ECE4574 – Large-Scale SW Development for Engineering Systems
Lecture 10 – Cloud Computing

Creed Jones, PhD

Course Updates

- Project
  - hope Sprint 1 is going well ☺
- Quiz 4 is next Monday, October 2

Next Week – Oct 2 and 4

Monday, Oct 2 – Project Day

- Come to class and sit in your project groups
  - Online team members should join by zoom or similar
- Use the day to catch up on your project work
  - Stand-up meeting
  - Start on the sprint retrospective
- I will meet briefly with each group

Wednesday, Oct 4 – NO CLASS

No office hours on Tuesday, Wednesday or Thursday (Oct 3, 4 and 5)

Key Topics for Today

- Cloud computing basics
- Cloud service providers
- A simple code example
- Virtual machines
- Kubernetes
- Docker

CLOUD COMPUTING

Cloud computing is the use of online resources for computation, storage and other key services – in a flexible and automatic manner

- In a cloud system, user management is not needed to request and release resources
- Cloud systems are built on the concept of virtualization – software runs on virtual machines that do not correspond to specific physical platforms
  - virtualization software provides software-based computers with flexible configurations
  - cloud providers make these resources available in a variety of pricing models

- The big three cloud providers these days are:
  - Amazon Web Services (AWS)
  - Google Cloud
  - Microsoft Azure
    - also IBM, Oracle, Adobe, Cisco…

The convenience of cloud computing comes from the concept of delivering *services*

- Software as a Service (SaaS)
- Software is licensed and provided over the web – apps run on the cloud and are accessed via web protocols – often through a browser
- GoogleDocs, Salesforce, Slack

- Many more specific areas of functionality are being touted as "as a service" technologies
- Analytics as a Service
- Blockchain as a Service
- Payments as a Service

What is Cloud Computing?

xorlogics.com

Cloud Computing Services: Who Manages What?

I: Infrastructure **P: Platform** **S: Software**

Traditional IT	IaaS	PaaS	Serverless	SaaS
Applications	Applications	Applications	Applications	Applications
Data	Data	Data	Data	Data
Runtime	Runtime	Runtime	Runtime	Runtime
Middleware	Middleware	Middleware	Middleware	Middleware
OS	OS	OS	OS	OS
Virtualization	Virtualization	Virtualization	Virtualization	Virtualization
Servers	Servers	Servers	Servers	Servers
Storage	Storage	Storage	Storage	Storage
Networking	Networking	Networking	Networking	Networking

You manage Provider manages

ibm.com

CLOUD SERVICE PROVIDERS

AWS Management Console

us-east-2.console.aws.amazon.com/console/home?nc2=h_ct&region=us-east-2&src=header-signin#

Apps VT gmail VT cal ECE internal ECE W OneCampus Canvas IEEE BBC Ms VT CITI CVL Wiki Library Commi Libr Comm TIAA C Chrome River DL nCoV O'R CoVA VT CoV

aws Services Globe trial account Ohio Support

AWS Management Console

AWS services

Find Services
You can enter names, keywords or acronyms.

Example: Relational Database Service, database, RDS

▶ All services

Build a solution

Get started with simple wizards and automated workflows.

Launch a virtual machine
With EC2
2-3 minutes

Build a web app
With Elastic Beanstalk
6 minutes

Build using virtual servers
With Lightsail
1-2 minutes

Register a domain
With Route 53
3 minutes

Connect an IoT device
With AWS IoT
5 minutes

Start migrating to AWS
With CloudEndure Migration
1-2 minutes

Start a development project
With CodeStar
5 minutes

Deploy a serverless microservice
With Lambda, API Gateway
2 minutes

Stay connected to your AWS resources on-the-go

Download the AWS Console Mobile App to your iOS or Android mobile device. Learn more

Explore AWS

Amazon SageMaker Autopilot
Get hands-on with AutoML. Learn more

AWS Storage Gateway
Get on-premises low latency access to virtually unlimited cloud storage with this hybrid cloud storage service. Learn more

AWS Lambda Extensions
Use AWS Lambda with your favorite operational tools for monitoring, observability, security, and governance.
Learn more

AWS Certification
Explore the resources available to help you prepare for your AWS Certification. Learn more

Feedback English (US)

