TFAWS Interdisciplinary Paper Session

Fast GPU based ray tracing methods for radiation calculations: Applications to thermal analysis for space systems.

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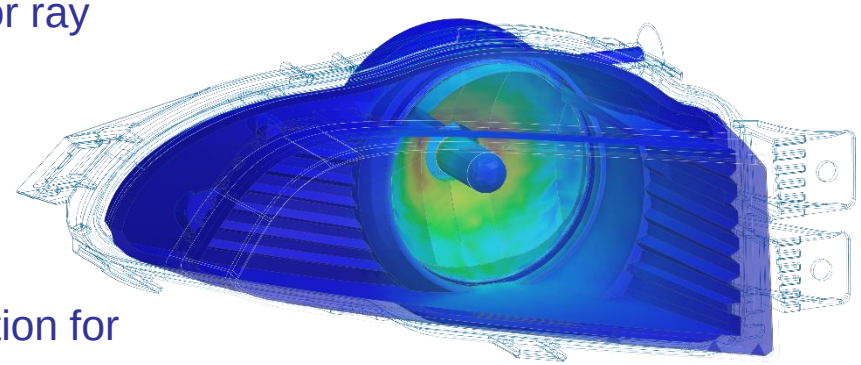
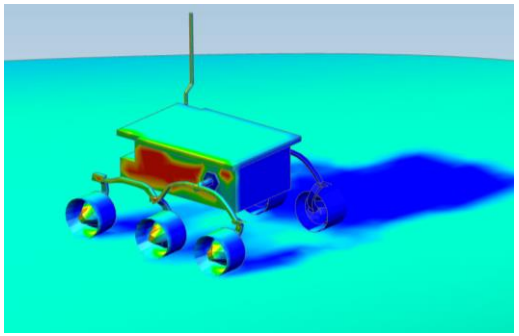
College Park, MD

Radiative heat transfer simulations

Computing radiative heat transfer with view factors or ray tracings is the most time-consuming part



It can take **days** to get the results of a single simulation for high fidelity **detailed** models (~50k-100k elements)



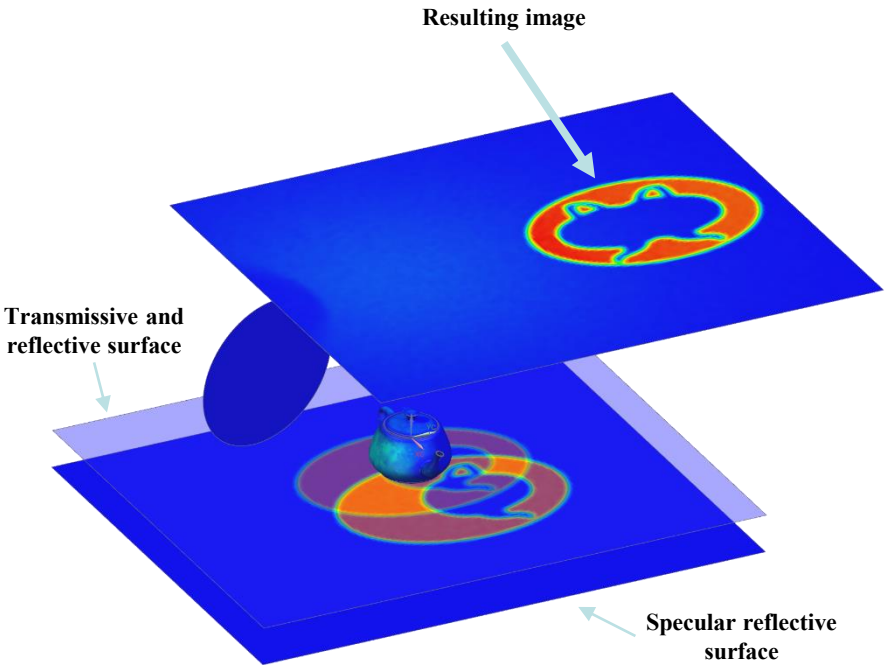
GPU For Enclosure Radiation

- Capability added to Simcenter 3D Thermal Multiphysics and Space systems thermal since 2021

- view factor calculation is a perfect type of calculation to be performed on Graphics Processing Units or GPUs since these calculations can be performed in parallel on the hundreds of cores that a typical GPU processes.

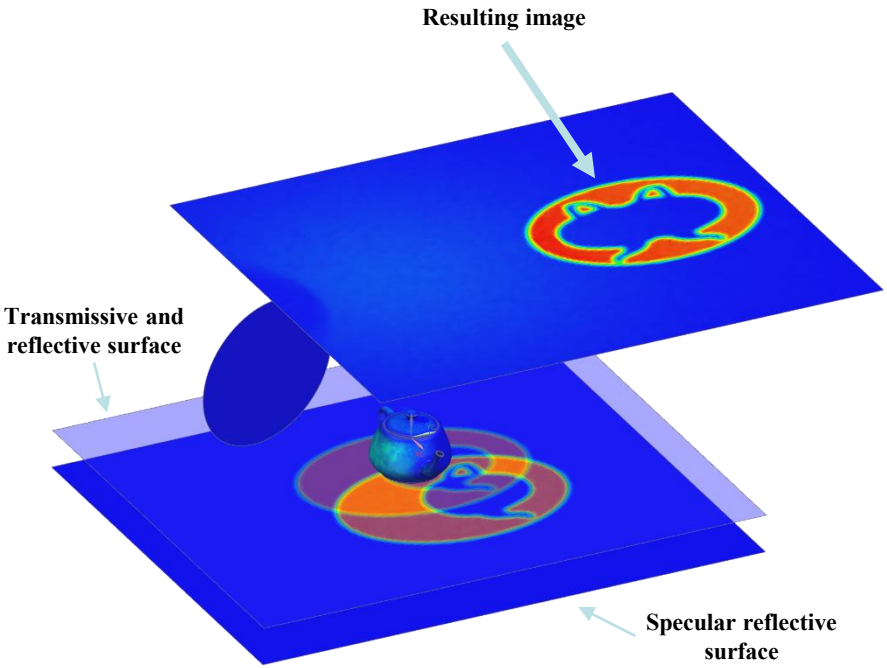
- View factor computations and ray tracing is performed on NVIDIA GPUs, based on a modified Monte Carlo ray tracing method implemented using CUDA v11.8.

