ECS container's CloudWatch logs are automatically formatted as JSON objects and include JSON-formatted properties for `ecs_cluster`,`ecs_task_arn`, `ecs_task_definition`, `container_id`, `container_name`, and `ec2_instance_id`. The fluent host is exposed to your container through the `FLUENT_HOST` and `FLUENT_PORT` environment variables when you specify the `awsfirelens` driver. This means that you can directly log to the log router from your code by using fluent logger libraries. For example, your application might include the `fluent-logger-python` library to log to Fluent Bit by using the values available from the environment variables.

If you choose to use FireLens for Amazon ECS, you can configure the same settings as the `awslogs` log driver and use other settings as well. For example, you can use the ecs-task-nginx-firelense.json Amazon ECS task definition that launches an NGINX server configured to use FireLens for logging to CloudWatch. It also launches a FireLens Fluent Bit container as a sidecar for logging.

Metrics for Amazon ECS

Amazon ECS provides standard CloudWatch metrics (for example, CPU and memory utilization) for the EC2 and Fargate launch types at the cluster and service level with the Amazon ECS container agent. You can also capture metrics for your services, tasks, and containers by using CloudWatch Container Insights, or capture your own custom container metrics by using the embedded metric format.

Container Insights is a CloudWatch feature that provides metrics such as CPU utilization, memory utilization, network traffic, and storage at the cluster, container instance, service, and task levels. Container Insights also creates automatic dashboards that help you analyze services and tasks, and see the average memory or CPU utilization at the container level. Container Insights publishes custom metrics to the `ECS/ContainerInsights` custom namespace that you can use for graphing, alarming, and dashboarding.

You can turn on Container Insight metrics by enabling Container Insights for each individual Amazon ECS cluster. If you also want to see metrics at the container instance level, you can launch the CloudWatch agent as a daemon container on your Amazon ECS cluster. You can use the cwagent-ecs-instance-metric-cfn.yaml AWS CloudFormation template to deploy the CloudWatch agent as an Amazon ECS service. Importantly, this example assumes that you created an appropriate custom CloudWatch agent configuration and stored it in Parameter Store with the key `ecs-cwagent-daemon-service`.

The CloudWatch agent deployed as a daemon container for CloudWatch Container Insights includes additional disk, memory, and CPU metrics such as `instance_cpu_reserved_capacity` and

`instance_memory_reserved_capacity` with the `ClusterName`, `ContainerInstanceId`, `InstanceId` dimensions. Metrics at the container instance level are implemented by Container Insights by using the CloudWatch embedded metric format. You can configure additional system-level metrics for your Amazon ECS container instances by using the approach from from the Set up State Manager and Distributor for CloudWatch agent deployment and configuration (p. 21) section of this guide.

Creating custom application metrics in Amazon ECS

You can create custom metrics for your applications by using the CloudWatch embedded metric format. However, you need to send embedded metric format entries to an embedded metric format endpoint because the `awslogs` log driver doesn't interpret CloudWatch embedded metric format statements. If you configure the CloudWatch agent sidecar container as an embedded metric format endpoint, you can run the CloudWatch agent as a sidecar container in your Amazon ECS task to ingest embedded metric format statement.

The `CW_CONFIG_CONTENT` environment variable in the following example is set to the contents of the `cwagentconfig` Systems Manager Parameter Store parameter. You can run the agent with this basic configuration to configure it as an embedded metric format endpoint.

```
  {
  "logs": {
    "metrics_collected": {
      "emf": { }
    }
  }
}
```

If you have Amazon ECS deployments across multiple accounts and Regions, you can use an AWS Secrets Manager secret to store your CloudWatch configuration and configure the secret policy to share it with your organization. You can use the secrets option in your task definition to set the `CW_CONFIG_CONTENT` variable.

You can use the AWS provided open-source embedded metric format libraries in your application and specify the `AWS_EMF_AGENT_ENDPOINT` environment variable to connect to your CloudWatch agent sidecar container acting as an embedded metric format endpoint. For example, you can use the ecs_cw_emf_example sample Python application to send metrics in embedded metric format to a CloudWatch agent sidecar container configured as an embedded metric format endpoint.

The Fluent Bit plugin for CloudWatch also supports `json/emf` as a format option, which means that you can create metrics through your logs with the FireLens container log driver. If you use this option, you should specify the `log_key` option and set it to *log* so that CloudWatch correctly recognizes the embedded metric format messages. You can also use the ecs_firelense_emf_example sample Python application to send metrics in embedded metric format to a Firelens for Amazon ECS sidecar container.

If you don't want to use embedded metric format, you can create and update CloudWatch metrics through the AWS API or AWS SDK. We don't recommend this approach unless you have a specific use case, because it adds maintenance and management overhead to your code.

Logging and monitoring on Amazon EKS

Amazon Elastic Kubernetes Service (Amazon EKS) integrates with CloudWatch Logs for the Kubernetes control plane. The control plane is provided as a managed service by Amazon EKS and you can turn on logging without installing a CloudWatch agent. The CloudWatch agent can also be deployed to capture Amazon EKS node and container logs. Fluent Bit and Fluentd are also supported for sending your container logs to CloudWatch Logs.

CloudWatch Container Insights provides a comprehensive metrics monitoring solution for Amazon EKS at the cluster, node, pod, task, and service level. Amazon EKS also supports multiple options for metrics capture with Prometheus. The Amazon EKS control plane provides a metrics endpoint that exposes metrics in a Prometheus format. You can deploy Prometheus into your Amazon EKS cluster to consume these metrics.

You can also set up the CloudWatch agent to scrape Prometheus metrics and create CloudWatch metrics, in addition to consume other Prometheus endpoints. Container Insights monitoring for Prometheus can also automatically discover and capture Prometheus metrics from supported, containerized workloads and systems.

You can install and configure the CloudWatch agent on your Amazon EKS nodes, in a similar way to the approach used for Amazon EC2 with Distributor and State Manager, to align your Amazon EKS nodes with your standard system logging and monitoring configurations.

Logging for Amazon EKS

Kubernetes logging can be divided into control plane logging, node logging, and application logging. The Kubernetes control plane is a set of components that manage Kubernetes clusters and produce logs used for auditing and diagnostic purposes. With Amazon EKS, you can turn on logs for different control plane components and send them to CloudWatch.

Kubernetes also runs system components such as `kubelet` and `kube-proxy` on each Kubernetes node that runs your pods. These components write logs within each node and you can configure CloudWatch and Container Insights to capture these logs for each Amazon EKS node.

Containers are grouped as pods within a Kubernetes cluster and are scheduled to run on your Kubernetes nodes. Most containerized applications write to standard output and standard error, and the container engine redirects the output to a logging driver. In Kubernetes, the container logs are found in the `/var/log/pods` directory on a node. You can configure CloudWatch and Container Insights to capture these logs for each of your Amazon EKS pods.

Amazon EKS control plane logging

An Amazon EKS cluster consists of a high availability, single-tenant control plane for your Kubernetes cluster and the Amazon EKS nodes that run your containers. The control plane nodes run in an account managed by AWS. The Amazon EKS cluster control plane nodes are integrated with CloudWatch and you can turn on logging for specific control plane components.

Logs are provided for each Kubernetes control plane component instance. AWS manages the health of your control plane nodes and provides a service-level agreement (SLA) for the Kubernetes endpoint.

Amazon EKS node and application logging

We recommend that you use CloudWatch Container Insights to capture logs and metrics for Amazon EKS. Container Insights implements cluster, node, and pod-level metrics with the CloudWatch agent, and Fluent Bit or Fluentd for log capture to CloudWatch. Container Insights also provides automatic dashboards with layered views of your captured CloudWatch metrics. Container Insights is deployed as CloudWatch DaemonSet and Fluent Bit DaemonSet that runs on every Amazon EKS node. Fargate nodes are not supported by Container Insights because the nodes are managed by AWS and don't support DaemonSets. Fargate logging for Amazon EKS is covered separately in this guide.

The following table shows the CloudWatch log groups and logs captured by the default Fluentd or Fluent Bit log capture configuration for Amazon EKS.

`/aws/containerinsights/Cluster_Name/application`	All log files in `/var/log/containers`. This directory provides symbolic links to all the Kubernetes container logs in the `/var/log/pods` directory structure. This captures your application container logs writing to `stdout` or `stderr`. It also includes logs for Kubernetes system containers such as `aws-vpc-cni-init`, `kube-proxy`, and `coreDNS`.
`/aws/containerinsights/Cluster_Name/host`	Logs from `/var/log/dmesg`, `/var/log/secure`, and `/var/log/messages`.
`/aws/containerinsights/Cluster_Name/dataplane`	The logs in `/var/log/journal` for `kubelet.service`, `kubeproxy.service`, and `docker.service`.

If you don't want to use Container Insights with Fluent Bit or Fluentd for logging, you can capture node and container logs with the CloudWatch agent installed on Amazon EKS nodes. Amazon EKS nodes are EC2 instances, which means you should include them in your standard system-level logging approach for Amazon EC2. If you install the CloudWatch agent using Distributor and State Manager, then Amazon EKS nodes are also included in the CloudWatch agent installation, configuration, and update.

The following table shows logs that are specific to Kubernetes and that you must capture if you aren't using Container Insights with Fluent Bit or Fluentd for logging.

`/var/log/containers`	This directory provides symbolic links to all the Kubernetes container logs under the `/var/log/pods` directory structure. This effectively captures your application container logs writing to `stdout` or `stderr`. This includes logs for Kubernetes system containers such as `aws-vpc-cni-init`, `kube-proxy`, and `coreDNS`. **Important**: This is not required if you are using Container Insights.

`var/log/aws-routed-eni/ipamd.log`
 	
`/var/log/aws-routed-eni/plugin.log`
	The logs for the L-IPAM daemon can be found here

You must make sure that Amazon EKS nodes install and configure the CloudWatch agent to send appropriate system-level logs and metrics. However, the Amazon EKS optimized AMI doesn't include the Systems Manager agent. By using launch templates, you can automate the Systems Manager agent installation and a default CloudWatch configuration that captures important Amazon EKS specific logs with a startup script implemented through the user data section. Amazon EKS nodes are deployed using an Auto Scaling group as either a managed node group or as self-managed nodes.

With managed node groups, you supply a launch template that includes the user data section to automate the Systems Manager agent installation and CloudWatch configuration. You can customize and use the amazon_eks_managed_node_group_launch_config.yaml AWS CloudFormation template to create a launch template that installs the Systems Manager agent, CloudWatch agent, and also adds an Amazon EKS specific logging configuration to the CloudWatch configuration directory. This template can be used to update your Amazon EKS managed node groups launch template with an infrastructure-as-code (IaC) approach. Each update to the AWS CloudFormation template provisions a new version of the launch template. You can then update the node group to use the new template version and have the managed lifecycle process update your nodes without downtime. Make sure that the IAM role and instance profile applied to your managed node group includes the `CloudWatchAgentServerPolicy` and `AmazonSSMManagedInstanceCore` AWS managed policies.

