arcAstroVR

Software for visualization of archaeological structures and the background celestial body

Users Manual

Ver.0.19

(June 21, 2023) 1077559vw

Table of Contents

Change log

App	Update date	Update content
0.8.1	March 26, 2021	**First draft**
0.9.1	May 6, 2021	**Correction of description due to the latest status of Stellarium** -Since the precautions for "1-1.Stellarium App" are no longer necessary, the description has been deleted. **The following corrections due to data file format changes** -Corrected the terrain data file name in "2-2-1 Terrain accuracy" "4-1. Data set file configuration" "4-2. Base terrain data creation" **The following corrections due to data management changes** -Additional description to "3-1. Stellarium settings" to specify the ArchaeoLines plug-in settings and the save destination of screen shots on Windows and Linux. -Corrected the description of "4-3. Creation of configuration file (dataset.txt)" **The following corrections due to UI changes** -Added time update key (1h UP, 1h DOWN, 10min UP, 10min Down) -Change the viewpoint change key, change the camera operation -Addition of Archaeological Auxiliary Lines (ArchaeoLines) key -Corrected the description of "6-1. Date and time setting", "6-2. Move operation", and "6-3. Display switching"
0.12.1	August 23, 2021	**Combined the manual and the operation manual.** **Changed and Added Stellarium settings.** -Corrected the description of "3-2. Recommended display settings" -Added "3-3. Time zone setting" **The following corrections due to data file format changes** -Added reference point / marker function -Added display / non-display function for reference points / markers / objects, etc. -Supports multiple coordinate system reference points such as 19 plane rectangular coordinates and UTM coordinate systems. -Corresponds to the correction of the true north direction angle at the origin of the reference point to which it belongs. -The x, y, z axis directions differ depending on the type of 3D format, and it is easy to confuse them, so the x, y, z notation in the dataset has been changed to the E, N, H notation. -Added time series management to 3D models -Support for reading avatars (Unity "Humanoid" type model) -Supports marker color specification -Supports file specification including directories -Corrected the description in "4-3. Creating a configuration file (dataset.txt)" **The following corrections due to UI changes** -Added the direction and altitude display of the cursor position. -Added the function to display the latitude and longitude of the current position. -Added the function to display the longitude / latitude of the reference point / marker and the direction / altitude / distance from the current position (camera position). -Zoom speed adjustment -Added a function to turn off flares such as the sun and moon when the viewing angle is zoomed to 60 degrees or more. -Date and time InputField is now key compatible -Marker display ON / OFF -Added list of 3D objects to InfoWindow -Added a check box function to show / hide in the information window. -Added a function to move to the reference point / marker in the information window (you can also click the marker) -Added elevation display to the information window -Added Copy function to Information Window (Ctrl + C or Cmd + C is also possible) -Added the name display of the reference point and marker that overlaps the cursor in the information window. -Added the name display of reference points, markers, remains, and 3D objects to the information window. -Supports scrolling and variable size of information window -Supports display / non-display of information window -Corrected the description of "6-1. Date and time setting", "6-3. Display switching", and

		"6-4. Information display". **Bug fixes** -Fixed a bug that the date and time cannot be specified in BC -Fixed a bug that the display change by the key and the icon status display are not synchronized. -To avoid malfunction, the key required for setting input is abolished from the shortcut registration key. -Fixed a bug that seconds are displayed as 1 digit in date input. -Corrected the starting point of azimuth / altitude angle calculation in the information window from the camera position to the human visual position. -Corrected the starting point of elevation calculation in the information window from the camera position to the human foot position. -Fixed one step forward when landing from Jump or Fly mode -Fixed that when Fly mode is canceled, it is forcibly released from the 1st viewpoint to the 3rd viewpoint. -Fixed the phenomenon that your body can be seen from the inside when you are in the 1st viewpoint. -Fixed a bug that the cursor moves when it overlaps with the reference point / marker while the viewpoint is moving. **others** -Migrate 3D engine from unity2019 base to unity2021 base -Added version notation -Multiple bug fixes and optimizations -Added "8. List of programs used in ArcAstroVR" -Added 3D model placement to Cartesian coordinates for placement height / tilt correction to match the Earth ellipsoid. -Adjust walking speed and running speed -Adjust the height of the steps that can be climbed -To support the operating environment with a trackpad or 1-key mouse, etc. -Change the viewpoint change operation to left-click drag -Changed enlargement / reduction operation to Ctrl + wheel -Corrected the description of "6-2. Move operation" -Multiple optimizations
0.13.2	November 28, 2021	**The following corrections due to data file format changes** -Added area setting to dataset.txt to support the data format output by the QGIS plugin terrain maker for arcAstroVR. At the same time, the setting of the down area is abolished. -Added dataset [].rot_x, dataset [].rot_y, dataset [].rot_z as the rotation setting of 3D object. At the same time, the setting of dataset [].rotation is abolished. -Corrected the description of "4-3. Creation of configuration file (dataset.txt)" **others** -Changed the basic height of the avatar from 180 cm to 160 cm. Collision detection changed to 140 cm. -Supports pasting textures on Terrain -Addition of detailed Terrain00 (corresponding to any resolution) -Compatible with Stellarium orbit after starting arcAstroVR -Since the geoid model is now included in the terrain generation in the QGIS plugin terrain maker for arcAstroVR, the altitude notation has been changed from altitude to ellipsoidal height. -When the ellipse height, EN coordinates, etc. exceed 1000 m, the display is changed to km (two digits after the decimal point).
0.14.4	March 9, 2022	**Additions** -Added auxiliary line -Added add markers and auxiliary lines in the operation screen. -Added move and edit markers, auxiliary lines, and objects in the operation screen. -Added multi-language display -Added ambient light control for screens -Added selection of display coordinate system -Added vertical ascent of avatar -Added compass map -Add output of dataset.txt for various edited settings -Added game controller support -Added Head Mount Display support **Modified the following due to the change of data file format.** -Changed dataset.txt specification Deleted the following description

		area, rp[], dataset[].rp_no, dataset[].rp_meridian, dataset[].rp_E, dataset[].rp_N, dataset[].rp_H, dataset[].rot_x, dataset[].rot_y, dataset[].rot_z Added the following description mesh, type, center, height, line[], dataset[].origin, dataset[].height, dataset[].rot_E, dataset[].rot_N, dataset[].rot_H The definition of rp[0], the reference point at the center of the terrain, has been eliminated. The center point is now defined by center and height. -Layout review to different screen sizes and resolutions; supports WXGA (1366 x 768) screens and above.
0.15.1	May 22, 2022	**Additions** -Added label display to the compass map -Added Japanese and Spanish to language settings -Added the function to save preference values and carry over the settings the next time they are opened. **Bug fixes** -Fixed resizing of the information window when settings are made in the various settings dialogs. -Fixed shifting of the compass map center and line display when moving the marker position on the compass map screen. -Fixed disappearance of corresponding auxiliary lines when LineEdit dialog is opened on the compass map screen. -Fixed disorder of information display when the designated marker of an auxiliary line is deleted. -Fixed auxiliary lines appearing vertically above the viewpoint when the end marker of an auxiliary line is deleted. -Fixed a bug that Preferences dialog could not be canceled when opened with the Info window closed. **others** - Updated Compatible with Unity Editor 2021.3.3f1 (LTS) - Updated Compatible with embedded asset Input System 1.30 - Updated Compatible with Embedded Asset Localization 1.31 - Updated Compatible with built-in asset XR Interaction Toolkit 2.02 - Updated Compatible with built-in asset 3rd Person Controller + Fly Mode 2.15 - Updated Compatible with embedded assets TriLib2 2.16 - Supports built-in asset JSON Object 2.12
0.16.1	July 25, 2022	**Additions** - Add read object display when reading the dataset - Add progress percentage display when loading datasets - Added dome master format output - Added setting to switch output to HMD after starting arcAstroVR **Bug fixes** -Fixed dataset loading algorithm to Improve stability -Fixed auxiliary line drawing algorithm to improve the uniformity of auxiliary line thickness -Fixed the phenomenon that the long-distance display is clipped in HMD. -Fixed an issue where analog sticks would stop working on HMDs. -Fixed an issue where the compass map label display width was short and line breaks were common. - Reviewed resource management and greatly reduced program size **others** -Update with complete migration to Unity's new InputSystem

0.17.3	2022年12月22日	**Additions** ・Add fixed camera function to marker ・Added water surface object function ・Added a function to display the copyright information of the model on the screen. ・Add UI for HMD ・Added gamepad UI ・Added UI for dome master ・Addition of dome master angle of view, rotation, tilt angle, fixed azimuth setting ・Added avatar height setting ・Added UI display size setting ・Added UI display switching function ・Added normal map support for 3D Objects ・Add progress display for SkyBox loading - Added his 3-axis Scale setting to ObjectEdit **Bug fixes** ・Strengthen grammar check of dataset.txt ・Fixed that Display Output of Setting did not support multiple languages. ・Fixed that CopyInfo output was not multilingual. **Changes** ・Change the format of dataset.txt ・Change the operation button of the game pad ・Changed mouse viewpoint movement from left mouse drag to right mouse drag. **others** ・Update embedded asset TriLib2 to 2.17a (Native support for Silicon Mac)
0.18.4	2023年3月17日	**Additions** ・Added Cesium's WorldTertain function (using Cesium for Unity Assets) ・Add fire object (using REAL FIRE Assets) ・Add mirror object (using Mirrors and reflections for VR Assets) - Added Skybox mode (F1-F12) that can save the current starry sky ・Added Skybox pseudo-rotation function that responds to changes in date and time in real time. ・Added UI resizing function ・Added a function that increases the movement speed according to the altitude of the Avatar ・Added a function that changes the amount of viewpoint movement according to the zoom ratio. ・Added type attribute to dataset to specify water, flame, and mirror objects. **Bug fixes** ・Fixed a bug when selecting a gamepad outside the infoview display area. ・Fixed a bug where movement would remain if menu selection was performed while moving. -Fixed an issue where an Avatar would spawn before terrain generation was completed and permanently fall below the ground. ・Fixed a bug that may cause an error if the definition order of datasets is inconsistent. ・Fixed a bug that an error may occur if there is no entry after = in dataset **Changes** ・Change rendering from Built-in Render Pipeline to Scriptable Render Pipeline (URP) ・Domemaster output is temporarily disabled due to a change in rendering method. ・Changed the water object representation from Assets to URP Water ・Changed display of top bar altitude to 2 digits after the decimal point ・Changed water object specification of dataset to type attribute notation

		others ・Update Unity Editor to 2021.3.16

0.19.5	2023年6月21日	**Additions** ・Added Asset ID / TOKEN / URL settings for Cesium ion (dataset/ setting) ・Added geoid height setting (dataset/ setting) ・Added settings for loading self-made terrain data (dataset) ・Added automatic terrain correction function (dataset) ・Added free-form model function to water object (dataset) ・Added freeform model function to mirror object (dataset) ・Add water wave height setting (setting) ・Added mouse/controller sensitivity settings (setting) ・Added a function that the light range and intensity are proportional to the size of the fire. **Bug fixes** - Modified so that cesium attribute, type attribute, and geoid attribute are also output when saving. - Fixed Domemaster output that was temporarily disabled in 0.18.4 ・Fixed a problem with shadows caused by sunlight projected from below the horizon when using CesiumWorldTertain. ・Fixed a bug that sometimes caused CesiumWorldTertain to fall under the terrain when switching terrain levels. ・Fixed a bug that ambient light projection on the terrain was incorrect due to incorrect embedding of TerrainShader for URP. -Fixed a bug that the viewpoint camera penetrates the wall ・Fixed a bug that stopped working when the Stellarium output file unityData.txt was lost. ・Fixed a bug when Skybox loading was not completed. **Changes** ・Unified terms by changing dataset[] of dataset to object[] (old notation is also valid) ・Unified terminology by changing dataset mesh to narrow_mesh (old notation is also valid) -Changed the back of the model, which was previously transparent, to be visible (passing through is possible as usual) **others** ・Update Cesium from v0.2 to v1.3.1 ・Update TriLib from v2.1.8 to v2.2.0

1. File structure

Two apps and one dataset are required to operate arcAstroVR.

