The LuNaMaps Project: Advancing Capabilities for Developing and Validating Digital Elevation Models of Rocky Surfaces from Orbital Data

The LuNaMaps Team | AGU24 | December 10, 2024

Outline

- Introduction
- Building Digital Elevations Models
- Pre-built Maps
- Map Validation
- TRN Validation
- Synthetically Enhanced Digital Elevation Models

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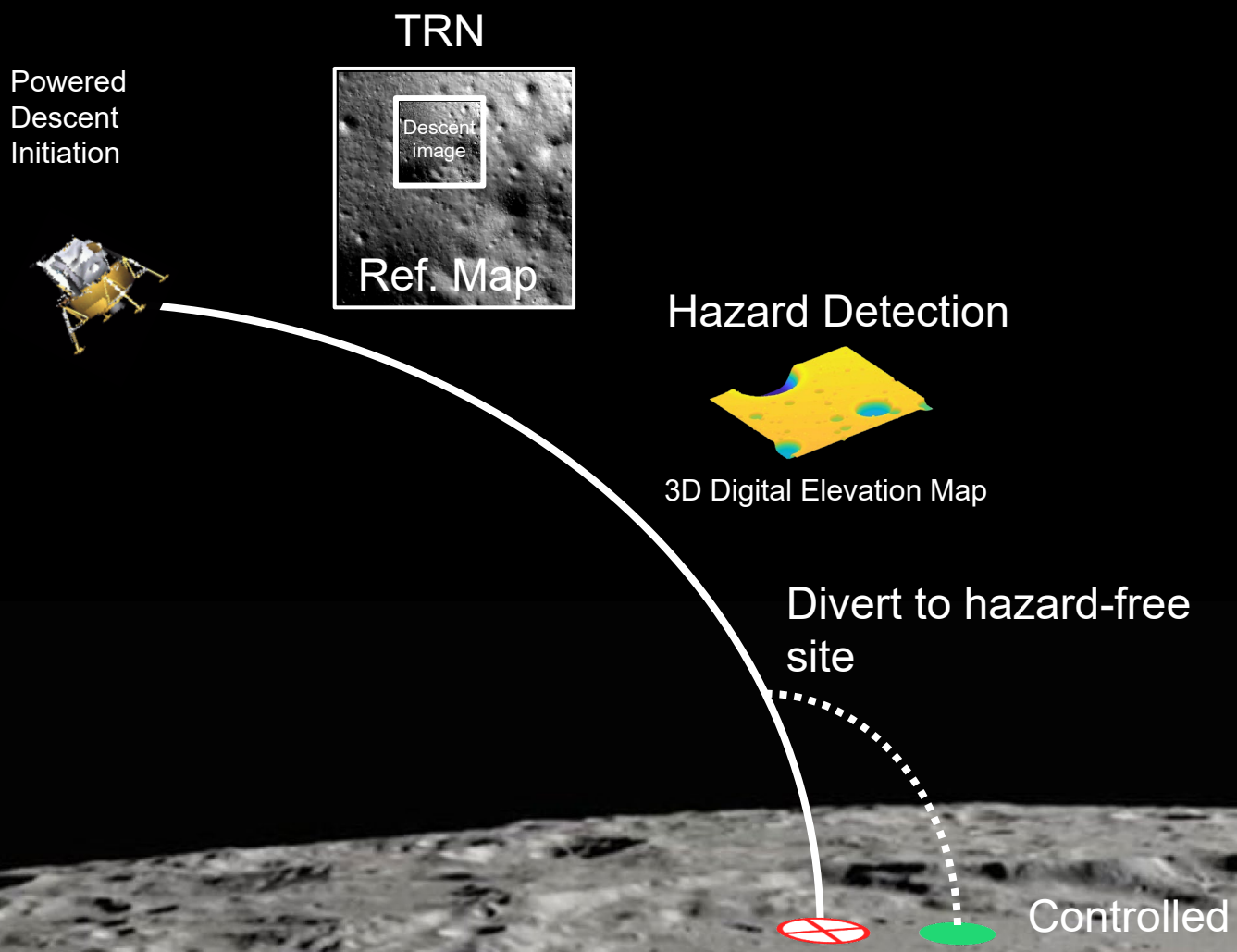
The Need for Better Lunar Map Products



