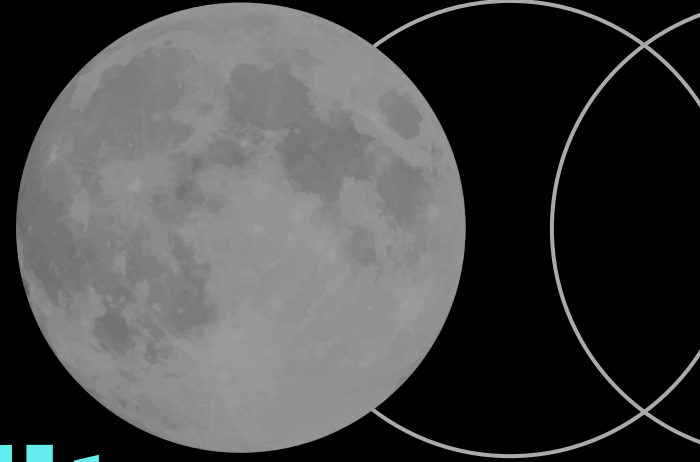




**JPL**

# MoonTrek Augmented Reality



Nadir Abdusemed, Jackson Bentley, Jesus Cruz, Youssef Elzein, Derek Guevara,  
Joe Hineno, Rich Ho, Owen Ramirez, Salman Sheikh, Alex Sherzai

# Advisor and Liaisons

Weronika Cwir



Natalie Gallegos



Shan Malhotra



# Team Roles

Coordinate Mapping - Jesus Cruz

3D Modeling - Alex Sherzai, Jackson Bentley

Image Registration - Jesus Cruz, Joe Hineno

Image Database - Derek Guevara, Rich Ho, Nadir Abdusemed, Owen Ramirez

Project Leads - Youssef Elzein, Salman Sheikh

# Agenda

1

## MoonTrek Explained

Salman Sheikh, Jesus Cruz

4

## Image Registration

Joe Hineno, Jackson Bentley

2

## Coordinate Mapping

Jesus Cruz

5

## Image Database

Derek Guevara, Rich Ho, Alex Sherzai

3

## 3D Modeling

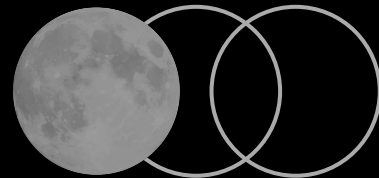
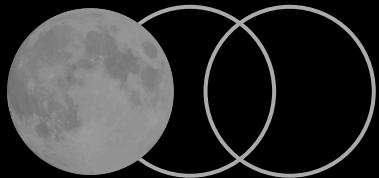
Jesus Cruz, Youssef Elzein

6

## Future Work

Nadir Abdusemed, Owen Ramirez



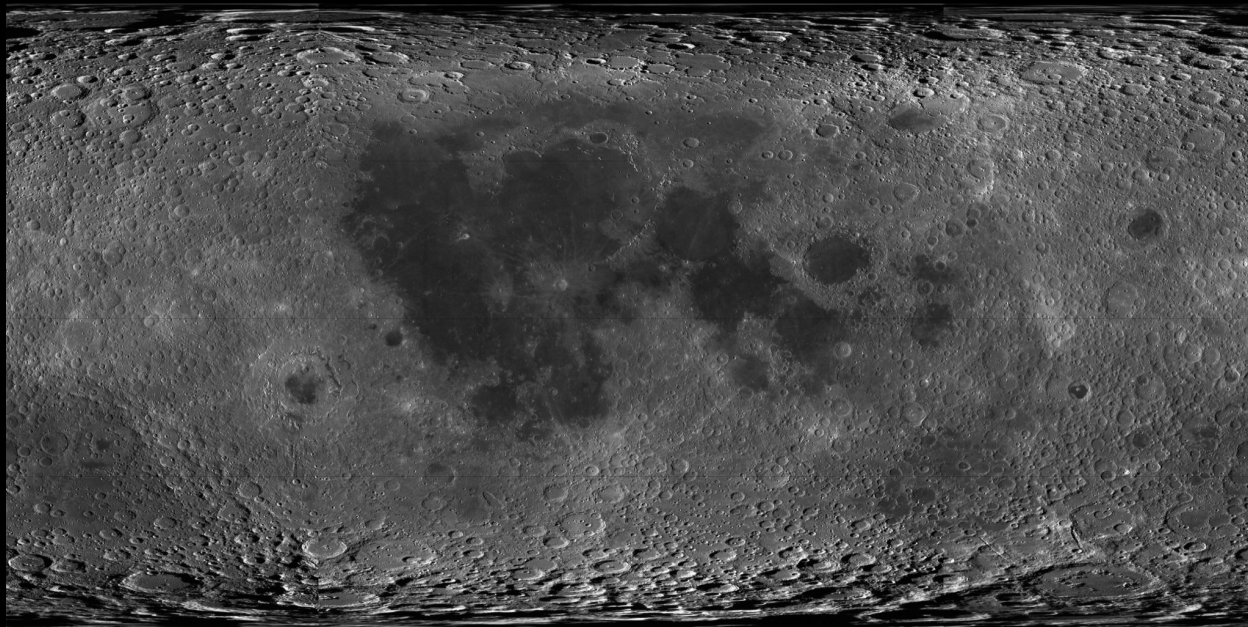


1

# Moontrek Explained

Salman Sheikh, Jesus Cruz

<https://trek.nasa.gov/moon/>



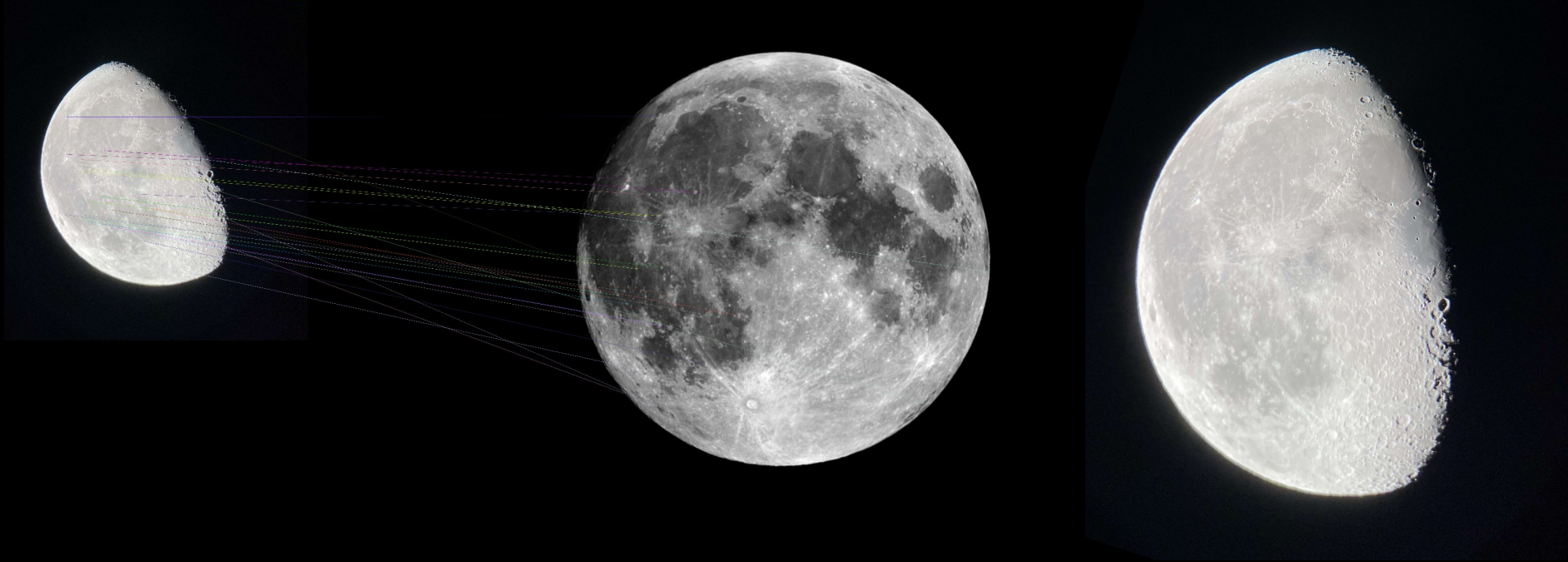
# Demo: MoonTrek



# Goals

- Achieve correct overlays
  - Coordinate mapping
  - 3D model of the Earth, Moon, and Sun
  - Create database of images to test registration model
  - Context-aware image registration

