Large Terrain Modeling and Visualization for Planets

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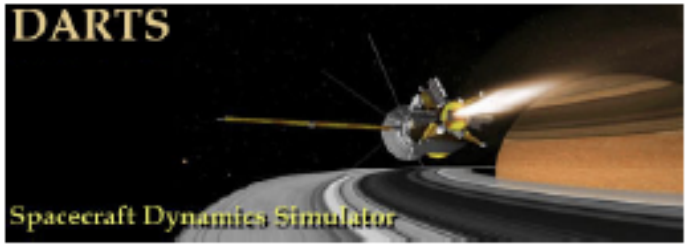
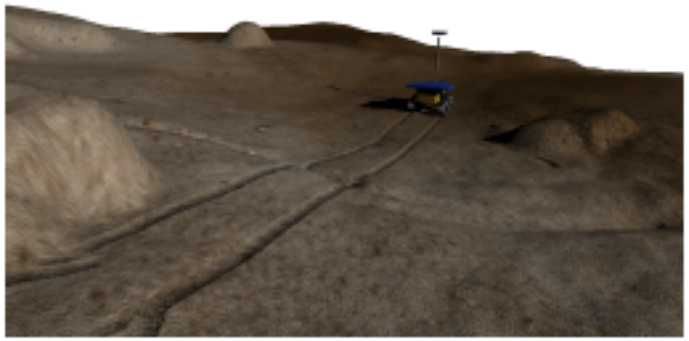
Use cases

Our real-time simulations often require large terrain modeling/visualization support.

- EDL simulations
- Rover simulations



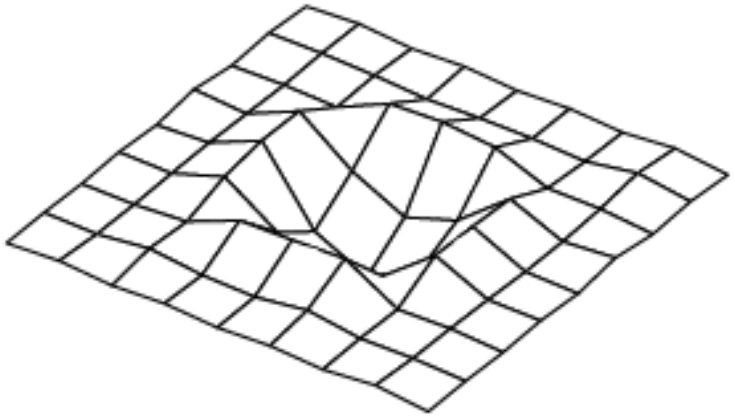


SimScape terrain framework

- Models DEMs, planets, and arbitrary meshes
- C++ and Python APIs
- Store data in HDF5 (Hierarchical Data Format) for fast random access
- Import data from various data formats (PDS, ISIS, GeoTiff, etc.)

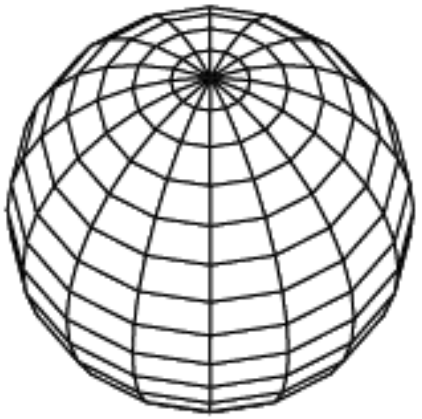
Digital Elevation Maps

- Regular rectangular height data
- Fast access without much arithmetic
- Useful for modeling relatively small areas
- Used extensively in rover simulations



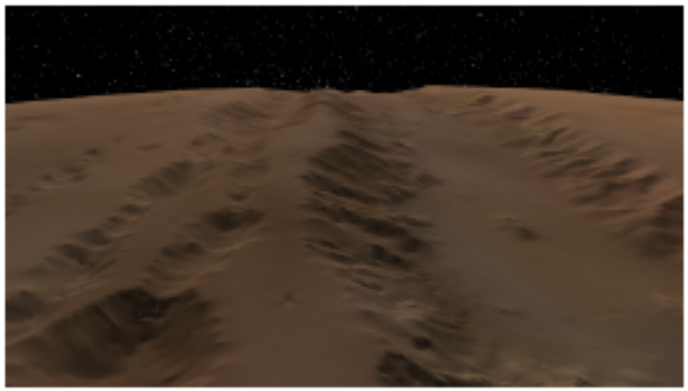
Planets

- Grid of height data in spherical coordinates
- Useful for larger areas when we must consider planet curvature



