

Jet Propulsion Laboratory
California Institute of Technology



A Cloud-based Architecture for Processing 3D Mars Terrain

Parker Abercrombie

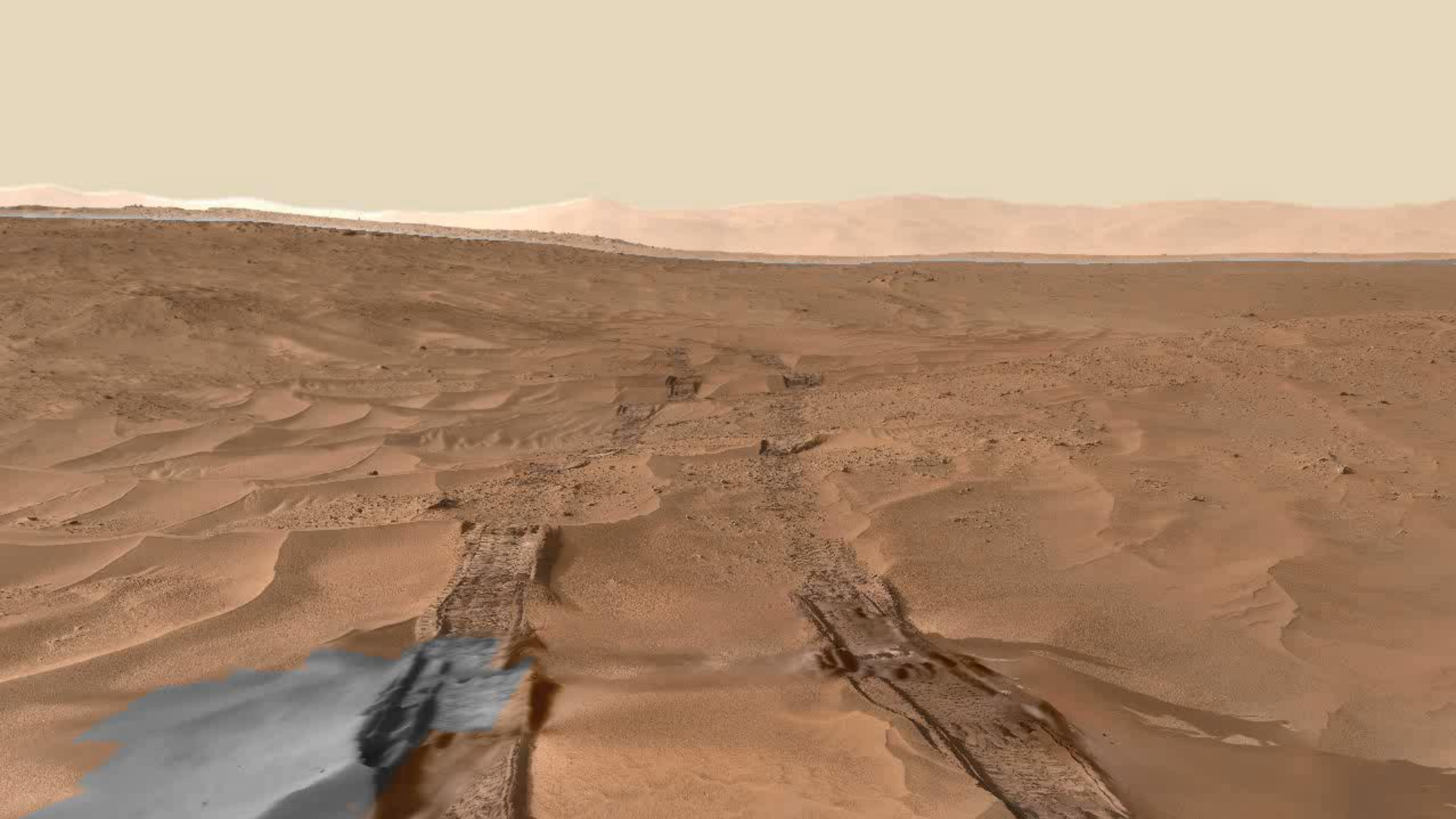
Jet Propulsion Laboratory, California Institute of Technology

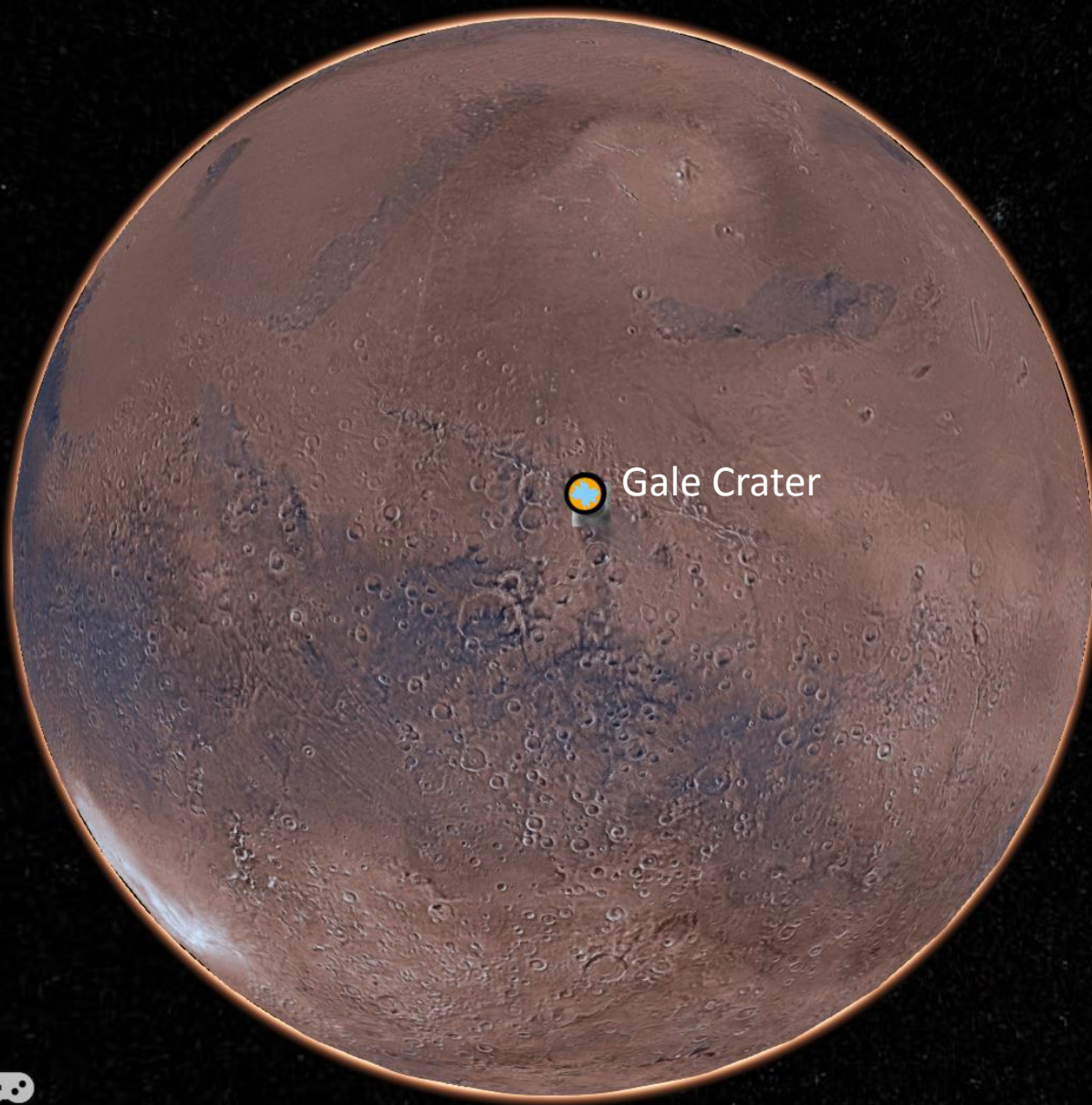
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Curiosity Mars Rover

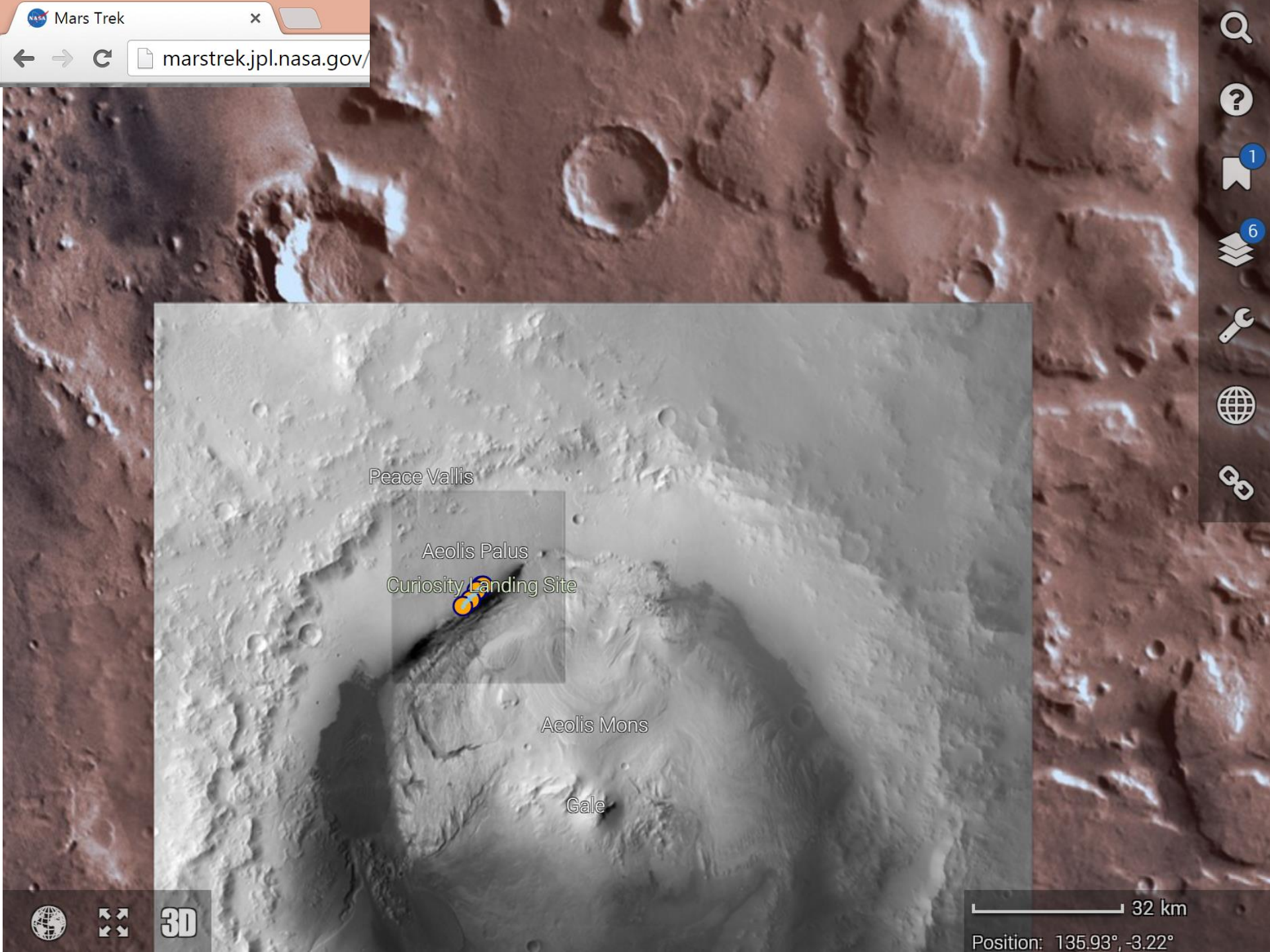






Gale Crater





Peace Vallis

Aeolis Palus

Curiosity Landing Site

Aeolis Mons

Gale



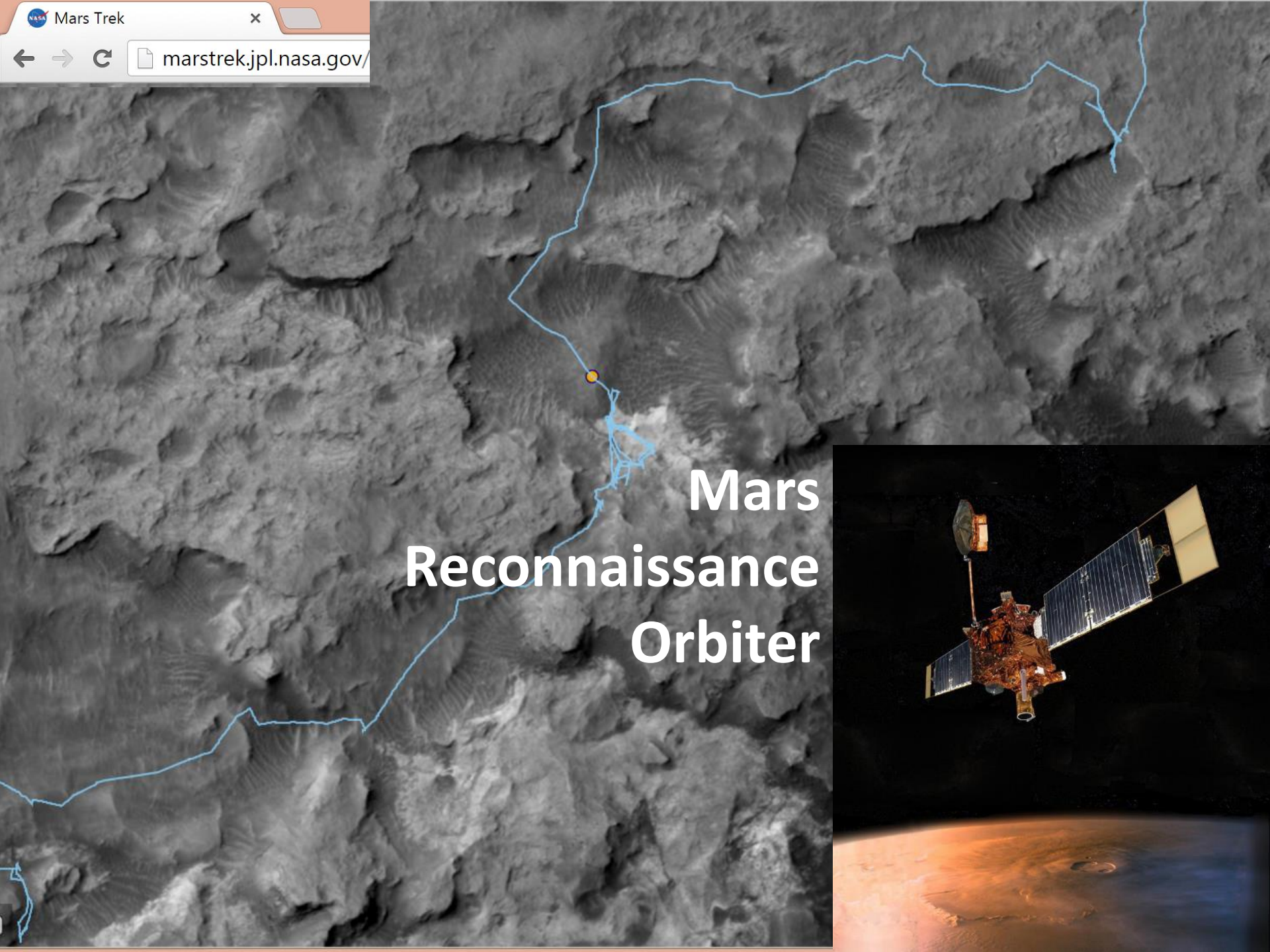
3D

32 km

Position: 135.93°, -3.22°

Curiosity Landing Site

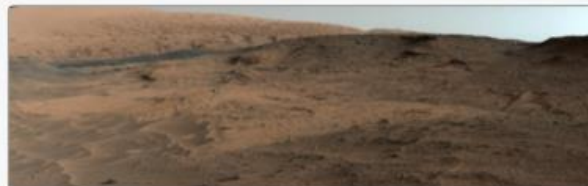




Mars Reconnaissance Orbiter

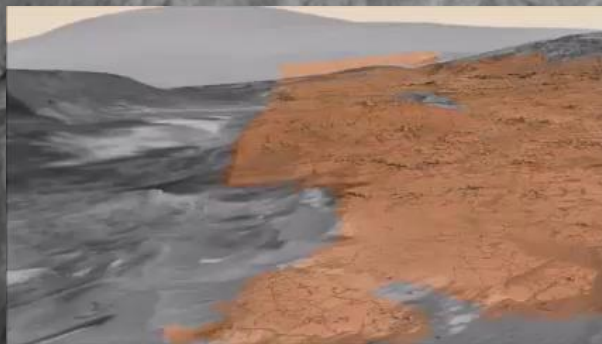


Pahrump Hills

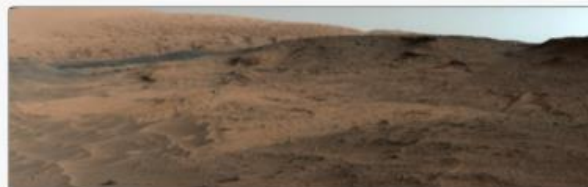


Pahrump Hills outcrop and surrounding terrain. NASA/JPL-Caltech/MSSS

On sol 753 of its mission, Curiosity arrived at the base of Mt. Sharp. The foothills at the base of the mountain here are named the Pahrump Hills. These are part of the Murray formation, which underlies all of the other exposed rock layers of Mt Sharp. Researchers expect that this represents the oldest geological unit that Curiosity will encounter in its journey. Within the Pahrump Hills, Curiosity drilled at three sites, Confidence Hills (sol 759), Mojave (sol 882), and Telegraph Peak (sol 908). At the Mojave site, a preliminary analysis indicated the presence of jarosite, which would point to rock forming in more acidic water that was found in previous sites, and further illustrate the variety in the history of water on Mars. While at the Pahrump Hills, Curiosity took some time to point its cameras up from the rocks below it to observe the comet Siding Spring as it passed closer to Mars.