- Currently there are no lunar orbiters that can provide navigation solutions to landers or surface assets
- Landers must rely on Terrain Relative Navigation (TRN) for precision landing
- TRN systems use a **reference map** to localize the spacecraft in lunar coordinates
- Hazard Detection and Avoidance (HDA) systems can quickly scan surface for hazards and perform divert maneuvers
- HDA system development needs **realistic terrain models**

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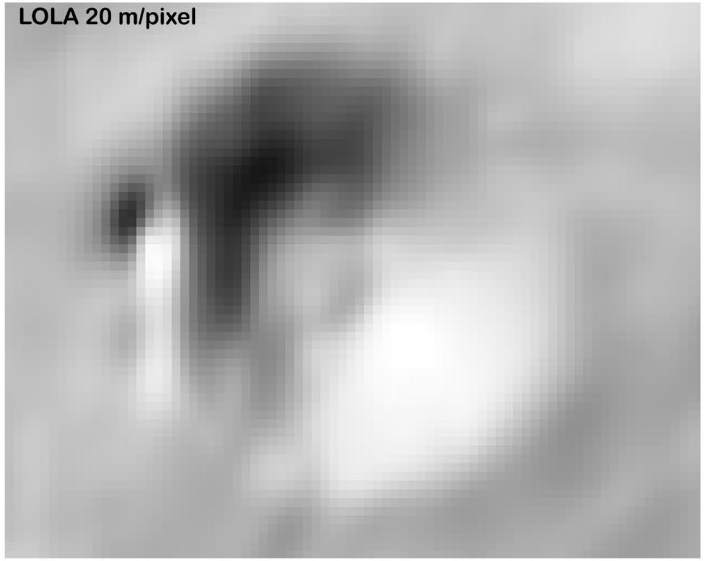
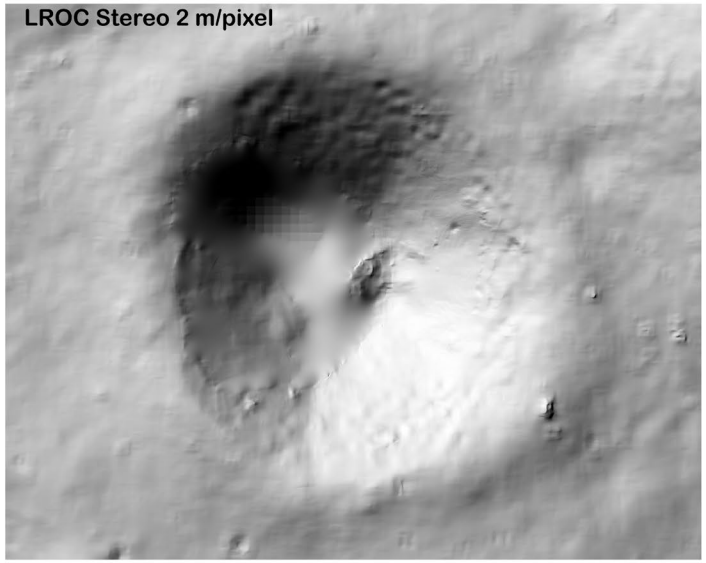
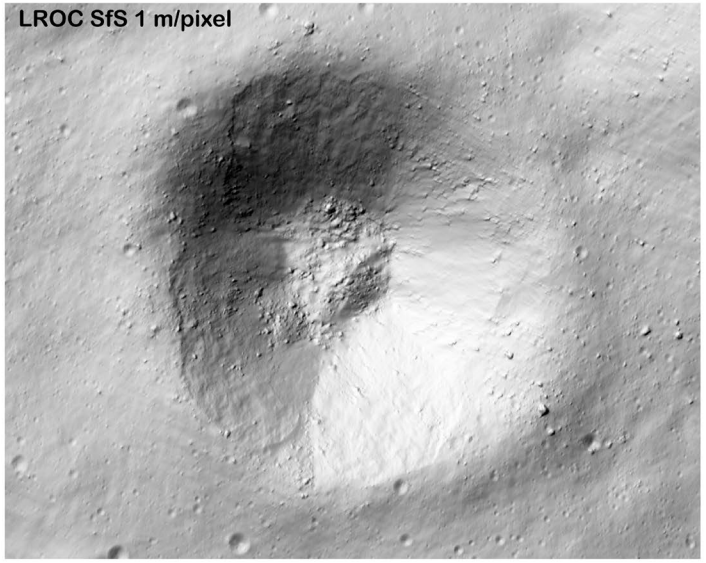
Ames Stereo Pipeline