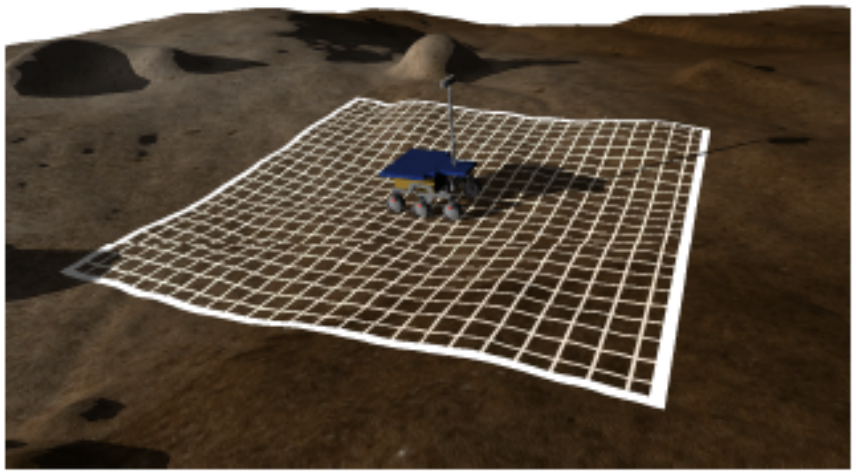
Large terrain modeling

- Support storing and loading of large planetary scale data
- Be able to access the data in real time



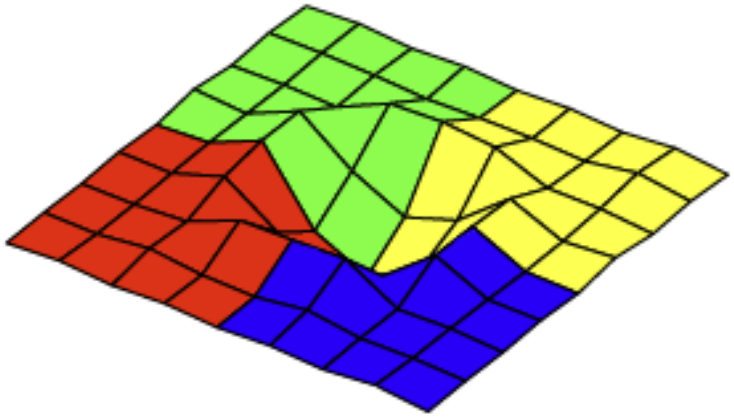
Paging

- Only a subset of terrain data is paged in
- We build on top of HDF5 to support paging
- In the rover example, only a small patch of data under the rover is loaded



Data tiling

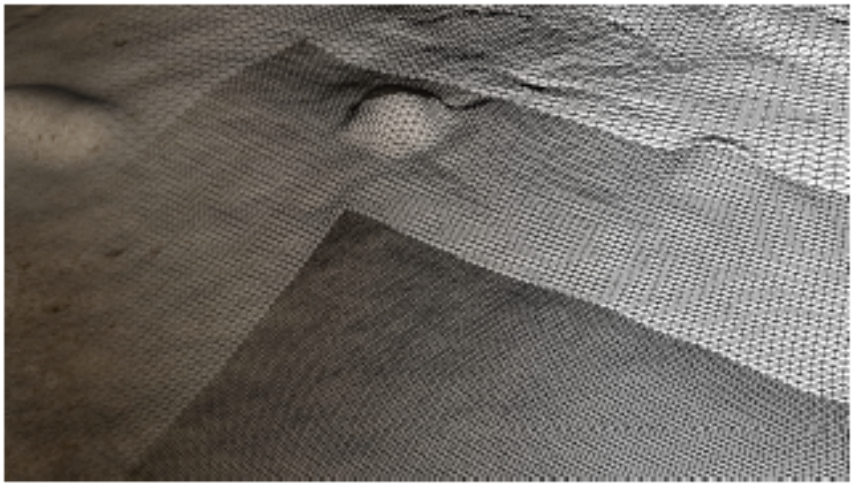
- Large data sets are sometimes broken up into separate tiles
- Transparent to the data loading API
- Tiling makes is convenient when writing data (less memory consumption at any one time)



Continuous level of detail visualization

A CLOD technique allows us to render high resolution data only where we want it (e.g, where the camera is pointing).

