



CLOUD-BASED PROCESSING OF FLIGHT DYNAMICS DATA PIPELINES

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WHO ELSE HAS SOLVED PROBLEMS LIKE THIS AT SCALE?



Computational Biologists

Genomic data pipelines are complex and consist of many stages and tools

Many institutions use the cloud infrastructure for scaling analysis

Familiar with developing analyses that can run in cloud environments



Data Scientists & Data Engineers

Businesses that generate a lot of data need to have infrastructure that scales

Analysts and data scientists need to perform a lot of ad-hoc data processing

Familiar with how data flows through complex architectures



Web Platform Developers

Many e-commerce websites have complex architectures to orchestrate business transactions

Business analytics teams could demand a lot of data processing

Familiar with deploying and running services in the cloud



MY BACKGROUND



Aerospace Engineering

Software developer for FreeFlyer, a space mission design software product

Worked on NASA MMS's mission design team

B.S. in Mechanical/Aerospace Engineering



Computational Biology

Worked as a software engineer in a computational biology department at a university

Built data pipelines & infrastructure for cancer research workflows

Worked alongside researchers who performed complex/large data analyses



Data Science & Data Engineering

Built search and business intelligence infrastructure

Trained and deployed machine learning models in production environments

M.S. in Computational Science



Web Platform Development

Worked a lot with Ruby on Rails

Familiar with building apps to integrate with many services

AWS Certified Developer Associate



ABOUT A.I. SOLUTIONS

Small engineering services company
founded in 1996

Flight dynamics and mission engineering for
NASA, NOAA, USSF, USAF, MDA

Makers of **FreeFlyer**, an astrodynamics
modeling and space mission design software
product used on hundreds of space missions



