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Fly Elise-ng
Immersive Calibration PRO
Step-By-Step Guide
360 Panorama Multiple camera views calibration

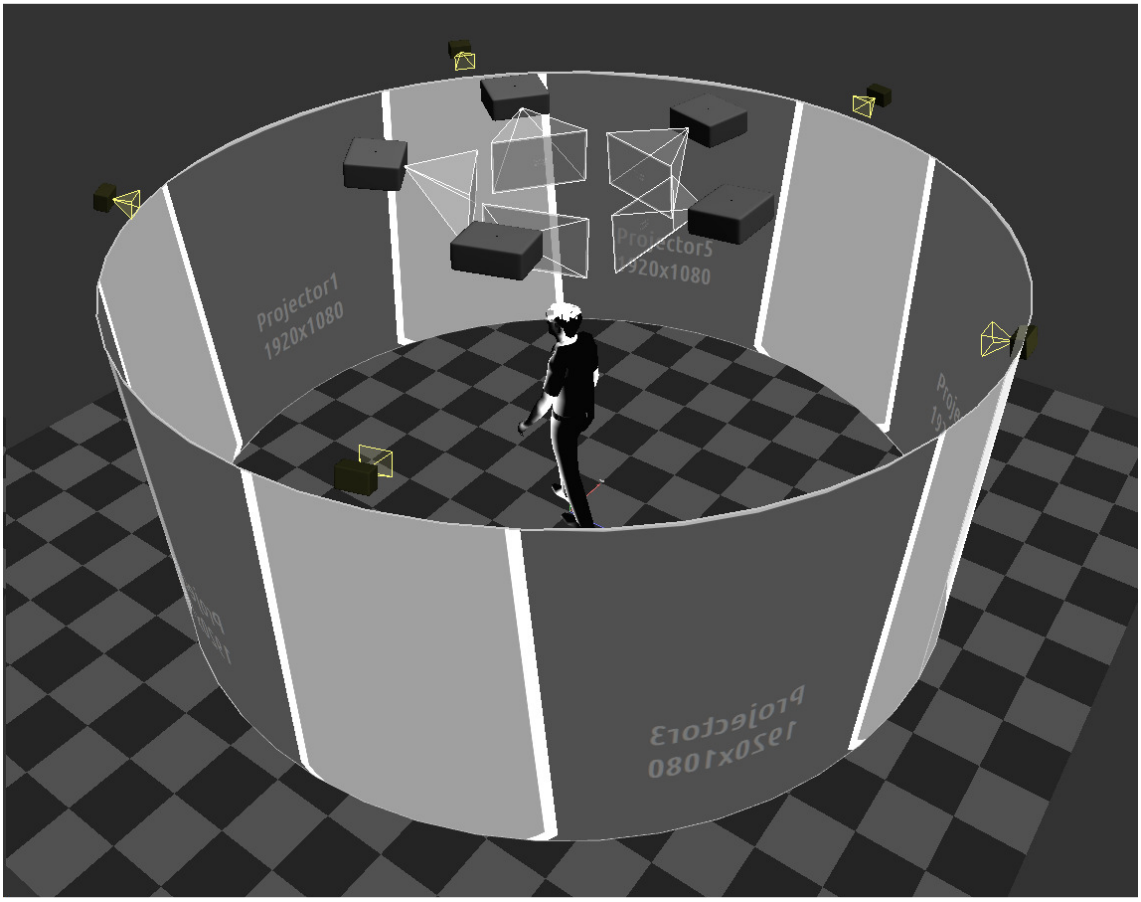
1 Introduction

This is a step-by-step guide for setting-up a seamless immersive projection using 360-degree cylindrical projection screen with overlapping projectors.
The calibration produces a perfectly aligned and geometrically correct image by taking into account the projector positions and the screen shape.
At the end of the calibration, Immersive Calibration PRO exports the perspective camera frustum settings (position, orientation and field of view), which can be used directly in the game or other 3D engine to produce the images for each projector. For this step by step guide we will use Unity Engine.
Immersive Calibration PRO also exports the warping and blending configuration to be loaded and used in Immersive Display PRO for warping and blending the projected image to get a seamless display.