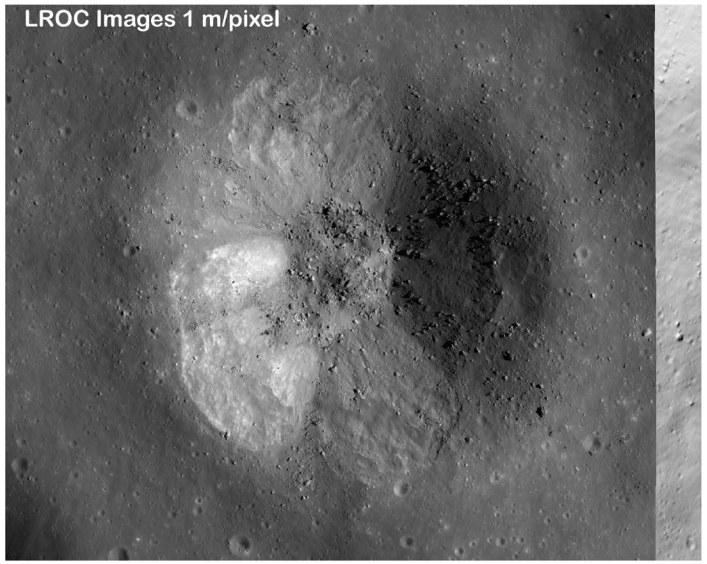
A suite of free and open-source automated geodesy and stereogrammetry tools designed for processing stereo images captured from satellites (around Earth and other planets), robotic rovers, aerial cameras, and historical images, with and without accurate camera pose information.

ASP produces cartographic products, including digital terrain models (DTMs, synonymous with digital elevation models, DEMs), ortho-projected images, 3D models, and bundle-adjusted networks of cameras. These data products are suitable for science analysis, mission planning, and public outreach.



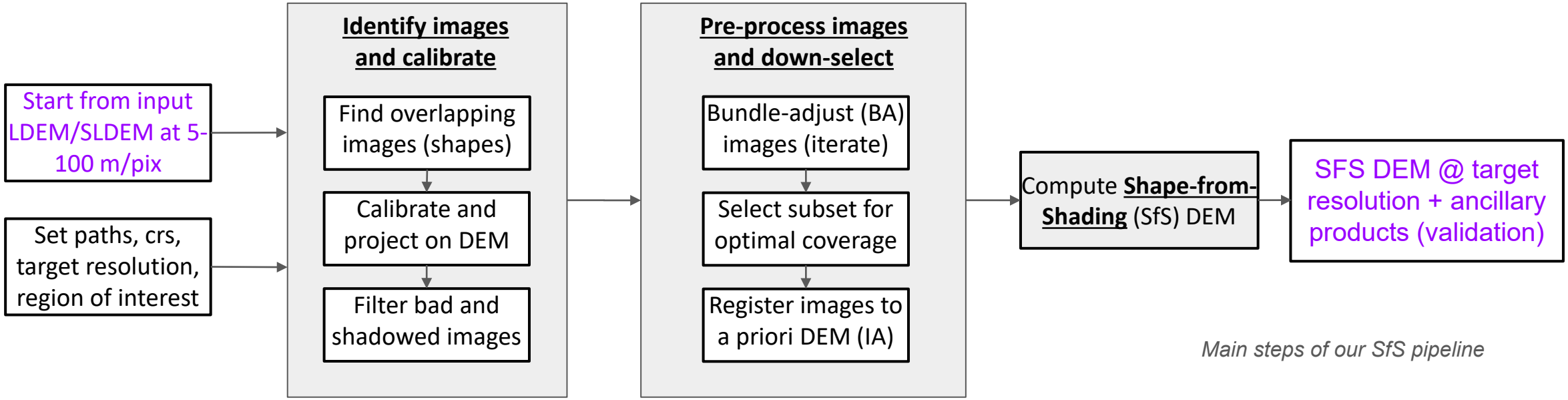






Semi-automated Ground Track Digital Elevation Model Construction

- Semi-automated pipeline of python scripts, USGS ISIS + Ames Stereo Pipeline (ASP) wrappers, and geospatial libraries (gdal, xarray, geopandas)
- Published and ongoing applications to the Moon and Mercury
- Successfully applied to large (e.g., 16x16 km, 300x300 km) regions and 2500+ LROC or MDIS NAC images
- Can run in distributed environment