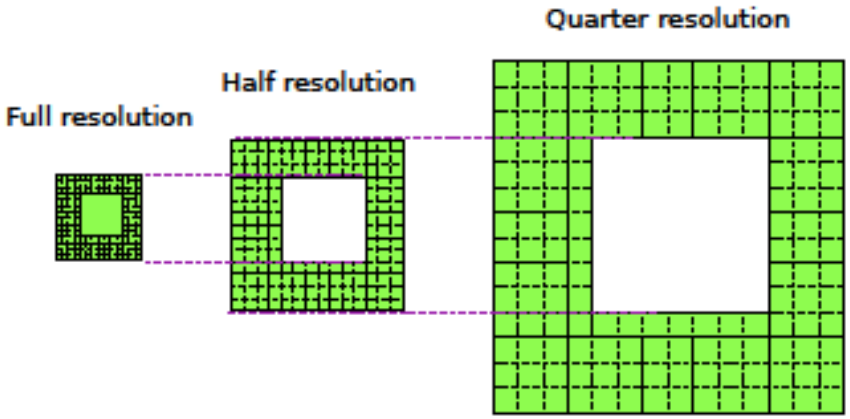
- Render very large data sets that can't normally be rendered all at once by the graphics card
- Render in real time
- Support overlaying textures (like wheel tracks) in a dynamic fashion



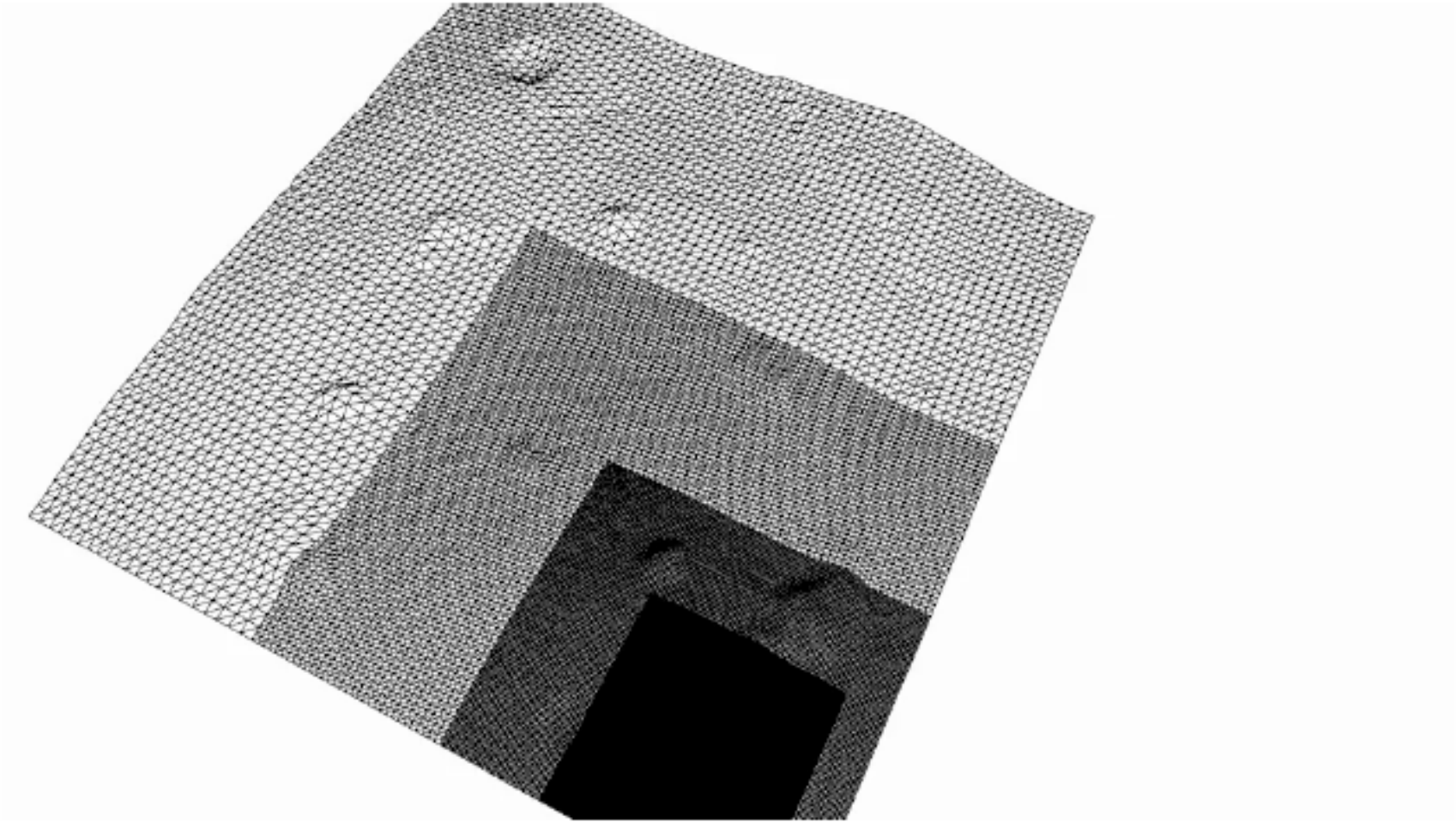
Continuous level of detail visualization example