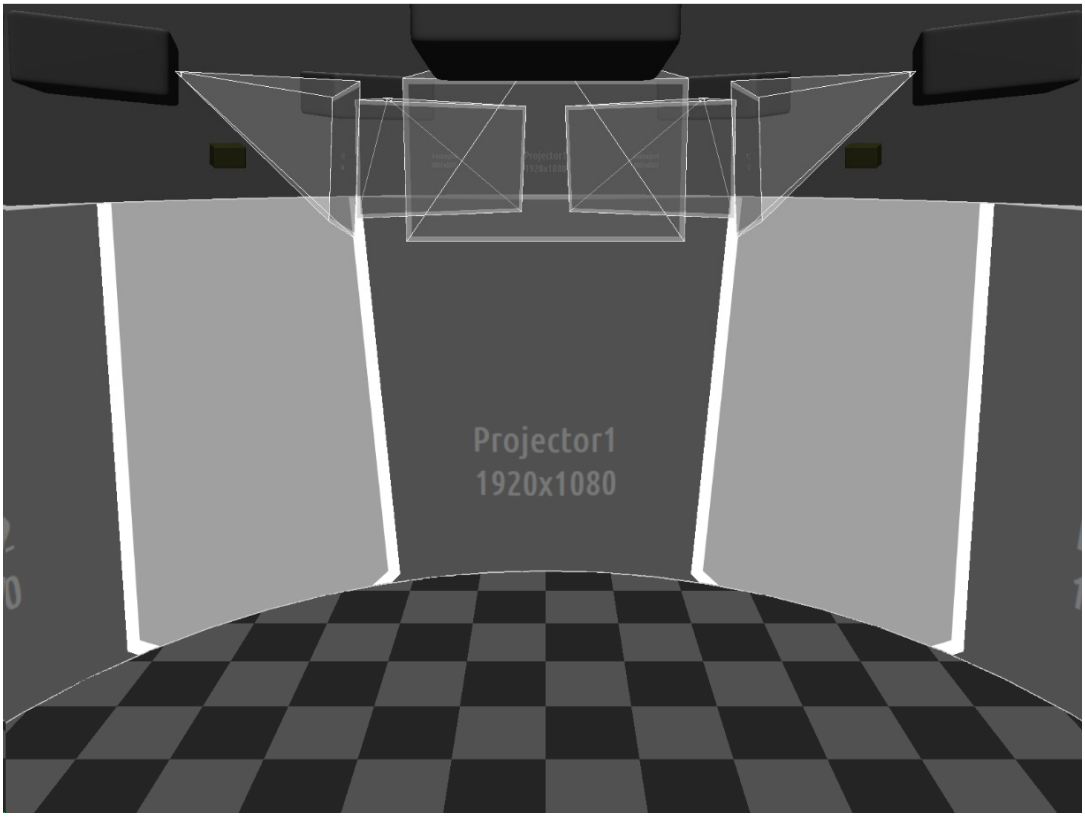
For multi-camera calibration we can use one or more HD webcams to automatically map the projector images to the screen and automatically calculate the needed warping and blending. Either a single camera can be used, or multiple cameras can be used for each view. When a single camera is used the camera has to be repositioned for each view.

For this step by step guide we will use an extended setup of 5 x HD projector and 5 Logitech HD Webcam C920 cameras to capture part of the screen and projectors images.

