

The Journey to the Clouds at NASA's Jet Propulsion Laboratory

Cloud Adoption Strategies and Solutions

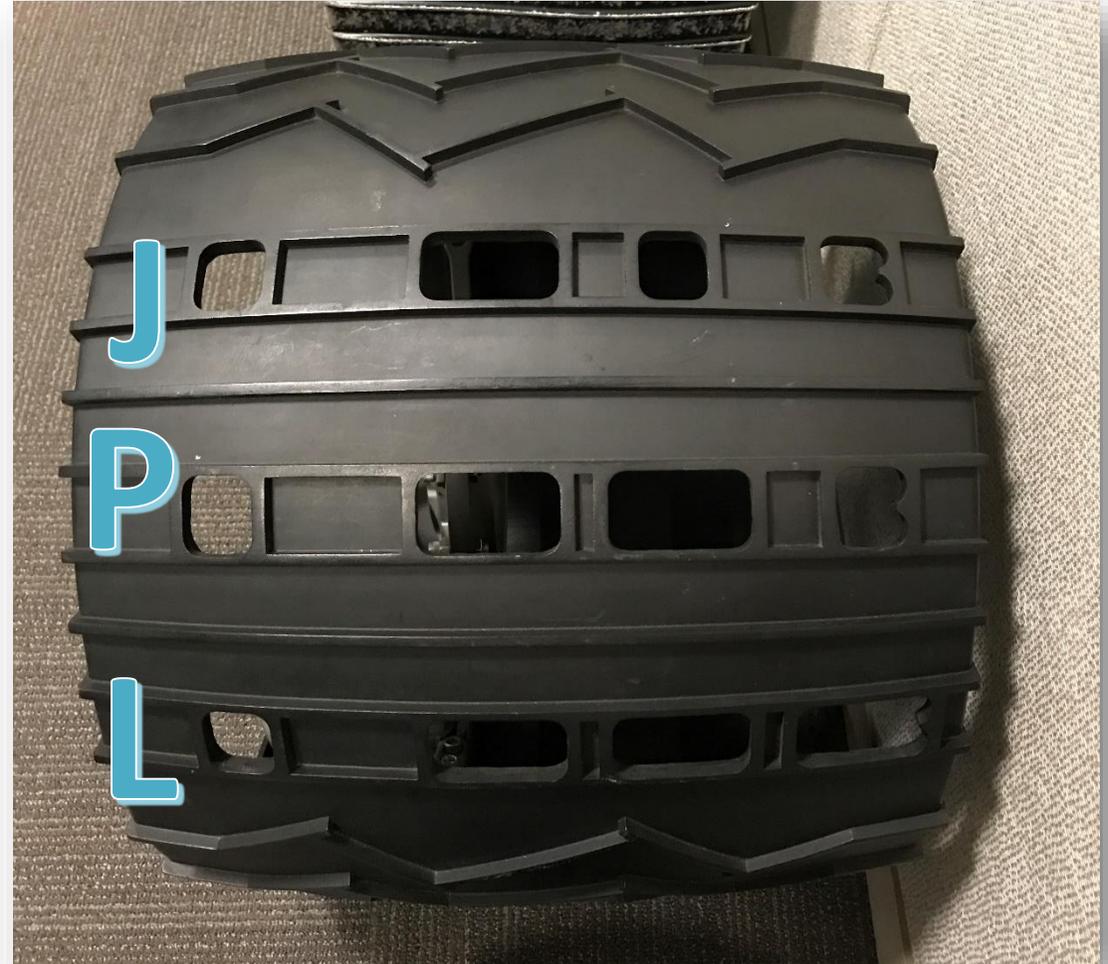
Michael Stefanini

Jet Propulsion Laboratory, California Institute of Technology.

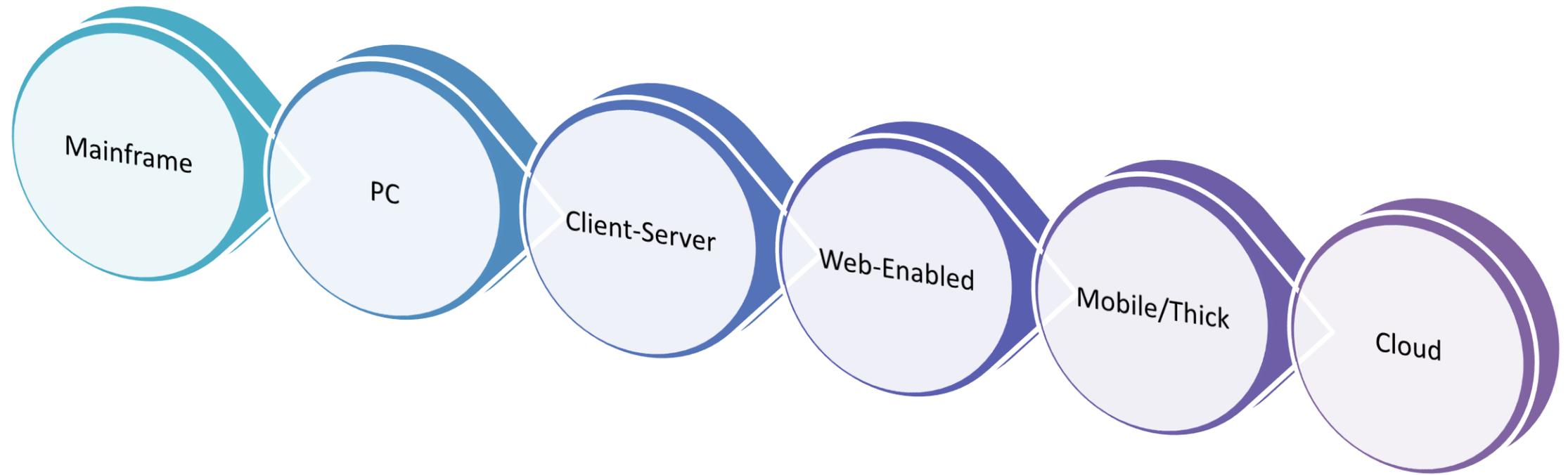
- We are a federal agency for space exploration and development, managed by Caltech
- We are a federal agency for space exploration and development, managed by Caltech
- We have 2 main programs
 - 17 space exploration programs
 - 10 instruments
- We manage the Mars Science Laboratory Network (MSL)
- We “Dare”



Mars Science Laboratory Wheel Designs

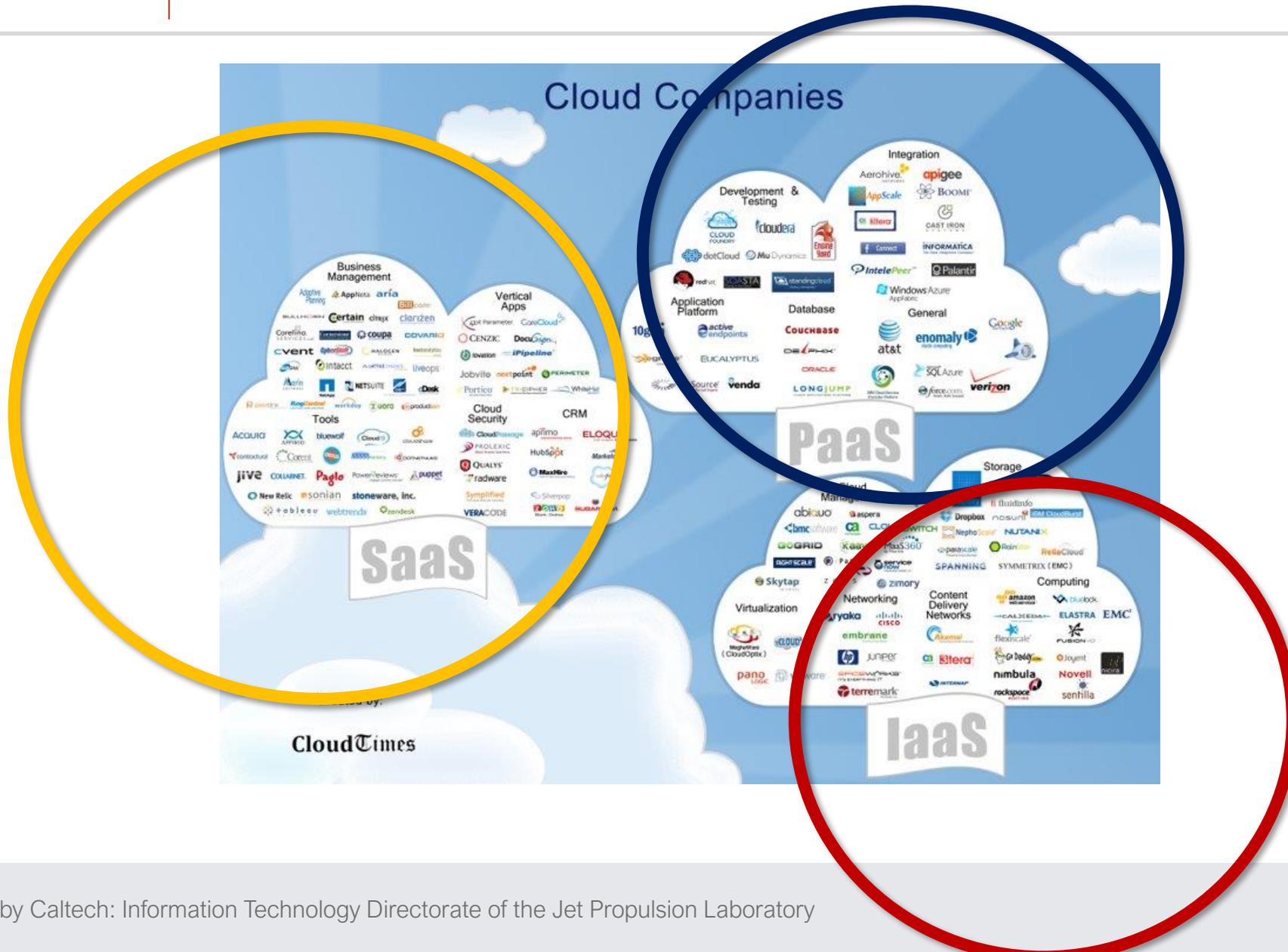


Cloud in a Historical Context

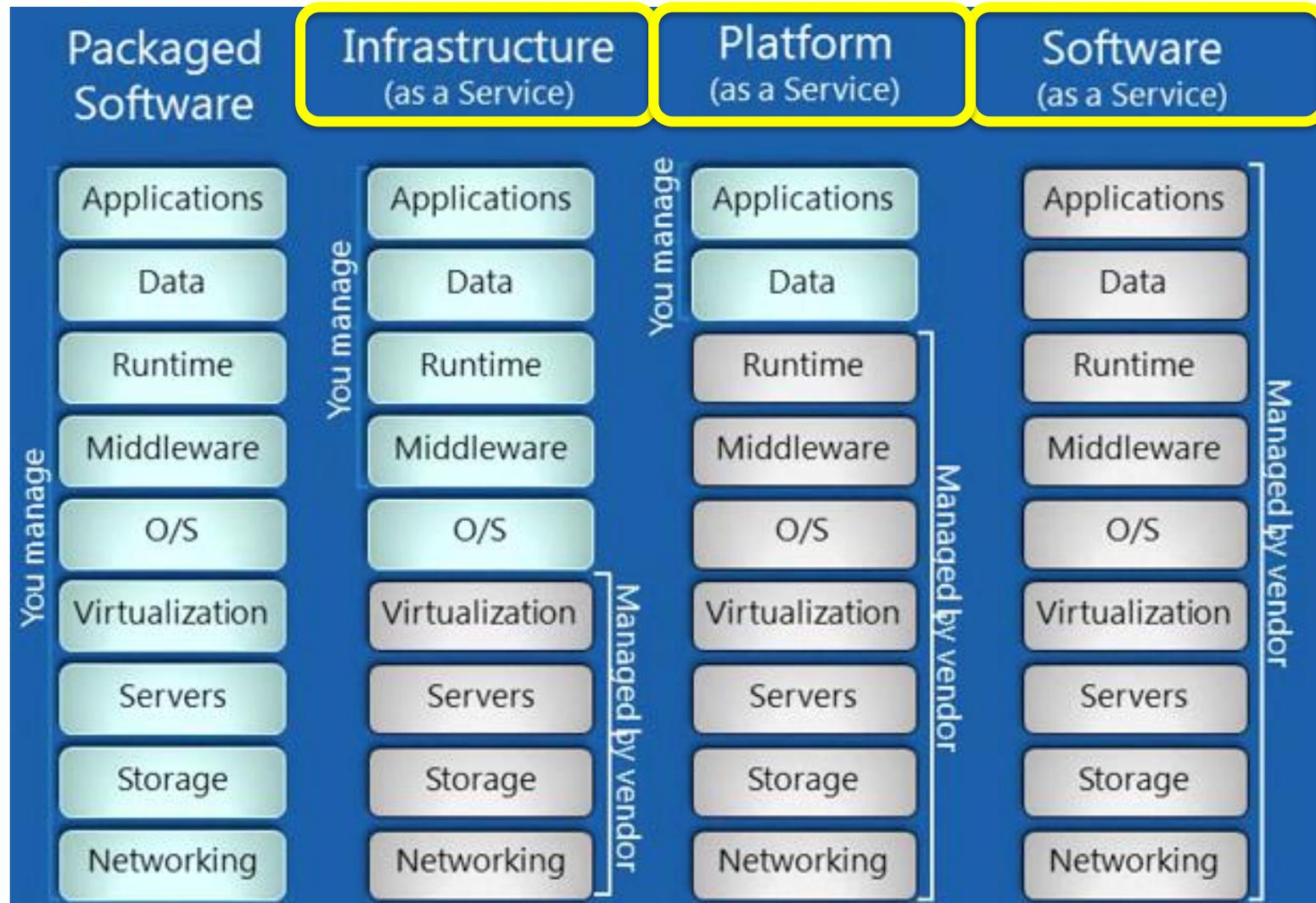


Six Ages of Computing Capacity

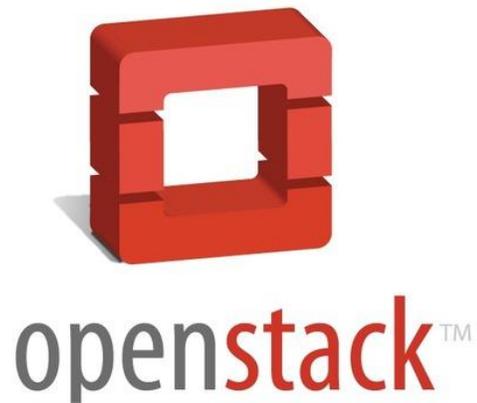
There are many cloud providers



Type of Cloud Services (X-aaS)