With self-managed nodes, you directly provision and manage the lifecycle and update strategy for your Amazon EKS nodes. Self-managed nodes allow you to run Windows nodes on your Amazon EKS cluster and Bottlerocket, along with other options. You can use AWS CloudFormation to deploy self-managed nodes into your Amazon EKS clusters, which means you can use an IaC and managed change approach for your Amazon EKS clusters. AWS provides the amazon-eks-nodegroup.yaml AWS CloudFormation template that you can use as-is or customize. The template provisions all required resources for Amazon EKS nodes in a cluster (for example, a separate IAM role, security group, Amazon EC2 Auto Scaling group, and a launch template). The amazon-eks-nodegroup.yaml AWS CloudFormation template is an updated version that installs the required Systems Manager agent, CloudWatch agent, and also adds an Amazon EKS specific logging configuration to the CloudWatch configuration directory.

Logging for Amazon EKS on Fargate

With Amazon EKS on Fargate, you can deploy pods without allocating or managing your Kubernetes nodes. This removes the need to capture system-level logs for your Kubernetes nodes. To capture the logs from your Fargate pods, you can use Fluent Bit to forward the logs directly to CloudWatch. This enables you to automatically route logs to CloudWatch without further configuration or a sidecar container for your Amazon EKS pods on Fargate. For more information about this, see Fargate logging in the Amazon EKS documentation and Fluent Bit for Amazon EKS on the AWS Blog. This solution captures the `STDOUT` and `STDERR` input/output (I/O) streams from your container and sends them to CloudWatch through Fluent Bit, based on the Fluent Bit configuration established for the Amazon EKS cluster on Fargate.

Metrics for Amazon EKS and Kubernetes

Kubernetes provides a metrics API that allows you to access resource usage metrics (for example, CPU and memory usage for nodes and pods), but the API only provides point-in-time information and not historical metrics. The Kubernetes metrics-server is typically used for Amazon EKS and Kubernetes deployments to aggregate metrics, provide short-term historical information on metrics, and support features such as Horizontal Pod Autoscaler.

Amazon EKS exposes control plane metrics through the Kubernetes API server in a Prometheus format and CloudWatch can capture and ingest these metrics. CloudWatch and Container Insights can also be configured to provide comprehensive metrics capture, analysis, and alarming for your Amazon EKS nodes and pods.

Kubernetes control plane metrics

Kubernetes exposes control plane metrics in a Prometheus format by using the `/metrics` HTTP API endpoint. You should install Prometheus in your Kubernetes cluster to graph and view these metrics with a web browser. You can also ingest the metrics exposed by the Kubernetes API server into CloudWatch.

Node and system metrics for Kubernetes

Kubernetes provides the Prometheus metrics-server pod that you can deploy and run on your Kubernetes clusters for cluster, node, and pod-level CPU and memory statistics. These metrics are used with the Horizontal Pod Autoscaler and Vertical Pod Autoscaler. CloudWatch can also provide these metrics.

You should install the Kubernetes Metrics Server if you use the Kubernetes Dashboard or the horizontal and vertical pod autoscalers. The Kubernetes Dashboard helps you browse and configure your Kubernetes cluster, nodes, pods and related configuration, and view the CPU and memory metrics from the Kubernetes Metrics Server. You can deploy this solution for individual clusters by following the steps from the Deploy the Kubernetes Dashboard in the Amazon EKS documentation.

The metrics provided by the Kubernetes Metrics Server can't be used for non-auto scaling purposes (for example, monitoring). The metrics are meant for point-in-time analysis and not historical analysis. The Kubernetes Dashboard deploys the `dashboard-metrics-scraper` to store metrics from the Kubernetes Metrics Server for a short time window.

Container Insights uses a containerized version of the CloudWatch agent that runs in a Kubernetes DaemonSet to discover all running containers in a cluster and provide node-level metrics. It collects performance data at every layer of the performance stack. You can use the Quick Start from AWS Quick Starts or configure Container Insights separately. The Quick Start sets up metrics monitoring with the CloudWatch agent and logging with Fluent Bit so you only need to deploy it once for logging and monitoring.

Because Amazon EKS nodes are EC2 instances, you should capture systems-level metrics, in addition to metrics captured by Container Insights, by using the standards you defined for Amazon EC2. You can use the same approach from the Set up State Manager and Distributor for CloudWatch agent deployment and configuration (p. 21) section of this guide to install and configure the CloudWatch agent for your Amazon EKS clusters. You can update your Amazon EKS specific CloudWatch configuration file to include metrics as well as your Amazon EKS specific log configuration.

The CloudWatch agent with Prometheus support can automatically discover and scrape the Prometheus metrics from supported, containerized workloads and systems. It ingests them as CloudWatch logs in embedded metric format for analysis with CloudWatch Logs Insights and automatically creates CloudWatch metrics.

> **Important**
> You must deploy a specialized version of the CloudWatch agent to collect Prometheus metrics. This is a separate agent from the CloudWatch agent deployed for Container Insights. You can use the prometheus_jmx sample Java application, which includes the deployment and configuration files for the CloudWatch agent and Amazon EKS pod deployment to demonstrate Prometheus metrics discovery. For more information, see Set up Java/JMX sample workload on Amazon EKS and Kubernetes in the CloudWatch documentation. You can also configure the CloudWatch agent to capture metrics from other Prometheus targets running in your Amazon EKS cluster.

Application metrics

You can create your own custom metrics with the CloudWatch embedded metric format. To ingest embedded metric format statements, you need to send embedded metric format entries to an

embedded metric format endpoint. The CloudWatch agent can be configured as a sidecar container in your Amazon EKS pod. The CloudWatch agent configuration is stored as a Kubernetes ConfigMap and read by your CloudWatch agent sidecar container to start the embedded metric format endpoint.

You can also set up your application as a Prometheus target and configure the CloudWatch agent, with Prometheus support, to discover, scrape, and ingest your metrics into CloudWatch. For example, you can use the open-source JMX exporter with your Java applications to expose JMX Beans for Prometheus consumption by the CloudWatch agent.

If you don't want to use the embedded metric format, you can also create and update CloudWatch metrics by using AWS API or AWS SDK. However, we don't recommend this approach because it mixes monitoring and the application logic.

Metrics for Amazon EKS on Fargate

Fargate automatically provisions Amazon EKS nodes to run your Kubernetes pods so you don't need to monitor and collect node-level metrics. However, you must monitor metrics for pods running on your Amazon EKS nodes on Fargate. Container Insights isn't currently available for Amazon EKS on Fargate because it requires the following capabilities that aren't currently supported:

- DaemonSets aren't currently supported. Container Insights is deployed by running the CloudWatch agent as a DaemonSet on each cluster node.
- HostPath persistent volumes aren't supported. The CloudWatch agent container uses hostPath persistent volumes as a prerequisite for gathering container metric data.
- Fargate prevents privileged containers and access to host information.

You can use the built-in log router for Fargate to send embedded metric format statements to CloudWatch. The log router uses Fluent Bit, which has a CloudWatch plugin that can be configured to support embedded metric format statements.

You can retrieve and capture pod-level metrics for your Fargate nodes by deploying the Prometheus server in your Amazon EKS cluster to gather metrics from your Fargate nodes. Because Prometheus requires persistent storage, you can deploy Prometheus on Fargate if you use Amazon Elastic File System (Amazon EFS) for persistent storage. You can also deploy Prometheus on an Amazon EC2 backed node. For more information, see Monitoring Amazon EKS on AWS Fargate using Prometheus and Grafana on the AWS Blog.

Prometheus monitoring on Amazon EKS

Amazon Managed Service for Prometheus provides a scalable, secure, AWS managed service for open-source Prometheus. You can use Prometheus query language (PromQL) to monitor the performance of containerized workloads without managing the underlying infrastructure for ingesting, storing, and querying operational metrics. You can collect Prometheus metrics from Amazon EKS and Amazon ECS by using AWS Distro for OpenTelemetry (ADOT) or Prometheus servers as collection agents.

CloudWatch Container Insights monitoring for Prometheus enables you to configure and use the CloudWatch agent to discover Prometheus metrics from Amazon ECS, Amazon EKS, and Kubernetes workloads, and ingest them as CloudWatch metrics. This solution is appropriate if CloudWatch is your primary observability and monitoring solution. However, the following list outlines use cases where Amazon Managed Service for Prometheus provides more flexibility for ingesting, storing, and querying Prometheus metrics:

- Amazon Managed Service for Prometheus enables you to use existing Prometheus servers deployed in Amazon EKS or self-managed Kubernetes and configure them to write to Amazon Managed Service for Prometheus instead of a locally configured data store. This removes the undifferentiated heavy lifting of managing a highly available data store for your Prometheus servers and its infrastructure. Amazon Managed Service for Prometheus is a suitable choice when you have a mature Prometheus deployment that you want to leverage in the AWS Cloud.
- Grafana directly supports Prometheus as a data source for visualization. If you want to use Grafana with Prometheus instead of CloudWatch Dashboards for your container monitoring, then Amazon Managed Service for Prometheus could meet your requirements. Amazon Managed Service for Prometheus integrates with Amazon Managed Grafana to provide a managed open-source monitoring and visualization solution.
- Prometheus enables you to perform analysis on your operational metrics by using PromQL queries. In contrast, the CloudWatch agent ingests Prometheus metrics in embedded metric format into CloudWatch Logs which result in CloudWatch metrics. You can query the embedded metric format logs by using CloudWatch Logs Insights.
- If you don't plan to use CloudWatch for monitoring and metrics capture, then you should use Amazon Managed Service for Prometheus with your Prometheus server and a visualization solution such as Grafana. You need to configure your Prometheus server to scrape metrics from your Prometheus targets and configure the server to remote write to your Amazon Managed Service for Prometheus workspace. If you use Amazon Managed Grafana, then you can directly integrate Amazon Managed Grafana with your Amazon Managed Service for Prometheus data source by using the included plugin. Because metric data is stored in Amazon Managed Service for Prometheus, there is no dependency to deploy the CloudWatch agent or requirement to ingest data into CloudWatch. The CloudWatch agent is required for Container Insights monitoring for Prometheus.

You can also use the ADOT Collector to scrape from a Prometheus-instrumented application and send the metrics to Amazon Managed Service for Prometheus. For more information about ADOT Collector, see the AWS Distro for OpenTelemetry documentation.

Logging and metrics for AWS Lambda

Lambda removes the need to manage and monitor servers for your workloads and automatically works with CloudWatch Metrics and CloudWatch Logs without further configuration or instrumentation of your application's code. This section helps you understand the performance characteristics of the systems used by Lambda and how your configuration choices influence performance. It also helps you log and monitor your Lambda functions for performance optimization and diagnosing application-level issues.