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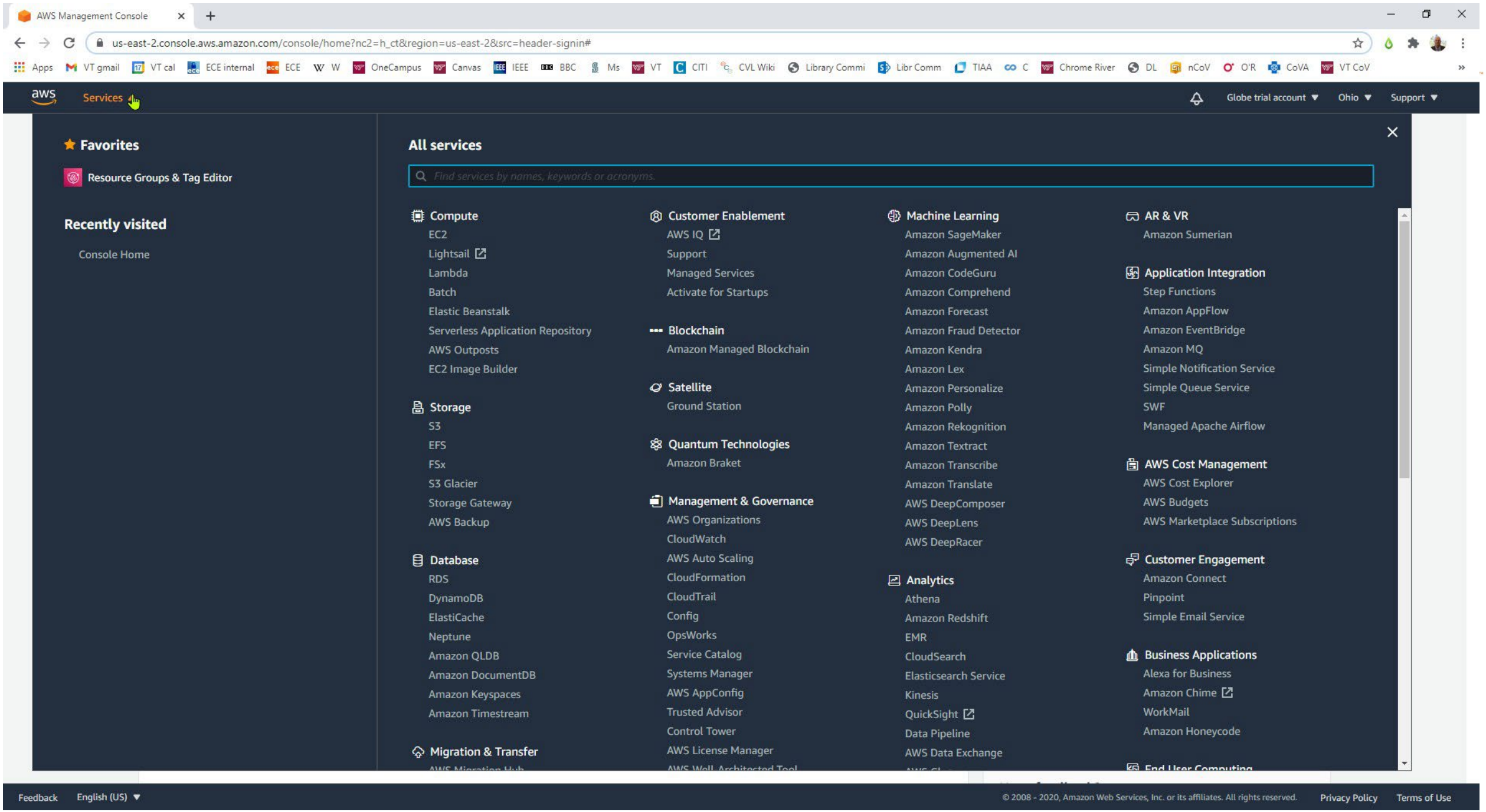
AWS Management Console
us-east-2.console.aws.amazon.com/console/home?nc2=h_ct&region=us-east-2&src=header-signin#
Apps VT gmail VT cal ECE internal ECE W OneCampus Canvas IEEE BBC Ms VT CITI CVL Wiki Library Commi Libr Comm TIAA C Chrome River DL nCoV O'R CoVA VT CoV
aws Services
Globe trial account Ohio Support
Favorites
Resource Groups & Tag Editor
Recently visited
Console Home
All services
Find services by names, keywords or acronyms.
Compute
EC2
Lightsail
Lambda
Batch
Elastic Beanstalk
Serverless Application Repository
AWS Outposts
EC2 Image Builder
Storage
S3
EFS
FSx
S3 Glacier
Storage Gateway
AWS Backup
Database
RDS
DynamoDB
ElastiCache
Neptune
Amazon QLDB
Amazon DocumentDB
Amazon Keyspaces
Amazon Timestream
Migration & Transfer
Customer Enablement
AWS IQ
Support
Managed Services
Activate for Startups
Blockchain
Amazon Managed Blockchain
Satellite
Ground Station
Quantum Technologies
Amazon Braket
Management & Governance
AWS Organizations
CloudWatch
AWS Auto Scaling
CloudFormation
CloudTrail
Config
OpsWorks
Service Catalog
Systems Manager
AWS AppConfig
Trusted Advisor
Control Tower
AWS License Manager
Machine Learning
Amazon SageMaker
Amazon Augmented AI
Amazon CodeGuru
Amazon Comprehend
Amazon Forecast
Amazon Fraud Detector
Amazon Kendra
Amazon Lex
Amazon Personalize
Amazon Polly
Amazon Rekognition
Amazon Textract
Amazon Transcribe
Amazon Translate
AWS DeepComposer
AWS DeepLens
AWS DeepRacer
Analytics
Athena
Amazon Redshift
EMR
CloudSearch
Elasticsearch Service
Kinesis
QuickSight
Data Pipeline
AWS Data Exchange
AR & VR
Amazon Sumerian
Application Integration
Step Functions
Amazon AppFlow
Amazon EventBridge
Amazon MQ
Simple Notification Service
Simple Queue Service
SWF
Managed Apache Airflow
AWS Cost Management
AWS Cost Explorer
AWS Budgets
AWS Marketplace Subscriptions
Customer Engagement
Amazon Connect
Pinpoint
Simple Email Service
Business Applications
Alexa for Business
Amazon Chime
WorkMail
Amazon Honeycode
Feedback English (US)
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Cloud providers offer families of services – for example, here are the choices for "Storage" for AWS

Free Trial Available
Amazon Simple Storage Service (S3)
Scalable Storage in the Cloud

Free Trial Available
Amazon Elastic Block Store (EBS)
EC2 block storage volumes

Free Trial Available
Amazon Elastic File System (EFS)
Fully managed file system for EC2

Amazon FSx for Lustre
High-performance file system integrated with S3

Amazon FSx for Windows File Server
Fully managed Windows native file system

Amazon S3 Glacier
Low-cost Archive Storage in the Cloud

AWS Backup
Centralized backup across AWS services

AWS Snow Family
Physical edge computing and storage devices for rugged or disconnected environments

Free Trial Available
AWS Storage Gateway
Hybrid Storage Integration

CloudEndure Disaster Recovery
Highly automated disaster recovery

“Storage” is not to be confused with “Database” – here are the AWS offerings in that family

Amazon Aurora
High Performance Managed Relational Database

Amazon Aurora Serverless v2 (Preview)
Instantly scale to >100,000 transactions per second