- Support for both diffuse and advanced thermo-optical surface properties including specular reflectivity, transmissivity, and refraction.



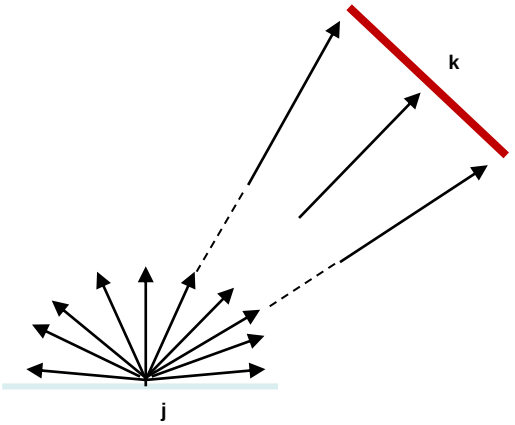
Why CUDA?

- Actively supported and improved
- Ability to program at lower level
  - **More easily tune solve process**
  - **Optimize based on application needs**
- Rich supporting toolset
- Partnership with NVIDIA and ongoing collaboration



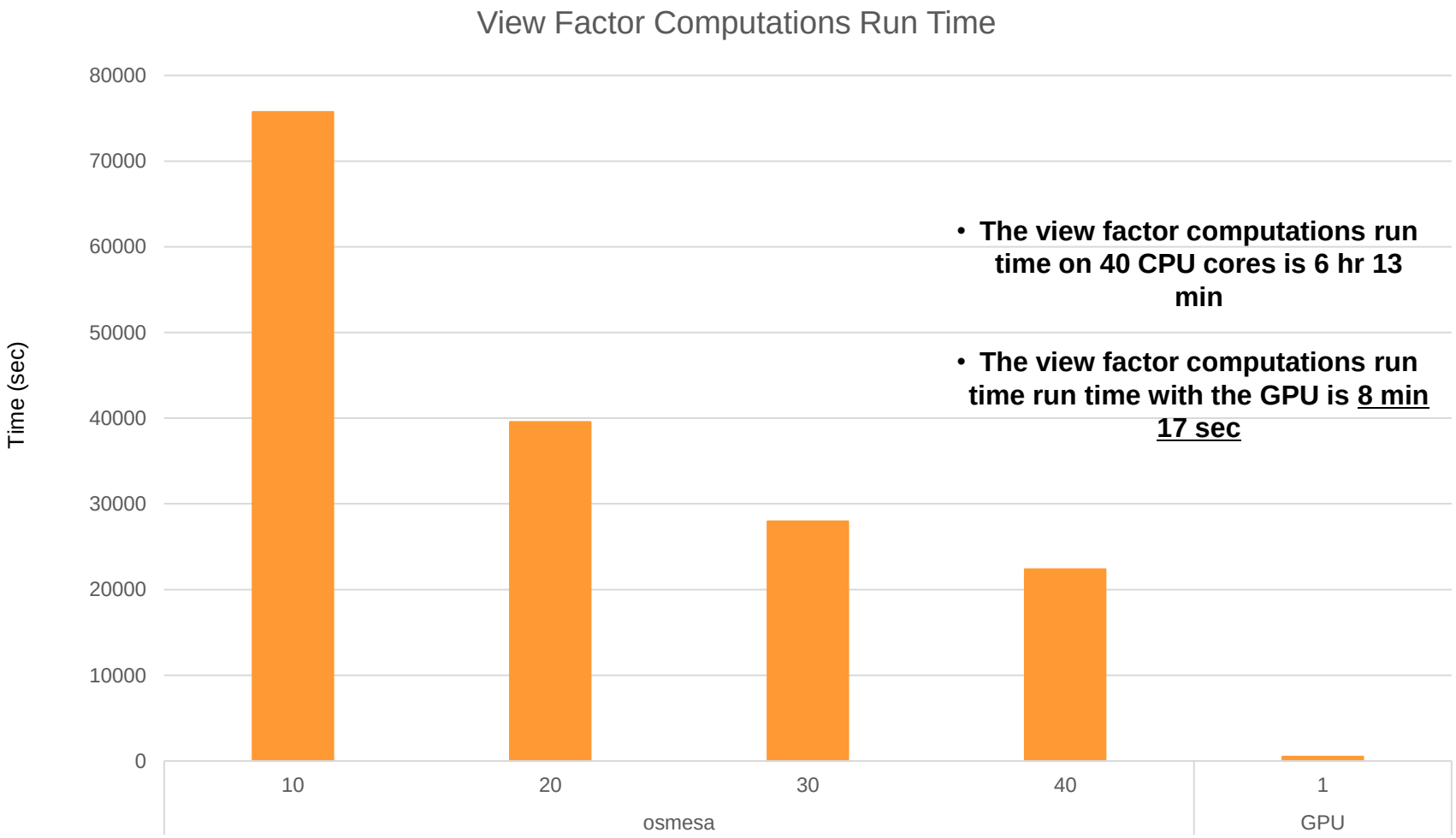
Technical Overview

- The Monte Carlo computation method is a ray-casting or ray-tracing method used in many applications including the calculation of view factors.
- Rays are launched in random directions from the jth element
- The fraction of rays that hits the kth element is used to compute the view factor from j to k
- Number of rays cast influences results accuracy and precision