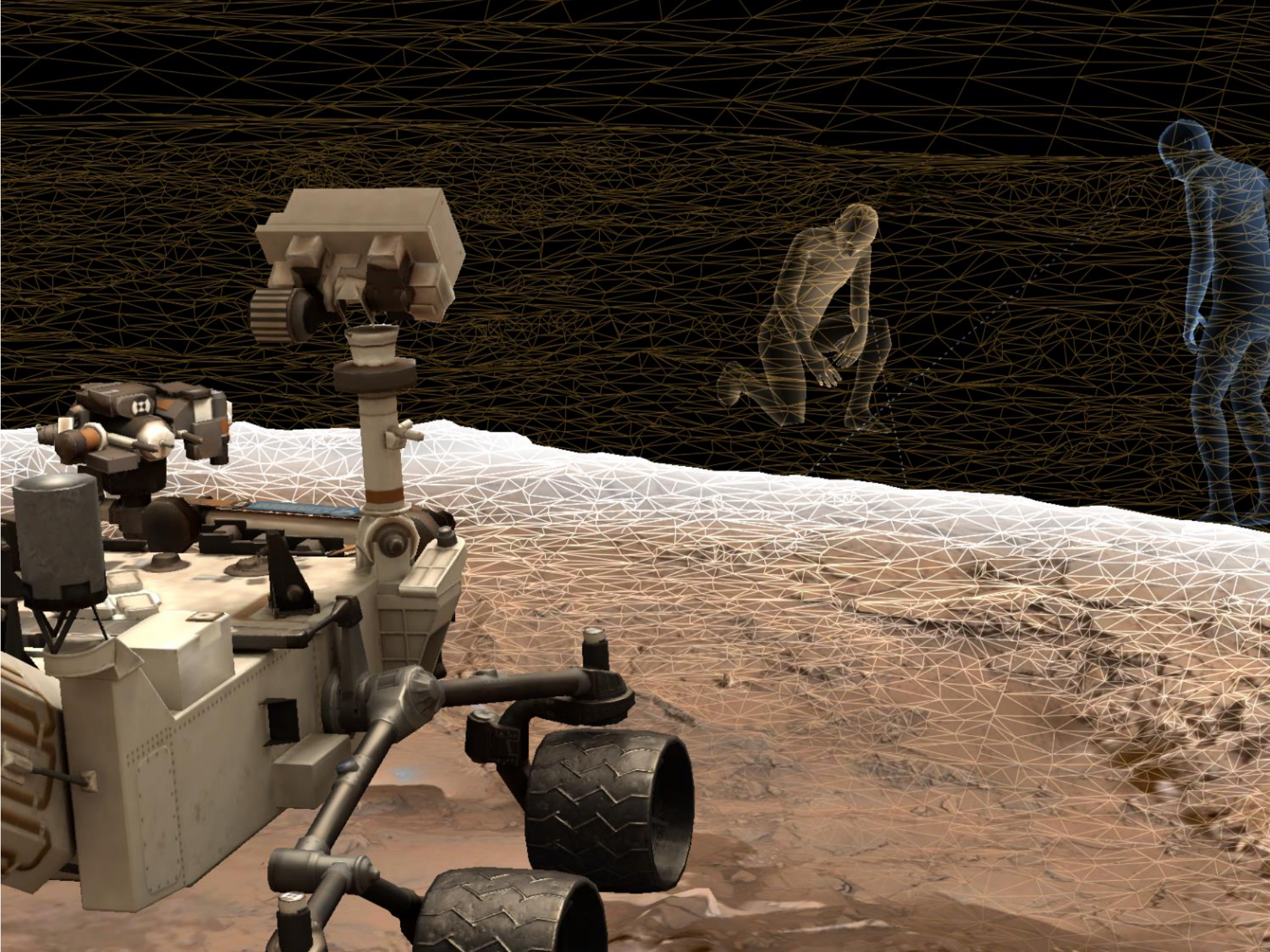


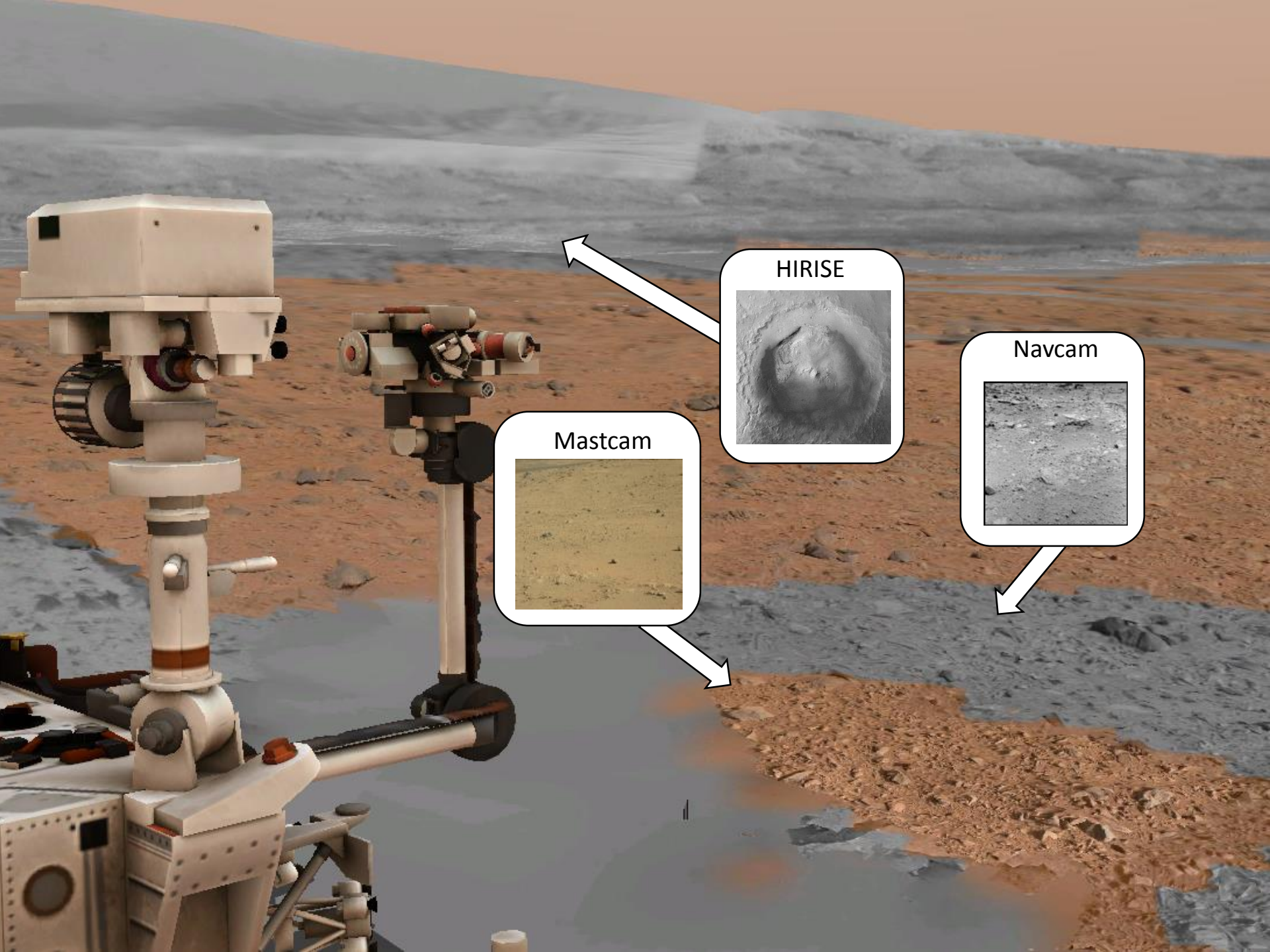
Pahrump Hills



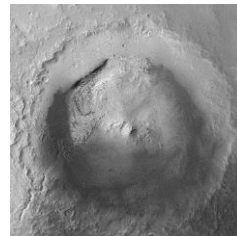
Pahrump Hills outcrop and surrounding terrain. NASA/JPL-Caltech/MSSS

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HIRISE



Mastcam



Navcam



Terrain Pipeline

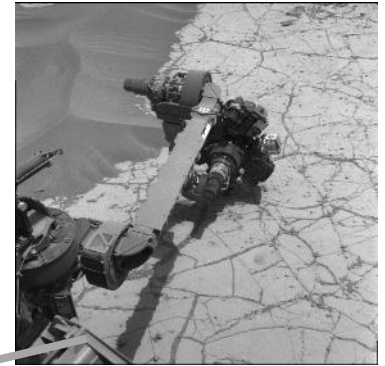
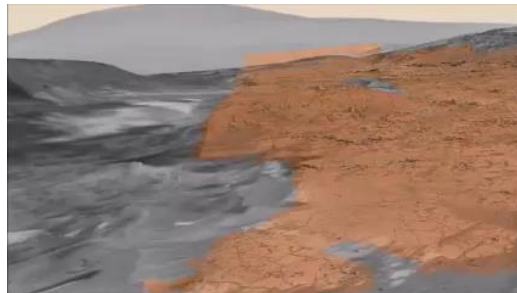


Image Processing Pipeline
Magic!

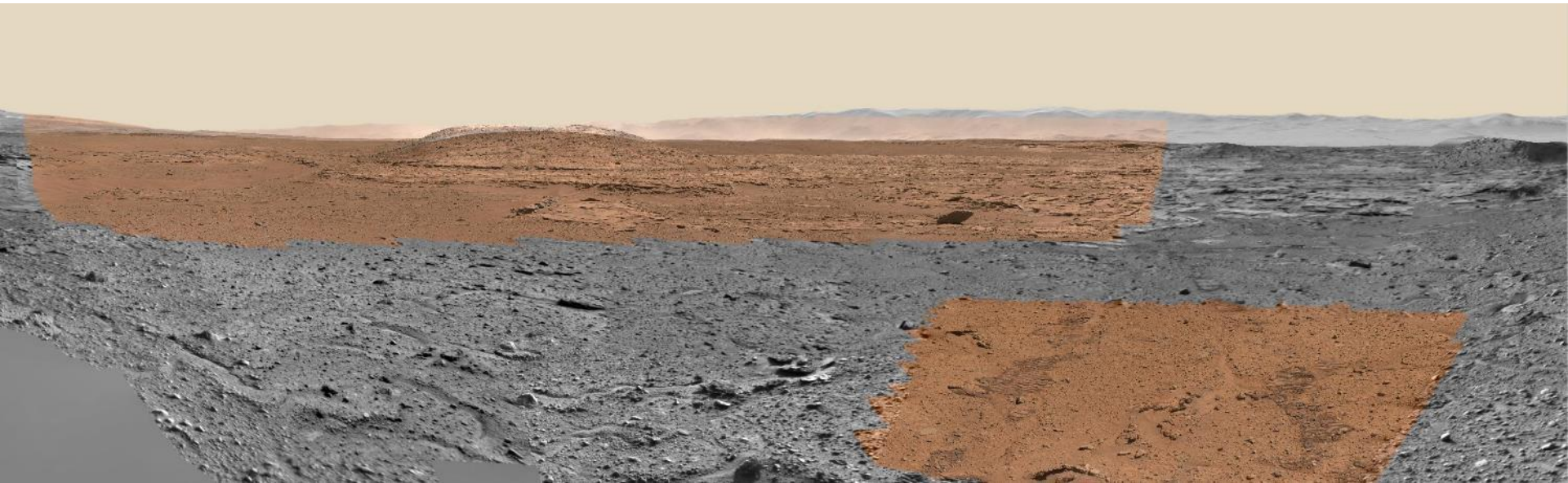
Mesh &
texture



Hololens

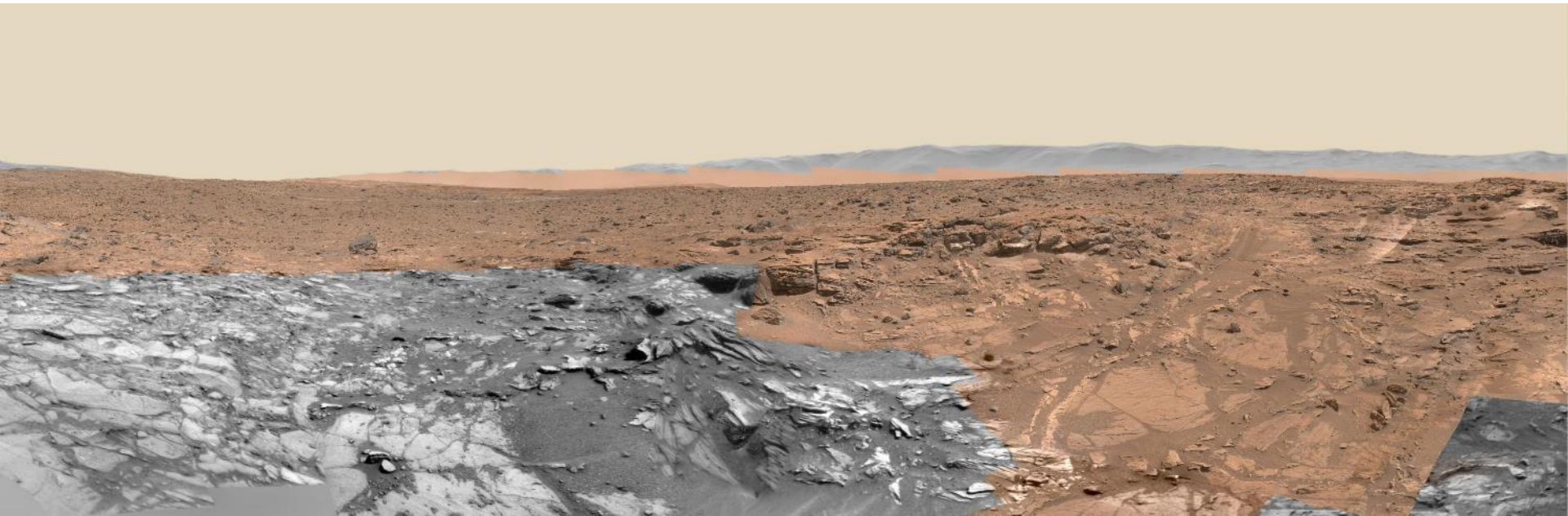
Stats

- ~430 scenes built (and more every day)
- 1 scene = ~1000 input images (5 GB)
- 1 build = 100-300 MB of mesh and texture files
- ~2.5 hr runtime (on 1 computer)



High-level Needs

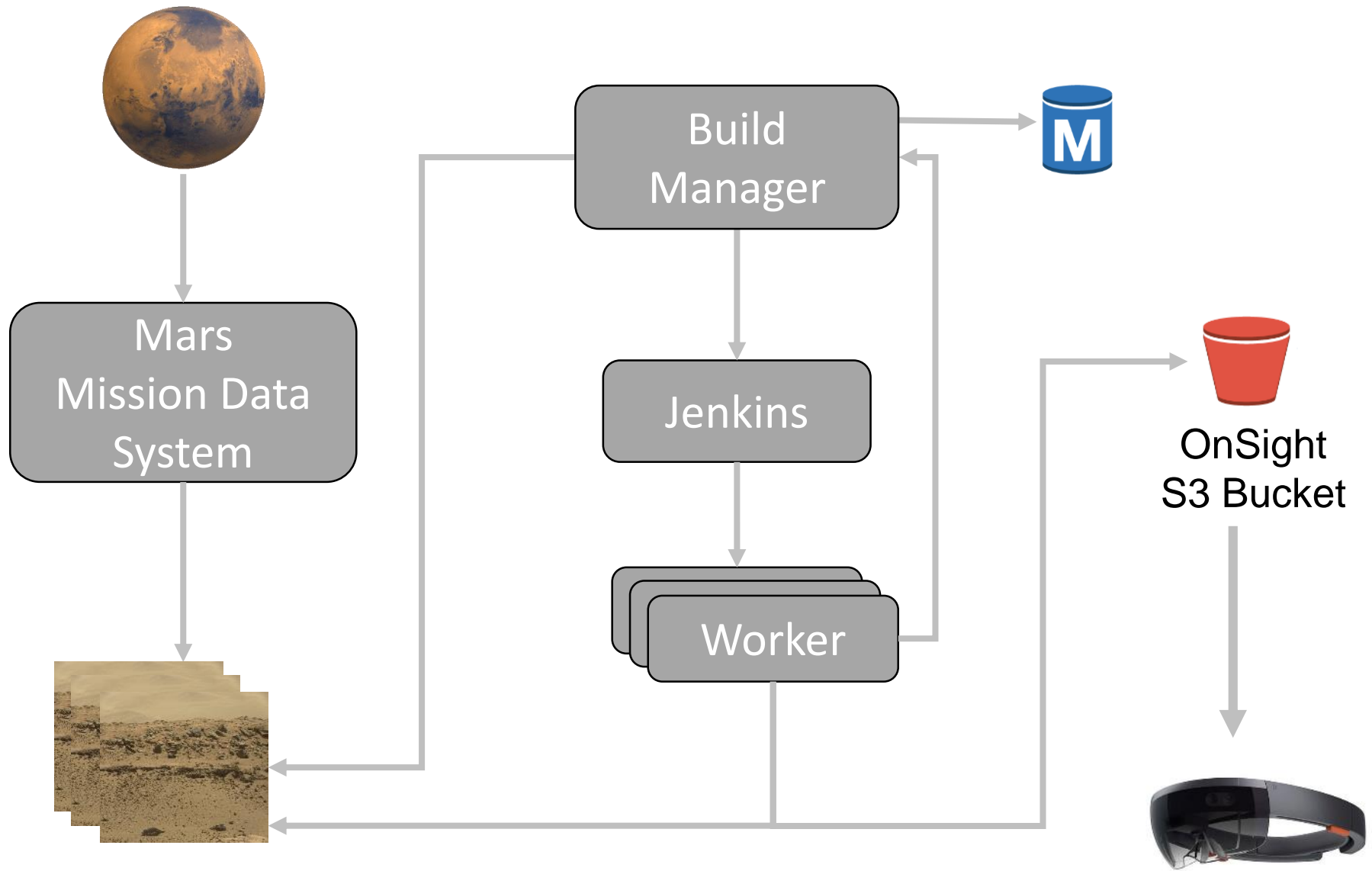
- Detect when new data is available
- Long running, resource intensive task
- See what's happening
- Make results available to users
- Bursty workload

