Exploring Ancient Skies

Archaeoastronomy with *arcAstro-VR*

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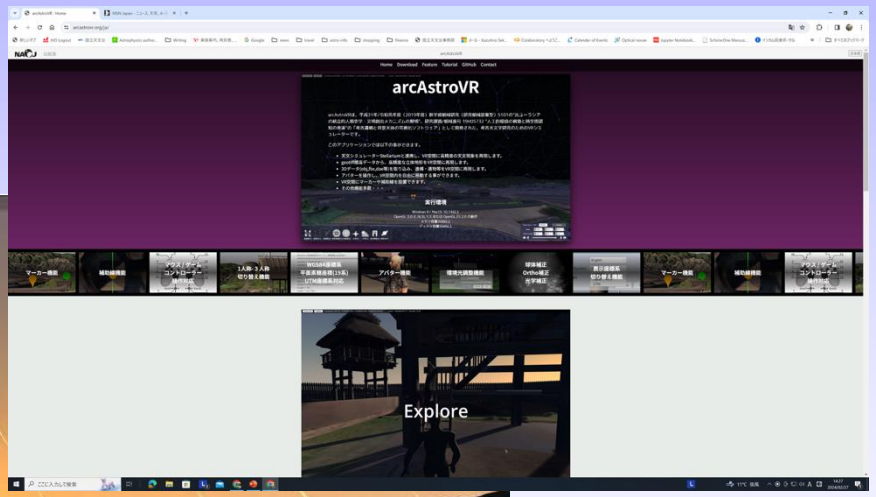
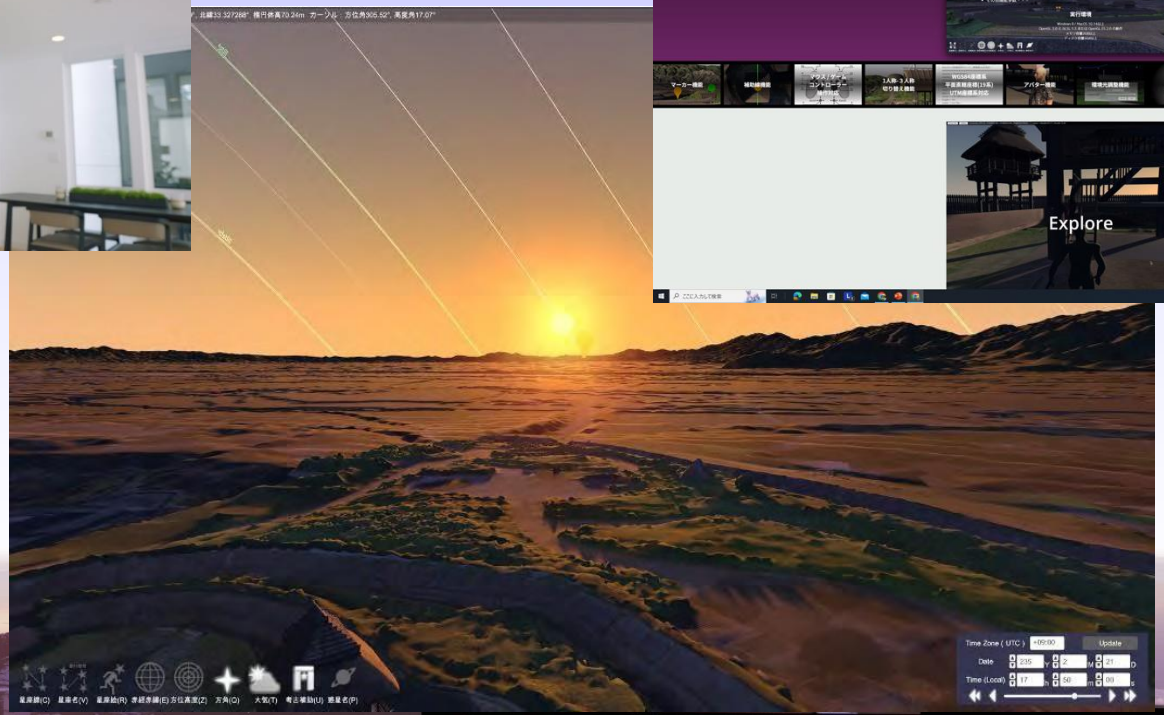
Overview

- What is *arcAstro-VR*?
- Key Features
- Tools & Data Workflow
- Astronomical Accuracy
- Case Study
- Advanced Use and Future Directions
- Q&A

What is *arcAstro-VR*?

arcAstro-VR (https://arcastrovr.org/en/) is a Unity-based VR app that shows 3D archaeological sites on realistic terrain with sky simulation from *Stellarium*.

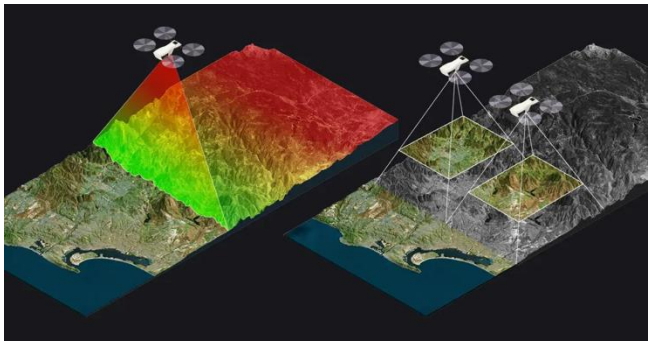




Unity

Key Features

- Real-time celestial simulation (sun, moon, stars)