Lambda function logging

Lambda automatically streams standard output and standard error messages from a Lambda function to CloudWatch Logs, without requiring logging drivers. Lambda also automatically provisions containers that run your Lambda function and configures them to output log messages in separate log streams.

Subsequent invocations of your Lambda function can reuse the same container and output to the same log stream. Lambda can also provision a new container and output the invocation to a new log stream.

Lambda automatically creates a log group when your Lambda function is first invoked. Lambda functions can have multiple versions and you can choose the version that you want to run. All logs for the Lambda function's invocations are stored in the same log group. The name cannot be changed and is in the `/aws/lambda/<YourLambdaFunctionName>` format. A separate log stream is created in the log group for each Lambda function instance. Lambda has a standard naming convention for log streams that uses a `YYYY/MM/DD/[<FunctionVersion>]<InstanceId>` format. The `InstanceId` is generated by AWS to identify the Lambda function instance.

We recommend that you use a logging library to help format and classify log messages. For example, if your Lambda function is written in Python, you can use the Python logging module to log messages and control the output format. We also recommend that you log messages in JSON format because you can query them more easily with CloudWatch Logs Insights. They can also be more easily filtered and exported.

Another best practice is to set the log output level by using a variable and adjust it based on the environment and your requirements. Your Lambda function's code, in addition to the libraries used, could output a large amount of log data depending on the log output level. This can impact your logging costs and affect performance.

Lambda allows you to set environment variables for your Lambda function runtime environment without updating your code. For example, you can create a `LAMBDA_LOG_LEVEL` environment variable that defines the log output level that you can retrieve from your code. The following example attempts to retrieve a `LAMBDA_LOG_LEVEL` environment variable and use the value to define the logging output. If the environment variable is not set, it defaults to the `INFO` level.

```
import logging
from os import getenv

logger = logging.getLogger()
log_level = getenv("LAMBDA_LOG_LEVEL", "INFO")
level = logging.getLevelName(log_level)
logger.setLevel(level)
```

Sending logs to other destinations from CloudWatch

You can send logs to other destinations (for example, Amazon OpenSearch Service or a Lambda function) by using subscription filters. If you don't use Amazon OpenSearch Service, you can use a Lambda function to process the logs and send them to an AWS service of your choice using the AWS SDKs.

You can also use SDKs for log destinations outside the AWS Cloud in your Lambda function to directly send log statements to a destination of your choice. If you choose this option, we recommend that you consider the impact of the latency, additional processing time, error and retry handling, and coupling of operational logic to your Lambda function.

Lambda function metrics

Lambda lets you run your code without managing or scaling servers and this almost removes the burden of system-level auditing and diagnostics. However, it's still important to understand performance and invocation metrics at the system level for your Lambda functions. This helps you optimize the resource configuration and improve code performance. Effectively monitoring and measuring performance can improve user experience and lower your costs by appropriately sizing your Lambda functions. Typically, workloads running as Lambda functions also have application-level metrics that need to be captured and analyzed. Lambda directly supports the embedded metric format to make capturing application-level CloudWatch metrics easier.

System-level metrics

Lambda automatically integrates with CloudWatch Metrics and provides a set of standard metrics for your Lambda functions. Lambda also provides a separate monitoring dashboard for each Lambda function with these metrics. Two important metrics that you need to monitor are errors and invocation errors. Understanding the differences between invocation errors and other error types helps you diagnose and support Lambda deployments.

Invocation errors prevent your Lambda function from running. These errors occur before your code is run so you can't implement error handling within your code to identify them. Instead, you should configure alarms for your Lambda functions that detect these errors and notify the operations and workload owners. These errors are often related to a configuration or permission error and can occur because of a change in your configuration or permissions. Invocation errors might initiate a retry, which causes multiple invocations of your function.

A successfully invoked Lambda function returns an HTTP 200 response even if an exception is thrown by the function. Your Lambda functions should implement error handing and raise exceptions so that the `Errors` metric captures and identifies failed runs of your Lambda function. You should return a formatted response from your Lambda function invocations that includes information to determine whether the run failed completely, partially, or was successful.

CloudWatch provides CloudWatch Lambda Insights that you can enable for individual Lambda function. Lambda Insights collects, aggregates, and summarizes system-level metrics (for example, CPU time, memory, disk and network usage). Lambda Insights also collects, aggregates, and summarizes diagnostic

information (for example, cold starts and Lambda worker shutdowns) to help you isolate and quickly resolve issues.

Lambda Insights uses the embedded metric format to automatically emit performance information to the `/aws/lambda-insights/` log group with a log stream name prefix based on your Lambda function's name. These performance log events create CloudWatch metrics that are the basis for automatic CloudWatch dashboards. We recommend that you enable Lambda Insights for performance testing and production environments. Additional metrics created by Lambda Insights include `memory_utilization` that helps correctly size Lambda functions so that you avoid paying for unrequired capacity.

Application metrics

You can also create and capture your own application metrics in CloudWatch using the embedded metric format. You can leverage AWS provided libraries for embedded metric format to create and emit embedded metric format statements to CloudWatch. The integrated Lambda CloudWatch logging facility is configured to process and extract appropriately formatted embedded metric format statements.

Searching and analyzing logs in CloudWatch

After your logs and metrics are captured into a consistent format and location, you can search and analyze them to help improve operational efficiency, in addition to identifying and troubleshooting issues. We recommend that you capture your logs in a well-formed format (for example, JSON) to make it easier to search and analyze your logs. Most workloads use a collection of AWS resources such as network, compute, storage, and databases. Where possible, you should collectively analyze the metrics and logs from these resources and correlate them in order to effectively monitor and manage all of your AWS workloads.

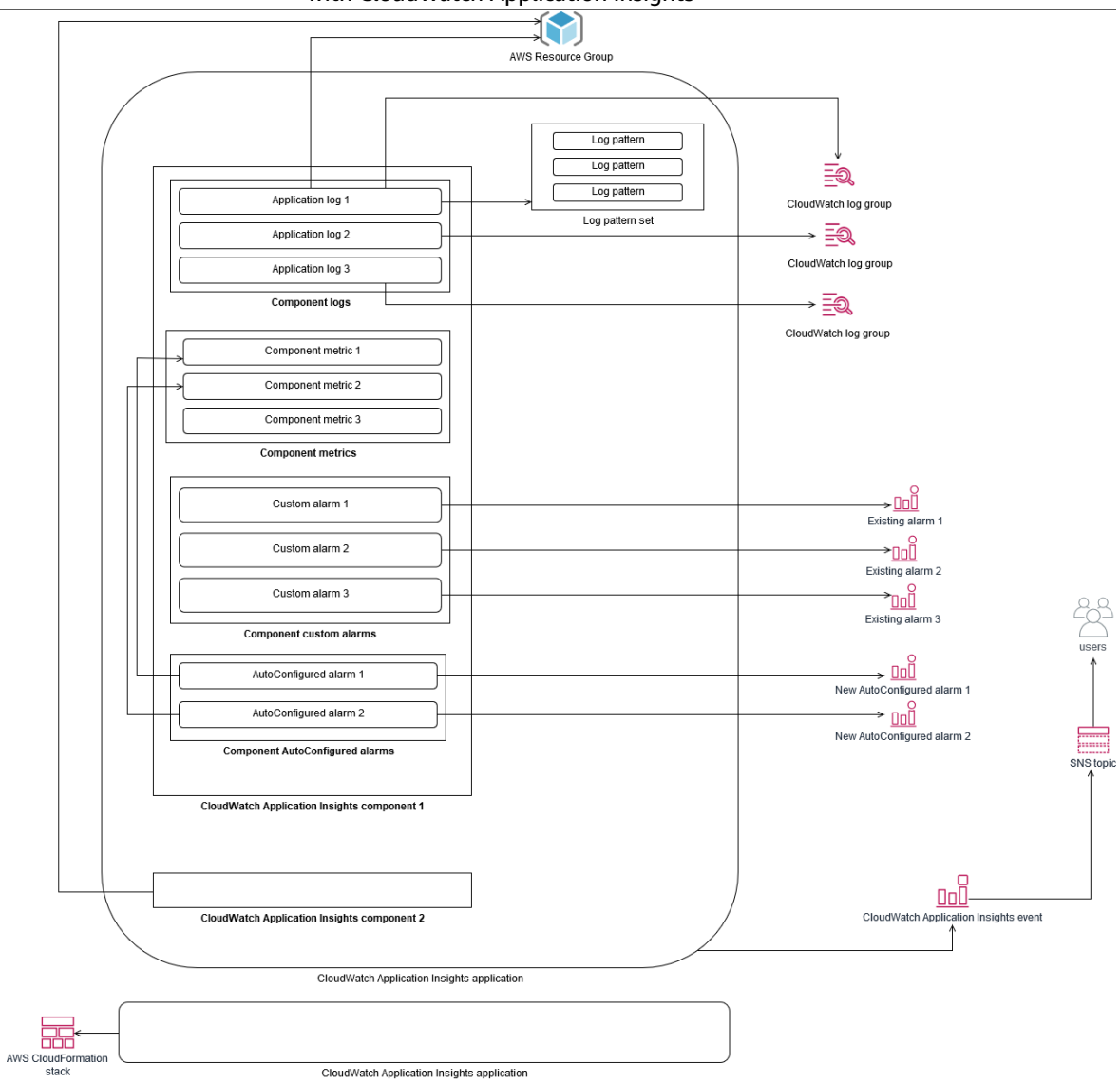
CloudWatch provides several features to help analyze logs and metrics, such as CloudWatch Application Insights to collectively define and monitor metrics and logs for an application across different AWS resources, CloudWatch Anomaly Detection to surface anomalies for your metrics, and CloudWatch Log Insights to interactively search and analyze your log data in CloudWatch Logs.

Collectively monitor and analyze applications with CloudWatch Application Insights

Application owners can use Amazon CloudWatch Application Insights to set up automatic monitoring and analysis for workloads. This can be configured in addition to standard systems-level monitoring configured for all workloads in an account. Setting up monitoring through CloudWatch Application Insights can also help application teams proactively align to operations and reduce mean time to recovery (MTTR). CloudWatch Application Insights can help reduce the effort required to establish application-level logging and monitoring. It also provides a component-based framework that assists teams in dividing logging and monitoring responsibilities.

CloudWatch Application Insights uses resource groups to identify the resources that should be collectively monitored as an application. The supported resources in the resource group become individually defined components of your CloudWatch Application Insights application. Each component of your CloudWatch Application Insights application has its own logs, metrics, and alarms.

For logs, you define the log pattern set that should be used for the component and within your CloudWatch Application Insights application. A log pattern set is a collection of log patterns to search for based on regular expressions, along with a low, medium, or high severity for when the pattern is detected. For metrics, you choose the metrics to monitor for each component from a list of service-specific and supported metrics. For alarms, CloudWatch Application Insights automatically creates and configures standard or anomaly detection alarms for the metrics being monitored. CloudWatch Application Insights has automatic configurations for metrics and log capture for the technologies outlined in the Logs and metrics supported by CloudWatch Application Insights in the CloudWatch documentation. The following diagram shows the relationships between CloudWatch Application Insights components and their logging and monitoring configurations. Each component has defined its own logs and metrics to monitor using CloudWatch logs and metrics.