Main steps of our SfS pipeline

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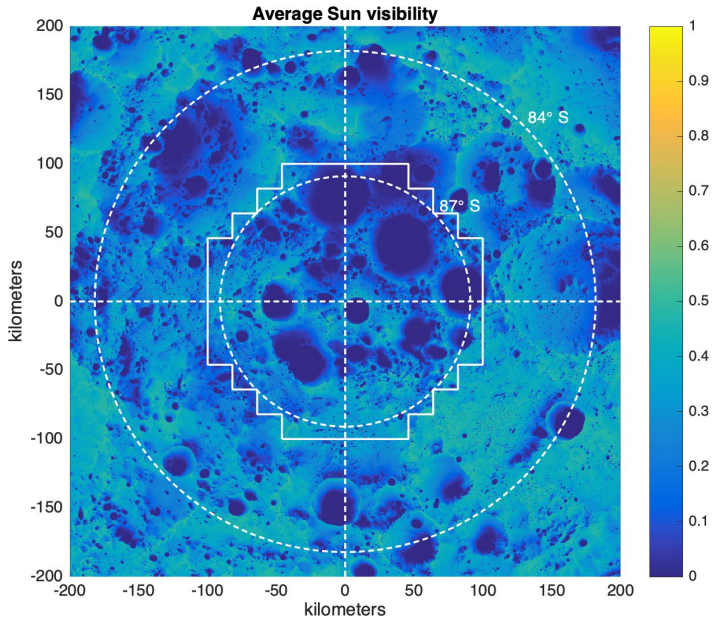
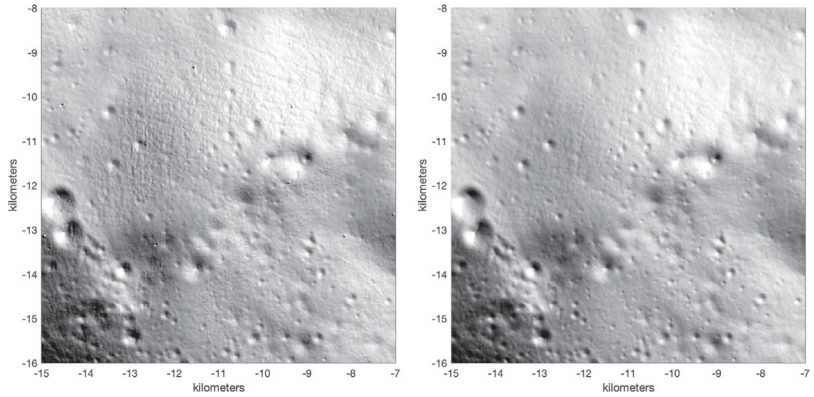
Pre-built maps

- The project built high-quality digital elevation models of the lunar surface at key points of interest.
- Cleaned and higher-resolution LOLA DEMs of the south pole:
  - 80º – 87º south 20 m/pix: https://pgda.gsfc.nasa.gov/products/90
  - 87º – 90º south 5 m/pix: https://pgda.gsfc.nasa.gov/products/81
  - Specific Sites 5 m/pix: https://pgda.gsfc.nasa.gov/products/78
- 1 m/pix shape from shading DEM of the Apollo 16 site:
  - Will soon be available at the Planetary Data System (PDS) Cartography and Imaging Sciences Node Annex
- Additional sites may be released after evaluation of data sensitivity





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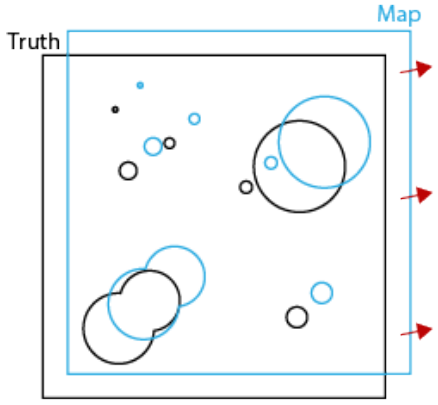
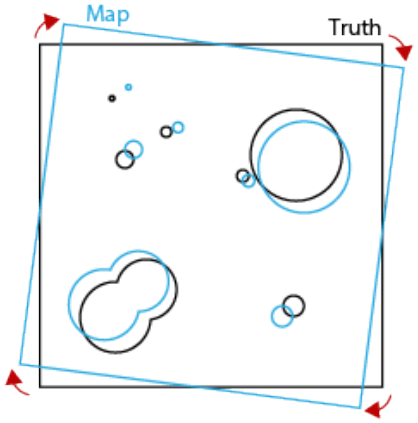
Map Validation

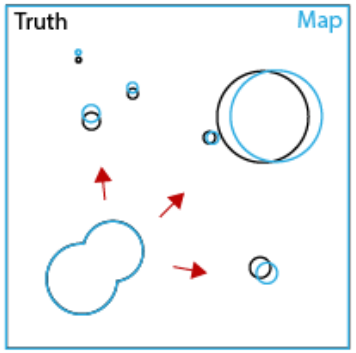
Compare maps from generated using different techniques/data sets.