- Stellarium app
- arcAstroVR app
- Dataset for arcAstroVR

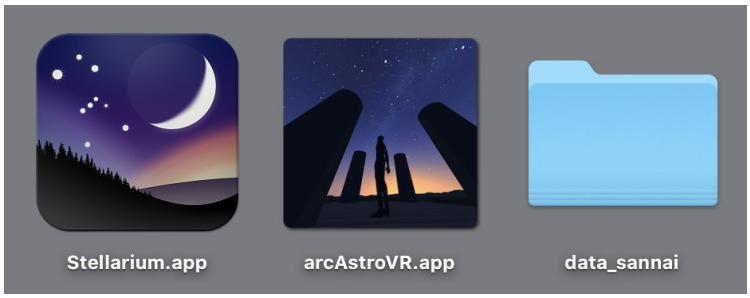


Fig 1 : Two applications and data sets

1.1 Stellarium app

Stellarium is a planetarium app that runs on Linux, Windows, and macOS. It is provided under the GNU General Public License and can be obtained free of charge.

Please download and obtain the latest version (Ver 0.21.0 or later) from the official Stellarium website (http://stellarium.org).

Stellarium operating requirements

- OS: Linux / Unix or Windows 7 or higher or Mac OS X 10.12.0 or higher
- Graphics: OpenGL 3.0 and GLSL 1.3 or OpenGL ES 2.0 behavior
- Memory guidelines: 512 MB or more
- Disk procedure: 420 MB or more

1.2 arcAstroVR app

Please download and use the arcAstroVR app from the website (https://arcastrovr.org/download.html?id=app) to your PC.

The arcAstroVR app is prepared for each OS.

- For Windows : arcAstroVR-Win-0.16.1/arcAstroVR.exe
- For Mac : arcAstroVR-Mac-0.16.1/arcAstroVR.app

1.3 Dataset for arcAstroVR

The data set for arcAstroVR contains undulation data of land, 3D model data of buildings, and setting information. You will need to prepare this dataset yourself. For details on creating a dataset file, please refer to "4. Creating a Dataset".

Datasets that are available as samples can be downloaded from the Dataset Download page of arcAstroVR WEB (https://arcastrovr.org/download.html?id=dataset). Please use this dataset if you would like to check the operation.

1.4 Quick start

1.4.1 Configuring Stellarium

Start Stellarium and make the following settings.

1. Setting up the sky image (Skybox) transfer function
   "Setting screen (Config) [F2] > Scripts > skybox.ssc"
   ・Close window when script runs: ON
2. Setting the destination of transferring the sky image (Skybox).
   ・Destination: The path where the Stellarium configuration file is saved on each OS.[*1]
   *1: For Win, specify C:/Users/<USERNAME>/AppData/Roaming/Stellarium.
   For Mac, specify /Users/<USERNAME>/Library/Application Support/Stellarium.
   <USERNAME> is the user name registered on the computer. If your username is iwashiro, then
   C:/Users/iwashiro/AppData/Roaming/Stellarium (on Windows)
   /Users/iwashiro/Library/Application Support/Stellarium (for Mac).
   ・File Format: png
3. Communication settings with arcAstroVR
   "Setting screen (Config) [F2] > Plugins > Remote Control"
   ・Run at startup (Load at startup): ON
   ・Server enabled: ON
   ・Enable automatically at startup: ON
   ・Port number (port): 8090
4. Saveing the above settings

   "Setting screen (Config) [F2] > Main (Main) > Save settings"

*The above settings are the minimum requirements, but please refer to "3.1 Stellarium settings" for detailed setting procedures and other settings.

1.4.2 Preparation of the dataset

The bare minimum required for the dataset is the coordinates of your current location and terrain data.

Prepare a text file containing the following three lines (the attached dataset_sample.txt is also acceptable).

```
type = WGS84
center = 138.727220,35.360833,3800
cesium_terrain_ID/URL = 1
```

*type is the specification of the coordinate format, and WGS84 is specified for the latitude and longitude system.
*center is the specification of the center coordinates, and is specified in the order of longitude, latitude, and height.
* If you specify 1 for cesium_terrain_ID/URL, you can use the terrain published by Cesium ion.
*For other detailed dataset specifications, please refer to "4.3 Creating a configuration file (dataset.txt)".

1.4.3 To Start

1. Launch Stellrium.
2. Launch arcAstroVR.
3. Load the dataset file created above.
4. arcAstroVR will start running the simulation.

In the case of the coordinates of the dataset above, the summit of Mt. Fuji is reproduced.

* Please refer to "6. Operation of arcAstroVR" for the operation method.
*If an error is displayed when reading the dataset, please check that the capitalization is correct and not in full-width notation.
*If arcAstroVR is set to full screen or Stellarium is hidden, communication between arcAstroVR and Stellarium may not work. In that case, try placing it so that part of Stellarium is visible on the screen.

2. Overview

arcAstroVR is a VR program that uses Unity as a 3D engine, reads Terrain data (terrain) and 3D Object data (remains, etc.) from datasets, and imports and displays Skybox textures (sky) from Stellarium.

2.1 Functional overview

arcAstroVR works in conjunction with the planetarium app Stellarium. Therefore, both arcAstroVR and Stellarium apps must run at the same time. arcAstroVR is in charge of spatial display of land and buildings, movements, and overall control, while Stellarium calculates and displays celestial bodies.

For cooperation between arcAstroVR and Stellarium, we use the following communication plug-in for Stellarium, output script, and collaboration assets for Unity created by Georg Zotti and others. Please note that arcAstroVR is created using the VR engine Unity.

Stellarium：**Remote Control (Plugin)**

- Authors: Florian Schaukowitsch, Georg Zotti
- License: GNU GPLv2 or later

※This plugin was created in the 2015 campaign of the ESA Summer of Code in Space programme.

Stellarium：**Skybox Tiles (Script)**

- Author: Georg Zotti
- License: Public Domain

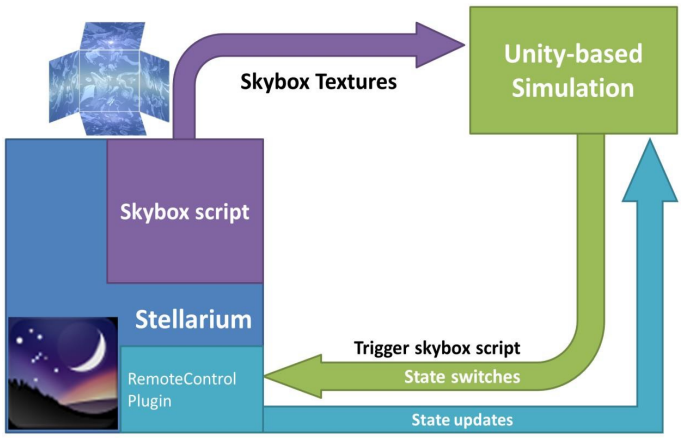
Unity：**Stellarim - Unity (Assets for Unity, https://unitylist.com/p/11ul/stellarium-Unity)**

- Author: Georg Zotti, John Fillwalk, David Rodriguez, Neil Zehr
- License: GNU General Public License v3.0

※This is a collaboration between Georg Zotti (LBI ArchPro Vienna) and John Fillwalk, David Rodriguez and Neil Zehr (IDIA Lab, Ball State University) suggested by Bernard Frischer (Indiana University).

The cooperation between arcAstroVR and Stellarium is as follows.

1. Send a request from arcAstroVR to Stellarium's RemortControl plugin.
2. Stellarium Skybox script outputs 6 tiles global image.
3. Stellarium notifies arcAstroVR of updates through the Remort Control plugin
4. Unity automatically detects the global image output of 6 tiles, loads the global image into Unity, and synthesizes it by reflecting it on the celestial sphere.



F 2：Diagram of the linkage between arcAstroVR (Unity program) and Stellarium Linkage diagram taken from Serious Gaming for Virtual Archaeoastronom（https://doi.org/10.14434/sdh.v4i1.31041）

2.2 Reproduction accuracy

2.2.1 Terrain accuracy

For arcAstroVR's terrain, use the Terrain data based on elevation image data and 3D terrain data created with a 3D model.

For terrain data, Cesium World Terrain data, which is automatically loaded via the Internet, can be used to create wide-area and narrow-area Terrain data you have created using the elevation image data published by the national or local government.

Cesium World Terrain is a terrain created from 3D map data in tile format provided by Cesium GS, Inc. of the United States. Terrain terrain data of specified coordinates is read from the Internet and a spherical earth is constructed in VR space. The advantage is that you don't have to create your own Terrain data. The disadvantage is that it does not work unless you have an internet connection. Also, the accuracy of the 3D maps provided by Cesium GS, Inc. (approximately 30m mesh) varies. In addition, since there is no optical correction (equivalent earth format correction), there is no expansion of the field of view due to the refraction effect of the air (described later).

On the other hand, wide-area terrain data and narrow-area terrain data are terrain data created using the plugin "terrain4aAVR" for the GIS software "QGIS". This plugin can be downloaded from the arcAstroVR WEB Plugin Download page (https://arcastrovr.org/download.html?id=plugin). The advantages of creating your own Terrain data are that you can handle areas not covered by Cesium World Terrain, that it works even without an internet environment, and that you can use terrain with more detail than Cesium World Terrain. Wide-area terrain data is limited to a fixed 24m mesh and has almost the same accuracy as Cesium World Terrain, but narrow-area terrain data can support resolutions of 0.1 to 10m mesh. It also supports expansion of the field of view through optical correction (equivalent earth format correction). Disadvantages include the need to be familiar with GIS operations and having to procure data for GIS yourself.

Wide-area Terrain data forms a VR space using shaded relief data (16-bit gray image file in raw format) divided into 9 tiles (3 rows and 3 columns). Each tile can extend up to an area of 100 x 100 km*Unity's specification limit, resulting in a total terrain area of 300 x 300 km. Also, since a maximum of 4096 x 4096px of hillshade data can be set in one tile*Unity's specification limit, wide-area terrain data can have a horizontal resolution of 100km ÷ 4096 = 24m. In addition, in the height direction, the range from -1000m to 9000m is expressed in 16 bits (65536), so it can have a vertical resolution of 10000m ÷ 65536 = 15.26cm.

Wide-area terrain data is stored in the dataset's terrain folder with file names terrain11.raw to terrain33.raw. These wide-area terrain files are arranged as shown in Fig 3.