# Image Registration



Reference



Combined



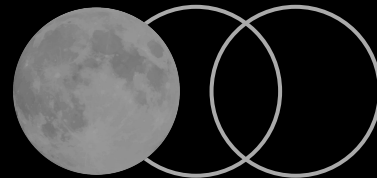
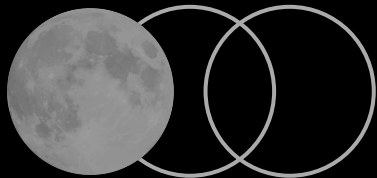
Sensed Image after Transformation





# Pre-Context-Aware Image Registration





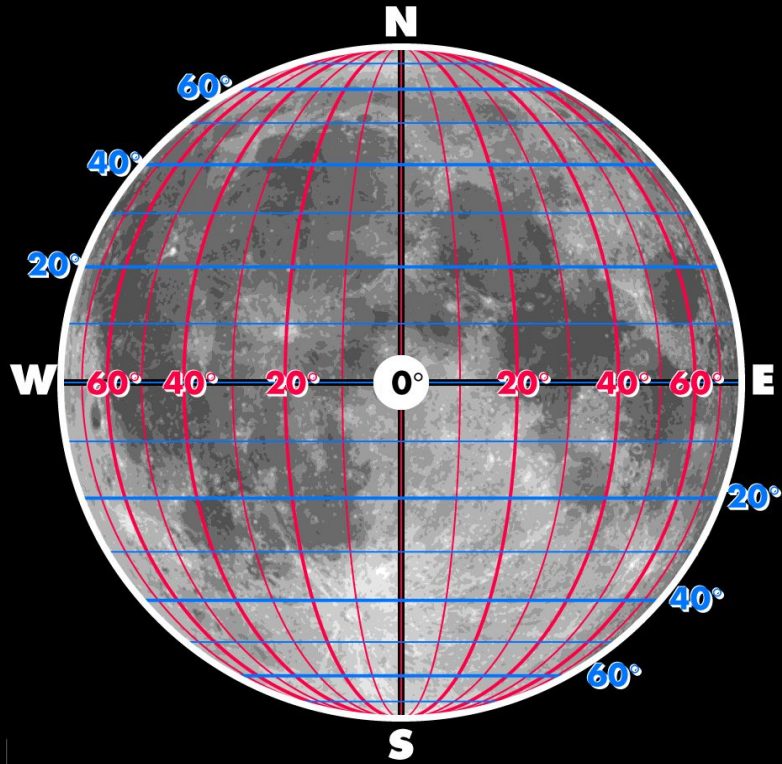
2

# Coordinate Mapping

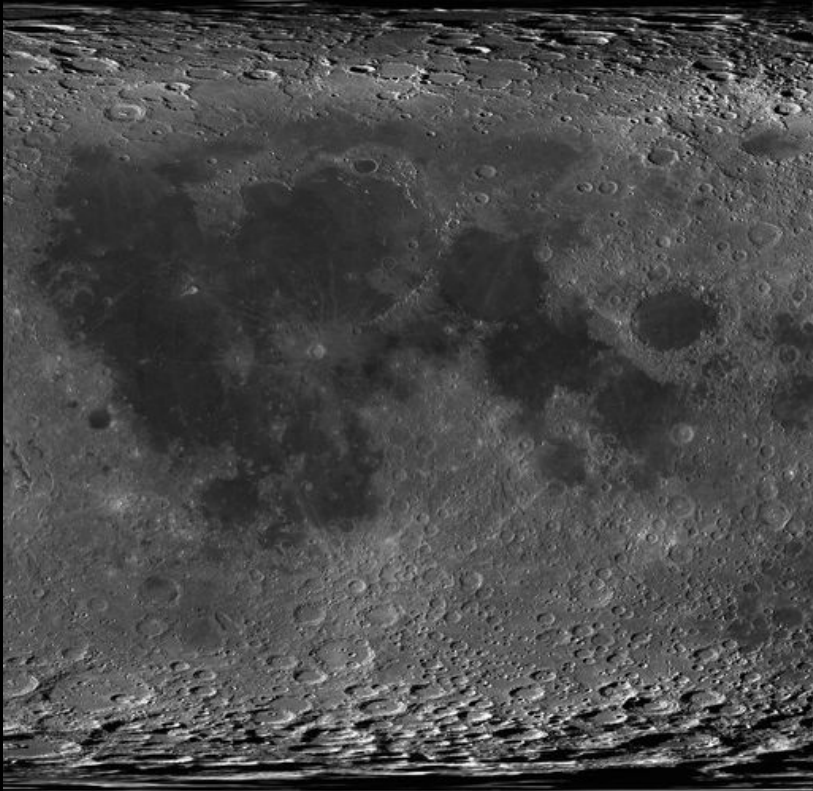
Jesus Cruz



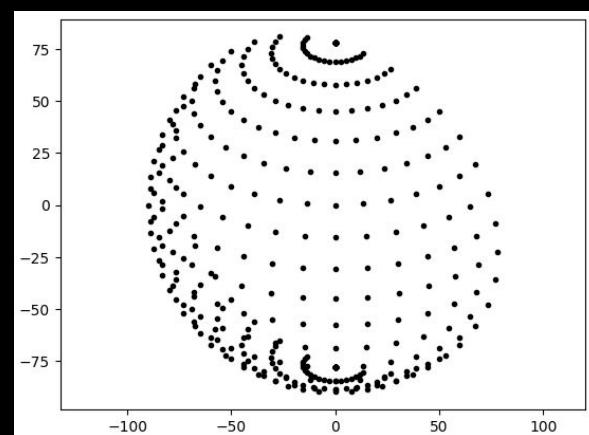
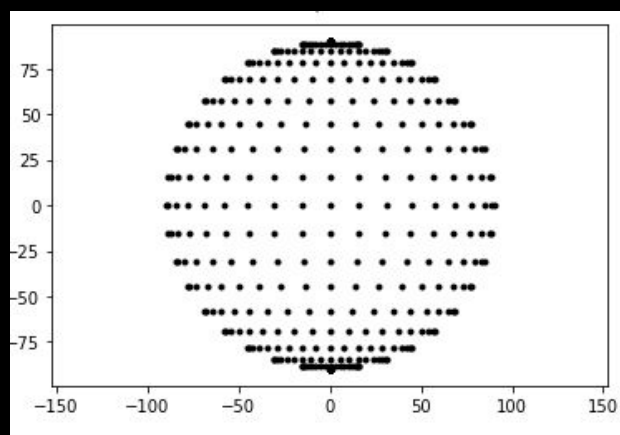
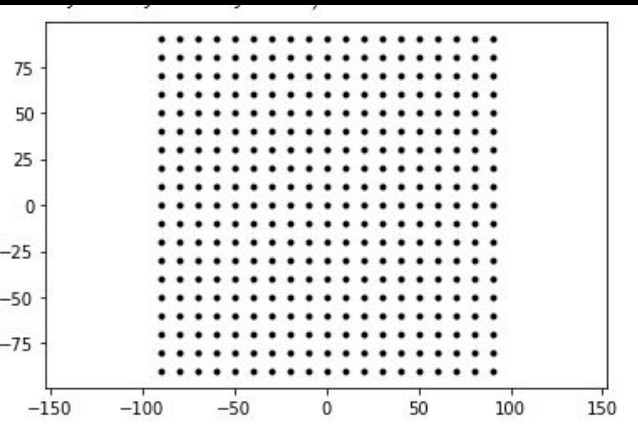
# Selenographic Coordinates



