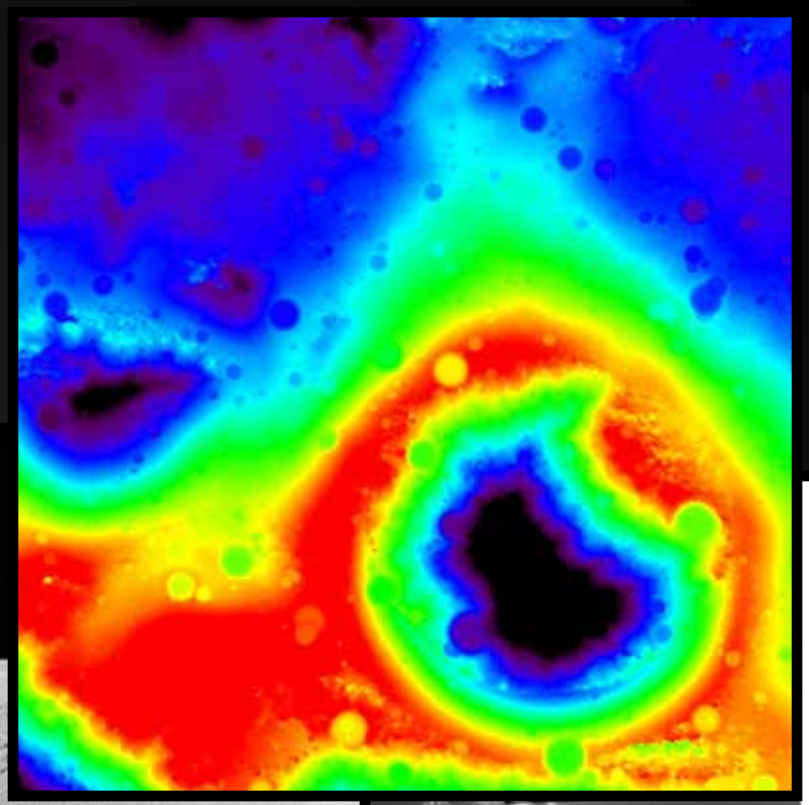
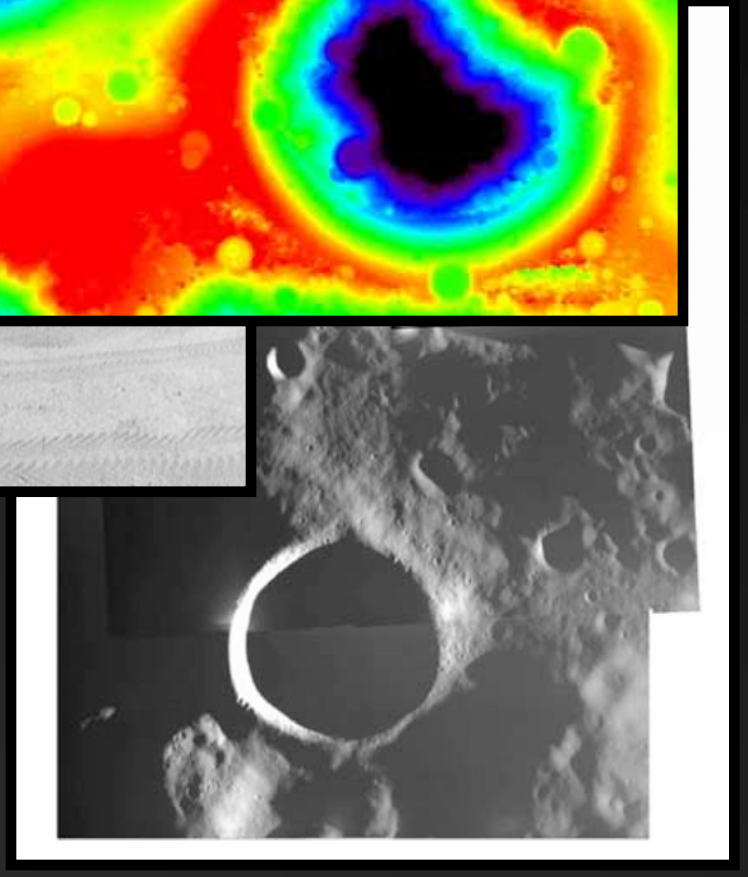
Characterizing Potential Lunar Landing Sites using Synthetic DEMs





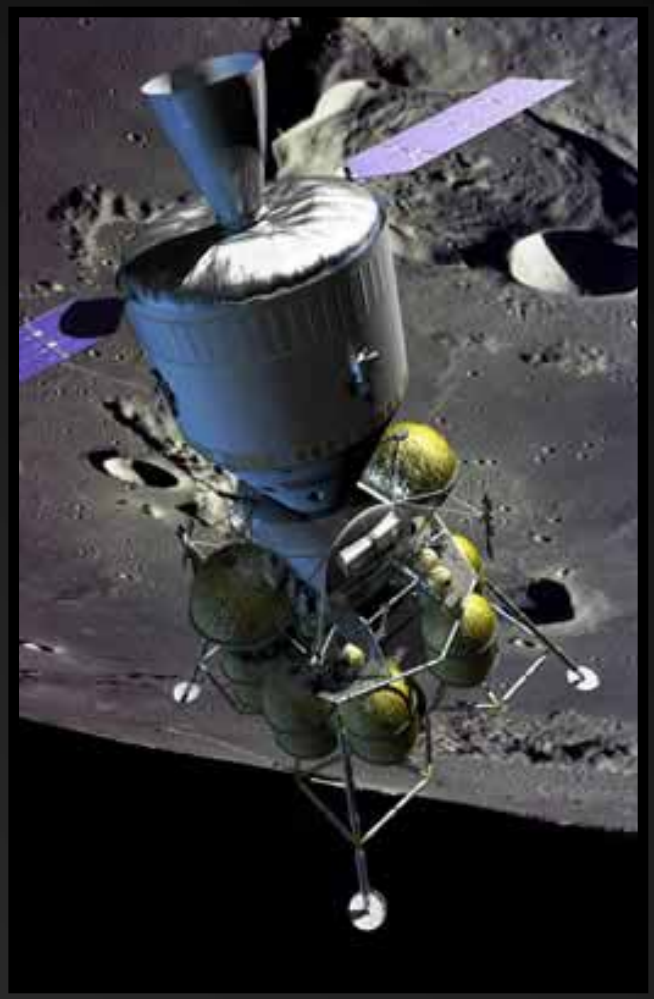
G. Wesley Patterson, N. Lopez,
D. Blewett, A. McGovern
Applied Physics Laboratory