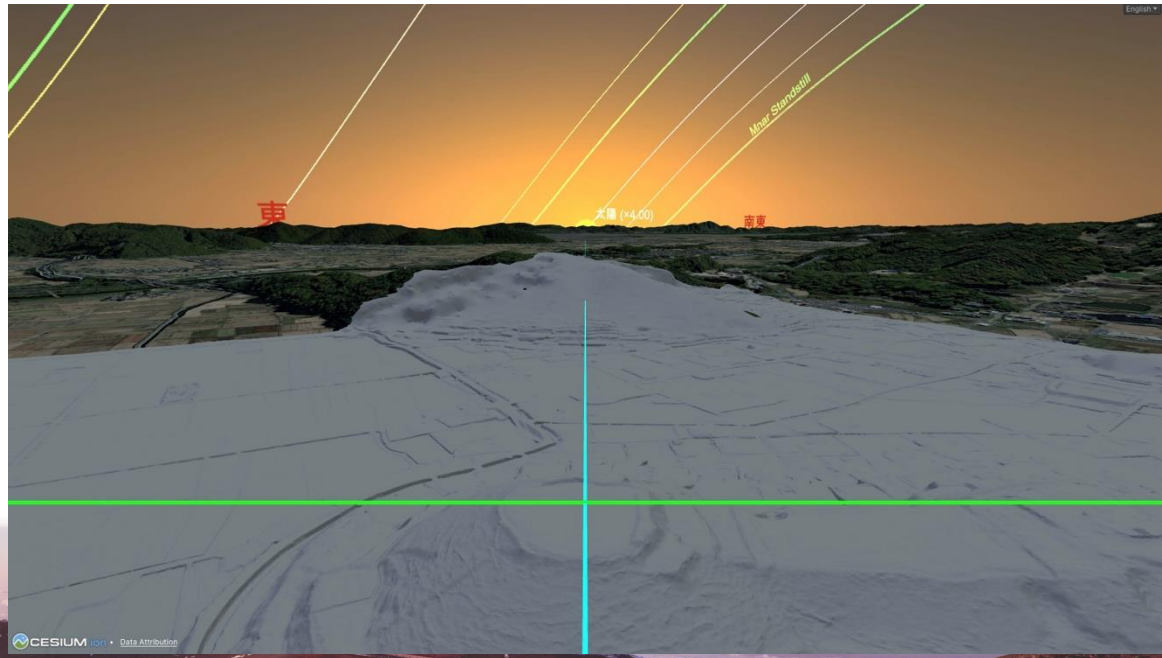
- Terrain and Structure reconstruction from LiDAR/photogrammetry

- Interactive VR experience: avatars, markers, spatial lines

- Custom terrain creation using QGIS plugin

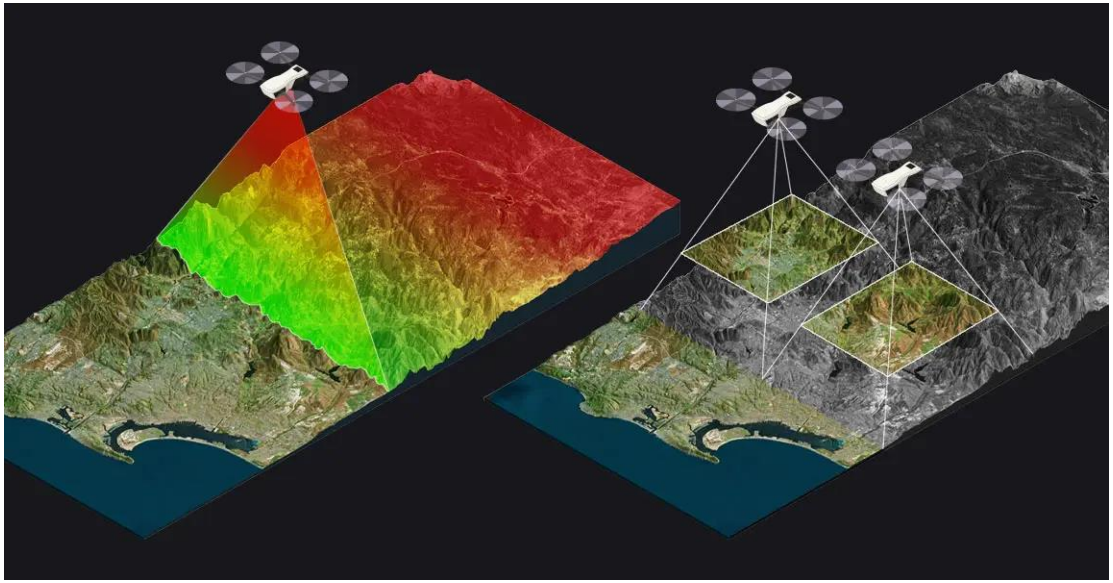
• Real-time celestial simulation (sun, moon, stars)

Integration with ***Stellarium***:
arcAstro-VR works in tandem with *Stellarium*, to accurately simulate celestial events such as sunrises, moonrises, and star positions within the VR space.