- The GPU implementation is a modified implementation of the Monte Carlo method.

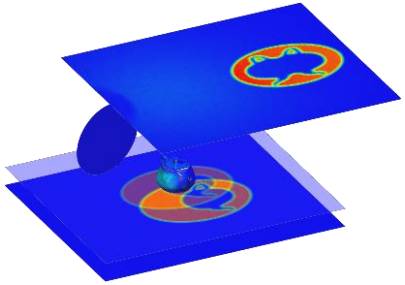
View Factor Computations on the GPU



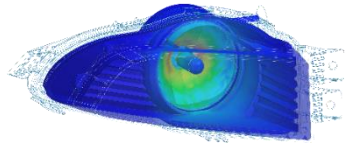
- **The view factor computations run time on 40 CPU cores is 6 hr 13 min**
- **The view factor computations run time run time with the GPU is 8 min 17 sec**

Benchmark Overview

Model	Number of elements
Teapot	168,929



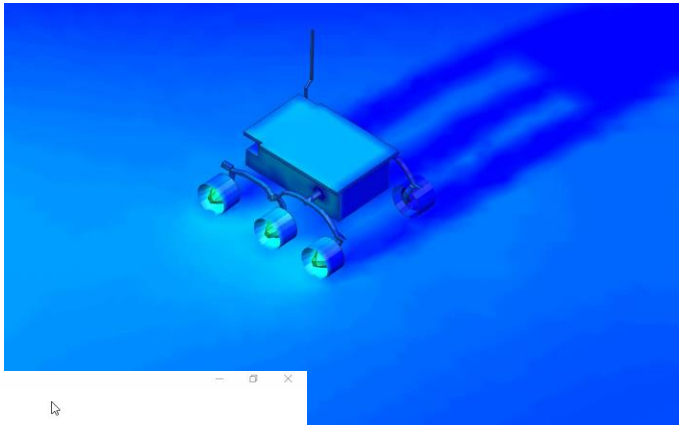
Customer models	Number of elements
Model 1	700,910
Model 2	813,000
Model 3	445,487
Model 4	511,687