AGENDA



Introducing Intra-Constellation
Conjunction Assessment Pipeline



How we Deployed the Pipeline to
Cloud Infrastructure

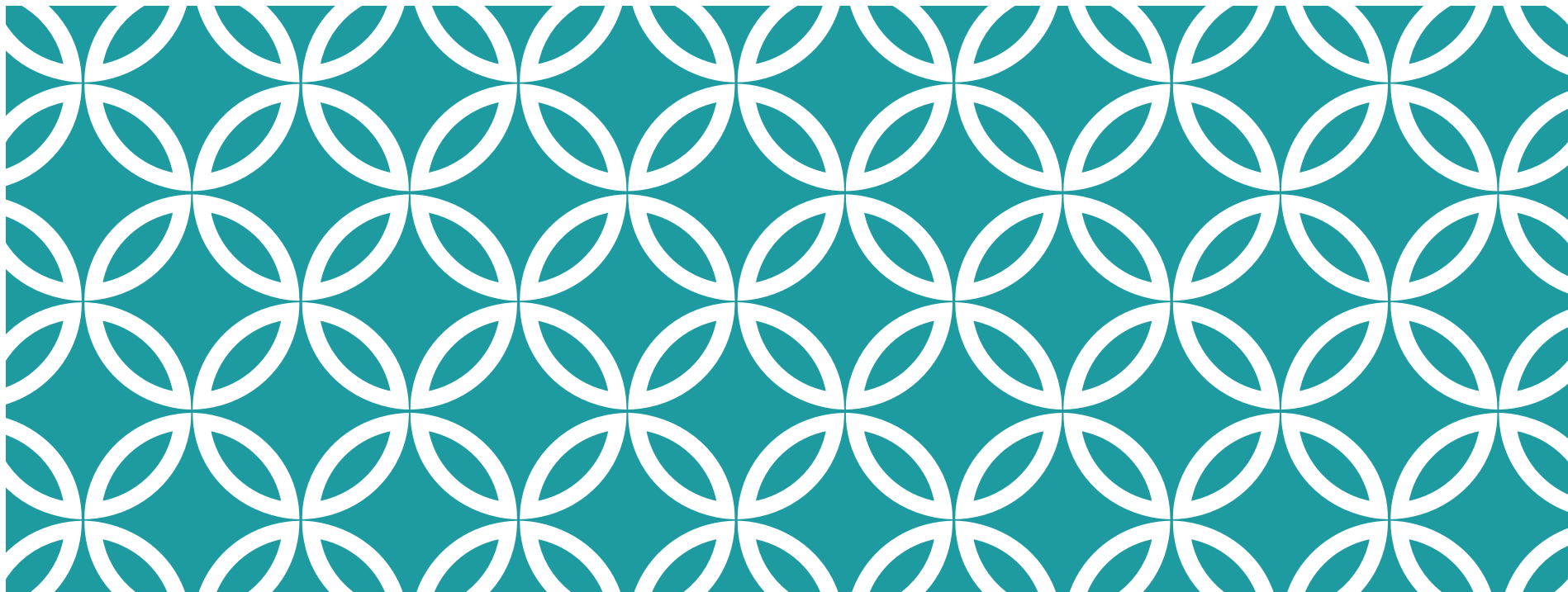


Lessons Learned



Summary

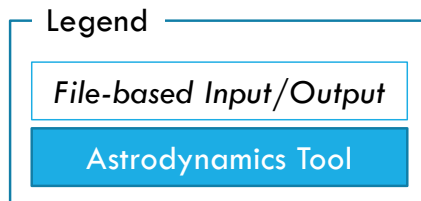
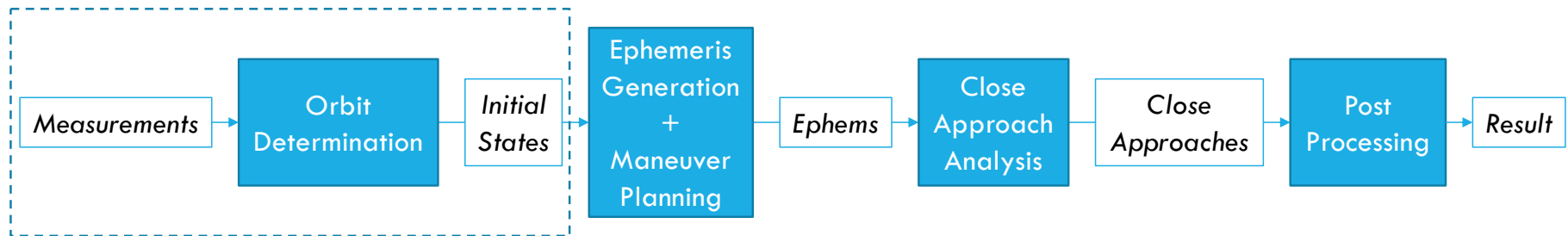