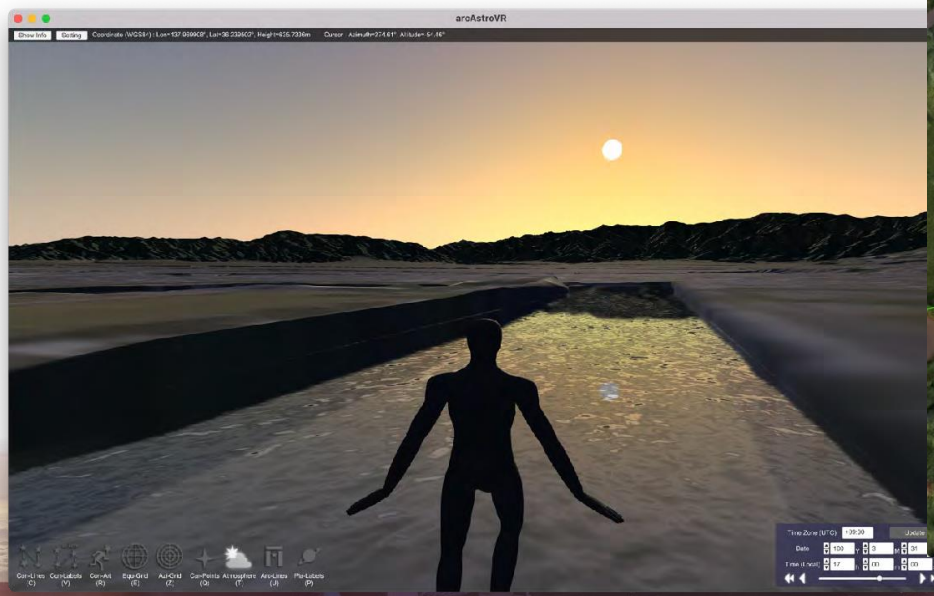
• Terrain & Structure reconstruction from LiDAR/photogrammetry

3D Terrain and Structure Visualization:
Utilizing geotiff elevation data and 3D object files (e.g., .obj, .fbx, .dae), the software reconstructs high-precision terrains and archaeological structures, allowing users to explore.



- **Interactive VR experience: avatars, markers, spatial lines**

Users can navigate the VR environment using avatars, place markers, and draw auxiliary lines to study spatial relationships between structures and celestial bodies.



• Custom terrain creation using QGIS plugin

Terrain Data Creation:
The software supports the creation of custom terrain data through QGIS, a free GIS software, using the *terrain4arcAstroVR* plugin.

This allows for the incorporation of detailed elevation and texture data into the VR simulations.


arcAstroVR
Select File - 'dataset.txt'

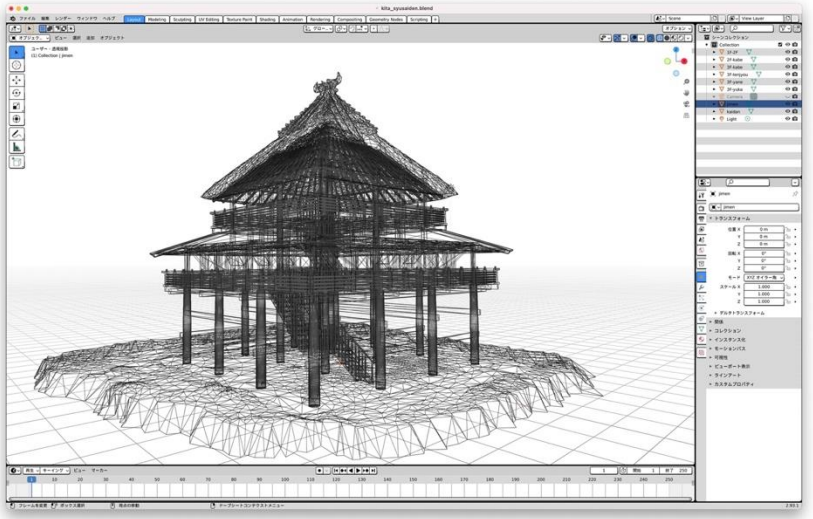
Tools & Data Workflow

Data formats of terrain and buildings that can be read

Terrain data: GeoTIFF file format

GeoTIFF: Planar image data with elevation in grayscale

Building data: 3D file format (obj, fbx, ply, etc.)



3D file: Three-dimensional space data in which points, lines, and planes are arranged with xyz coordinates