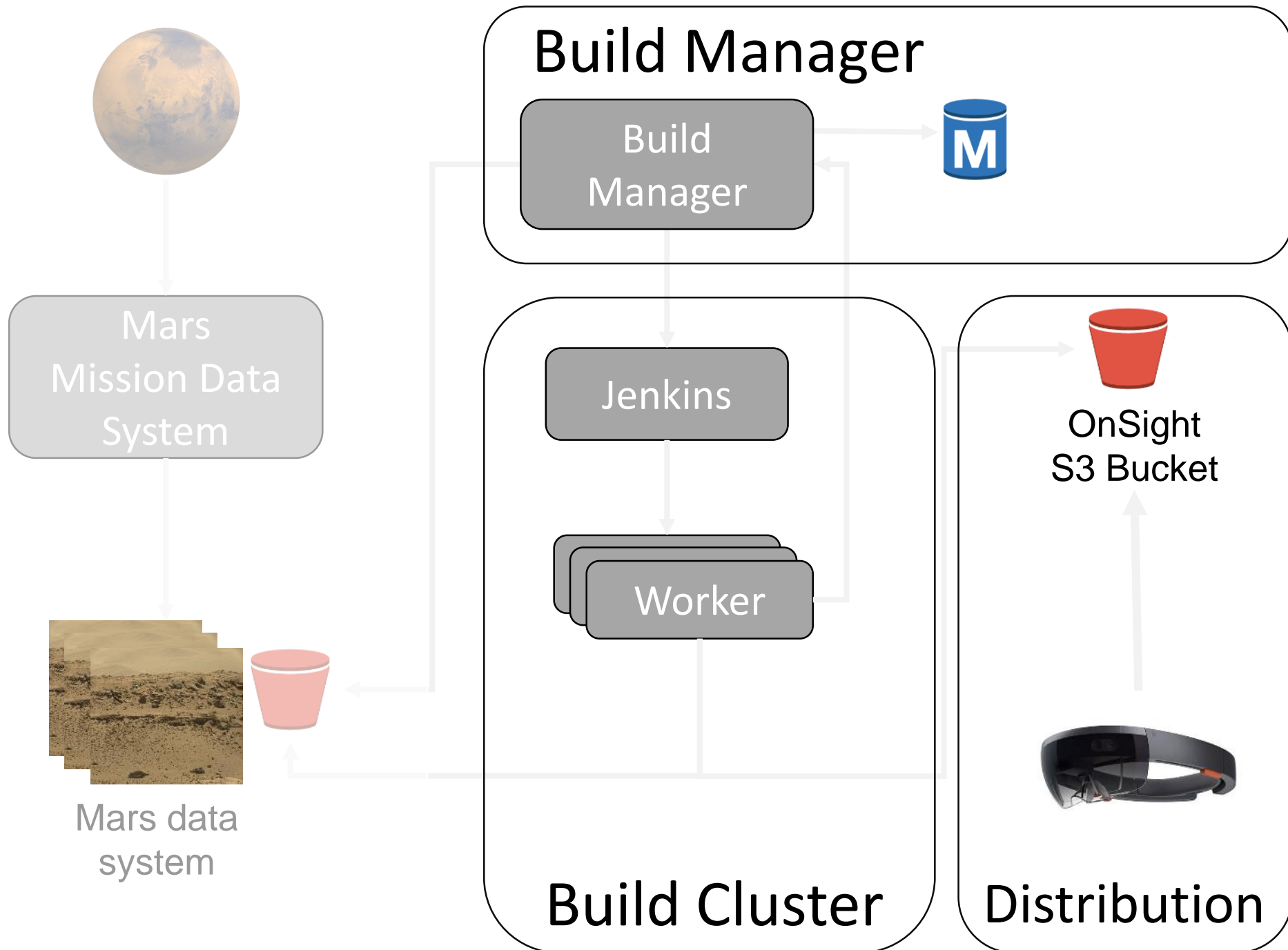


Technology Stack*

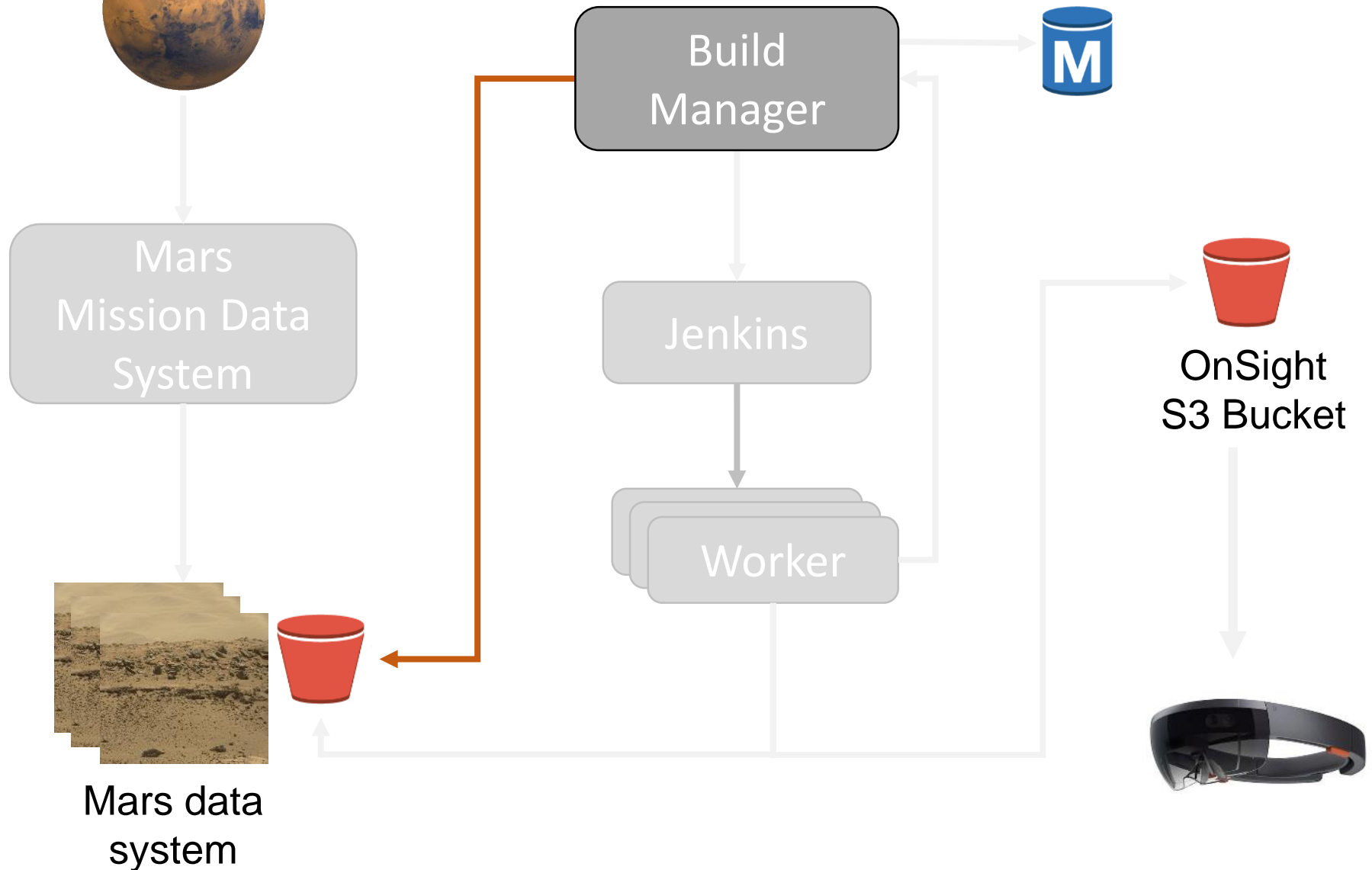


*Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not constitute or imply its endorsement by the United States Government or the Jet Propulsion Laboratory, California Institute of Technology.