Introduction

ALHAT

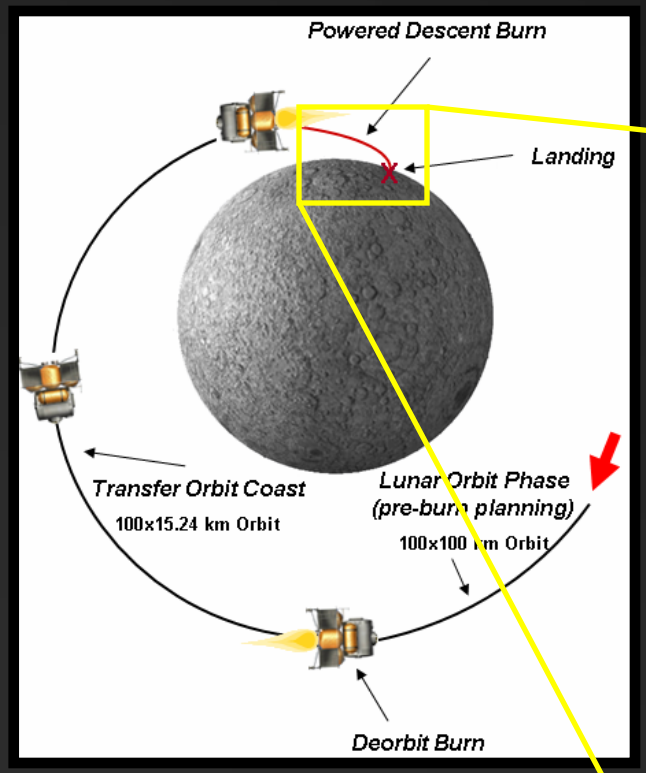
ALHAT Goal

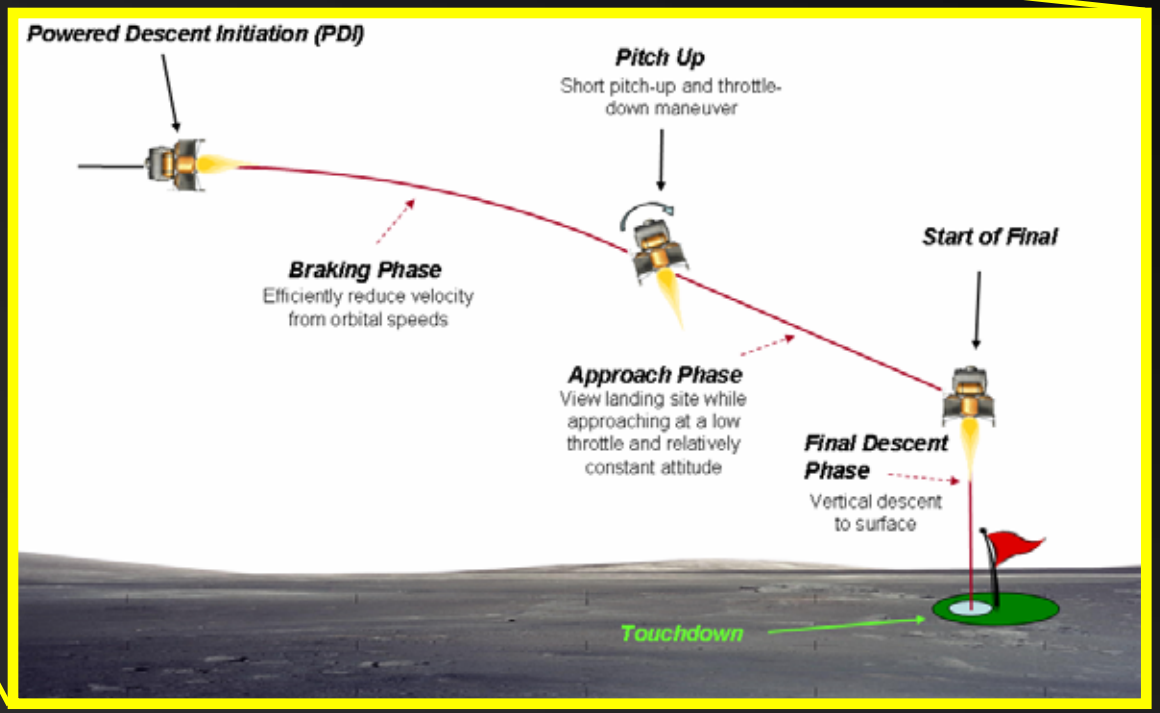
- Develop and bring to TRL 6 an autonomous lunar landing GN&C and sensing system for crewed, cargo, and robotic lunar descent vehicles.
  - The system will be capable of identifying and avoiding surface hazards to enable precision landing (10s of meters) anywhere on the Moon and under any lighting conditions



Introduction

ALHAT





Motivation

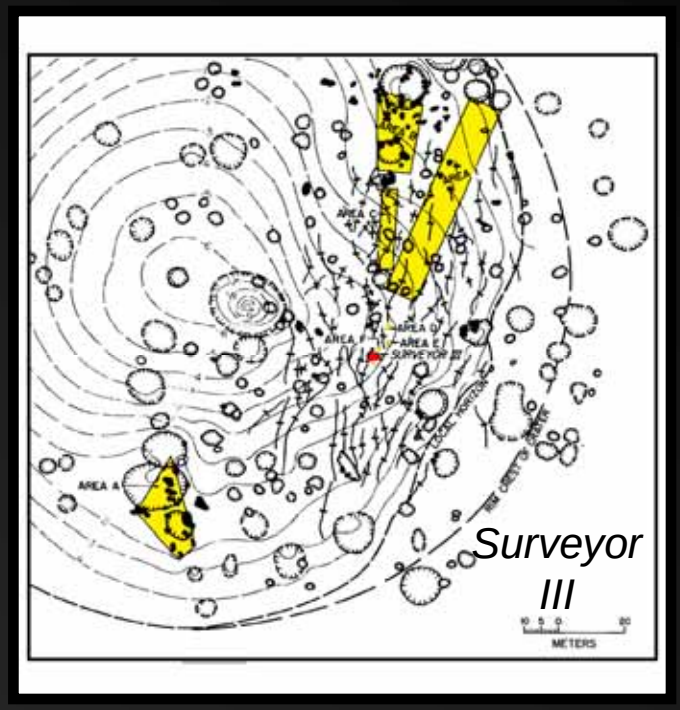
ALHAT

LEM set down on the rim of a small crater, tilting the lander by ~10º and damaging the engine bell

Motivation

ALHAT

- Can we accurately represent the density of hazards that may be encountered by future landed missions to the Moon?
- There is a gap between the resolution coverage we currently have for potential landing sites at the Lunar South Pole and what we need to detect hazards.

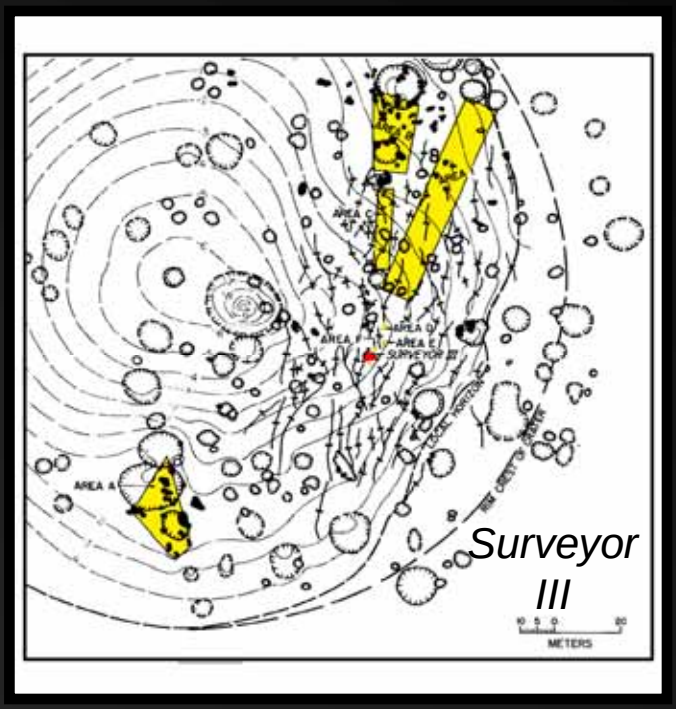


Apollo 16

Motivation

ALHAT

- Can we accurately represent the density of hazards that may be encountered by future landed missions to the Moon?
- There is a gap between the resolution coverage we currently have for potential landing sites at the Lunar South Pole and what we need to detect hazards.
  - We can bridge that gap with statistical methods



Apollo 16

Procedure

ALHAT

Generating cratered surfaces

- Crater morphometry
  - The geometric characteristics of lunar craters can be represented mathematically using equations of the form:

$$N = kD^m$$

where N is a given characteristic (e.g., depth, rim height, etc.), D is the crater diameter, and *k* and *m* are constants specific to a particular characteristic [*Heiken et al., 1991*].

D < 15 km

	k	m
Depth	0.196	1.010
Rim height	0.036	1.014
Rim width	0.257	1.011
Floor diameter	0.031	1.765

Procedure

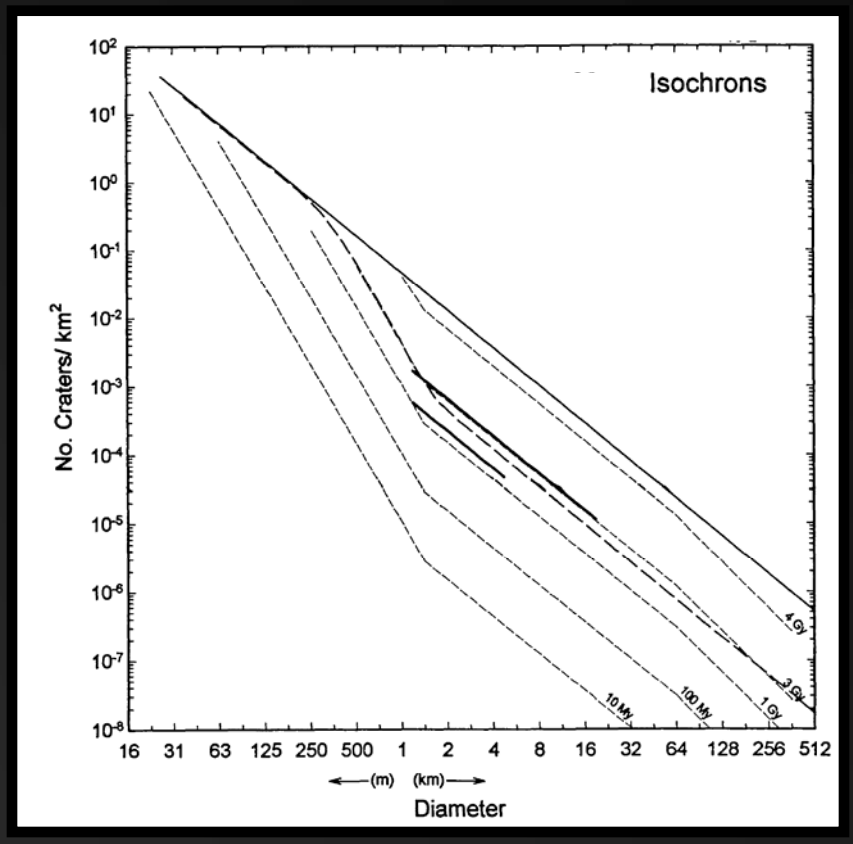
ALHAT

Generating cratered surfaces

- Crater distribution
  - Each portion of a crater distribution can also be represented by the equation:

$$N = kD^m$$

where N = number of craters
k = saturation constant
D = crater diameter
m = slope of distribution