Free Trial Available
Amazon DynamoDB
Managed NoSQL Database

Amazon DocumentDB (with MongoDB compatibility)
Fully managed document database

Free Trial Available
Amazon ElastiCache
In-memory Caching System

Free Trial Available
Amazon Keyspaces (for Apache Cassandra)
Managed Cassandra-compatible database

Amazon MemoryDB for Redis
Redis-compatible, durable, in-memory database that delivers ultra-fast performance

Amazon Neptune
Fully Managed Graph Database Service

Amazon Quantum Ledger Database (QLDB)
Fully managed ledger database

Free Trial Available
Amazon RDS
Managed Relational Database Service for MySQL, PostgreSQL, Oracle, SQL Server, and MariaDB

Amazon RDS on VMware
Automate on-premises database management

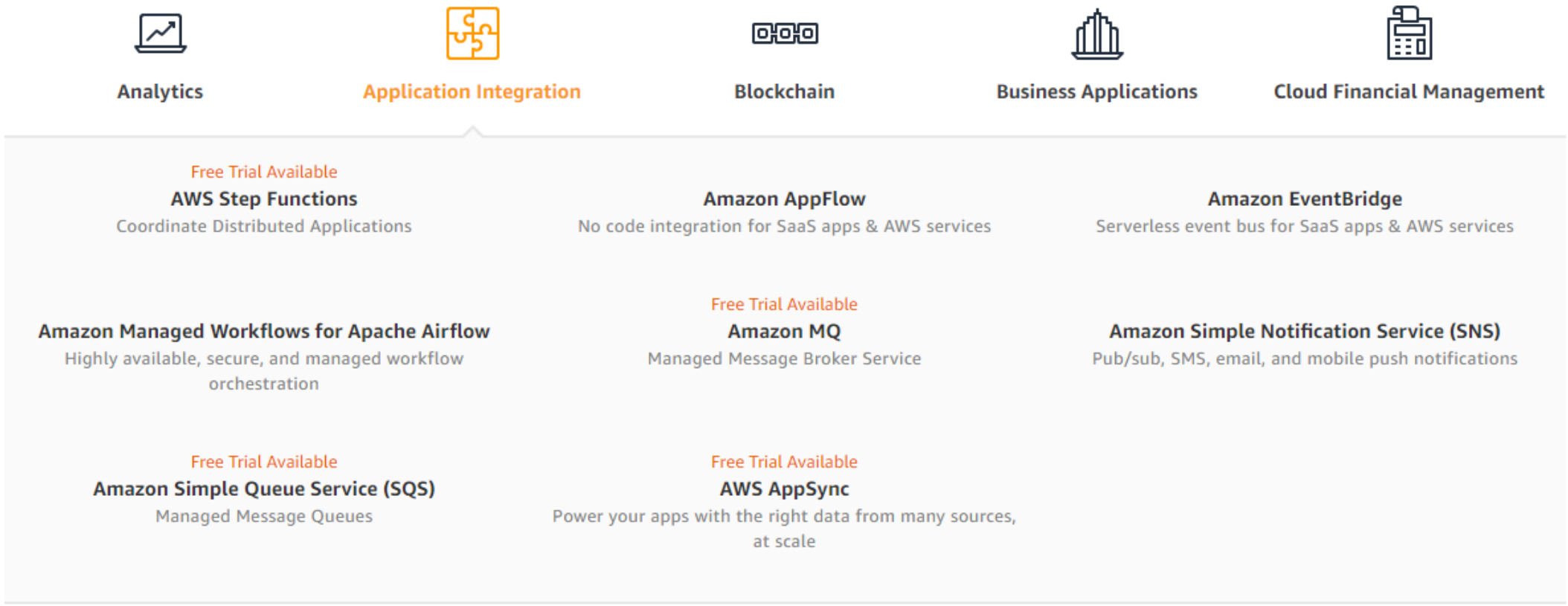
Free Trial Available
Amazon Redshift
Fast, Simple, Cost-effective Data Warehousing

Amazon Timestream
Fully managed time series database

Free Trial Available
AWS Database Migration Service
Migrate Databases with Minimal Downtime

AWS Glue
Simple, scalable, and serverless data integration

Middleware and messaging components are offered in the "Application Integration" family of AWS