EC2 instances monitored by CloudWatch Application Insights require Systems Manager and CloudWatch agents and permissions. For more information about this, see Prerequisites to configure an application with CloudWatch Application Insights in the CloudWatch documentation. CloudWatch Application Insights uses Systems Manager to install and update the CloudWatch agent. The metrics and logs configured in CloudWatch Application Insights create a CloudWatch agent configuration file that is stored in a Systems Manager parameter with the `AmazonCloudWatch-ApplicationInsights-SSMParameter` prefix for each CloudWatch Application Insights component. This results in a separate CloudWatch agent configuration file being added to the CloudWatch agent configuration directory on the EC2 instance. A Systems Manager command is run to append this configuration to the active configuration on the EC2 instance. Using CloudWatch Application Insights doesn't impact existing CloudWatch agent configuration settings. You can use CloudWatch Application Insights in addition to your own system and application-level CloudWatch agent configurations. However, you should ensure that the configurations don't overlap.

Performing log analysis with CloudWatch Logs Insights

CloudWatch Logs Insights makes it easy to search multiple log groups by using a simple query language. If your application logs are structured in JSON format, CloudWatch Logs Insights automatically discovers the JSON fields across your log streams in multiple log groups. You can use CloudWatch Logs Insights to analyze your application and system logs, which saves your queries for future use. The query syntax for CloudWatch Logs Insights supports functions such as aggregation with functions, for example, sum(), avg(), count(), min(), and max(), that can be helpful for troubleshooting your applications or performance analysis.

If you use the embedded metric format to create CloudWatch metrics, you can query your embedded metric format logs to generate one-time metrics by using the supported aggregation functions. This helps reduce your CloudWatch monitoring costs by capturing data points necessary to generate specific metrics on an as-needed basis, instead of actively capturing them as custom metrics. This is especially effective for dimensions with high cardinality that would result in a large number of metrics. CloudWatch Container Insights also takes this approach and captures detailed performance data but only generates CloudWatch metrics for a subset of this data.

For example, the following embedded metric entry only generates a limited set of CloudWatch metrics from the metric data that is captured in the embedded metric format statement:


```
{
 "AutoScalingGroupName": "eks-e0bab7f4-fa6c-64ba-dbd9-094aee6cf9ba",
 "CloudWatchMetrics": [
 {
 "Metrics": [
 {
 "Unit": "Count",
 "Name": "pod_number_of_container_restarts"
 }
 ],
 "Dimensions": [
 [
 "PodName",
 "Namespace",
 "ClusterName"
 ]
 ],
 "Namespace": "ContainerInsights"
 }
 ],
 "ClusterName": "eksdemo",
 "InstanceId": "i-03b21a16b854aa4ca",
 "InstanceType": "t3.medium",
 "Namespace": "amazon-cloudwatch",
 "NodeName": "ip-172-31-10-211.ec2.internal",
 "PodName": "cloudwatch-agent",
 "Sources": [
 "cadvisor",
 "pod",
 "calculated"
 ],
 "Timestamp": "1605111338968",
 "Type": "Pod",
 "Version": "0",
 "pod_cpu_limit": 200,
 "pod_cpu_request": 200,
 "pod_cpu_reserved_capacity": 10,
 "pod_cpu_usage_system": 3.268605094109382,
```

```
 "pod_cpu_usage_total": 8.899539221131045,
 "pod_cpu_usage_user": 4.160042847048305,
 "pod_cpu_utilization": 0.44497696105655227,
 "pod_cpu_utilization_over_pod_limit": 4.4497696105655224,
 "pod_memory_cache": 4096,
 "pod_memory_failcnt": 0,
 "pod_memory_hierarchical_pgfault": 0,
 "pod_memory_hierarchical_pgmajfault": 0,
 "pod_memory_limit": 209715200,
 "pod_memory_mapped_file": 0,
 "pod_memory_max_usage": 43024384,
 "pod_memory_pgfault": 0,
 "pod_memory_pgmajfault": 0,
 "pod_memory_request": 209715200,
 "pod_memory_reserved_capacity": 5.148439982463127,
 "pod_memory_rss": 38481920,
 "pod_memory_swap": 0,
 "pod_memory_usage": 42803200,
 "pod_memory_utilization": 0.6172094650851303,
 "pod_memory_utilization_over_pod_limit": 11.98828125,
 "pod_memory_working_set": 25141248,
 "pod_network_rx_bytes": 3566.4174629544723,
 "pod_network_rx_dropped": 0,
 "pod_network_rx_errors": 0,
 "pod_network_rx_packets": 3.3495665260575094,
 "pod_network_total_bytes": 4283.442421354973,
 "pod_network_tx_bytes": 717.0249584005006,
 "pod_network_tx_dropped": 0,
 "pod_network_tx_errors": 0,
 "pod_network_tx_packets": 2.6964010534762948,
 "pod_number_of_container_restarts": 0,
 "pod_number_of_containers": 1,
 "pod_number_of_running_containers": 1,
 "pod_status": "Running"
}
```


However, you can query the captured metrics to gain further insights. For example, you can run the following query to see the latest 20 pods with memory page faults:

```
fields @timestamp, @message
| filter (pod_memory_pgfault > 0)
| sort @timestamp desc
| limit 20
```

Performing log analysis with Amazon OpenSearch Service

CloudWatch integrates with Amazon OpenSearch Service by enabling you to stream log data from CloudWatch log groups to an Amazon OpenSearch Service cluster of your choice with a subscription filter. You can use CloudWatch for primary log and metrics capture and analysis, and then augment it with Amazon OpenSearch Service for the following use cases:

- **Fine-grained data access control** – Amazon OpenSearch Service enables you to limit access to data down to the field level and helps anonymize data in fields based on user permissions. This is useful if you want support troubleshooting without exposing sensitive data.
- **Aggregate and search logs across multiple accounts, Regions, and infrastructure** – You can stream your logs from multiple accounts and Regions into a common Amazon OpenSearch Service cluster. Your centralized operations teams can analyze trends, issues, and perform analytics across accounts

and Regions. Streaming CloudWatch logs to Amazon OpenSearch Service also helps you search and analyze a multi-Region application in a central location.

- **Ship and enrich logs directly to Amazon OpenSearch Service by using ElasticSearch agents** – Your application and technology stack components can use OSs that are not supported by the CloudWatch agent. You might also want to enrich and transform log data before it is shipped to your logging solution. Amazon OpenSearch Service supports standard Elasticsearch clients such as the Elastic Beats family data shippers and Logstash that support log enrichment and transformation before sending the log data to Amazon OpenSearch Service.
- **Existing operations management solution uses an ElasticSearch, Logstash, Kibana (ELK) Stack for logging and monitoring** – You might already have a significant investment in Amazon OpenSearch Service or open-source Elasticsearch with many workloads already configured. You might also have operational dashboards that have been created in Kibana that you want to continue to use.

If you don't plan to use CloudWatch logs, you can use Amazon OpenSearch Service supported agents, log drivers, and libraries (for example, Fluent Bit, Fluentd, logstash, and the Open Distro for ElasticSearch API) to ship your logs directly to Amazon OpenSearch Service and bypass CloudWatch. However, you should also implement a solution to capture logs generated by AWS services. CloudWatch Logs is the primary log capture solution for many AWS services and multiple services automatically create new log groups in CloudWatch. For example, Lambda creates a new log group for every Lambda function. You can set up a subscription filter for a log group to stream its logs to Amazon OpenSearch Service. You can manually configure a subscription filter for each individual log group that you want to stream to Amazon OpenSearch Service. Alternatively, you can deploy a solution that automatically subscribes new log groups to ElasticSearch clusters. You can stream logs to an ElasticSearch cluster in the same account or a centralized account. Streaming logs to an ElasticSearch cluster in the same account helps workload owners to better analyze and support their workloads.

You should consider setting up an ElasticSearch cluster in a centralized or shared account for aggregating logs across your accounts, Regions, and applications. For example, AWS Control Tower sets up a Log Archive account that is used for centralized logging. When a new account is created in AWS Control Tower, its AWS CloudTrail and AWS Config logs are delivered to an S3 bucket in this centralized account. The logging instrumented by AWS Control Tower is for configuration, change, and audit logging.

To establish a centralized application log analysis solution with Amazon OpenSearch Service, you can deploy one or more centralized Amazon OpenSearch Service clusters to your centralized logging account and configure log groups in your other accounts to stream logs to the centralized Amazon OpenSearch Service clusters.

You can create separate Amazon OpenSearch Service clusters to handle different applications or layers of your cloud architecture that might be distributed across your accounts. Using separate Amazon OpenSearch Service clusters helps you reduce your security and availability risk and having a common Amazon OpenSearch Service cluster can make it easier to search and relate data within the same cluster.

Alarming options with CloudWatch

Performing one-time and automated analysis of important metrics helps you detect and resolve issues before they impact your workloads. CloudWatch makes it easy to graph and compare multiple metrics by using multiple statistics over a specific time period. You can use CloudWatch to search across all metrics with the required dimension values to find the metrics that you need for your analysis.

We recommend that you begin your metrics capture approach by including an initial set of metrics and dimensions to use as a baseline for monitoring a workload. Over time, the workload matures and you can add additional metrics and dimensions to help you further analyze and support it. Your applications or workloads might use multiple AWS resources and have their own custom metrics, you should group these resources under a namespace to make them easier to identify.

You should also consider how logging and monitoring data is correlated so that you can quickly identify the relevant logging and monitoring data to diagnose specific issues. You can use CloudWatch ServiceLens to correlate traces, metrics, logs, and alarms for diagnosing issues. You should also consider including additional dimensions in metrics and identifiers in logs for your workloads to help you quickly search for and identify issues across systems and services.

Using CloudWatch alarms to monitor and alarm

You can use CloudWatch alarms to reduce manual monitoring in your workloads or applications. You should begin by reviewing the metrics that you are capturing for each workload component and determine the appropriate thresholds for each metric. Make sure that you identify which team members must be notified when a threshold is breached. You should establish and target distribution groups, rather than individual team members.

CloudWatch alarms can integrate with your service management solution to automatically create new tickets and run operational workflows. For example, AWS provides the AWS Service Management Connector for ServiceNow and Jira Service Desk to help you quickly set up integrations. This approach is critical to ensuring that raised alarms are acknowledged and aligned to your existing operations workflows that might already be defined in these products.