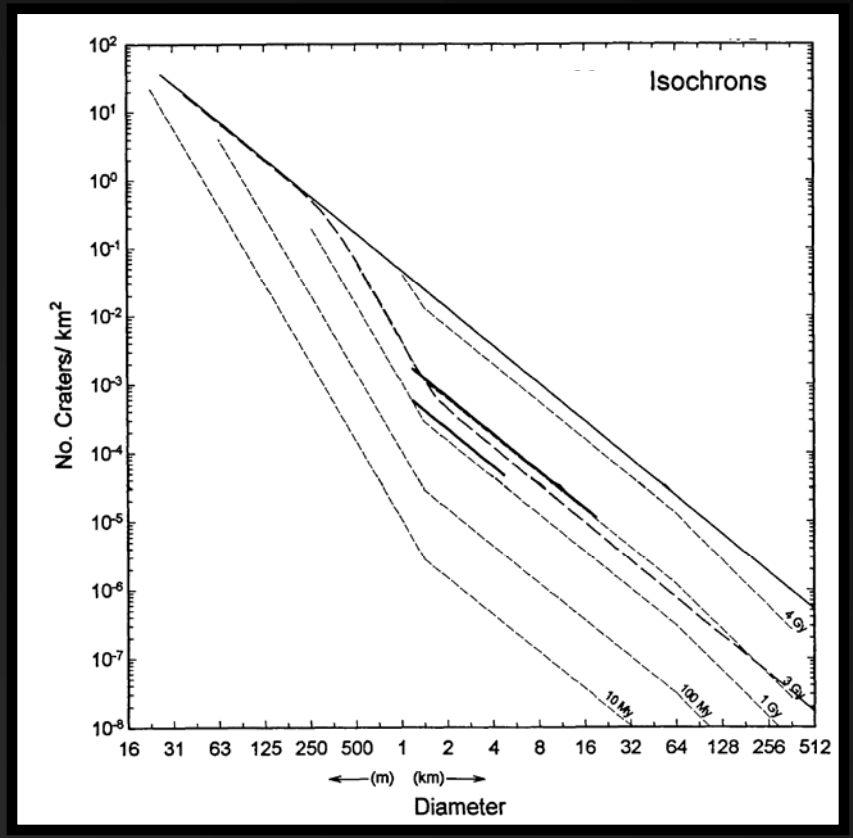


Procedure

ALHAT

Generating cratered surfaces

- Crater distribution
  - The ‘shape’ of a given distribution is dependent on the age of the surface

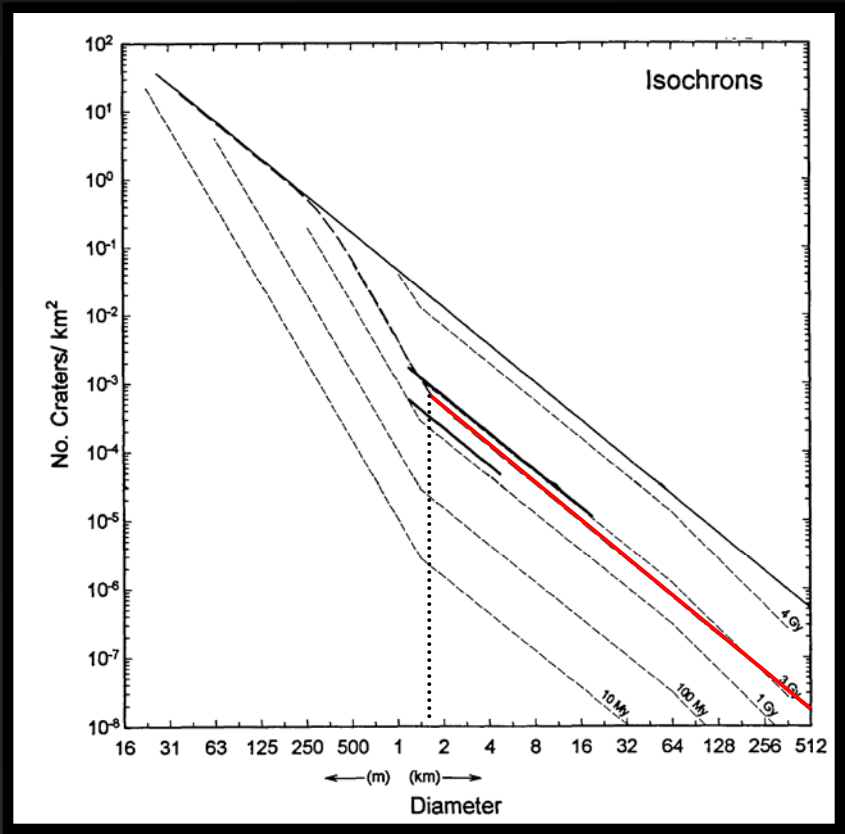


Procedure

ALHAT

Generating cratered surfaces

- Crater distribution
  - The ‘shape’ of a given distribution is dependent on the age of the surface
  - The distribution of craters can be divided into three components
    - Production slope

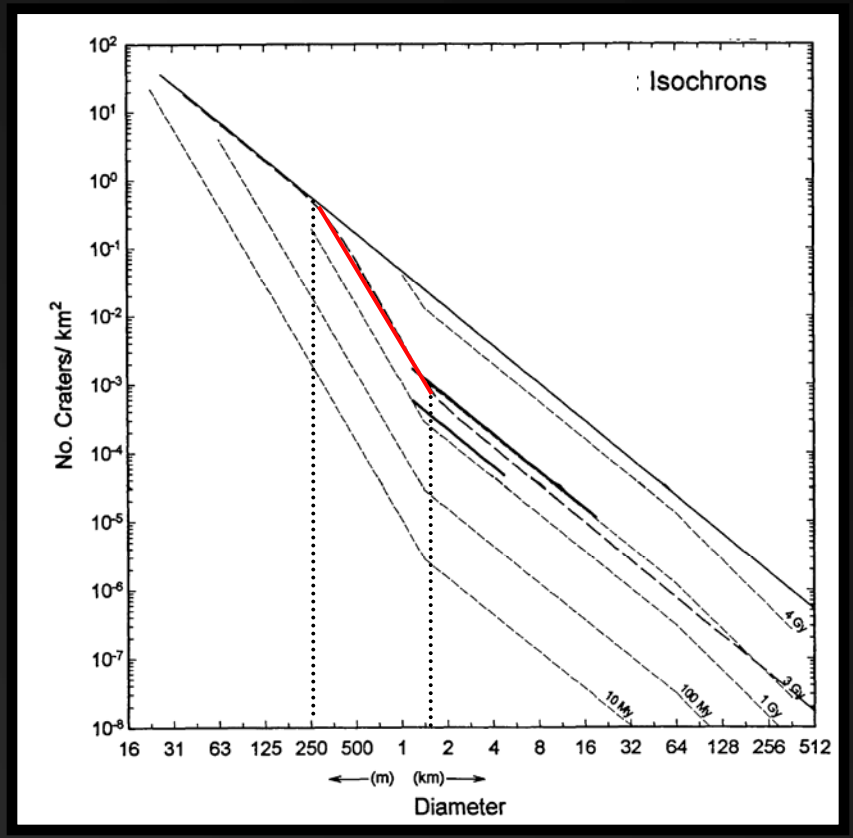


Procedure

ALHAT

Generating cratered surfaces

- Crater distribution
  - The ‘shape’ of a given distribution is dependent on the age of the surface
  - The distribution of craters can be divided into three components
    - Production slope
    - Secondary slope

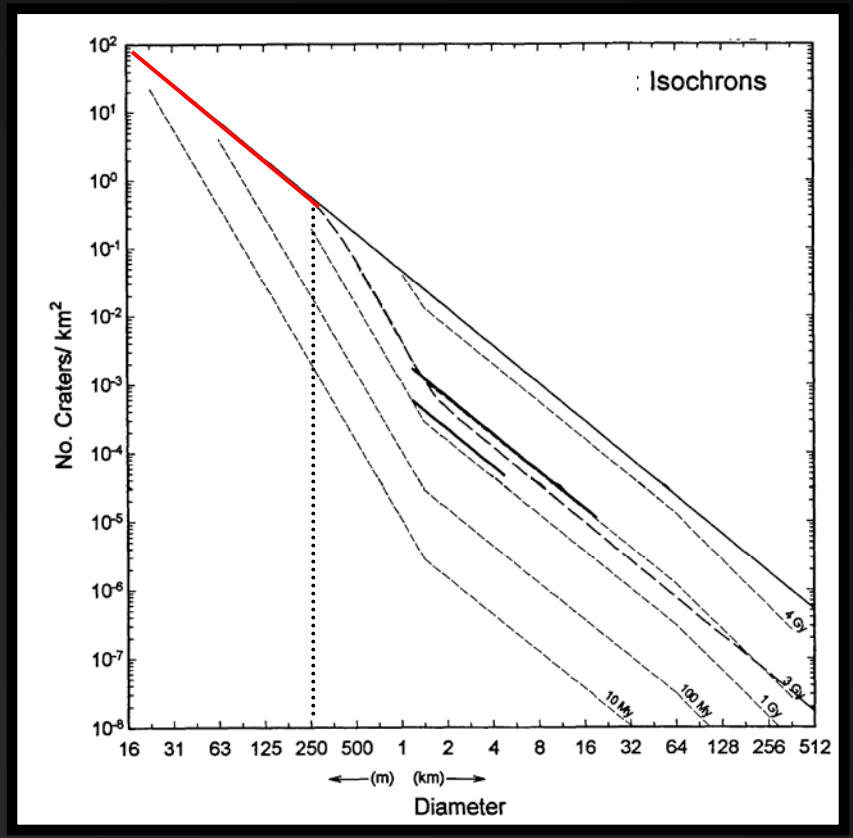


Procedure

ALHAT

Generating cratered surfaces

- Crater distribution
  - The ‘shape’ of a given distribution is dependent on the age of the surface
  - The distribution of craters can be divided into three components
    - Production slope
    - Secondary slope
    - Saturation slope