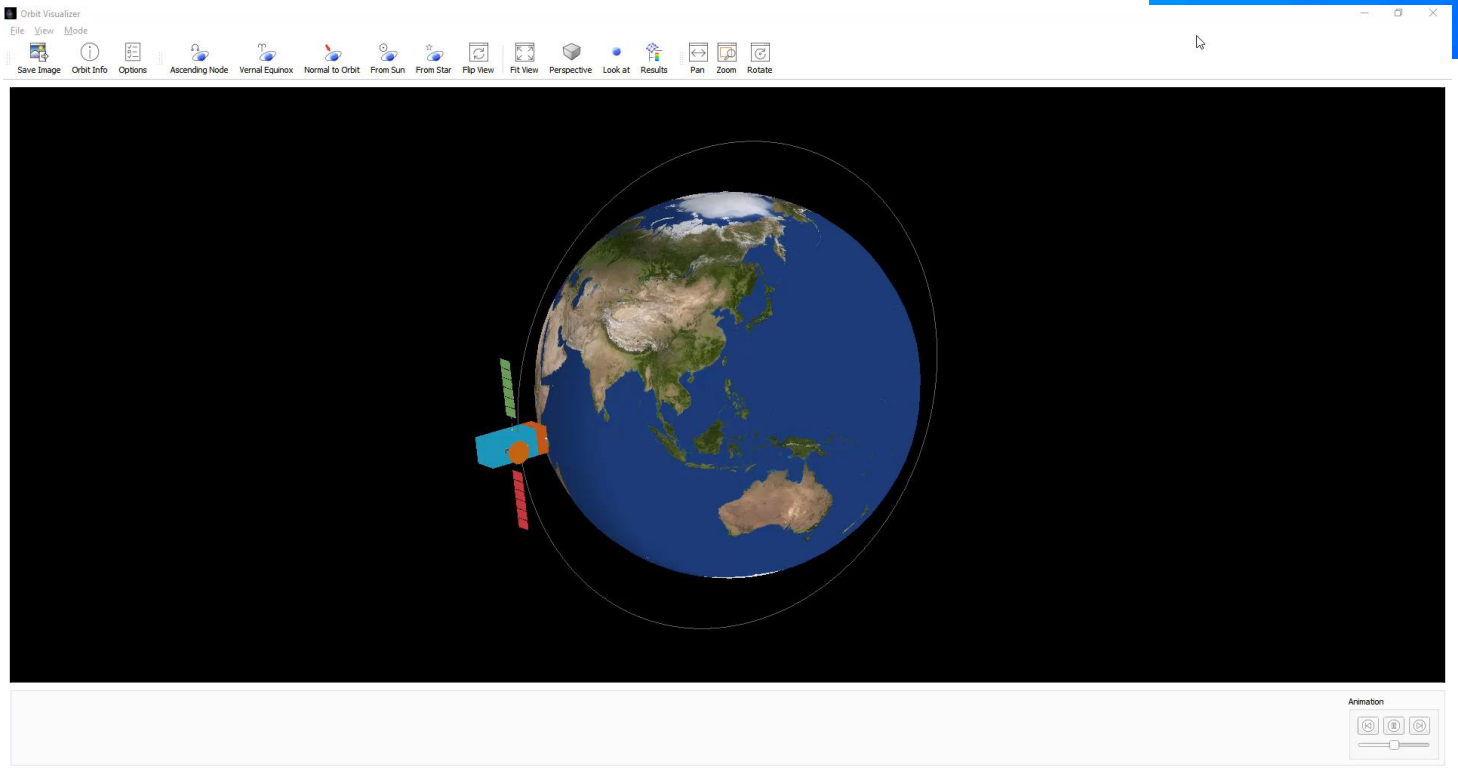


	Ray tracing time (s)		
	CPU Monte Carlo	GPU ray tracing	Improvement
Teapot	3,681	252	**15x**

	View Factor Computation Time (S)		
	CPU view factors	GPU view factors	Improvement
Model 1	8 cores: 68,050	1,451	**46x**
Model 2	6 cores: 44,436	1,307	**34x**
Model 3	6 cores: 118,406*	297	**399x**
Model 4	6 cores: 127,233*	311	**409x**

Extending to Solar and Orbital Fluxes

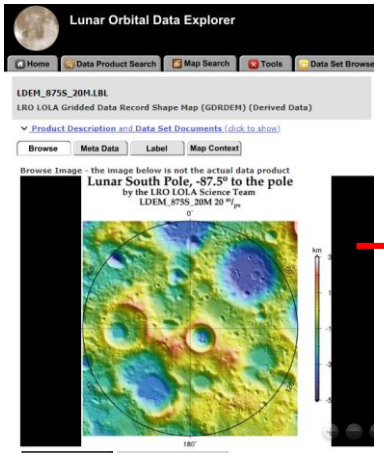


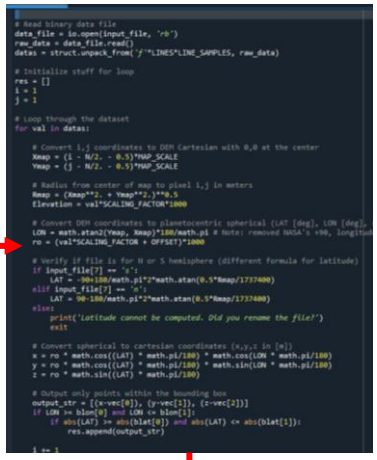


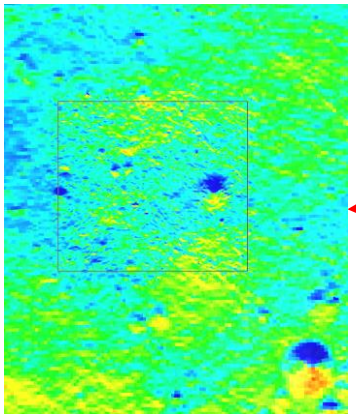
Solar Heating test: Detailed Moon Surface

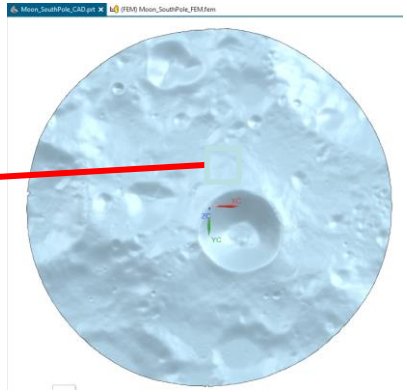
- In order to fully test our new implementation for the GPU we used a detailed Moon Surface model.

- This model was created, based on NASA Lunar Handbook methodology:
  - The topography for the zone of interest is retrieved from the NASA database
  - A custom script converts the binary files to an NX-readable format
  - The thermal model is prepared using properties correlated from surface temperature measurements (from NASA's LRO mission)