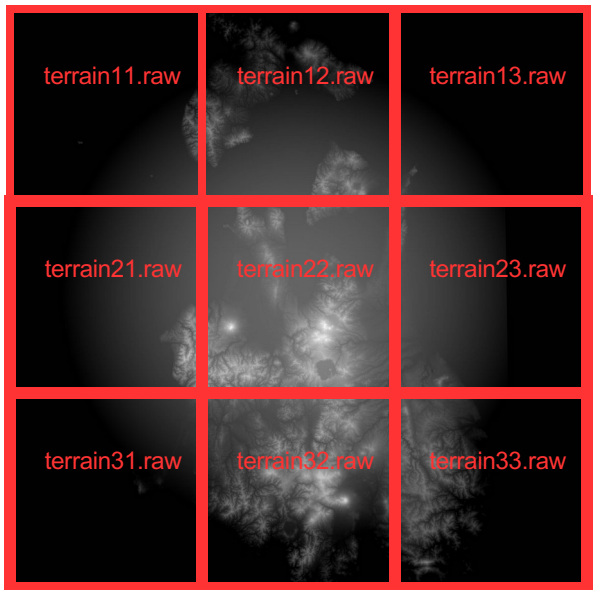
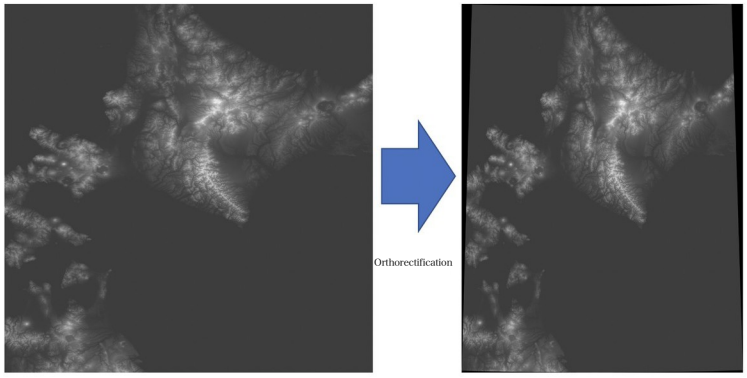
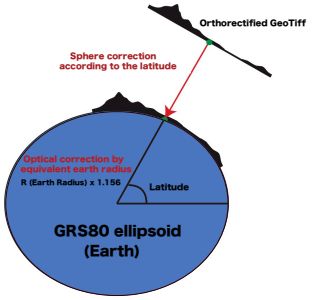


Fig 3：Placement of large area terrain files

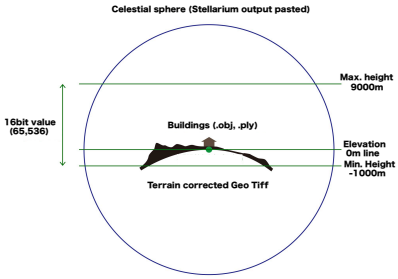


Equal latitude and longitude projection

Orthographic projection



Terrain correction
(GRS80 ellipsoid + equivalent earth radius)



Terrain, buildings, and celestial sphere placement in Unity space

Fig 4: Orthorectification, sphere correction/optical correction (terrain correction)

Data for wide-area terrain must be orthorectified, spherically corrected, and optically corrected (equivalent earth format correction) in advance. (Fig 4)

Apart from wide-area terrain with fixed resolution and range, a narrow-area terrain with arbitrary resolution and variable range can be used. However, the narrow terrain can have only one tile with a size of 4096 x 4096px. The resolution of 1px can be specified arbitrarily (0.1 to 10m), and if 1px is 5m resolution, it will be a narrow terrain with a range of 4096 × 5m = 20480m.

arcAstroVR superimposes 3D models of 3D that cannot be expressed using elevation data) and ruins on top of these terrain data to reproduce them in VR space (Fig. 5). Each terrain data is superimposed at the center coordinates. The center coordinates are defined by the coordinates specified by center in dataset.txt. Coordinates can be specified in WGS84 (latitude and longitude), plane rectangular coordinate system (19 system), or UTM coordinate system. When creating terrain in QGIS, specify the center coordinates above. For details on settings, see "4-3. Creating a settings file (dataset.txt).

2.2.2 Astronomical accuracy

Stellarium supports VSOP87/ELP2000-82B as standard for calculating solar system objects and higher precision DE430 and DE431 as an extension.

VSOP87 guarantees an accuracy of within 1" for the centroids of Mercury, Venus, and the Moon-Earth system for 4000 years before and after A.D. 2000. The same accuracy is guaranteed for Jupiter and Saturn for 2000 years and Uranus and Neptune for 6000 years before and after A.D. 2000.

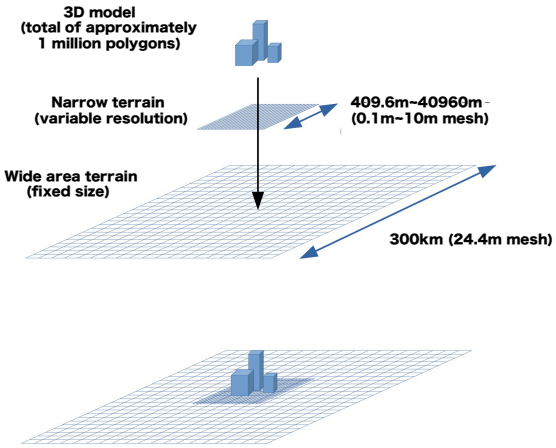


Fig 5: Superposition of wide-area terrain, narrow-area terrain, and 3D models

DE430 and DE431 are lunar and planetary almanacs compiled and published by JPL (Jet Propulsion Laboratory), a NASA agency, for planetary exploration. DE430 supports the period from December 21, A.D. 1549 (Julian date: 2287184.5) to January 25, A.D. 2650 (Julian date: 2688976.5). DE431 supports August 15, B.C. 13200 (Julian date: - 0.3100015.5) to March 15, A.D. 17191 (Julian date: 8000016.5).

Note that since the representation accuracy on arcAstroVR is less than the calculation accuracy of VSOP87, there is no need to intentionally incorporate DE430 or DE431 (described later in 2-2-3).

2.2.3 Light and shadow accuracy

arcAstroVR uses Directional Light to display shadows based on the azimuthal altitudes of the Sun, Moon, and Venus calculated by Stellarium. Therefore, the accuracy of light and shadow depends on Stellarium's calculation angle accuracy and Unity's light source setting angle accuracy.

When using VSOP87 in Stellarium, the angular accuracy of Venus, Earth, and Moon calculations is guaranteed to be within 1″ (0.00028 degrees) for 4000 years before and after 2000 AD.
On the other hand, arcAstroVR's collimated light configuration has an angular accuracy of 0.001 degrees*Unity Asset: Stellarim – Unity specifications.

It can be seen that the accuracy of the directional light source setting is lower than the calculated angular accuracy of VSOP87, so the angular accuracy of light and shadow depends on the directional light angular accuracy of arcAstroVR.

The rotation of the celestial sphere during diurnal motion is 15 arc seconds (0.004 degrees) per second, so with arcAstroVR's parallel light source angle accuracy (0.001 degrees), light and shadow are simulated with a temporal resolution of about 0.25 seconds.

3. Installation and configuration

3.1 Stellarium settings

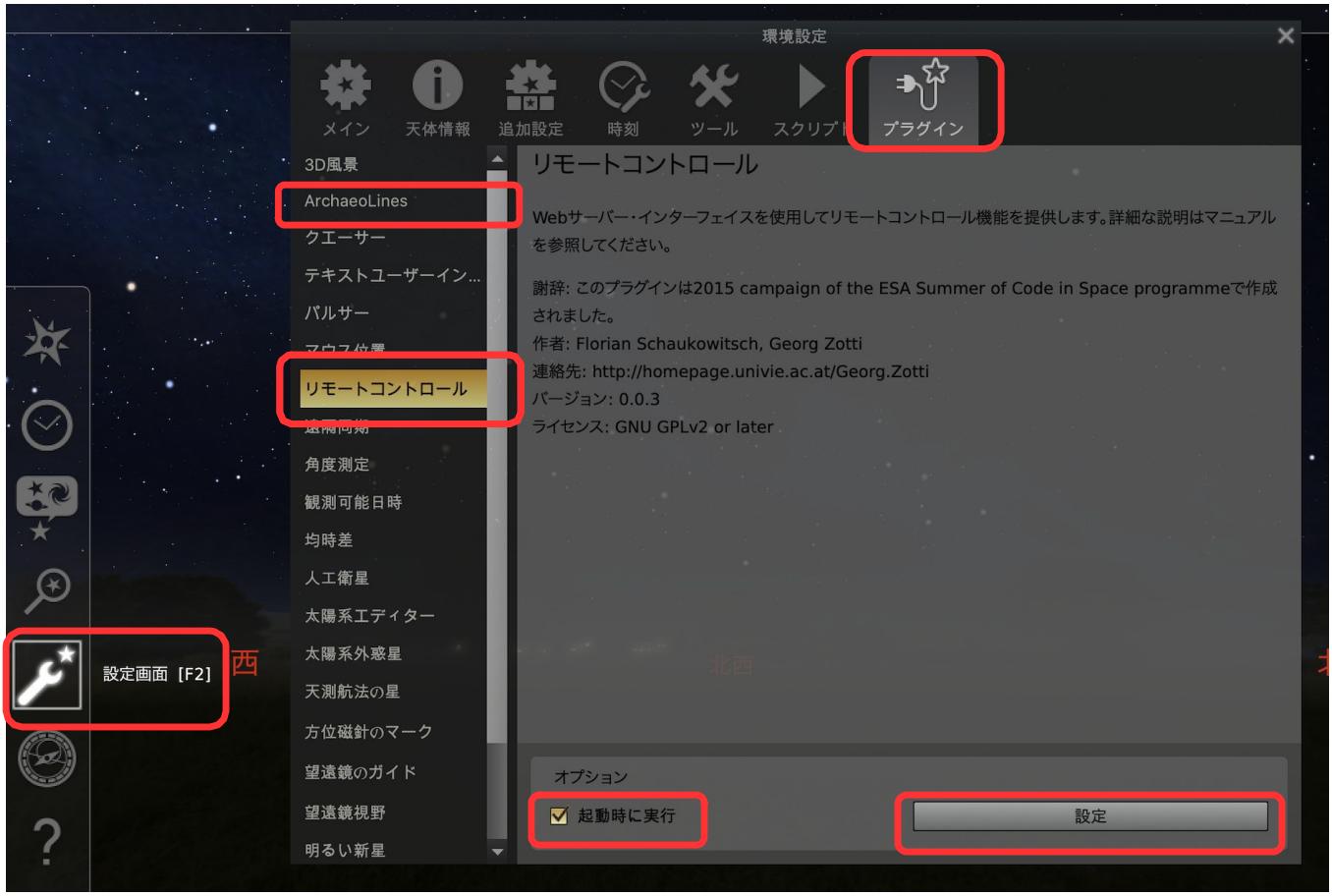
After installing the latest version from the Stellarium official website (http://stellarium.org), launch it and perform the following settings.