Clipmapping

- Concentric rings of data
- Innermost rings have the highest resolution data
- Inner rings can be culled to improve performance

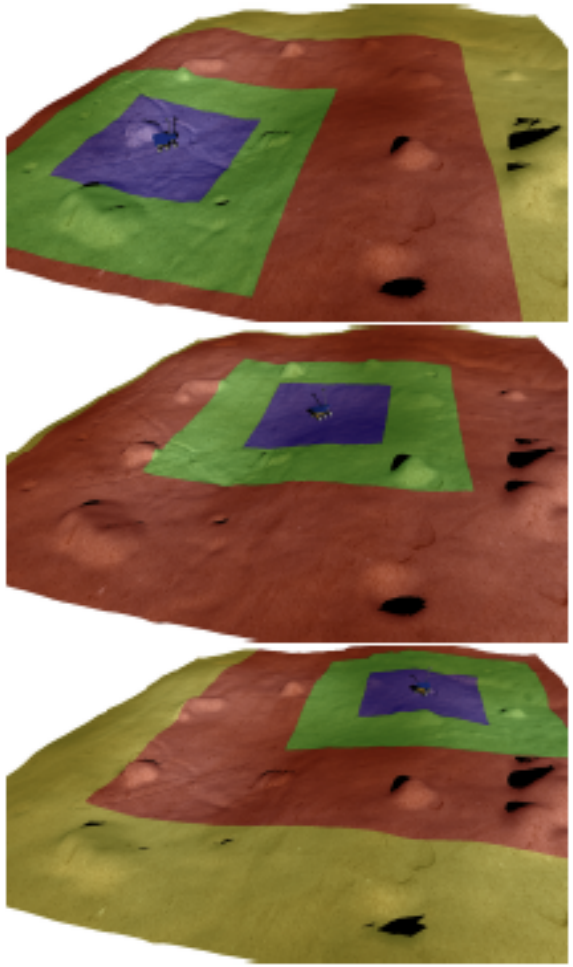


Clipmapping (continued)



Moving clipmaps

The high resolution area is moved by moving all clipmap rings.

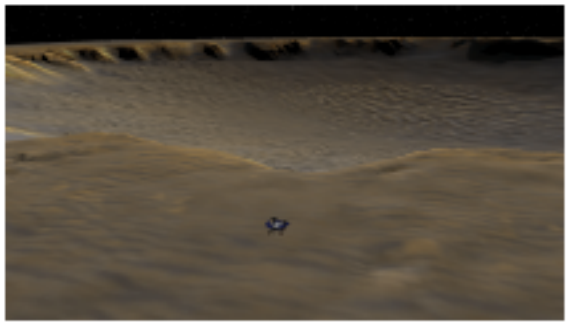


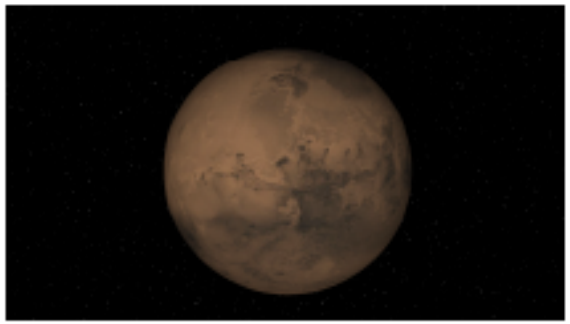
GPU implementation

Implementing clipmapping on the GPU allows us to utilize hundreds of GPU cores.

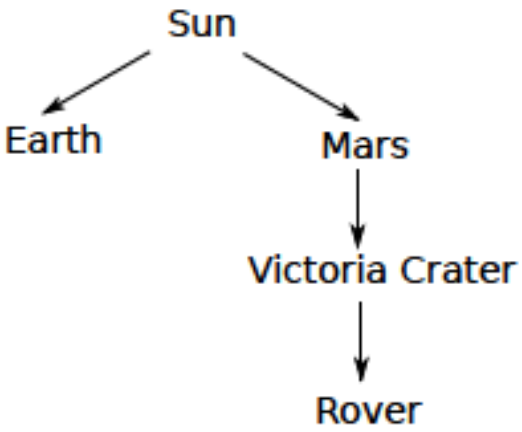
- Upload height map data to the GPU as a texture
- Vertex shader computes vertex positions based on:
  - Center position of all clipmaps
  - Clipmap ring level
  - Height map texture