IaaS Providers

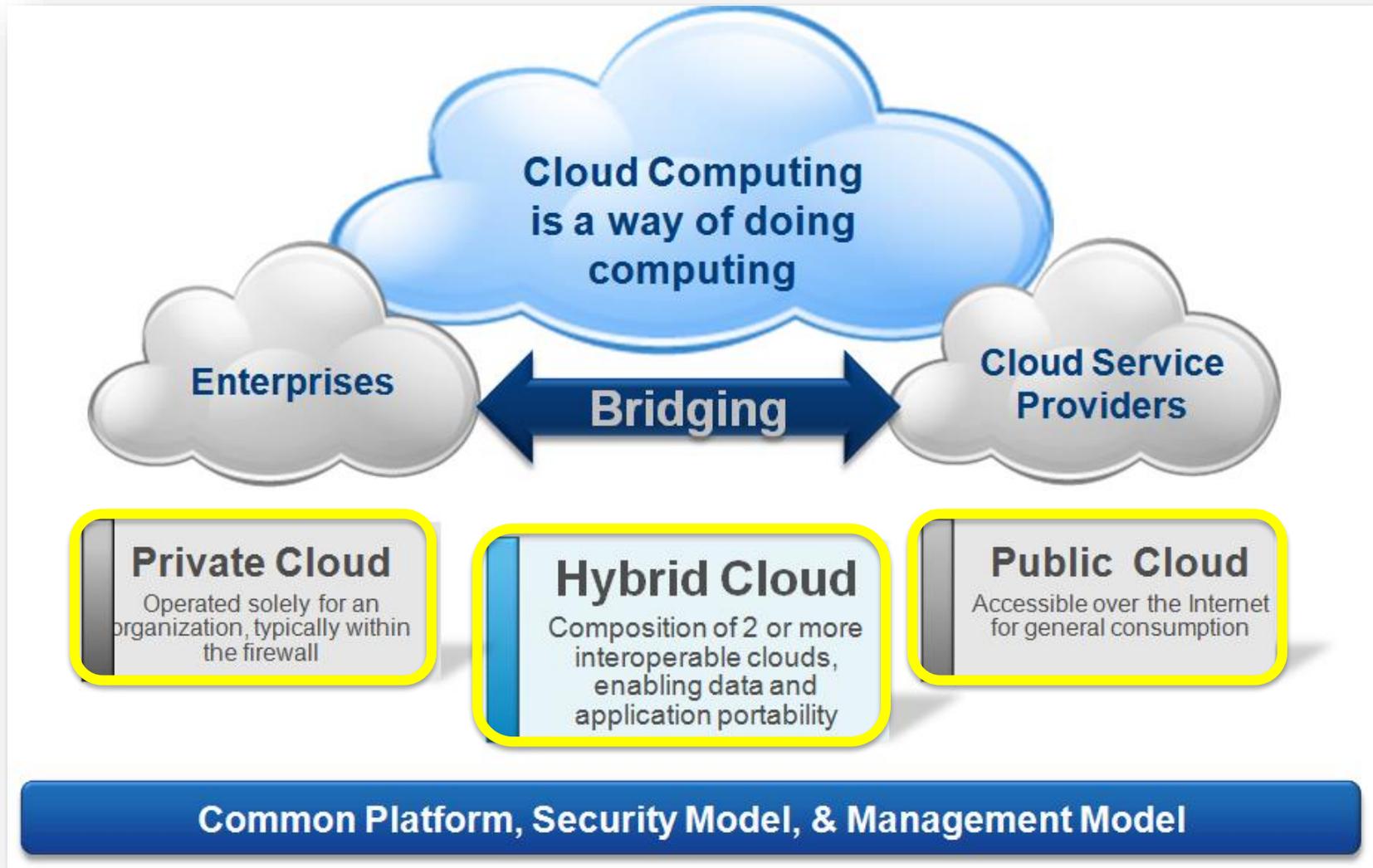


Characteristic Benefits of the Cloud

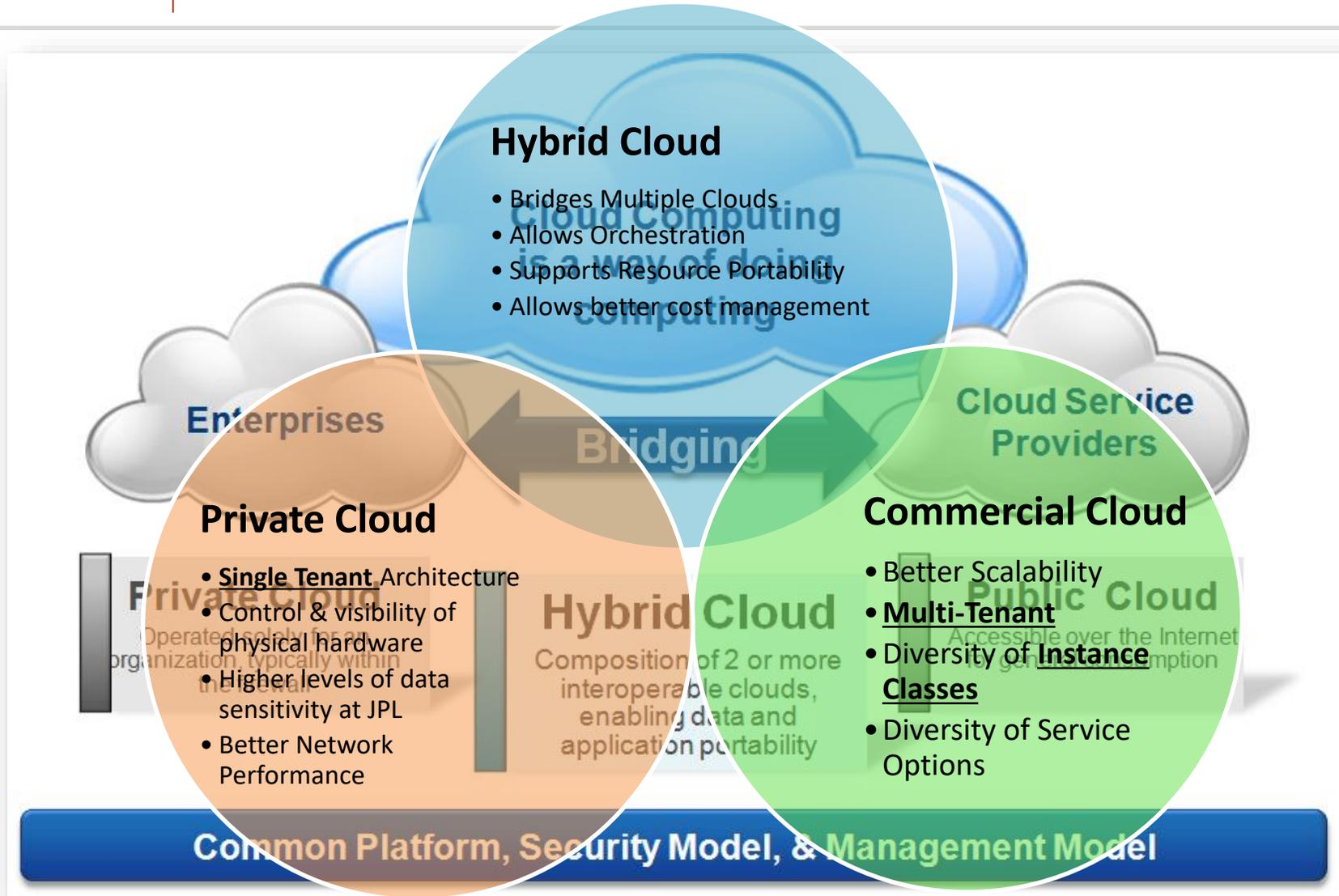


- **Scalability/Elasticity** : Scale up to meet sudden and/or temporary peaks of traffic automatically or on demand.
- **More Efficient Per-Resource Utilization** : Match capacity to current need
- **Business agility** : Reduces the time required to provision resources to minutes as well as provide customized capacity
- **No Touch Disaster recovery and Back up** : High availability with backups, stand-by virtual resources, and by seamlessly moving failed instances of virtual resources
- **Better Automation** : Self-healing, support for Bursting and Better Resiliency

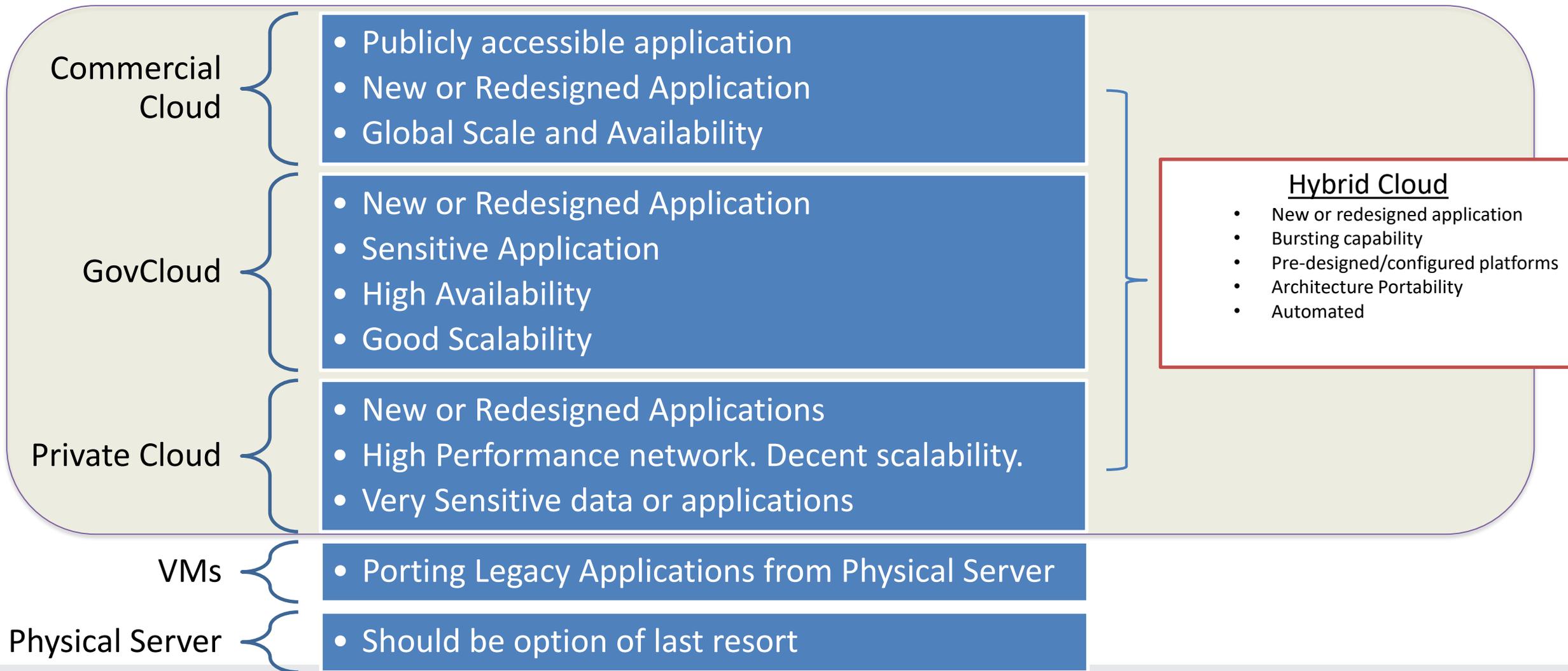
Cloud service models



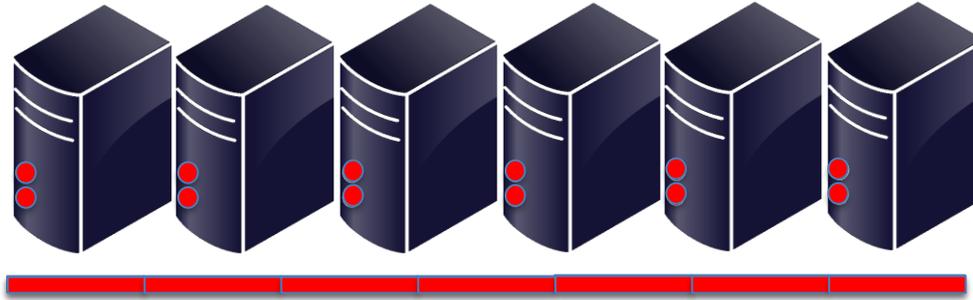
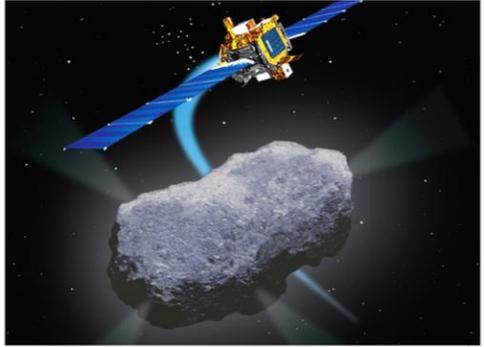
Benefits of the Various Cloud Models