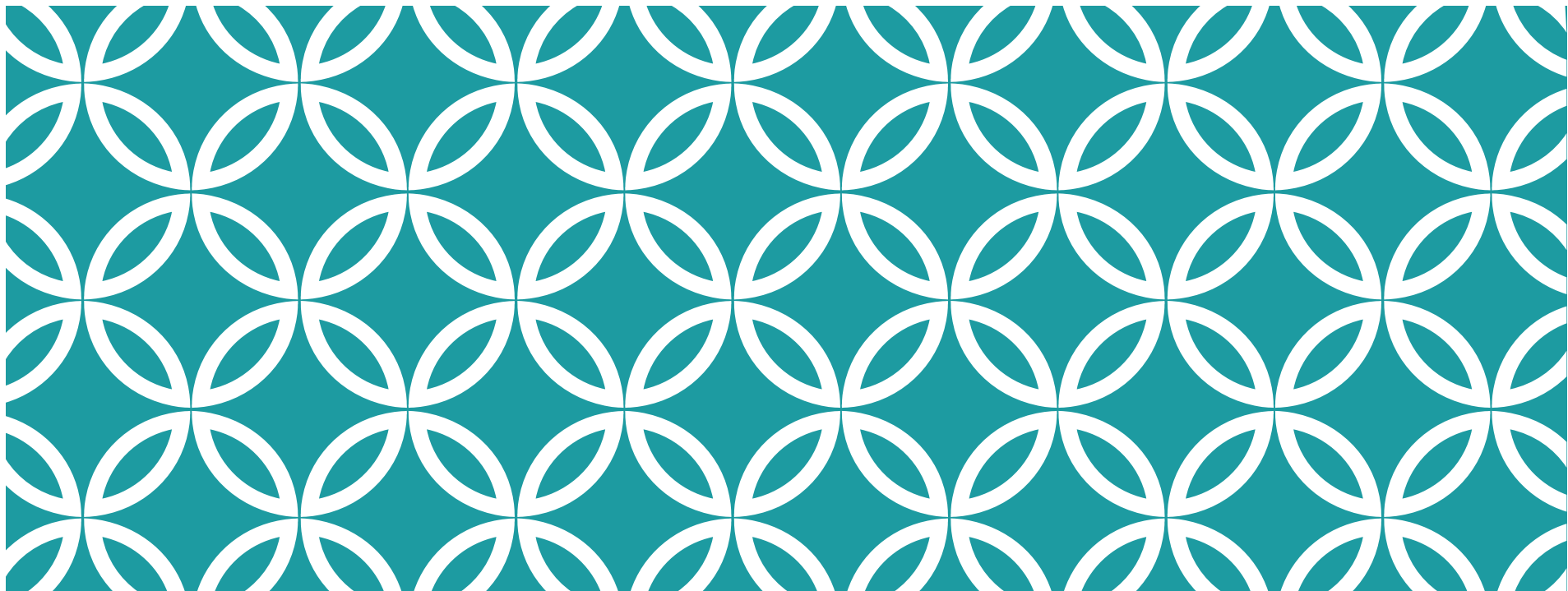


THE INTRA-CONSTELLATION CONJUNCTION ASSESSMENT PIPELINE



THE INTRA-CONSTELLATION CONJUNCTION ASSESSMENT PIPELINE

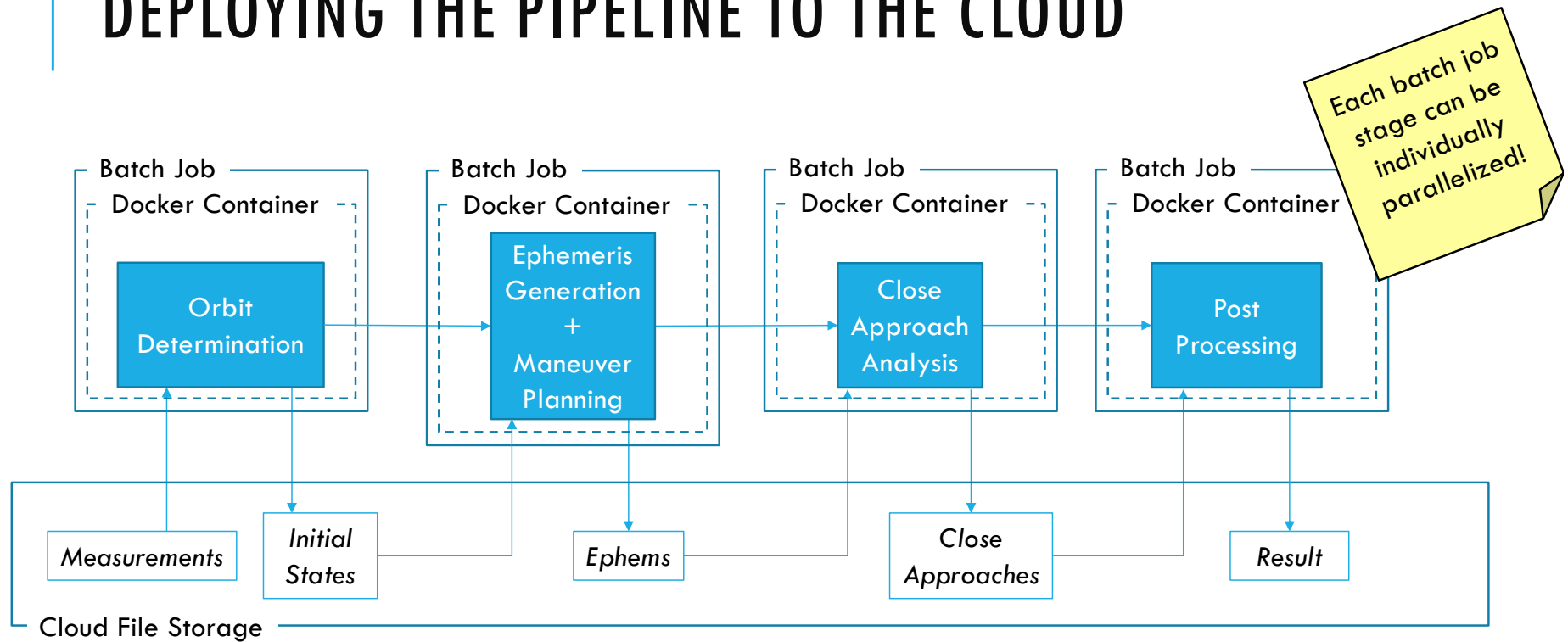




HOW WE DEPLOYED THE PIPELINE TO CLOUD INFRASTRUCTURE



DEPLOYING THE PIPELINE TO THE CLOUD



aws

Services

Flight Dynamics Ground SystemOregonSupport

AWS Batch

New Batch experience

Dashboard

Jobs

Job definitions

Job queues

Compute environments

Wizard

AWS Batch > Jobs > ephemeris-generation-and-maneuver-planning-test

ephemeris-generation-and-maneuver-planning-test

SUBMITTED

PENDING

RUNNABLE

STARTING

RUNNING

SUCCEEDED

FAILED

0

0

0

0

4

3

0

ephemeris-generation-and-maneuver-planning-test (7)

Clone job

Cancel parent job

Terminate parent job

Filter resources by property or value

< 1 >

Job index	Created at	Started at	Stopped at	Status
1	Nov 19 2020 19:37:58	Nov 19 2020 19:43:13	--	RUNNING
3	Nov 19 2020 19:37:58	Nov 19 2020 19:43:13	--	RUNNING
5	Nov 19 2020 19:37:58	Nov 19 2020 19:43:14	--	RUNNING
0	Nov 19 2020 19:37:58	Nov 19 2020 19:43:14	Nov 19 2020 19:43:50	SUCCEEDED
2	Nov 19 2020 19:37:58	Nov 19 2020 19:43:43	Nov 19 2020 19:44:15	SUCCEEDED
4	Nov 19 2020 19:37:58	Nov 19 2020 19:43:13	Nov 19 2020 19:44:17	SUCCEEDED

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aws

Services

Flight Dynamics Ground System

Global

Support

Amazon S3

Buckets

Access points

Batch Operations

Access analyzer for S3

Account settings for Block Public Access

Storage Lens

Dashboards

AWS Organizations settings

Feature spotlight

Amazon S3 > ica-pipeline-test- > 2020-11-19-19-37-55/ > orbit-determination/

orbit-determination/

Folder overview

Region	S3 URI	Amazon resource name (ARN)
US West (Oregon) us-west-2	s3://ica-pipeline-test-55/orbit-determination/	arn:aws:s3:::ica-pipeline-test-55/orbit-determination/

Drag and drop files and folders you want to upload here, or choose Upload.