You can also create multiple alarms for the same metric that have different thresholds and evaluation periods, which helps establish an escalation process. For example, if you have a `OrderQueueDepth` metric that tracks customer orders, you might define a lower threshold over a short one-minute average period that notifies application team members by email or Slack. You can also define another alarm for the same metric over a longer 15-minute period at the same threshold and that pages, emails, and notifies the application team and application team's lead. Finally, you can define a third alarm for a hard average threshold over a 30-minute period that notifies upper-management and notifies all team members previously notified. Creating multiple alarms helps you take different actions for different conditions. You can begin with a simple notification process and then adjust and improve it as required.

Using CloudWatch anomaly detection to monitor and alarm

You can use CloudWatch anomaly detection if you are unsure about the thresholds to apply for a particular metric or if you want an alarm to automatically adjust the threshold values based on observed, historical values. CloudWatch anomaly detection is particularly useful for metrics that might have

regular, predictable changes in activity, for example, daily purchase orders for same-day delivery increasing before a cutoff time. Anomaly detection enables thresholds that adjust automatically and can help reduce false alarms. You can enable anomaly detection for each metric and statistic, and configure CloudWatch to alarm based on outliers.

For example, you can enable anomaly detection for the `CPUUtilization` metric and the `AVG` statistic on an EC2 instance. Anomaly detection then uses up to 14 days of historical data to create the machine learning (ML) model. You can create multiple alarms with different anomaly detection bands to establish an alarm escalation process, similar to creating multiple standard alarms with different thresholds.

For more information about this section, see Creating a CloudWatch alarm based on anomaly detection in the CloudWatch documentation.

Alarming across multiple Regions and accounts

Application and workload owners should create application-level alarms for workloads that span multiple Regions. We recommend creating separate alarms within each account and Region that your workload is deployed in. You can simplify and automate this process by using account and Region agnostic AWS CloudFormation StackSets and templates to deploy application resources with the required alarms. templateYou can configure the alarm actions to target a common Amazon Simple Notification Service (Amazon SNS) topic, which means the same notification or remediation action is used regardless of the account or Region.

In multi-account and multi-Region environments, we recommend that you create aggregated alarms for your accounts and Regions to monitor account and Regional issues by using AWS CloudFormation StackSets and aggregate metrics, such as average `CPUUtilization` across all EC2 instances.

You should also consider creating standard alarms for each workload that is configured for the standard CloudWatch metrics and logs that you capture. For example, you can create a separate alarm for each EC2 instance that monitors the CPU utilization metric and notifies a central operations team when average CPU utilization is over 80% on a daily basis. You can also create a standard alarm that monitors average CPU utilization under 10% on a daily basis. These alarms help the central operations team to work with specific workload owners to change the size of the EC2 instances when required.

Automating alarm creation with EC2 instance tags

Creating a standard set of alarms for your EC2 instances can be time consuming, inconsistent, and error prone. You can accelerate the alarm creation process by using the amazon-cloudwatch-auto-alarms solution to automatically create a standard set of CloudWatch alarms for your EC2 instances and create custom alarms based on EC2 instance tags. The solution removes the need to manually create standard alarms and can be useful during a large-scale migration of EC2 instances that uses tools such as CloudEndure. You can also deploy this solution with AWS CloudFormation StackSets to support multiple Regions and accounts. For more information, see Use tags to create and maintain Amazon CloudWatch alarms for Amazon EC2 instances on the AWS Blog.

Monitoring application and service availability

CloudWatch helps you monitor and analyze the performance and runtime aspects of your applications and workloads. You should also monitor the availability and reachability aspects of your applications and workloads. You can achieve this by using an active monitoring approach with Amazon Route 53 health checks and CloudWatch Synthetics.

You can use Route 53 health checks when you want to monitor connectivity to a webpage through HTTP or HTTPS, or network connectivity through TCP to a public Domain Name System (DNS) name or IP address. Route 53 health checks initiate connections from the Regions that you specify on ten-second or 30-second intervals. You can choose multiple Regions for the health check to run in, each health check runs independently, and you must choose at least three Regions. You can search the response body of an HTTP or HTTPS request for a specific substring if it appears in the first 5,120 bytes of data returned for health check evaluation. An HTTP or HTTPS request is considered healthy if it returns a 2xx or 3xx response. Route 53 health checks can be used to create a composite health check by checking the health of other health checks. You can do this if you have multiple service endpoints and you want to perform the same notification when one of them becomes unhealthy. If you use Route 53 for DNS, you can configure Route 53 to fail over to another DNS entry if a health check becomes unhealthy. For each critical workload, you should consider setting up Route 53 health checks for external endpoints that are critical for normal operations. Route 53 health checks can help you avoid writing failover logic into your applications.

CloudWatch synthetics allows you to define a canary as a script to evaluate the health and availability of your workloads. Canaries are scripts written in Node.js or Python and work over HTTP or HTTPS protocols. They create Lambda functions in your account that use Node.js or Python as a framework. Each canary that you define can perform multiple HTTP or HTTPS calls to different endpoints. This means you can monitor the health of a series of steps, such as a use case or an endpoint with downstream dependencies. Canaries create CloudWatch metrics that include each step that was run so you can alarm and measure different steps independently. Although canaries require more planning and effort to develop than Route 53 health checks, they provide you with a highly customizable monitoring and evaluation approach. Canaries also support private resources running within your virtual private cloud (VPC), which makes them ideal for availability monitoring when you don't have a public IP address for the endpoint. You can also use canaries to monitor on-premises workloads as long as you have connectivity from within the VPC to the endpoint. This is particularly important when you have a workload that includes endpoints that exist on premises.

Tracing applications with AWS X-Ray

A request through your application might consist of calls to databases, applications, and web services running in on-premises servers, Amazon EC2, containers, or Lambda. By implementing application tracing, you can quickly identify the root cause of issues in your applications that use distributed components and services. You can use AWS X-Ray to trace your application requests across multiple components. X-Ray samples and visualizes requests on a service graph when they flow through your application components and each component is represented as a segment. X-Ray generates trace identifiers so that you can correlate a request when it flows through multiple components, which helps you view the request from end to end. You can further enhance this by including annotations and metadata to help uniquely search for and identify the characteristics of a request.

We recommend that you configure and instrument each server or endpoint in your application with X-Ray. X-Ray is implemented in your application code by making calls to the X-Ray service. X-Ray also provides AWS SDKs for multiple languages, including instrumented clients that automatically send data to X-Ray. The X-Ray SDKs provide patches to common libraries used for making calls to other services (for example, HTTP, MySQL, PostgreSQL, or MongoDB).

X-Ray provides an X-Ray daemon that you can install and run on Amazon EC2 and Amazon ECS to relay data to X-Ray. X-Ray creates traces for your application that capture performance data from the servers and containers running the X-Ray daemon that serviced the request. X-Ray automatically instruments your calls to AWS services, such as Amazon DynamoDB, as subsegments through patching the AWS SDK. X-Ray can also automatically integrate with Lambda functions.

If your application components make calls to external services that can't configure and install the X-Ray daemon or instrument the code, you can create subsegments to wrap calls to external services. X-Ray correlates CloudWatch logs and metrics with your application traces if you are using the AWS X-Ray SDK for Java, which means you can quickly analyze the related metrics and logs for requests.

Deploying the X-Ray daemon to trace applications and services on Amazon EC2

You need to install and run the X-Ray daemon on the EC2 instances that your application components or microservices run on. You can use a user data script to deploy the X-Ray daemon when EC2 instances are provisioned or you can include it in the AMI build process if you create your own AMIs. This can be particularly useful when EC2 instances are ephemeral.

You should use State Manager to ensure that the X-Ray daemon is consistently installed on your EC2 instances. For Amazon EC2 Windows instances, you can use the Systems Manager AWS-RunPowerShellScript document to run the Windows script that downloads and installs the X-Ray agent. For EC2 instances on Linux, you can use the AWS-RunShellScript document to run the Linux script that downloads and installs the agent as a service.

You can use the Systems Manager AWS-RunRemoteScript document to run the script in a multi-account environment. You must create an S3 bucket that is accessible from all your accounts and we recommend creating an S3 bucket with an organization-based bucket policy if you use AWS Organizations. You then upload the scripts to the S3 bucket but make sure that the IAM role for your EC2 instances has permission to access the bucket and scripts.

You can also configure State Manager to associate the scripts to EC2 instances that have the X-Ray agent installed. Because all of your EC2 instances might not require or use X-Ray, you can target the association

with instance tags. For example, you can create the State Manager association based on the presence of `InstallAWSXRayDaemonWindows` or `InstallAWSXRayDaemonLinux` tags.

Deploying the X-Ray daemon to trace applications and services on Amazon ECS or Amazon EKS

You can deploy the X-Ray daemon as a sidecar container for container-based workloads such as Amazon ECS or Amazon EKS. Your application containers can then connect to your sidecar container with container linking if you use Amazon ECS, or the container can directly connect to the sidecar container on localhost if you use awsvpc network mode.

For Amazon EKS, you can define the X-Ray daemon in your application's pod definition and then your application can connect to the daemon over localhost on the container port that you specified.

Configuring Lambda to trace requests to X-Ray

Your application might include calls to Lambda functions. You don't need to install the X-Ray daemon for Lambda because the daemon process is fully managed by Lambda and cannot be configured by the user. You can enable it for your Lambda function by using the AWS Management Console and checking the **Active Tracing** option in the X-Ray console.

For further instrumentation, you can bundle the X-Ray SDK with your Lambda function to record outgoing calls and add annotations or metadata.

Instrumenting your applications for X-Ray

You should evaluate the X-Ray SDK that aligns with your application's programming language and classify all calls that your application makes to other systems. Review the clients provided by the library that you chose and see if the SDK can automatically instrument tracing for your application's request or response. Determine if the clients provided by the SDK can be used for other downstream systems. For external systems that your application calls and that you can't instrument with X-Ray, you should create a custom subsegments to capture and identify them in your trace information.

When you instrument your application, make sure that you create annotations to help you to identify and search for requests. For example, your application might use an identifier for customers, such as `customer id`, or segment different users based on their role in the application.

You can create a maximum of 50 annotations for each trace but you can create a metadata object containing one or more fields as long as the segment document doesn't exceed 64 kilobytes. You should selectively use annotations to locate information and use the metadata object to provide more context that helps troubleshoot the request after it is located.

Configuring the X-Ray sampling rules

By customizing sampling rules, you can control the amount of data that you record and modify the sampling behavior without modifying or redeploying your code. Sampling rules tell the X-Ray SDK how many requests to record for a set of criteria. By default, the X-Ray SDK records the first request each second and five percent of any additional requests. One request per second is the reservoir. This ensures

that at least one trace is recorded each second as long as the service is serving requests. Five percent is the rate at which additional requests are sampled beyond the reservoir size.

You should review and update the default configuration to determine an appropriate value for your account. Your requirements might vary in development, test, performance test, and production environments. You might have applications that require their own sampling rules based on the amount of traffic that they receive or their level of criticality. You should begin with a baseline and regularly re-evaluate whether the baseline meets your requirements.