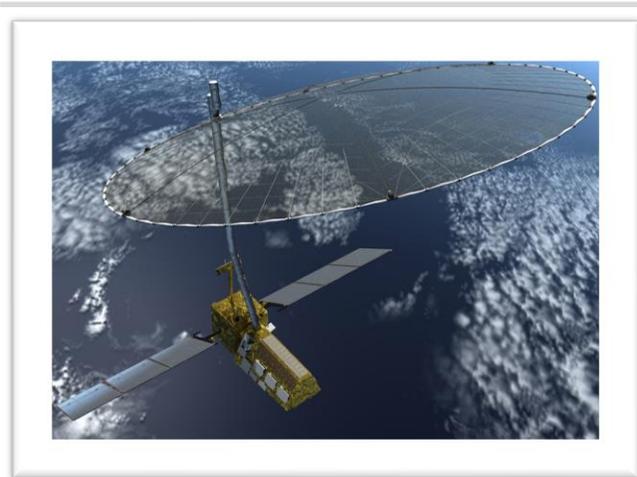
Choices and Flexibility



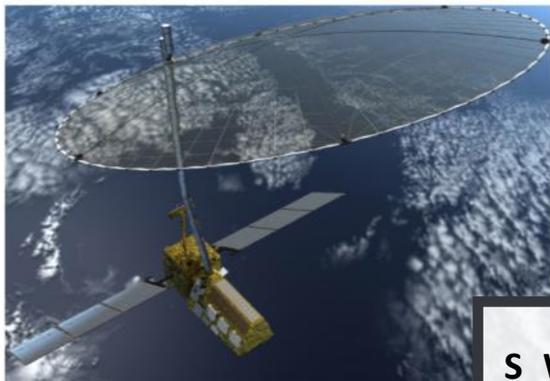
The Goal: Cloud Computing for Spacecraft



The Goal: Cloud Computing for Spacecraft



The Goal: Cloud Computing for Spacecraft



S W O T &
N I S A R
2021

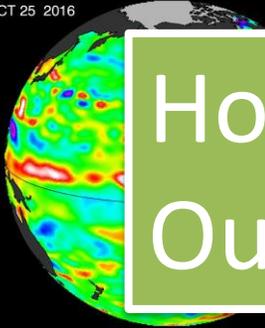
S M A P
2015

O C O - 2
2009

Over 100X More Data

OCT 25 2016

Jason-3



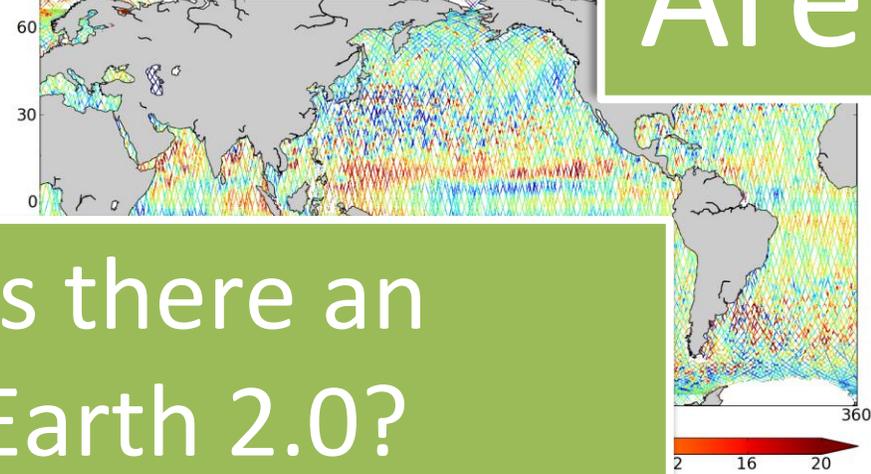
How do we protect
Our Earth?



Was there life
on Mars?

Are we alone?

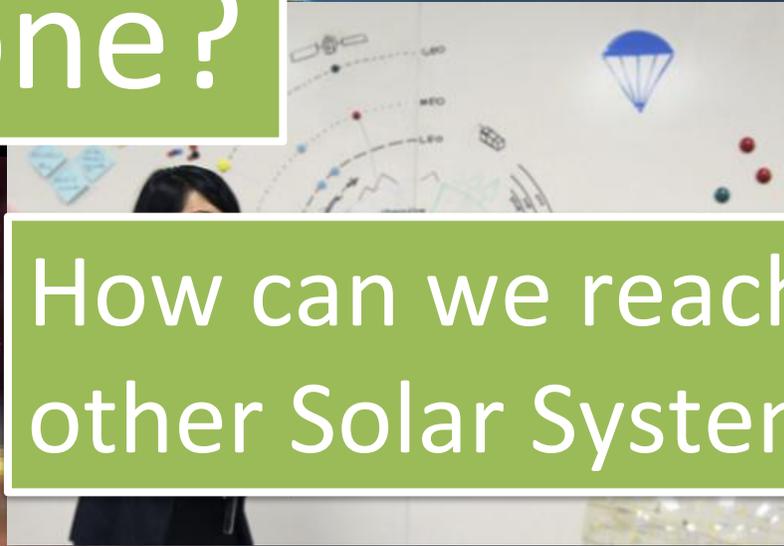
Sea Surface Height Anomaly: SARAL, Jason-2 and Jason-3 Measurements



Is there an
Earth 2.0?



How can we reach
other Solar Systems?



The Journey: A JPL Cloud



Cloud Vendors



Windows Azure

Vision

*Position cloud computing
as not only a standard IT infrastructure option,
but as the preferred Infrastructure option.*

*Use the Cloud Service organizational model
as a proof-of-concept for future end-to-end IT Service
Delivery initiatives*

Through education, infusion, consulting, influence,
and strategic direction

Setup

- We must Define:
 - Current state,
 - Desired state
 - Work required to Transition



The 6 Cloud Service Vectors



Vector 1: Define

*“A full IT Service Management capability
Providing or Enabling
All Infrastructure Cloud Computing products.”*



Sample Objectives

Strategy
Development

Business
Opportunity
Development

Financial
Management

Reporting and
Analysis

Service-Level
Management team

Service
Architecture,
Engineering and
Innovation

Innovation,
Technology, and
Service
Improvement

Communications
and Change
Management

Vendor
Management

Service Definition Basics

Products:

- A 3-year cloud computing tactical roadmap
- A budget, cost model, and rate structure
- A repository and a survey mechanism to collect issues and feedback

- Ensure the cloud service is Sufficient and Relevant
- Manage the implementation of the cloud roadmap

This data compiled by Caltech: Information Technology Directorate of the Jet

- Consolidated and Truthful Metrics
- Alignment with the customer's needs
- Evolve the service with the customer

Sample Products

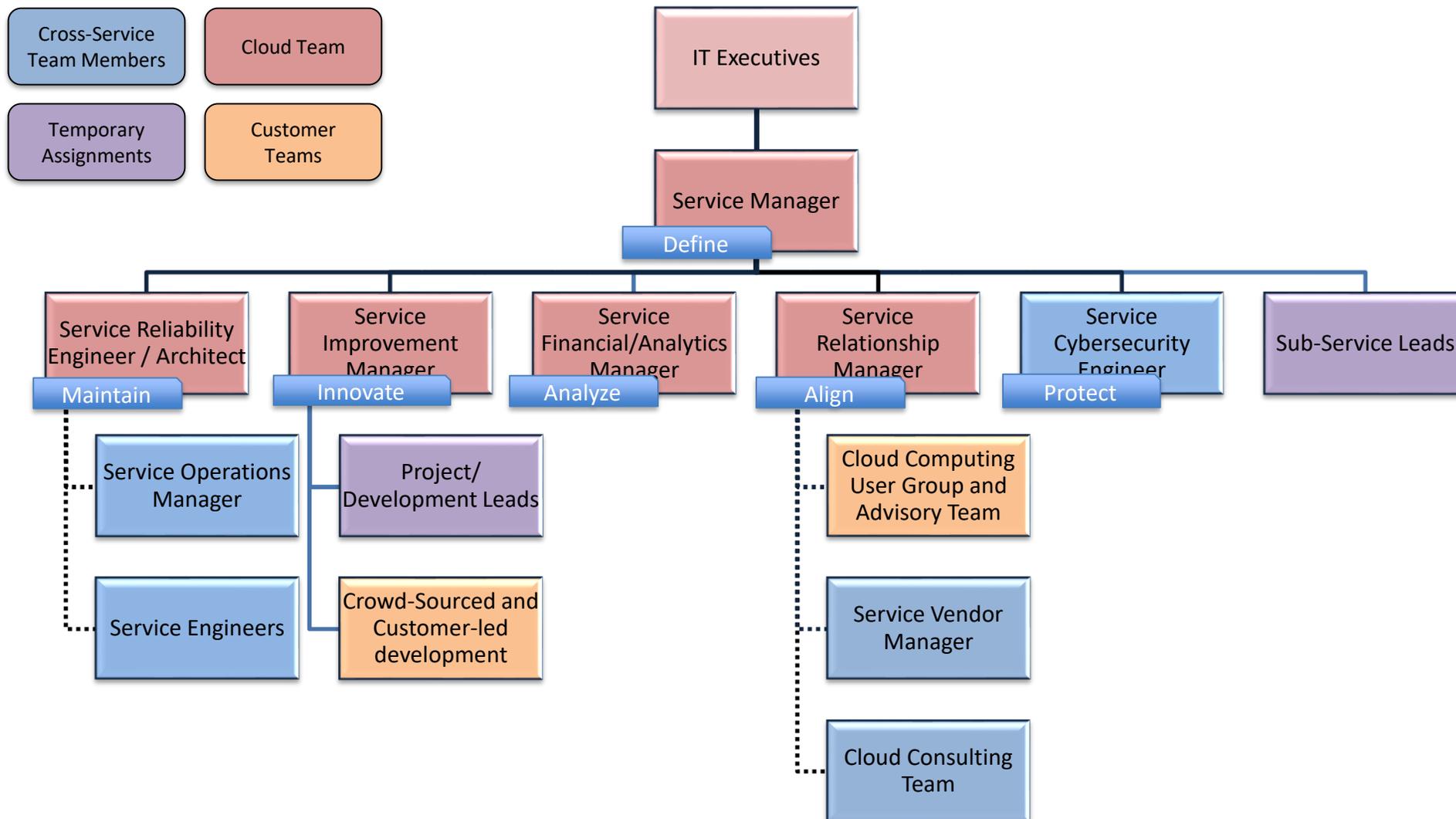
the cloud Sustaining,
, and Innovation Budget
list of desired capabilities

and requirements

Values:

- Consolidated and Truthful Metrics
- Close and frequent communication with the customer
- Automate everything anywhere
- Bias towards action rather than study

Sample Organization

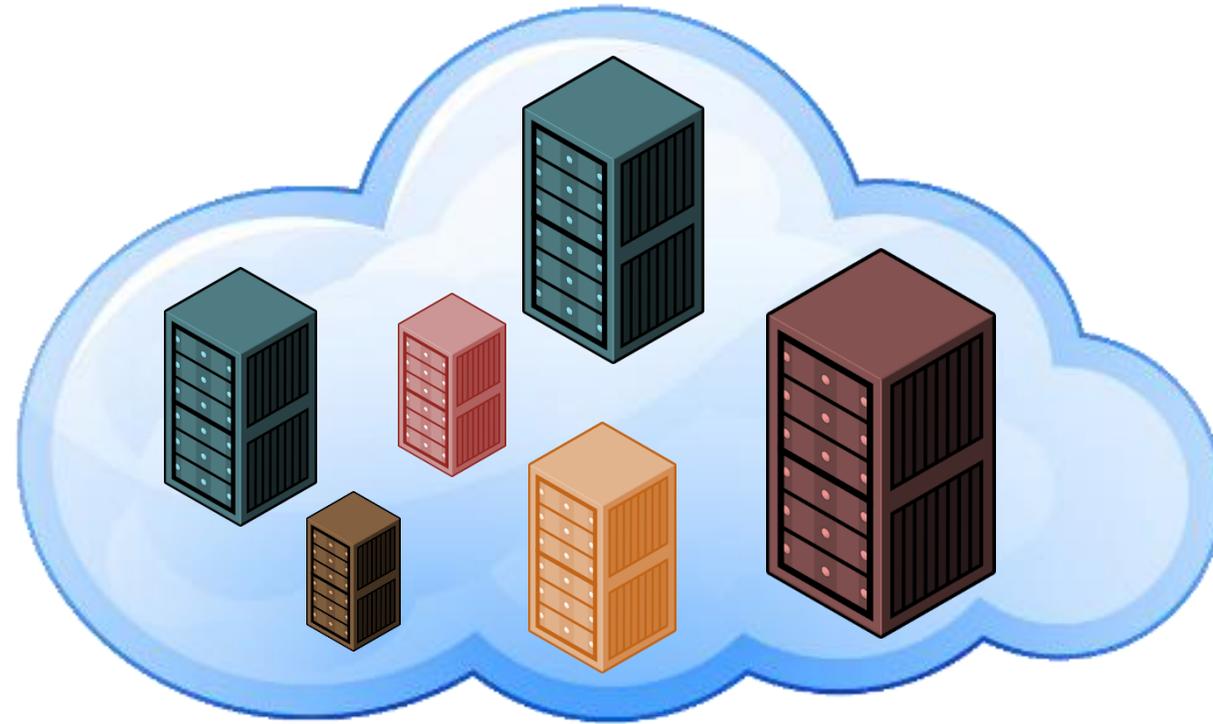


Vector 2: Maintain

*“A Service that cannot be
Trusted
to deliver
Consistent Quality
has Failed its Customers.”*