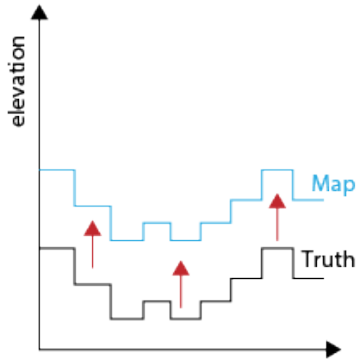
a.) Map Tie Error



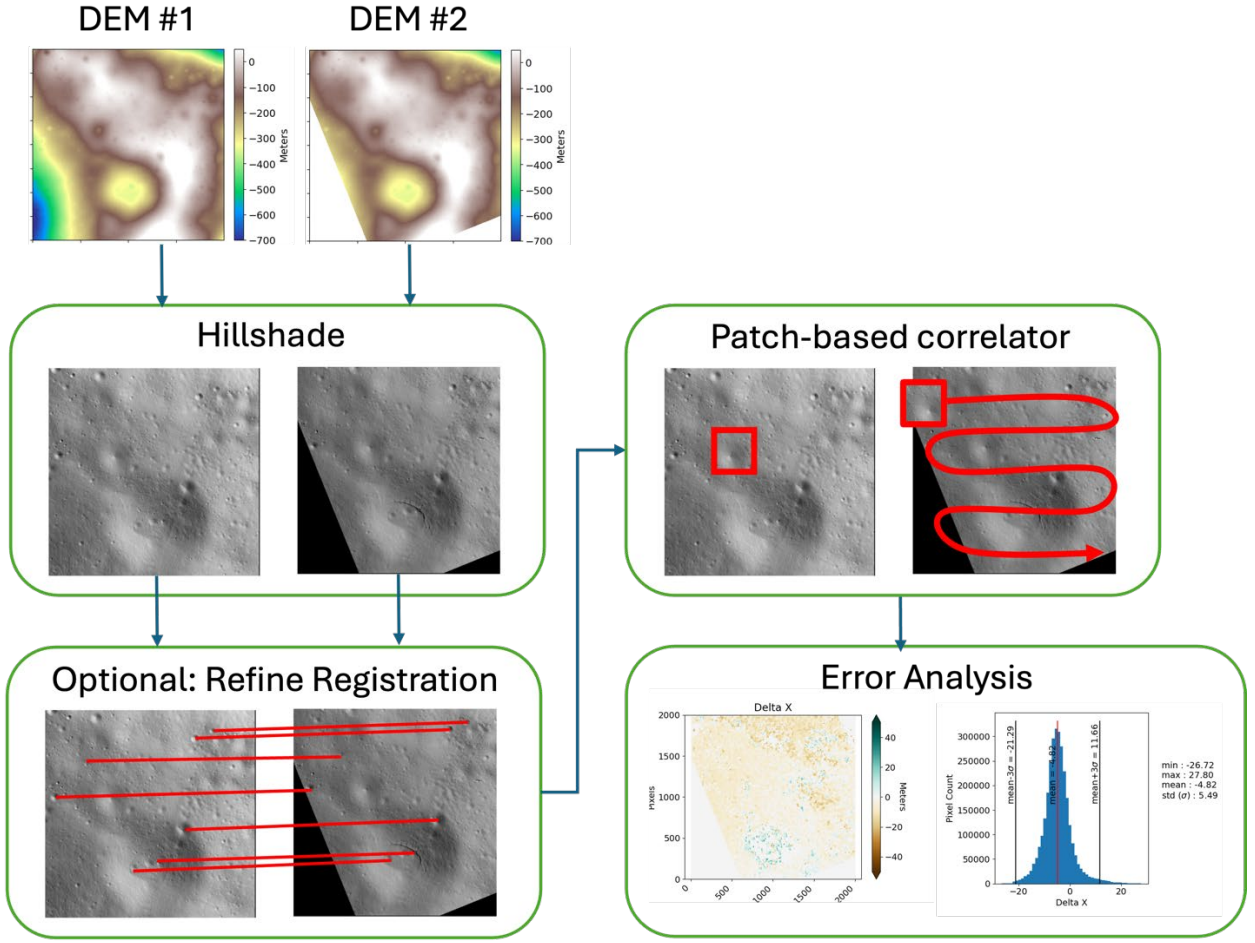
b.) Map Orientation Error



c.) Geometric Distortion



d.) Elevation Error



For more details visit poster “Exploring the Effect of Map Distortion on Optical Terrain Relative Navigation” in session G31B on

Tools available open source at https://github.com/nasa-jpl/landmark_tools

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LuNaMaps TRN Validation Pipeline