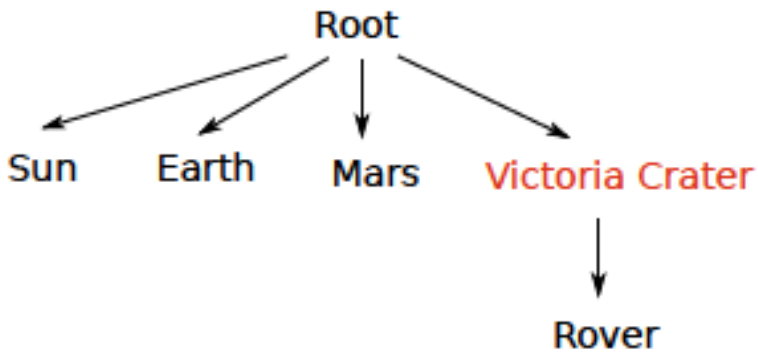
Combining multiple data sets





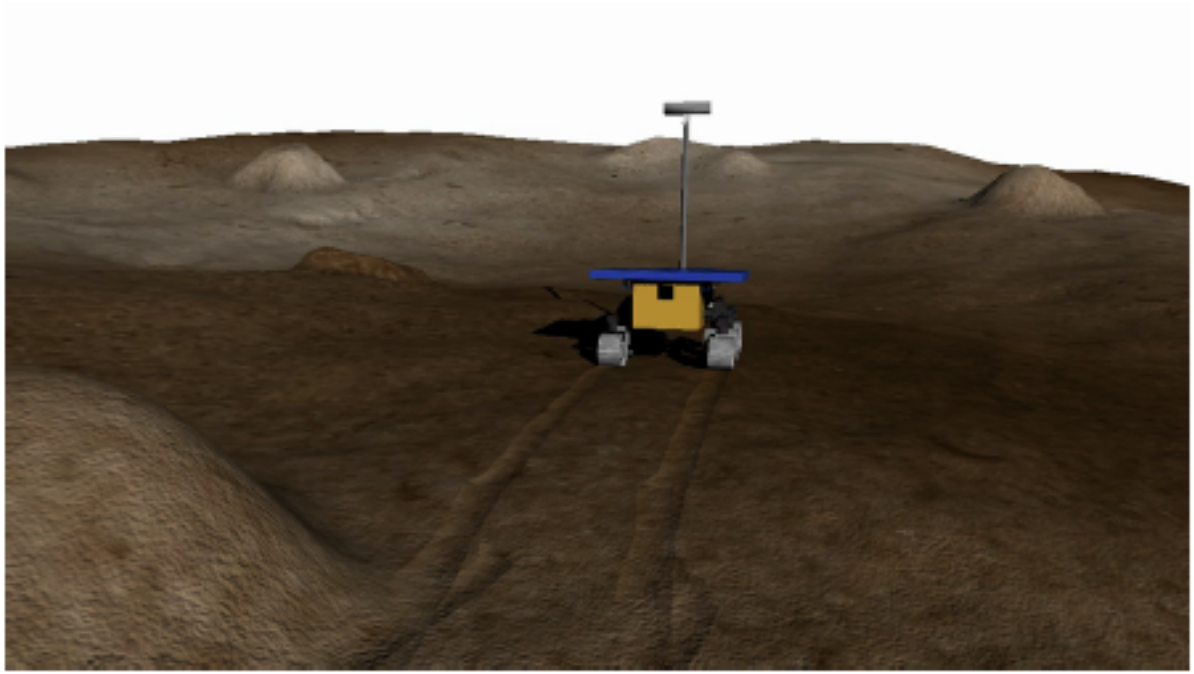
Combining multiple data sets (continued)





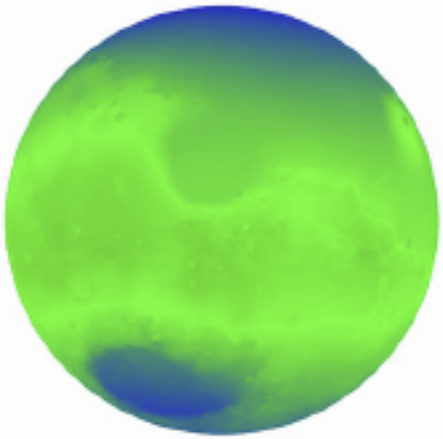
Overlays

Wheel tracks are overlaid on the terrain by perturbing the surface normals on a per-pixel basis.



Overlays (continued)

- Height maps
- Albedo maps
- Slope maps



Questions