Cloud Flavors – Commercial Cloud



Commercial Cloud

Cloud Flavors – Gov Cloud

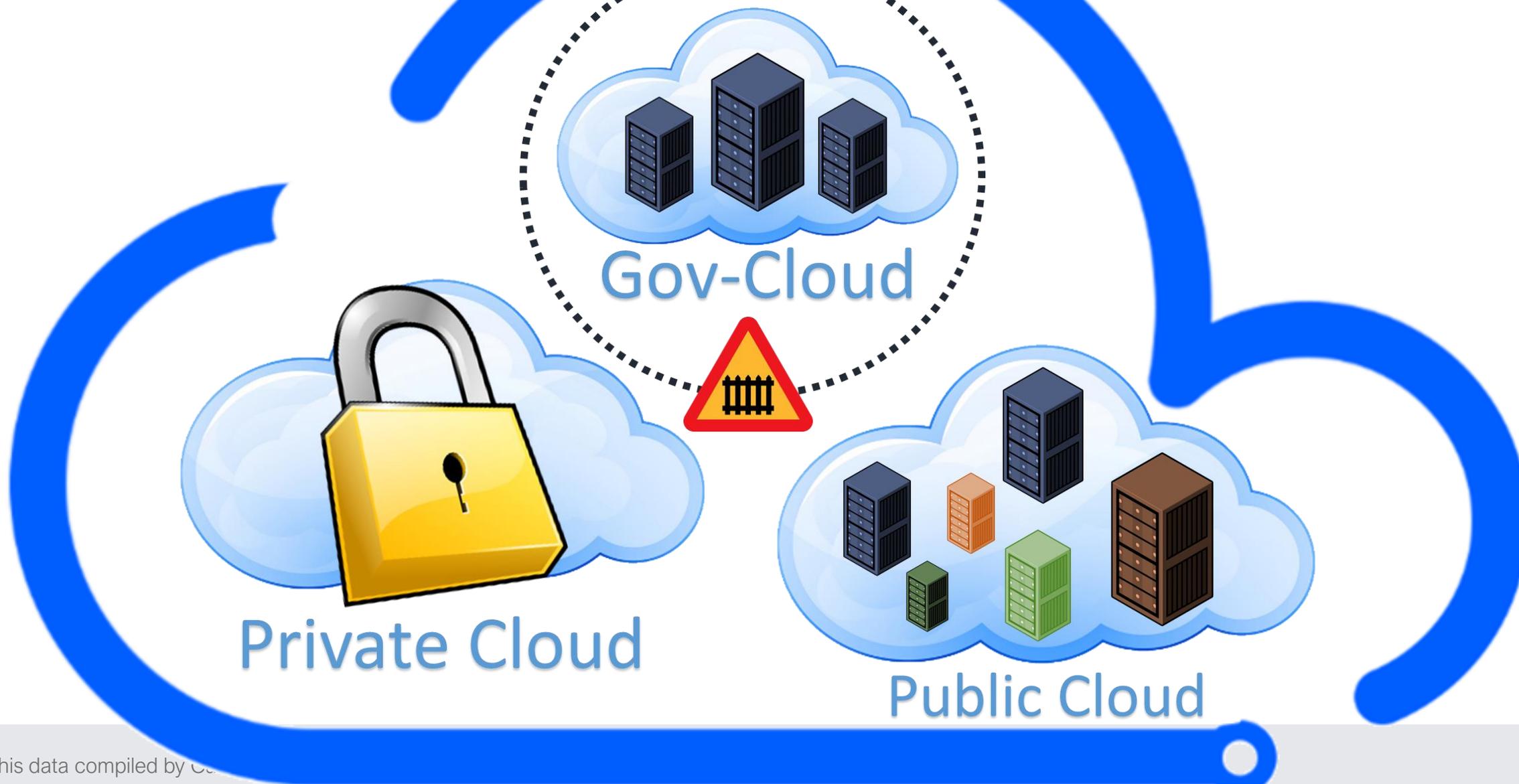


Cloud Flavors – Private Cloud

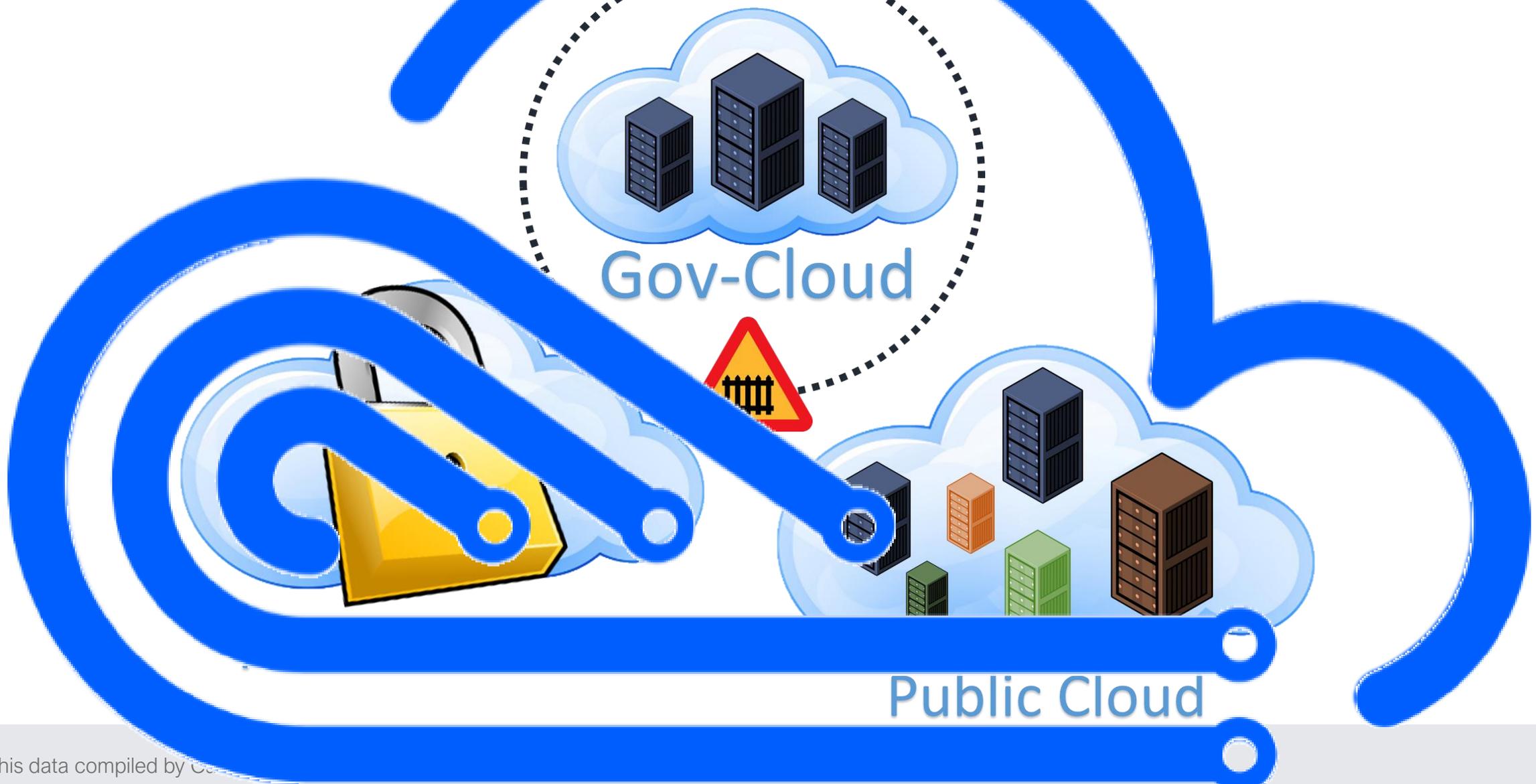


Private Cloud

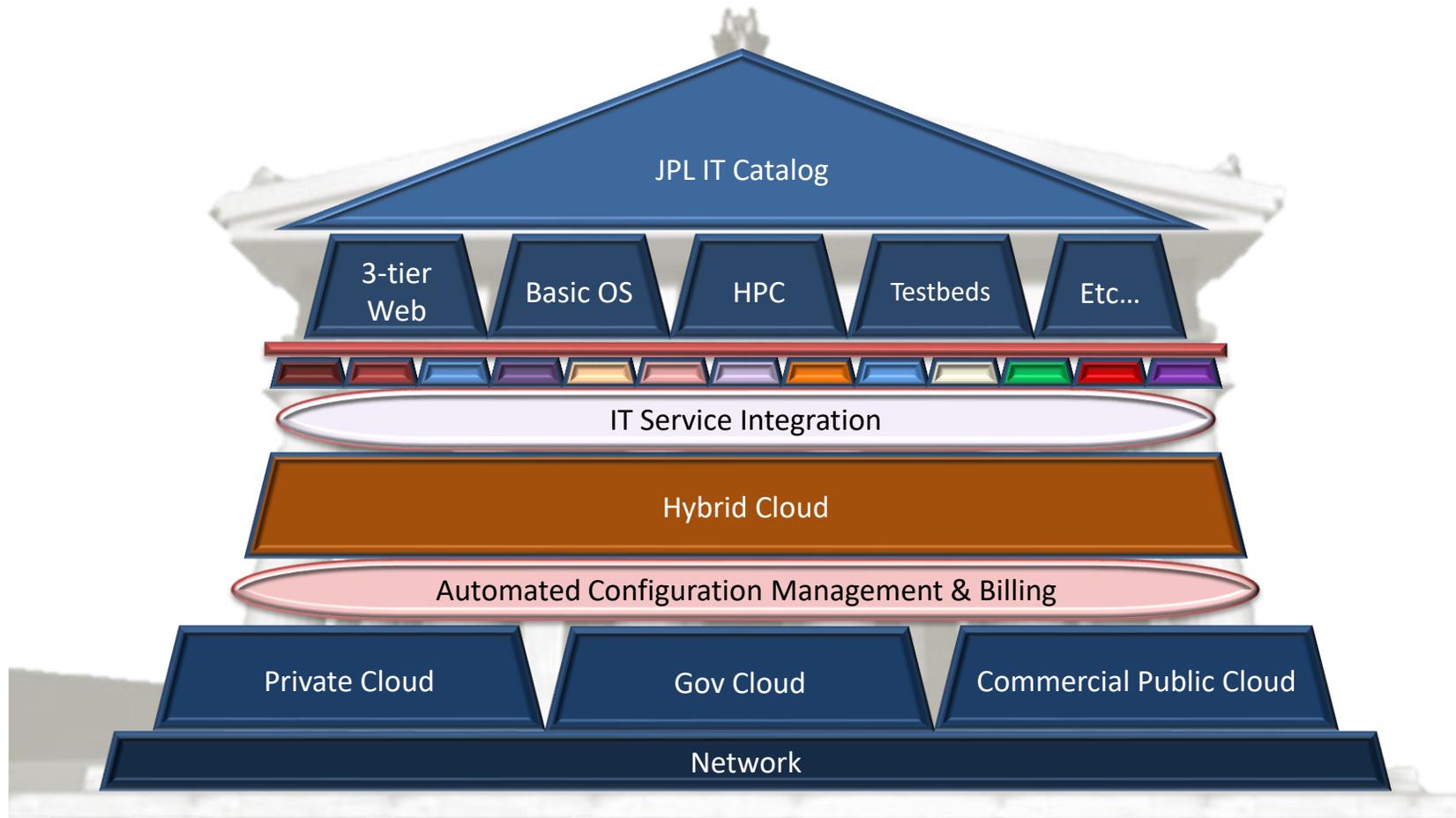
Clouds Favor Hybrid Cloud



1 Logical Compute Cloud



JPL's Cloud Layers

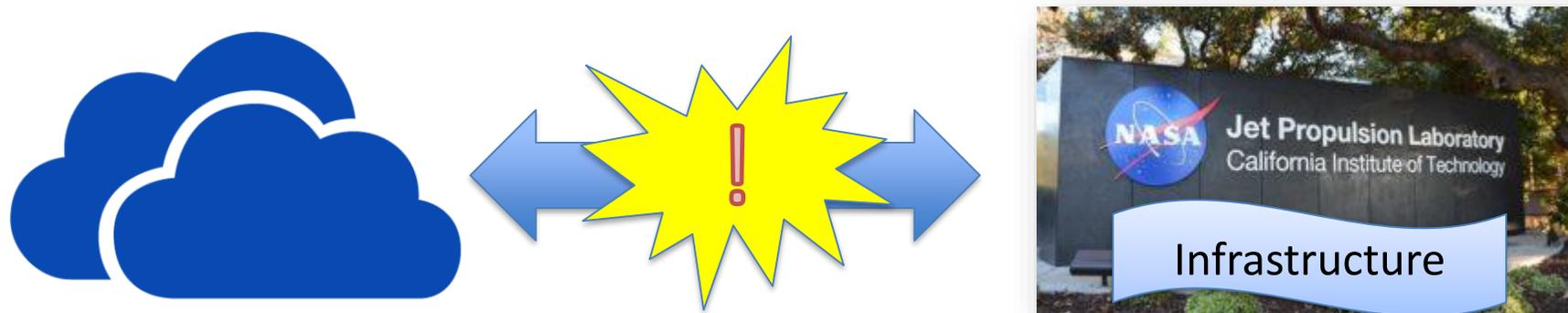


In-Cloud Infrastructure

- Cloud forces us to evolve to support new fundamental network constructs

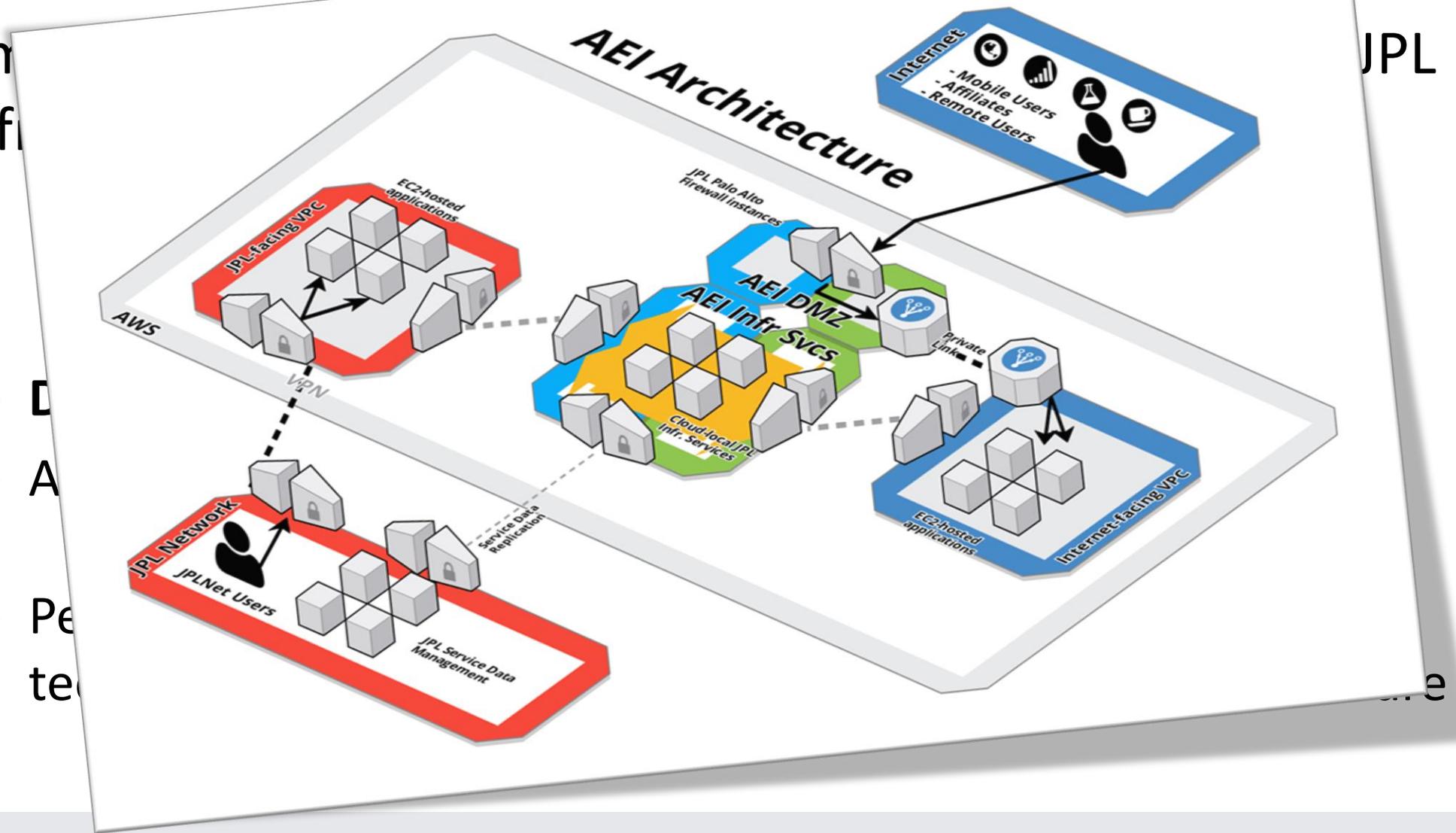


- Our infrastructure must evolve too



Essential Cloud Infrastructure

- An
Inf



SA Managed Cloud Services

Sustaining infrastructure can be hard in today's fast-paced world of shifting cybersecurity standards and vulnerabilities.

Why Run your Own Datacenter!

Drop off your well-behaved
applications and we'll manage them!

Managed Cloud Services

Basic Service includes:

- RedHat, Centos and Windows
- Patching and Security updates