Dashboards and visualizations with CloudWatch

Dashboards help you quickly focus on areas of concern for applications and workloads. CloudWatch provides automatic dashboards and you can also easily create dashboards that use CloudWatch metrics. CloudWatch dashboards provide more insight than viewing metrics in isolation because they help you correlate multiple metrics and identify trends. For example, a dashboard that includes orders received, memory, CPU utilization, and database connections can help you correlate changes in workload metrics across multiple AWS resources while your order count is increasing or decreasing.

You should create dashboards at the account and application-level to monitor workloads and applications. You can get started by using CloudWatch automatic dashboards, which are AWS service-level dashboards preconfigured with service-specific metrics. Automatic service dashboards display all the standard CloudWatch metrics for the service. The automatic dashboards graph all resources used for each service metric and help you quickly identify outlier resources across your account. This can help you identify resources with high and low utilization, which can help you optimize your costs.

Creating cross-service dashboards

You can create cross-service dashboards by viewing the automatic service-level dashboard for an AWS service and using the **Add to dashboard** option from the **Actions** menu. You can then add metrics from other automatic dashboards to your new dashboard and remove metrics to narrow the dashboard's focus. You should also add your own custom metrics to track key observations (for example, orders received or transactions per second). Creating your own custom cross-service dashboard helps you focus on the most relevant metrics for your workload. We recommend that you create account-level, cross-service dashboards that cover key metrics and display all of the workloads in an account.

If you have a central office space or common area for your cloud operations teams, you can display the CloudWatch dashboard on a large TV monitor in full screen mode with automatic refresh.

Creating application or workload-specific dashboards

We recommend that you create application and workload-specific dashboards that focus on key metrics and resources for every critical application or workload in your production environment. Application and workload-specific dashboards focus on your custom application or workload metrics and important AWS resource metrics that influence their performance.

You should regularly evaluate and customize your CloudWatch application or workload dashboards to track key metrics after incidents occur. You should also update application or workload-specific dashboards when features are introduced or retired. Updates to workload and application-specific dashboards should be a required activity for continuous improvement in quality, in addition to logging and monitoring.

Creating cross-account or cross-Region dashboards

AWS resources are primarily Regional and the metrics, alarms, and dashboards are specific to the Region that the resources are deployed in. This can require you to change Regions to view metrics, dashboards,

and alarms for cross-Region workloads and applications. If you separate your applications and workloads into multiple accounts, you might also be required to re-authenticate and sign in to each account. However, CloudWatch supports cross-account and cross-Region data viewing from a single account, which means that you can view metrics, alarms, dashboards, and log widgets in a single account and Region. This is very useful if you have a centralized logging and monitoring account.

Account owners and application team owners should create dashboards for account-specific, cross-Region applications to effectively monitor key metrics in a centralized location. CloudWatch dashboards automatically support cross-Region widgets, which means you can create a dashboard that includes metrics from multiple Regions without further configuration.

An important exception is the CloudWatch Logs Insights widget because log data can only be displayed for the account and Region that you are currently logged into. You can create Region-specific metrics from your logs by using metric filters and these metrics can be displayed on a cross-Region dashboard. You can then switch to the specific Region when you need to further analyze those logs.

Operations teams should create centralized dashboard that monitor important cross-account and cross-Region metrics. For example, you can create a cross-account dashboard that includes the aggregate CPU utilization in each account and Region. You can also use metric math to aggregate and dashboard data across multiple accounts and Regions.

Using metric math to fine-tune observability and alarming

You can use metric math to help calculate metrics in formats and expressions that are relevant for your workloads. The calculated metrics can be saved and viewed on a dashboard for tracking purposes. For example, standard Amazon EBS volume metrics provide the number of read (`VolumeReadOps`) and write (`VolumeWriteOps`) operations performed over a specific period.

However, AWS provides guidelines on Amazon EBS volume performance in IOPS. You can graph and calculate the IOPS for your Amazon EBS volume in metric math by adding the `VolumeReadOps` and `VolumeWriteOps` and then dividing by the period chosen for these metrics.

In this example, we sum up the IOPS in the period and then divide by the period length to get the IOPS. You can then set an alarm against this metric math expression to alert you when your volume's IOPS approaches maximum capacity for its volume type. For more information and examples about using metric math to monitor Amazon Elastic File System (Amazon EFS) file systems with CloudWatch metrics, see Amazon CloudWatch metric math simplifies near real-time monitoring of your Amazon EFS file systems and more on the AWS Blog.

Using automatic dashboards for Amazon ECS, Amazon EKS, and Lambda with CloudWatchContainer Insights and CloudWatch Lambda Insights

CloudWatch Container Insights creates dynamic, automatic dashboards for container workloads running on Amazon ECS and Amazon EKS. You should enable Container Insights to have observability of CPU, memory, disk, network, and diagnostic information such as container restart failures. Container Insights generates dynamic dashboards that you can quickly filter at the cluster, container instance or node,

service, task, pod, and individual container level. Container Insights is configured at the cluster and node or container instance level depending on the AWS service.

Similar to Container Insights, CloudWatch Lambda Insights creates dynamic, automatic dashboards for your Lambda functions. This solution collects, aggregates, and summarizes system-level metrics, including CPU time, memory, disk, and network. It also collects, aggregates, and summarizes diagnostic information such as cold starts and Lambda worker shutdowns to help you isolate and quickly resolve issues with your Lambda functions. Lambda is enabled at the function level and doesn't require any agents.

Container Insights and Lambda Insights also help you quickly switch to the application or performance logs, X-Ray traces, and a service map to visualize your container workloads. They both use the CloudWatch embedded metric format to capture CloudWatch metrics and performance logs.

You can create a shared CloudWatch dashboard for your workload that uses the metrics captured by Container Insights and Lambda Insights. You can do this by filtering and viewing the automatic dashboard through CloudWatch Container Insights and then choosing the **Add to Dashboard** option that allows you to add the metrics displayed to a standard CloudWatch dashboard. You can then remove or customize the metrics and add other metrics to correctly represent your workload.

CloudWatch integration with AWS services

AWS provides many services that include additional configuration options for logging and metrics. These services often enable you to configure CloudWatch Logs for log output and CloudWatch metrics for metrics output. The underlying infrastructure used to provide these services is managed by AWS and is inaccessible, but you can use the logging and metric options for your provisioned services to gain further insights and troubleshoot issues. For example, you can publish VPC flow logs to CloudWatch, or you can also configure Amazon Relational Database Service (Amazon RDS) instances to publish logs to CloudWatch.

Most AWS services log their API calls with integration to AWS CloudTrail. CloudTrail also supports integration with CloudWatch Logs and this means that you can search and analyze activity in AWS services. You can also use Amazon CloudWatch Events or Amazon EventBridge to create and configure automation and notifications with CloudWatch Events event rules for specific actions performed in AWS services. Certain services integrate directly with CloudWatch Events and EventBridge. You can also create events delivered through CloudTrail.

Amazon Managed Grafana for dashboarding and visualization

Amazon Managed Grafana can be used to observe and visualize your AWS workloads. Amazon Managed Grafana helps you visualize and analyze your operational data at scale. Grafana is an open-source analytics platform that helps you query, visualize, alert on, and understand your metrics wherever they are stored. Amazon Managed Grafana is particularly useful if your organization already uses Grafana for visualization of existing workloads and you want to extend coverage to AWS workloads. You can use Amazon Managed Grafana with CloudWatch by adding it as a data source, which means that you can create visualizations using CloudWatch metrics. Amazon Managed Grafana supports AWS Organizations and you can centralize dashboards using CloudWatch metrics from multiple accounts and Regions.

The following table provides the advantages and considerations for using Amazon Managed Grafana instead of CloudWatch for dashboarding. A hybrid approach might be suitable based on the different requirements of your end users, workloads, and applications.

Create visualizations and dashboards that integrate with data sources supported by Amazon Managed Grafana and open-source Grafana	Amazon Managed Grafana helps you create visualizations and dashboards from many different data sources, including CloudWatch metrics. Amazon Managed Grafana includes a number of built-in data sources that span AWS services, open-source software, and COTS software. For more information about this, see Built-in data sources in the Amazon Managed Grafana documentation. You can also add support for more data sources by upgrading your workspace to Grafana Enterprise. Grafana also supports data source plugins that allow you to communicate with different external systems. CloudWatch dashboards require a CloudWatch metric or CloudWatch Logs Insights query for data to be displayed display on a CloudWatch dashboard.
Manage access to your dashboarding solution separately from your AWS account access	Amazon Managed Grafana requires the use of AWS IAM Identity Center (successor to AWS Single Sign-On) (IAM Identity Center) and AWS Organizations for authentication and authorization. This enables you to authenticate users to Grafana by using identity federation that you might already use with IAM Identity Center or AWS Organizations. However, if you aren't using IAM Identity Center or AWS Organizations, then it is set up as a part of the Amazon Managed Grafana setup process. This might become an issue if your organization has limited the use of IAM Identity Center or AWS Organizations.

Ingest and access data across multiple accounts and Regions with AWS Organizations integration	Amazon Managed Grafana integrates with AWS Organizations to enable you to read data from AWS sources such as CloudWatch and Amazon OpenSearch Service across all your accounts. This makes it possible to create dashboards that display visualizations using data across your accounts. To automatically enable data access across AWS Organizations, you need to set up your Amazon Managed Grafana workspace in the AWS Organizations management account. This is not recommended based on AWS Organizations best practices for the management account. In contrast, CloudWatch also supports cross-account, cross-Region dashboards for CloudWatch metrics.
Use advanced visualization widgets and Grafana definitions available in the open-source community	Grafana provides a large collection of visualizations that you can use when creating your dashboards. There is also a large library of community-contributed dashboards that you can edit and reuse according to your requirements.
Use dashboards with new and existing Grafana deployments	If you already use Grafana, you can import and export dashboards from your Grafana deployments and customize them for use in Amazon Managed Grafana. Amazon Managed Grafana allows you to standardize on Grafana as your dashboarding solution.
Advanced setup and configuration for workspaces, permissions, and data sources	Amazon Managed Grafana enables you to create multiple Grafana workspaces that have their own set of configured data sources, users, and policies. This can help you meet more advanced use case requirements, as well as advanced security configurations. The advanced capabilities might require your teams to grow their experience with Grafana if they don't already have these skills.

Designing and implementing logging and monitoring with CloudWatch FAQ

This section provides answers to commonly raised questions about designing and implementing logging and monitoring solution with CloudWatch.

Where do I store my CloudWatch configuration files?

The CloudWatch agent for Amazon EC2 can apply multiple configuration files that are stored in the CloudWatch configuration directory. Ideally, you should store your CloudWatch configuration as a set of files because you can version control and use them again across multiple accounts and environments. For more information about this, see the Storing CloudWatch configuration files in an S3 bucket (p. 9) section of this guide. Alternatively, you can store your configuration files in a repository on GitHub and automate the retrieval of the configuration files when a new EC2 instance is provisioned.