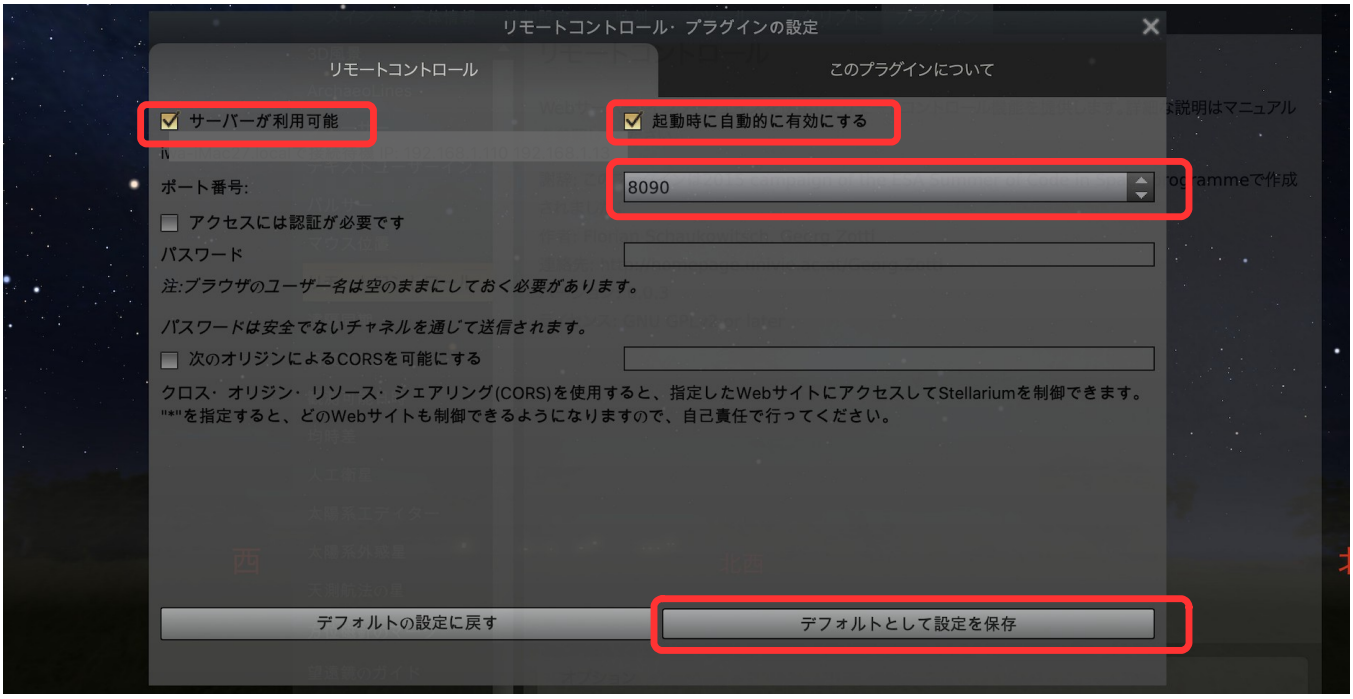
1 Open the settings screen (Config) [F2] > Plugins > Remote Control and check "Load at startup"

2 Open the settings screen (Config) [F2] > Plugins > ArchaeoLines and check "Load at startup"

3 Restart Stellarium

4 Open the settings screen (Config) [F2] > Plugins > Remote Control and click the "configure" button.



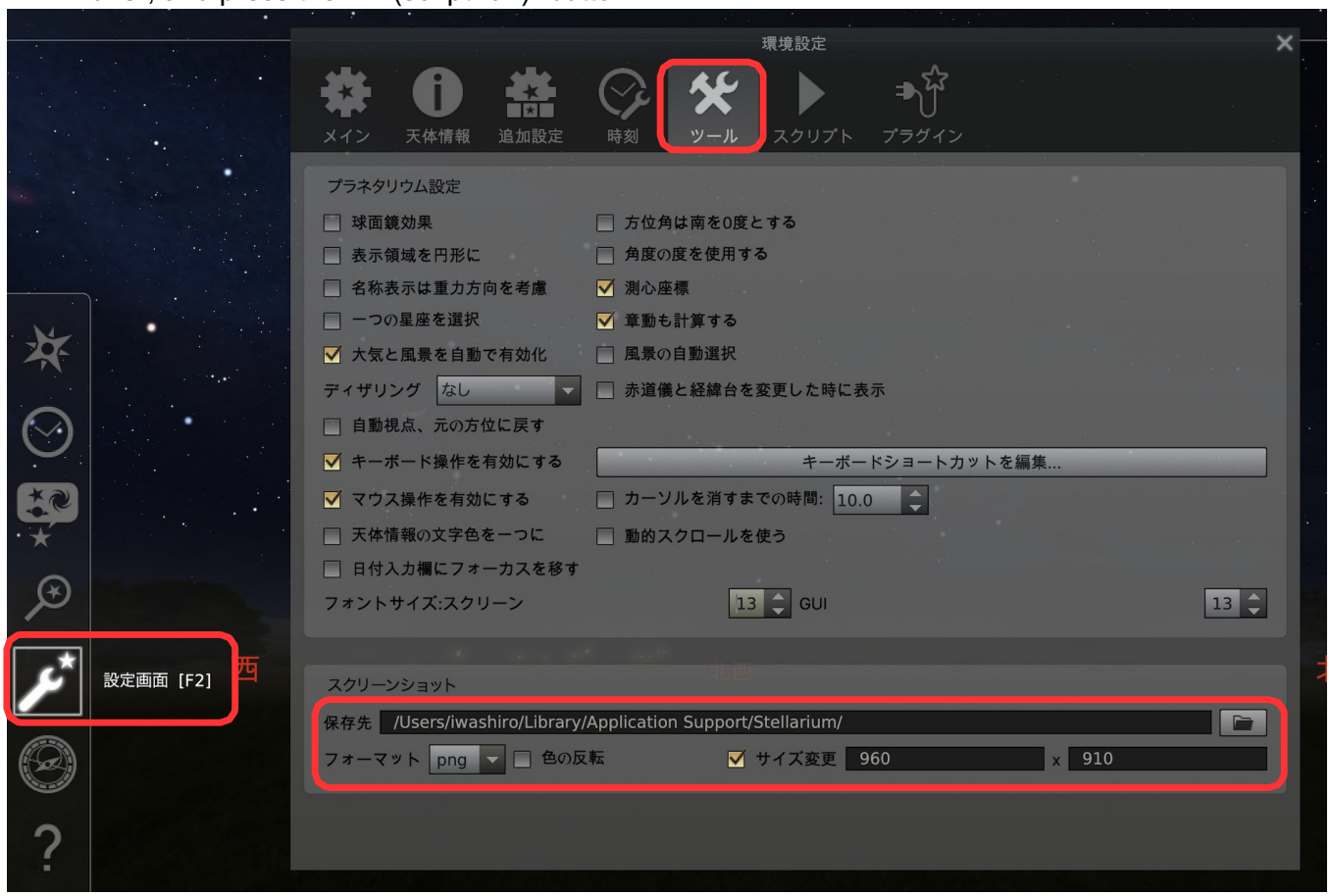


5 Check "Server enabled" and "Enable automatically at startup"

6 Set 8090 for “port number”

7 Click the "Save settings as default" button to close the settings screen.

8 Open the settings screen (Config) [F2] > Scripts > skybox.ssc, check "Close window when script runs", and press the "▶ (script run)" button.



9 Open Config [F2] > Tool > Screenshot and set the following.

Storage location: Path to the storage location of the Stellarium configuration file*1

Format: png

Resize (check on): 960 x 910

※1：For Win OS, please specify C:/Users/<USERNAME>/AppData/Roaming/Stellarium/.
For Mac OS, specify /Users/<USERNAME>/Library/Application Support/Stellarium/.
Note that <USERNAME> is the user name registered on the computer.

3.2 Recommended display settings

If you want to reproduce the sky under the best conditions that people can see with little light pollution, we recommend setting the display settings [F4] to the following.

Sky tab

- Milky Way Brightness/Saturation ON 1.50 / 1.00
- Atmosphere ON
- Light pollution Manual installation: Bortle Class 1 (far left of the bar)
- Stars ON
- Absolute scale 1.20
- Relative scale 0.80
- Blink OFF
- Grade limit ON: 8.00

Solar system objects tab

- Solar system objects ON
- Display moon halo OFF
- Show Sun's Glare OFF

3.3 Time zone setting

In Stellarium's default settings, if you specify a year before 1848 (before time zones were introduced), the local mean solar time or local true solar time zone will be automatically set so that it may deviate from the time zone setting in arcAstroVR. In that case, please adjust the time zone of arcAstroVR's dataset.txt to the local mean solar time or local true solar time, or adjust the time zone of Stellarium to the time zone of dataset.txt.

To change Stellarium's time zone, open Current Location [F6], turn on Customize Time Zone, and select the desired time zone from the "Time Zone" dropdown.

4. Creating a dataset

4.1 Dataset file structure

The dataset consists of three parts:

- ataset.txt: Dataset configuration file (required)
- object folder: stores 3D objects
  This folder stores 3D models such as ruins and nearby shadow elevation files. This folder is not needed if you do not use 3D models.
- terrain folder: storage of terrain data
  Wide area terrain requires 9 files: terrain11.raw to terrain33.raw. For narrow terrain, one file, terrain00.raw, is required. This folder is unnecessary if you only handle Cesium World Terrain data loaded from the Internet.

4.2 Creating detailed wide- and narrow-area topographic data

When dealing with areas not covered by Cesium World Terrain or more detailed terrain, use two types of self-made terrain: wide and narrow.

The wide area terrain is a 24m mesh shaded elevation data file that covers a wide area of 300 x 300 km.

The narrow terrain is a shaded elevation data file with any mesh resolution that covers the range of mesh resolution *4096 (20480*20480m for 5m mesh).

You can create terrain data for arcAstroVR using the QGIS plugin "terrain4aAVR".

For instructions on installing and using QGIS and terrain4aAVR, please refer to the attached "terrain4aAVR_Manual.pdf".

Place the terrain files terrain00.raw~terrain33.raw and terrain00.jpg~terrain33.jpg generated by the QGIS plugin "terrain4aAVR" into the terrain folder of the dataset.

4.3 Creating a configuration file (dataset.txt)

Dataset.txt contains basic data information and installation information (Note: The format has changed from ver. 0.19).
Set items are described below.

Basic information items

*Write in the format of "attribute name=value".

Attribute	Value	Note
location	"title name" Initial value: unspecified	English notation only (because Stellarium only accepts English) Example: location = "Yoshinogari"
country	"country name" Initial value: unspecified	English notation only (because Stellarium only accepts English) Example: country = "Japan"
timezone	± hour:minute Initial value: +00:00	Timezone settings (-12:00 to +13:00) Example: timezone = +09:00
date	year/month/day Initial value: 1/1/1	Start date Example: date = 216/12/12
time	hour: minutes: seconds Initial value: 01:01:01	Start time Example: time = 16:00:00
narrow_mesh	Initial mesh resolution: unspecified	Mesh resolution of narrow terrain (m). Enter the numerical value specified in the QGIS plugin terrain4aAVR. Example: narrow_mesh = 5
type	coordinate system symbol (required) Initial value: unspecified	For latitude and longitude notation: WGS84 For Japanese plane rectangular coordinate 19 system: JPR01~19 (2-digit number is zone number) For UTM coordinate system: UTM01~60 (2-digit number is zone number) Example: type = JPR05
center	easting coordinate, northing coordinate, ellipsoid height (required) Initial value: unspecified	Specify the coordinates of the terrain center point. For WGS84, longitude (°), latitude (°), and ellipsoid height (m). For JP**, the Y coordinate (m), X coordinate (m), and ellipsoid height (m) of the specified zone number**. For UTM**, the E coordinate (m), N coordinate (m), and ellipsoid height of the specified zone number** (m) Example: center = 130.386319,33.326944,56
avatar	file name Initial value: unspecified	Specify the avatar file name (with extension) saved in the object folder. Example: avatar = arex.fbx
avatar_height	numerical value Initial value: 176	Avatar height (cm) Example: avatar_height = 140
geoid	numerical value Initial value: 0	If the terrain data is ellipsoid height and the 3D Object is elevation data, specify the geoid height. Usually, the relationship is ellipsoid height = elevation + geoid height. Example: geoid = 63.3
cesium_terrain_ID/URL	character string Initial value: unspecified	Set the Cesium ion ID of terrain data or the URL of 3DTiles data. Example (Cesium World Terrain): cesium_terrain_ID/URL = 1 Example (Project Platue: Geospatial Information Authority of Japan): cesium_terrain_ID/URL = 770371
cesium_terrain_TOKEN	character string Initial value: unspecified	If TOKEN is set in the terrain data of Cesium ion ID, enter TOKEN. Example (Project Platue/Geographical Survey Institute): cesium_terrain_TOKEN = eyJhbGciOiJIUzI1NiIsInR5cCI6IkpXVCJ9.eyJqdGkiOiI5N2UyMjcwOS00MDY1LTQxYjEtYjZjMy00YTU0ZTg5MmViYWQiLCJpZCI6ODAzMDYsImlhdCI6MTY0Mjc0ODI2MX0.dkwAL1CcljUV7NA7fDbhXXnmyZQU_c-G5zRx8PtEcxE
cesium_build_ID/URL	character string Initial value: unspecified	Set the Cesium ion ID of the building data or the URL of the 3DTiles data. Example (OpenStreatMap): cesium_build_ID/URL = 96188 Example (Project Platue: Matsumoto City): cesium_build_ID/URL = https://plateau.geospatial.jp/main/data/3d-tiles/bldg/20202_matsumoto/notexture/tileset.json
cesium_build_TOKEN	character string Initial value: unspecified	If TOKEN is set in the terrain data of Cesium ion ID, enter TOKEN. Example: cesium_build_TOKEN = sInR5cCI6IkpXVCJ9.eyJqdGkiOiI5N2UyMjcwOS00
raw_terrain	True or False Default value: True	Set up loading of custom-made terrain data (raw file). If you only want to use Cesium's 3D Tiles terrain and do not want to overlay your own terrain data, specify False to stop loading the Terrain raw file. Example: raw_terrain = False

copyright	"Broad area credit", "Narrow area credit" Initial value: unspecified	Credit settings are used for custom-made terrain data. Credits will also be displayed when the corresponding terrain is displayed. You can also specify just the wide-area terrain. Example: copyright = "Jaxa ALOS(30m mesh DTM)/Google Earth(Photo)", "GSI(5m mesh DTM)/Google Earth(Photo)"

Marker information item (maker[ ])

*Write in the format "maker[ ].attribute name=value".