- Goal: Determine if it's possible to derive concrete metrics or parameter ranges that relate DEM quality to TRN system performance.
  - Use a combination of camera images and lidar measurements
  - Use different TRN algorithms and implementations and different simulation pipelines
  - Use different quality maps and different kinds of map errors and deformations

Maps
- Create Lunar digital elevation maps of varying quality using LOLA altimetry data

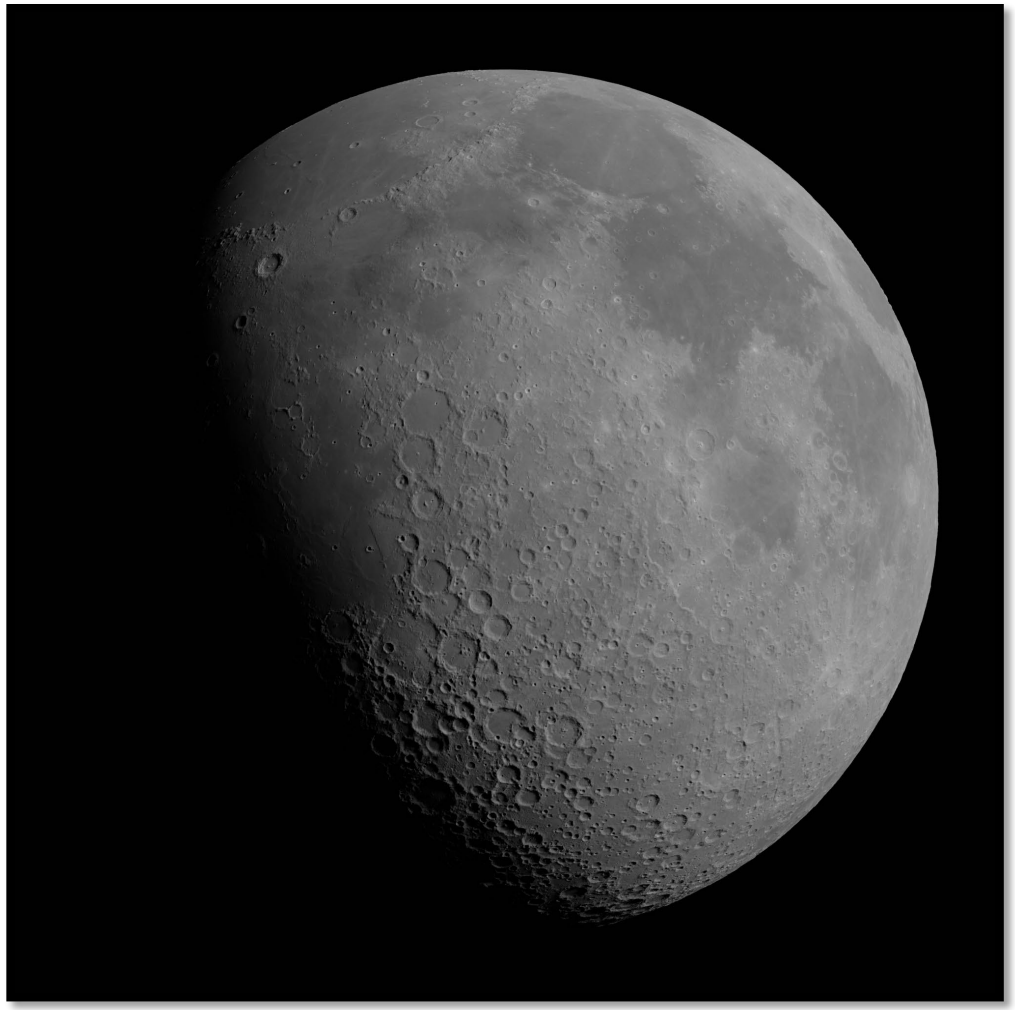
Measurements
- Test various TRN methods on the maps to generate results