Objects (7)

Objects are the fundamental entities stored in Amazon S3. For others to access your objects, you'll need to explicitly grant them permissions. [Learn more](#)

Find objects by prefix

	Name	Type	Last modified	Size	Storage class
<input type="checkbox"/>	550_GPSProcessOD_Inputs_1.txt	txt	November 19, 2020, 19:43 (UTC-08:00)	855.0 B	Standard
<input type="checkbox"/>	550_OD_States_0.txt	txt	November 19, 2020, 19:43 (UTC-08:00)	7.5 KB	Standard
<input type="checkbox"/>	550_OD_States_1.txt	txt	November 19, 2020, 19:43 (UTC-08:00)	7.5 KB	Standard
<input type="checkbox"/>	550_OD_States_2.txt	txt	November 19, 2020, 19:42 (UTC-08:00)	7.5 KB	Standard
<input type="checkbox"/>	550_OD_States_3.txt	txt	November 19, 2020, 19:43 (UTC-08:00)	7.5 KB	Standard
<input type="checkbox"/>	550_OD_States_4.txt	txt	November 19, 2020, 19:42 (UTC-08:00)	7.5 KB	Standard
<input type="checkbox"/>	550_OD_States_5.txt	txt	November 19, 2020, 19:43 (UTC-08:00)	7.5 KB	Standard

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Amazon S3 ×

Buckets

Access points

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▼ Storage Lens

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AWS Organizations settings

Feature spotlight 2

Amazon S3 > ica-pipeline-test- > 2020-11-19-19-37-55/ > post-processing/ > results.png

results.png

Object actions ▾

Details

Versions

Object overview

Owner

stefan.novak

AWS Region

US West (Oregon) us-west-2

Last modified

November 19, 2020, 19:47 (UTC-08:00)

Size

105.2 KB

Type

png

Key

2020-11-19-19-37-55/post-processing/results.png

S3 URI

s3://ica-pipeline-test- /2020-11-19-19-37-55/post-processing/results.png

Amazon resource name (ARN)

arn:aws:s3:::ica-pipeline-test- /2020-11-19-19-37-55/post-processing/results.png

Entity tag (Etag)

5f4e9a7b511720c012b0d90efd1429f0

Object URL

https://ica-pipeline-test-.s3-us-west-2.amazonaws.com/2020-11-19-19-37-55/post-processing/results.png

Object management overview

The following bucket properties and object management configurations impact the behavior of this object.

Bucket properties

Bucket Versioning

When enabled, multiple variants of an object can be stored in the bucket to easily recover from unintended user actions and application failures.