How can I create a ticket in my service management solution when an alarm is raised?

You integrate your service management system with an Amazon Simple Notification Service (Amazon SNS) topic and configure the CloudWatch alarm to notify the SNS topic when an alarm is raised. Your integrated system receives the SNS message and can create a ticket using your service management systems APIs or SDKs.

How do I use CloudWatch to capture log files in my containers?

Amazon ECS tasks and Amazon EKS pods can be configured to automatically send the STDOUT and STDERR output to CloudWatch. The recommended approach for logging containerized applications is to have containers send their output to STDOUT and STDERR. This is also covered in the Twelve-Factor App manifesto.

However, if you want to send specific log files to CloudWatch then you can mount a volume in your Amazon EKS pod or Amazon ECS task definition to where your application will write its lot files and use a sidecar container for Fluentd or Fluent Bit to send the logs to CloudWatch. You should consider symbolic linking a specific log file in your container to `/dev/stdout` and `/dev/stderr`. For more information about this, see View logs for a container or service in the Docker documentation.

How do I monitor health issues for AWS services?

You can use the AWS Health Dashboard to monitor AWS health events. You can also refer to the aws-health-tools GitHub repository for sample automation solutions related to AWS health events.

How can I create a custom CloudWatch metric when no agent support exists?

You can use the embedded metric format to ingest metrics into CloudWatch. You can also use AWS SDK (for example, put_metric_data), AWS CLI (for example, put-metric-data), or AWS API (for example, PutMetricData) to create custom metrics. You should consider how any custom logic will be maintained long term. One approach would be to use Lambda with integrated embedded metric format support to create your metrics, along with a CloudWatch Events event schedule rule to establish the period for the metric.

How do I integrate my existing logging and monitoring tools with AWS?

You should refer to guidance provided by the software or service vendor for integrating with AWS. You might be able to use agent software, SDK, or an API provided to send logs and metrics to their solution. You might also be able to use an open-source solution, such as Fluentd or Fluent Bit, configured to the vendor's specifications. You can also use the AWS SDK and CloudWatch Logs subscription filters with Lambda and Kinesis Data Streams to create custom log processors and shippers. Finally, you should also consider how you will integrate the software if you are using multiple accounts and Regions.

Resources

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- logging-monitoring-apg-guide-examples
- Six advantages of cloud computing

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- AWS Systems Manager Quick Setup
- Collecting metrics and logs from Amazon EC2 instances and on-premises servers with the CloudWatch agent
- cloudwatch-config-s3-bucket.yaml
- Create the CloudWatch agent configuration file with the wizard
- Enterprise DevOps: Why you should run what you build
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- Burstable performance instances
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- How can I configure on-premises servers that use Systems Manager agent and the unified CloudWatch agent to use only temporary credentials?
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- Amazon ECS CloudWatch metrics
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- Deploying the CloudWatch agent to collect EC2 instance-level metrics on Amazon ECS
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- Retrieving Amazon ECS optimized AMI metadata
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- Container Insights Prometheus metrics monitoring
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- Send logs to CloudWatch Logs
- Set up FluentD as a DaemonSet to send logs to CloudWatch Logs
- Set up Java/JMX sample workload on Amazon EKS and Kubernetes
- Tutorial for adding a new Prometheus scrape target: Prometheus API Server metrics
- Vertical Pod Autoscaler

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- Lambda invocation errors
- logging – Logging facility for Python
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- Working with Lambda function metrics

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- Elastic Logstash
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- Streaming CloudWatch Logs data to Amazon OpenSearch Service

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- CloudWatch Events event examples from supported services
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AWS Prescriptive Guidance glossary

AI and ML terms (p. 65) | Migration terms (p. 66) | Modernization terms (p. 70)

AI and ML terms

The following are commonly used terms in artificial intelligence (AI) and machine learning (ML)-related strategies, guides, and patterns provided by AWS Prescriptive Guidance. To suggest entries, please use the **Provide feedback** link at the end of the glossary.

binary classification	A process that predicts a binary outcome (one of two possible classes). For example, your ML model might need to predict problems such as “Is this email spam or not spam?" or "Is this product a book or a car?"
classification	A categorization process that helps generate predictions. ML models for classification problems predict a discrete value. Discrete values are always distinct from one another. For example, a model might need to evaluate whether or not there is a car in an image.
data preprocessing	To transform raw data into a format that is easily parsed by your ML model. Preprocessing data can mean removing certain columns or rows and addressing missing, inconsistent, or duplicate values.
deep ensemble	To combine multiple deep learning models for prediction. You can use deep ensembles to obtain a more accurate prediction or for estimating uncertainty in predictions.
deep learning	An ML subfield that uses multiple layers of artificial neural networks to identify mapping between input data and target variables of interest.
exploratory data analysis (EDA)	The process of analyzing a dataset to understand its main characteristics. You collect or aggregate data and then perform initial investigations to find patterns, detect anomalies, and check assumptions. EDA is performed by calculating summary statistics and creating data visualizations.
features	The input data that you use to make a prediction. For example, in a manufacturing context, features could be images that are periodically captured from the manufacturing line.
feature importance	How significant a feature is for a model’s predictions. This is usually expressed as a numerical score that can be calculated through various techniques, such as Shapley Additive Explanations (SHAP) and integrated gradients. For more information, see Machine learning model interpretability with AWS.

feature transformation	To optimize data for the ML process, including enriching data with additional sources, scaling values, or extracting multiple sets of information from a single data field. This enables the ML model to benefit from the data. For example, if you break down the “2021-05-27 00:15:37” date into “2021”, “May”, “Thu”, and “15”, you can help the learning algorithm learn nuanced patterns associated with different data components.
interpretability	A characteristic of a machine learning model that describes the degree to which a human can understand how the model’s predictions depend on its inputs. For more information, see Machine learning model interpretability with AWS.
multiclass classification	A process that helps generate predictions for multiple classes (predicting one of more than two outcomes). For example, an ML model might ask "Is this product a book, car, or phone?" or "Which product category is most interesting to this customer?"
regression	An ML technique that predicts a numeric value. For example, to solve the problem of "What price will this house sell for?" an ML model could use a linear regression model to predict a house's sale price based on known facts about the house (for example, the square footage).
training	To provide data for your ML model to learn from. The training data must contain the correct answer. The learning algorithm finds patterns in the training data that map the input data attributes to the target (the answer that you want to predict). It outputs an ML model that captures these patterns. You can then use the ML model to make predictions on new data for which you don’t know the target.
target variable	The value that you are trying to predict in supervised ML. This is also referred to as an *outcome variable*. For example, in a manufacturing setting the target variable could be a product defect.
tuning	To change aspects of your training process to improve the ML model's accuracy. For example, you can train the ML model by generating a labeling set, adding labels, and then repeating these steps several times under different settings to optimize the model.
uncertainty	A concept that refers to imprecise, incomplete, or unknown information that can undermine the reliability of predictive ML models. There are two types of uncertainty: *Epistemic uncertainty* is caused by limited, incomplete data, whereas *aleatoric uncertainty* is caused by the noise and randomness inherent in the data. For more information, see the Quantifying uncertainty in deep learning systems guide.

Migration terms

The following are commonly used terms in migration-related strategies, guides, and patterns provided by AWS Prescriptive Guidance. To suggest entries, please use the **Provide feedback** link at the end of the glossary.

7 Rs	Seven common migration strategies for moving applications to the cloud. These strategies build upon the 5 Rs that Gartner identified in 2011 and consist of the following: • Refactor/re-architect – Move an application and modify its architecture by taking full advantage of cloud-native features to improve agility, performance, and scalability. This typically involves porting the operating system and database. Example: Migrate your on-premises Oracle database to the Amazon Aurora PostgreSQL-Compatible Edition.

	• Replatform (lift and reshape) – Move an application to the cloud, and introduce some level of optimization to take advantage of cloud capabilities. Example: Migrate your on-premises Oracle database to Amazon Relational Database Service (Amazon RDS) for Oracle in the AWS Cloud. • Repurchase (drop and shop) – Switch to a different product, typically by moving from a traditional license to a SaaS model. Example: Migrate your customer relationship management (CRM) system to Salesforce.com. • Rehost (lift and shift) – Move an application to the cloud without making any changes to take advantage of cloud capabilities. Example: Migrate your on-premises Oracle database to Oracle on an EC2 instance in the AWS Cloud. • Relocate (hypervisor-level lift and shift) – Move infrastructure to the cloud without purchasing new hardware, rewriting applications, or modifying your existing operations. This migration scenario is specific to VMware Cloud on AWS, which supports virtual machine (VM) compatibility and workload portability between your on-premises environment and AWS. You can use the VMware Cloud Foundation technologies from your on-premises data centers when you migrate your infrastructure to VMware Cloud on AWS. Example: Relocate the hypervisor hosting your Oracle database to VMware Cloud on AWS. • Retain (revisit) – Keep applications in your source environment. These might include applications that require major refactoring, and you want to postpone that work until a later time, and legacy applications that you want to retain, because there's no business justification for migrating them. • Retire – Decommission or remove applications that are no longer needed in your source environment.
application portfolio	A collection of detailed information about each application used by an organization, including the cost to build and maintain the application, and its business value. This information is key to the portfolio discovery and analysis process and helps identify and prioritize the applications to be migrated, modernized, and optimized.
artificial intelligence operations (AIOps)	The process of using machine learning techniques to solve operational problems, reduce operational incidents and human intervention, and increase service quality. For more information about how AIOps is used in the AWS migration strategy, see the operations integration guide.
AWS Cloud Adoption Framework (AWS CAF)	A framework of guidelines and best practices from AWS to help organizations develop an efficient and effective plan to move successfully to the cloud. AWS CAF organizes guidance into six focus areas called perspectives: business, people, governance, platform, security, and operations. The business, people, and governance perspectives focus on business skills and processes; the platform, security, and operations perspectives focus on technical skills and processes. For example, the people perspective targets stakeholders who handle human resources (HR), staffing functions, and people management. For this perspective, AWS CAF provides guidance for people development, training, and communications to help ready the organization for successful cloud adoption. For more information, see the AWS CAF website and the AWS CAF whitepaper.
AWS landing zone	A landing zone is a well-architected, multi-account AWS environment that is scalable and secure. This is a starting point from which your organizations can quickly launch and deploy workloads and applications with confidence in their security and infrastructure environment. For more information about landing zones, see Setting up a secure and scalable multi-account AWS environment.
AWS Workload Qualification Framework (AWS WQF)	A tool that evaluates database migration workloads, recommends migration strategies, and provides work estimates. AWS WQF is included with AWS Schema