Estimation
- Use observed and computed measurements in filter to generate state estimations

Analysis
- Complete parametric runs to see how map quality affects TRN performance

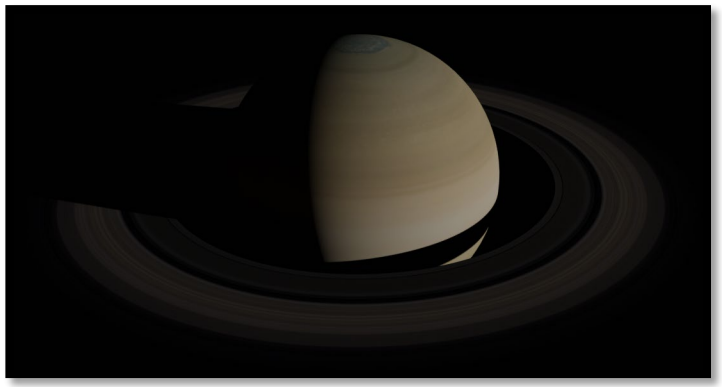
Vira – Rendering Tool

SLDEM2015 + LDEM60S DEMs wrapped with WAC albedo



Bennu rendered with OSIRIS-Rex SPK/CK kernels

Textured Saturn with Rings



Lunar Descent Images

67P SPC Maplets Level-of-Detail System

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LuNaSynth: Synthetic Lunar Terrains for Autonomous Navigation

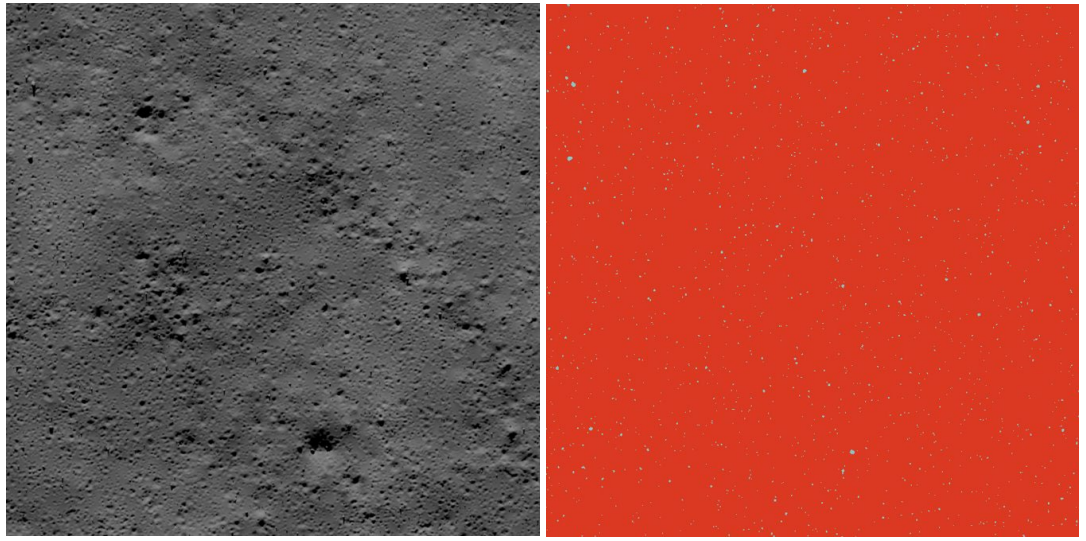
- **Enhance lunar digital elevation maps (DEM)** to create high resolution maps for autonomous navigation
  - **Sculpt craters into the DEM** using current best empirical distributions of crater profile and crater placements
  - **Add a rock field** from empirical rock distributions in representative terrains. Use procedural rocks and scanned rocks models from Apollo missions and terrestrial lunar analog sites.