Management configurations

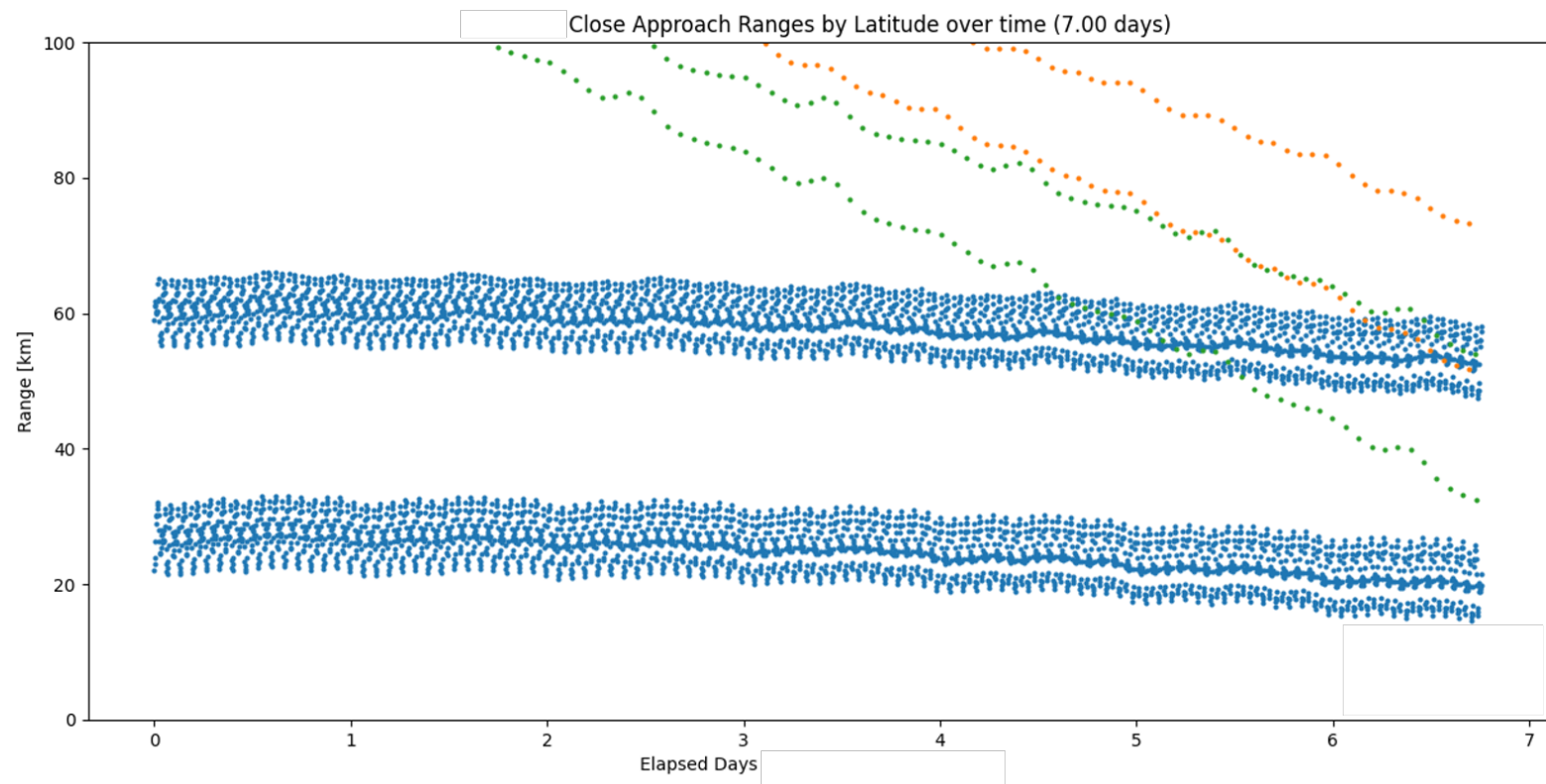
Replication status

When a replication rule is applied to an object the replication status indicates the progress of the operation.

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PIPELINE CONFIGURATION AS INFRASTRUCTURE CONFIGURATION WITH TERRAFORM

```
# In variables.tf
variable "stages" {
  description = "Names of the stages corresponding to configuration/image names"
  type        = list(string)
  default     = [
    "orbit-determination",
    "ephemeris-generation-and-maneuver-planning",
    "close-approach-analysis",
    "post-processing"
  ]
}
```

```
# In main.tf
resource "aws_batch_job_definition" "stage" {
  for_each = toset(var.stages)

  name = "${each.key}-${var.env}"
  type = "container"

  container_properties = <<EOF
  {
    "image": "${var.repository_url}:${each.key}",
    "memory": 2048,
    "vcpus": 1,
    "environment": []
  }
} EOF
```

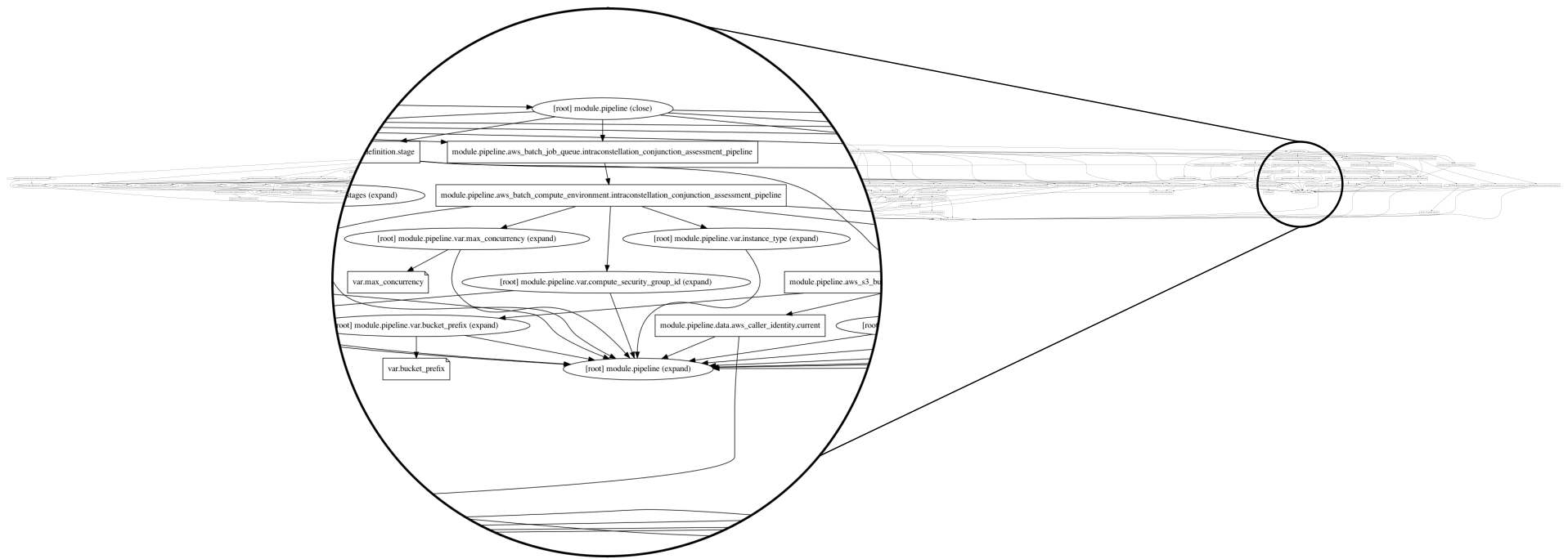
Note how we
parameterize
each stage
name...