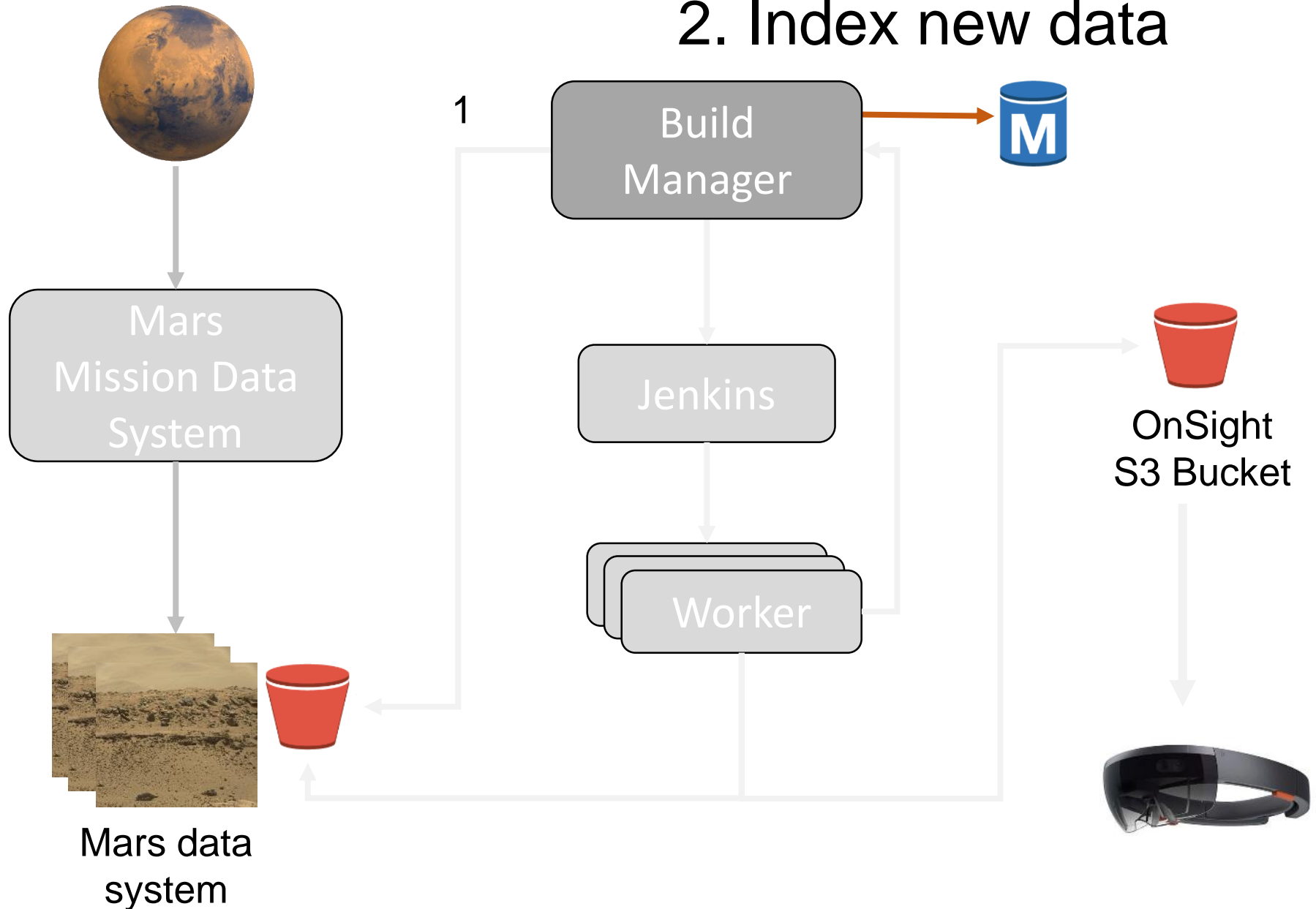


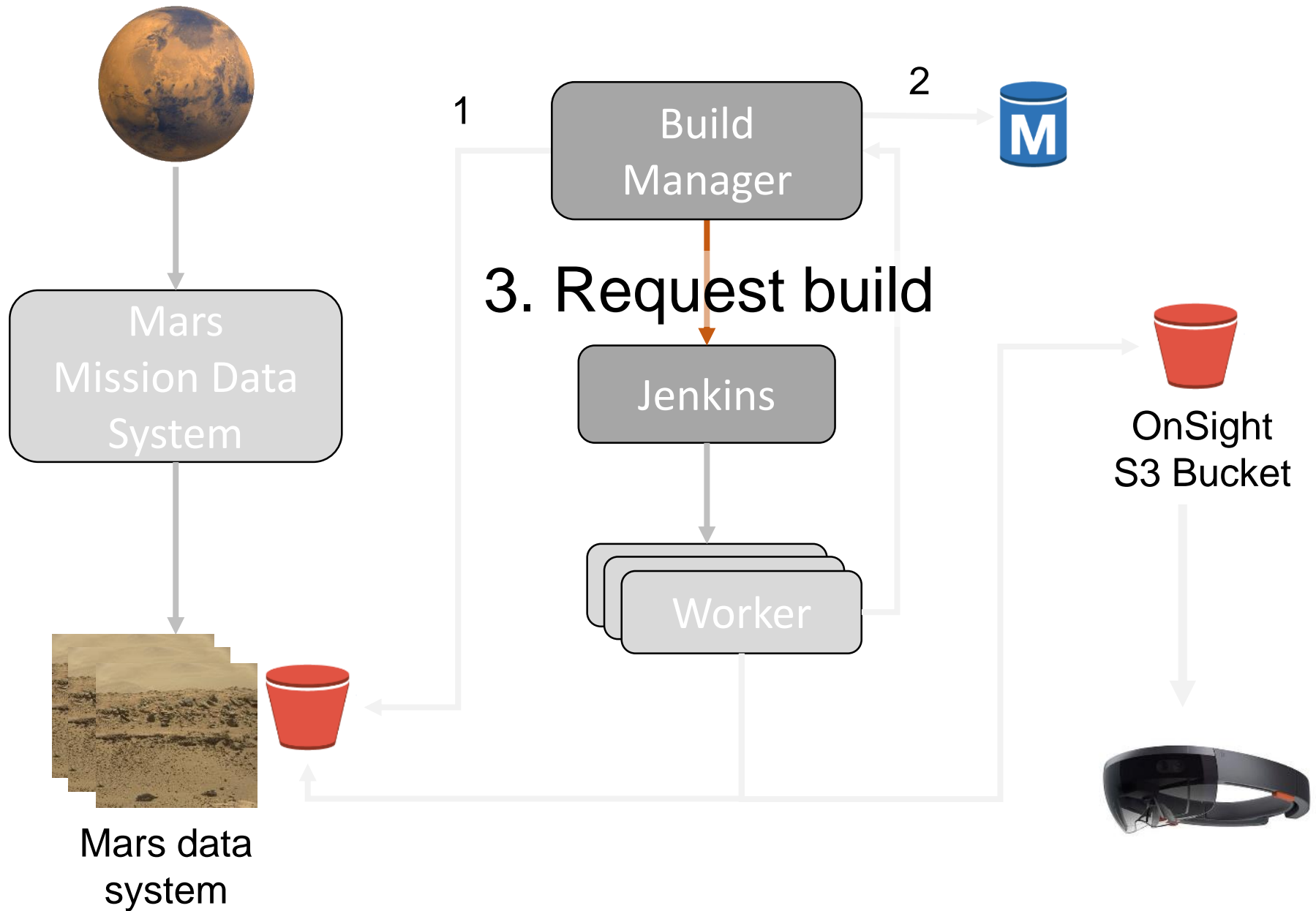


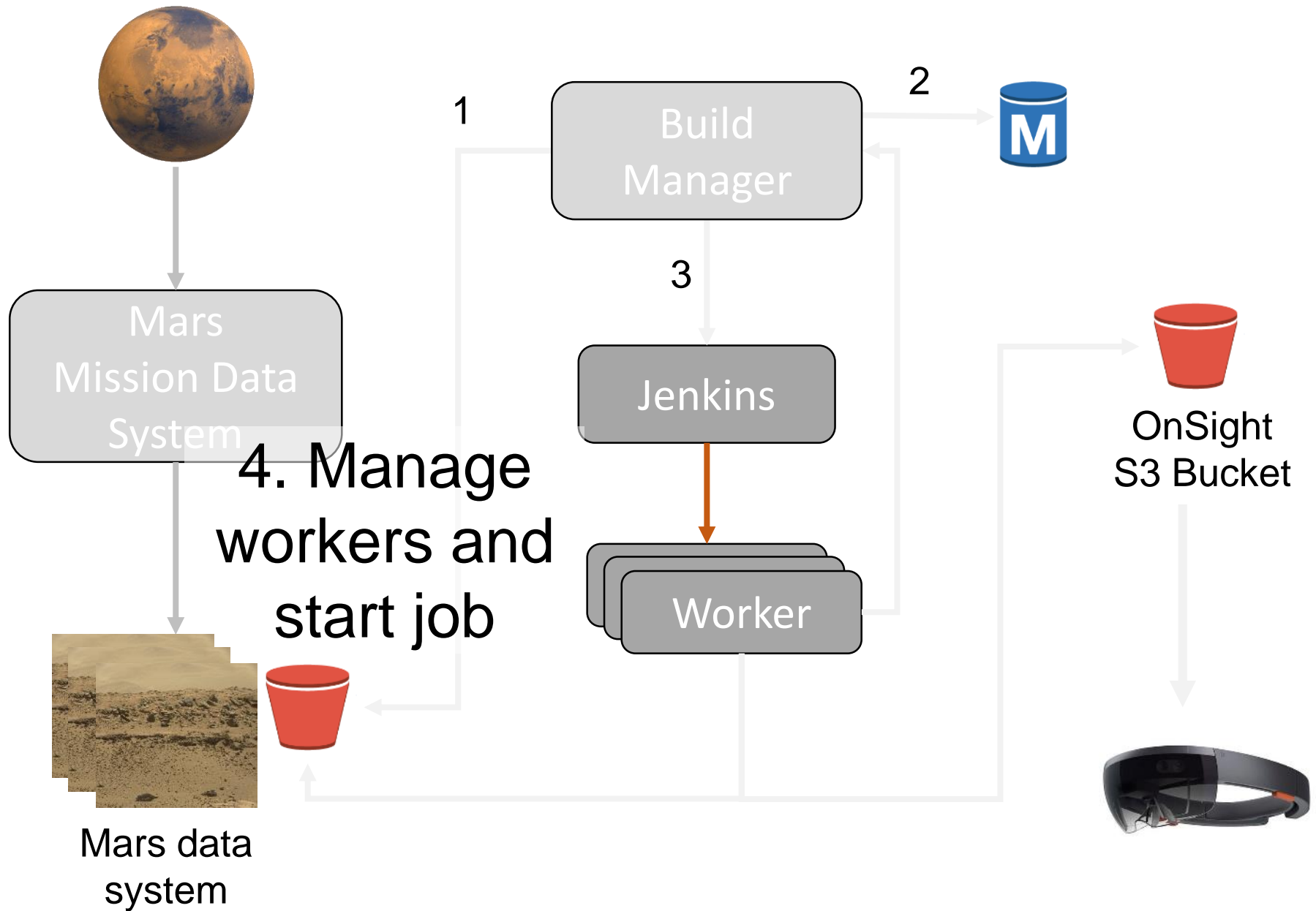
1. Poll for new data

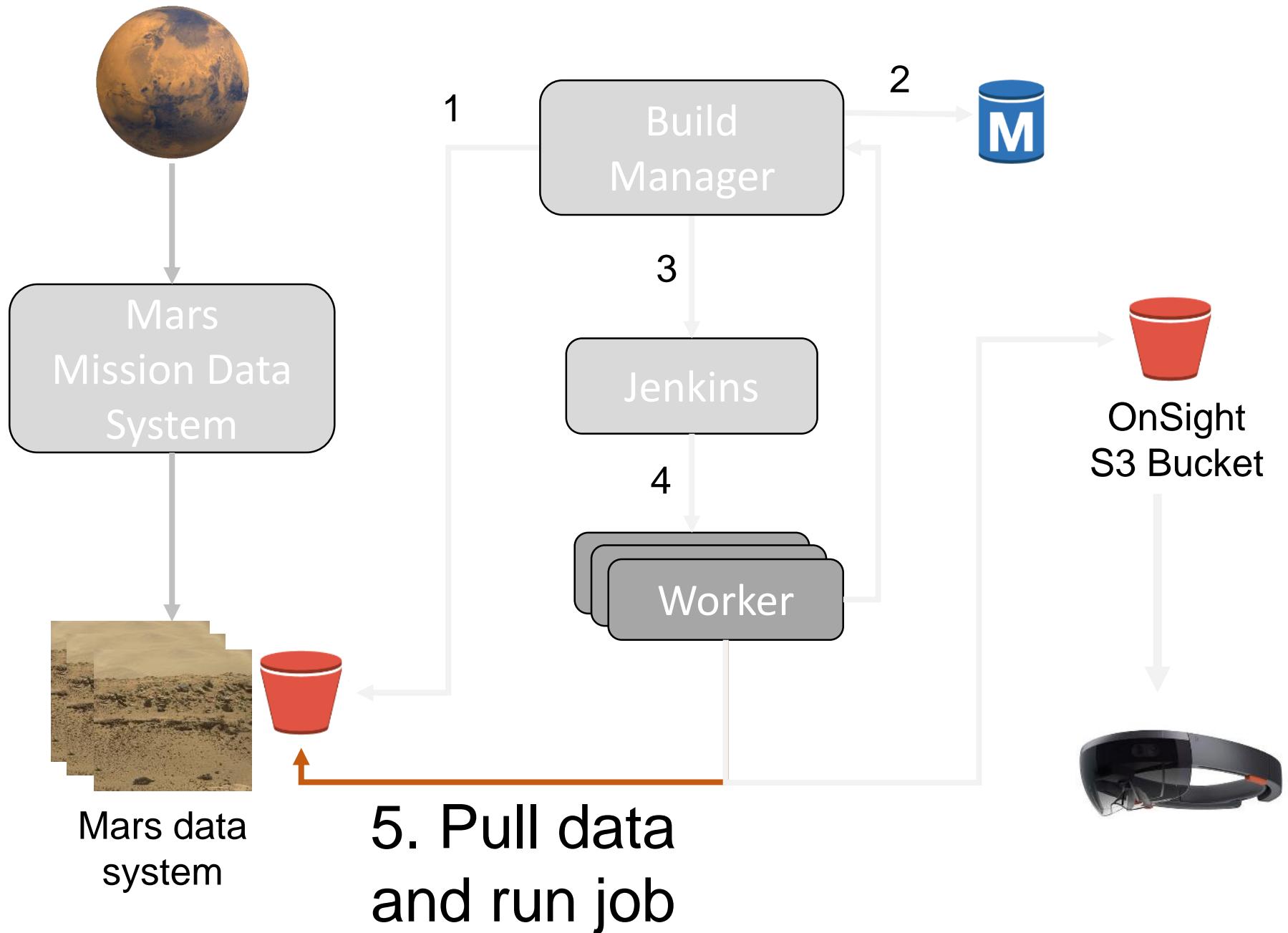


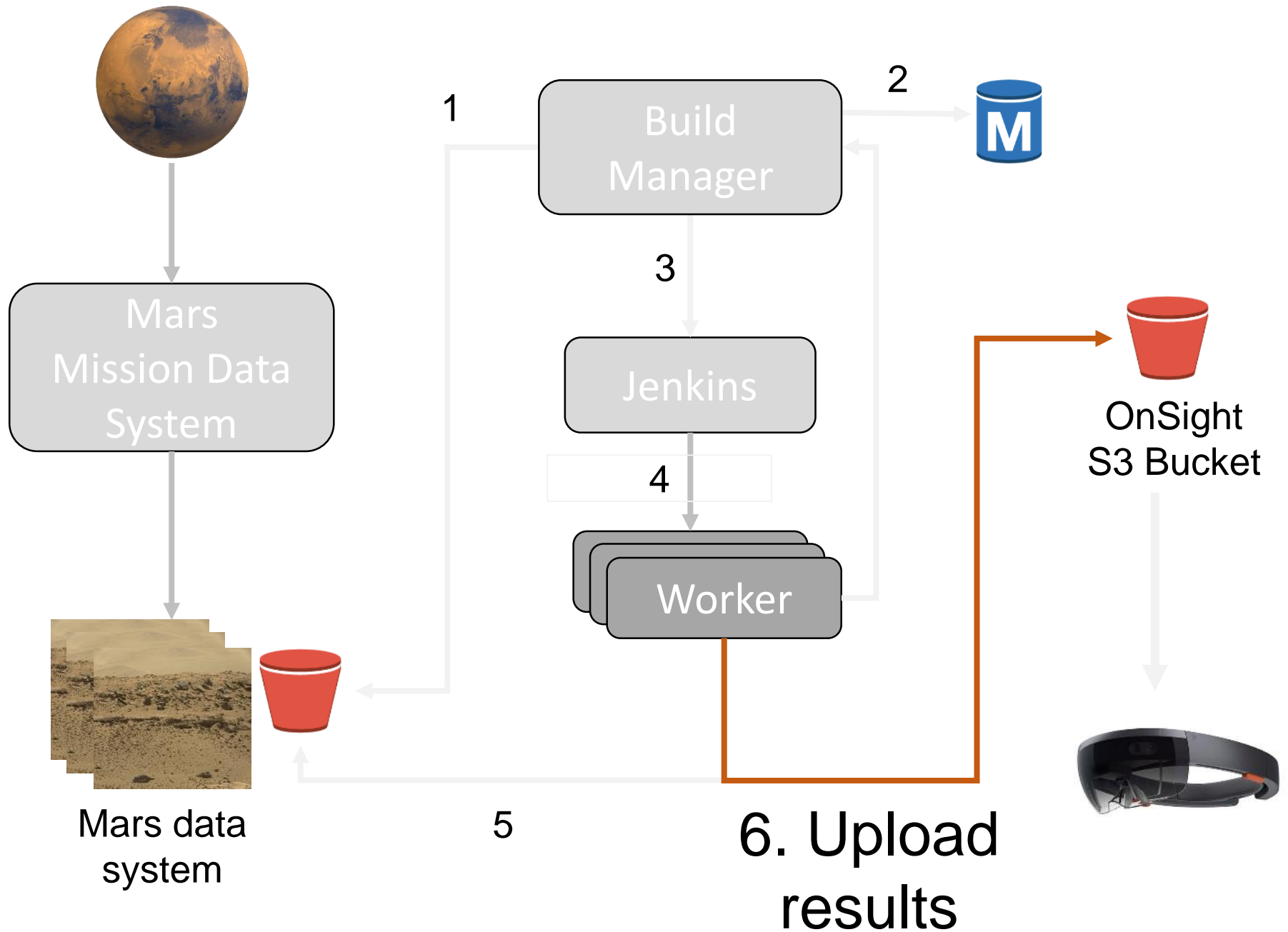
2. Index new data

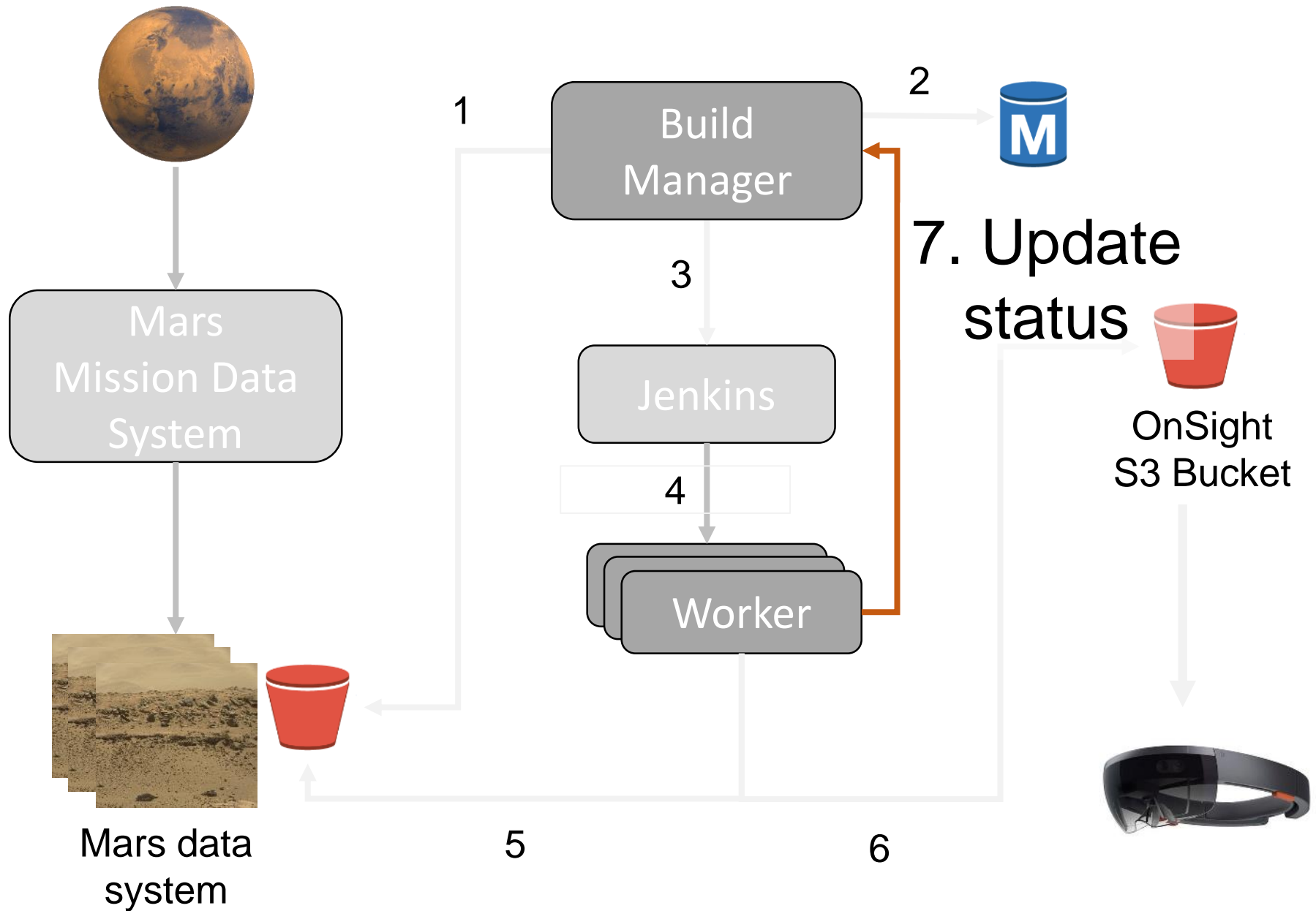


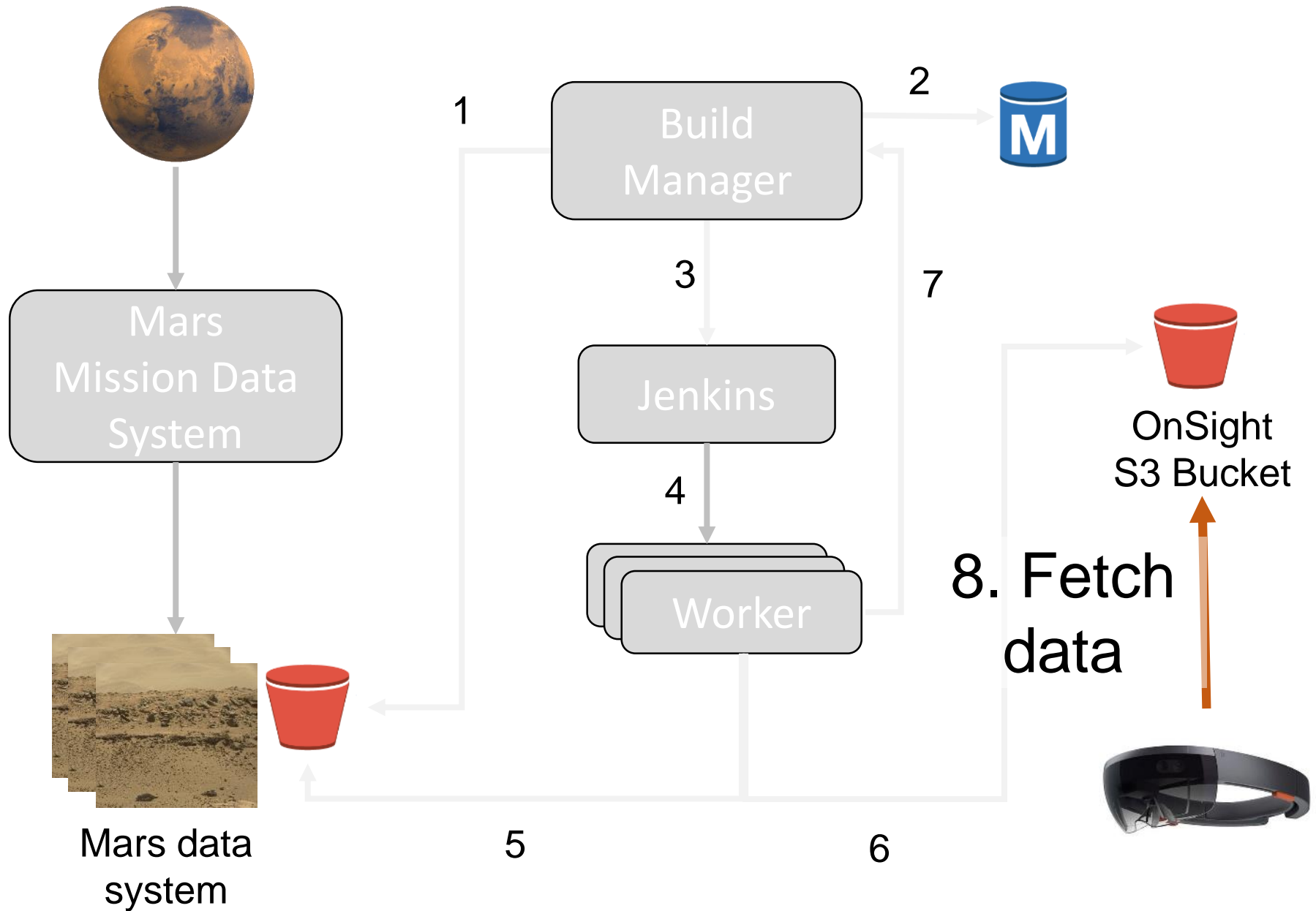


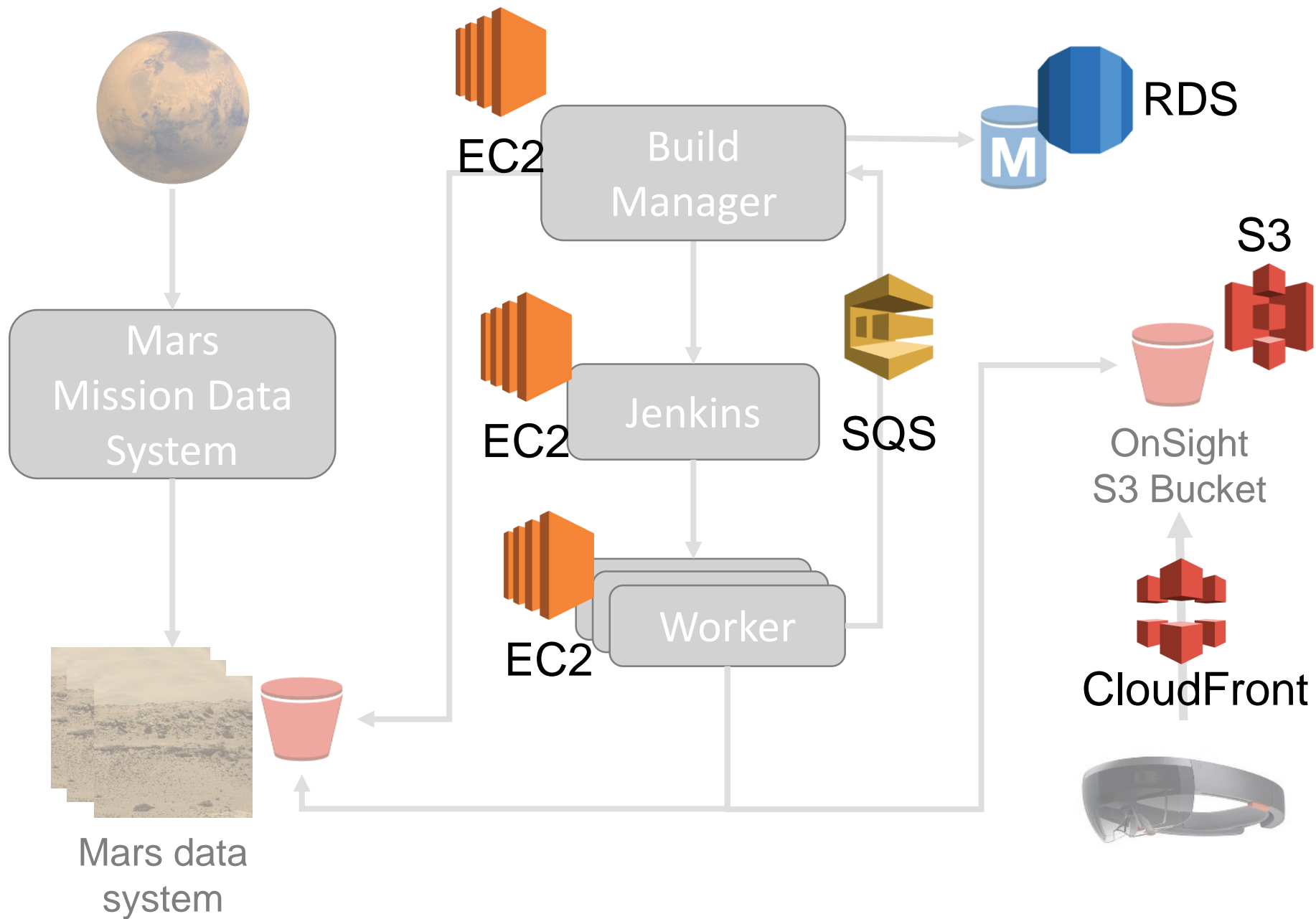


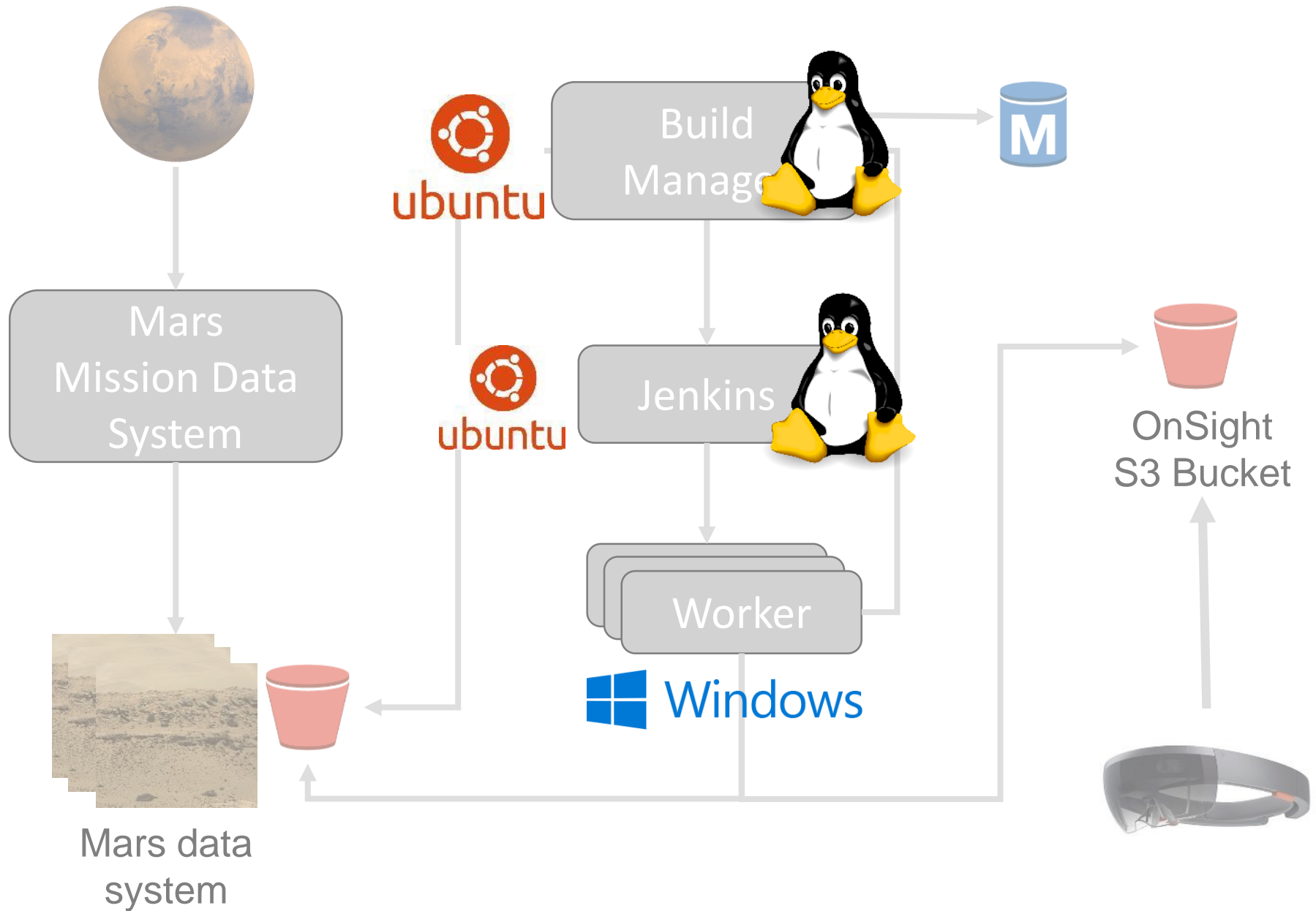




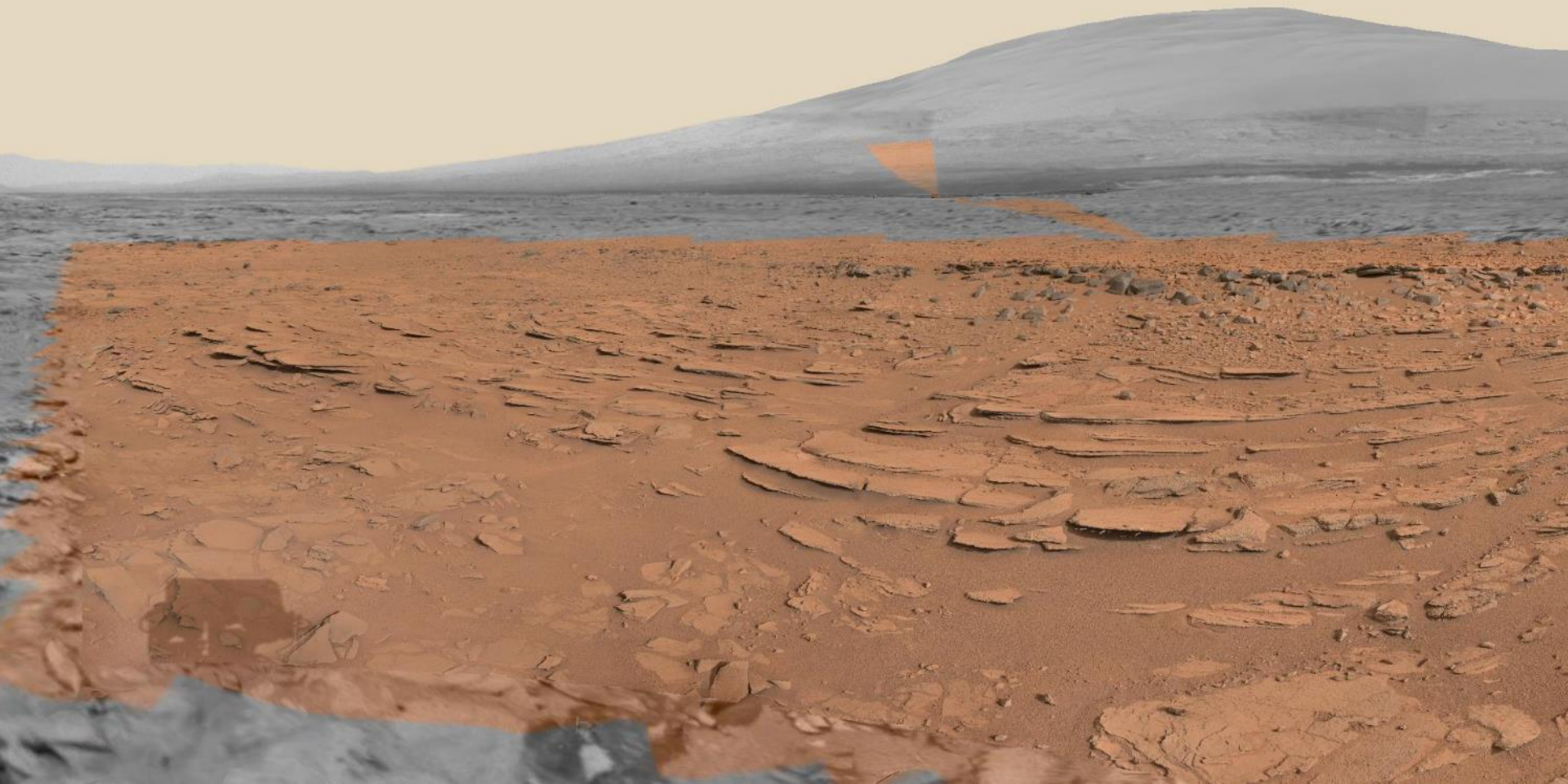








Build Manager



Build Manager

- Purpose:
 - Orchestrates image pipeline builds
 - Dashboard
- Technologies
 - Loopback framework - RESTful API
 - Twitter Bootstrap & Angularjs – frontend
 - RDS - database

Powered by



ANGULARJS



AWS



Amazon SNS



Amazon SQS



CloudWatch



Amazon EC2



Amazon EBS



Amazon RDS

Stats



431

Scenes

[View Details](#)

1412

Terrain Builds

[View Details](#)

0/3

Workers

[View Details](#)

0 | 0

Builds Queued | Running

[View Details](#)

Builds Trend

Builds Time

300 min

225 min

150 min

Mon Dec 21 2015 03:55:24 GMT-0800 (Pacific Standard Time)

Failed Build:

Succeeded Build: 134.6545 min

2015-12-19 2015-12-21 2015-12-23 2015-12-25 2015-12-27 2015-12-29

Manifests

[Master Manifest XML](#)[SiteDrives Manifest](#)

Builds In Progress

Recent Build Failures

Jenkins Job	Sitedrive	Code Branch	Build Log	Duration	Timestamp	Ack	Action
View	0005101120	production	View	a few seconds	a month ago	<input checked="" type="checkbox"/>	Acknowledge
View	0005101108	production	View	a minute	a month ago	<input checked="" type="checkbox"/>	Acknowledge

Stats



431

Scenes

[View Details](#)

1412

Terrain Builds

[View Details](#)

0/3

Workers

[View Details](#)

0 | 0

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View	0005101108	production	View	a minute	a month ago	<input checked="" type="checkbox"/>	Acknowledge


Stats



431

Scenes


View Details ➔



1412

Terrain Builds


View Details ➔



0/3

Workers

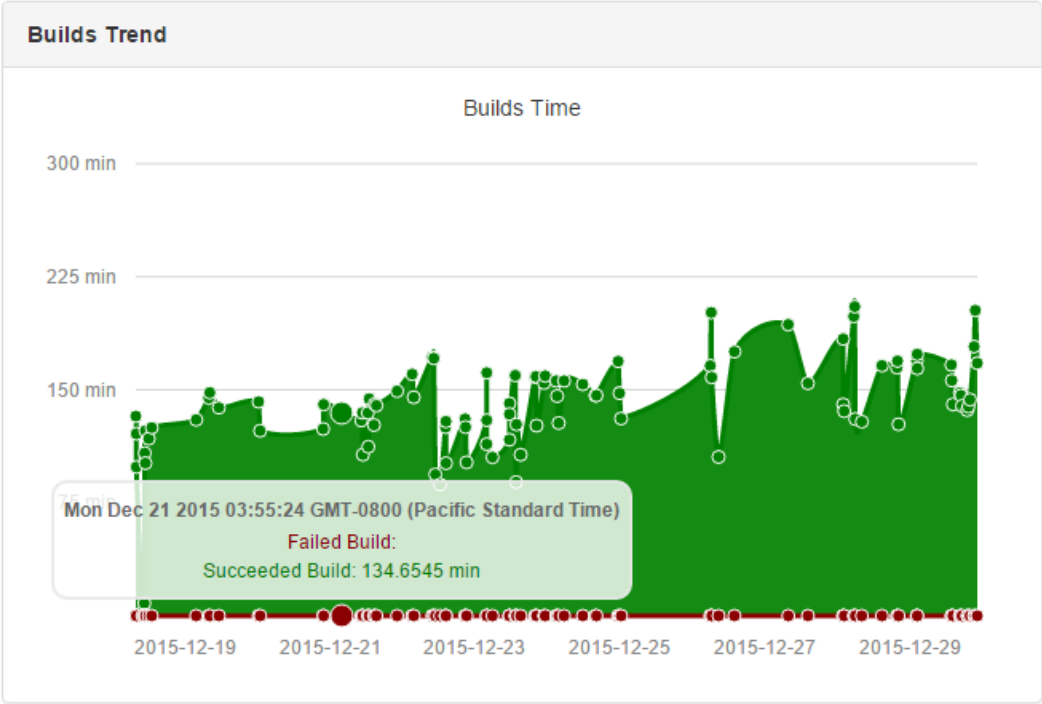
View Details ➔



0 | 0

Builds Queued | Running

View Details ➔



Manifests

Master Manifest XML

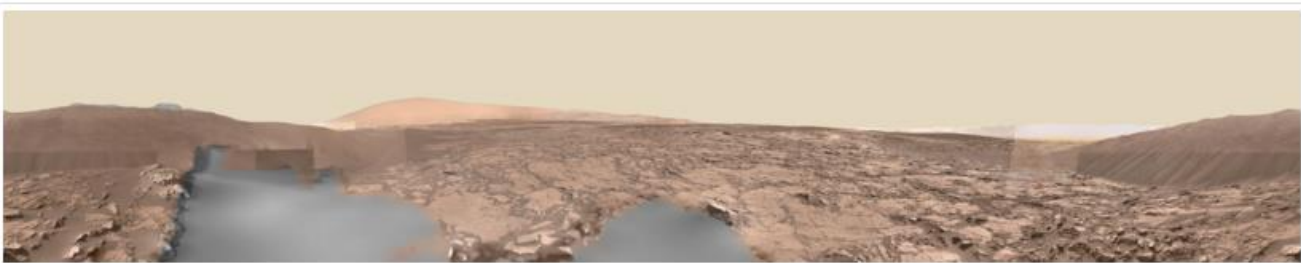
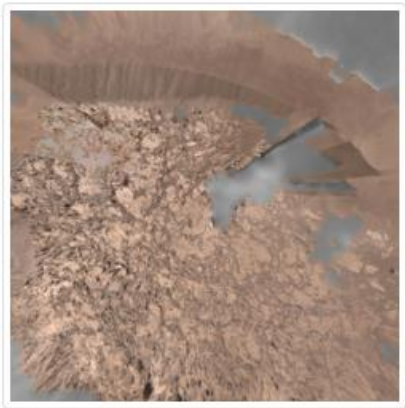
SiteDrives Manifest

Builds In Progress

Recent Build Failures

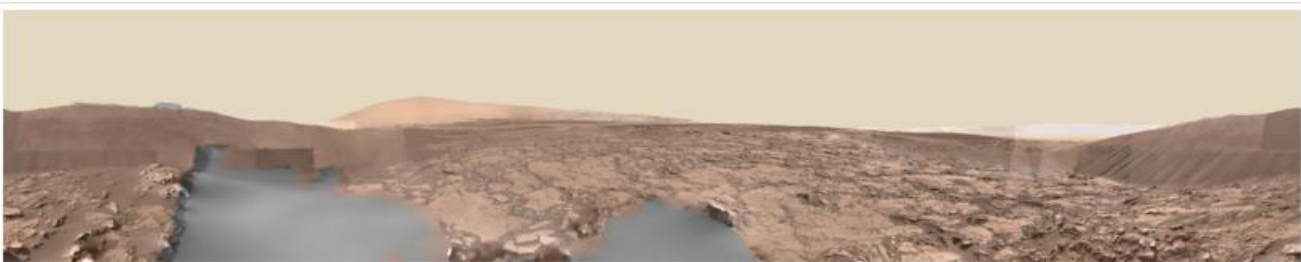