	Conversion Tool (AWS SCT). It analyzes database schemas and code objects, application code, dependencies, and performance characteristics, and provides assessment reports.
business continuity planning (BCP)	A plan that addresses the potential impact of a disruptive event, such as a large-scale migration, on operations and enables a business to resume operations quickly.
Cloud Center of Excellence (CCoE)	A multi-disciplinary team that drives cloud adoption efforts across an organization, including developing cloud best practices, mobilizing resources, establishing migration timelines, and leading the organization through large-scale transformations. For more information, see the CCoE posts on the AWS Cloud Enterprise Strategy Blog.
cloud stages of adoption	The four phases that organizations typically go through when they migrate to the AWS Cloud: • Project – Running a few cloud-related projects for proof of concept and learning purposes • Foundation – Making foundational investments to scale your cloud adoption (e.g., creating a landing zone, defining a CCoE, establishing an operations model) • Migration – Migrating individual applications • Re-invention – Optimizing products and services, and innovating in the cloud These stages were defined by Stephen Orban in the blog post The Journey Toward Cloud-First & the Stages of Adoption on the AWS Cloud Enterprise Strategy blog. For information about how they relate to the AWS migration strategy, see the migration readiness guide.
configuration management database (CMDB)	A database that contains information about a company's hardware and software products, configurations, and inter-dependencies. You typically use data from a CMDB in the portfolio discovery and analysis stage of migration.
epic	In agile methodologies, functional categories that help organize and prioritize your work. Epics provide a high-level description of requirements and implementation tasks. For example, AWS CAF security epics include identity and access management, detective controls, infrastructure security, data protection, and incident response. For more information about epics in the AWS migration strategy, see the program implementation guide.
heterogeneous database migration	Migrating your source database to a target database that uses a different database engine (for example, Oracle to Amazon Aurora). Heterogeneous migration is typically part of a re-architecting effort, and converting the schema can be a complex task. AWS provides AWS SCT that helps with schema conversions.
homogeneous database migration	Migrating your source database to a target database that shares the same database engine (for example, Microsoft SQL Server to Amazon RDS for SQL Server). Homogeneous migration is typically part of a rehosting or replatforming effort. You can use native database utilities to migrate the schema.
idle application	An application that has an average CPU and memory usage between 5 and 20 percent over a period of 90 days. In a migration project, it is common to retire these applications or retain them on premises.
IT information library (ITIL)	A set of best practices for delivering IT services and aligning these services with business requirements. ITIL provides the foundation for ITSM.

IT service management (ITSM)	Activities associated with designing, implementing, managing, and supporting IT services for an organization. For information about integrating cloud operations with ITSM tools, see the operations integration guide.
large migration	A migration of 300 or more servers.
Migration Acceleration Program (MAP)	An AWS program that provides consulting support, training, and services to help organizations build a strong operational foundation for moving to the cloud, and to help offset the initial cost of migrations. MAP includes a migration methodology for executing legacy migrations in a methodical way and a set of tools to automate and accelerate common migration scenarios.
Migration Portfolio Assessment (MPA)	An online tool that provides information for validating the business case for migrating to the AWS Cloud. MPA provides detailed portfolio assessment (server right-sizing, pricing, TCO comparisons, migration cost analysis) as well as migration planning (application data analysis and data collection, application grouping, migration prioritization, and wave planning). The MPA tool (requires login) is available free of charge to all AWS consultants and APN Partner consultants.
Migration Readiness Assessment (MRA)	The process of gaining insights about an organization's cloud readiness status, identifying strengths and weaknesses, and building an action plan to close identified gaps, using the AWS CAF. For more information, see the migration readiness guide. MRA is the first phase of the AWS migration strategy.
migration at scale	The process of moving the majority of the application portfolio to the cloud in waves, with more applications moved at a faster rate in each wave. This phase uses the best practices and lessons learned from the earlier phases to implement a *migration factory* of teams, tools, and processes to streamline the migration of workloads through automation and agile delivery. This is the third phase of the AWS migration strategy.
migration factory	Cross-functional teams that streamline the migration of workloads through automated, agile approaches. Migration factory teams typically include operations, business analysts and owners, migration engineers, developers, and DevOps professionals working in sprints. Between 20 and 50 percent of an enterprise application portfolio consists of repeated patterns that can be optimized by a factory approach. For more information, see the discussion of migration factories and the Cloud Migration Factory guide in this content set.
migration metadata	The information about the application and server that is needed to complete the migration. Each migration pattern requires a different set of migration metadata. Examples of migration metadata include the target subnet, security group, and AWS account.
migration pattern	A repeatable migration task that details the migration strategy, the migration destination, and the migration application or service used. Example: Rehost migration to Amazon EC2 with AWS Application Migration Service.
migration strategy	The approach used to migrate a workload to the AWS Cloud. For more information, see the 7 Rs (p. 66) entry in this glossary and see Mobilize your organization to accelerate large-scale migrations.
operational-level agreement (OLA)	An agreement that clarifies what functional IT groups promise to deliver to each other, to support a service-level agreement (SLA).
operations integration (OI)	The process of modernizing operations in the cloud, which involves readiness planning, automation, and integration. For more information, see the operations integration guide.

organizational change management (OCM)	A framework for managing major, disruptive business transformations from a people, culture, and leadership perspective. OCM helps organizations prepare for, and transition to, new systems and strategies by accelerating change adoption, addressing transitional issues, and driving cultural and organizational changes. In the AWS migration strategy, this framework is called *people acceleration*, because of the speed of change required in cloud adoption projects. For more information, see the OCM guide.
playbook	A set of predefined steps that capture the work associated with migrations, such as delivering core operations functions in the cloud. A playbook can take the form of scripts, automated runbooks, or a summary of processes or steps required to operate your modernized environment.
portfolio assessment	A process of discovering, analyzing, and prioritizing the application portfolio in order to plan the migration. For more information, see Evaluating migration readiness.
responsible, accountable, consulted, informed (RACI) matrix	A matrix that defines and assigns roles and responsibilities in a project. For example, you can create a RACI to define security control ownership or to identify roles and responsibilities for specific tasks in a migration project.
runbook	A set of manual or automated procedures required to perform a specific task. These are typically built to streamline repetitive operations or procedures with high error rates.
service-level agreement (SLA)	An agreement that clarifies what an IT team promises to deliver to their customers, such as service uptime and performance.
task list	A tool that is used to track progress through a runbook. A task list contains an overview of the runbook and a list of general tasks to be completed. For each general task, it includes the estimated amount of time required, the owner, and the progress.
workstream	Functional groups in a migration project that are responsible for a specific set of tasks. Each workstream is independent but supports the other workstreams in the project. For example, the portfolio workstream is responsible for prioritizing applications, wave planning, and collecting migration metadata. The portfolio workstream delivers these assets to the migration workstream, which then migrates the servers and applications.
zombie application	An application that has an average CPU and memory usage below 5 percent. In a migration project, it is common to retire these applications.

Modernization terms

The following are commonly used terms in modernization-related strategies, guides, and patterns provided by AWS Prescriptive Guidance. To suggest entries, please use the **Provide feedback** link at the end of the glossary.

business capability	What a business does to generate value (for example, sales, customer service, or marketing). Microservices architectures and development decisions can be driven by business capabilities. For more information, see the Organized around business capabilities section of the Running containerized microservices on AWS whitepaper.
domain-driven design	An approach to developing a complex software system by connecting its components to evolving domains, or core business goals, that each component serves. This concept was introduced by Eric Evans in his book, *Domain-Driven Design: Tackling Complexity in the Heart of Software* (Boston: Addison-Wesley

	Professional, 2003). For information about how you can use domain-driven design with the strangler fig pattern, see Modernizing legacy Microsoft ASP.NET (ASMX) web services incrementally by using containers and Amazon API Gateway.
microservice	A small, independent service that communicates over well-defined APIs and is typically owned by small, self-contained teams. For example, an insurance system might include microservices that map to business capabilities, such as sales or marketing, or subdomains, such as purchasing, claims, or analytics. The benefits of microservices include agility, flexible scaling, easy deployment, reusable code, and resilience. For more information, see Integrating microservices by using AWS serverless services.
microservices architecture	An approach to building an application with independent components that run each application process as a microservice. These microservices communicate through a well-defined interface by using lightweight APIs. Each microservice in this architecture can be updated, deployed, and scaled to meet demand for specific functions of an application. For more information, see Implementing microservices on AWS.
modernization	Transforming an outdated (legacy or monolithic) application and its infrastructure into an agile, elastic, and highly available system in the cloud to reduce costs, gain efficiencies, and take advantage of innovations. For more information, see Strategy for modernizing applications in the AWS Cloud.
modernization readiness assessment	An evaluation that helps determine the modernization readiness of an organization's applications; identifies benefits, risks, and dependencies; and determines how well the organization can support the future state of those applications. The outcome of the assessment is a blueprint of the target architecture, a roadmap that details development phases and milestones for the modernization process, and an action plan for addressing identified gaps. For more information, see Evaluating modernization readiness for applications in the AWS Cloud.
monolithic applications (monoliths)	Applications that run as a single service with tightly coupled processes. Monolithic applications have several drawbacks. If one application feature experiences a spike in demand, the entire architecture must be scaled. Adding or improving a monolithic application's features also becomes more complex when the code base grows. To address these issues, you can use a microservices architecture. For more information, see Decomposing monoliths into microservices.
polyglot persistence	Independently choosing a microservice's data storage technology based on data access patterns and other requirements. If your microservices have the same data storage technology, they can encounter implementation challenges or experience poor performance. Microservices are more easily implemented and achieve better performance and scalability if they use the data store best adapted to their requirements. For more information, see Enabling data persistence in microservices.
split-and-seed model	A pattern for scaling and accelerating modernization projects. As new features and product releases are defined, the core team splits up to create new product teams. This helps scale your organization's capabilities and services, improves developer productivity, and supports rapid innovation. For more information, see Phased approach to modernizing applications in the AWS Cloud.
strangler fig pattern	An approach to modernizing monolithic systems by incrementally rewriting and replacing system functionality until the legacy system can be decommissioned. This pattern uses the analogy of a fig vine that grows into an established tree and eventually overcomes and replaces its host. The pattern was introduced by Martin Fowler as a way to manage risk when rewriting monolithic systems. For an

	example of how to apply this pattern, see Modernizing legacy Microsoft ASP.NET (ASMX) web services incrementally by using containers and Amazon API Gateway.
two-pizza team	A small DevOps team that you can feed with two pizzas. A two-pizza team size ensures the best possible opportunity for collaboration in software development. For more information, see the Two-pizza team section of the Introduction to DevOps on AWS whitepaper.

Document history

The following table describes significant changes to this guide. If you want to be notified about future updates, you can subscribe to an RSS feed.

Change	Description	Date
Removed preview notices (p. 73)	Amazon Managed Grafana is generally available.	May 25, 2022
Removed section (p. 73)	CloudWatch SDK Metrics is no longer supported.	January 7, 2022
Initial publication (p. 73)	—	April 30, 2021