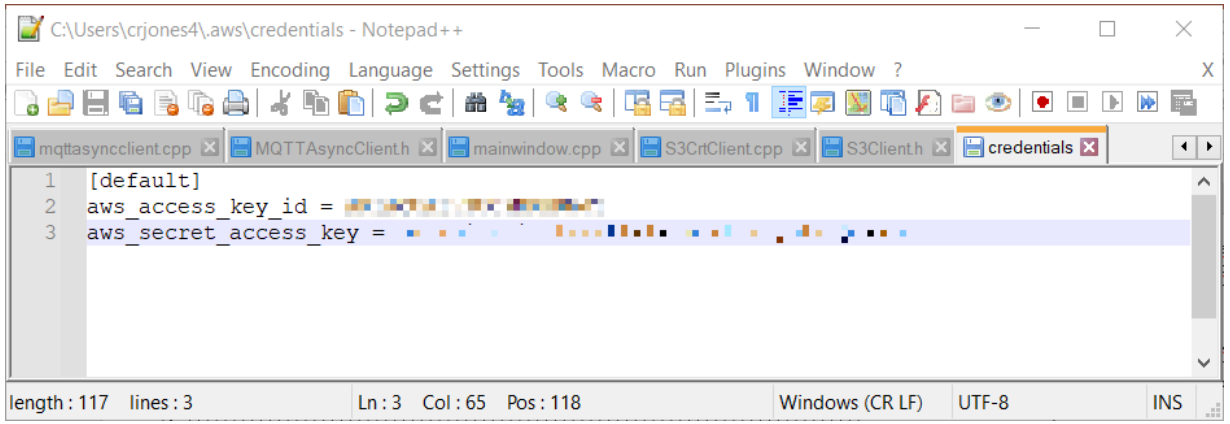


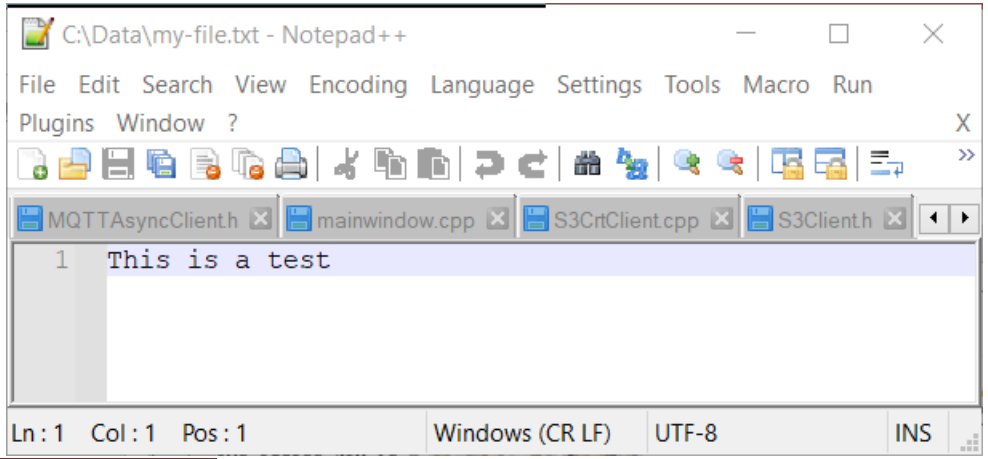
Here is a simple example of using a cloud service; I am using Amazon Web Services S3 to store and retrieve a simple text file

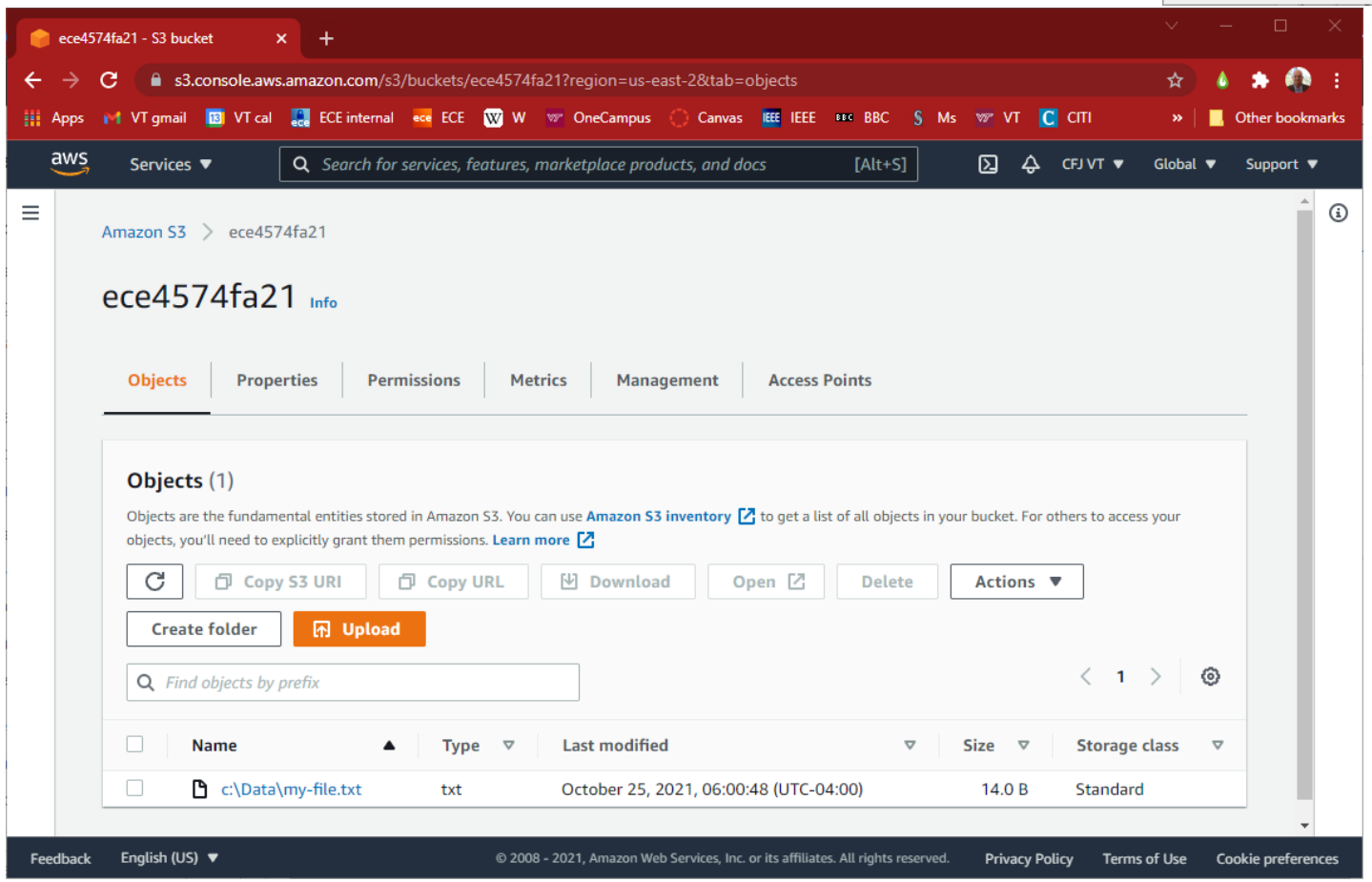
1. Sign up for an AWS account – there is a free tier
   https://aws.amazon.com/free/
2. Create a user and obtain credentials
   `aws_access_key_id` and `aws_secret_access_key`
   See https://docs.aws.amazon.com/sdk-for-cpp/v1/developer-guide/credentials.html for more information
3. Install the libraries for the AWS C++ client
   https://docs.aws.amazon.com/sdk-for-cpp/v1/developer-guide/setup-windows-vcpkg.html
4. Write code to use the C++ client libraries to access the cloud service you need