- Infrastructure Service Integration (LDAP, etc.)
- Security Plan Management and Operating System layer 5
- Backups and Data Retention
- Operating System Availability Monitoring and Response
- Consultation on architecture setup
- Business Hours Support (9 am - 5 pm PST)

BASIC SA MANAGEMENT

Managed Operating System and Infrastructure Support (CIS)

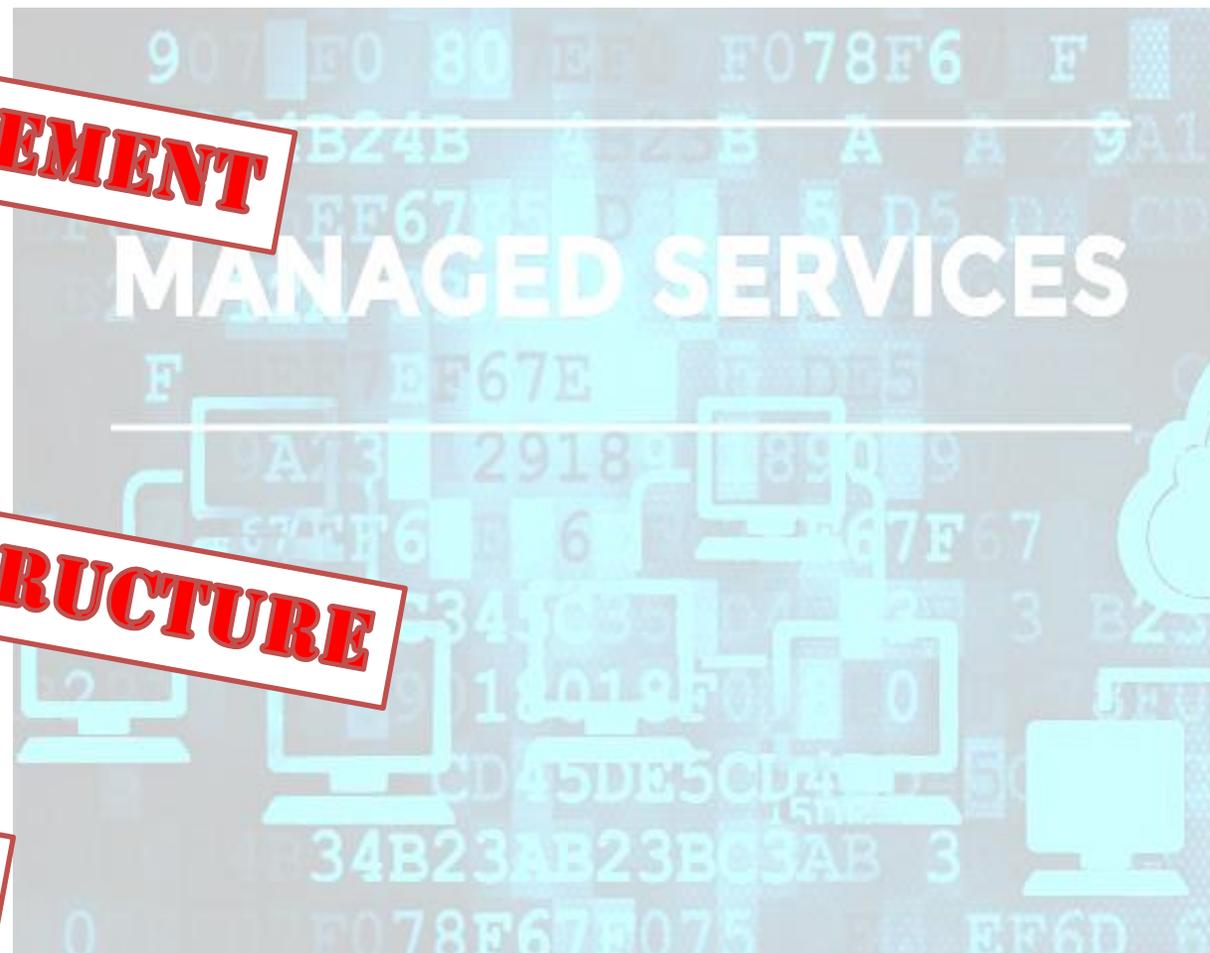
- All of the above plus
- 24/7 SA Response
- After-Hours Incident Escalation
- After-Hours response to Monitoring alerts
-

CRITICAL INFRASTRUCTURE

Per Incident After Hours Emergency Support

- For those only subscribed to Basic Support:
- Per-Incident charge
- After Hours SA Response
- After-Hours Coordination with customer

PER INCIDENT



Vector 3: Analyze

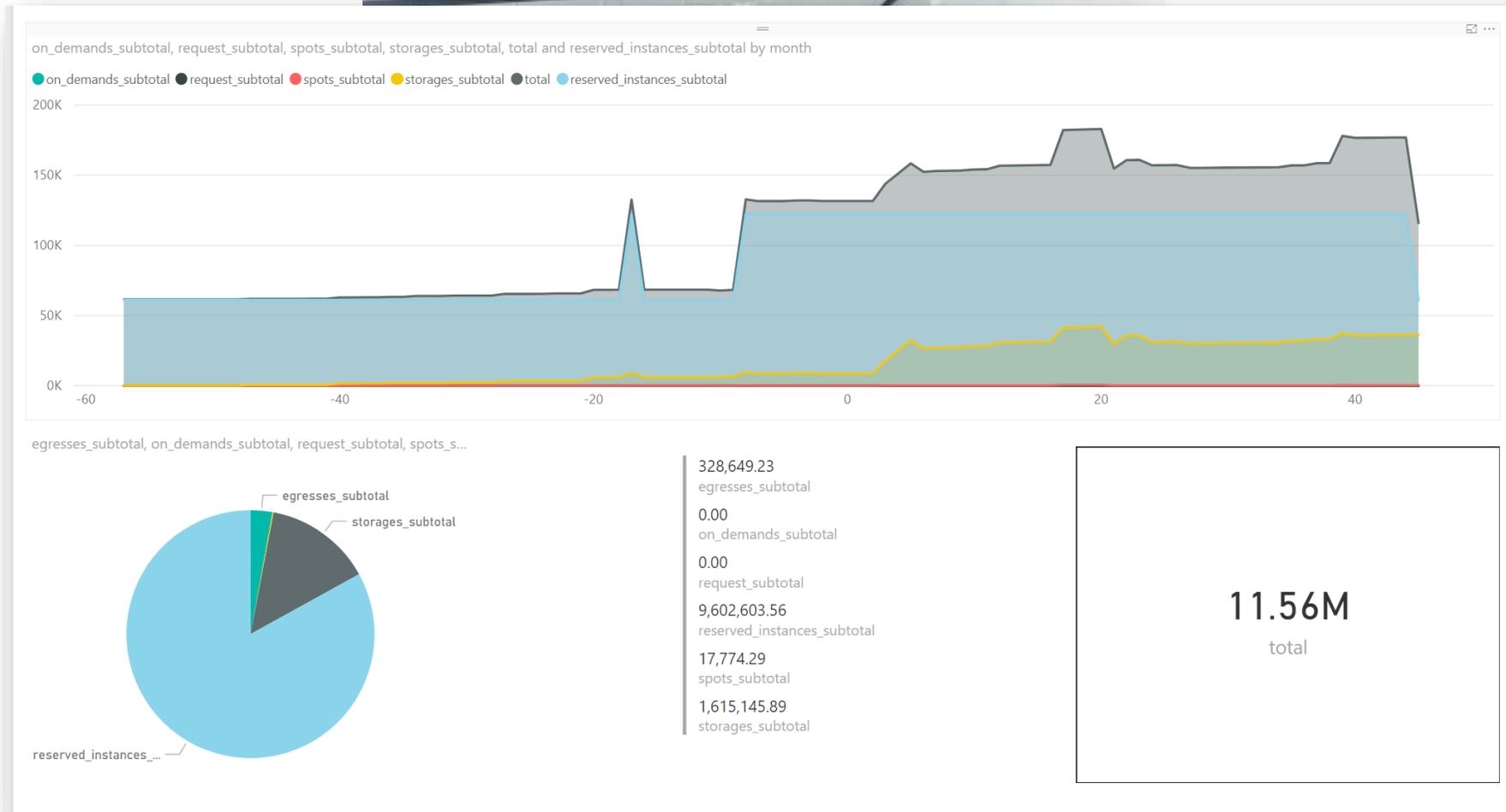
*“It is a capital mistake to theorize
before one has data.*

*Insensibly one begins to twist facts to
suit theories, instead of theories to
suit facts.”*