# Cartesian to Selenographic

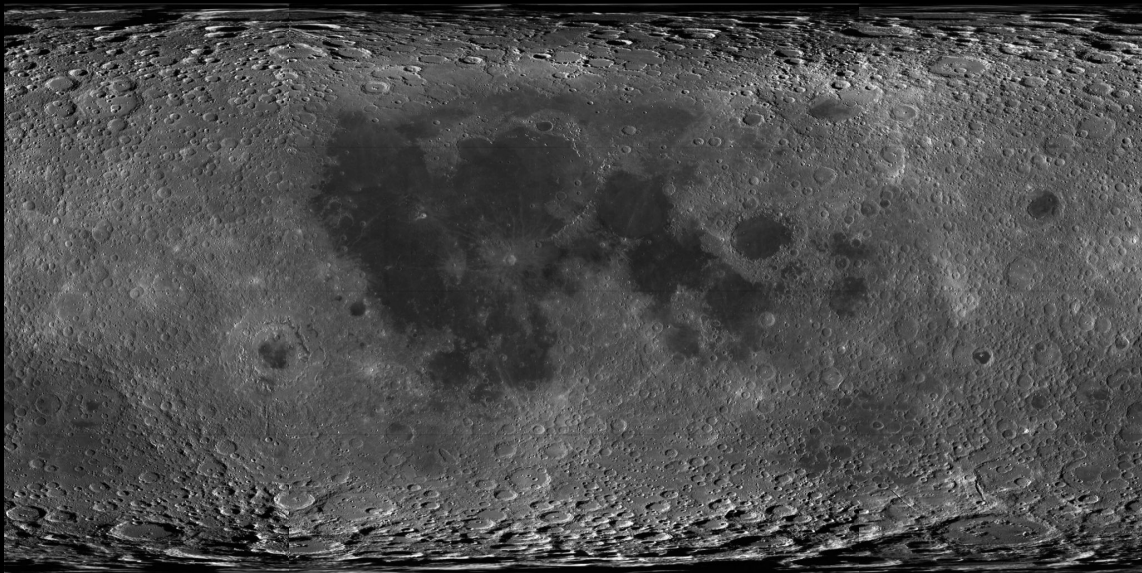


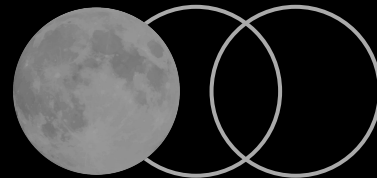
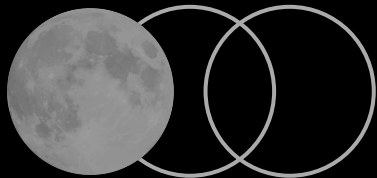
# Coordinate Mapping