*Enter marker ID numbers in order starting from 1 in [ ]. There is no limit to the number of markers that can be registered.

Attribute	Value	Note
name	"Marker name" Initial value: unspecified	Can be written in Japanese Example: marker[1].name = "北内郭中心"
origin	Easting coordinate, northing coordinate, ellipsoid height (required) Initial value: unspecified	If the type setting of the basic information item is WGS84, the coordinate unit is degrees, and if it is JP or UTM, the coordinate unit is m. All ellipsoid heights are m. Example: marker[1].origin = 130.386319,33.326944,60
cam_rotation	Azimuth, angle of attack, angle of rotation Initial value: 0,0,0	Specifies the fixed camera rotation in degrees. It can be omitted, and if one element is specified, only the azimuth rotation will be performed. If two elements are listed, the azimuth angle and angle of attack will be rotated. Example: marker[1].cam_rotation = 0.4,0,0
cam_fov	Angle of view Initial value: 60	Specifies the fixed camera view angle in degrees. Example: marker[1].cam_fov = 60.4
color	hex color value Initial value: #ffa500	Specify a 6-digit hexadecimal color value starting with #. Example: marker[1].color = #ffa500
visible	True or False Default value: True	Specify True to display, False to hide. Example: marker[1].visible = True

Auxiliary line information item (line[ ])

*Write in the format "line[ ].attribute name=value".

*Enter the auxiliary line ID numbers in order starting from 1 in [ ].

There is no limit to the number of auxiliary lines that can be registered.

Attribute	Value	Note
name	"Auxiliary line name" Initial value: unspecified	"Auxiliary line name" Initial value: unspecified
marker	starting point marker number, End marker number (required) Initial value: unspecified	A line segment is drawn between the start and end markers. If the end point marker number is not specified, a line will be drawn from the start point marker in the direction specified by angle. Example: line[1].marker = 1,
angle	Direction Initial value: 0	Specifies the direction of the auxiliary line extending from the starting point marker in degrees. Multiple entries can be written by separating them with ",". Example: line[1].angle = 55.8,235.8
color	hex color value Initial value: #00ff00	Specify a 6-digit hexadecimal color value starting with #. Example: line[1].color = #00ff00
visible	True or False Default value: True	Specify True to display, False to hide. Example: line[1].visible = True

Object information item (object[ ])

*Describe in the format "object[ ].attribute name=value".

*Enter object ID numbers in order starting from 1 in [ ]. There is no limit to the number of objects that can be registered.

Attribute	Value	Note
name	"Object name" Initial value: unspecified	Japanese notation possible Example: object[1].name = "turret"
type	type name Initial value: normal	Specify the type of object (normal), water surface (water), flame (fire), or mirror (mirror). If not specified, normal is set. Example: object[1].type = fire
file	file name Initial value: unspecified	If the type attribute is normal, specify the file name (with extension) of the 3D data saved in the object folder. If the type attribute is water, specifying 1 will install a 1m*1m*10cm square of water. If you specify 2, circular water will be installed. If you specify a 3D data file name, water with that shape will be installed (However, please note that regardless of the shape, the direction of water surface reflection is fixed in the upward (Unity Y axis) direction when installed without rotation). If not specified, type 1 of the water surface will be used. If the type attribute is fire, 1 to 5 types of flames will be installed. If not specified, type 1 of the flame will be used. If the type attribute is mirror, specifying 1 will install a 1m*1m*1cm square mirror. If you specify 2, a circular mirror will be installed. If you specify a 3D data file name, a mirror with that shape will be installed. (However, regardless of the shape, the reflection direction is fixed to the south (Unity - Z axis) direction when installed without rotation. Create the mirror surface in advance to face the -Z axis direction, and change the direction of the mirror surface using the rotation specification.) If not specified, a type 1 mirror will be used. Change the size of the water surface, flames, and mirrors using the scale attribute. Example: object[1].file = sannai_build.fbx
origin	Easting coordinate, northing coordinate, ellipsoid height (required) Initial value: unspecified	Set the coordinates of the 3D data origin. If the type setting of the basic information item is WGS84, the coordinate unit is degrees, and if it is JP or UTM, the coordinate unit is m. All ellipsoid heights are m. Example: object[1].origin = 140.6967474,40.81215562,62
rotation	East axis rotation, North axis rotation, Vertical axis rotation Initial value: 0,0,0	Sets the rotation from the 3D data origin. It can be omitted, and only the vertical axis rotation will be used if one element is specified. Example: object[1].rotation = 0.4,0,0
scale	Angle of view East axis magnification, North axis magnification, Vertical axis magnification Initial value: 1,1,1	Set the magnification from the 3D data origin. If one element is described, a common magnification will be set for all three axes. Example: object[1].scale = 400,400,10
exist	start year, end year Initial value: unspecified	Specify the year to start and end the display of 3D data. It is also possible to specify only the start year or only the end year. If unspecified, it will always be present. Example: object[1].exist = 80,
terrain_correction	True or False Default value: True	Corrects the terrain to match the object shape to prevent the terrain from penetrating the object. If terrain correction is performed during execution, it will not be possible to return to the original shape. If you want to reproduce the terrain before terrain correction, such as to adjust the position of an object, turn off the terrain correction setting (False) and reload. Example: object[1].terrain_correction = False
copyright	"credit" Initial value: unspecified	Provide credit for 3D data. When this 3D data is displayed on the screen, a credit will be displayed in the copyright column. Example: object[1].copyright = "scienceNODE(3D Model)"
visible	True or False Default value: True	Specify True to display, False to hide. Example: object[1].visible = True

Flame type list

If you specify type = fire in the object information, you can handle the following types of flames.

File #	Overview	Sample Image
1	Gas type flame. No Smoke.	
2	Torch-shaped flame. With Smoke.	
3	Charcoal type flame. No Smoke.	
4	Wildfire type flame. No Smoke.	
5	Smoke type flame. With Smoke.	

5. Startup

Start by following the steps below.

i. Start Stellarium (For Windows, press F11 key etc. to cancel full screen)
ii. Start arcAstroVR (leave Stellarium running)
iii. Press the “Select File – ‘dataset.txt’” button, select the configuration file “dataset.txt” for the dataset you want to load, and press “Open”.

6. Operation of arcAstroVR

6.1 Day and Time setting

in the date and time panel, set;

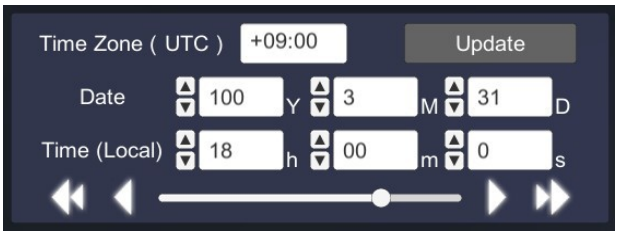
- TimeZone
- Date (long press the increase/decrease button to increase/decrease quickly)
- Time (you can also input using the slide bar)

When you do this and press the update button, the sky image on arcAstroVR will be updated.

On either side of the slide bar are forward and backward buttons for 1 hour or 10 minutes. The forward and backward buttons automatically update the sky image, so there is no need to press the update button.

The date and time panel can be moved to any position you like.

*It takes about 5 seconds for 6 tiles to be output in Stellarium and reflected in ArcAstroVR.
*If the connection of the sky images is strange, please try pressing the Update button again.

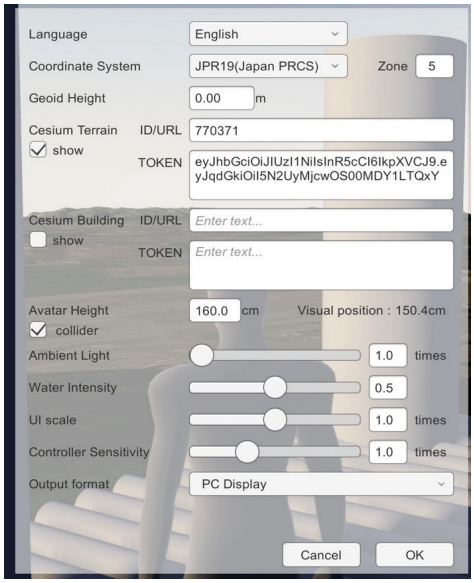


6.2 Move/display switching operations

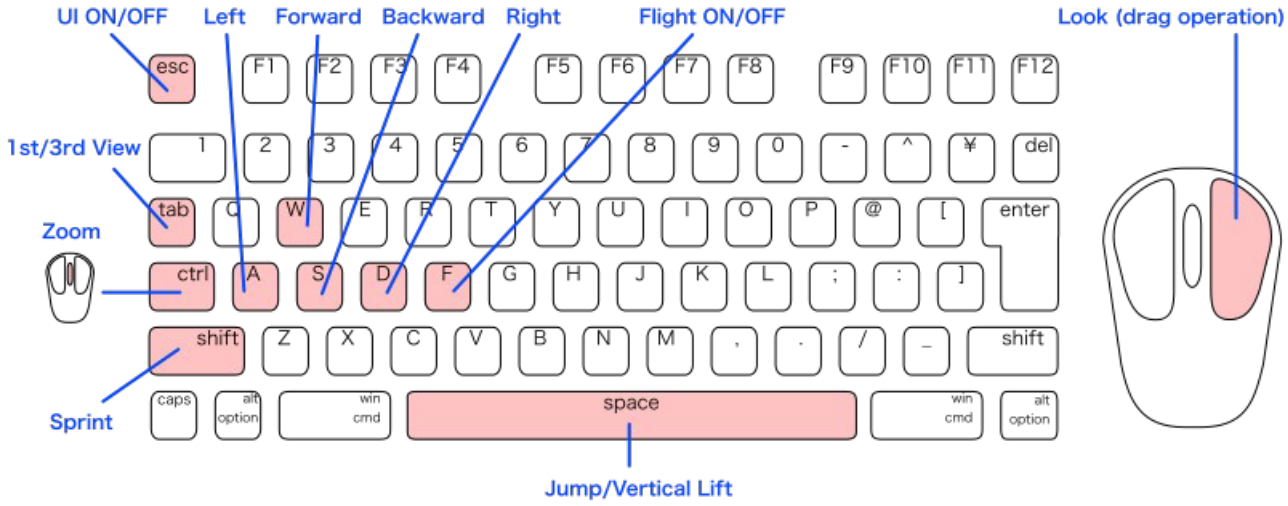
Observer movement/display switching operations use a keyboard, mouse, or game controller.