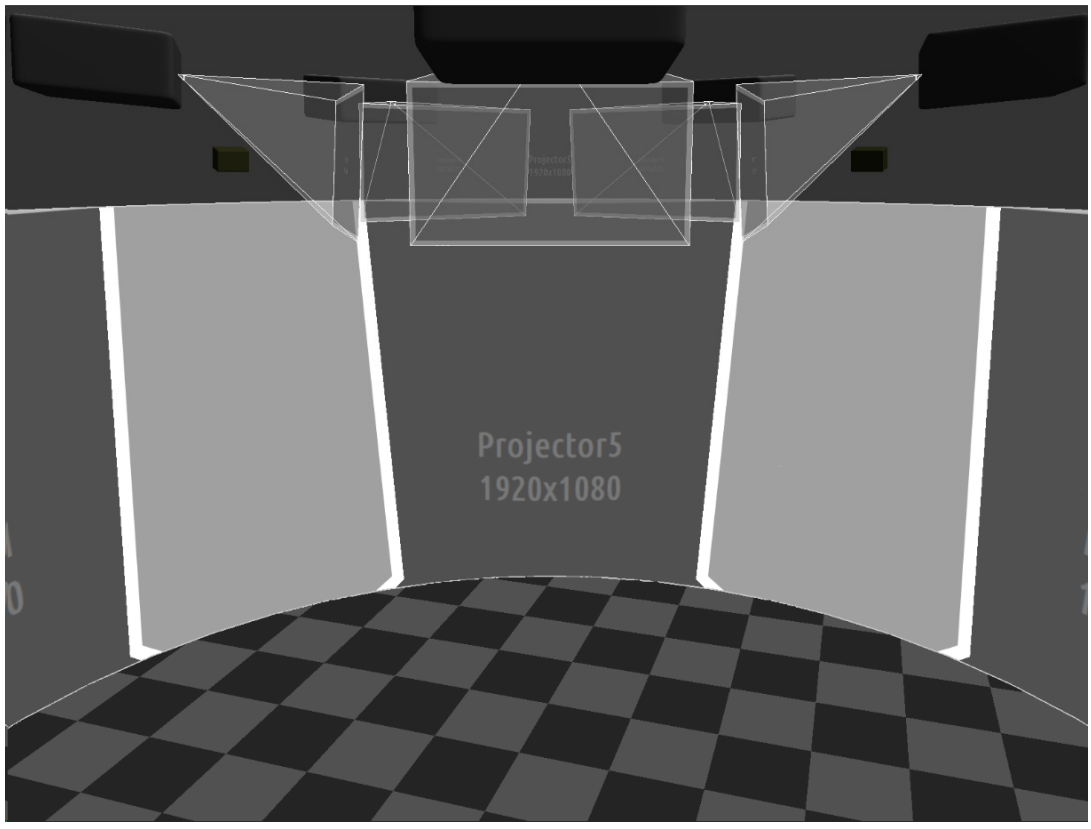
For the purpose of this step-by-step guide we will use a cylindrical projection screen with the following parameters: horizontal angle 360 degrees (panorama), height 1.7 meters and radius 2.0 meters (diameter 4.0 meters). The 5 projectors are positioned in such a way that the complete projection screen is covered by a projection images from projectors and that the projector images overlap by about 15%.



The cameras are positioned just below the projectors to capture part of the projection screen and the full projector image on the screen, as well as the overlap areas from the other projectors.