# Recreating Moon Images





3

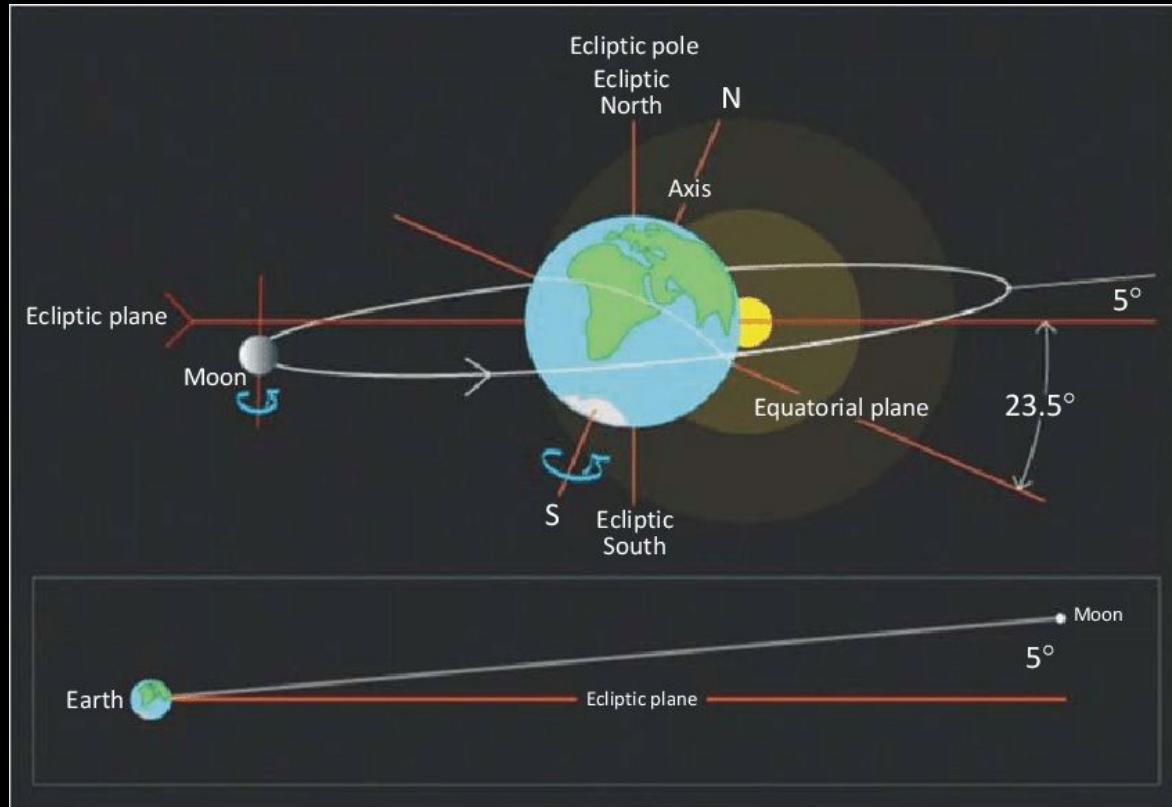
# 3D Model

Jesus Cruz, Youssef Elzein

# Tidally Locked vs Non-Tidally Locked



# Lunar Orbit

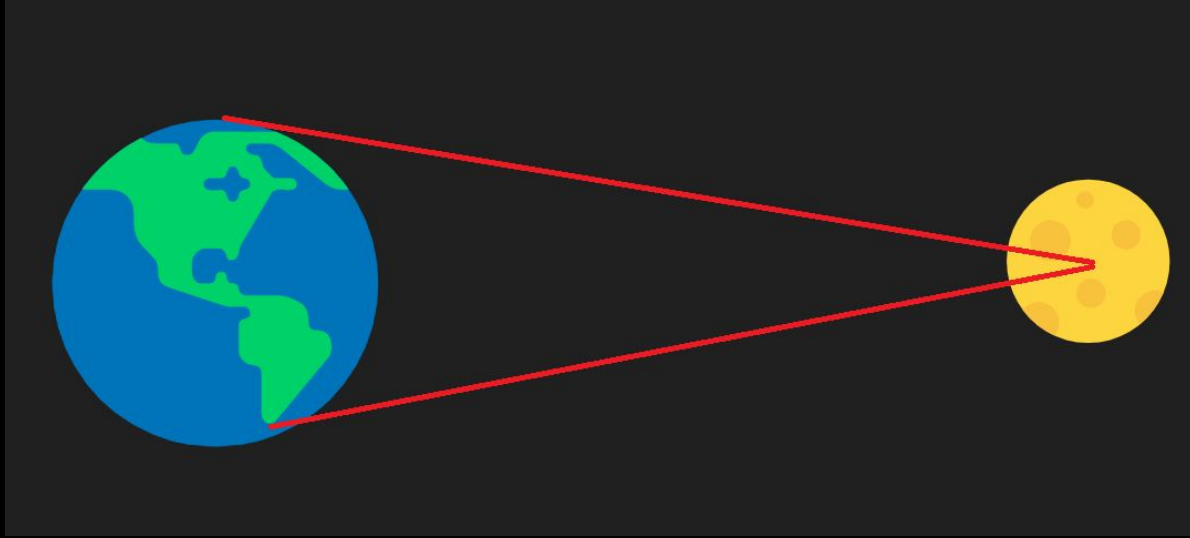


# Lunar Librations





# Shifting Viewpoints

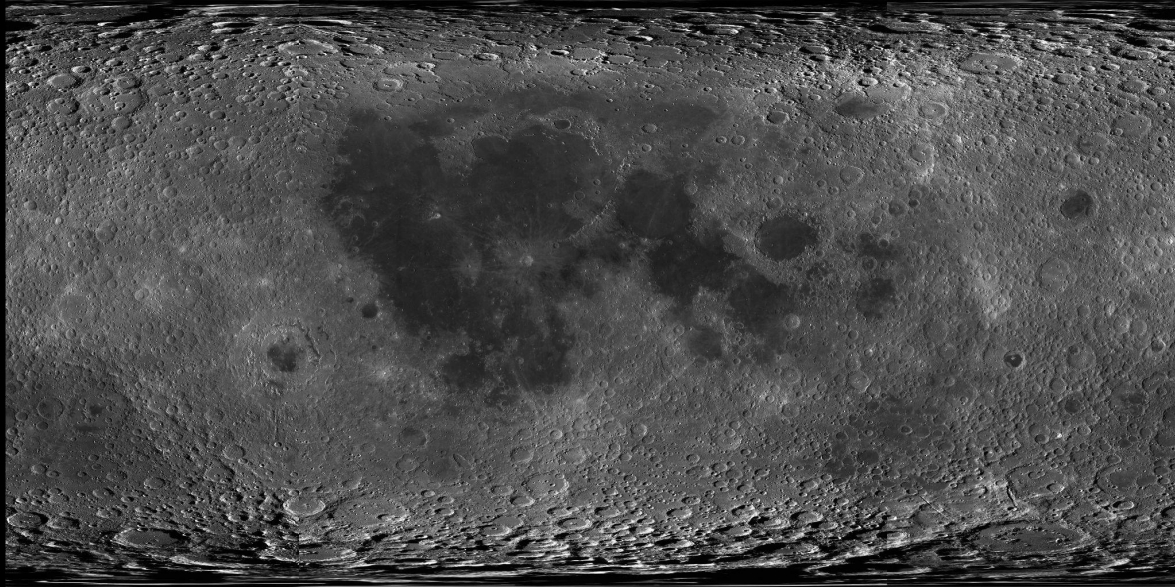


# Atmospheric Interference



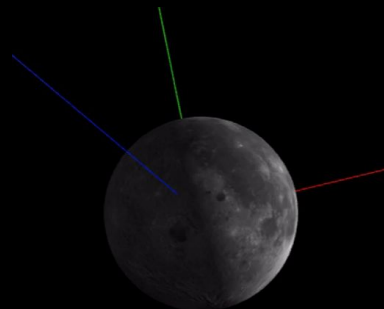
# JPL Data & Texture

- 5GB & 109,000 pixels wide -> 2MB & 4,000 pixels wide



# JPL API

- Planetary Positions and Rotations
  - For any time stamp
    - Position of Earth, Moon, and Sun
    - Orientation of Moon
  - With respect to any other planet



```
{
  "status": "Successfully retrieved
    positions",
  "person": {
    "x": -2.479751894059037,
    "y": 3.5627480550699824,
    "z": 4.663717580189115
  },
  "sun": {
    "x": 134580.75192010455,
    "y": 42199.91105673109,
    "z": -53522.721261972925
  },
  "moon": {
    "x": -349.439246995403,
    "y": -103.4528365835297,
    "z": 112.46799003871952,
    "nearestPoint": {
      "x": 1.7282711781143525,
      "y": 0.04880530681138987,
      "z": 0.17094398530385382
    },
    "libration_lon": -5.3085,
    "libration_lat": 0.8043
  }
}
```

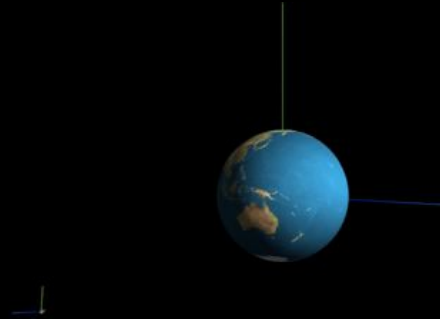
# Sorry Copernicus!!

Our model is Earth-centric



# Three Body Debugger

- Instead of a static model based on positions for one moment
- We can now check the position data over time and analyze how each body moves over time
- Can check hour by hour or day by day



```
{  
  "status": "Successfully retrieved  
    positions",  
  "person": {  
    "x": -2.479751894059037,  
    "y": 3.5627480550699824,  
    "z": 4.663717580189115  
  },  
  "sun": {  
    "x": 134580.75192010455,  
    "y": 42199.91105673109,  
    "z": -53522.721261972925  
  },  
  "moon": {  
    "x": -349.439246995403,  
    "y": -103.4528365835297,  
    "z": 112.46799003871952,  
    "nearestPoint": {  
      "x": 1.7282711781143525,  
      "y": 0.04880530681138987,  
      "z": 0.17094398530385382  
    },  
    "libration_lon": -5.3085,  
    "libration_lat": 0.8043  
  }  
}
```



# Generated Context-Aware Reference Image

Sensed Image



**Meta Data**  
(Time Stamp & Location)



Reference Image



# Generated Context-Aware Reference Image

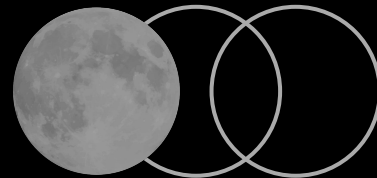
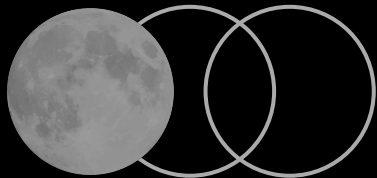
**User Image**