6.2.1 Keyboard & Mouse

Drag the right mouse key to set the direction of movement, and press the "W" and "S" keys to move forward and backward.

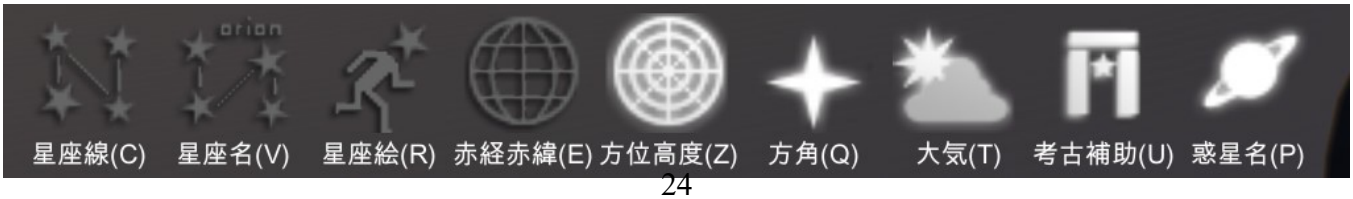


- Viewpoint：Right mouse button drag (Viewpoint shifts)
- Movement : "W" Key (Forward to viewpoint direction)
  "S" Key (Backward from viewpoint direction)
  "A" Key (Left shift)
  "D" Key (Right shift)
- Sprint : "Shift" Key (Press and hold to move at high speed)
- Jump / Vertical Lift : "Space" Key (Jumps when in walking mode and lifts vertically when in flight mode)
- Flight : "F" Key (Switches to flight mode and can fly in the direction of the viewpoint. Press again to return to walking mode.)
- Zoom In / Out : "Ctrl" Key + "Mouse Wheel" (change viewing angle)
- Viewpoint switching : "tab" Key (Switch between 1st and 3rd person view)
- UI On/Off：”esc” Key (show or hide the UI)



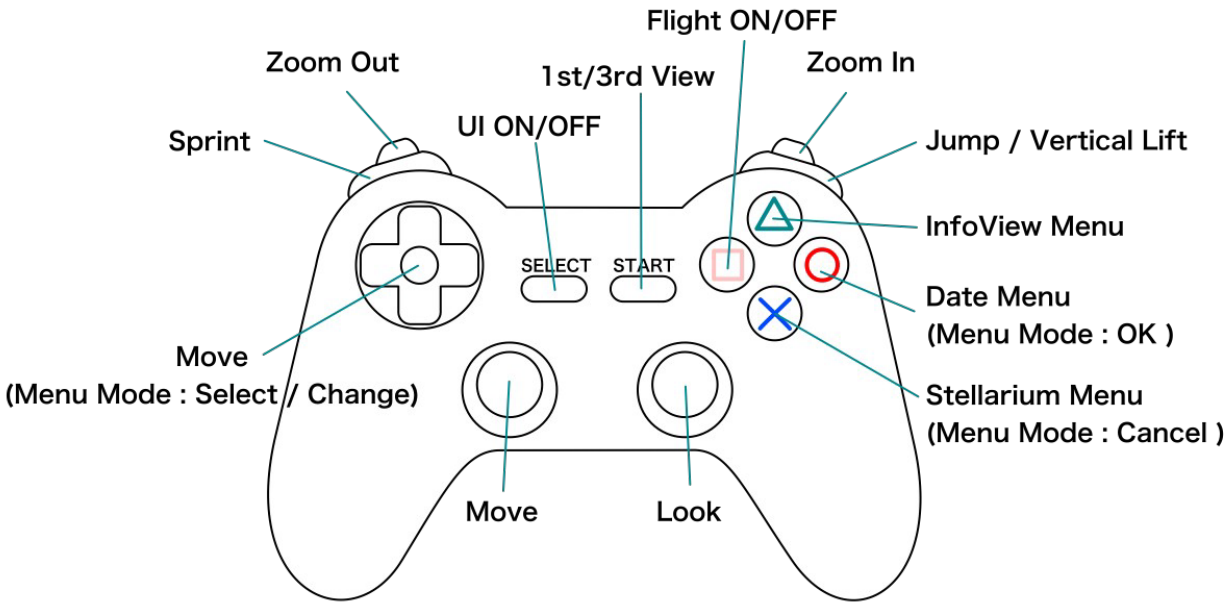
Switch the display with the menu key or the keyboard.

- Constellation Lines : Icon Click or "C" Key
- Constellation Labels : Icon Click or "V" Key
- Constellation Art : Icon Click or "R" Key
- Equatorial Grid : Icon Click or "E" Key
- Azimuthal Grid : Icon Click or "Z" Key
- Cardinal Points : Icon Click or "Q" Key
- Atmosphere : Icon Click or "T" Key
- ArchaeoLines : Icon Click or "U" Key
- Planet Labels : Icon Click or "P" Key



6.2.2 GamePad

- Viewpoint：Right stick (Viewpoint shifts)
- Movement : "Lefy stick or D-Pad" (avatar moves)
- Sprint : "Left Bumper" Button (move at high speed while holding down)
- Jump / Vertical Lift : "Right Bumper" Button (Jumps when in walking mode, rises when in flight mode)
- Flight : "□（X）" Button
  (Switch to flight mode and use movement controls to fly. Press again to return to walking mode)
- Zoom In / Out : "Right Trigger / Left Trigger" Buttons (Enlargement/reduction (viewing angle change) is possible.)
- Viewpoint switching : "START (OPYION)" Buttan (Switch between 1st and 3rd person view)
- UI On/Off：”SELECT (SHARE)” Buttan (show or hide the UI)
- Information Window menu: “△ (Y)” button
  Use the D-Pad to select the menu in the information window, press the "○ (B)" button to execute, and the "× (A)" button to cancel.
- Date and time setting menu: “○ (B)” button
  Menu selections for Date and Time settings are made using the left and right of the D-Pad. Change the numerical value by using the up and down of the D-Pad. To update, press the "○ (B)" button, and to exit the menu, press the "× (A)" button.
- Stellarium menu: “× (A)” button
  Menu selection in Stellarium is done using the left and right of the D-Pad. To turn on/off press the "○ (B)" button, and to exit the menu press the "× (A)" button.

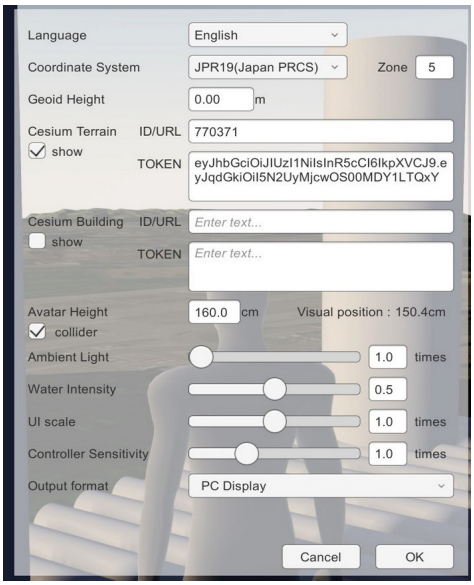


6.3 Display Settings

Click the "Setting" button on the top bar to configure the display settings.

6.3.1 Language

Select the display language from the Language pull-down menu.



6.3.2 Coordinate System

From the Coordinate System pull-down menu, select the coordinate system to be displayed in the Top Bar and Information Window. The coordinate systems that can be selected are as follows

- WGS84 : It is a world coordinate system of longitude and latitude (decimal notation).
- Japan PRCS : Japanese Plane Rectangular Coordinate System (System 19) (Y,X in m); zone number (1-19) is specified in Zone.
- UTM : UTM coordinate system (E,N in m notation); zone number (1-60) is specified in Zone.

6.3.3 Avatar height

The height of your avatar can be set. It will be set to 176cm if the height is not set.

Also, the viewing position is set to the height*0.94. If you are 176cm tall, your eye height will be 165.4cm.

6.3.4 Ambient Light

The intensity of the ambient light can be adjusted 1 to 2 times using the Ambient Light slide bar.

By adjusting the ambient light, the ground and indoors can be seen in pitch-black environments without moonlight at night.

6.3.5 Wave Height

The wave height of water objects can be adjusted from 0 to 1.

0 results in a mirrored state with no waves.

6.3.6 UI Display Size

The size of the UI can be adjusted from 0.5 to 1.5 times. Please adjust according to the dpi and screen size of your display.

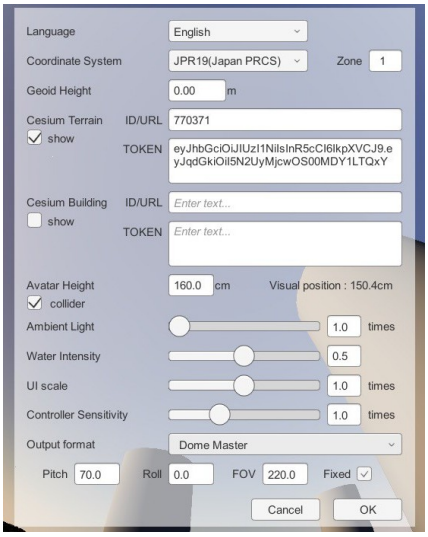
Note: Only valid when you select PC Display as the output format.

6.3.7 Controller Sensitivity

The rotational sensitivity of controllers such as mice and gamepads can be adjusted to 0.1 to 3 times.

6.3.8 Output Format

Output file format can be selected from "PC Display", "HMD", or "Dome Master" from Output Format.



Currently, HMD only supports Windows + Meta(Oculus) Rift / Quest / Quest2, and cannot be played on Mac or other HMDs. For details, see "7. HMD (Head Mount Display)."
If you choose the Dome Master format,

- Pitch (tilt angle): -90 to 90°
- Roll (rotation angle): -180 to 180°
- FOV (viewing angle): 0~360°
- Fixed rotation: You can additionally set whether to rotate according to the avatar's direction of travel. For more information, please see "8. Dome Master".

6.4 Top Bar and Information Window

Information about markers, auxiliary lines, and objects loaded into arcAstroVR is displayed in the information window.

The information window can be shown/hidden using the "Show (Close) Info" button on the top bar at the top of the screen. You can also change the size of the Information Window by dragging the resize box at the bottom right of the Information Window.

6.4.1 Display items

The display items of the top bar are as follows.

・Type of display coordinate system

・Current longitude, north latitude, altitude
(Note: Calculated from human feet position)

・Azimuth and altitude of the cursor

(Note: It is calculated from the camera position)

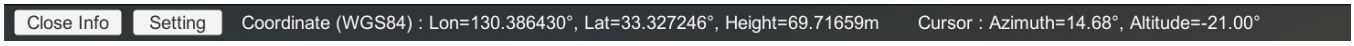


Fig 6: Top Bar

The display items of the information window are as follows.

・Coordinates and ellipsoid height of the marker. Azimuth angle, elevation angle, and distance of the marker from the current position.
(Note: It is calculated from the human eye position)

・Auxiliary line start marker number, end marker number or auxiliary line azimuth angle.

・Coordinates of object origin and ellipsoid height, angle of rotation from limited, scale, start and end year of existence.