-Sherlock Holmes



Cloud Forecasting Tool





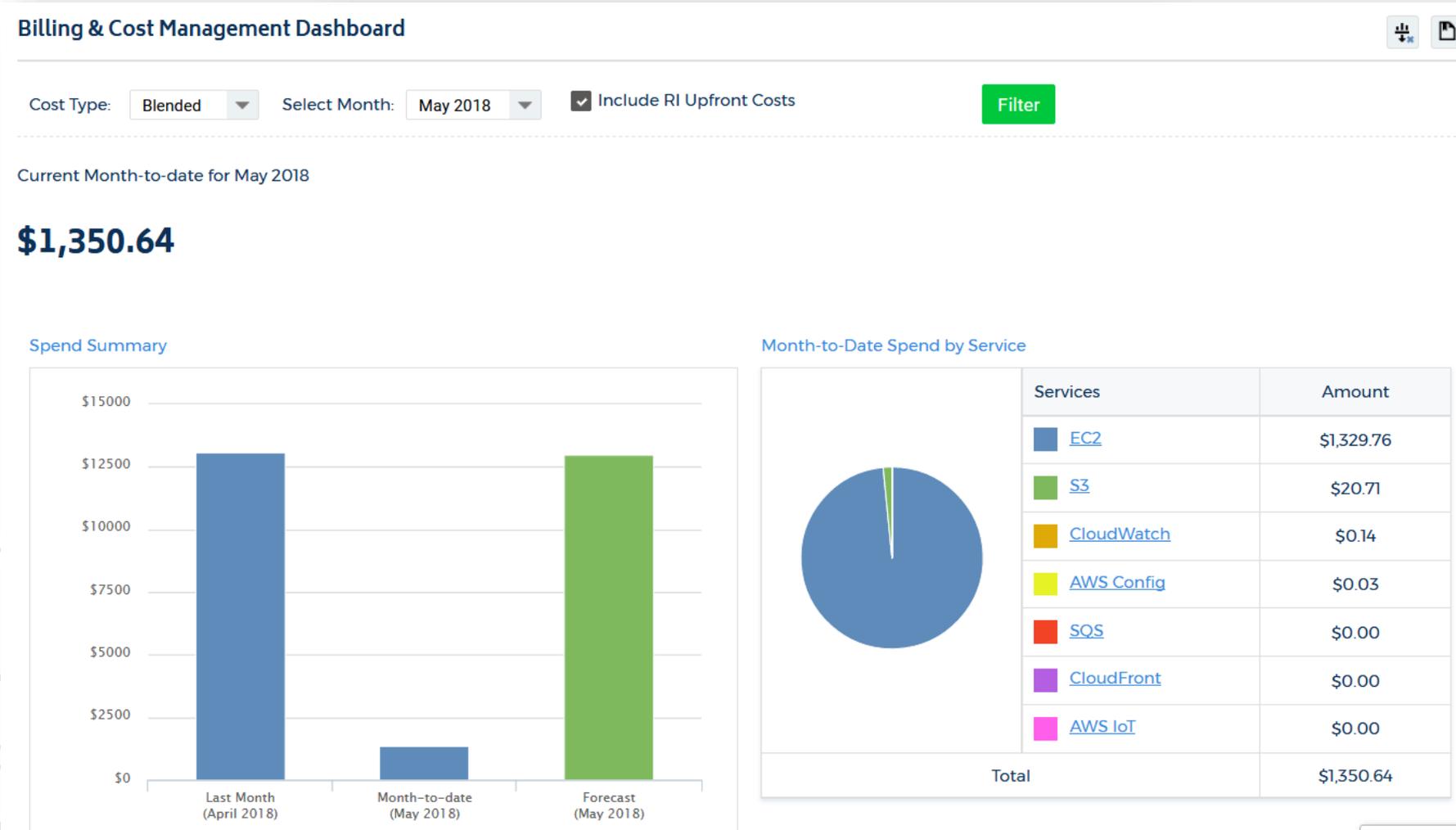
Possible Monthly Savings	
\$11,754.63	
Potential Spot Savings	
Idle Resources: \$3,200.97	Unused Resources: \$200.44
Mis-Provisioned Resources: \$0.00	Previous Generation Resources: \$810.72

Security (83 issues)	Cost (9 issues)	Availability (11 issues)	Usage (17 issues)
			3 EC2 Instance Stopped Due To Scheduled Retirement
			3 EC2 Instances Encountered Internal Error
			Auto Scaling Groups with Notifications Not Enabled
			16 EC2 Snapshots Of Deleted AMIs
			28 Under-Utilized EC2 Instances
			3 Under-Utilized Elastic Load Balancers
			3 CloudFront Distributions With Logging Not Enabled
			4 EBS Volumes With Excessive Snapshots
			EC2 Instances Not Attached To An Auto Scaling Group
			36 EC2-Classic Security Groups With No EC2 Instances
			14 EC2-VPC Security Groups with No Resources
			228 Untagged Resources
			Previous Generation EC2 Instances Should Be Migrated
			Reserved Purchase Recommendations
			EC2 Reserved Instance Purchase Recommendations

- Realtime
- Cost Data
- Resource
- Provider
- M
- M
- Sa

Sample Data

Real-Time Cloud Billing Estimates



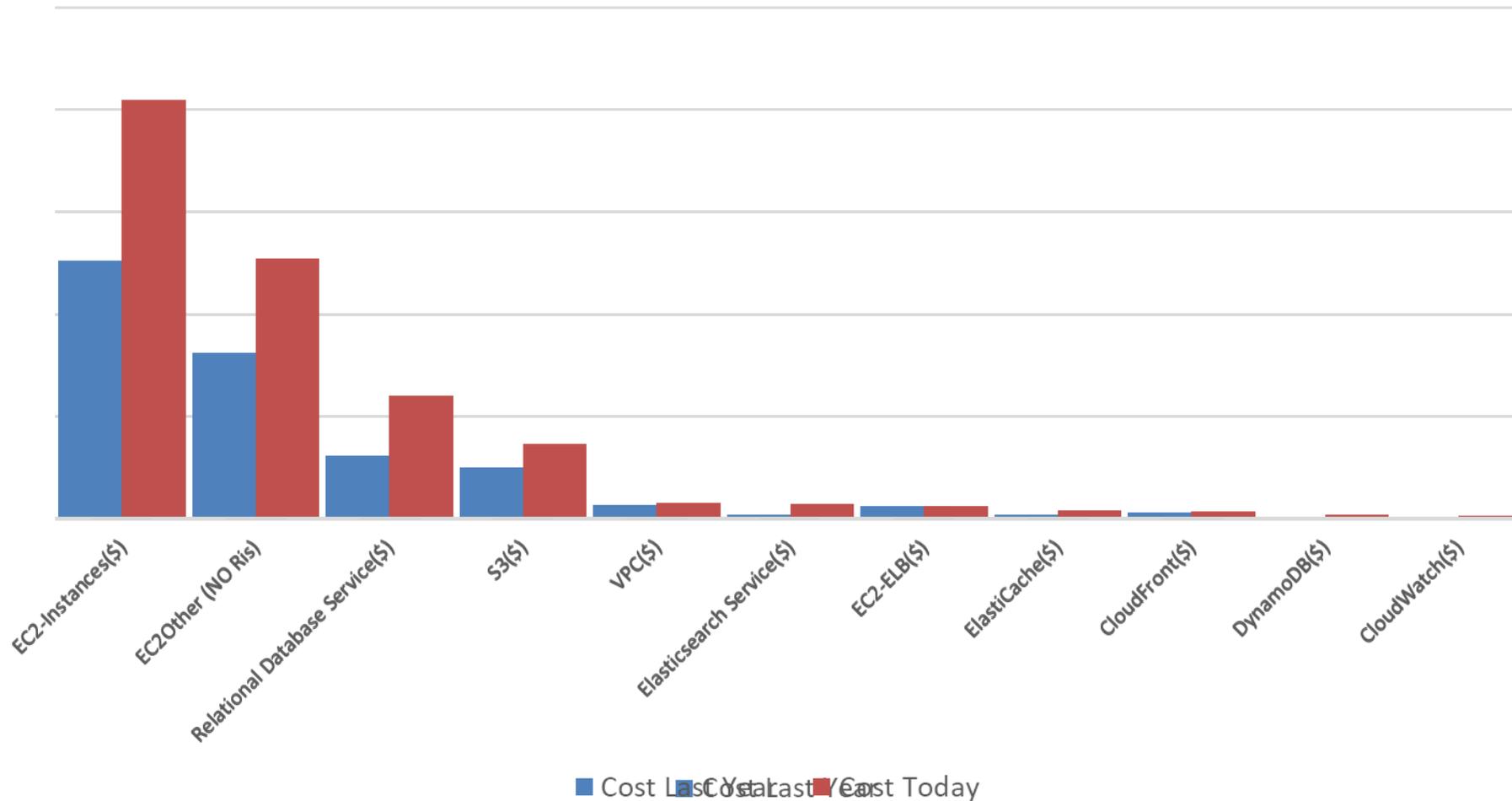
- This view
- Monthly
- Includes all cloud maintenance, service, and support

by to
 oenses

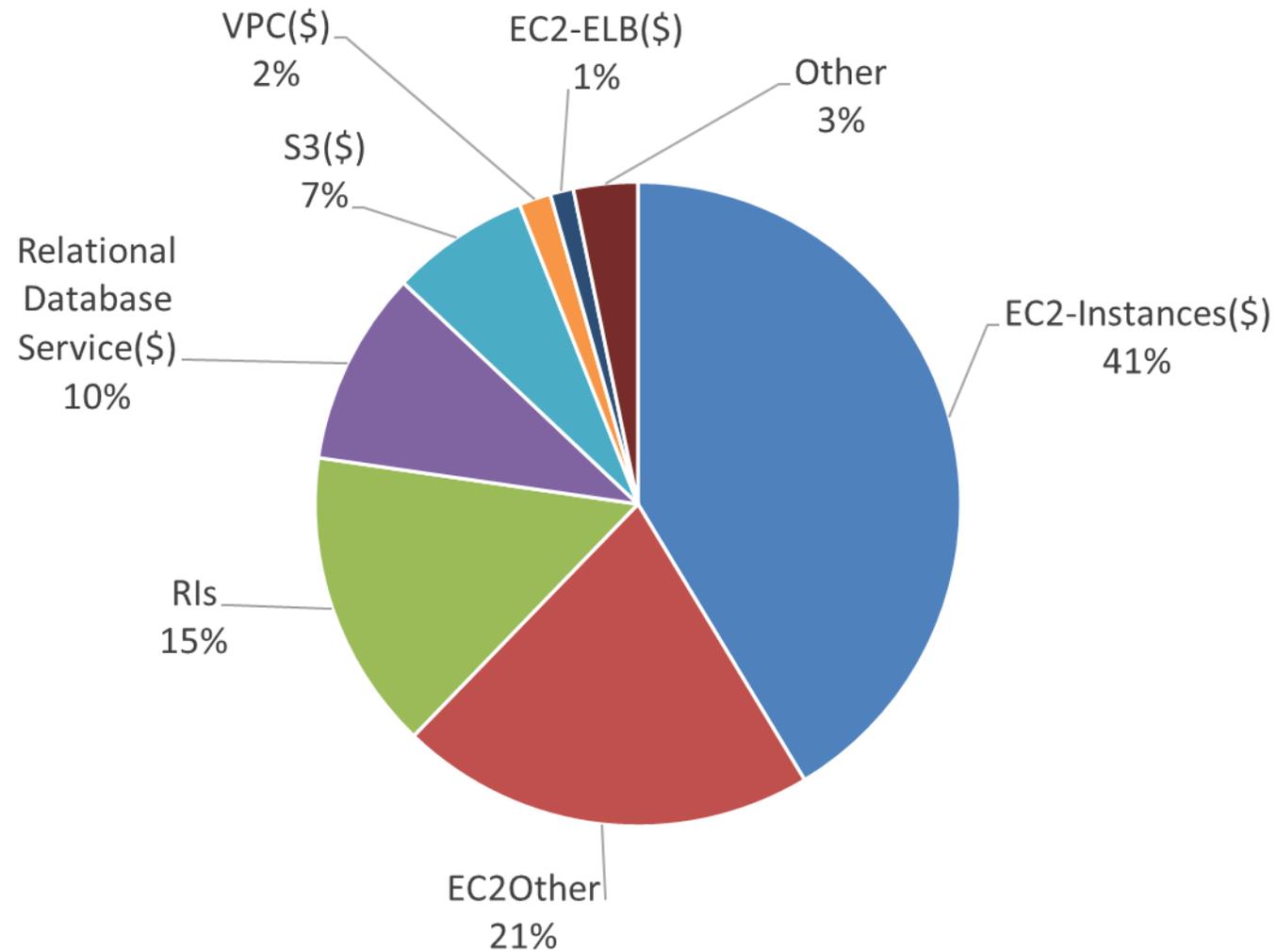
Sample Data

Services Comparison

Services Comparison



Spend by Percentage



Vector 4: Protect

*“CyberSecurity isn’t something you buy
or take, like a pill...”*

It’s like Hygiene,

*It’s built into how you think and behave,
like washing your hands.*

It’s just Good Hygiene”



Cloud Federated Login



Allows AWS Cloud resources to be managed centrally

Use single sign-on (SSO) to access accounts using their JPL Account

SAML (Security Assertion Markup Language 2.0) connects AWS roles to a JPL LDAP group

Configured in both Commercial and GovCloud

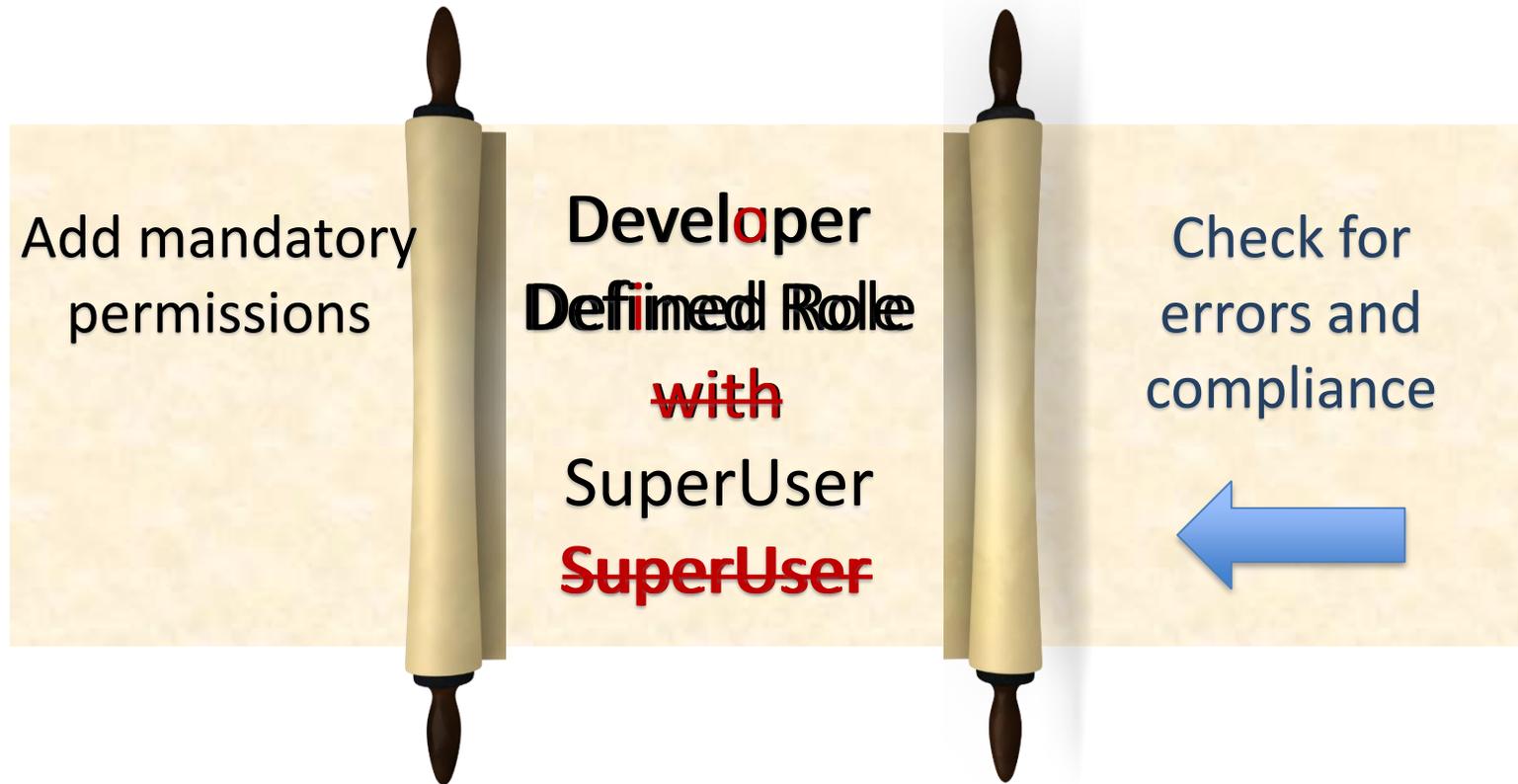
Why is Federated Login Exciting?