**Meta Data**   
(Time Stamp & Location)







4

# Image Registration

Joe Hineno, Jackson Bentley

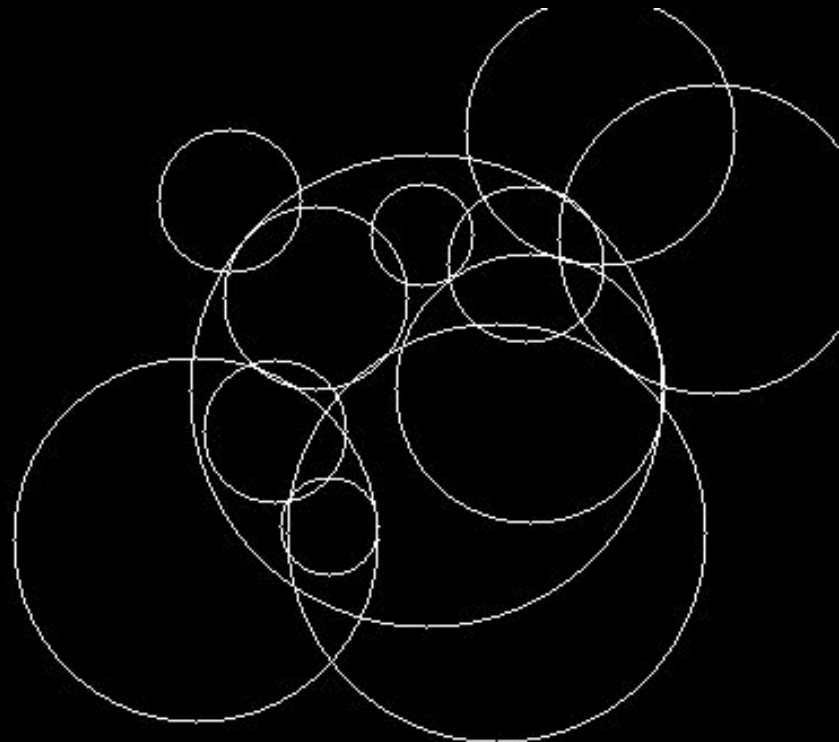
**Sensed Image**



**Reference Image**



# Circle Detection



# Equal Scale



**Sensed**



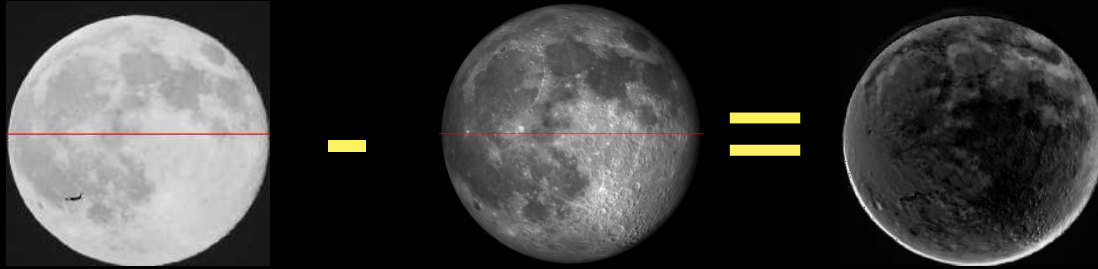
**Reference**



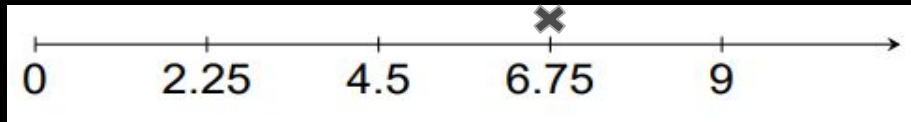
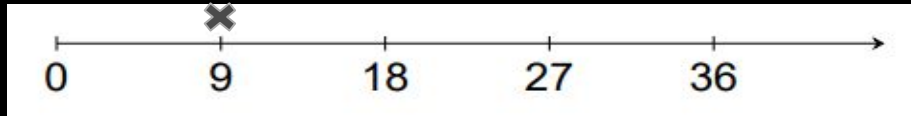
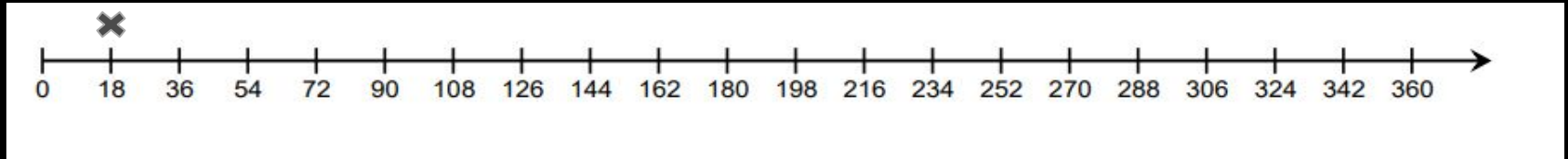
# Root Mean Squared Error