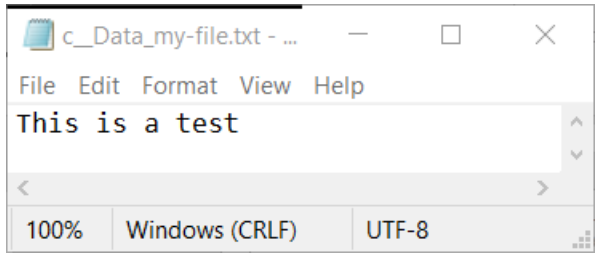
```
#include <iostream>
#include <fstream>
#include <sys/stat.h>
#include <aws/core/Aws.h>
#include <aws/s3/S3Client.h>
#include <aws/s3/model/PutObjectRequest.h>
#include "s3_examples.h"
//snippet-end:[s3.cpp.put_object.inc]

/* ////////////////////////////////////////////////////////////////////////
 * Purpose: Adds an object to an Amazon S3 bucket.
 * For an example of a multipart upload, see the s3-crt code example.
 *
 * Prerequisites: An Amazon S3 bucket and the object to be added.
 *
 * Inputs:
 * - bucketName: The name of the bucket.
 * - objectName: The name of the object.
 * - region: The AWS Region for the bucket.
 *
 * Outputs: true if the object was added to the bucket; otherwise, false.
 * //////////////////////////////////////////////////////////////////////// */

int main()
{
    Aws::SDKOptions options;
    Aws::InitAPI(options);
    {
        //TODO: Change bucket_name to the name of a bucket in your account.
        const Aws::String bucket_name = "ece4574fa21";
        //TODO: Create a file called "my-file.txt" in the local folder where your
executables are built to.
        const Aws::String object_name = "c:\\Data\\my-file.txt";
        //TODO: Set to the AWS Region in which the bucket was created.
        const Aws::String region = "us-east-2";

        if (!AwsDoc::S3::PutObject(bucket_name, object_name, region)) {

            return 1;
        }
    }
    Aws::ShutdownAPI(options);

    return 0;
}
```

```
bool AwsDoc::S3::PutObject(const Aws::String& bucketName,
    const Aws::String& objectName,
    const Aws::String& region)
{
    struct stat buffer;
    if (stat(objectName.c_str(), &buffer) == -1)  {
        std::cout << "Error: PutObject: File '" <<
            objectName << "' does not exist." << std::endl;
        return false;
    }

    Aws::Client::ClientConfiguration config;

    if (!region.empty())  {
        config.region = region;
    }

    Aws::S3::S3Client s3_client(config);

    Aws::S3::Model::PutObjectRequest request;
    request.SetBucket(bucketName);
    //We are using the name of the file as the key for the object in the bucket.
    //However, this is just a string and can set according to your retrieval needs.
    request.SetKey(objectName);

    std::shared_ptr<Aws::IOStream> input_data =
Aws::MakeShared<Aws::FStream>("SampleAllocationTag",
            objectName.c_str(),
            std::ios_base::in | std::ios_base::binary);
    request.SetBody(input_data);

    Aws::S3::Model::PutObjectOutcome outcome =
        s3_client.PutObject(request);

    if (outcome.IsSuccess()) {

        std::cout << "Added object '" << objectName << "' to bucket '"
            << bucketName << "'.";
        return true;
    }    else    {
        std::cout << "Error: PutObject: " <<
            outcome.GetError().GetMessage() << std::endl;

        return false;
    }
}
```