Fig 7: Information Window

6.4.2 Show/Hide Checkboxes

Checkboxes to the left of the Info Window control the display of markers, or Auxiliary lines or objects. (Note: In the case of remains/objects, even if the display check box is ON, it will not be displayed if it is a year before the existence start year or after the existence end year)

6.4.3 Add Button

The " Add " button can add Markers and auxiliary lines.

The initial position of the marker will be entered where the avatar is currently standing. You can add a marker by entering its name, coordinates, and color, and pressing "OK".

The initial position of the auxiliary line is set to Marker number 1 and Angle 0°. It can be added by entering a name, beginning, end, and color, and pressing "OK.

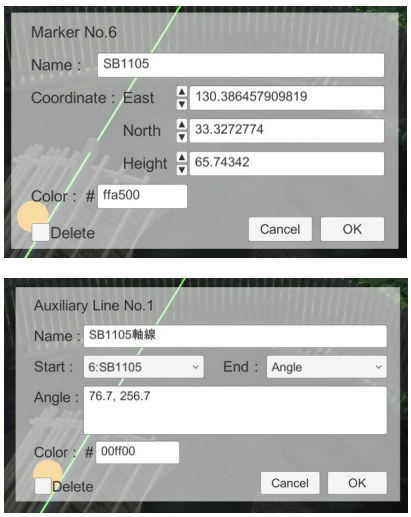


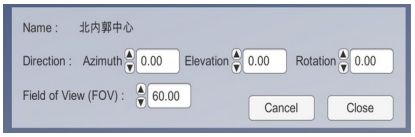
Fig XX: Edit screen with Add and Edit (markers and auxiliary lines)

6.4.4 Go Button

The "GO" button to the right of the marker information serves as a button to move to the marker location (it is also possible to move by left-clicking on the marker on the screen).

6.4.5 Fixed Camera Button

One fixed camera can be installed per marker. It can be used for fixed-point observation, and since there is no collision setting, it can be used to check the scenery in narrow places where people cannot enter.



By pressing the "Cam" button on the right side of the marker information, you can enter fixed camera mode and view images from the fixed camera.

In fixed camera mode, the settings dialog for azimuth, attack, rotation, and viewing angle will be displayed at the top right of the screen.

Press "Cancel" or "Close" to return from fixed camera mode in the settings dialog. "

If you press "Cancel", the changed azimuth, angle of attack, rotation angle, and viewing angle settings will be lost.

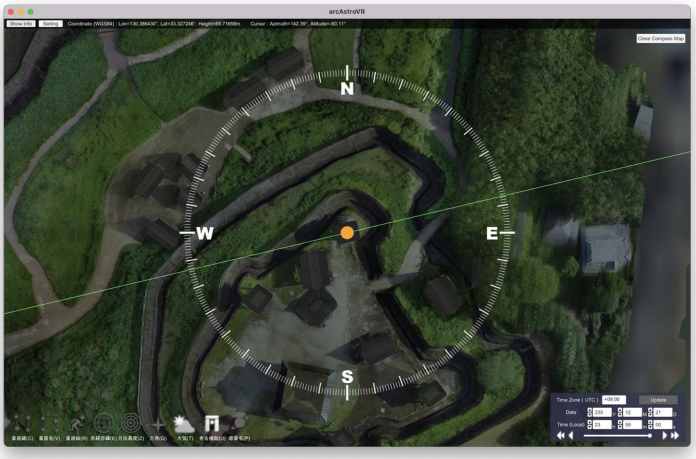
6.4.6 Edit Button

The "Edit" button on the right side of Marker Information / Auxiliary Line Information / Object Information allows you to edit the name, coordinates, color, etc. of each information.

Note that markers and auxiliary lines can be deleted by checking the "Delete" check box and clicking the "OK" button.

(Note: There is no button to add/delete objects. If you want to add an object, please modify the description in the configuration file (dataset.txt) and start up again)

6.4.7 Compass Map

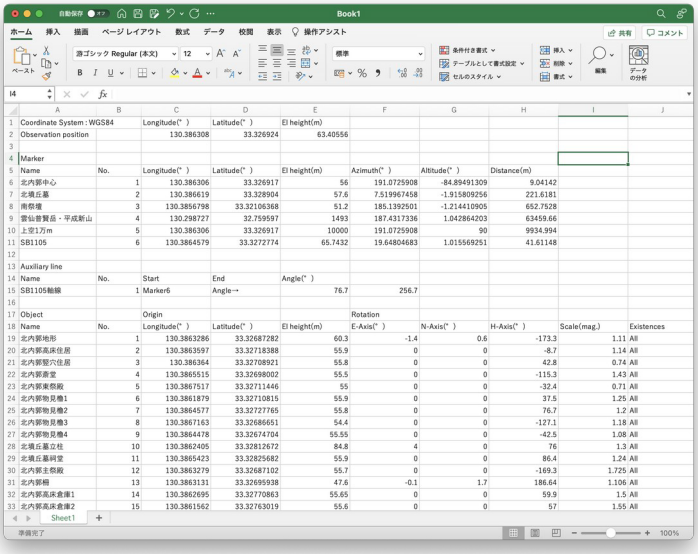


The "Map" button to the right of the auxiliary line information displays a compass map centered on the marker at the beginning of the auxiliary line.

Zooming in and out of the display area is the same as using Zoom In / Zoom Out (or Ctrl+mouse wheel with mouse / keyboard).

You can return to the normal screen by pressing the "Close Compass Map" button in the upper right corner of the screen.

6.4.8 Copy Information



The "Copy Info" button in the lower left corner of the Info Window allows the user to retrieve information from the Info Window to the clipboard (Ctrl+C or Cmd+C can also be used for copying).

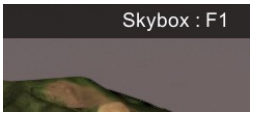
The information on the clipboard is tab-delimited, and when pasted into a spreadsheet, it is divided into cells and written.

6.4.9 Save

The "Save" button in the lower right corner of the Information Window exports the information added or edited by the Add and Edit buttons as a new dataset.txt file.

6.4.10 Restore

The "Restore" button in the lower right corner of the Information Window cancels information added or edited by the Add and Edit buttons and restores the information in dataset.txt, which is read at startup.



6.5 Skybox mode

arcAstroVR can cache (temporarily save) 12 Skybox settings (sky images and date and time information), which can be switched using the F1 to F12 function keys. The current Skybox mode can be checked from the display at the top left of the screen, and the date and time set in each Skybox mode and the latest transferred sky images are cached. If you move to another Skybox mode, the last sky image and the date and time information set in that Skybox mode will be displayed. Note that cache information is maintained even if you close the application.

Since high-speed switching is possible without image transfer from Stellarium, it is useful when you want to compare the sky at different dates and times or when you want to display a sky prepared in advance for presentations, etc.

7. HMD (Head Mount Display)

arcAstroVR uses a Head Mount Display (HMD) to provide a more immersive viewing experience with 6 degrees of freedom (6FOV). arcAstroVR supports the following HMDs.

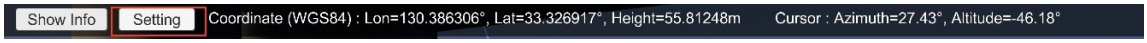
・Meta(Oculus) Rift / Quest / Quest2　　（Connect to PC in Quest Link / Air Link mode）

However, the PC must support OpenXR. Currently, Macs do not support OpenXR, so only Windows is supported. Also, please note that OpenXR requires a high-performance GPU and plenty of memory. Please refer to the compatibility list of each HMD to see if your PC is compatible with it.

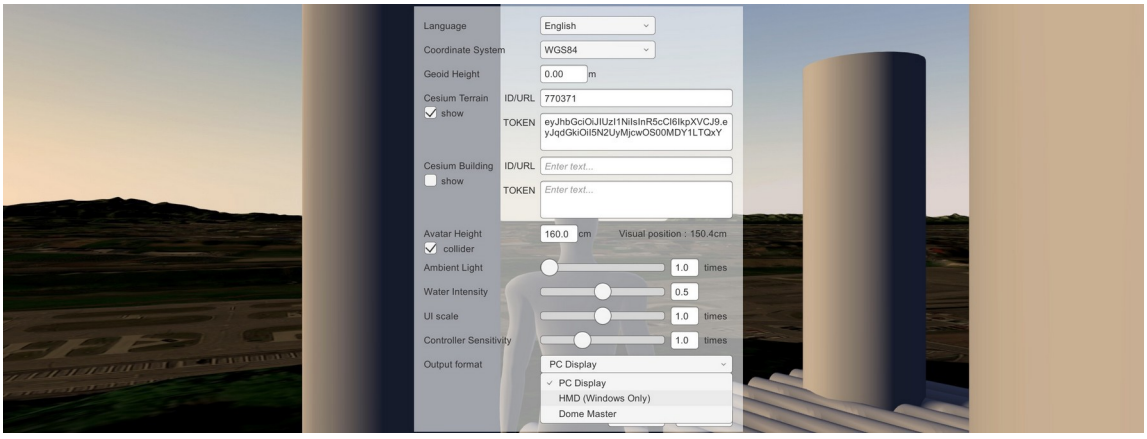
7.1 Connecting and starting the HMD

Please follow the steps below to start the HMD mode.

1. Connect Meta Quest and PC using Quest Link or Air Link.
   i. Launch the Oculus PC application.（https://www.oculus.com/setup/）
   ii. Connect the HMD to the PC with the Oculus Link (or Air Link) cable.
   iii. For Quest / Quest2, click Enable when Enable Oculus Link appears in the HMD. If Oculus Link is already turned on, it will not appear.
   iv. For Quest / Quest2, click on “Oculus Link” button from the home screen within the Head Mount Display to start the Quest Link mode..
2. Click Setting from the arcAstroVR top bar menu to open the Settings dialog.

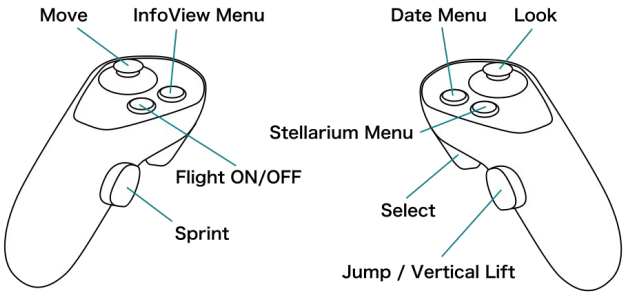


3. Select HMD from the Output format pulldown.
4. Wear the HMD.
5. Align the red line extending from the MD right controller with the "OK" button and press the trigger button on the HMD right controller to close the Settings dialog.



7.2 HMD Operation

The button operations on the HMD controller are as shown in the figure on the right.



The HMD screen has the following limitations.

・First person perspective only

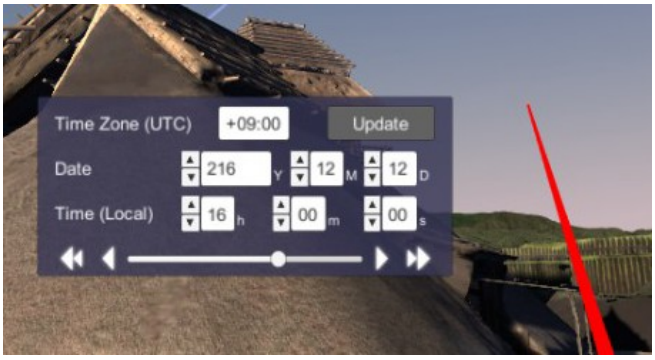
・Cannot be enlarged or reduced

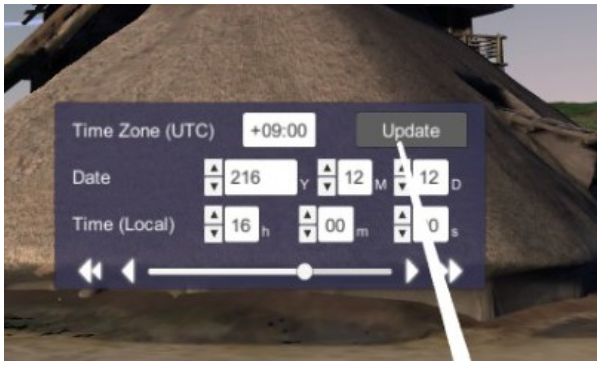
・Compass map cannot be displayed

- Fixed cameras cannot be displayed

Press the InfoView Menu / Date Menu / Stellarium Menu button on the HMD controller to display each menu.