$$RMSE = \sqrt{\sum_{i=1}^n \frac{(\hat{y}_i - y_i)^2}{n}}$$

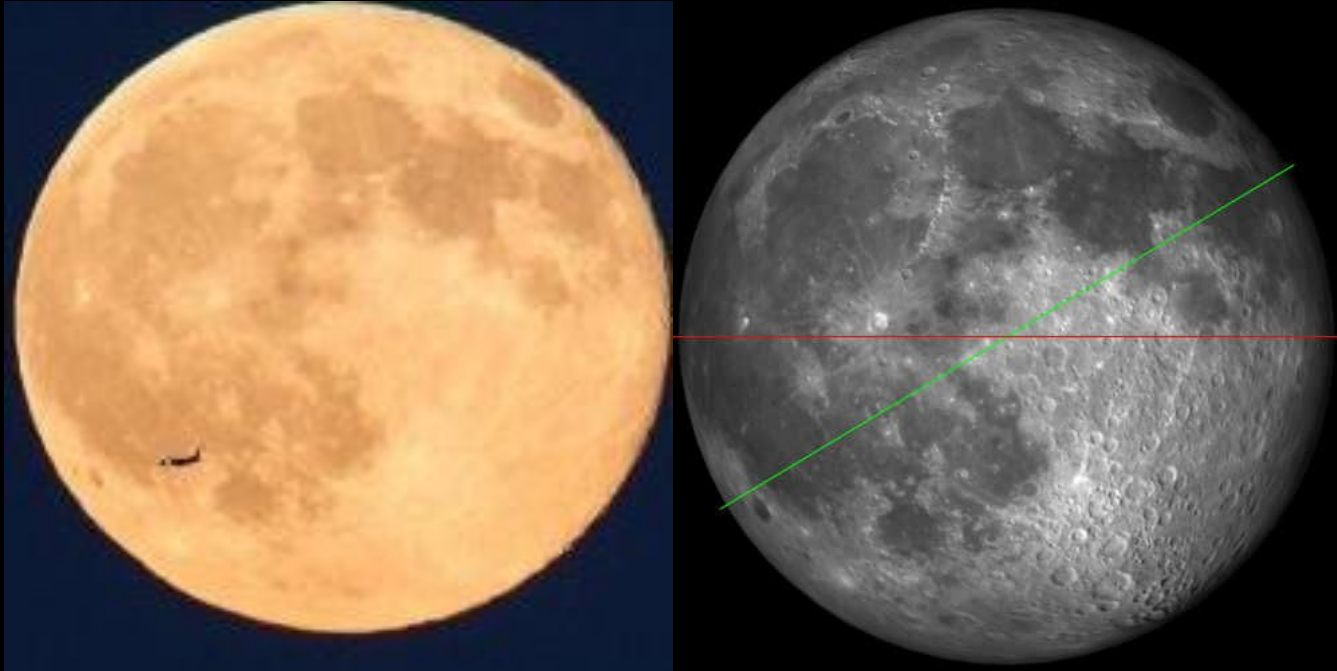


# Rotation Algorithm



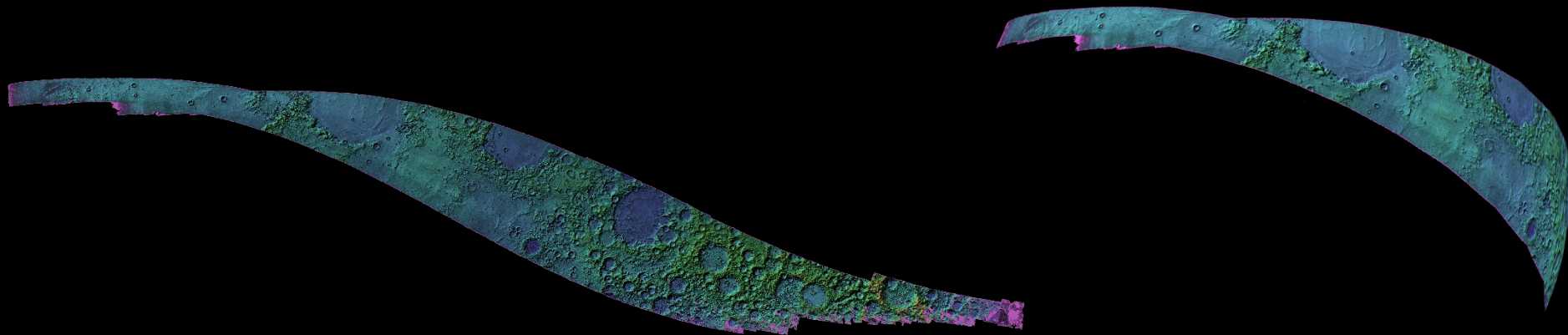


# Rotation Results

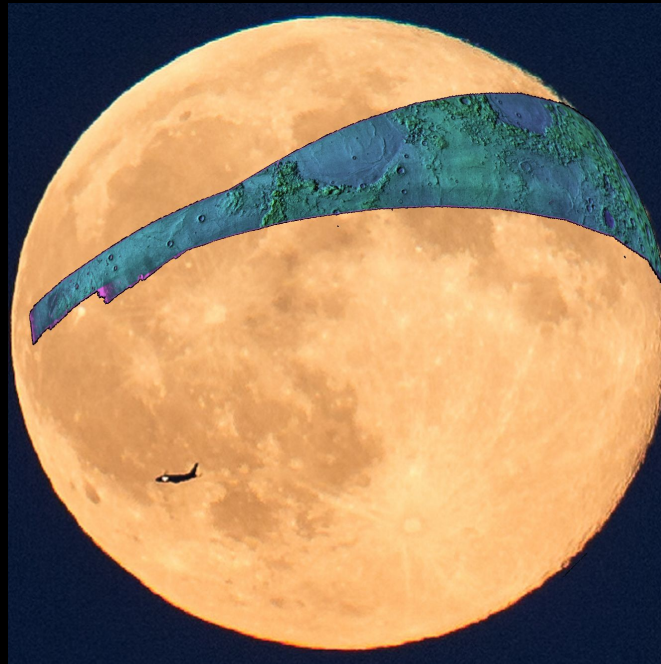




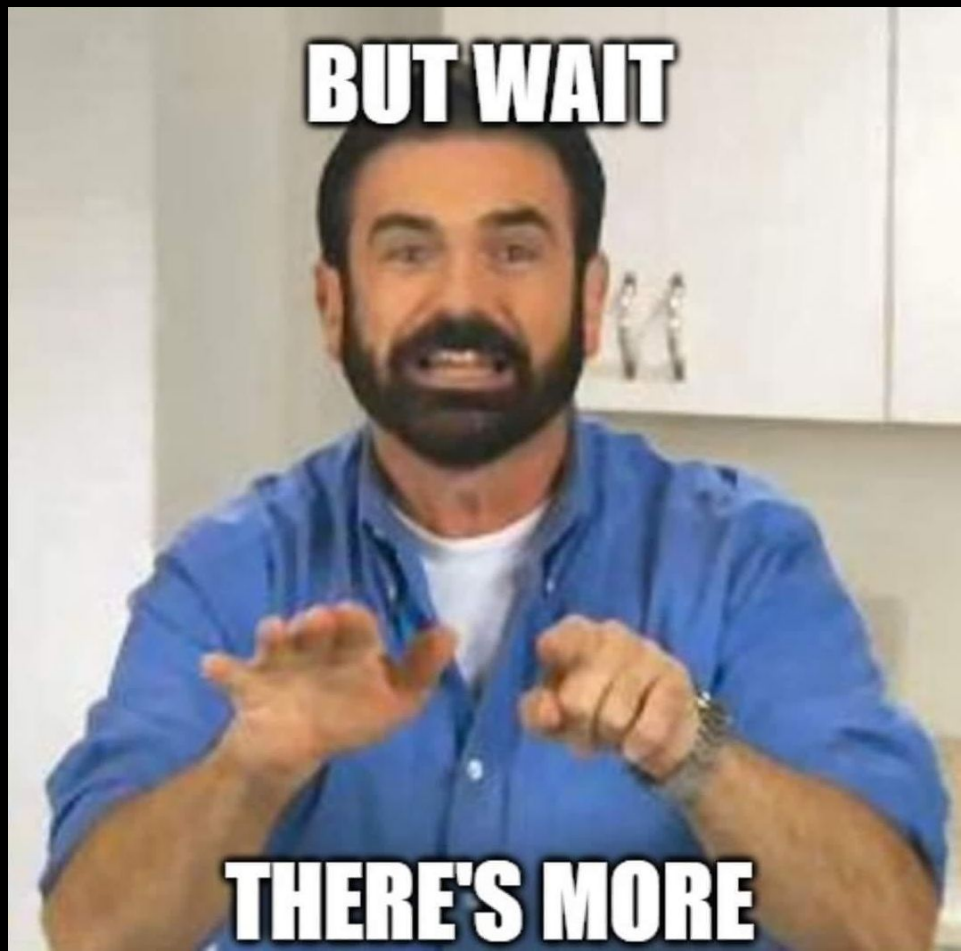
# Overlay Transformation



# Overlaid User Image



**BUT WAIT**



**THERE'S MORE**

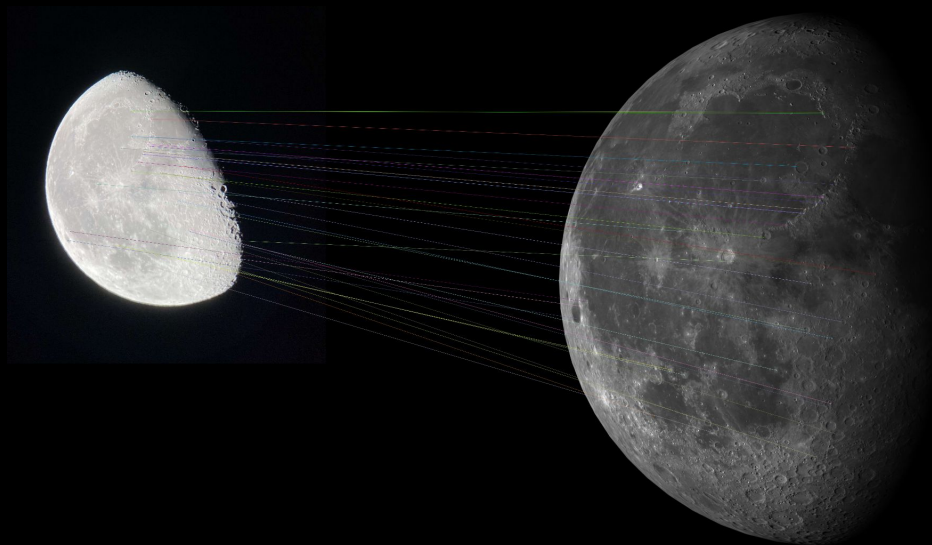
**Sensed**



**Reference**



## Registration Matches



## Transformed User Image

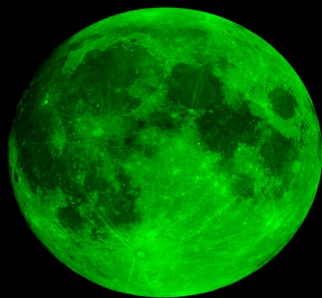


**Reference**

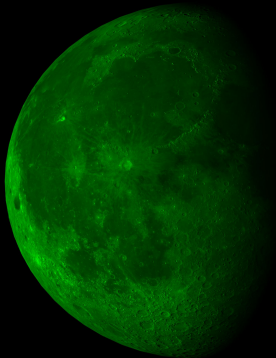
**Stacked**

**Transformed**

**No Context**



**Context-Aware**





# Overlaid Image



**No Context**



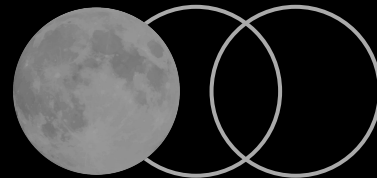
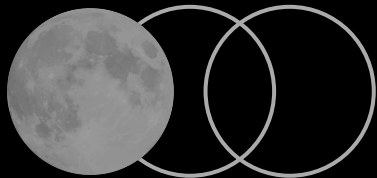
**With Context**