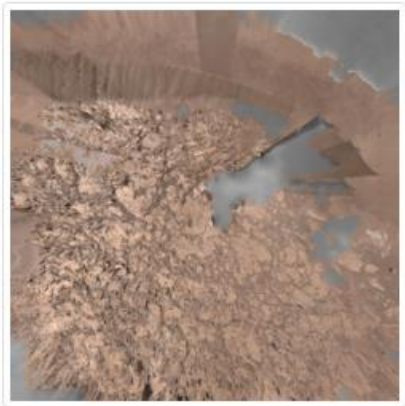
Jenkins Job	Sitedrive	Code Branch	Build Log	Duration	Timestamp	Ack	Action
View	0005101120	production	View	a few seconds	a month ago	<input checked="" type="checkbox"/>	Acknowledge
View	0005101108	production	View	a minute	a month ago	<input checked="" type="checkbox"/>	Acknowledge

Recent Build Previews



Site Name: [sd0005200004](#)
Version: 201512300855
Manifest: [Click Here](#)
Video: [Click Here](#)

a day ago



Site Name: [sd0005200000](#)
Version: 201512300848
Manifest: [Click Here](#)
Video: [Click Here](#)

a day ago

Completed Builds

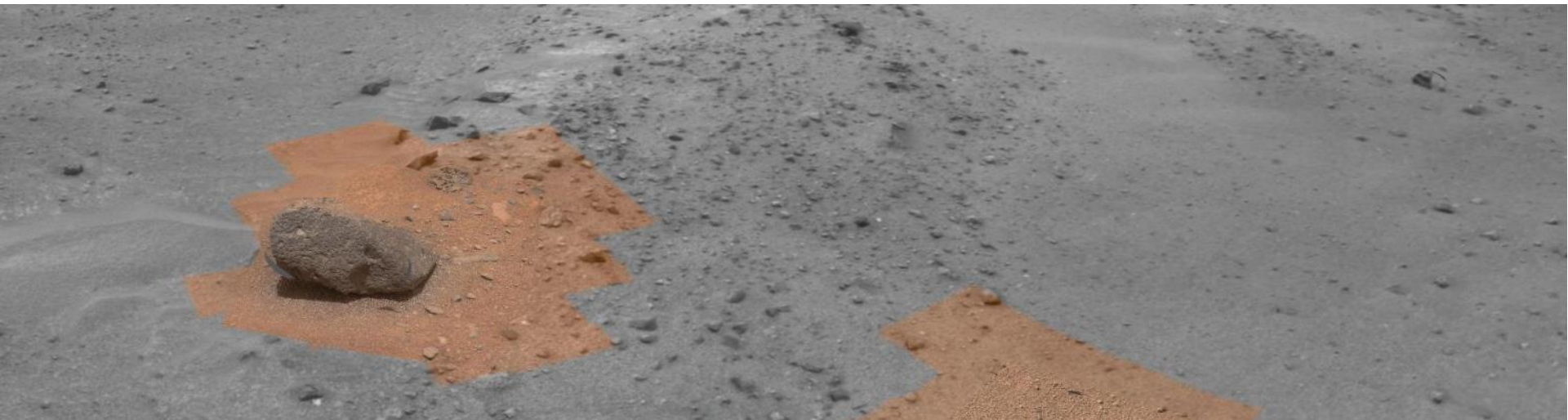
Show 25 ▾ entries

Search:

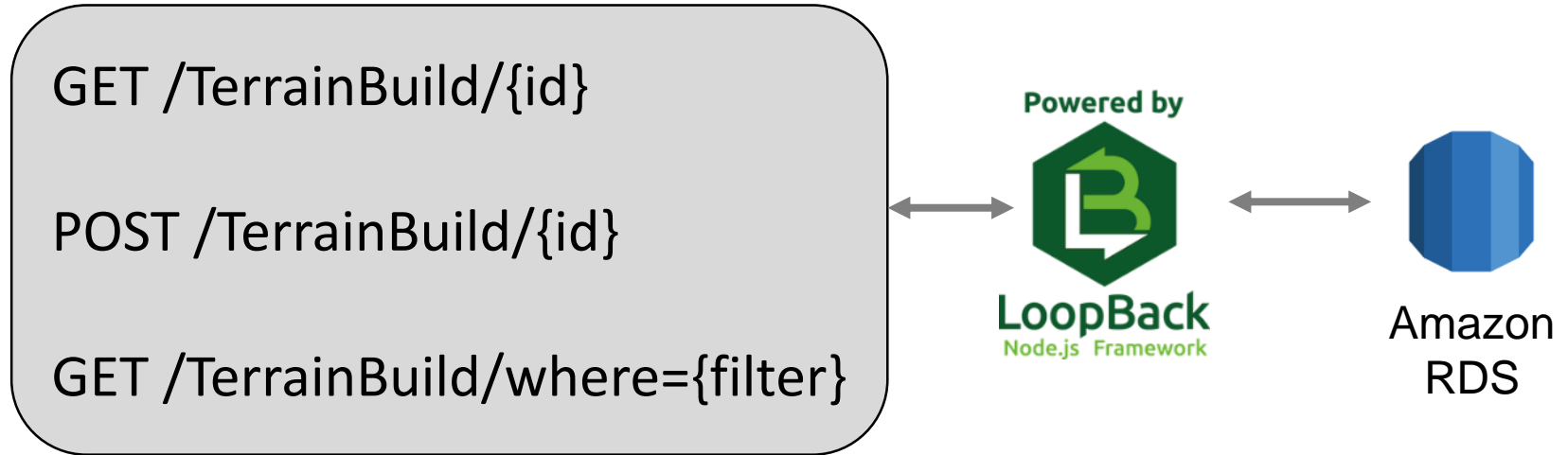
Version ▾	Pipeline ▾	Bucket ▾	Scenelnd ▾	SiteName	Status	Enabled	Action
201512300855	0.1.8	landlords-prod	442	sd0005200004	success	true	Q View 🔍 🔍 🗑
201512300848	0.1.8	landlords-prod	443	sd0005200000	success	true	Q View 🔍 🔍 🗑
201512300759	0.1.8	landlords-prod	442	sd0005200004	success	true	Q View 🔍 🔍 🗑
201512300607	0.1.8	landlords-prod	434	sd0005200000	success	true	Q View 🔍 🔍 🗑
201512300525	0.1.8	landlords-prod	434	sd0005200000	success	true	Q View 🔍 🔍 🗑
201512300501	0.1.8	landlords-prod	434	sd0005200000	success	true	Q View 🔍 🔍 🗑
201512300323	0.1.8	landlords-prod	434	sd0005200000	success	true	Q View 🔍 🔍 🗑
201512300306	0.1.8	landlords-prod	434	sd0005200000	success	true	Q View 🔍 🔍 🗑
201512300244	0.1.8	landlords-prod	434	sd0005200000	success	true	Q View 🔍 🔍 🗑
201512300023	0.1.8	landlords-prod	434	sd0005200000	success	false	Q View 🔍 🔍 🗑
201512300016	0.1.8	landlords-prod	434	sd0005200000	success	true	Q View 🔍 🔍 🗑
201512300016	0.1.8	landlords-prod	434	sd0005200000	success	false	Q View 🔍 🔍 🗑
201512291307	0.1.8	landlords-prod	442	sd0005200004	success	true	Q View 🔍 🔍 🗑
201512291253	0.1.8	landlords-prod	434	sd0005200000	success	true	Q View 🔍 🔍 🗑
201512291248	0.1.8	landlords-prod	434	sd0005200000	success	true	Q View 🔍 🔍 🗑
201512290628	0.1.8	landlords-prod	434	sd0005200000	success	true	Q View 🔍 🔍 🗑
201512290613	0.1.8	landlords-prod	434	sd0005200000	success	true	Q View 🔍 🔍 🗑
201512290611	0.1.8	landlords-prod	434	sd0005200000	success	true	Q View 🔍 🔍 🗑
201512290444	0.1.8	landlords-prod	434	sd0005200000	success	true	Q View 🔍 🔍 🗑