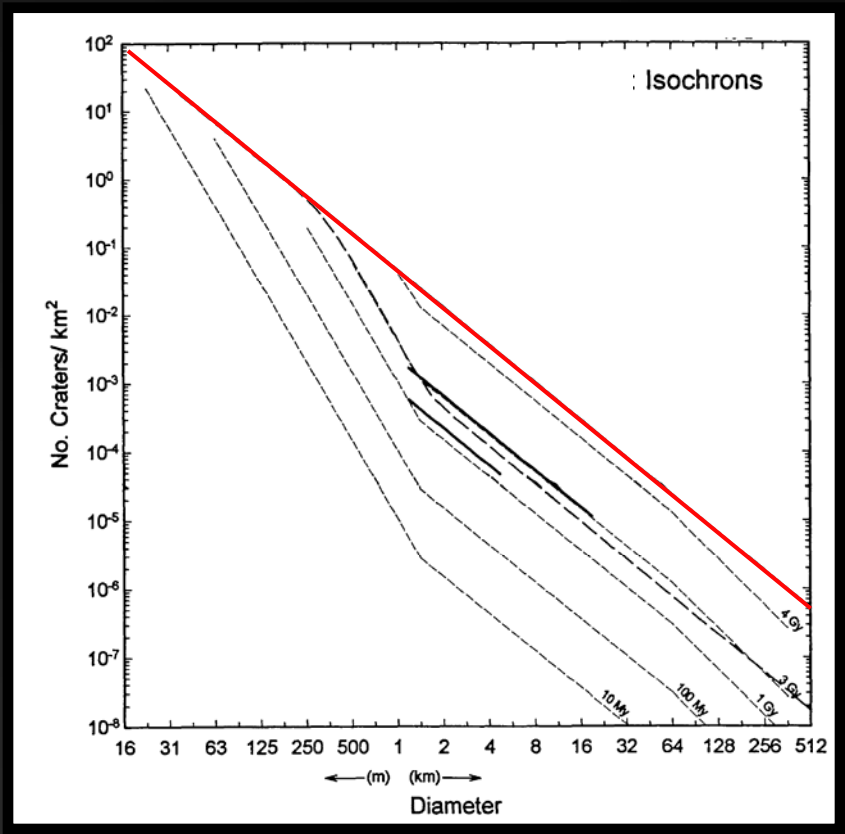


Procedure

ALHAT

Generating cratered surfaces

- Crater saturation
  - The maximum number of craters that can be expressed on a given surface without overlap
  - In theory, saturation for circular geometries is hexagonal-closest-packing (equivalent to 90.5% coverage of the reference area)
  - In reality, a saturation equilibrium is reached before geometric saturation can occur [*e.g., Gault, 1970; Hartmann, 1984, 1995; Neukum et al., 2001*]



Procedure

ALHAT

Lunar Endmembers

- Incremental size-frequency distributions [*Hartmann, 1995; Neukum et al., 2001*]
  - Ancient surface

    $N = 0.04677\ D^{-1.83}$
  - Young surface [Spudis et al., 2008]

    $N = 0.04677\ D^{-1.83}$ (D < 200m)

    $N = 0.002421\ D^{-3.82}$ (D < 1 km)

    $N = 0.001202\ D^{-1.80}$ (D > 1 km)

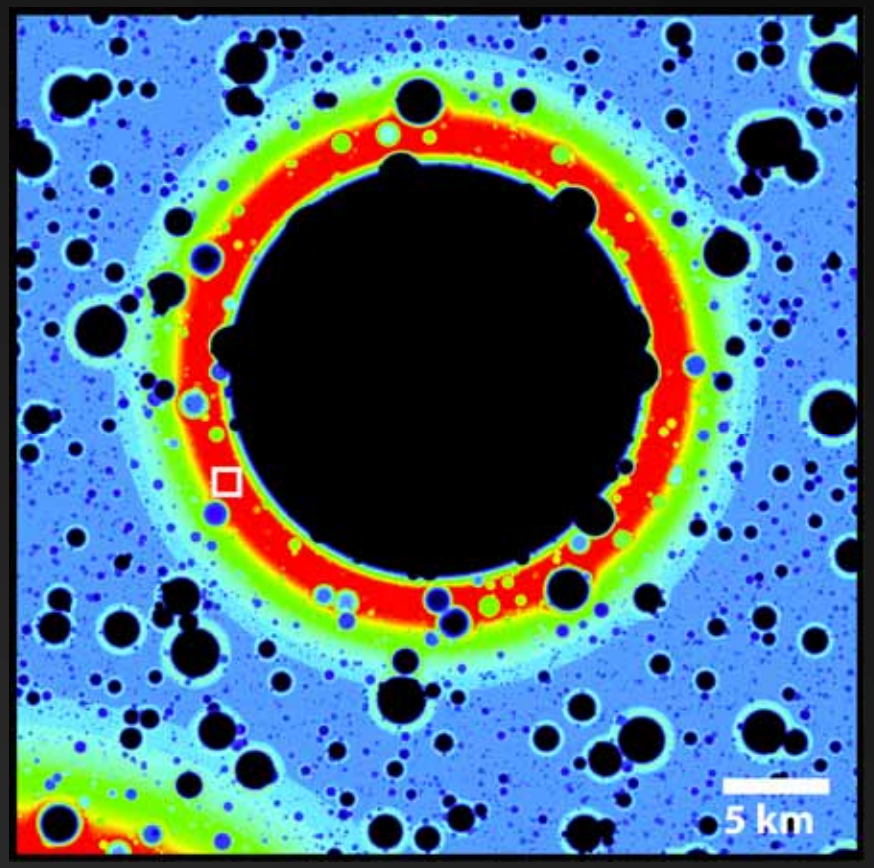
Smart-1 mosaic of Shackleton Crater

Results

ALHAT

Modeling Topography

- Synthetic DEM for an ancient surface crater distribution (1 m/pixel)
  - Polar stereographic projection

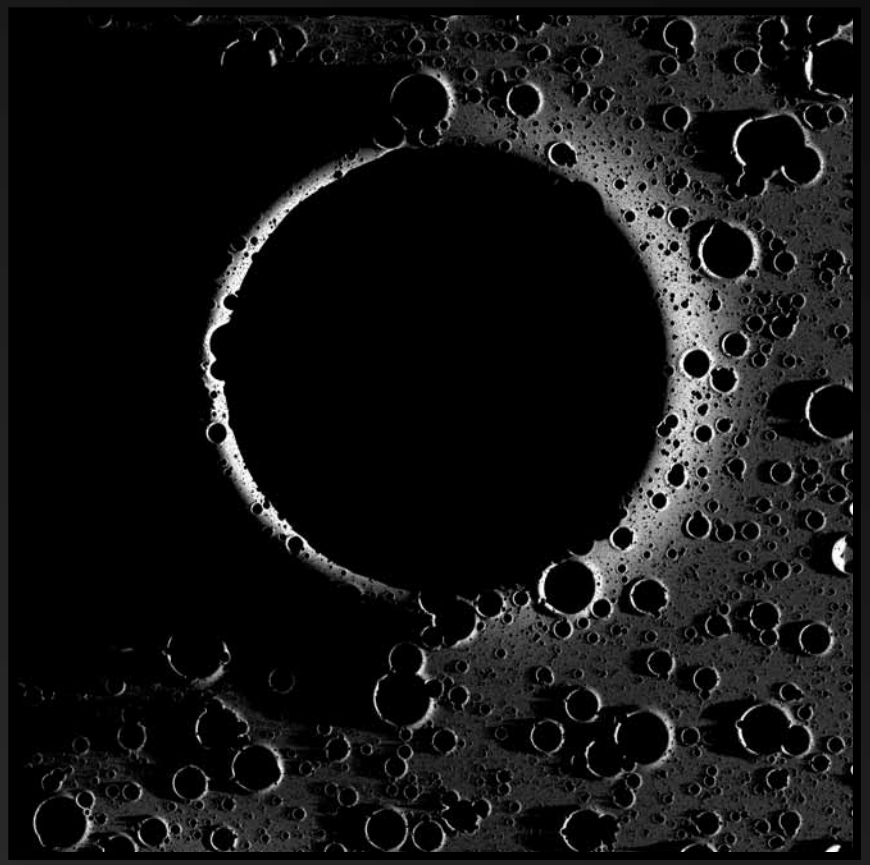


Results

ALHAT

Modeling Topography

- Synthetic DEM for an ancient surface crater distribution (1 m/pixel)
  - Polar stereographic projection
- Lighting conditions for a landing scenario
  - ALHAT trajectory 2011-218T13:51:44.191 (August 6th, 2011)