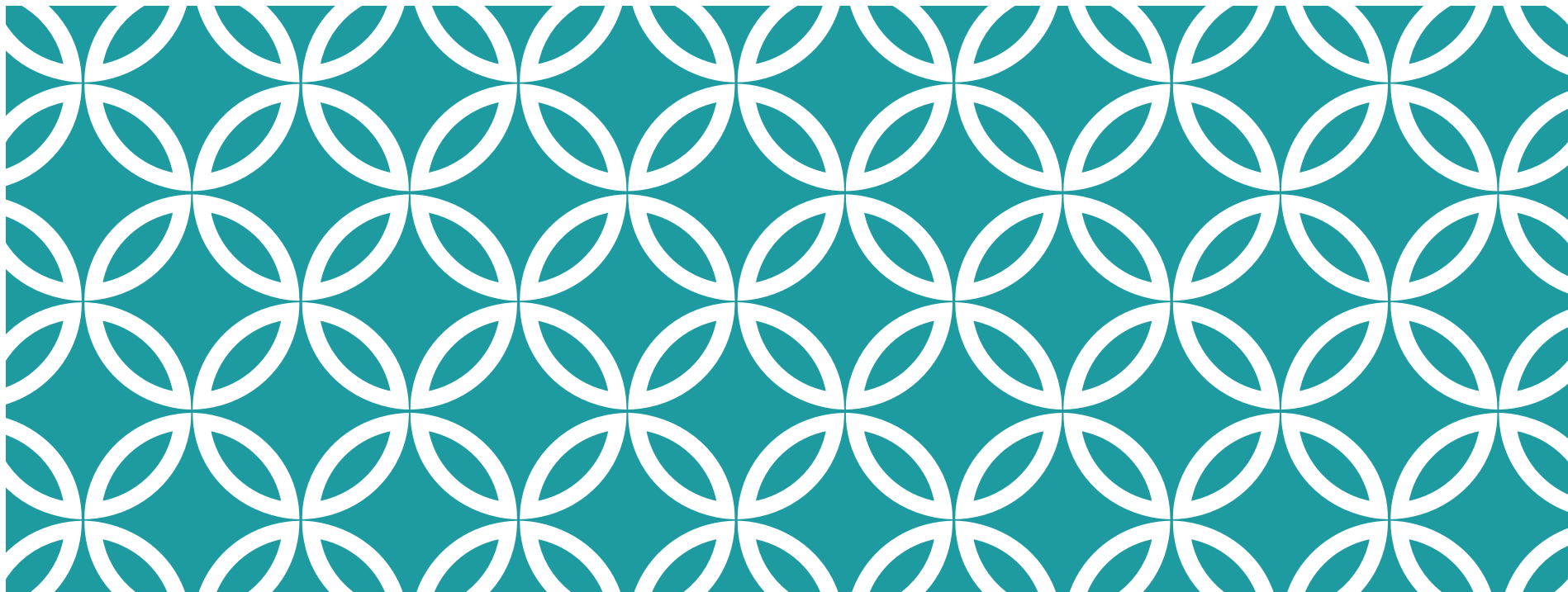
...then use the
name to define
an AWS Batch
Job definition

...and use the
name to look
up a Docker
image tag



VISUALIZING THE ARCHITECTURE WITH TERRAFORM





LESSONS LEARNED



BUILD FOR THE CLOUD FROM THE BEGINNING

Take advantage of cloud APIs in flight dynamics code

- Knowing this form of integration can simplify your architecture
- Minimizes glueware (pre-processing/post-processing)

Plan for supporting multiple environments

- Local vs cloud for pipeline code
- Development, test, production for services
- Continuous Integration/Delivery

Collaboration between astrodynamics and platform engineers is critical!

- Make sure they sit next to each other!



EXAMPLE OF INCORPORATING CLOUD APIS IN FLIGHT DYNAMICS CODE WITH FREEFLYER

```
Run "aws s3 copy s3://my_bucket/input.oem input.oem";

Spacecraft spacecraft;

spacecraft.SetPropagatorType("Ephemeris");

(spacecraft.Propagator AsType Ephemeris).LoadEphemeris("input.oem");

While (spacecraft.ElapsedTime < TimeSpan.FromDays(1));
    Report spacecraft.ShadowTimes() to "shadow_report.txt";

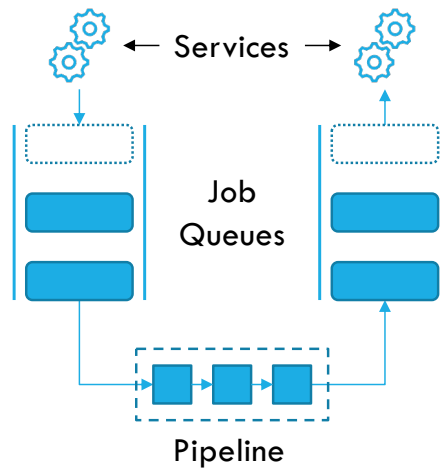
    Step spacecraft;
End;

Run "aws s3 copy shadow_report.txt s3://my_bucket/shadow_report.txt";
```