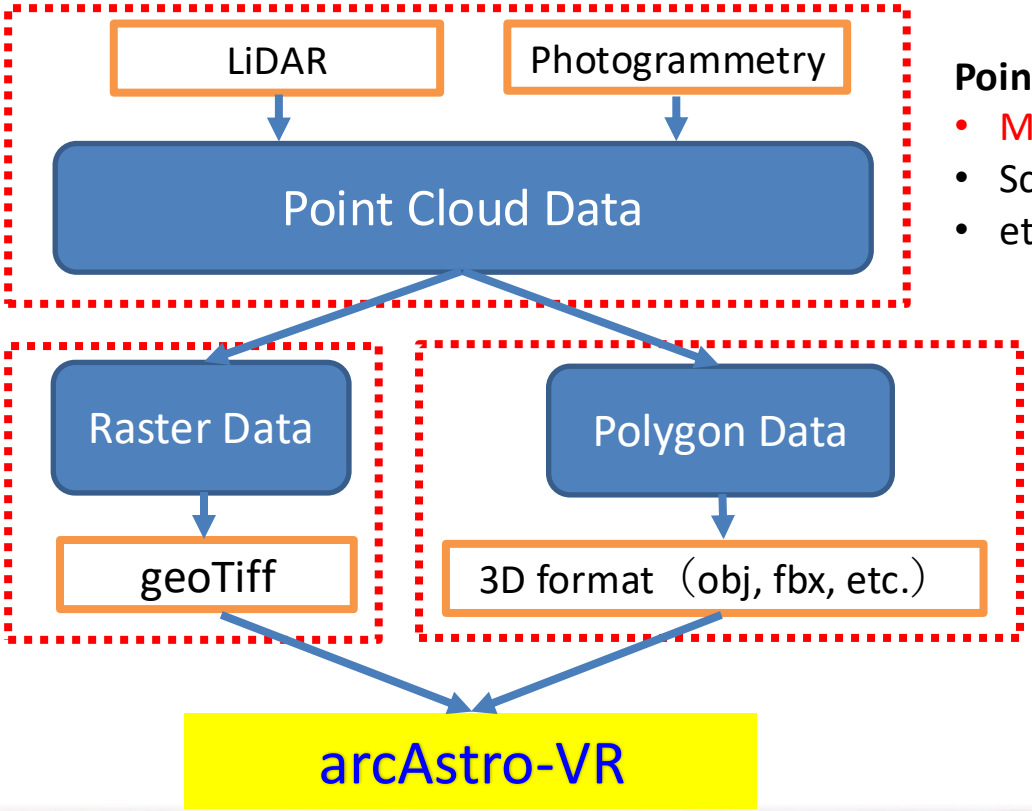
Tools & Data Workflow

The flow of data creation from various survey measurements

Terrain data processing

- QGIS(free)

dedicated plug-in （Create specially modified terrain with “terrain maker for arcAstroVR”)



Point cloud data processing

- MetaShape (old Photoscan)
- ScanSurvey Z
- etc…

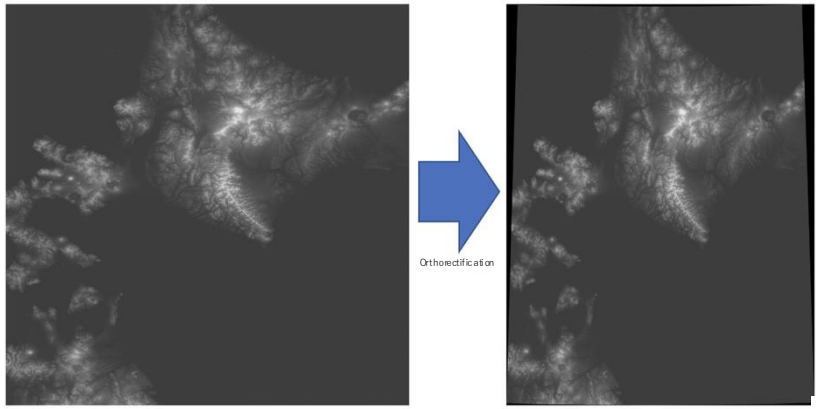
3D data processing for buildings, etc.

- Blender(free)
- Maya
- AutoCAD
- FreeCAD(free)
- etc…

Tools & Data Workflow

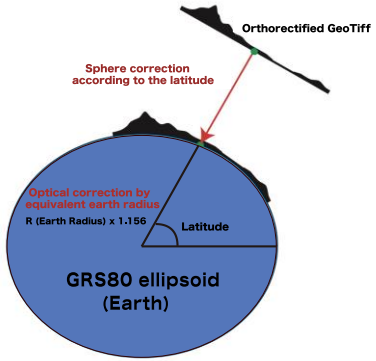
Terrain correction in the QGIS plugin

- orthorectification (orthographic projection)
- spherical shape correction
- Introducing the Geoid model
- Optical correction (Equivalent Earth Radius Correction)

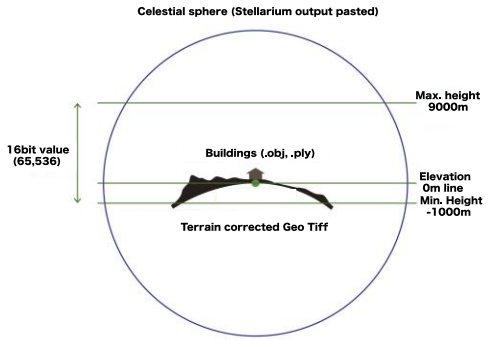


Equal latitude/longitude projection

Orthographic projection



Terrain Correction
(GRS80 Ellipsoid + Equivalent Earth Radius)