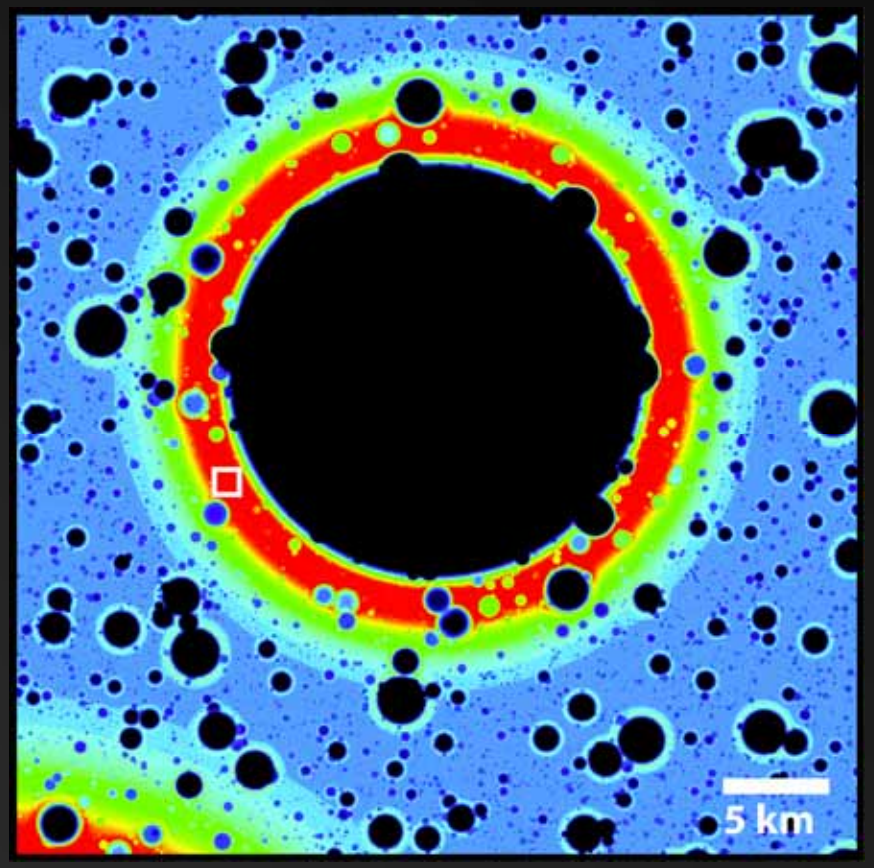


Results

ALHAT

Modeling Topography

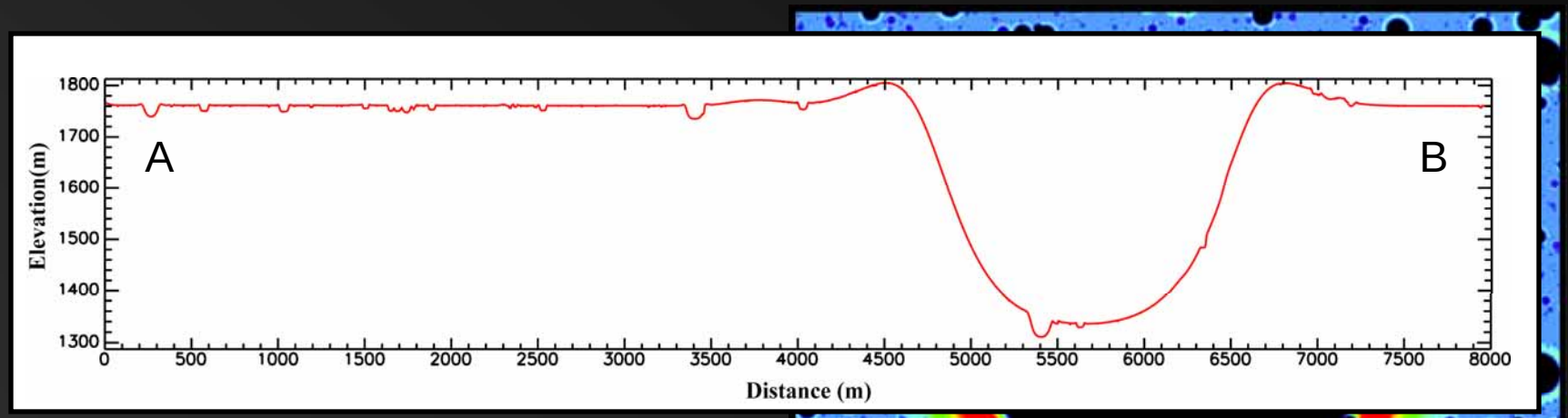
- Synthetic DEM for an ancient surface crater distribution (1 m/pixel)
  - Polar stereographic projection