Camera 1

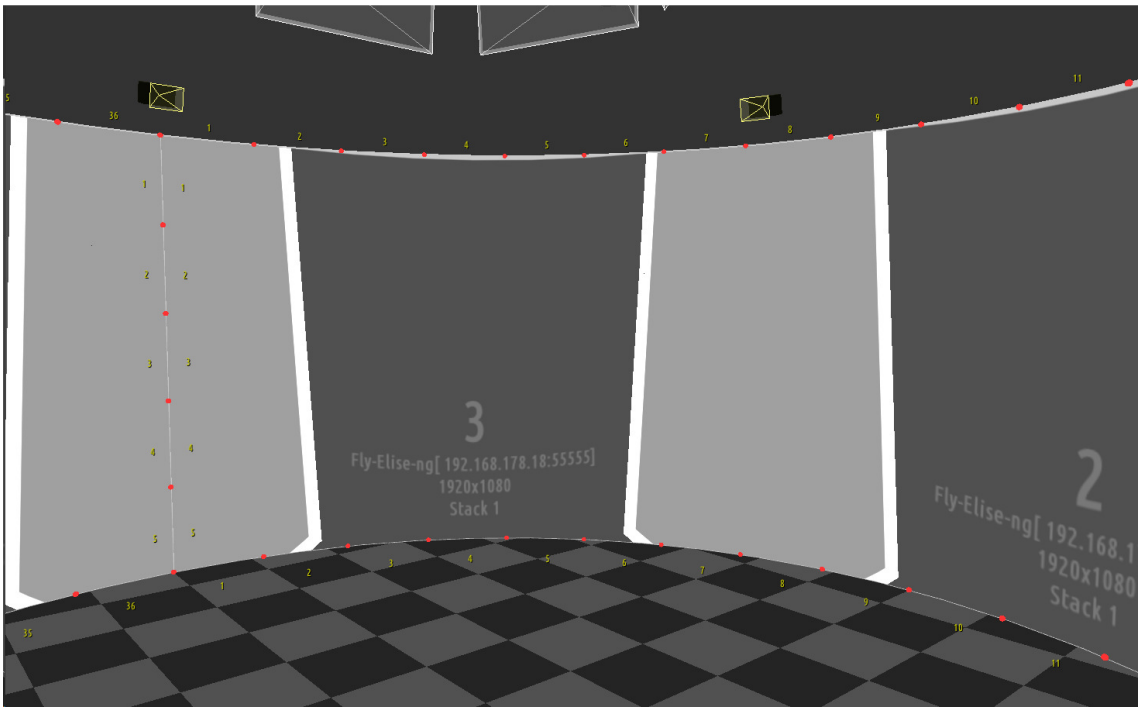


Camera5

Before we continue with the calibration we will need to divide the screen in equidistant horizontal and vertical sections (columns and rows). Those sections will be used as a reference for mapping the projectors images to the screen.
For this calibration we will divide the screen in 36 columns (every 10 degrees) and 5 rows. Because there is no screen curvature along the vertical axis, the number of divisions in rows can be smaller than the number of columns.
Depending on the curvature of the screen, the number of columns division can be increased or decreased. Generally, for 360 degree cylindrical screens a number between 30 and 60 columns is enough.

For this screen dimensions we can calculate:
The height of a single row section is:
1.7 m/5 = 0.34 m

The length of a single column section (along the screen edge arc) is:
(2 * PI * 2.0 m) / 36 = 0.349 m