VIRGINIA TECH

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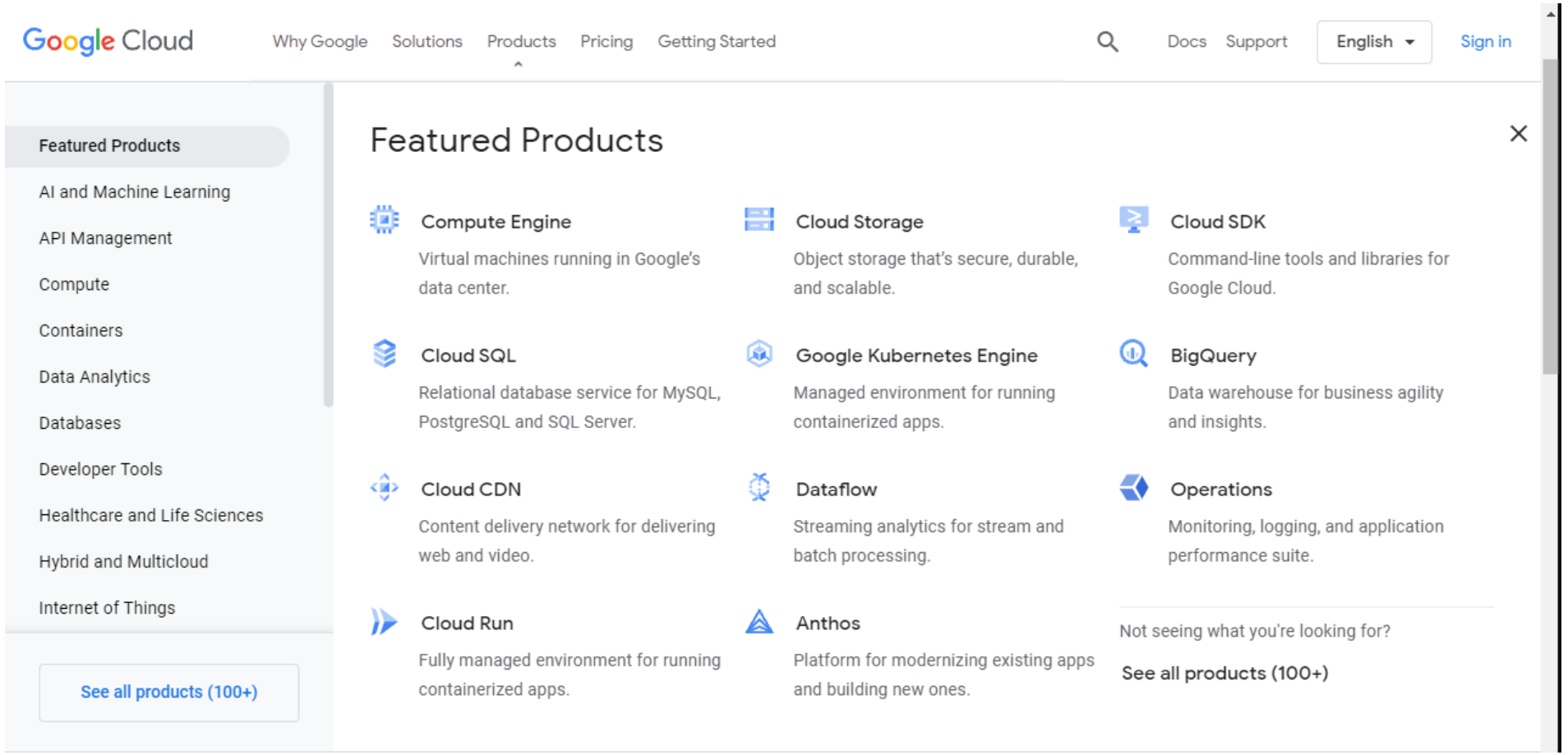
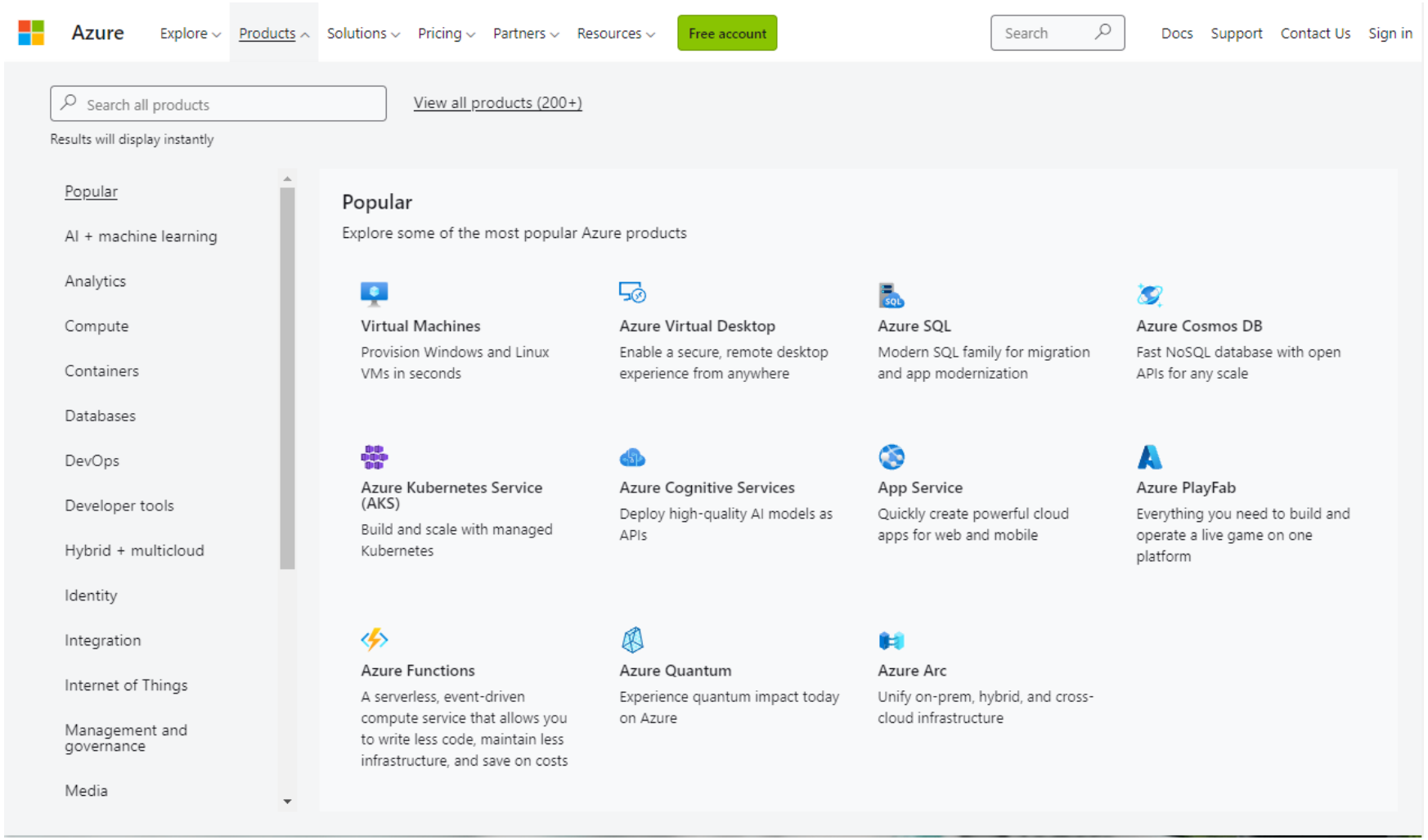
BRADLEY DEPARTMENT OF ELECTRICAL & COMPUTER ENGINEERING