Results

ALHAT

Modeling Topography

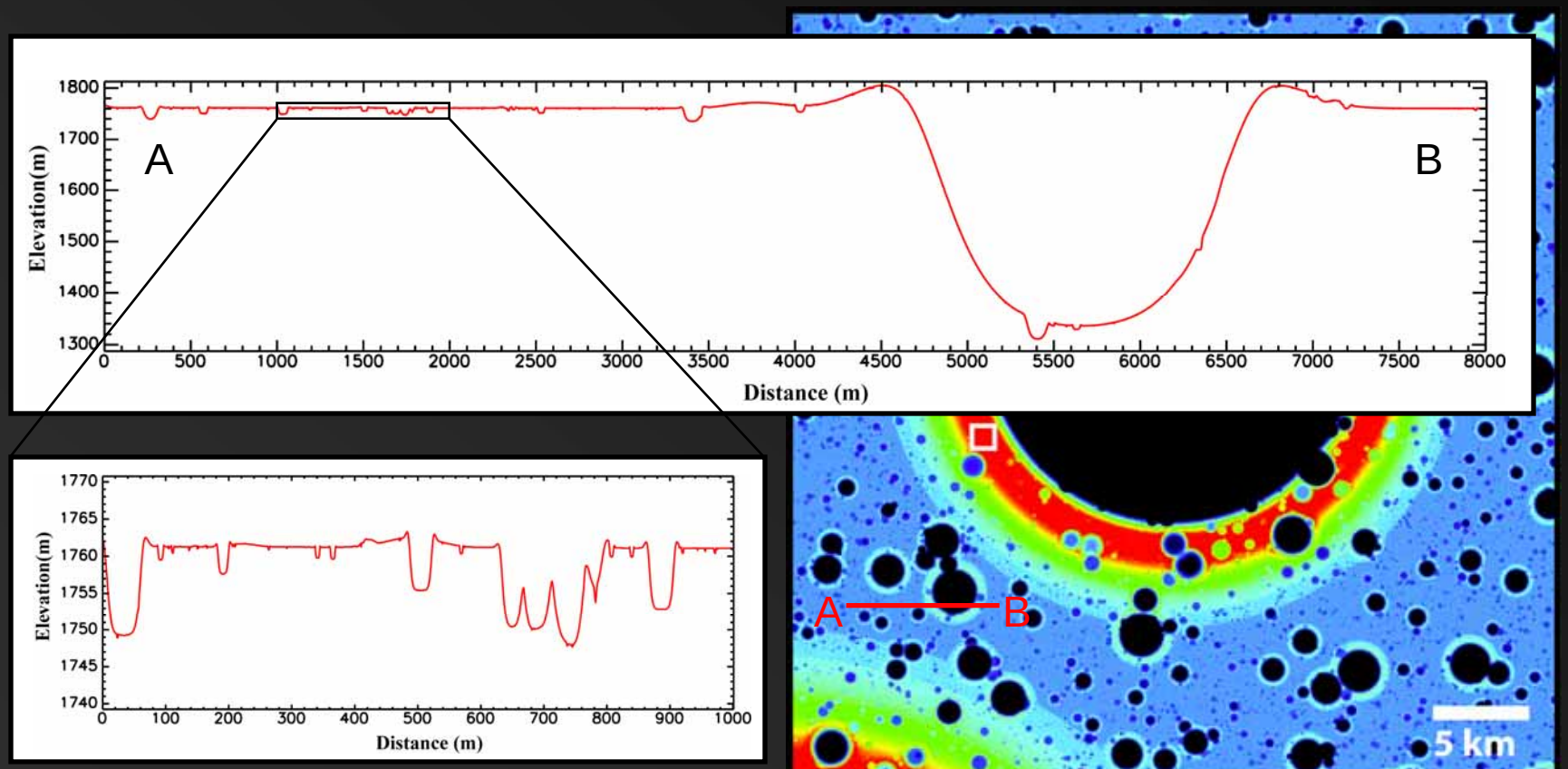


< 1600 Elevation (m) 2100

Results

ALHAT

Modeling Topography

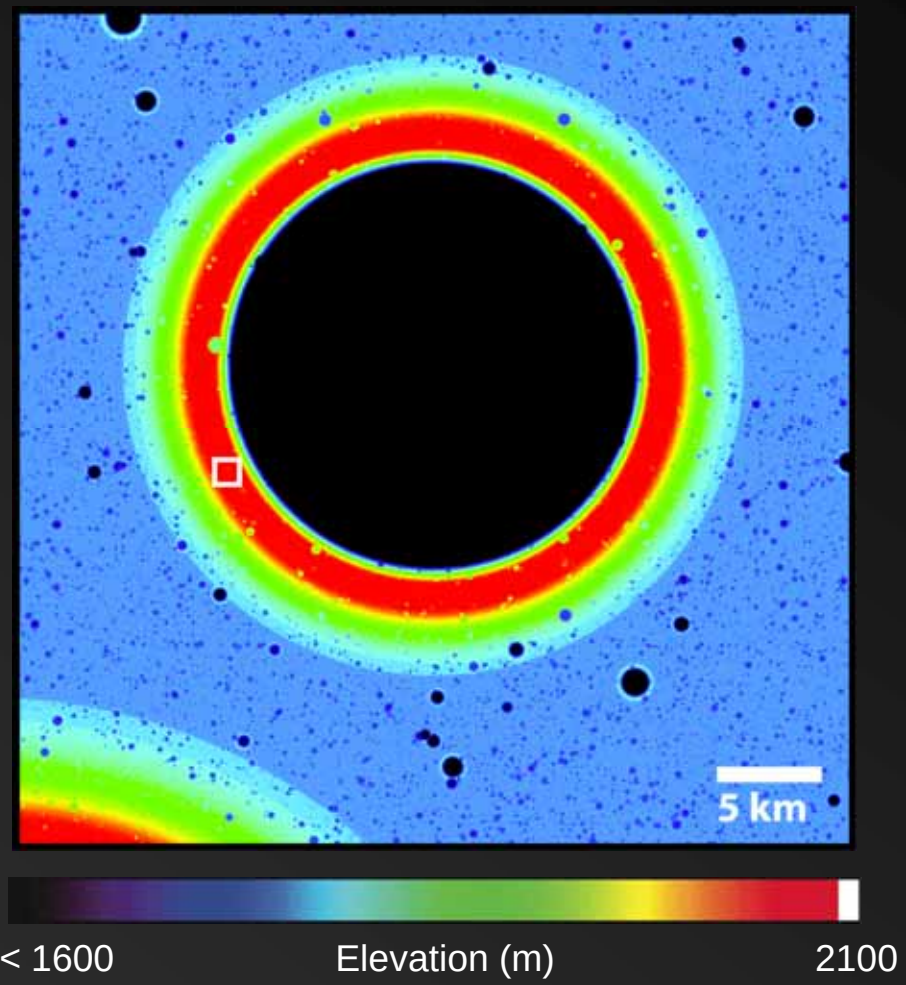


Results

ALHAT

Modeling Topography

- Synthetic DEM for an young surface crater distribution (1 m/pixel)
  - Polar stereographic projection

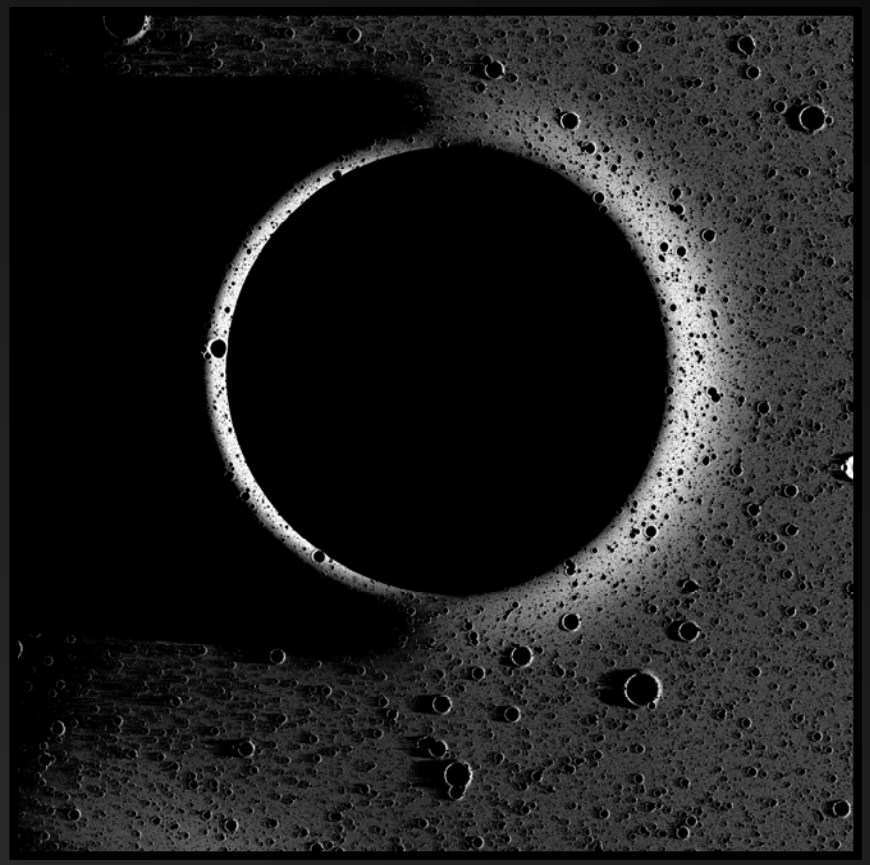


Results

ALHAT

Modeling Topography

- Synthetic DEM for an young surface crater distribution (1 m/pixel)
  - Polar stereographic projection
- Lighting conditions for a landing scenario
  - ALHAT trajectory 2011-218T13:51:44.191 (August 6th, 2011)

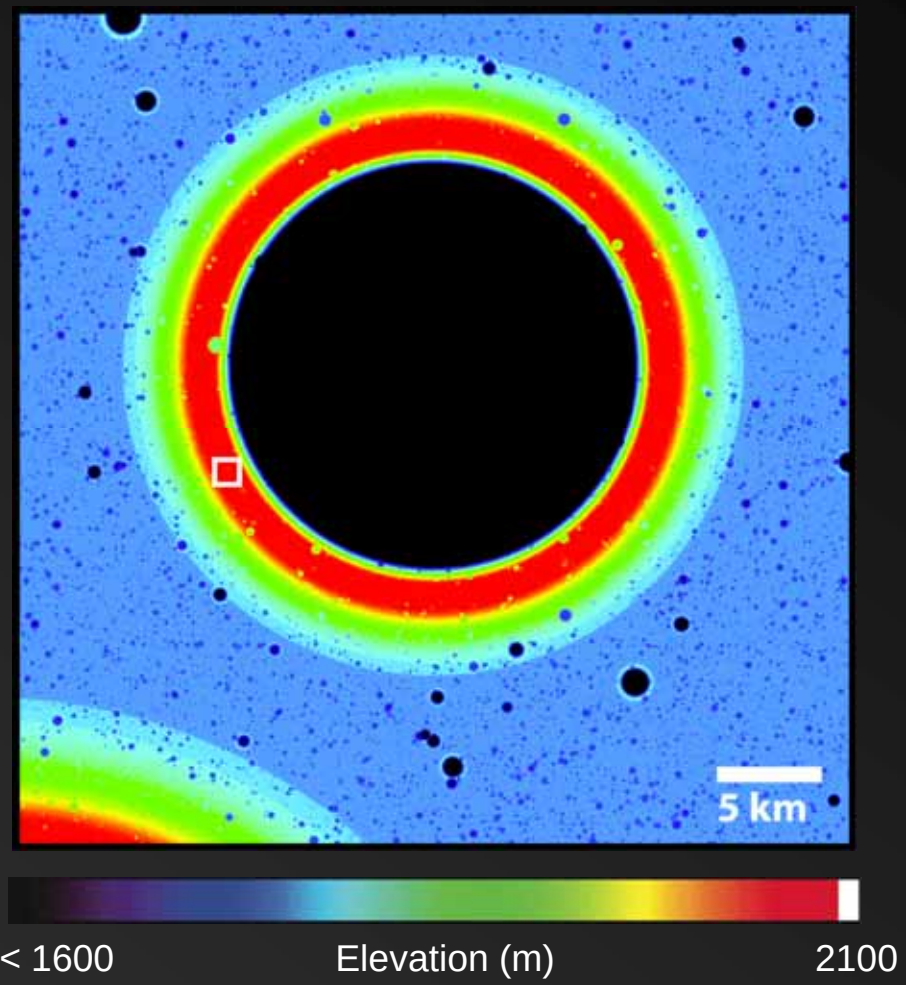


Results

ALHAT

Modeling Topography

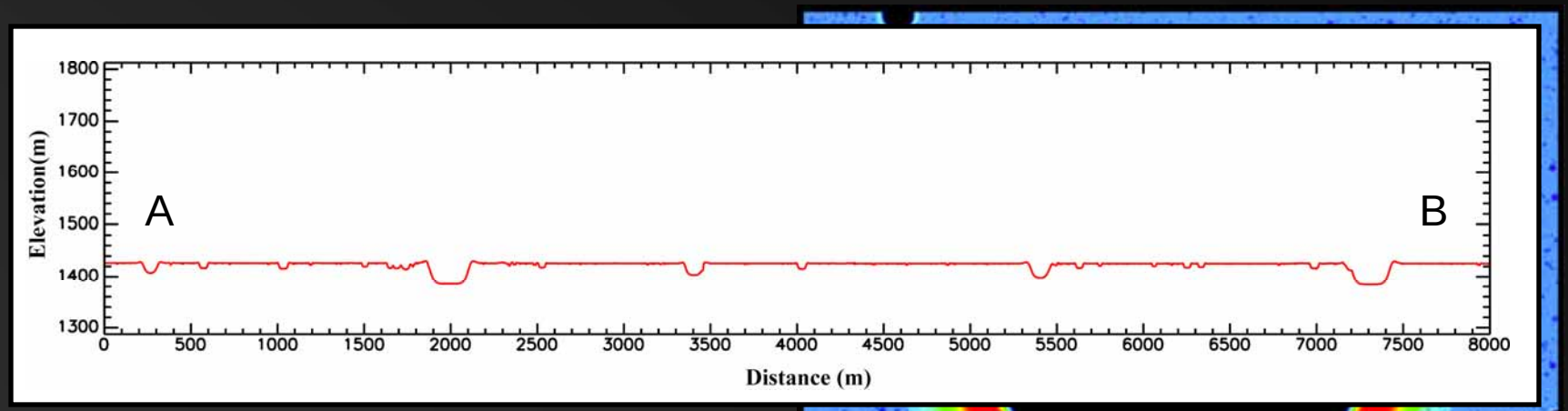
- Synthetic DEM for an young surface crater distribution (1 m/pixel)
  - Polar stereographic projection