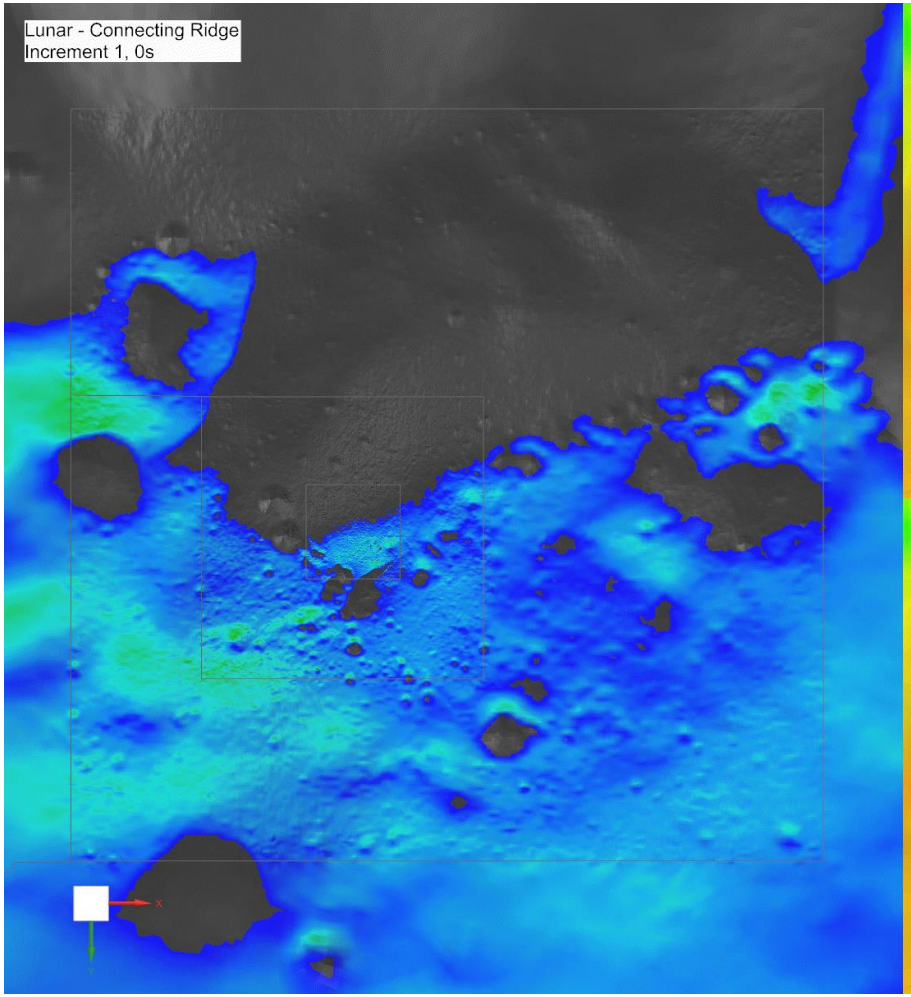


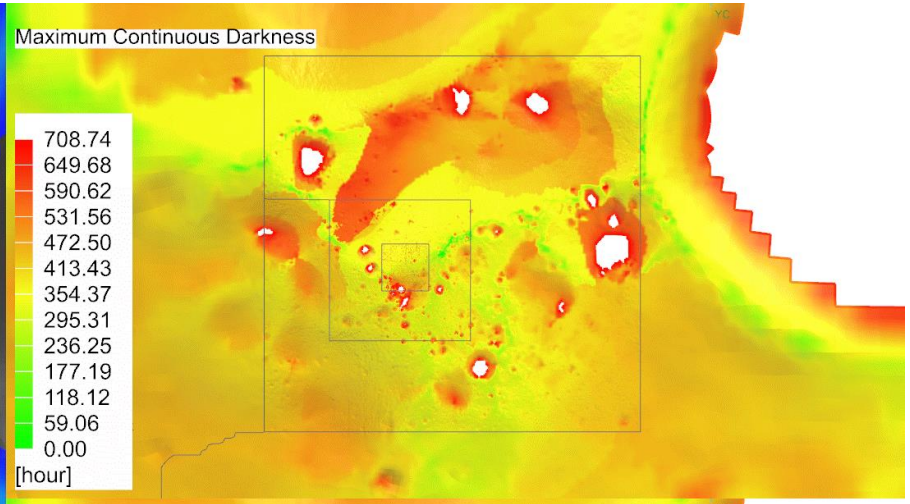


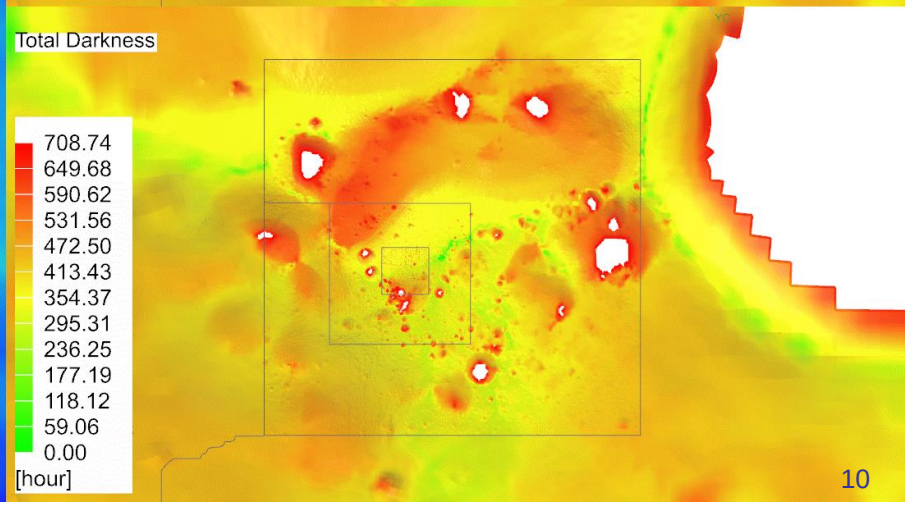
Lunar Surface Model

2km square at 5m, a 16km square at 20m, and the remainder of 88.5 deg S to Pole at 240m resolution