# Overlay With Points of Interest



Nearest Point Tycho Crater Copernicus Crater Mare Crisium



5

# Database

Derek Guevara, Rich Ho, Alex Sherzai

## Problem: Low Supply of Test Images

- Little to no metadata
- Not a true representation




1 Image



60 images  
stacked

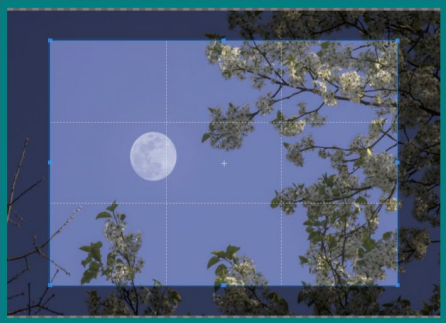
# Solution: YourMoon

 YourMoon Upload Images

Upload and crop your image.

Choose File

76.jpeg



Latitude

Longitude

Date

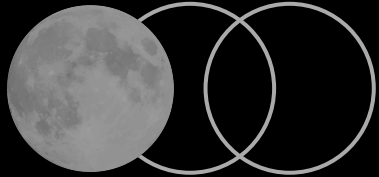
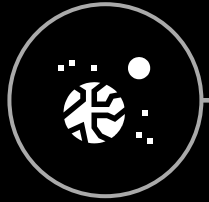
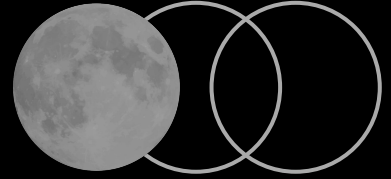
mm/dd/yyyy

Time

--:--:--

Upload

# About YourMoon



1

## Select

Users will select their own moon picture

2

## Crop

Crop to where only the moon is selected

3

## Machine Learning

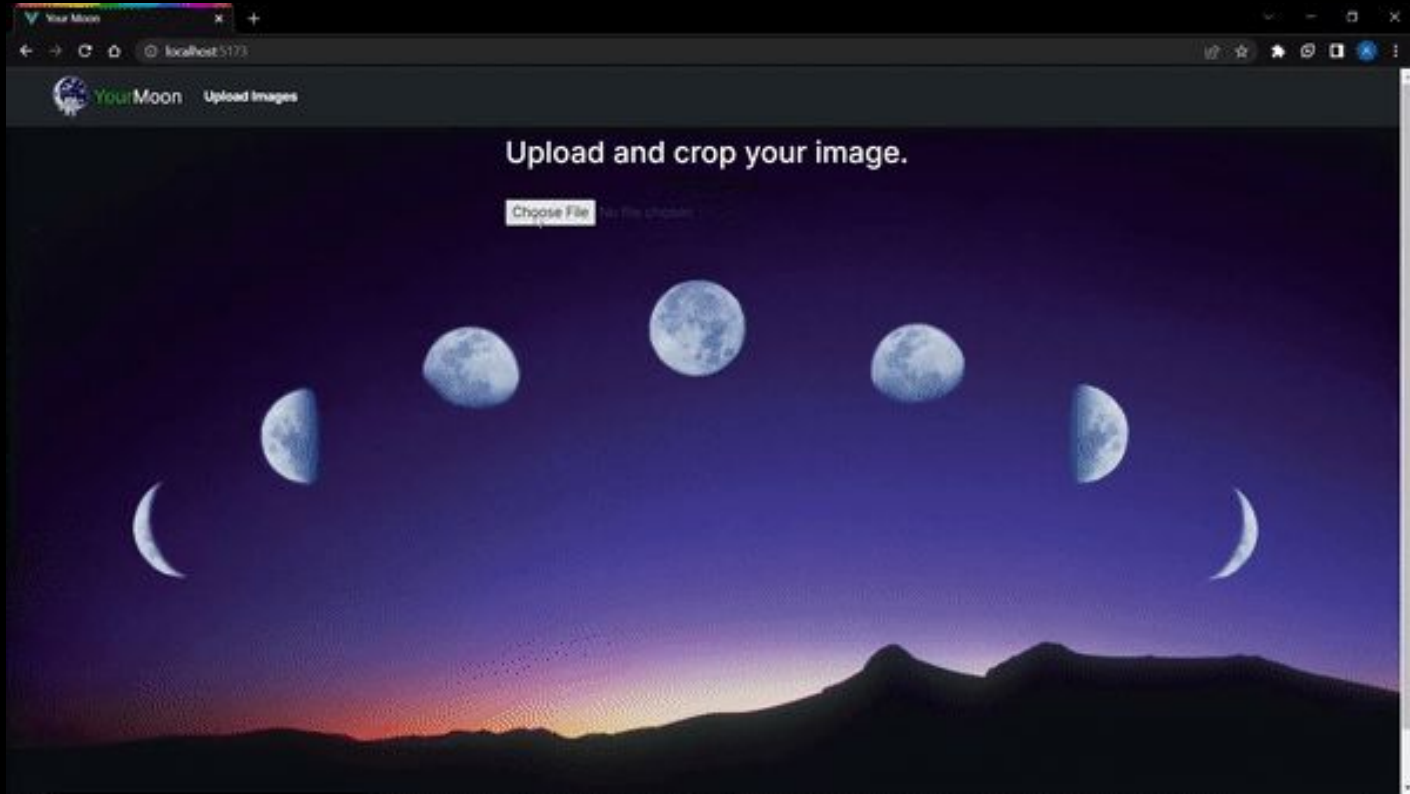
Check if it's a moon picture

4

## Database

Upload picture to database using Axios

# Demo: YourMoon



# Data Concern

Goal:

- Decrease effort of manual screening

A Solution:

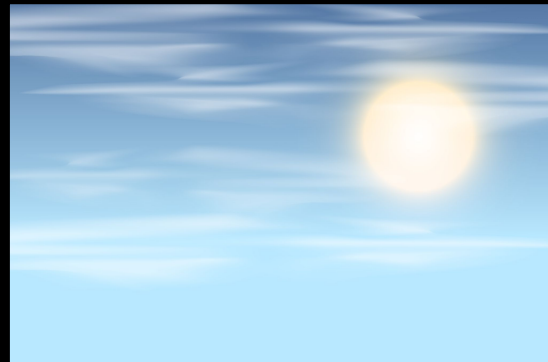
- Machine learning





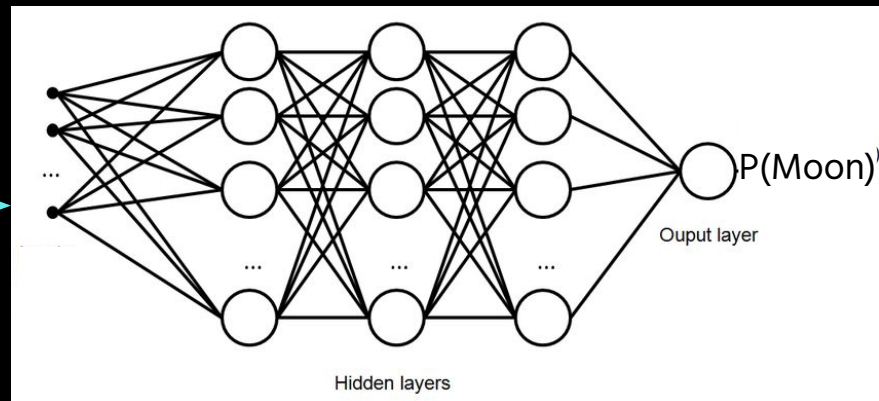
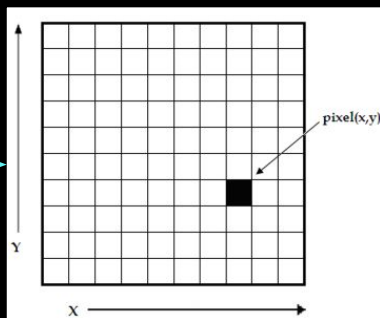
# Is This an Image of the Moon?