When the Menu is displayed, a red line will extend from the right controller, so align it with the button you want to press. When the button is ready to be pressed, the color changes to a white line. Click the Select trigger to execute it.





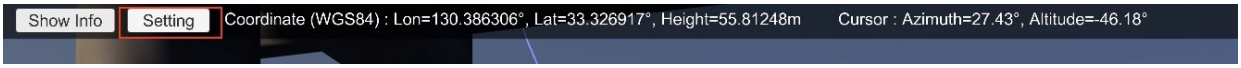
To clear the Menu, press each Menu button again.

8. Dome Master

arcAstroVR supports dome master format output, enabling dome projection using a projector with a fisheye lens.

8.1 Dome Master Settings

1. Click Setting from the top bar menu to open the Settings dialog.



2. Select Dome Master from the Output Display pull-down.

3. Set Pitch, Roll, FOV, and Fix according to the projector and dome shape to be projected.

Pitch	At 0°, the horizontal north direction is at the center of the dome master. At -90°, the zenith direction is at the center of the dome master. At 90°, the vertical down direction is at the center of the dome master. For a 20° inclined dome, a pitch of -70 (= -90 + 20) is specified.
Roll	if the direction of the dome tilt is forward, specify 0°. If the dome is tilted to the right, specify 90°. If the dome is tilted to the left, specify -90°. If the dome is sloping backward, specify 180°.
FOV	If it is a 180° hemispheric dome, specify 180°. If it is a 200° dome, specify 200°.
Fix	If checked, the forward direction is fixed to north. If unchecked, the avatar's direction of travel is forward.

4. To exit the Dome Master output, open the Settings dialog and select PC Display from the Output Display pull-down.

9. Advanced display using Stellarium

9.1 Starry sky display settings

You can make more advanced display settings by pressing the "Sky and display settings" button [F4] in Stellarium. To reflect the display settings in Stellarium in ArcAstroVR, press the Update button on the date and time panel in ArcAstroVR.

- Sky：

  You can set the brightness/saturation of the Milky Way, the brightness of the zodiacal light, the atmospheric refraction/absorption settings, the light pollution settings, the brightness of the star display, the size of the star display, the magnitude limit of the star display, etc.

- Solar system objects：

  You can set the orbit display, trajectory display, aberration calculation, moon enlargement settings, planet luminosity calculation formula settings, etc.

- Nebulas, star clusters, galaxies：

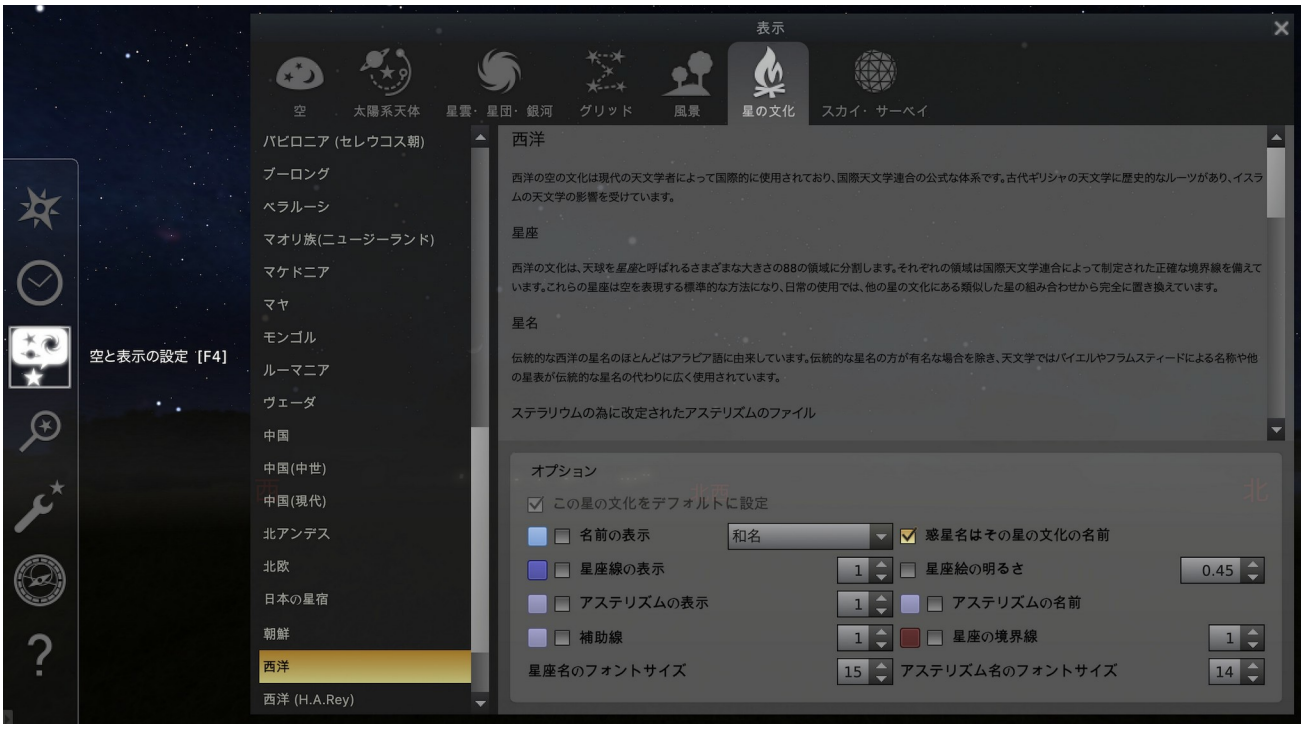
  You can select the display type and the celestial catalogue to display.

- Grid：

  You can select the grid lines to display.

- Star Culture：

  You can display constellation names, lines, and pictures related to various cultures worldwide.



9.2 Astronomical Calculation Window

You can calculate various astronomical phenomena in the "Astronomical Calculation Window" [F10].

- Ephemeris：

You can search for impulses and concealment between two celestial bodies.

- Eclipse：

You can search for all solar eclipses on Earth, solar and lunar eclipses that can be seen at observation points, and planets passing through the surface of the Sun.

9.3 Other settings

The "Configuration window" [F2] allows you to change basic settings.

- Main：

You can change your language settings. You can also save display settings so that you can start up with the same display settings next time.

- Time：

You can change the date display settings and rotation speed correction algorithm.

- Tools：

You can turn on/off Topocentric coordinates and Include nutation.

10. 3D map hosting (Cesium ion)

arcAstroVR is compatible with Cesium ion （https://cesium.com/platform/cesium-ion/）, a 3D map information hosting service provided by Cesium GS, inc.

By creating an account, you can register topographical data, 3D data, photos, etc., to Cesium ion by linking it with location information and creating your 3D map information (registration is free up to 5GB).

Data that can be registered are:

・3D model：.fbx, .obj, .dae, .gltf, .glb,
・Point cloud data：.las, .laz
・Map data：.citygml, .xml, .gml, .kml, .kmz
・Terrain data：.flt, .asc, .src, .tiff, .tif, .img, .dem, .terraindb
・Photographic data：.jpg, .jpeg, .png, .flt, .asc, .src, .tiff, .tif, .img, .dem, etc.
（https://cesium.com/learn/3d-tiling/tiler-data-formats/）

By specifying the Asset ID or TOKEN, set in the registered data, with various Cesium ion compatible applications, you can access it as Internet 3D map information.

For arcAstrVR, write each of the following elements of dataset.txt.

・terrain data：cesium_terrain_ID/URL
・terrain data：cesium_terrain_TOKEN
・building data：cesium_build_ID/URL
・building data：cesium_build_TOKEN

The following 3D map information is publicly available on Cesium ion.

内容	Asset ID	Asset TOKEN
Global terrain data（Cesium Terrain World） Data available from the U.S. Geological Survey, © CGIAR-CSI, Produced using Copernicus data and information funded by the European Union - EU-DEM layers, Data available from Land Information New Zealand, Data available from data.gov.uk, Data courtesy Geoscience Australia	1	Non
Geographical Survey Institute, All Japan topographic data（PLATEAU-Terrain） https://github.com/Project-PLATEAU/plateau-streaming-tutorial/blob/main/terrain/plateau-terrain- streaming.md ※Since this service is only a trial operation, we cannot guarantee the period of provision or service level.	770371	eyJhbGciOiJIUzI1NiIsInR5cCI6IkpXVCJ9.eyJqdGkiOiI5N2UyMjcwOS00MDY1LTQxYjEtYjZjMy00YTU0ZTg5MmViYWQiLCJpZCI6ODAzMDYsImlhdCI6MTY0Mjc0ODI2MX0.dkwAL1CcljUV7NA7fDbhXXnmyZQU_c-G5zRx8PtEcxE
Open Street Map Buildings data（Cesium OSM Buildings）	96188	Non

3D map information can also be handled in the 3DTiles format of hosting services other than Cesium ion.

In arcAstroVR, write the URL of the hosting data in cesium_terrain_ID/URL and cesium_build_ID/URL in dataset.txt.

The Ministry of Land, Infrastructure, Transport and Tourism of Japan's “Project PLATEAU” is promoting building data hosting in 3DTiles format (3D Tiles for 56 cities have been released as of the end of 2021), and you can also use that data. You can check the URL of the published city from the page below.

https://github.com/Project-PLATEAU/plateau-streaming-tutorial/blob/main/3d-tiles/plateau-3dtiles-streaming.md

11. Licenses

arcAstroVR was released on April 1, 2022 under the GPLv3 license.

11.1 Unity built-in package

- **Stellarium-unity-spout-JSONobject-U2017-3**
  Authors: Georg Zotti
  Contact: https://github.com/Stellarium/stellarium-unity
  Version: Released September 15, 2020
  Licence: GNU General Public License v3.0
- **3rd Person Controller + Fly Mode**
  Authors: Vinicius Marques
  Contact: https://ricardoreis.net
  Version: 2.1.5
  Licence: Unity Asset Store standard EULA
- **JSON Object**
  Authors: Defective Studios
  Contact: http://defectivestudios.com/company
  Version: 2.1.2
  Licence: Unity Asset Store standard EULA
- **TriLib2**
  Authors: Ricardo Reis
  Contact: https://ricardoreis.net
  Version: 2.1.8
  Licence: Unity Asset Store standard EULA
- **Cesium for Unity**
  Authors: Cesium
  Contact: https://cesium.com/platform/cesium-for-unity/
  Version: 0.2.0
  Licence: Apache License 2.0
- **URP Water**
  Authors: Yan Verde
  Contact: https://www.yvgrafix.com
  Version: 1.1.0
  Licence: Unity Asset Store standard EULA
- **Mirrors and reflections for VR**
  Authors: Tom Goethals
  Contact: https://fragilem17.wixsite.com/website
  Version: 1.1.1
  Licence: Unity Asset Store standard EULA
- **REAL FIRE [URP/HDRP]**
  Authors: RDR
  Contact: https://www.artstation.com/artist/rdr
  Version: 1.0
  Licence: Unity Asset Store standard EULA

12. Contact information

office@arcAstroVR.org