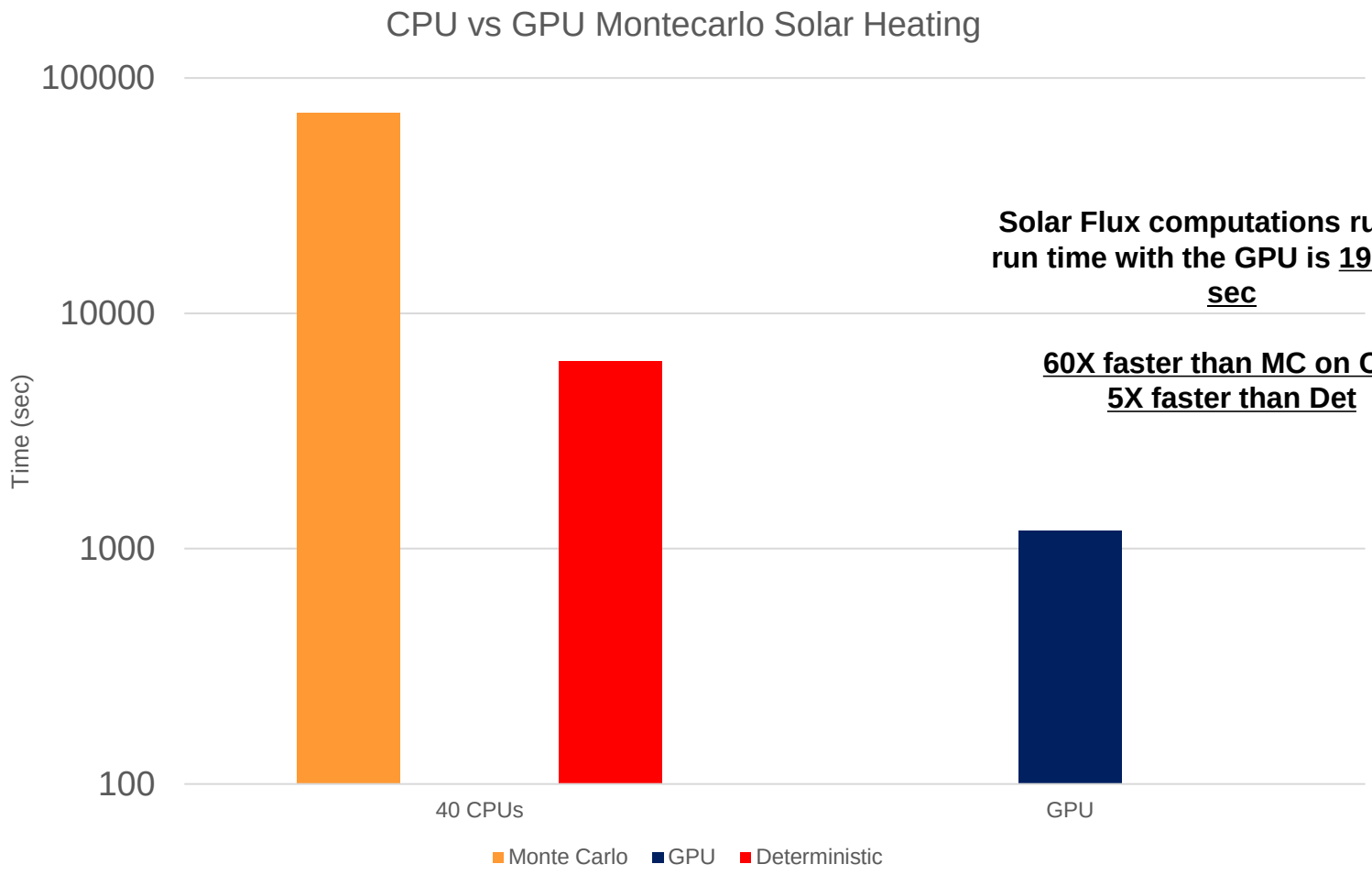
360 positions (1 lunar day cycle, every ~2 hours)