- Account Owners can manage which users have access to their account using LDAP Groups
- Users only need to remember two links to log in to their AWS accounts



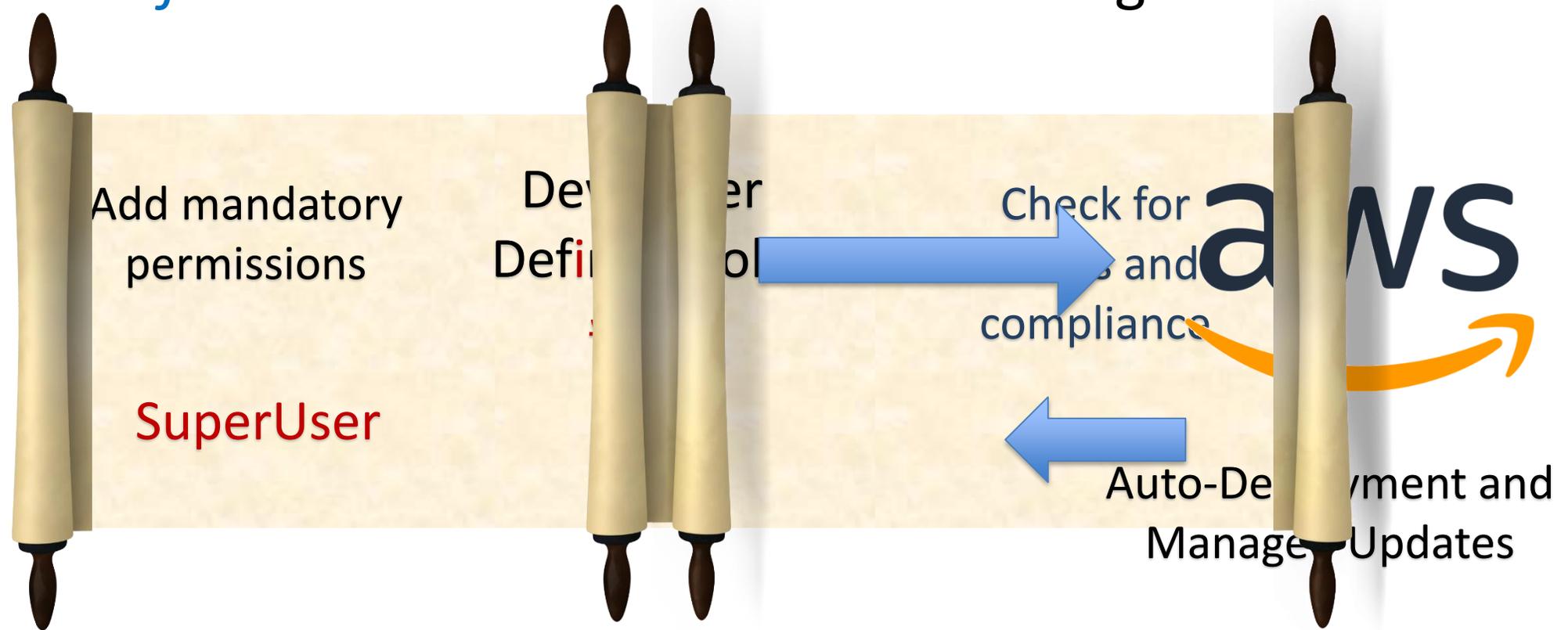
Roles as Code

Auditing, enforcement, and automation while allowing *self-service access* to create and manage roles.

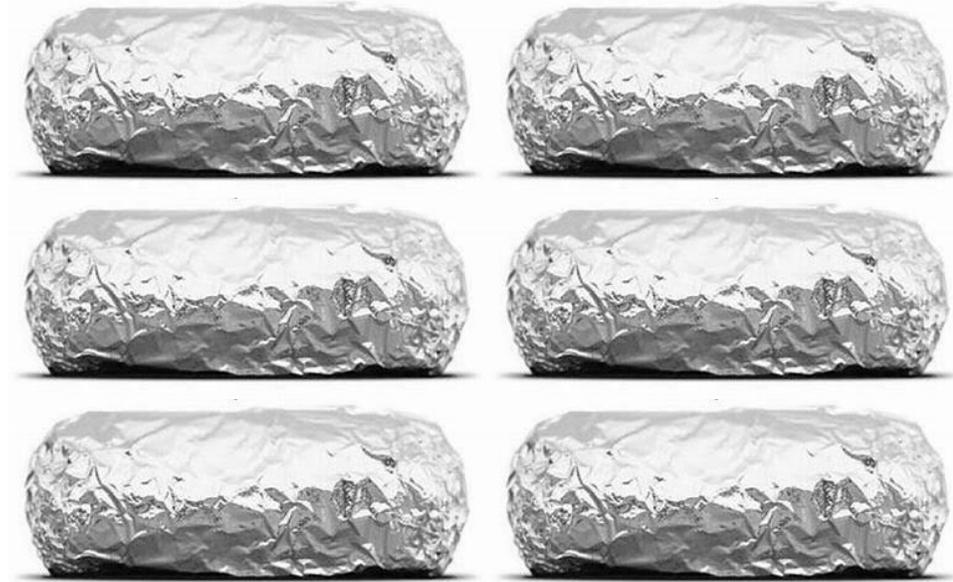
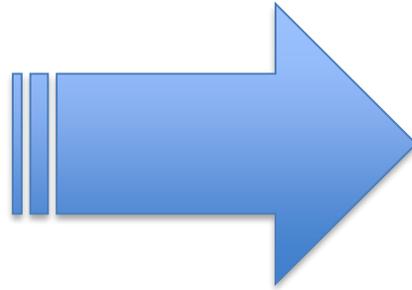


Roles as Code

Auditing, enforcement, and automation while allowing *self-service access* to create and manage roles.



OS Pipeline



Vector 5: Innovate

*“What does IT stand for?
Innovate. Together.”*



Think "services" not servers.

Cloud Computing Environments: AWS Gov Cloud

Compute

 **EC2**
Virtual Servers in the Cloud

 **Elastic Container Service**
Run and Manage Docker Containers

 **Elastic Beanstalk**
Run and Manage Web Apps

 **Lambda**
Run Code in Response to Events

Storage & Content Delivery

 **S3**
Scalable Storage in the Cloud

 **Glacier**
Archive Storage in the Cloud

 **Snowball**
Large Scale Data Transport

 **Storage Gateway**
Hybrid Storage Integration

Networking

 **VPC**
Isolated Cloud Resources

 **Direct Connect**
Dedicated Network Connection to AWS

Developer Tools

 **CodeDeploy**
Automate Code Deployments

Database

 **RDS**
Managed Relational Database Service

 **DynamoDB**
Managed NoSQL Database

 **ElastiCache**
In-Memory Cache

 **Redshift**
Fast, Simple, Cost-Effective Data Warehousing

 **DMS**
Managed Database Migration Service

Management Tools

 **CloudWatch**
Monitor Resources and Applications

 **CloudFormation**
Create and Manage Resources with Templates

 **CloudTrail**
Track User Activity and API Usage

 **Config**
Track Resource Inventory and Changes

Security & Identity

 **Identity & Access Management**
Manage User Access and Encryption Keys

 **Trusted Advisor**
Optimize Performance and Security

 **Certificate Manager**
Provision, Manage, and Deploy SSL/TLS Certificates

Analytics

 **EMR**
Managed Hadoop Framework

 **Elasticsearch Service**
Run and Scale Elasticsearch Clusters

 **Kinesis**
Work with Real-Time Streaming Data

Mobile Services

 **SNS**
Push Notification Service

Application Services

 **API Gateway**
Build, Deploy and Manage APIs

 **SQS**
Message Queue Service

 **SWF**
Workflow Service for Coordinating Application Components

Migration

 **Server Migration**
Migrate on-premises servers to AWS

Artificial Intelligence

 **Amazon Polly**
Turn Text into Lifelike Speech

 **Rekognition**
Search and Analyze Images

Cloud Computing Environments: AWS Commercial Cloud

<p>A</p> <ul style="list-style-type: none"> Alexa for Business Amazon Chime ↗ Amazon Comprehend Amazon Connect Amazon FreeRTOS Amazon GameLift Amazon Lex Amazon Macie ↗ Amazon MQ Amazon Polly Amazon Redshift Amazon SageMaker Amazon Sumerian ↗ Amazon Transcribe Amazon Translate API Gateway Application Discovery Service AppStream 2.0 Artifact Athena AWS AppSync AWS Auto Scaling AWS DeepLens AWS Glue AWS Migration Hub AWS Single Sign-On <p>B</p> <ul style="list-style-type: none"> Batch 	<p>C</p> <ul style="list-style-type: none"> Certificate Manager Cloud9 CloudFormation CloudFront CloudHSM CloudSearch CloudTrail CloudWatch CodeBuild CodeCommit CodeDeploy CodePipeline CodeStar Cognito Config <p>D</p> <ul style="list-style-type: none"> Data Pipeline Database Migration Service Device Farm Direct Connect Directory Service DynamoDB 	<p>E</p> <ul style="list-style-type: none"> EC2 EFS Elastic Beanstalk Elastic Container Service Elastic Transcoder ElastiCache Elasticsearch Service EMR <p>G</p> <ul style="list-style-type: none"> Glacier Greengrass GuardDuty <p>I</p> <ul style="list-style-type: none"> IAM Inspector IoT Analytics IoT Core IoT Device Management <p>K</p> <ul style="list-style-type: none"> Kinesis Kinesis Video Streams <p>L</p> <ul style="list-style-type: none"> Lambda Lightsail ↗ 	<p>M</p> <ul style="list-style-type: none"> Machine Learning Managed Services MediaConvert MediaLive MediaPackage MediaStore MediaTailor Mobile Analytics Mobile Hub <p>O</p> <ul style="list-style-type: none"> OpsWorks <p>P</p> <ul style="list-style-type: none"> Pinpoint <p>Q</p> <ul style="list-style-type: none"> QuickSight ↗ <p>R</p> <ul style="list-style-type: none"> RDS Rekognition Route 53 	<p>S</p> <ul style="list-style-type: none"> S3 Server Migration Service Service Catalog Simple Email Service Simple Notification Service Simple Queue Service Snowball Step Functions Storage Gateway SWF Systems Manager <p>T</p> <ul style="list-style-type: none"> Trusted Advisor <p>V</p> <ul style="list-style-type: none"> VPC <p>W</p> <ul style="list-style-type: none"> WAF & Shield WorkDocs WorkMail WorkSpaces <p>X</p> <ul style="list-style-type: none"> X-Ray
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EFS



File Storage

File shares that use the standard SMB 3.0 protocol

Data Box

Secure, ruggedized appliance for Azure data transfer

Storage Explorer

View and interact with Azure Storage resources

Archive Storage

Industry leading price point for storing rarely accessed data

Web

App Service

Quickly create powerful cloud apps for web and mobile

API Management

Publish APIs to developers, partners, and employees securely and at scale

Content Delivery Network

Ensure secure, reliable content delivery with broad global reach

Notification Hubs

Send push notifications to any platform from any back end

Azure Search

Fully-managed search-as-a-service

Web Apps

Quickly create and deploy mission critical web apps at scale

Cloud Computing Environments:

Azure

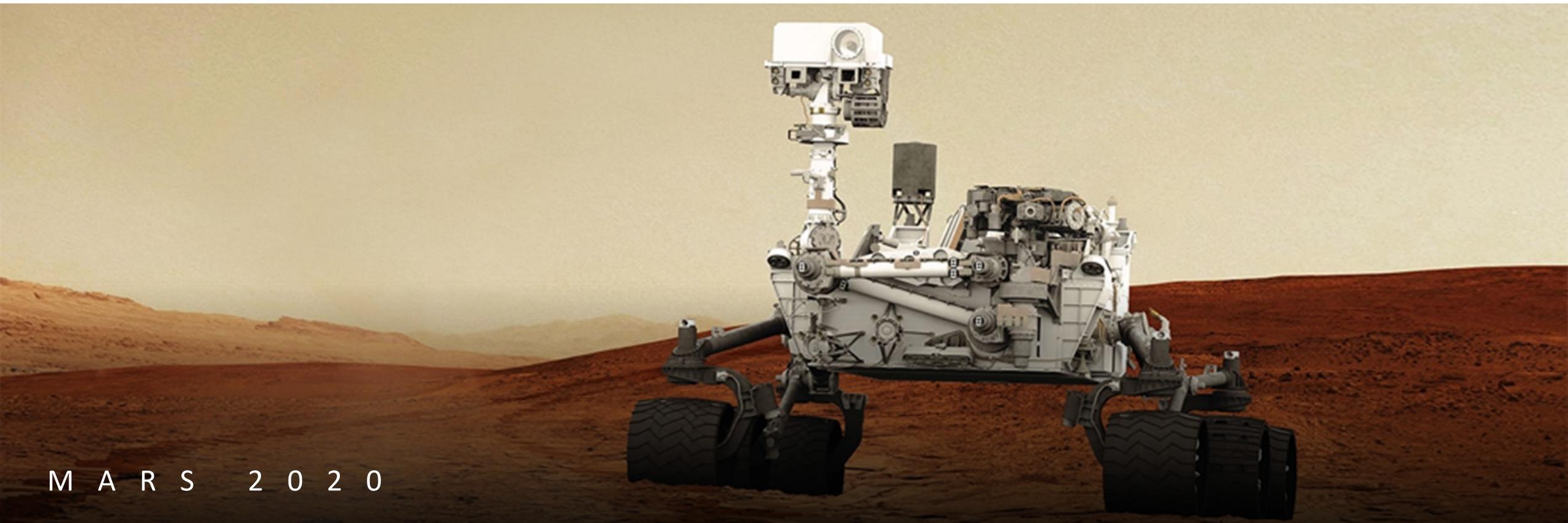
Europa

WHERE
COULD WE
FIND
LIFE?