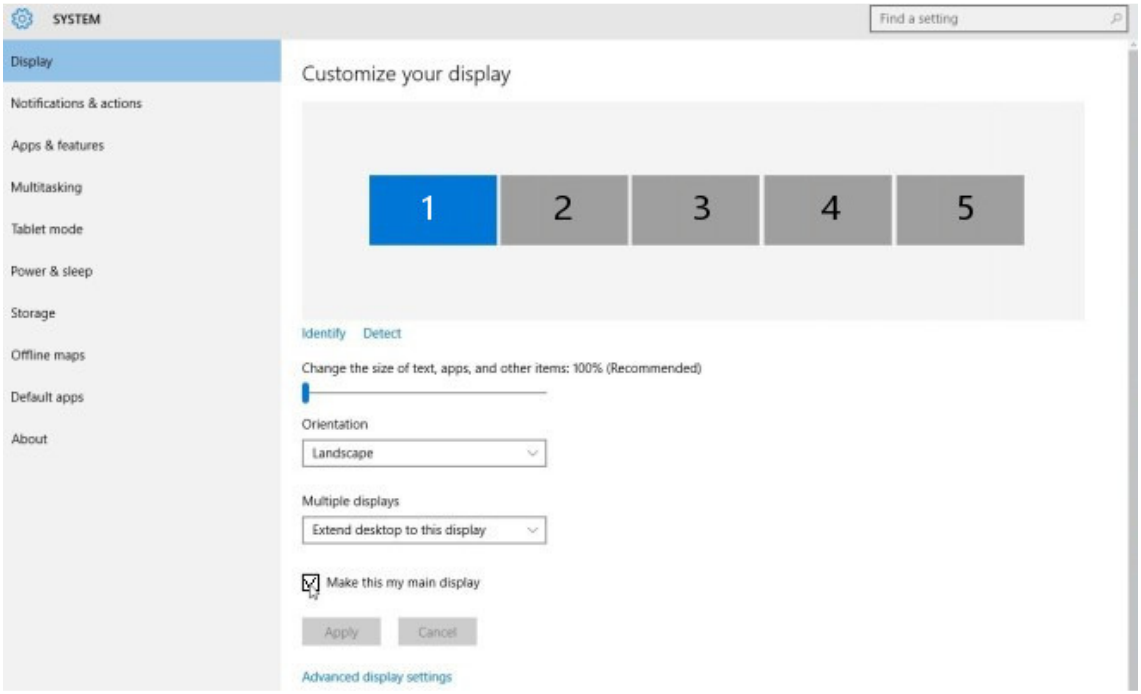


The columns sections are numbered from left to right starting from 1. Rows sections are numbered from top to bottom starting from 1. This numbering is important later when we define the views.

Note that the numbers on the image above are for illustrative purposes. Users can use different methods to mark the rows and columns, including stickers or other temporary markers.

Measure the edges of the screen and put physical markers on the screen edges to mark the rows and columns. Yu can use removable stickers to mark the rows and columns as well as put the correct columns numbers on the screen edges. Those markers are only needed during the auto-alignment of the cameras. They can be removed or hidden later.
Tip: A UV pen and UV light can be used to mark the screen with invisible markers that can be made visible with UV light during calibration.

We will use two computers to perform the calibration:
One PC has at least 5 outputs connected to the 5 projectors. Projectors are HD projectors with resolution of 1920x1080. The simplest configuration is to user any graphics card that supports 5 ungrouped outputs. For this step by step guide, Unity based software will run on this PC on all 5 projectors.



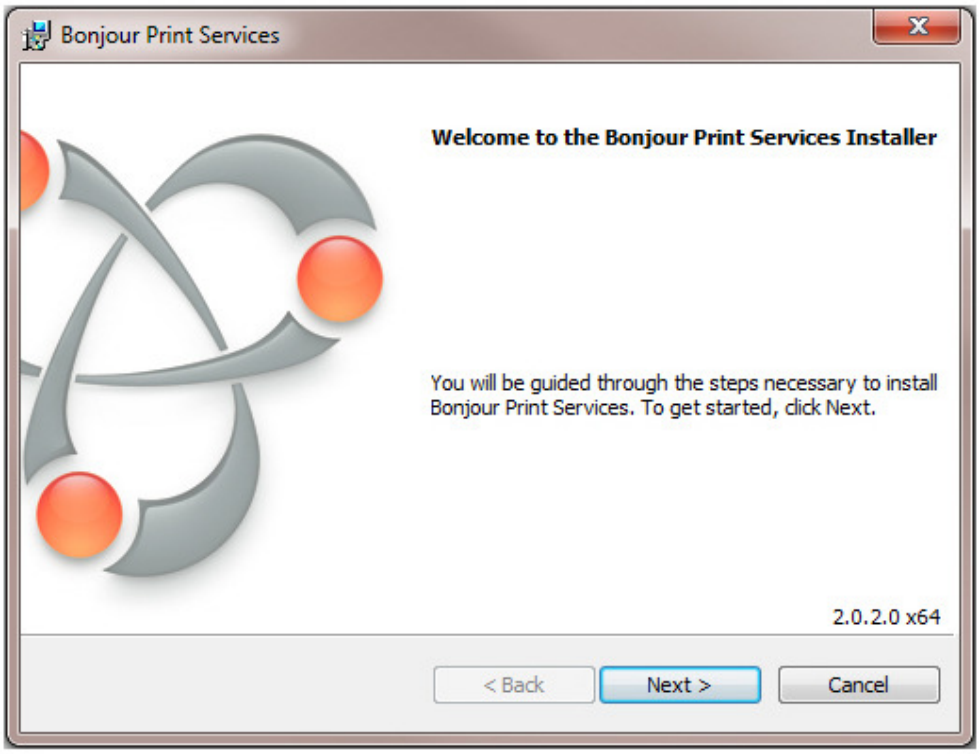
Make sure that the first display is set as a main(primary) display and connect it to the first projector. Re-order all other displays to the left of each other and connect the corresponding projector in the same order.