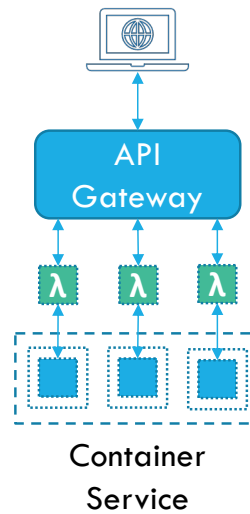


ALTERNATIVE ARCHITECTURAL PATTERNS

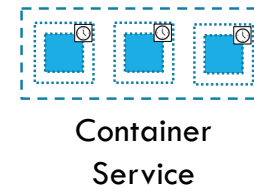
Decoupling pipelines from services



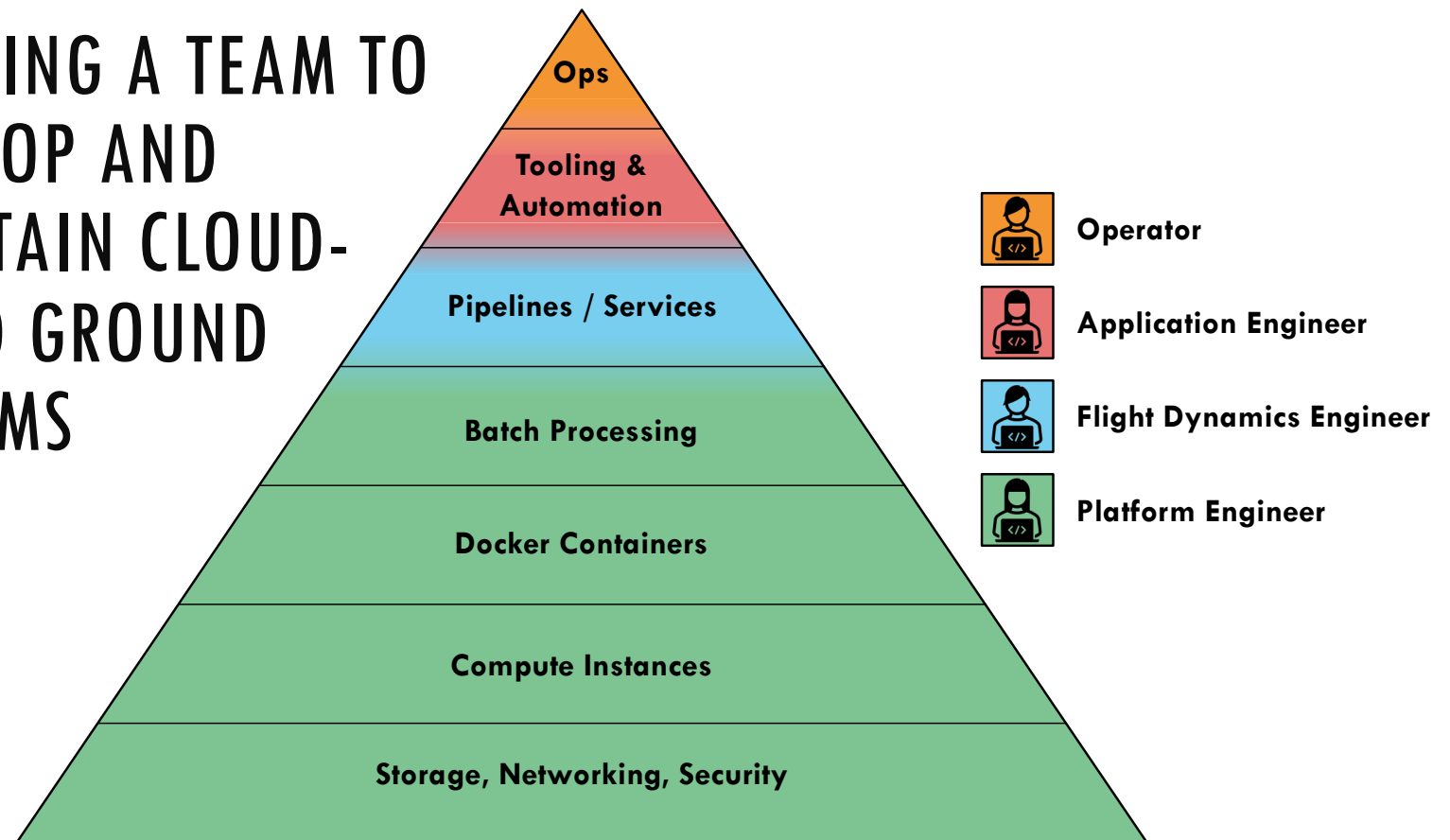
Microservices

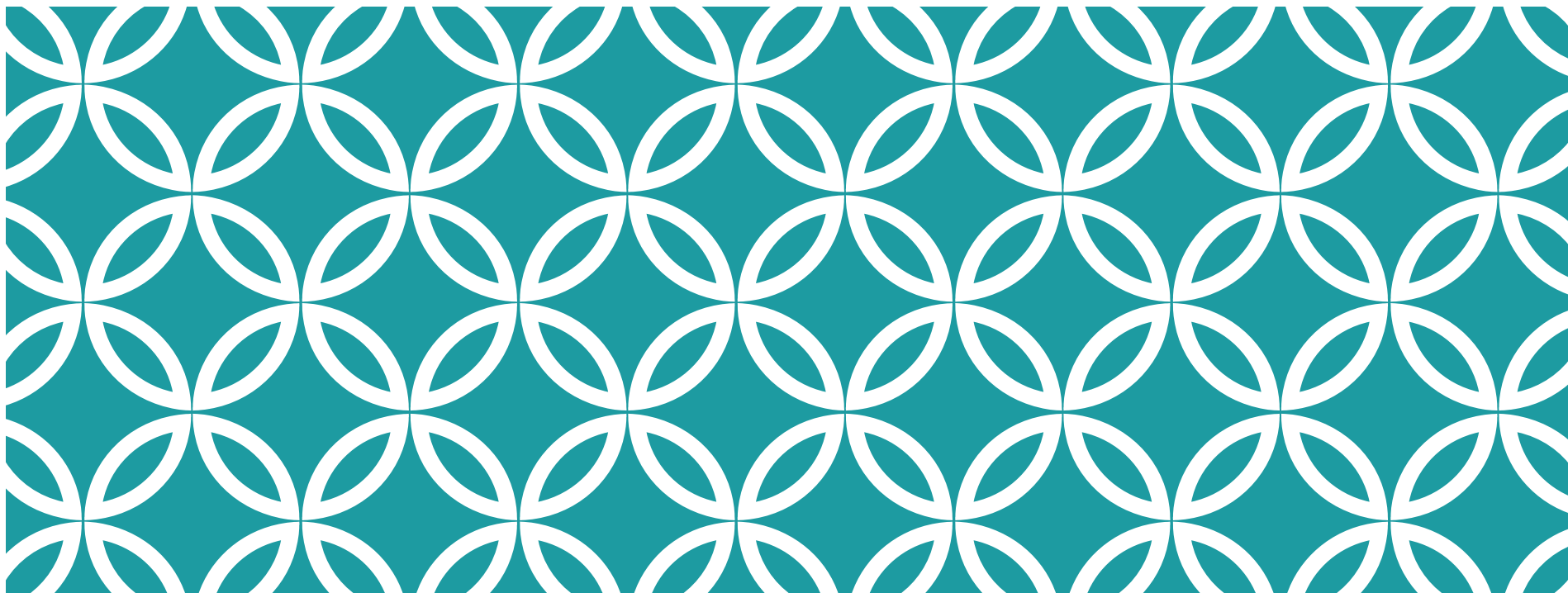


Scheduled Execution



BUILDING A TEAM TO DEVELOP AND MAINTAIN CLOUD- BASED GROUND SYSTEMS





SUMMARY



SUMMARY

We deployed an intra-constellation conjunction pipeline to a cloud environment