Amazon Relational Database Service (RDS)

- Auto snapshot
- Click to restore
- Zero maintenance required
- Why not NoSQL?
 - Scalability not an issue
 - More concern with capability with existing tools



Data API



- Access data through LoopBack REST API
- Database independent
- Easy to add business logic with JavaScript

CloudWatch Log Management

CloudWatch
Dashboards **NEW**
Alarms
ALARM 0
INSUFFICIENT 0
OK 0
Billing
Logs
Metrics
Selected Metrics
EBS
EC2
ElastiCache
RDS
S3
SNS
SQS
Linux System
Windows System

Log Groups > Streams for buildmanager-source-data-production > Events for populate-db-latest

Filter: Search for events x

Date/Time: 2015/12/23 10 01 : 00 : 05 UTC (GMT) →

⏪ ⏩ ⏴ ⏵

Event Data

▼ 2015-12-23T01:00:05.082Z	- info: About to scan NCAM for sol 01193
▼ 2015-12-23T01:00:05.083Z	- info: About to scan NCAM for sol 01192
▼ 2015-12-23T01:00:05.085Z	- info: About to scan NCAM for sol 01191
▼ 2015-12-23T01:00:23.231Z	- info: Done processing NCAM
▼ 2015-12-23T01:00:23.232Z	- info: About to scan MCAM for sol 01169
▼ 2015-12-23T01:00:23.233Z	- info: About to scan MCAM for sol 01168
▼ 2015-12-23T01:00:23.235Z	- info: About to scan MCAM for sol 01167
▼ 2015-12-23T01:00:23.236Z	- info: About to scan MCAM for sol 01166
▼ 2015-12-23T01:00:23.238Z	- info: About to scan MCAM for sol 01165
▼ 2015-12-23T01:00:23.239Z	- info: About to scan MCAM for sol 01164
▼ 2015-12-23T01:00:23.240Z	- info: About to scan MCAM for sol 01163
▼ 2015-12-23T01:00:23.241Z	- info: About to scan MCAM for sol 01162
▼ 2015-12-23T01:00:23.242Z	- info: About to scan MCAM for sol 01161
▼ 2015-12-23T01:00:23.244Z	- info: About to scan MCAM for sol 01160
▼ 2015-12-23T01:00:26.993Z	- info: Done processing NCAM
▼ 2015-12-23T01:00:26.993Z	- info: About to scan MCAM for sol 01200

Build Cluster



Jenkins



What is it?

Build system

Continuous Integration & Delivery

Similar tools: Bamboo, CruiseControl

What do we use it for?

Manage worker nodes

Compile and run pipeline code

AWS



Amazon SQS



CloudWatch



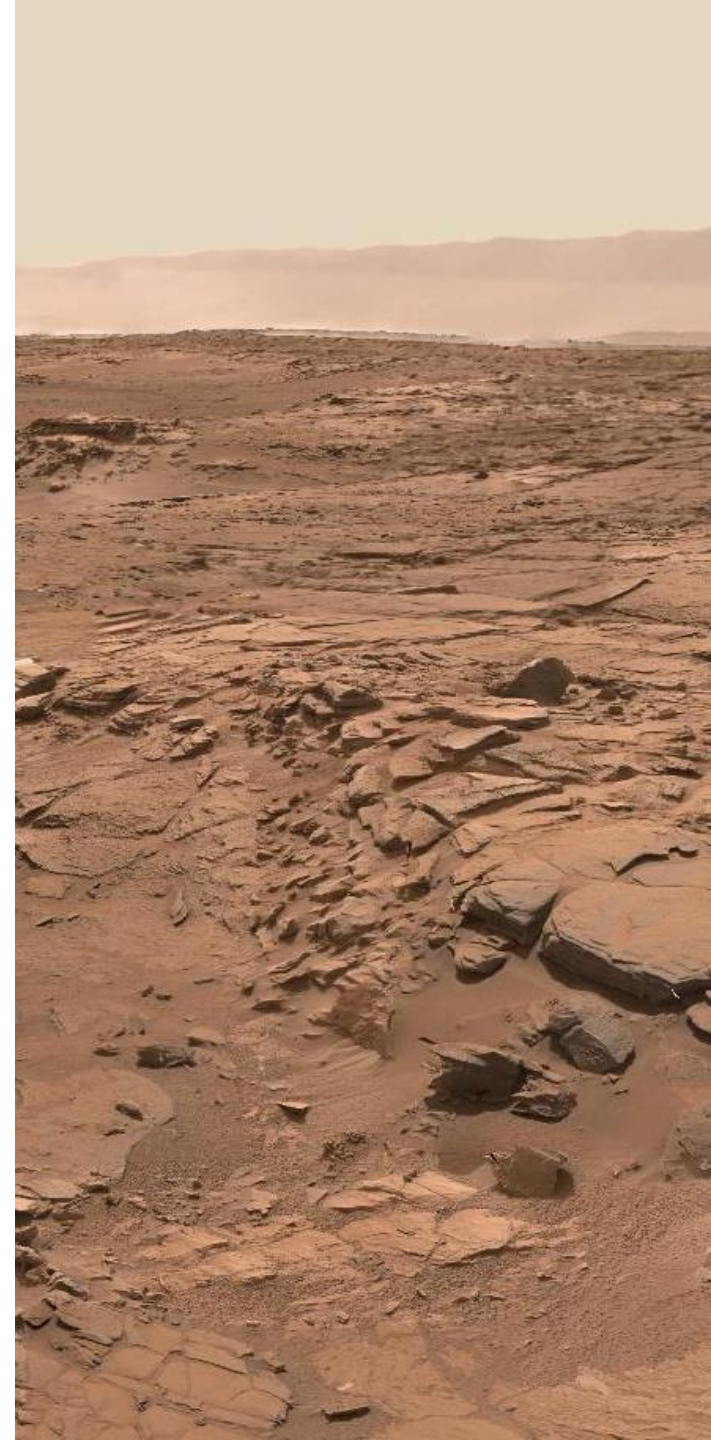
Amazon
EC2














Amazon
S3



Amazon
EBS



-  [New Item](#)
-  [People](#)
-  [Build History](#)
-  [Edit View](#)
-  [Delete View](#)
-  [Project Relationship](#)
-  [Check File Fingerprint](#)
-  [Manage Jenkins](#)
-  [Credentials](#)
-  [My Views](#)
-  [Purge Build Queue](#)

 [add description](#)

[All](#) [Management Jobs](#) [PVS](#) **Terrain Build Jobs** [+](#)

S	W	Name ↓	Last Success	Last Failure	Last Duration	
		Build_Scene_Staging	1 day 13 hr - #1235	10 days - #1193	2 hr 56 min	
		Build_Scene_Prod	1 day 13 hr - #1497	N/A	2 hr 47 min	
		Build_Preview	3 mo 20 days - #31	N/A	7 min 50 sec	
		Build_Generic	12 days - #540	13 days - #539	2 hr 13 min	
		Build_CI_Staging	3 mo 1 day - #90	2 mo 27 days - #96	2 hr 35 min	
		Build_CI_Master	12 days - #118	N/A	2 hr 44 min	

Icon:
[S](#) [M](#) [L](#)


[Legend](#)

 [RSS for all](#)

 [RSS for failures](#)

 [RSS for just latest builds](#)

Build Queue (1)

[Build_Scene_Staging](#)  

Build Executor Status

master

1 Idle

2 [ManageNodes](#) [#104930](#) 

 10.0.0.1 (offline)

 10.0.0.2 (offline)

 10.0.0.3

1 Occupied by [Build_Scene_Prod #1498](#) 

2 Occupied by [Build_Scene_Prod #1498](#) 

3 [Build_Scene_Prod](#) [#1498](#) 

4 Occupied by [Build_Scene_Prod #1498](#) 

New Item
 People
 Build History
 Edit View
 Delete View
 Project Relationship
 Check File Fingerprint
 Manage Jenkins
 Credentials
 My Views
 Purge Build Queue

[add description](#)

All Management Jobs PVS Terrain Build Jobs +						
S	W	Name ↓	Last Success	Last Failure	Last Duration	
		Build_Scene_Staging	1 day 13 hr - #1235	10 days - #1193	2 hr 56 min	
		Build_Scene_Prod	1 day 13 hr - #1497	N/A	2 hr 47 min	
		Build_Preview	3 mo 20 days - #31	N/A	7 min 50 sec	
		Build_Generic	12 days - #540	13 days - #539	2 hr 13 min	
		Build_CI_Staging	3 mo 1 day - #90	2 mo 27 days - #96	2 hr 35 min	
		Build_CI_Master	12 days - #118	N/A	2 hr 44 min	

Icon: [S](#) [M](#) [L](#) [Legend](#) [RSS for all](#) [RSS for failures](#) [RSS for just latest builds](#)












Build Queue (1)

[Build_Scene_Staging](#)

Build Executor Status

master


- 1 Idle
- 2 [ManageNodes](#) [#104930](#)
- 10.0.0.1 (offline)
- 10.0.0.2 (offline)
- 10.0.0.3
 - 1 Occupied by [Build_Scene_Prod #1498](#)
 - 2 Occupied by [Build_Scene_Prod #1498](#)
 - 3 [Build_Scene_Prod](#) [#1498](#)
 - 4 Occupied by [Build_Scene_Prod #1498](#)









-  [New Item](#)
-  [People](#)
-  [Build History](#)
-  [Edit View](#)
-  [Delete View](#)
-  [Project Relationship](#)
-  [Check File Fingerprint](#)
-  [Manage Jenkins](#)
-  [Credentials](#)
-  [My Views](#)
-  [Purge Build Queue](#)

Build Queue (1)

[Build_Scene_Staging](#)  



















Build Executor Status




 **master**




- 1 Idle
- 2 [ManageNodes](#) [#104930](#) 
-  10.0.0.1 (offline)
-  10.0.0.2 (offline)
-  10.0.0.3
 - 1 Occupied by [Build_Scene_Prod #1498](#) 
 - 2 Occupied by [Build_Scene_Prod #1498](#) 
 - 3 [Build_Scene_Prod](#) [#1498](#) 
 - 4 Occupied by [Build_Scene_Prod #1498](#) 

[add description](#)

All Management Jobs PVS **Terrain Build Jobs** +

S	W	Name ↓	Last Success	Last Failure	Last Duration	
		Build_Scene_Staging	1 day 13 hr - #1235	10 days - #1193	2 hr 56 min	
		Build_Scene_Prod	1 day 13 hr - #1497	N/A	2 hr 47 min	
		Build_Preview	3 mo 20 days - #31	N/A	7 min 50 sec	
		Build_Generic	12 days - #540	13 days - #539	2 hr 13 min	
		Build_CI_Staging	3 mo 1 day - #90	2 mo 27 days - #96	2 hr 35 min	
		Build_CI_Master	12 days - #118	N/A	2 hr 44 min	

Icon: [S](#) [M](#) [L](#) [Legend](#)  [RSS for all](#)  [RSS for failures](#)  [RSS for just latest builds](#)

 [Back to Project](#) [Status](#) [Changes](#) [Console Output](#) [View as plain text](#) [Edit Build Information](#) [Parameters](#) [Git Build Data](#) [No Tags](#) [Rebuild](#) [Previous Build](#)

Build

[Keep this build forever](#)

#1498


(Dec 31, 2015 6:45:30 PM)

Started 49 min ago

Build has been executing for 49 min on 10.0.0.1

Progress:   [add description](#)

Subproject Builds

[Prepare_TerrainSourceAssets](#)  #2607[TerrainToolsLib](#)  #4902[Clean_Result](#)  #4293




No changes.



Started by remote host 172.31.27.110

Revision: 77c8cc9a578d70eaa41233a7de70082bef81007f

- origin/production

 [Back to Project](#) **Status** [Changes](#) [Console Output](#) [View as plain text](#) [Edit Build Information](#) [Parameters](#) [Git Build Data](#) [No Tags](#) [Rebuild](#) [Previous Build](#)

Build

[Keep this build forever](#)

#1498


(Dec 31,
2015 6:45:30 PM)

Started 49 min ago
Build has been executing for 49 min on 10.0.0.1

Progress:  

 [add description](#)

Subproject Builds

[Prepare_TerrainSourceAssets](#)  #2607[TerrainToolsLib](#)  #4902[Clean_Result](#)  #4293

No changes.





Started by remote host 172.31.27.110

Revision: 77c8cc9a578d70eaa41233a7de70082bef81007f



- origin/production

 [Back to Project](#) **Status** [Changes](#) [Console Output](#) [View as plain text](#) [Edit Build Information](#) [Parameters](#) [Git Build Data](#) [No Tags](#) [Rebuild](#) [Previous Build](#)

Build

[Keep this build forever](#)

#1498


(Dec 31, 2015 6:45:30 PM)

Started 49 min ago

Build has been executing for 49 min on 10.0.0.1

Progress:   [add description](#)

Subproject Builds

[Prepare_TerrainSourceAssets](#)  #2607[TerrainToolsLib](#)  #4902[Clean_Result](#)  #4293

No changes.



Started by remote host 172.31.27.110

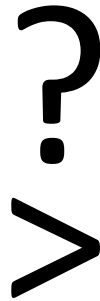
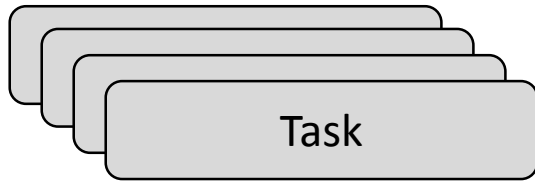
**Revision:** 77c8cc9a578d70eaa41233a7de70082bef81007f

• origin/production

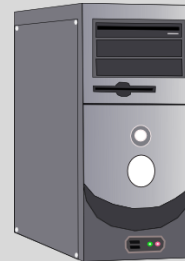
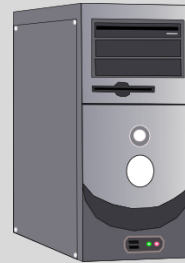
Cluster management with Jenkins