Solar Flux Computations on the GPU

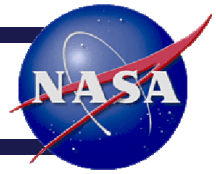


Solar Flux computations run time run time with the GPU is <u>19 min 48 sec</u>

<u>60X faster than MC on CPU</u>
<u>5X faster than Det</u>

Intel Xeon CPU E5 - 2698 v4 2.20GHz
MonteCarlo

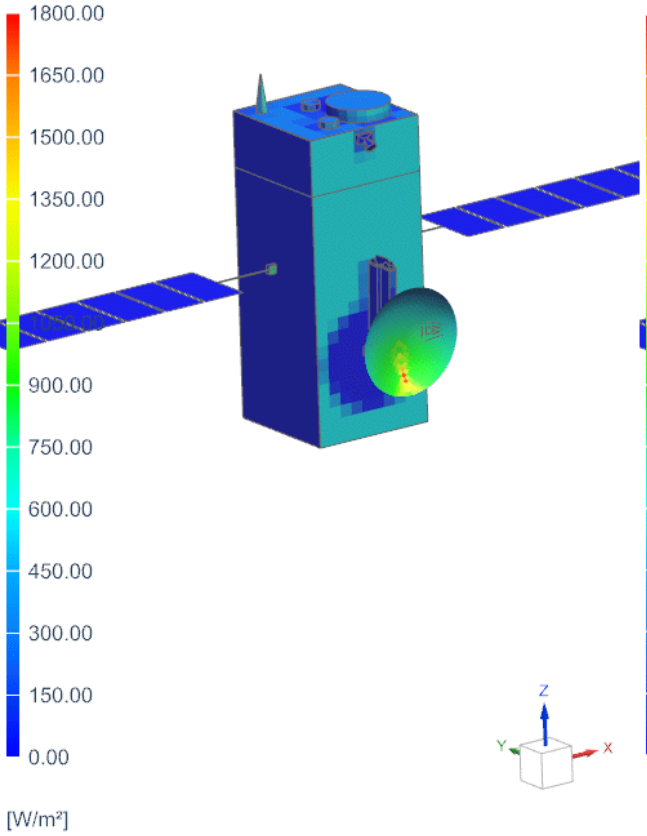
Nvidia
GeForce RTX
3080 Ti



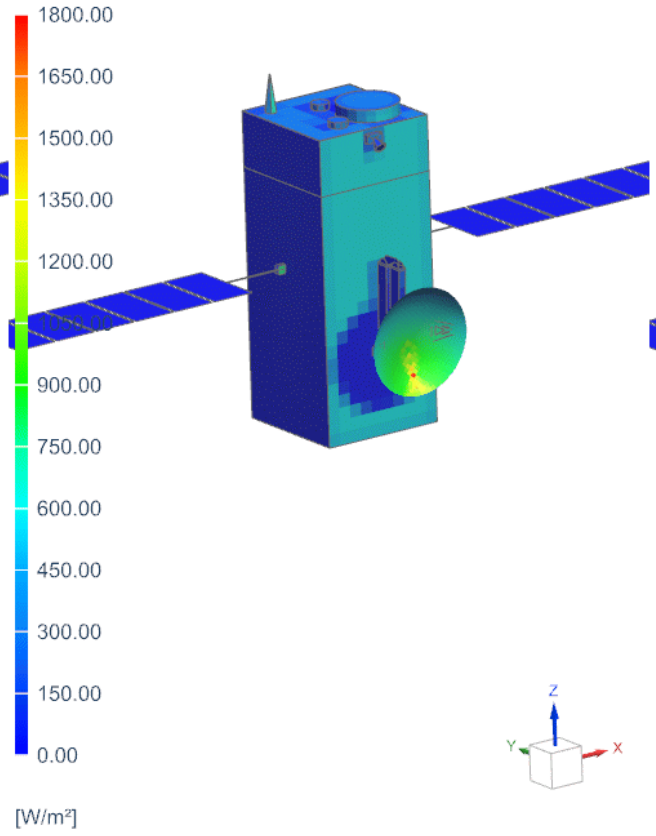
WORK IN PROGRESS

Orbital Solar Flux on the GPU

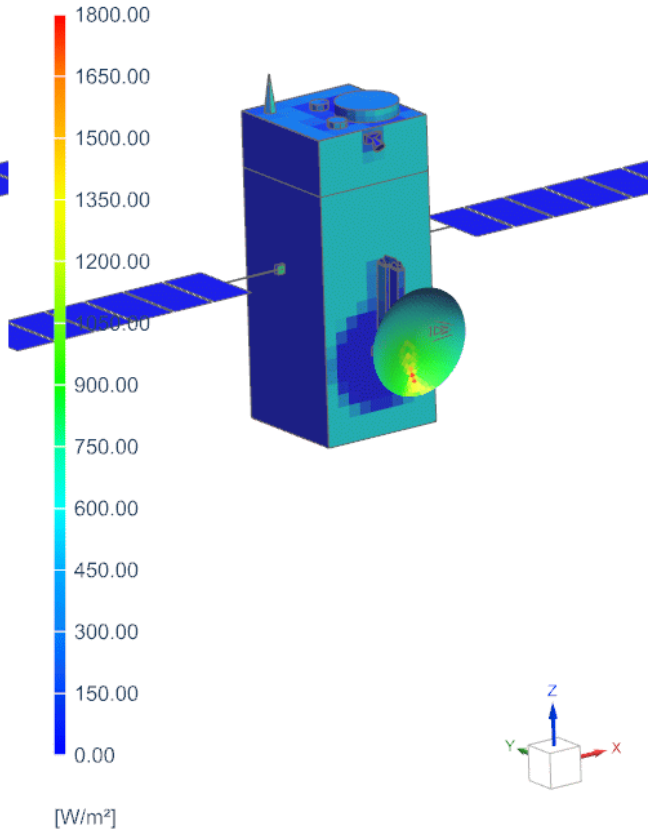
SJF-Assembly_s2306_Linear_articulation : Articulation-Det-Spec-Linea
Load Case 1, Increment 1, 0s