- Users could try to submit ANY images
- How can we assure that the image contains the Moon before being included in test data?



# Solution: Machine Learning

Classifying Images into Moon/Not Moon





# Solution

## Steps:

1. Assembling training data
2. Setting hyperparameters
3. Training model
4. Optimizing model

569 training images, 43 test images

497 images of the Moon, 114 images with no Moon

| Name  | ↓                              |
|---|--------------------------------|
|  | Sherzai No Moon                |
|  | Sheikh Waning Crescent         |
|  | Ramirez Third Quarter          |
|  | Ho Full Moon                   |
|  | Hineno New Moon                |
|  | Guevara First Quarter          |
|  | Elzein waning gibbo moon       |
|  | Cruz random negatives          |
|  | Bentley waxing gibbous         |
|  | Abdusemed Waxing Crescent Moon |

# Results

```
Epoch 50/50
```

```
18/18 [=====] - 11s
```

```
<keras.callbacks.History at 0x7fcf9f92c400>
```

```
val_accuracy: 0.9592
```

# Example Results

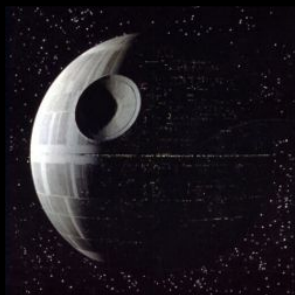
Prediction Made Using  
Trained Model



✓  
0s

```
[11] if result[0][0] == 0:  
      print("This image is of the moon!")  
      else:  
          print("There is no moon in this image!")
```

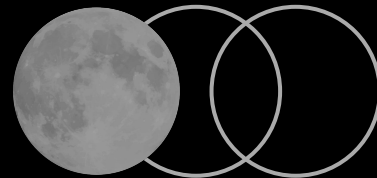
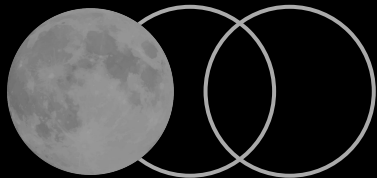
This image is of the moon!



✓  
0s

```
[9]  if result[0][0] == 0:  
      print("This image is of the moon!")  
      else:  
          print("There is no moon in this image!")
```

There is no moon in this image!



6

# Future Work

Nadir Abdusemed, Owen Ramirez

# Website/Server Security



- Use a Web Application Firewall (WAF)
- Implement Two-Factor Authentication (2FA)
- Use Encryption for SQL Data
- Implement Role-Based Access Control (RBAC)



# User Engagement

- Enhance user experience
  - See how the moon looked from user's location
  - See how the moon looked on your birthday
  - See how the moon looked a century ago
- Standard dataset for computer vision researcher



# Telescope Integration

- Allow for real time annotation of Telescope images in MoonTrek



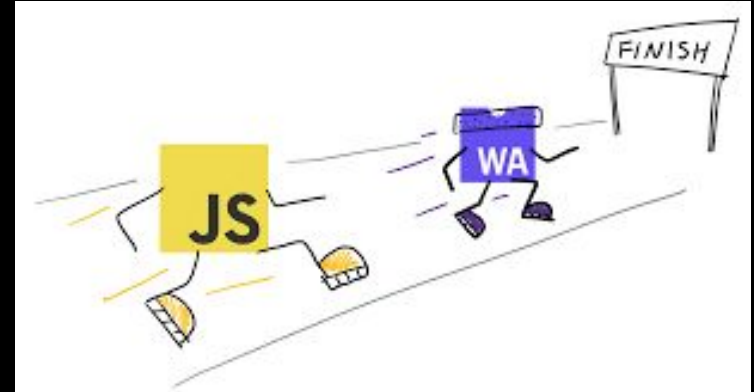
# Image Clarity

- Allow user to zoom in without the limitation of the user's telescope



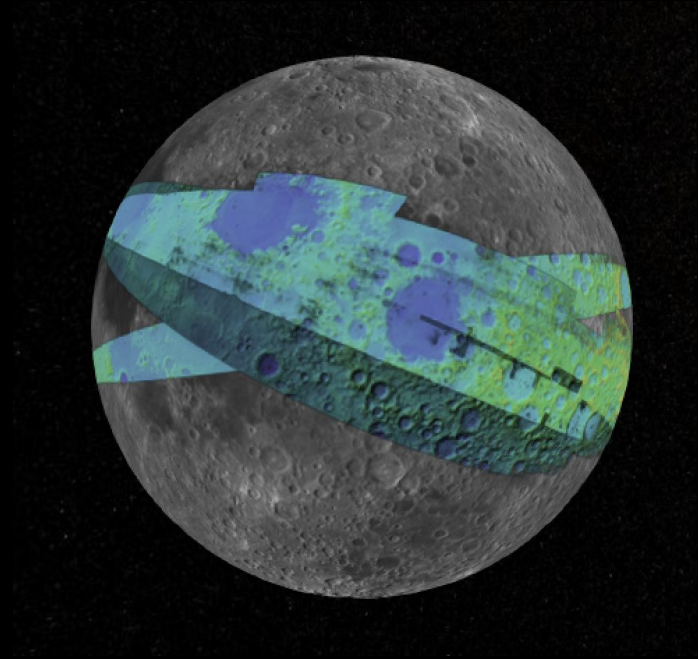
# Shift Processing to Frontside

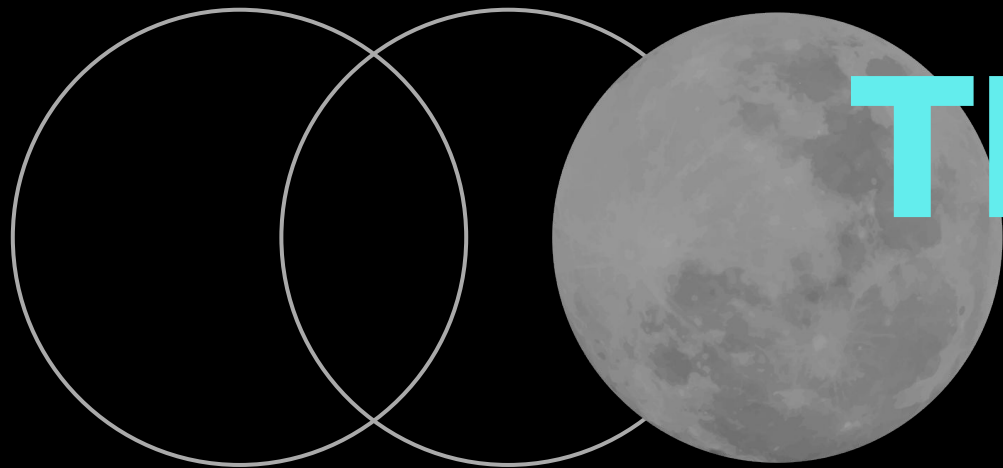
- Allow for all libraries to be ran in the front-end as opposed to the back-end



# GUI Development

- Extend GUI to allow the user to select multiple layers/annotations





# THANKS!

Questions?