The name of this PC is **WIN10_CLIENT** and will be used as **Rendering Client** during the calibration.

The second PC will be used as **Controller Server**. It can be any PC with a moderate graphical card and connected in a network with the Rendering Client WIN10_CLIENT PC. The Name of the Controller Server PC is **SERVER**.
The **SERVER** PC is needed only during the calibration and can be removed after the calibration is completed and calibration results are saved.

2 First time Bonjour installation

In order to automatically recognize and connect the client and the server PC on the network, a zero-configuration service is used. For this purpose the Bonjour service needs to be installed on both the client and the server PC.
From the Immersive Calibration PRO locate and double click on the INSTALL_FIRST_BONJOUR.bat script. This will start the installation of Bonjour. This installation step is needed only once and should be performed the first time Immersive Calibration PRO is used on the PC.
Follow the installation steps of Bonjour install script and finish the installation.



Note: If using firewall, make sure that the firewall is disabled on both the client and the server PC in order to allow the client and the server PC to connect to each other without being blocked by the firewall.

3 Start and configure the Rendering Client

On the rendering client PC, start the Client.exe program from Immersive Calibration PRO installation folder. Immersive Calibration PRO will start in client mode and will show the available displays. Initially projector configuration for each display is “None”.

Right-click on the display that is connected to the projectors and select projector configuration 1x1 from the popup menu.

The selected displays will be configured with 5 projectors and the rendering client will be prepared to be connected to the server.

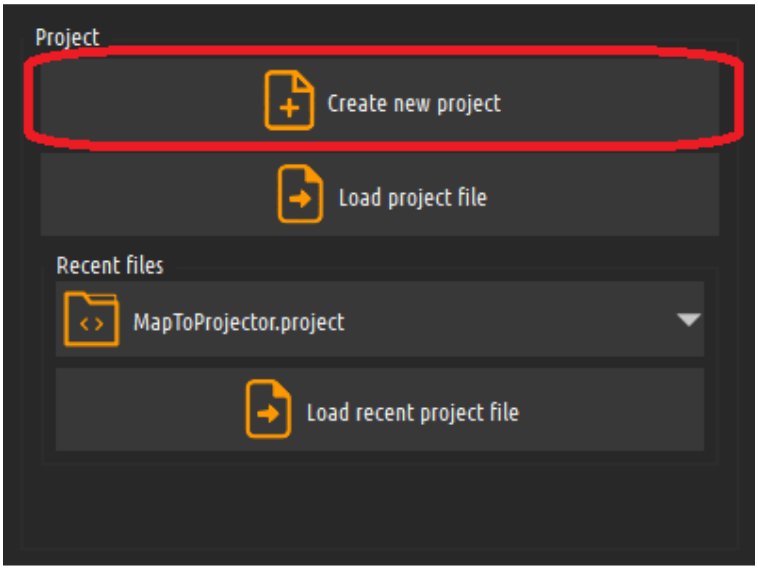
A tray icon will be shown on the system tray to indicate that the client is running.

Press the “Hide” button to minimize the client window. When the server is connected to the client, the client window will be opened in full screen mode on all 5 displays.

Note: The projector configuration will be automatically saved. The next time Client is started, it will automatically use the saved projector configuration.