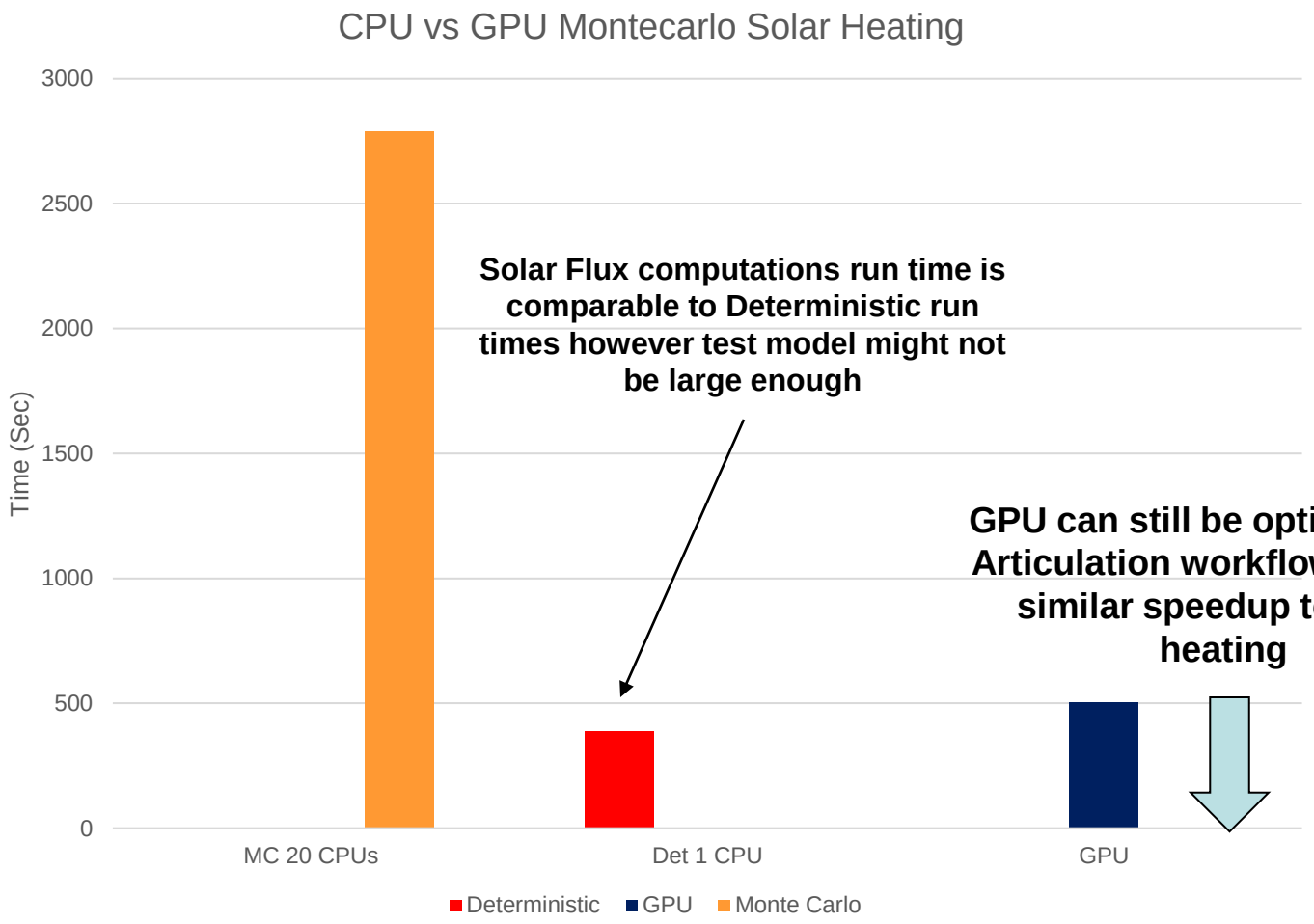
SJF-Assembly_s2306_Linear_articulation : Articulation-GPU-Spec-Line
Load Case 1, Increment 1, 0s



SJF-Assembly_s2306_Linear_articulation : Articulation-MC-Spec-L
Load Case 1, Increment 1, 0s



Orbital Solar Flux on the GPU

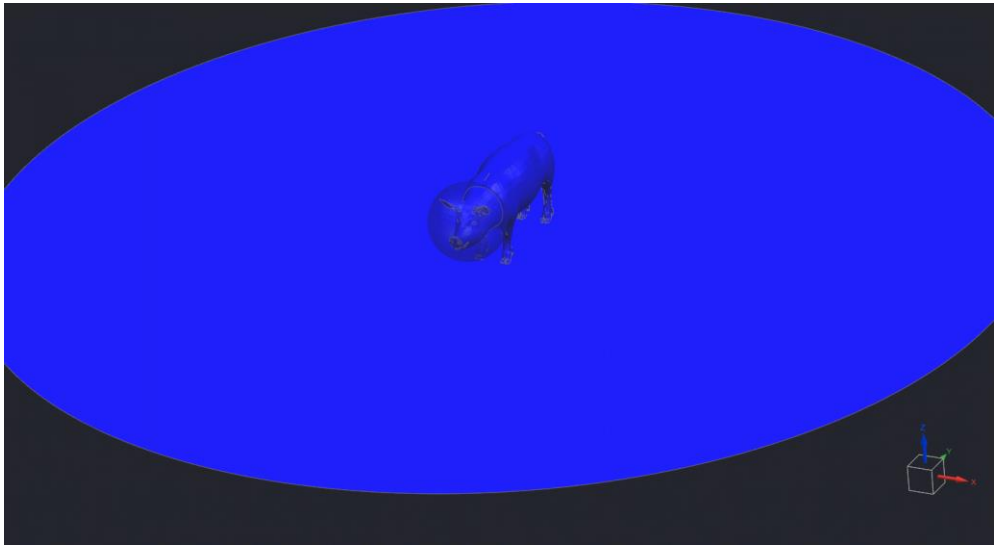


Intel Xeon CPU E5 - 2698 v4 2.20GHz
MonteCarlo / Deterministic

Nvidia GeForce RTX 3080 Ti

Conclusion

- GPU Enclosure radiation and solar heating calculation will be an early access feature in Simcenter 3D 2312



- Next for Simcenter 2406 (June 2024):
  - Add Earth IR and Albedo calculations to the GPU orbital heating algorithm
  - Parabolic Elements
  - Optimize GPU algorithm further for Articulation/spinning models

Thank You!

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For more information,
visit mayahtt.com