Leveraging existing cloud service APIs allowed us to move quickly

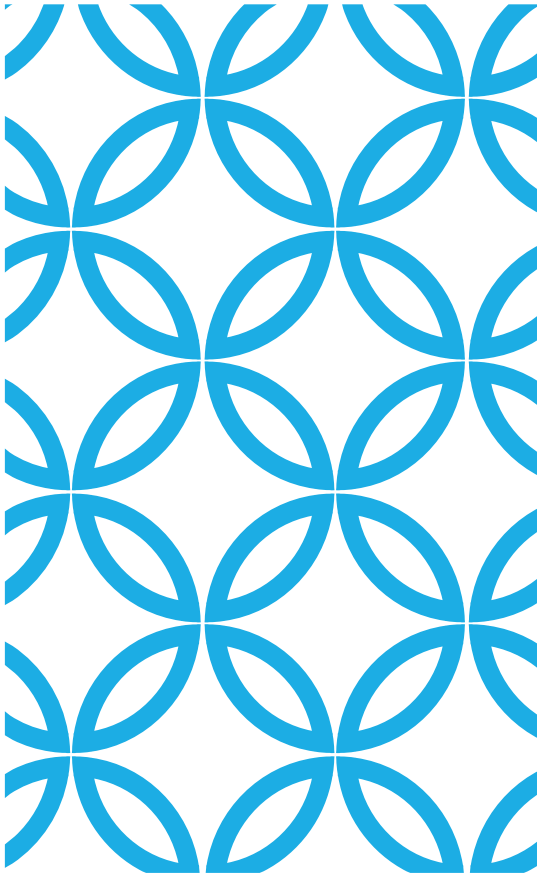
No up-front costs!

This approach can be used to design a variety of architectures

Calling directly into cloud service APIs from flight dynamics code can be very convenient

Collaboration between platform and flight dynamics engineers is key





THANK YOU!

Questions or comments? stefan.novak@ai-solutions.com