Periodic task checks work queue vs. cluster

Work queue

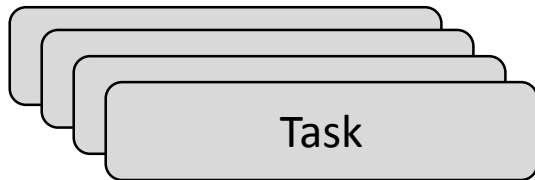


Build Cluster



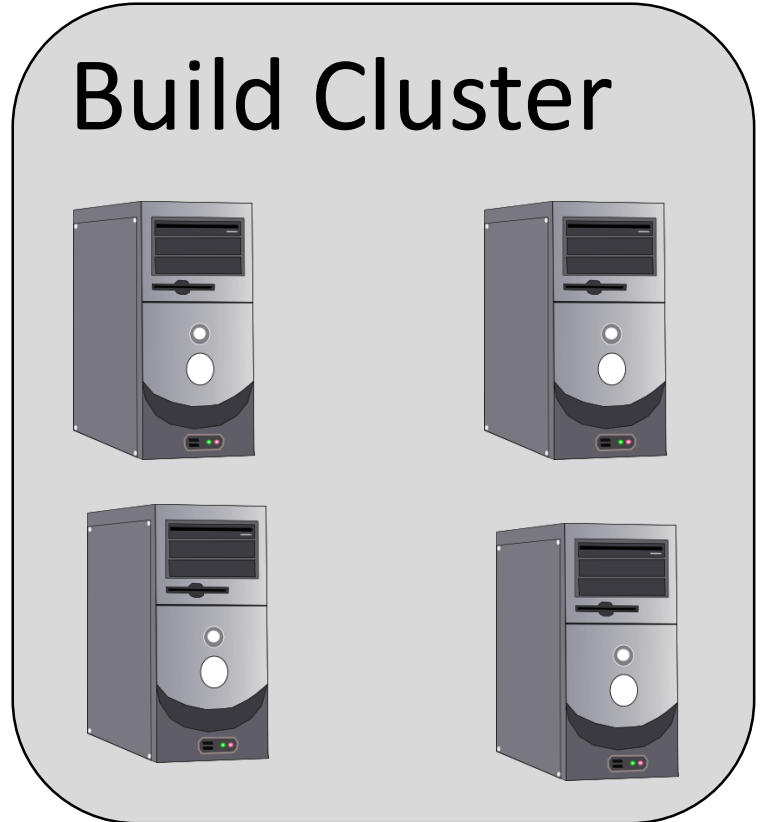
Cluster management with Jenkins

Work queue



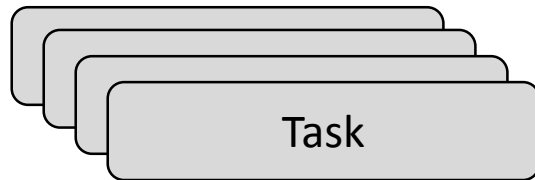
>

Build Cluster

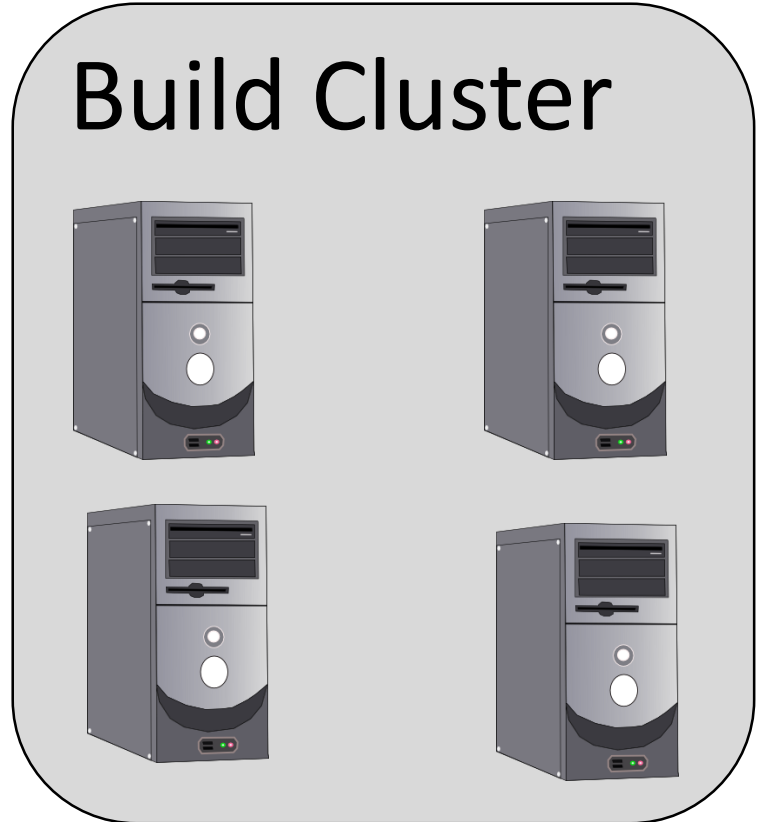


Cluster management with Jenkins

Work queue



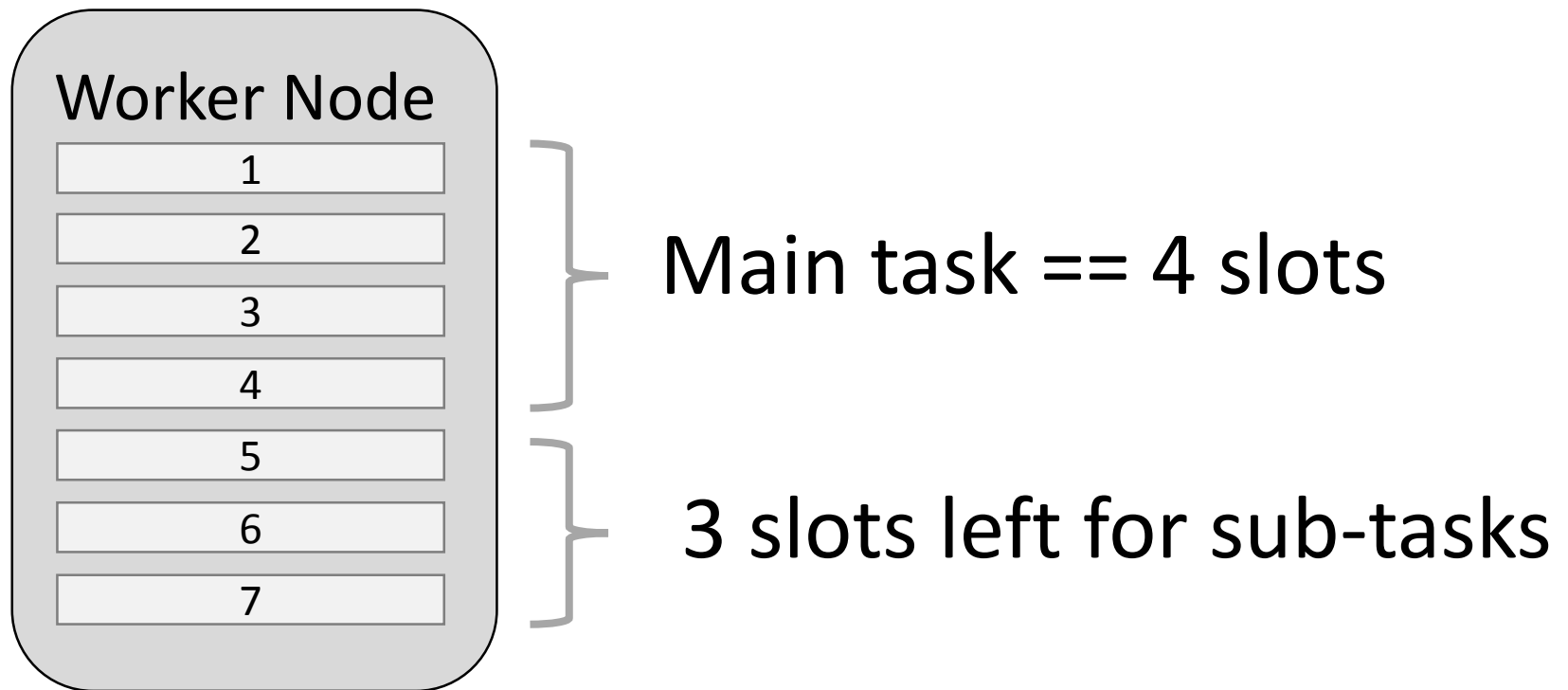
Build Cluster



Handling sub-tasks

Data intensive task, only want one per worker

...But want to be able to run sub-tasks



Jenkins cluster

- Periodic task to scale cluster
- Automation with Groovy scripts
- Use tags for different type of worker
 - e.g. dev vs. production

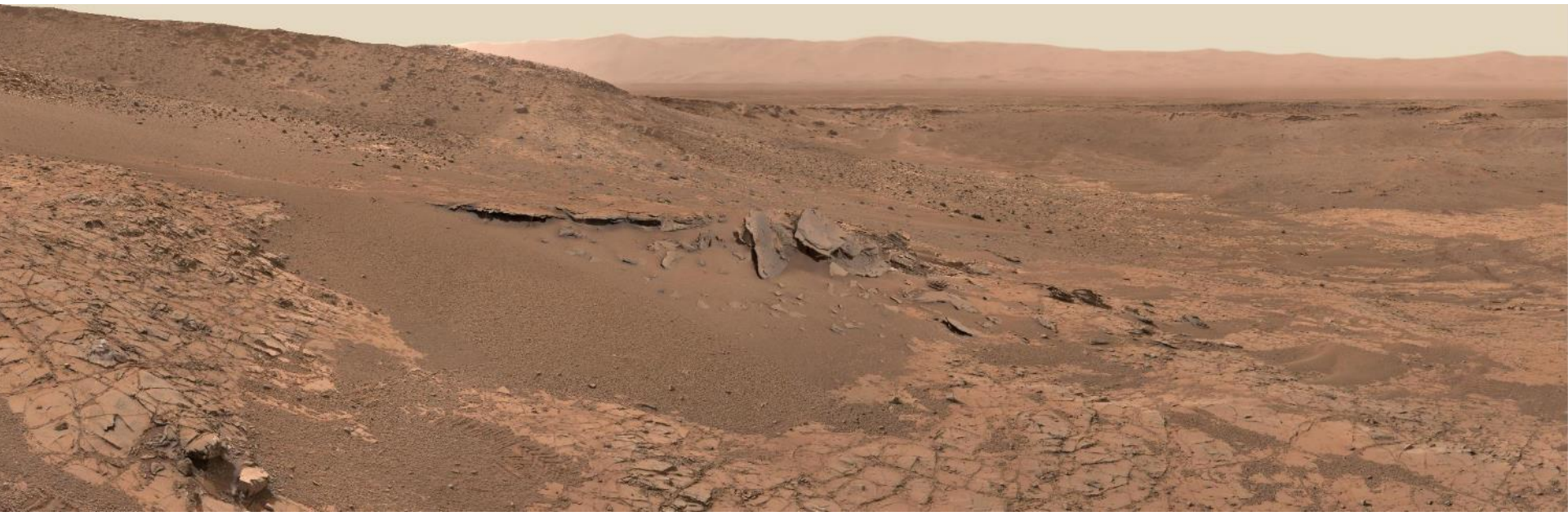


Worker Nodes



Workers

- GPU-enabled EC2 machines
- Windows 2012
- Run image processing code (C# binary)
- Created from base image with software installed

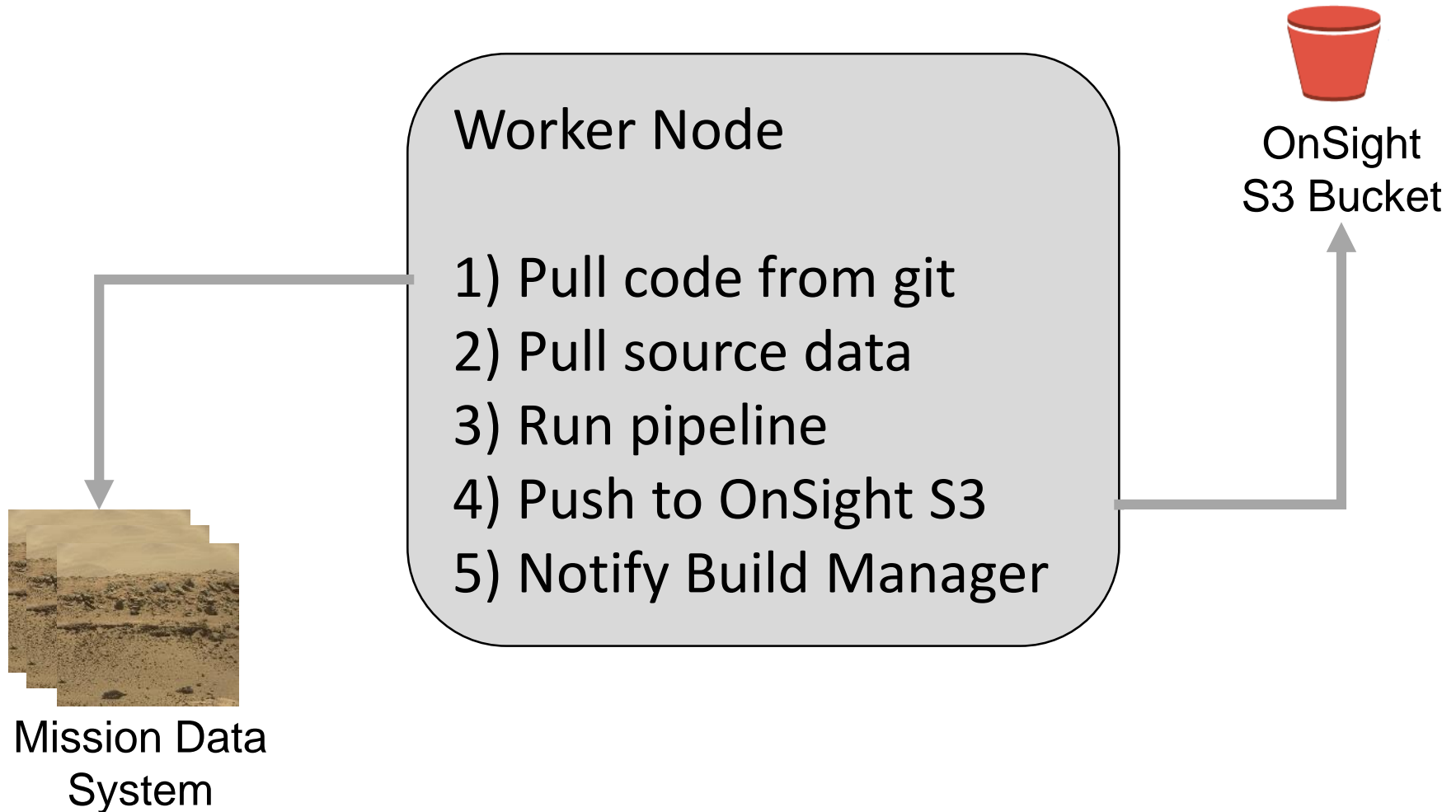


EC2 Instance Types

	GPU	vCPU	Mem (GB)	Cost*
g2.2xlarge	1	8	15	\$0.65/hr
g2.8xlarge	4	32	60	\$2.60/hr

*The cost information contained in this document is of a budgetary and planning nature and is intended for informational purposes only. It does not constitute a commitment on the part of JPL and/or Caltech.

Worker Lifecycle



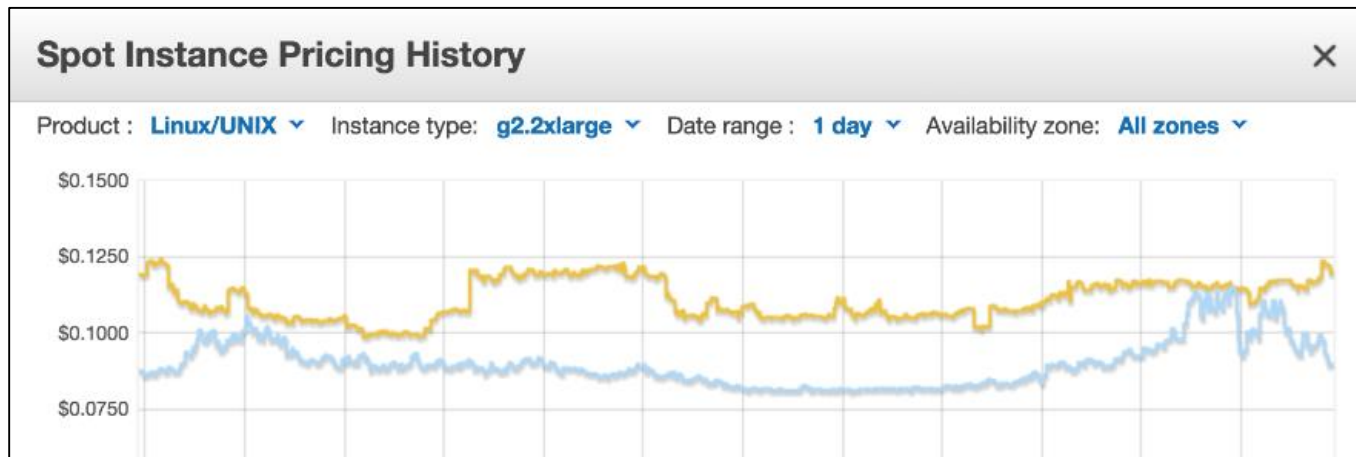
Workers – Lessons Learned

- Prefer keeping data and code outside of snapshot
- GPU on cloud machines is troublesome



Bonus – Spot Instances

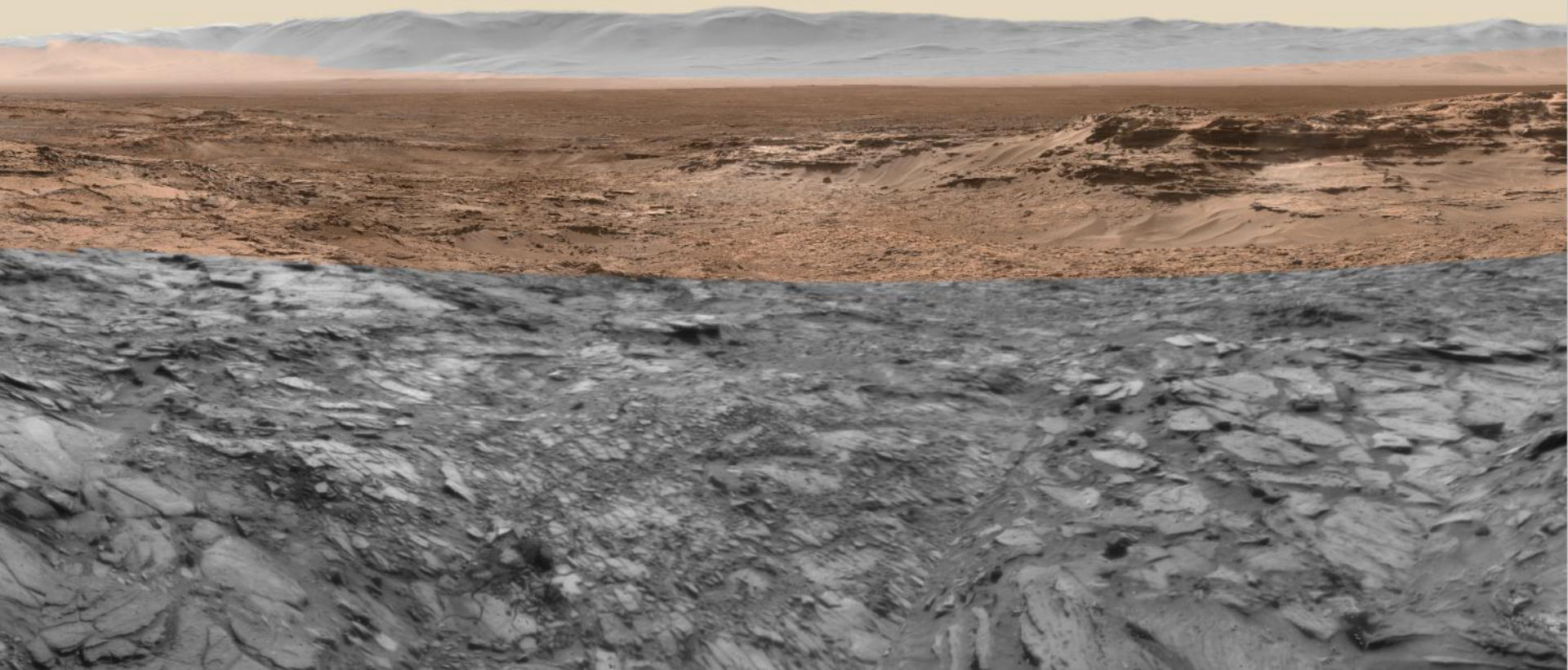
- 7x cheaper!
- \$0.10/hr*
- Used for non-critical work



Availability zone	
	us-west-1b
	us-west-1c

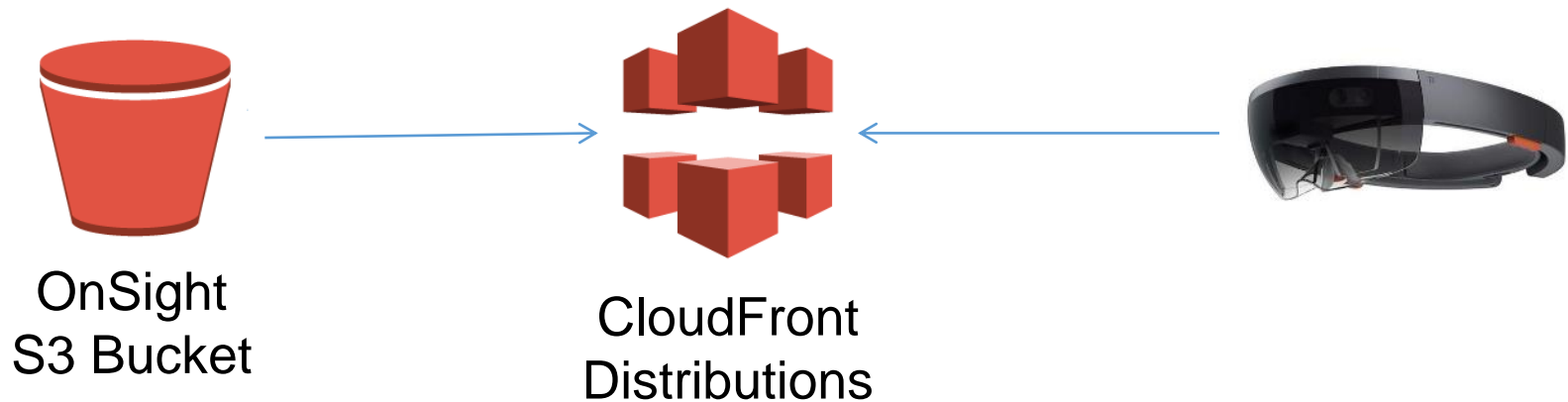
*The cost information contained in this document is of a budgetary and planning nature and is intended for informational purposes only. It does not constitute a commitment on the part of JPL and/or Caltech.