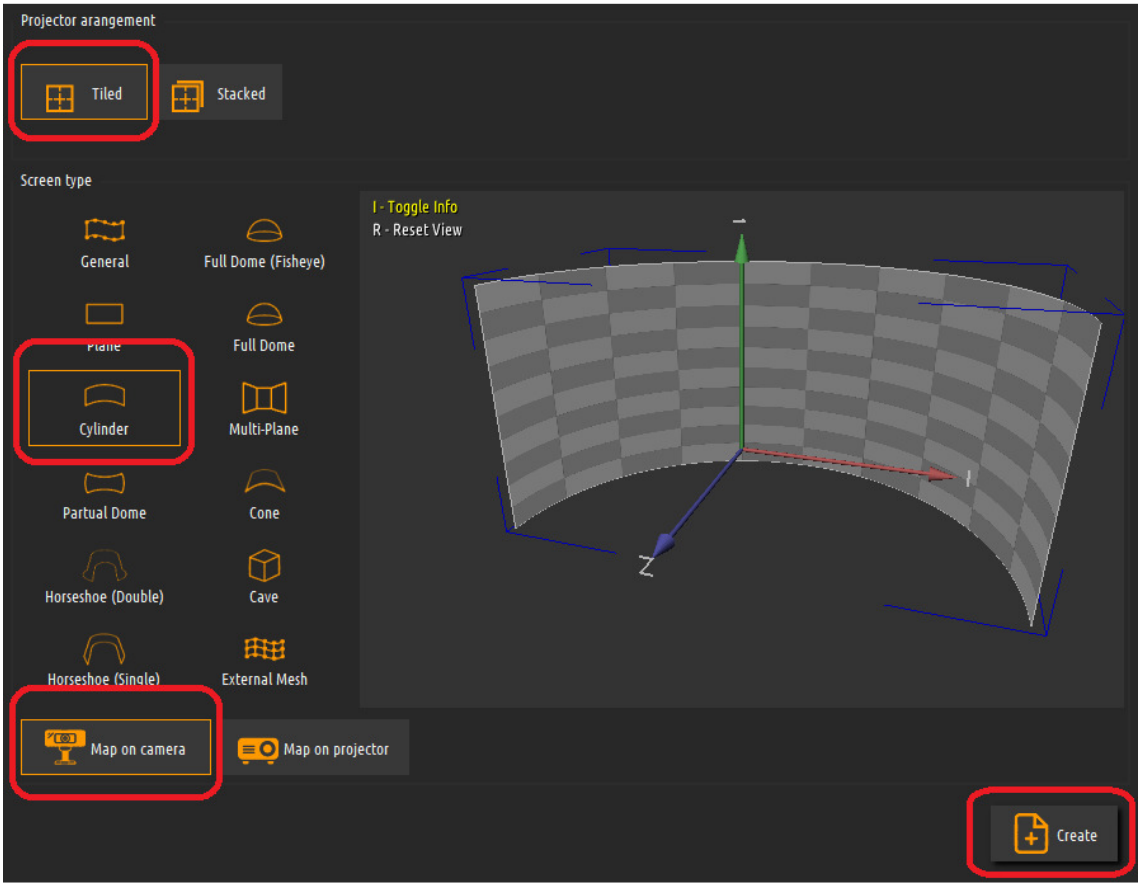
4 Start and configure the Controlling Server

On the controlling server PC, start the Server.exe program from Immersive Calibration PRO installation folder. Immersive Calibration PRO will start in server mode.