Mars 2020



M A R S 2 0 2 0

Mars 2020



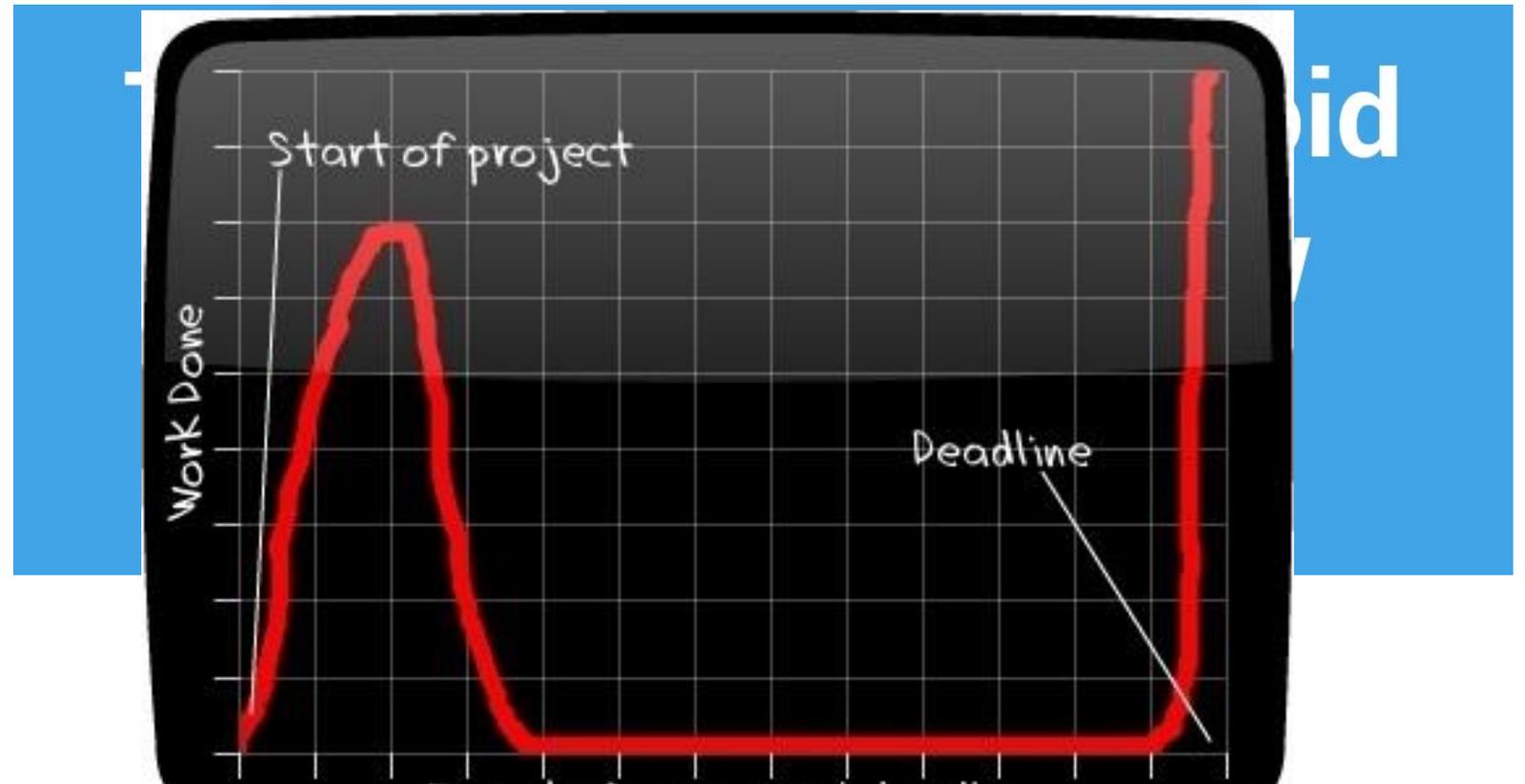
Vector 6: Align

*“Vision in a Vacuum
leads to Products
that Really **STINK**”*



Aligning

- Understand:
- Engage:
- Empower:
- Deliver:
- Expect:
- Reward:



Cloud Maturity Scale



Lift and Shift



Cloud Native
Architecture

Increasing Benefits

Example of a Webserver Lift & Shift

- Benefits:
 - Hardware Maintenance and Upgrades by Cloud Provider
 - Potential for Reduced Cost
- Concerns
 - Potential of Increased Risk of Outages
 - Cloud does not plan outages or respect flight freezes!
- You still need to
 - Continue to Patch, Upgrade, and Secure Instances
 - Manage Scaling and Load Balancing



Example of a Webserver Cloud Native

- Benefits:
 - Infinite AutoScaling
 - Reduced Risk of Outages
 - Serverless
 - No Instances or Servers to Maintain
 - No Maintenance or Patching
 - More Capabilities and Options as services Improve

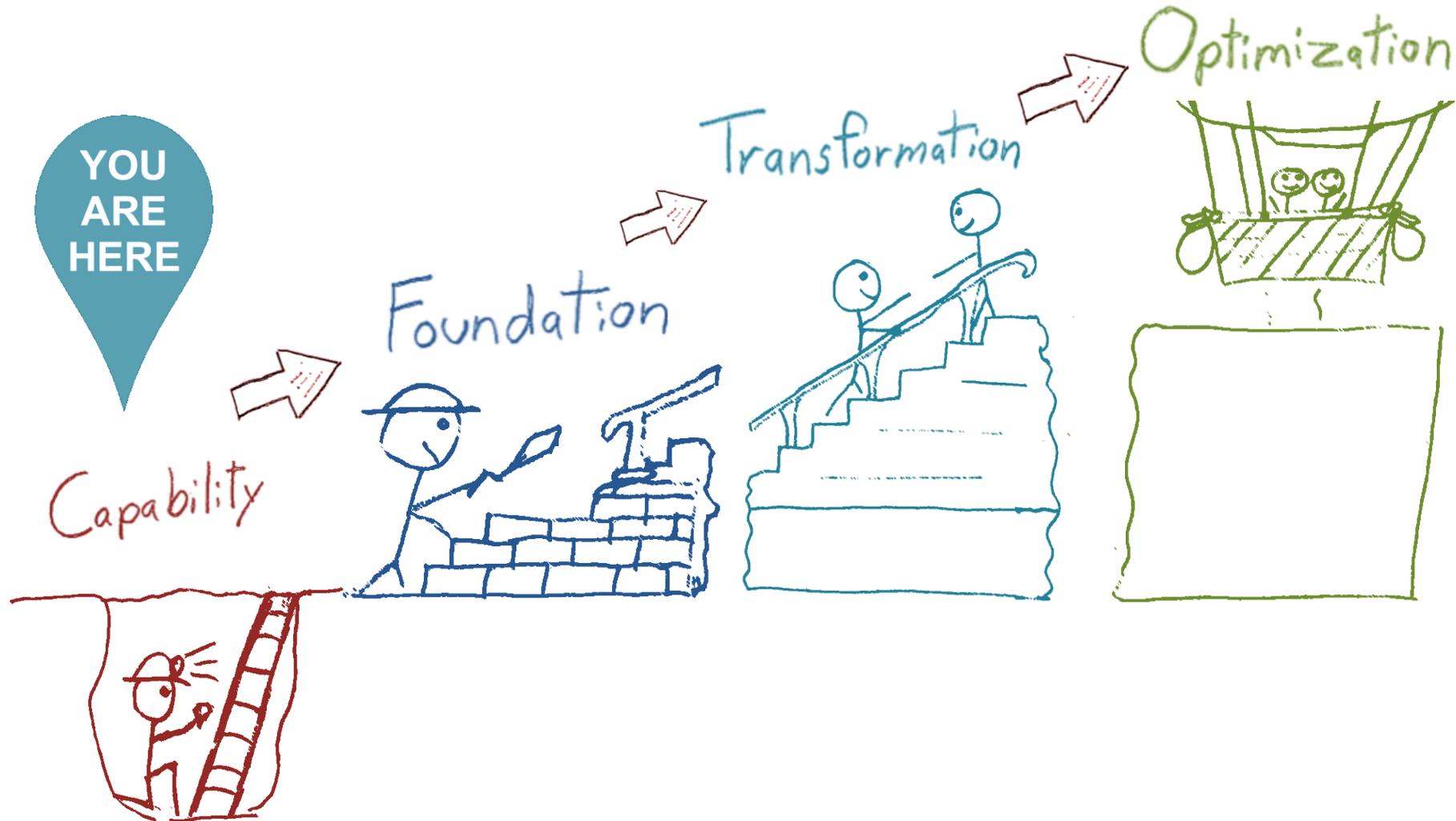


Adoption

*“Vision
without Execution
is simply
Hallucination”*



Adoption Strategy & Action Plan



Cloud Computing Currently in Use Today @ JPL

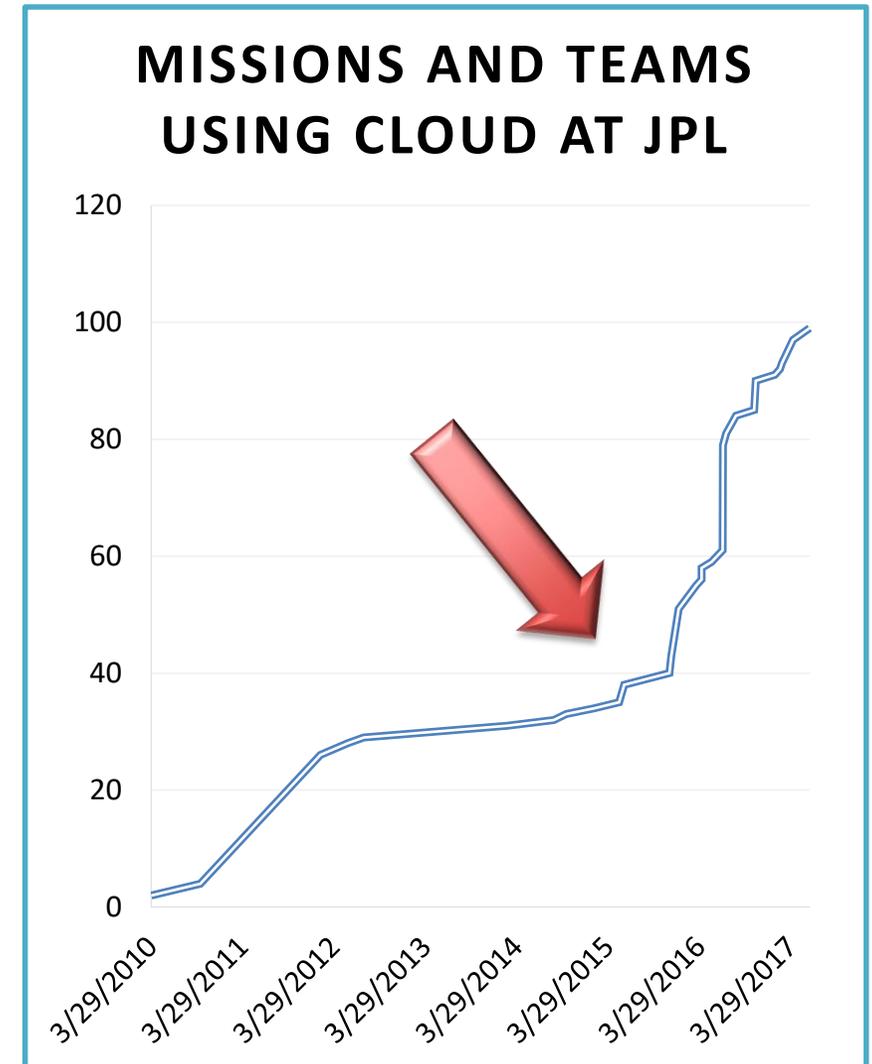
- Just a few examples

- Spacecraft telemetry processing
 - MSL, SMAP, DAWN, Jason- $\{2,3\}$, M2020, & more
- Science data processing
 - OCO-2, SMAP, ARIA, SWOT, NISAR
- DSN archival data storage
- IT Infrastructure Services



Does this Work?

- Adoption of Cloud by JPL Missions is rocketing upwards.
- Upgrades to the Cloud are now a critical component to JPL's infrastructure.
- In the last Quarter, IT has released over 21 new cloud Infrastructure Improvements including 11 major Rollouts



Thank You

- Presentation by:
 - Michael Stefanini, JPL
 - Senior Engineer and Associate CTO for IT
 - Manager of the IT Engineering and Project Management Office
 - Manager of JPL Cloud Services

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