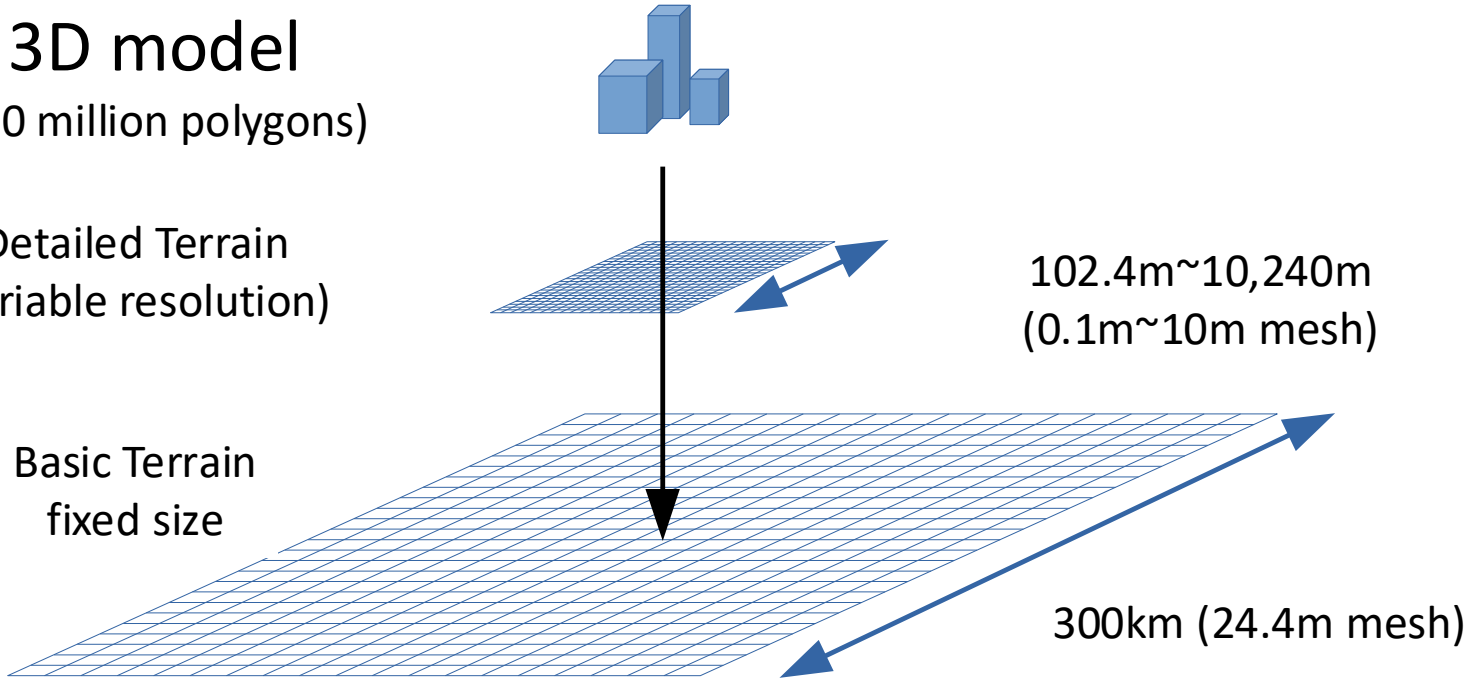


Terrain, Buildings, and Celestial Sphere
placement in Unity space

Orthorectification, sphere correction/optical correction
(terrain correction)

Tools & Data Workflow

Terrain reproduction in *arcAstro-VR*



Superposition of wide-area terrain, narrow-area terrain, and 3D models

Tools & Data Workflow

Sky reproduction with *arcAstro-VR*

Reproduce the sky in cooperation with the "*Stellarium*" (http://stellarium.org)

Use *Stellarium's* Remote Control (Plugin) and Skybox Tiles (Script) functions to transfer *Stellarium* sky images to *arcAstro-VR* and display them.

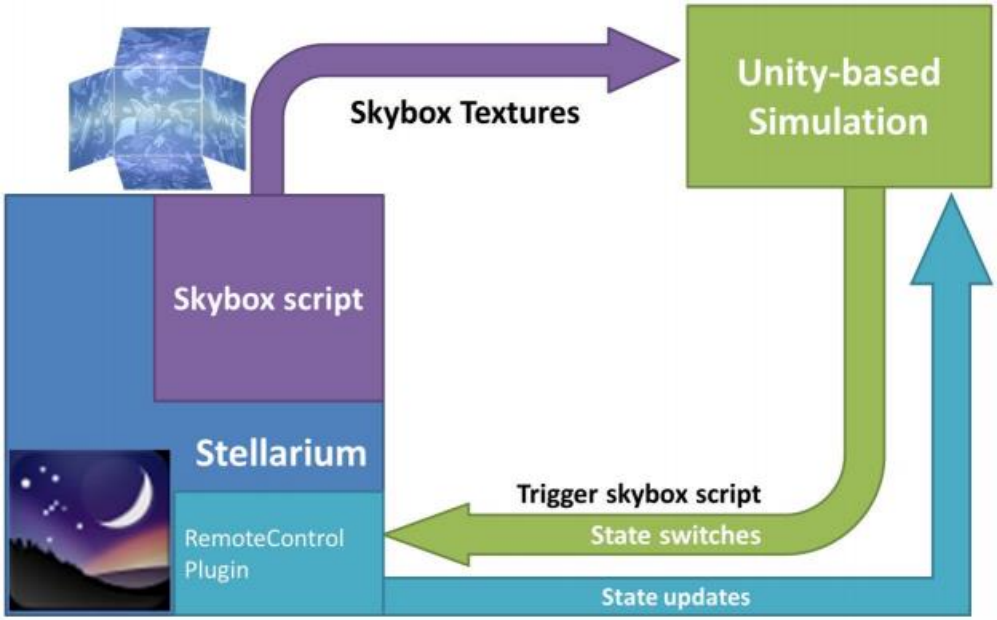


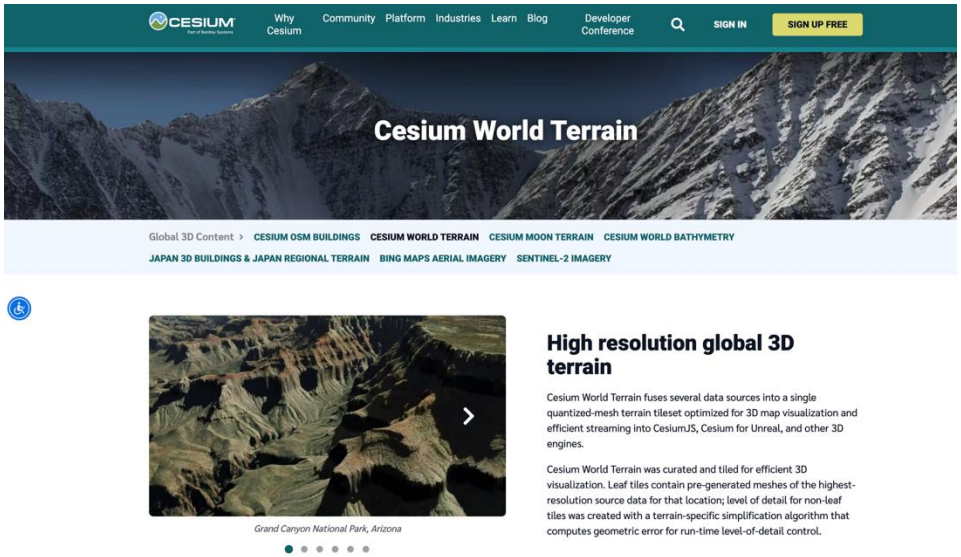
Diagram of the linkage between *arcAstroVR* (Unity program) and *Stellarium* Linkage diagram