Results

ALHAT

Modeling Topography

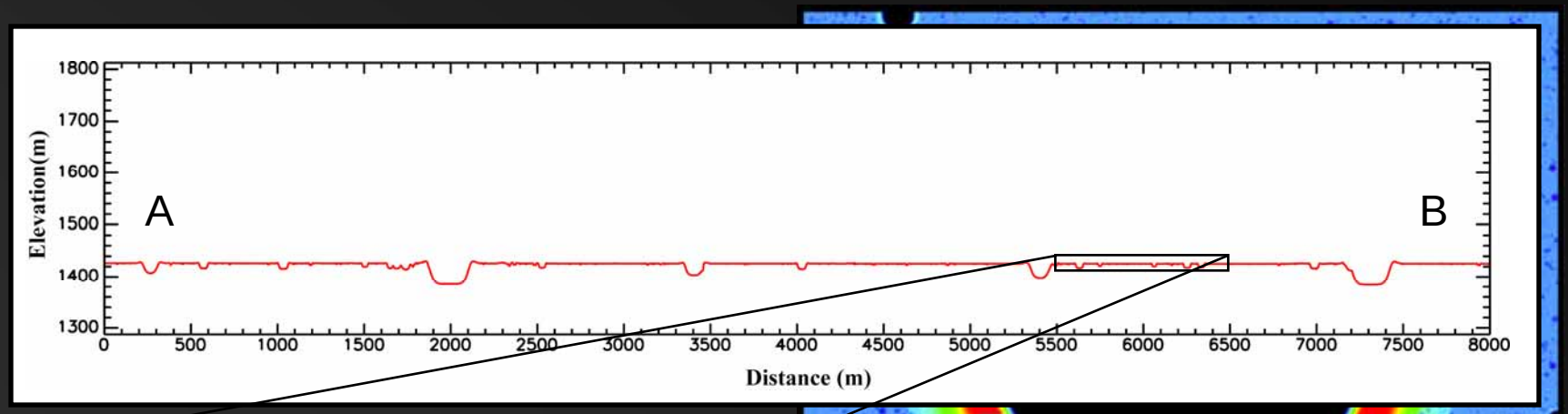


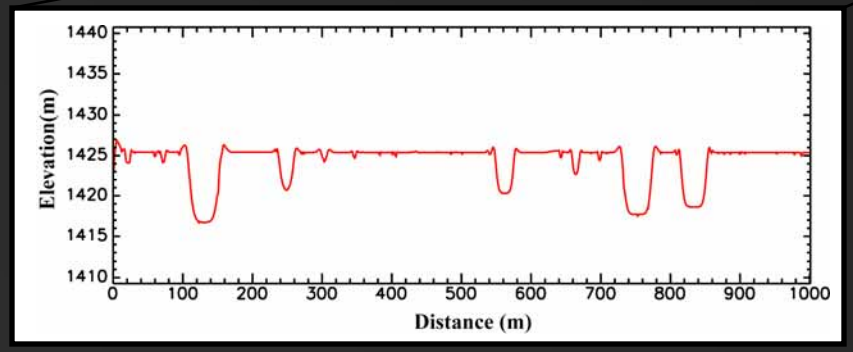
< 1600 Elevation (m) 2100

Results

ALHAT

Modeling Topography





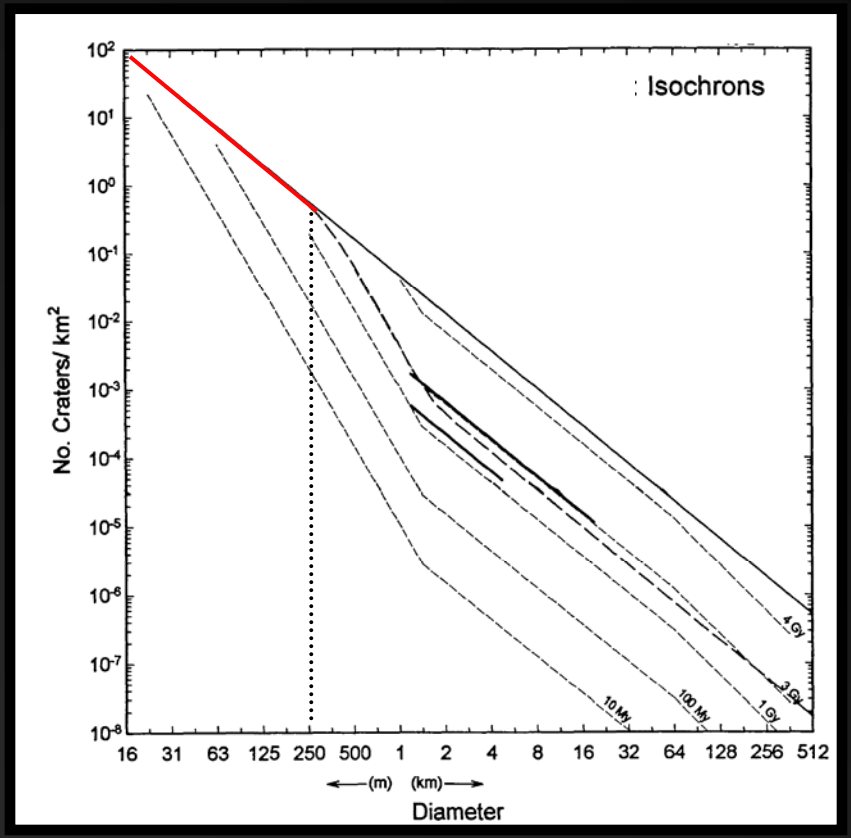
< 1600 Elevation (m) 2100

Results

ALHAT

Equilibrium Saturation

- Crater distribution
  - The ‘shape’ of a given distribution is dependent on the age of the surface
  - At smaller crater sizes, all lunar surfaces have reached equilibrium saturation



Summary

ALHAT

Hazard Avoidance

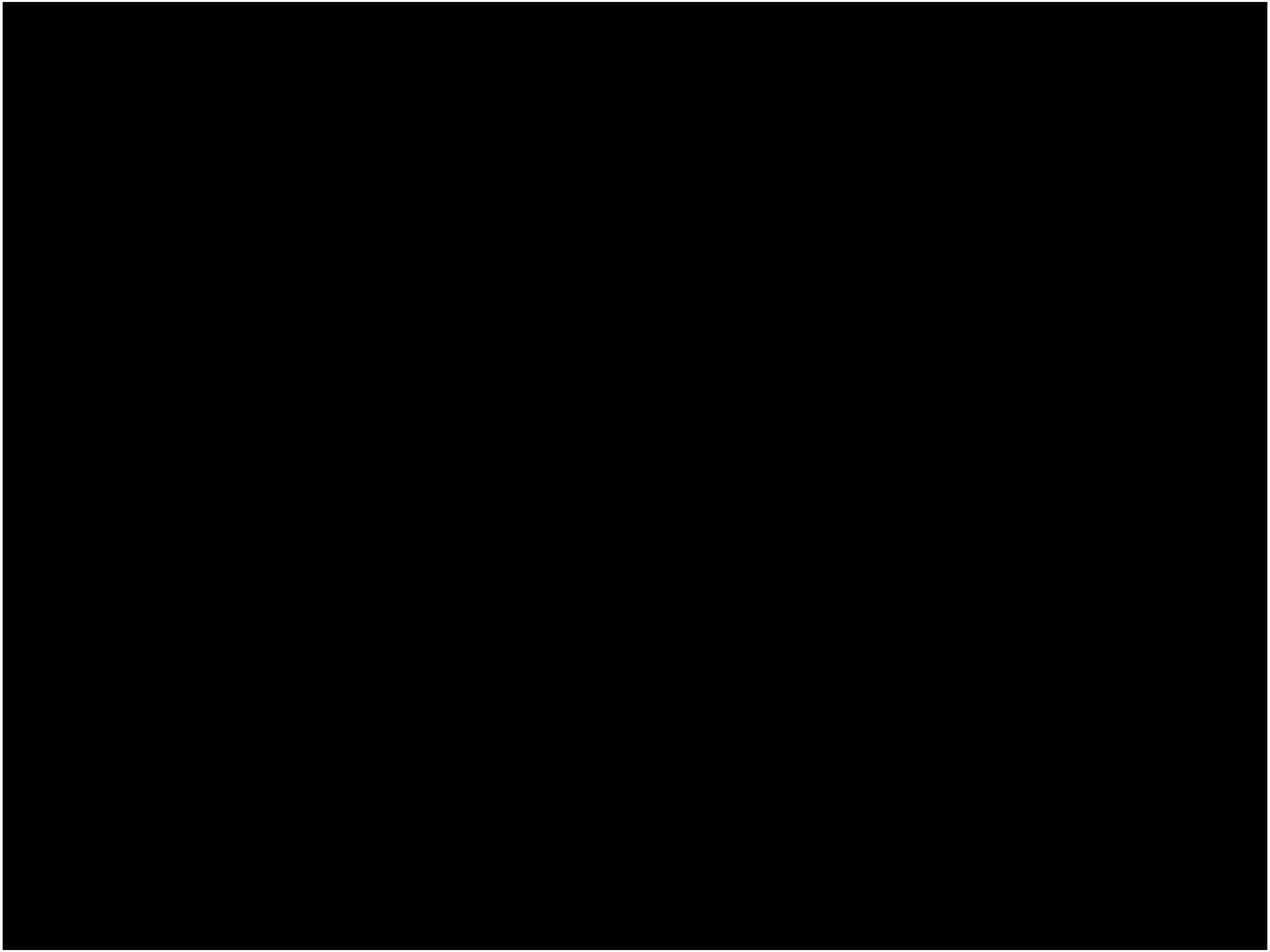
- Statistical methods of describing crater size-frequency distributions can give us valuable information regarding the density of hazards we should expect to be present at potential lunar landing sites
  - Small hazards on the Moon (< 100 meters) have the same statistical distribution regardless of surface age
- Synthetic DEMs can be used to model the likelihood of finding a suitable landing site for future missions to the Moon
  - Modeling site safety provides feedback to criteria guiding lander development
- Work incorporating additional hazards is ongoing
  - Rock distribution will likely be more variable at small sizes then is the case for small craters