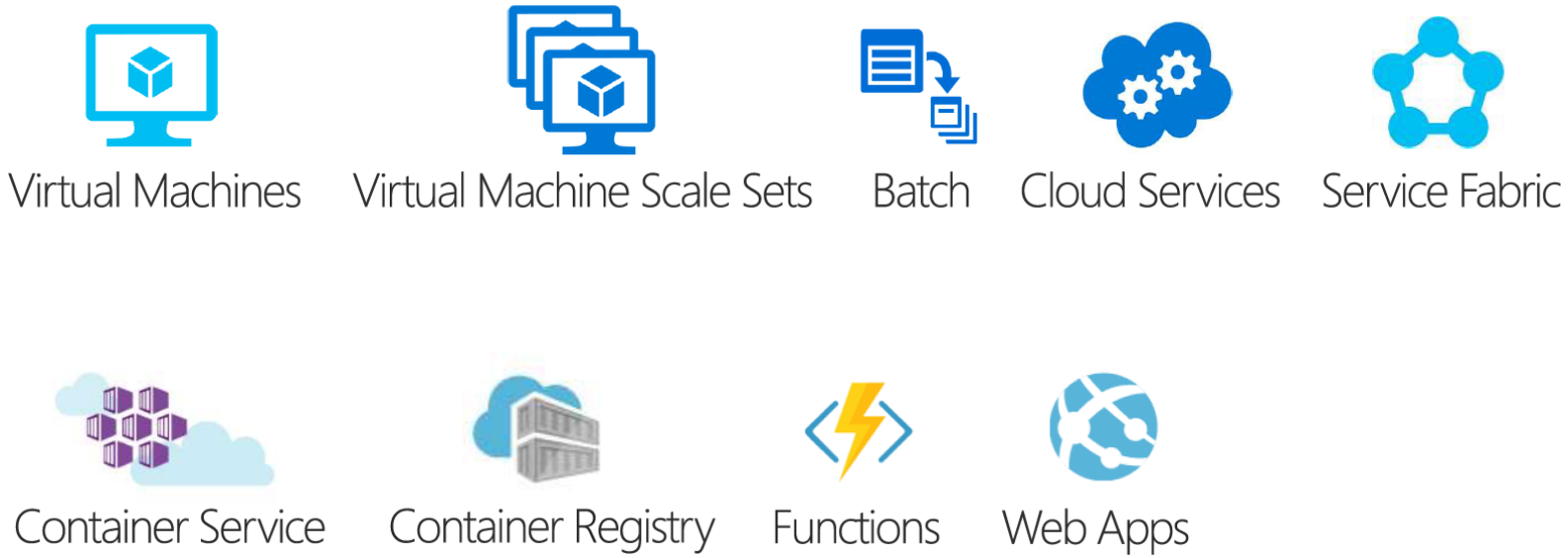
Google offers a similar set of service families – storage, database, etc.



Microsoft offers the Azure set of cloud services



One important cloud service is allocation of "virtual machines" – virtual Linux or Windows machines that can be used to run application code, and can be allocated/deallocated on demand



Find the compute product you need

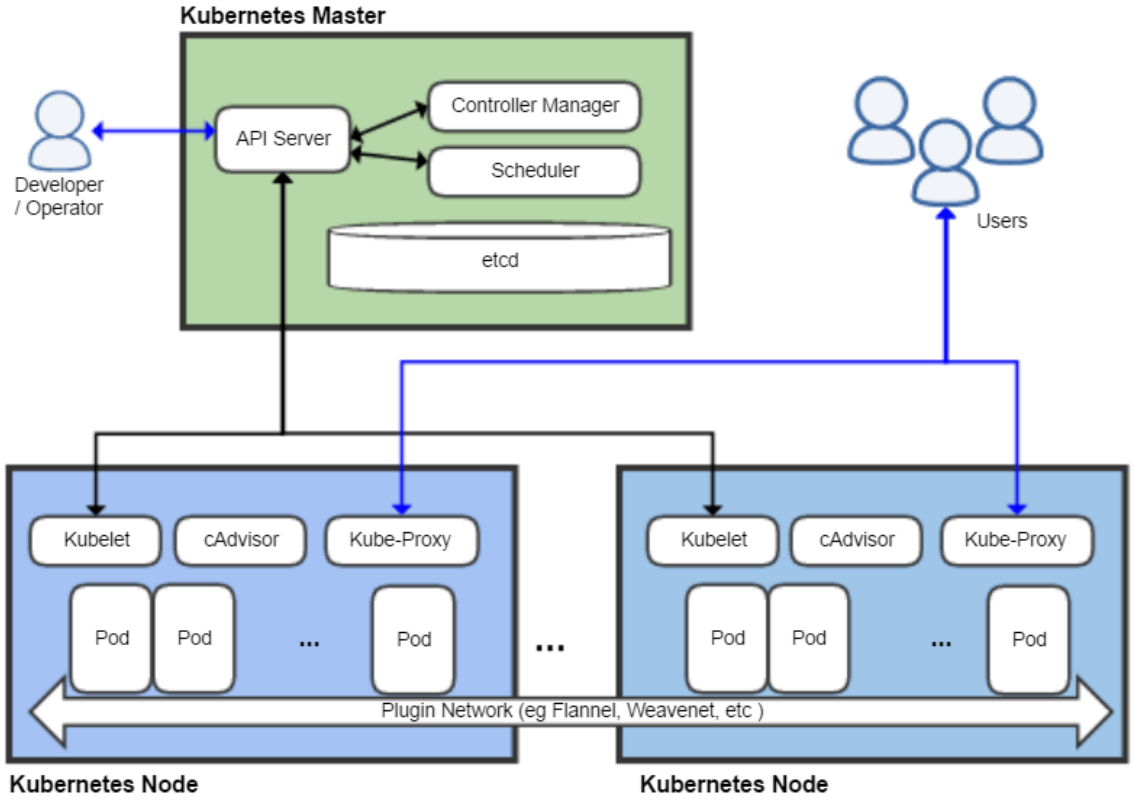
IF YOU WANT TO	USE THIS
Provision Linux and Windows virtual machines in seconds with the configurations of your choice	Virtual Machines
Achieve high availability by autoscaling to create thousands of VMs in minutes	Virtual Machine Scale Sets
Get deep discounts when you provision unused compute capacity to run your workloads	Azure Spot Virtual Machines
Build and scale with managed Kubernetes	Azure Kubernetes Service (AKS)
Accelerate app development using an event-driven, serverless architecture	Azure Functions
Develop microservices and orchestrate containers on Windows and Linux	Service Fabric
Quickly create cloud apps for web and mobile with fully managed platform	App Service
Containerize apps and easily run containers with a single command	Container Instances
Cloud-scale job scheduling and compute management with the ability to scale to tens, hundreds, or thousands of virtual machines	Batch
Create highly available, scalable cloud applications and APIs that help you focus on apps instead of hardware	Cloud Services
Deploy your Azure virtual machines on a physical server only used by your organization	Azure Dedicated Host