Storage & Distribution

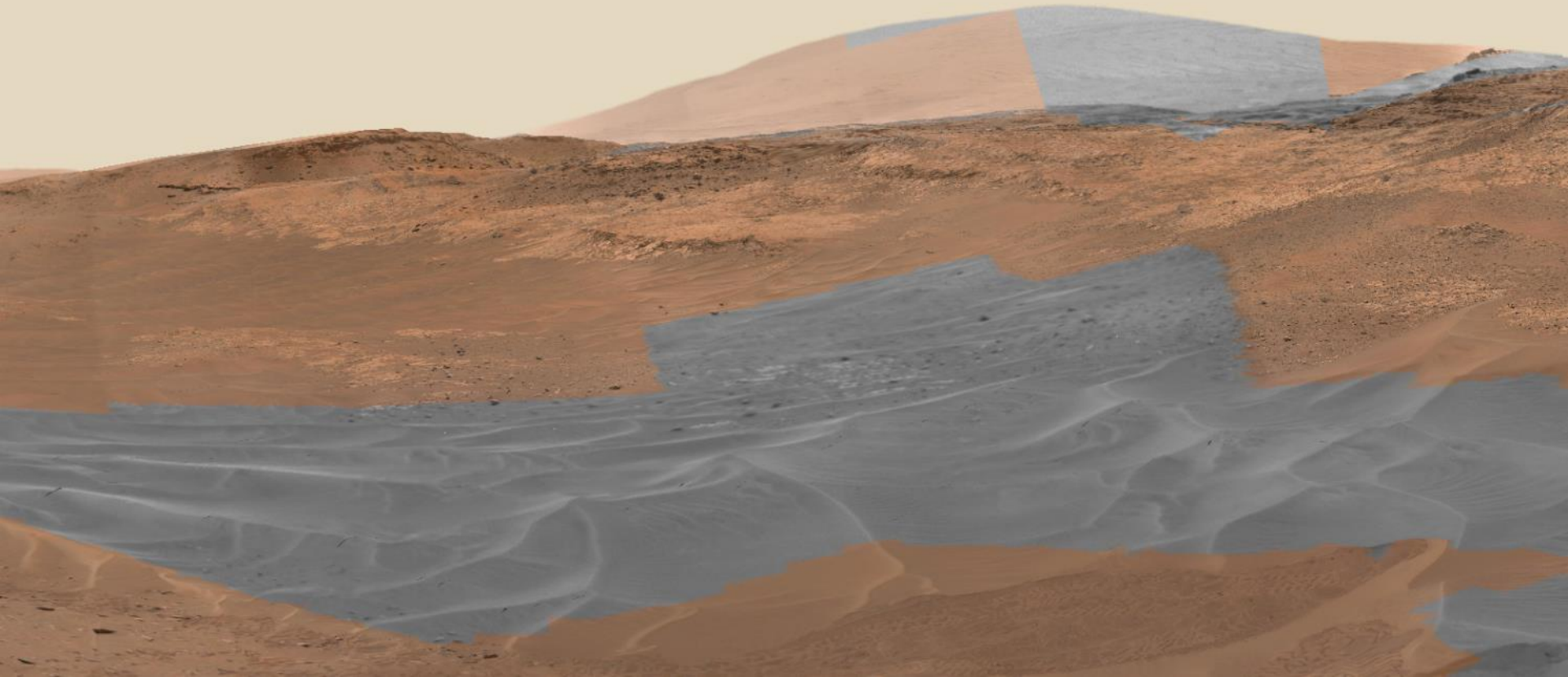


Data Storage & Distribution

- S3 – reliable storage
- CloudFront – distribution network
- Secured via signed cookies



Deployment

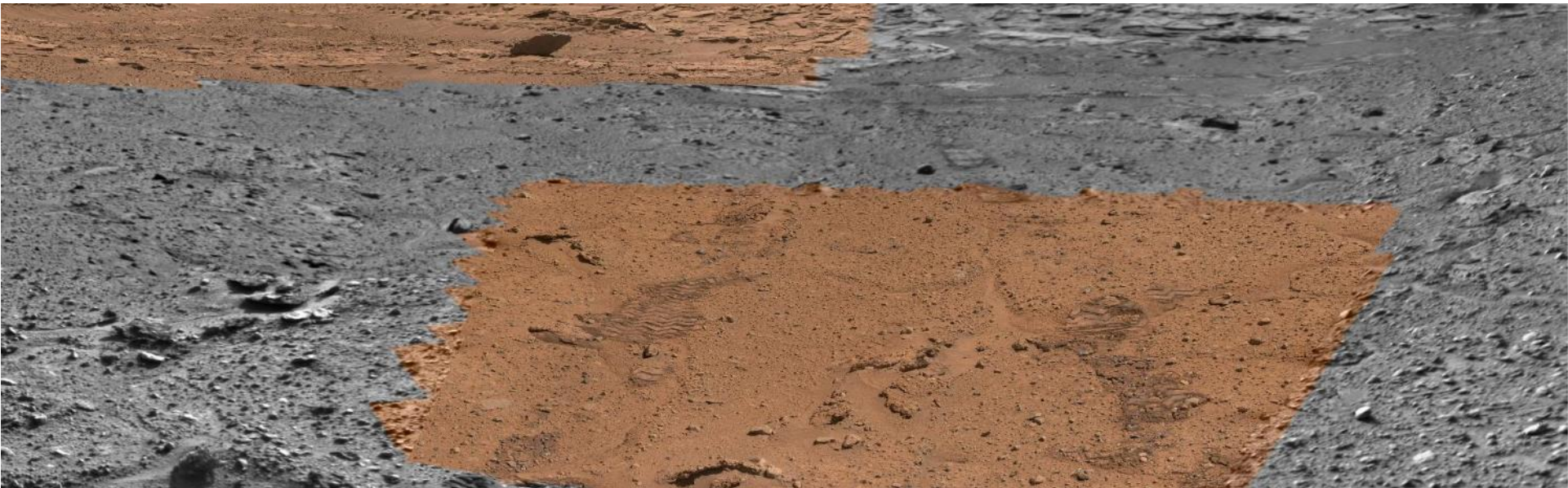


Ansible Overview



ANSIBLE

- IT Automation Tool
 - Software Deployment & Configuration
 - Infrastructure Management (including cloud)
- Similar tools: Chef, Puppet, Salt



Ansible Playbooks

```
- name: Create jenkins user  
sudo: yes  
user: name=jenkins
```

Ansible Playbooks

```
- name: ensure directories  
permissions  
  sudo: yes  
  file: path ~/.ssh  
owner=jenkins mode=0700  
state=directory
```

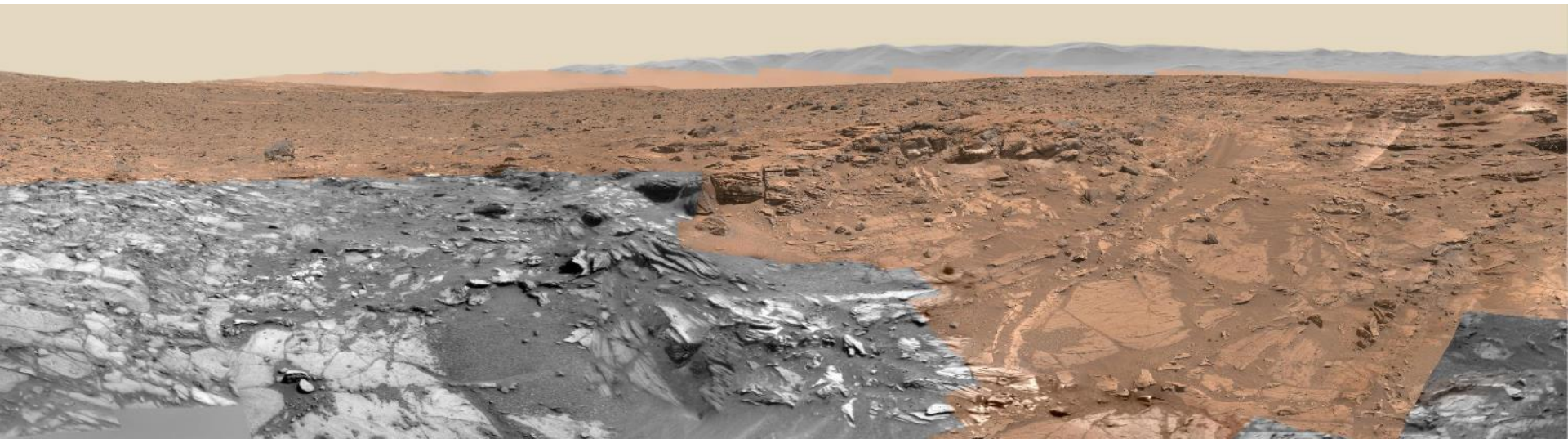

Ansible Playbooks

```
- name: copy template
  sudo: yes
  template:
    src=jenkins.conf.j2
    dest=/etc/default/jenkins
    backup=yes mode=0644
  notify:
    - restart jenkins
```

Deploying with Ansible

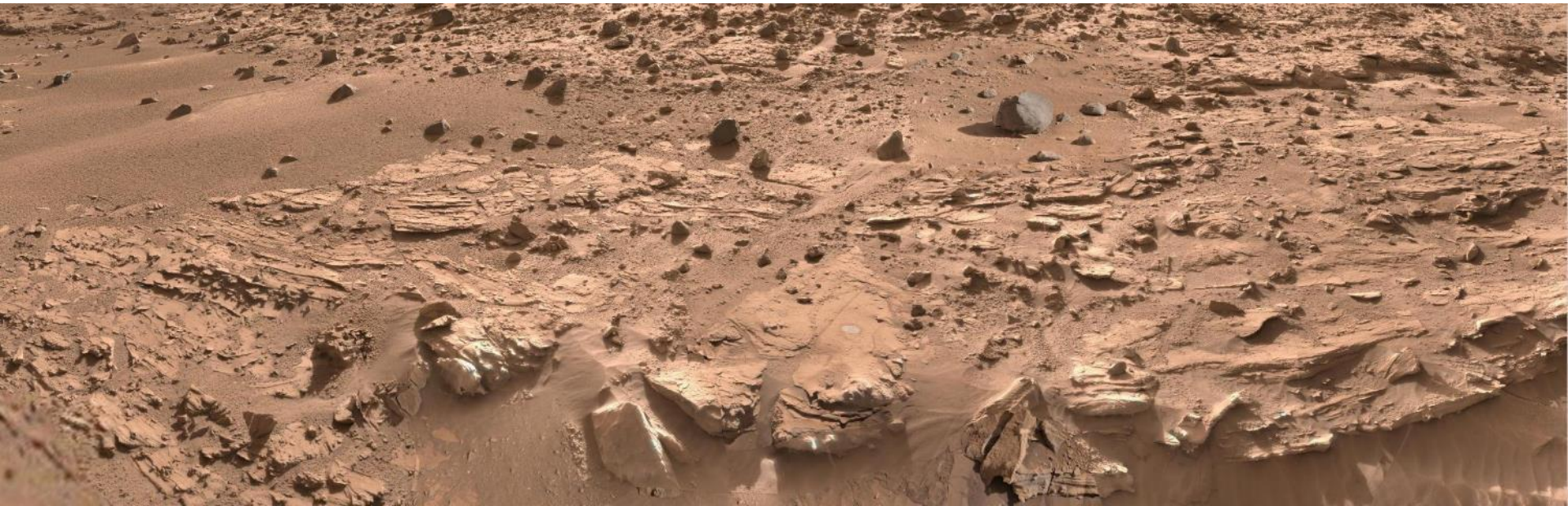
1) Create EC2 instance

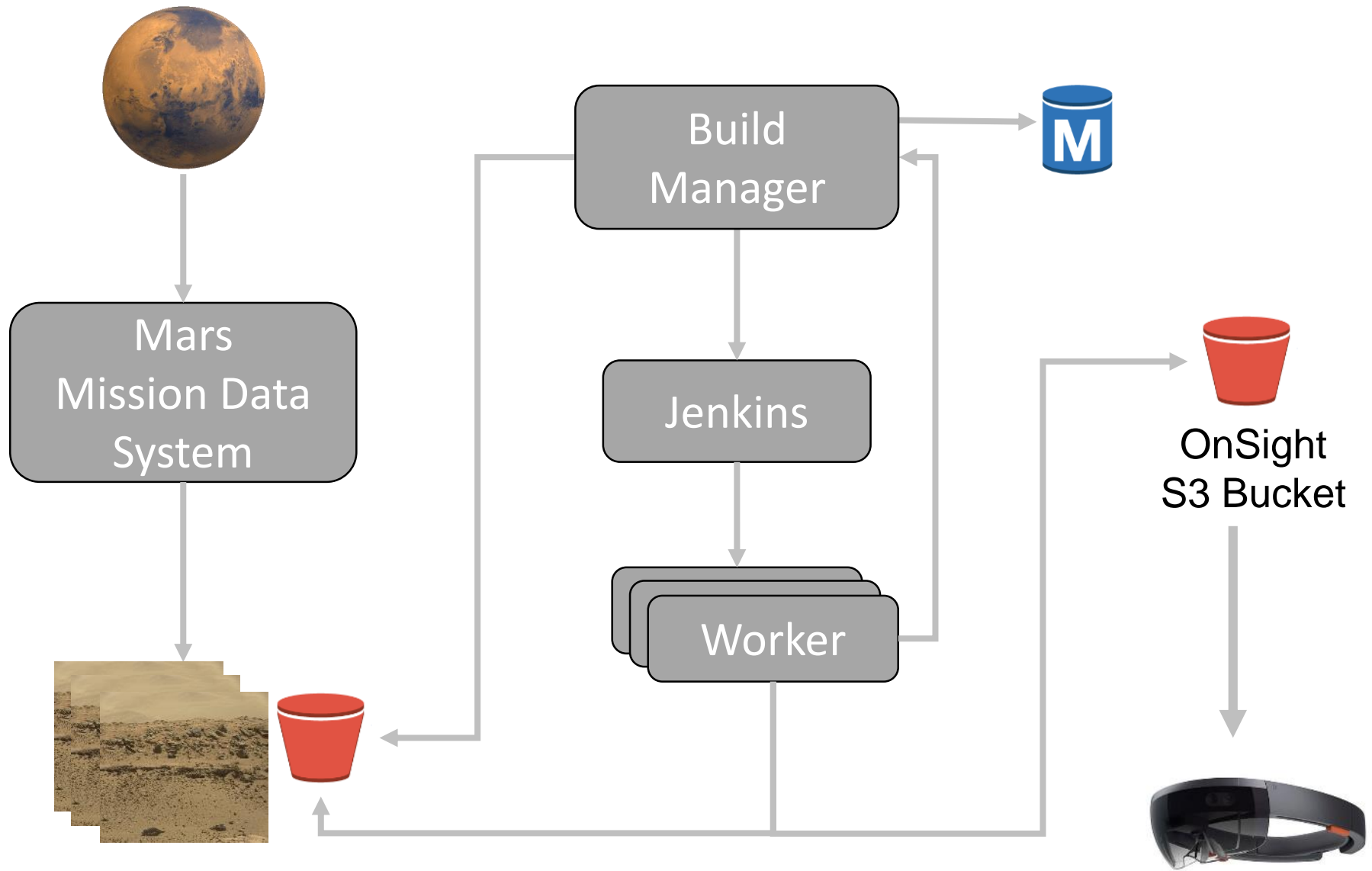
2) `ansible-playbook -i production deploy.yml \`
`--extra-vars "env=production" \`
`--vault-password-file VAULT_FILE`



Ansible

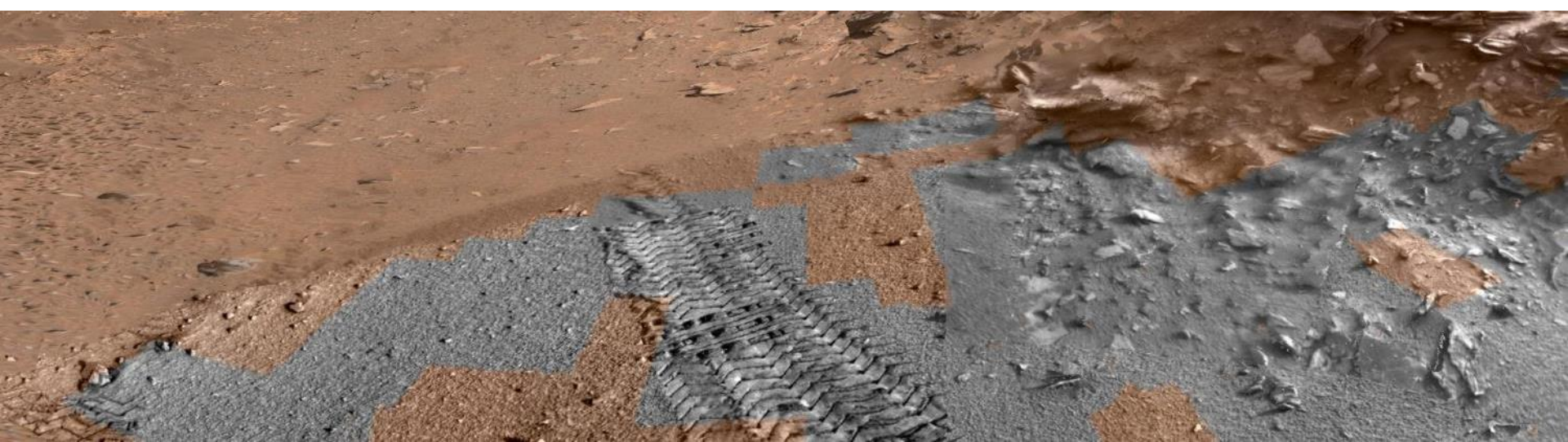
- Used to configure all Linux servers
- Not yet using for Windows





Future work

- (More) auto-scaling & management
- Use Ansible to manage worker AMIs
- Split pipeline into smaller services



Acknowledgements



Jeff Norris	Tom Crockett
Jay Torres	Charley Goddard
Alex Menzies	Alice Winter
Jesse Kriss	Matt Clausen
Darren Dao	Microsoft

Q & A



A Cloud-based Architecture for Processing 3D Mars Terrain

Parker Abercrombie

parker.abercrombie@jpl.nasa.gov

Jet Propulsion Laboratory, California Institute of Technology

More info: opslab.jpl.nasa.gov

Feedback: goo.gl/forms/yxhcMrksaS