taken from Figure 3 of Serious Gaming for Virtual Archaeoastronomy (https://doi.org/10.14434/sdh.v4i1.31041)

Tools & Data Workflow

Cesium Integration

- Supports **online 3D terrain/building data**
- You can specify **Cesium** asset IDs and tokens in dataset.txt
- Supports public sources like:
  - **Cesium World Terrain**[*1]
  - **Project PLATEAU**[*2]
  - **OpenStreetMap Buildings**[*3]



[*1] Cesium World Terrain: A service that provides detailed 3D terrain data for the entire Earth, creating realistic terrain models that include height information for mountains, valleys, plains, and other landforms. Data is collected from a variety of sources, providing high accuracy and global coverage.

[*2] PLATEAU is a project to realize digital twins of cities across Japan, promoted by the Ministry of Land, Infrastructure, Transport and Tourism in collaboration with various players. 3D city models are being developed as platform data for urban activities, and use cases are being developed in various fields. Furthermore, the 3D city models are being provided as open data so that anyone can freely extract city data.

[*3] OpenStreetMap (OSM) is a collaborative project that creates a free, editable map of the world. This 3D buildings layer is based on the OSM Daylight map distribution, hosted by Esri.

Tools & Data Workflow

Using in VR (HMD)

Supported: **Meta (Oculus) Rift / Quest / Quest2 / Quest3**
Requirements: **Windows with OpenXR**, strong GPU

Features:

- 6DoF movement
- VR controller UI
- Teleport or joystick movement
- Tunneling to reduce motion sickness

Meta Quest 3

Astronomical Accuracy in *arcAstro-VR*

arcAstro-VR relies on *Stellarium* to compute and render celestial bodies, importing this data into its own VR environment. *Stellarium* uses well-established ephemeris models:

Standard Model: VSOP87/ELP2000-82B

Accuracy: Within 1 arcsecond for:

Mercury, Venus, and Moon-Earth system:	±4000 years from A.D. 2000
Jupiter and Saturn:	±2000 years
Uranus and Neptune:	±6000 years

*This is sufficient for most historical, archaeological, and astronomical visualization applications.

Astronomical Accuracy in *arcAstro-VR*

High-Precision Models: DE430 and DE431 (JPL/NASA)

* Optional in *arcAstro-VR*.

Coverage:

DE430: 1549–2650 A.D.

DE431: 13200 B.C. to 17191 A.D.

Note: These models exceed the visual precision requirements of *arcAstro-VR*.

*The manual clarifies:"The representation accuracy on *arcAstro-VR* is less than the calculation accuracy of VSOP87, so there is no need to incorporate DE430 or DE431 intentionally."

Advanced Use

terrain4aAVR **QGIS plugin**:

For generating detailed terrain

Dome Master Output:

For fisheye projection in planetariums

Stellarium's **DE430/431 or VSOP87**:

For higher astronomical accuracy

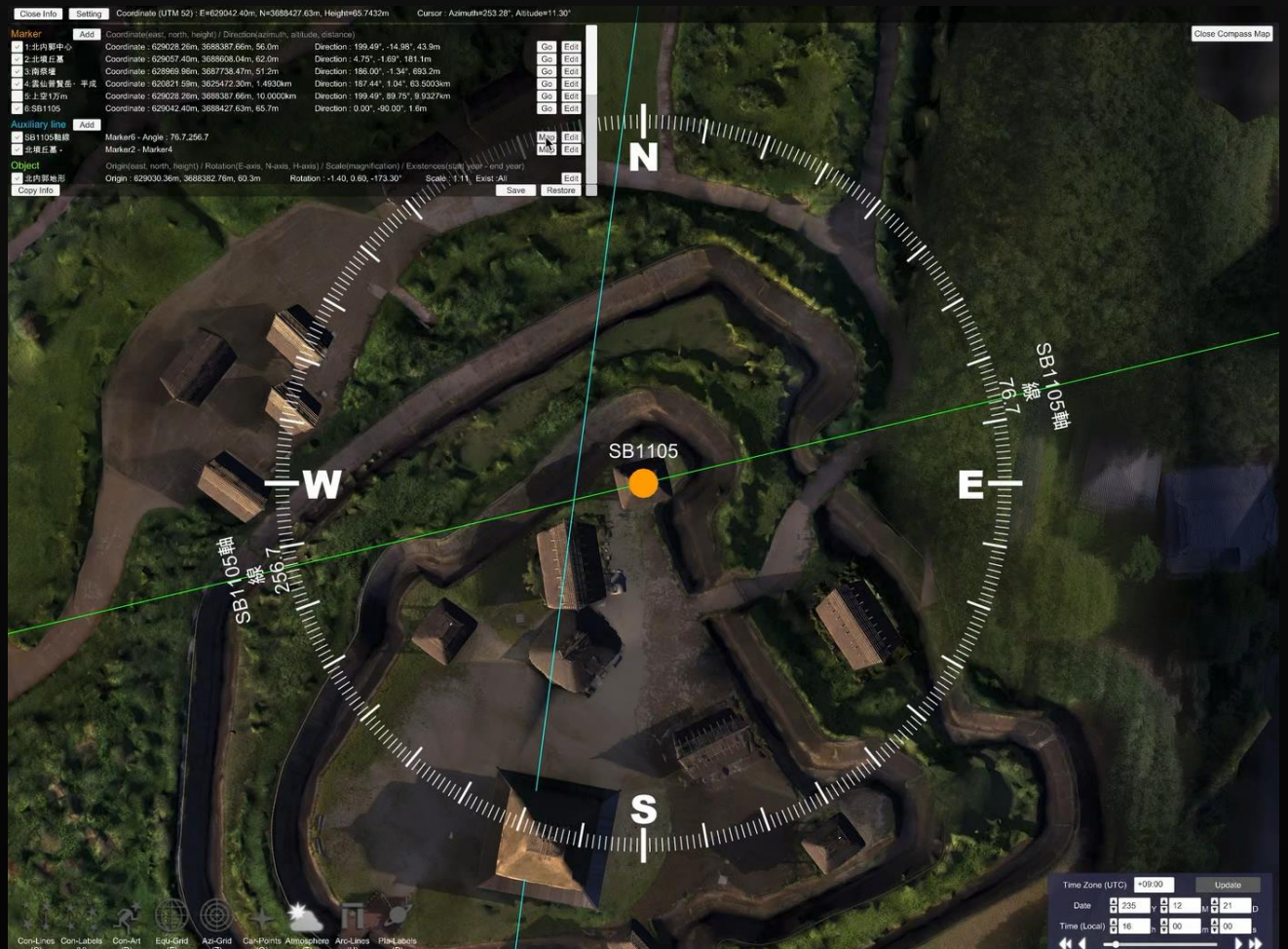
Applications

arcAstroVR has been employed to study the spatial and astronomical aspects of various archaeological sites.

For example, it has been used to analyze the Yoshinogari and Tsukuriyama sites in Japan, providing insights into how ancient structures align with celestial events.

Case Study: Yoshinogari Site

- Explored astronomical alignments



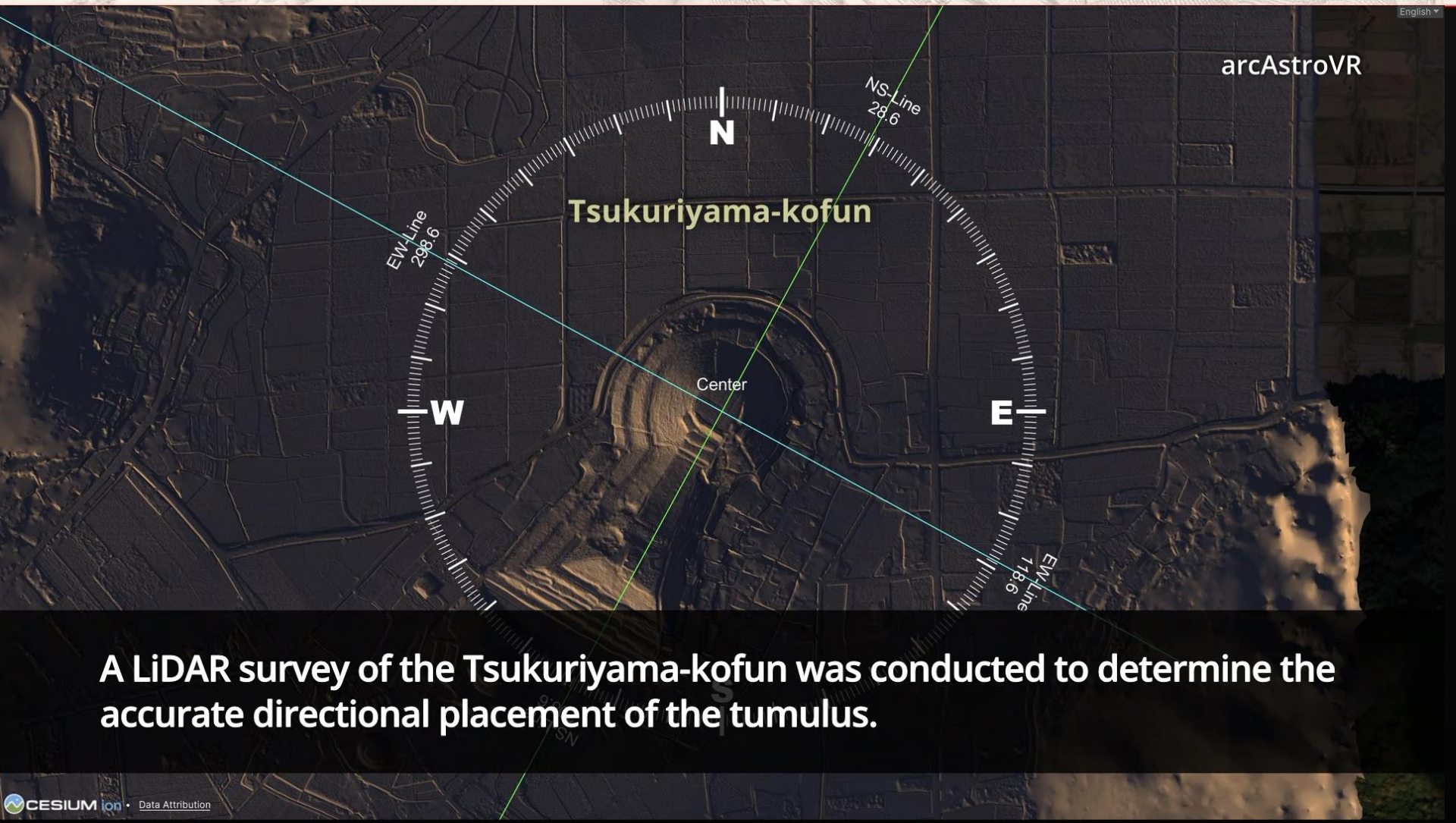
Unraveling the mystery of the Major Lunar Standstill

The video https://arcastrovr.org/movie/yoshinogari2021.mp4 was presented at the 4th Archaeological Astronomy Conference held at Yoshinogari Historical Park in December 2021.