Kubernetes is a tool for managing collections of computing resources and allocating what runs on each

- Kubernetes can be used on physical clusters of machines
  - But its most common use is for cloud services
- Kubernetes is built on the concept of *containers*
  - A container is a portion of a computer's resources (CPU cores, memory, interfaces) that can be allocated to a process
  - A *pod* is a set of containers co-located on the same *node* (compute machine)
- "Kubernetes maps out how applications should work and interact with other applications. Due to its elasticity, it can scale services up and down as required, perform rolling updates, switch traffic between different versions of your applications to test features or rollback problematic deployments."

  - Ubuntu

Code developed using the Kubernetes API manages pods and nodes to achieve performance and scale



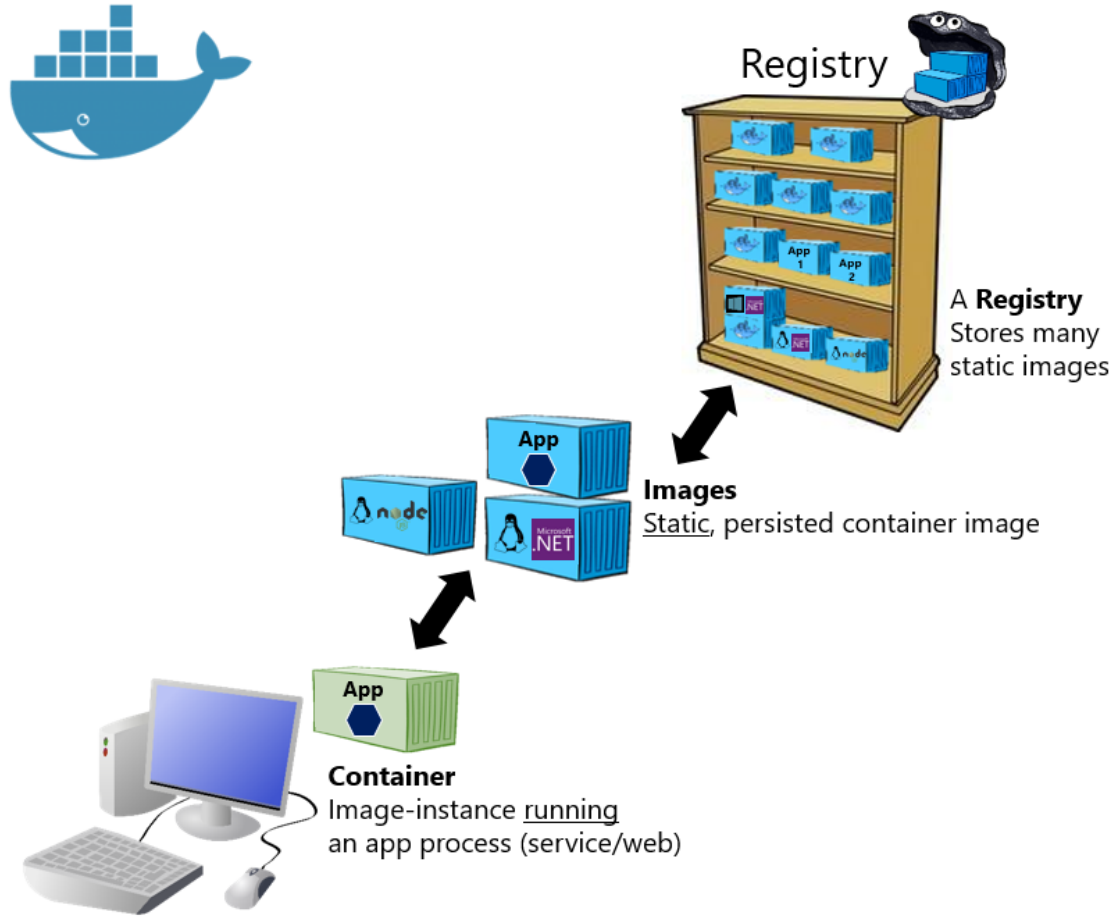
More information on Kubernetes

- https://ubuntu.com/kubernetes/what-is-kubernetes
- https://docs.microsoft.com/en-us/azure/aks/tutorial-kubernetes-deploy-cluster
- Online implementations:
  - https://cloud.google.com/kubernetes-engine
  - https://aws.amazon.com/eks
  - https://azure.microsoft.com/en-us/services/kubernetes-service
  - https://www.oracle.com/cloud-native/container-engine-kubernetes

Docker is a commonly used package for running containers

- "While Docker is a container runtime, Kubernetes is a platform for running and managing containers from many container runtimes. Kubernetes supports numerous container runtimes including Docker, containerd, CRI-O, and any implementation of the Kubernetes CRI (Container Runtime Interface).
- A good metaphor is Kubernetes as an "operating system" and Docker containers are "apps" that you install on the "operating system"."

Basic taxonomy in Docker



A **Registry**
Stores many static images

Images
Static, persisted container image

Container
Image-instance running an app process (service/web)

On-premises
('n' private organizations)

- **Hosted Docker Registry**
- **Docker Trusted Registry on-prem.**

Public Cloud
(specific vendors)

- **Docker Hub Registry**
- Docker Trusted Registry on-cloud
- **Azure Container Registry**
- AWS Container Registry
- Google Container Registry
- Quay Registry
- Other Cloud

More information on Docker

- https://www.docker.com/
- https://aws.amazon.com/docker/
- Docker in action: https://virginiatech.on.worldcat.org/oclc/1139335604

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