Implementations available at https://github.com/nasa-jpl/lunasynth and https://github.com/NeoGeographyToolkit/synthterrain

Terrain Creation Process

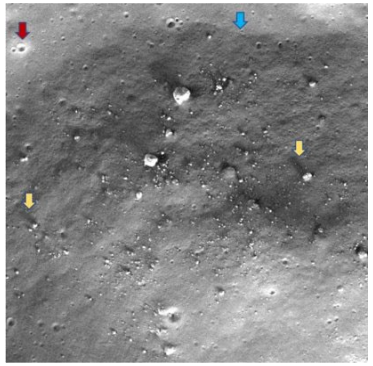
Base DEM | Detailed DEM | Rendered Terrain

Sample output

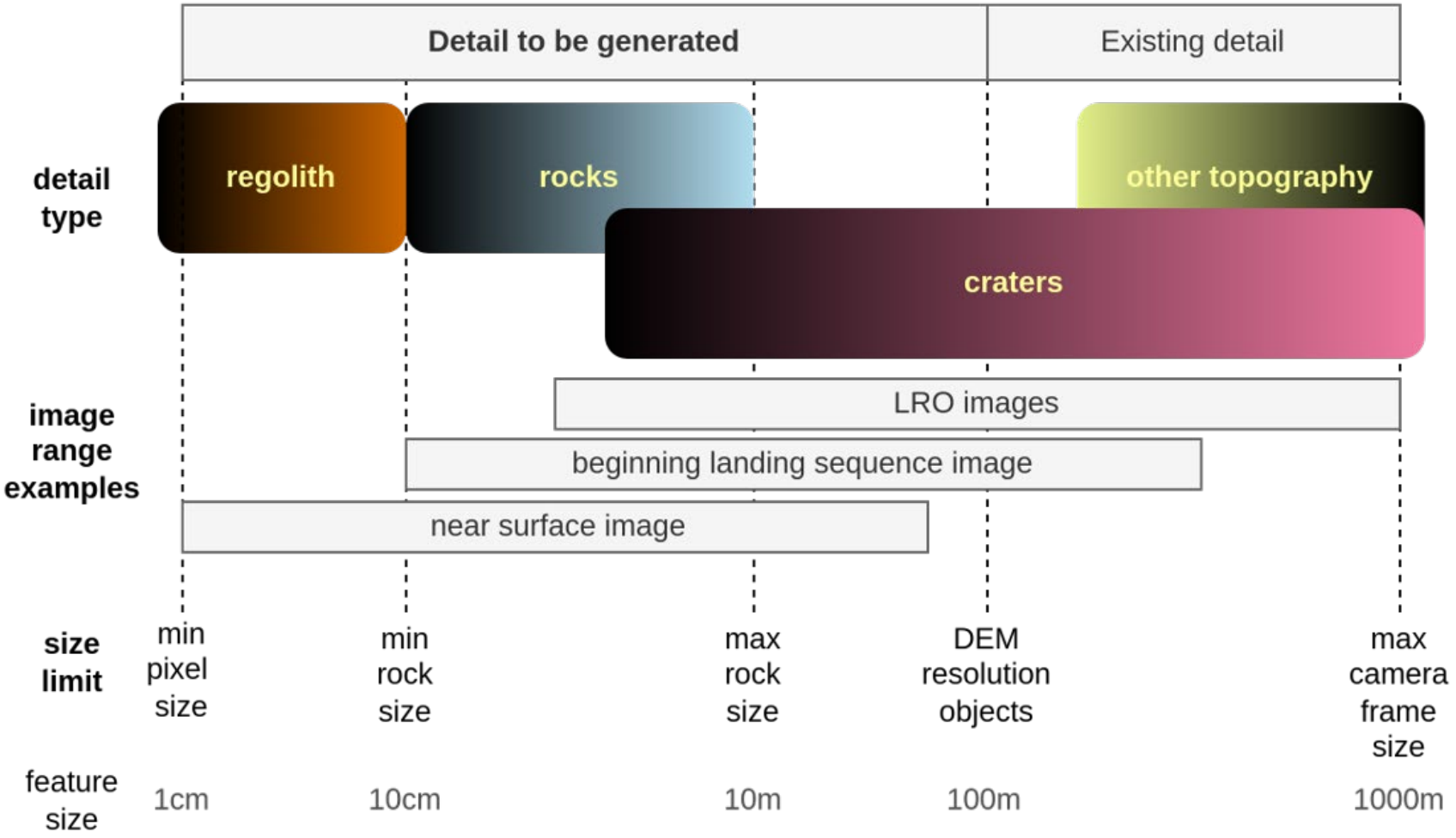


Rendered terrain | Rock field ground truth

Generation Process: from large scale DEM to regolith detail



Examples of **desired** level of detail



Example of **existing** level of detail