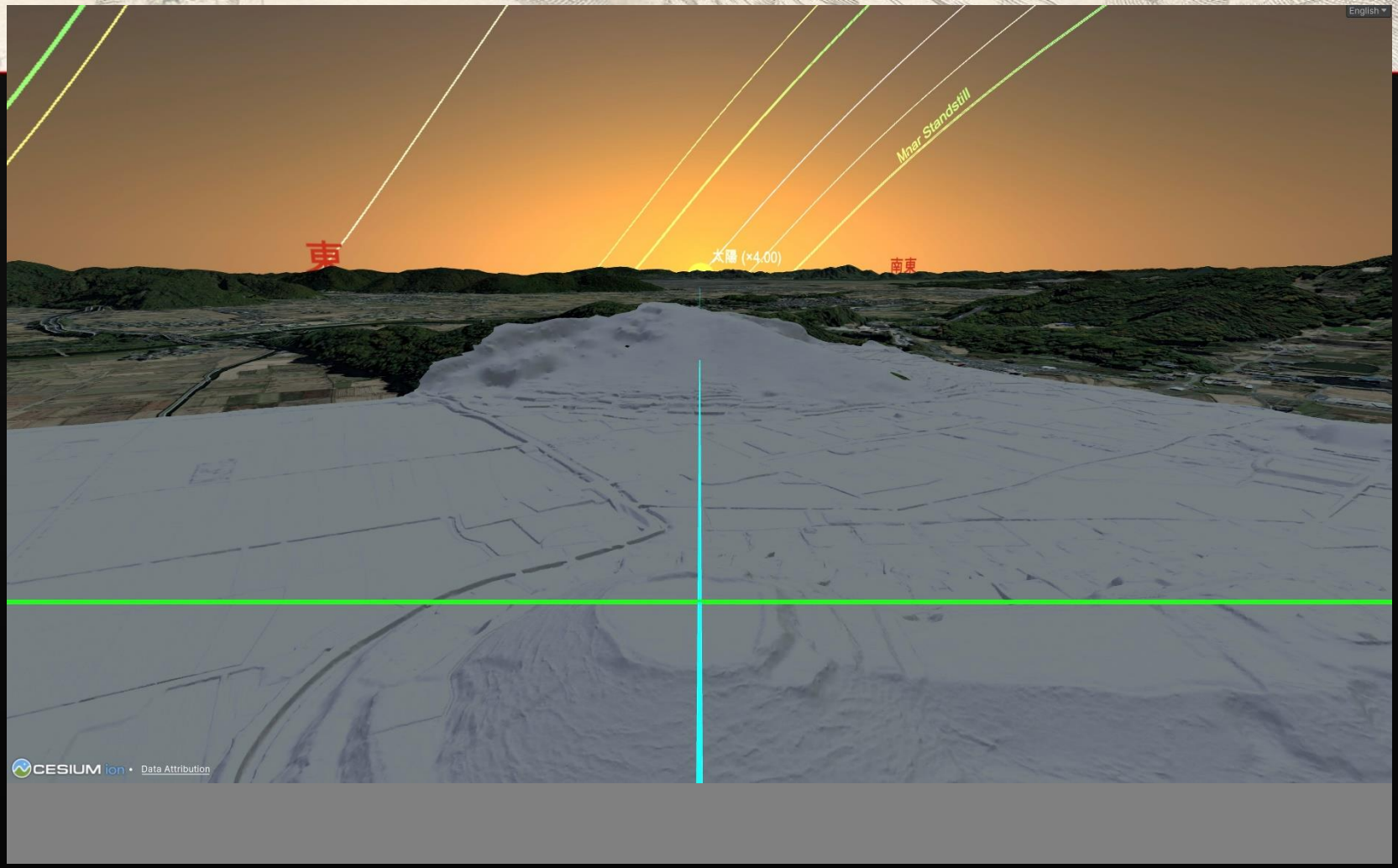
Sunrise and Moonrise as seen from the buildings

Utilizing ArcAstro-VR, the project aimed to investigate the correlation between celestial movements and the Yoshinogari archaeological site.

Case Study: Tsukuriyama Kofun



Tsukuriyama and Ishizuoka Kofuns



An image of the sun rising on the morning of December 22, 420, showing the direction perpendicular to the axis of the Tsukuriyama-kofun using arcAstroVR.

Future Development Goals

- Enhance daylight and twilight rendering
- Expand support for city-scale models (Cesium)
- Improve VR interactivity and educational interfaces
- Extend panoramic capabilities from real-world photos

Summary

- arcAstro-VR bridges archaeology and astronomy in immersive VR
- Uses the latest astronomical data for high accuracy
- Flexible for both academic research and public education

Learn more: https://arcastrovr.org/en/

Thank You

Questions?