Summary

ALHAT

Hazard Avoidance

- The glass is half-full!
  - We have done this before, multiple times, and with less capability

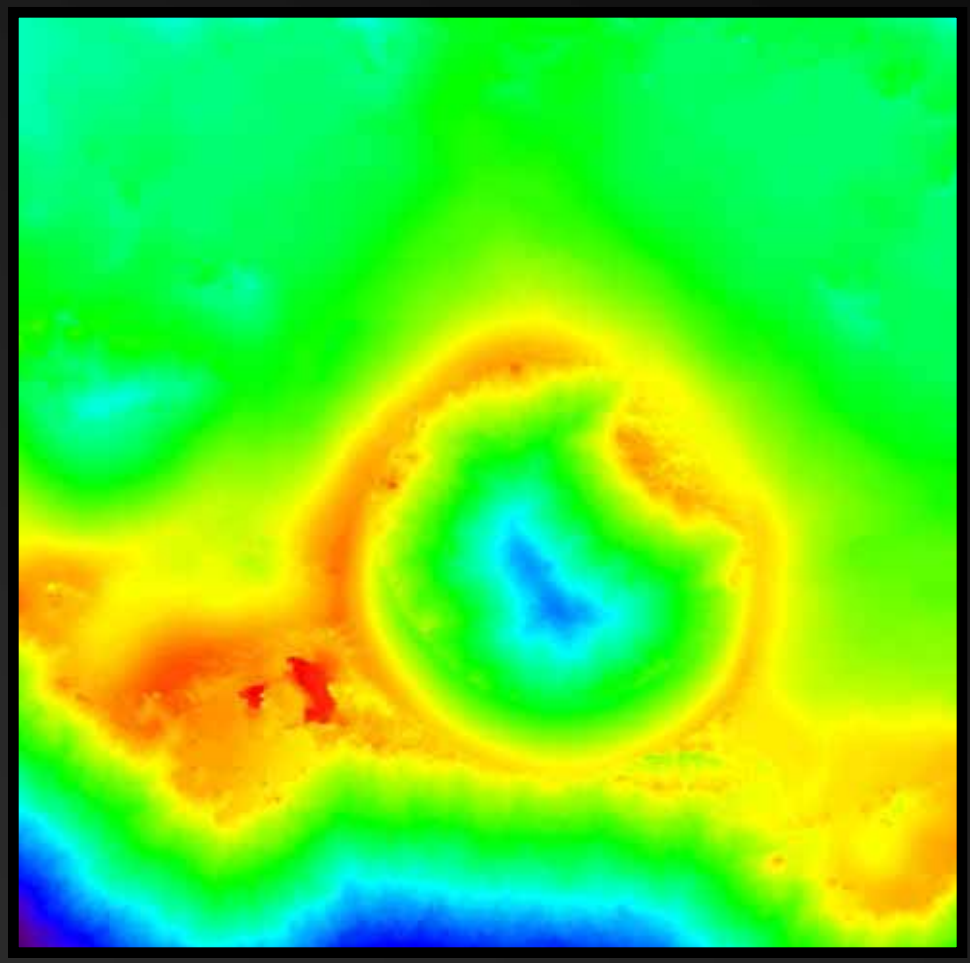


Ongoing Work

ALHAT

Available Topography

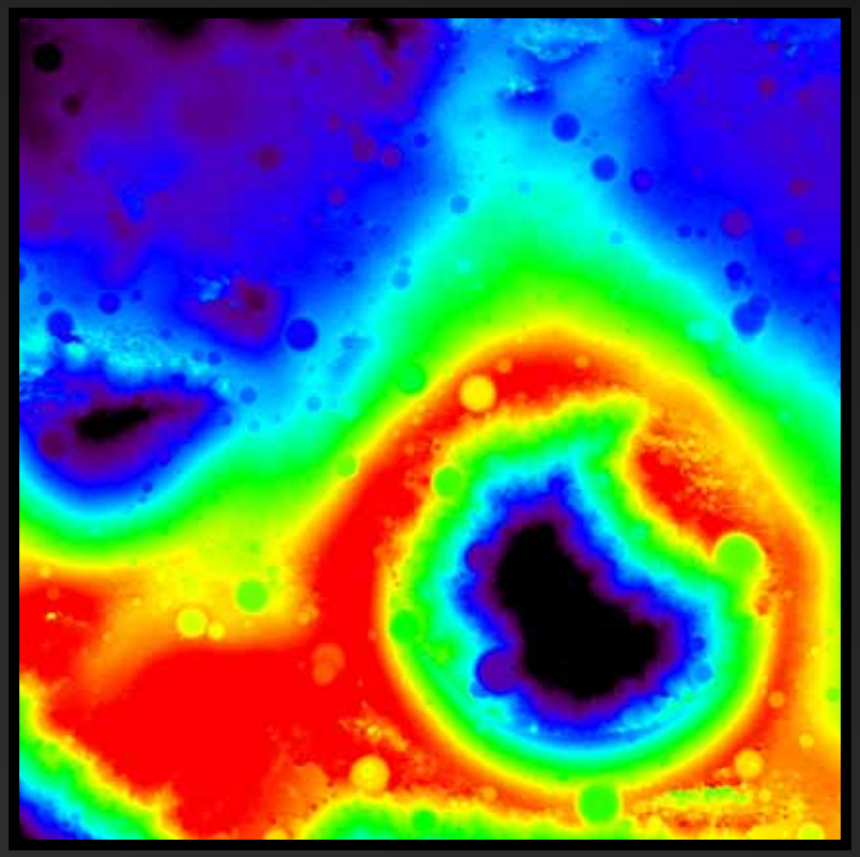
- Goldstone Radar DEM (~ 40 m/pixel)

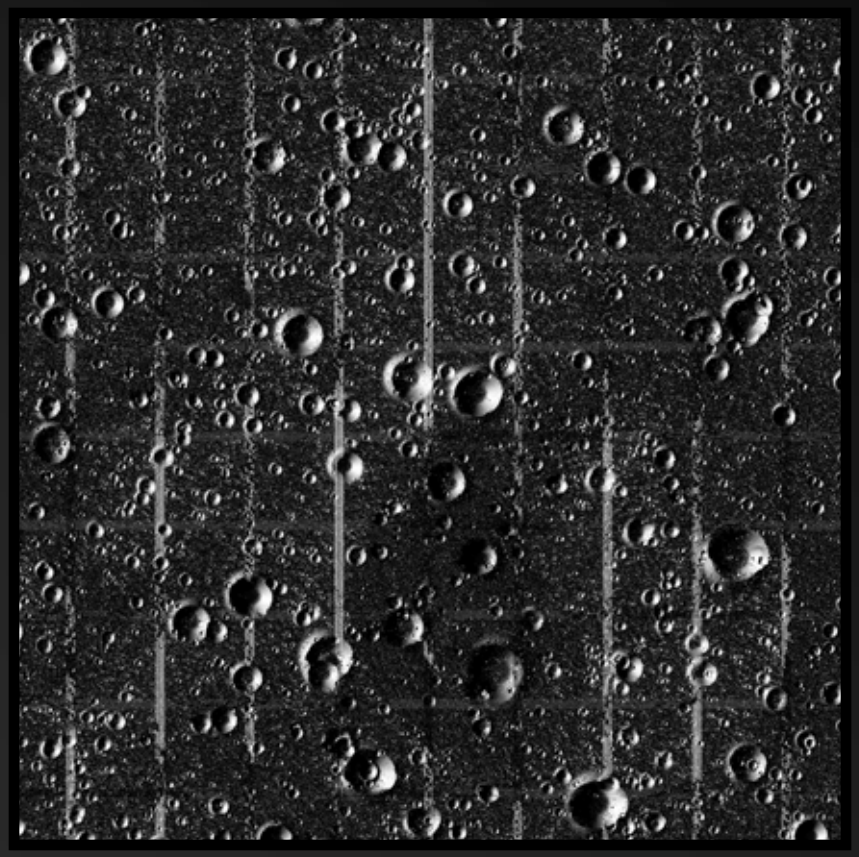


Ongoing Work

ALHAT

Available Topography





Synthethic/Goldstone