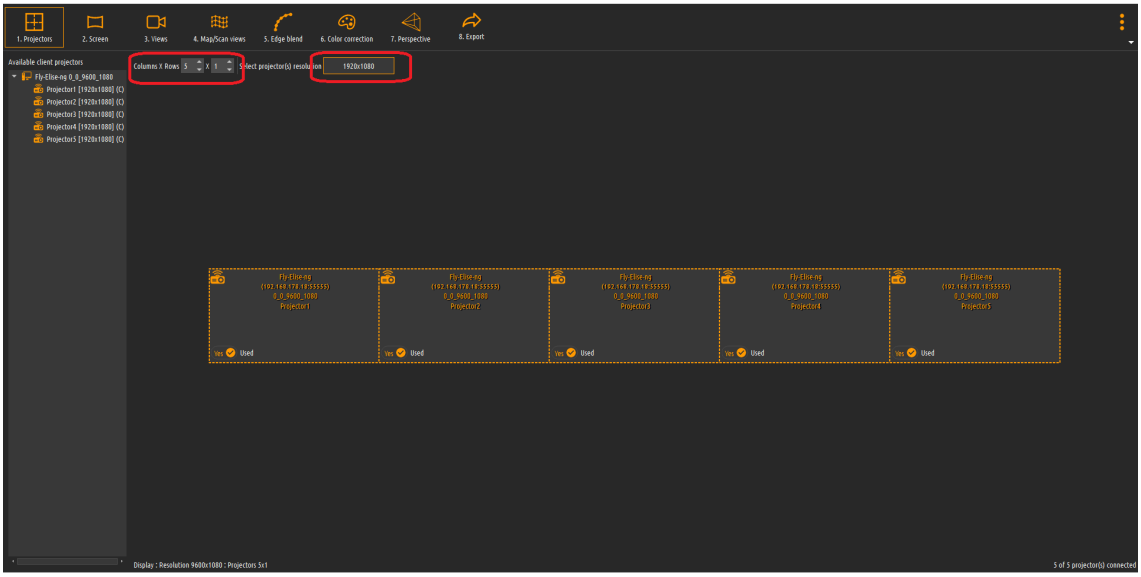
When starting for the first time, select “Create new project”. Once the project is saved, the project can be loaded by selecting “Load project file.

For this setup we do not use multiple projectors layers (multi-stacking). So from the projection stacking screen select “Tiled” projectors alignment.
Select the “Cylinder” screens shape and make sure the “Map to camera” is selected. Press the “Create” button.

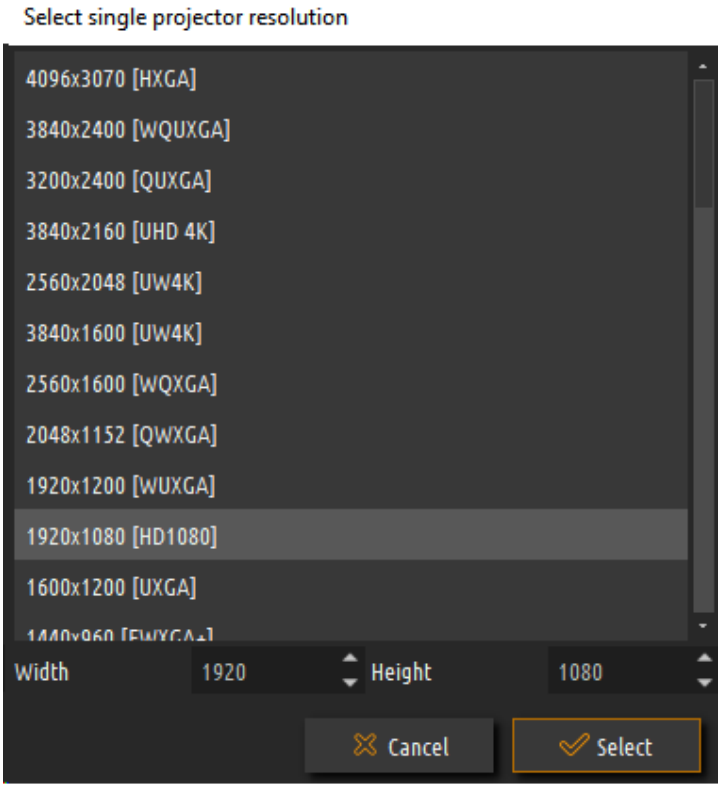


We will enter the size and the divisions of the projection screen later.

The Controller Server window will be started that shows the “Virtual Display”.



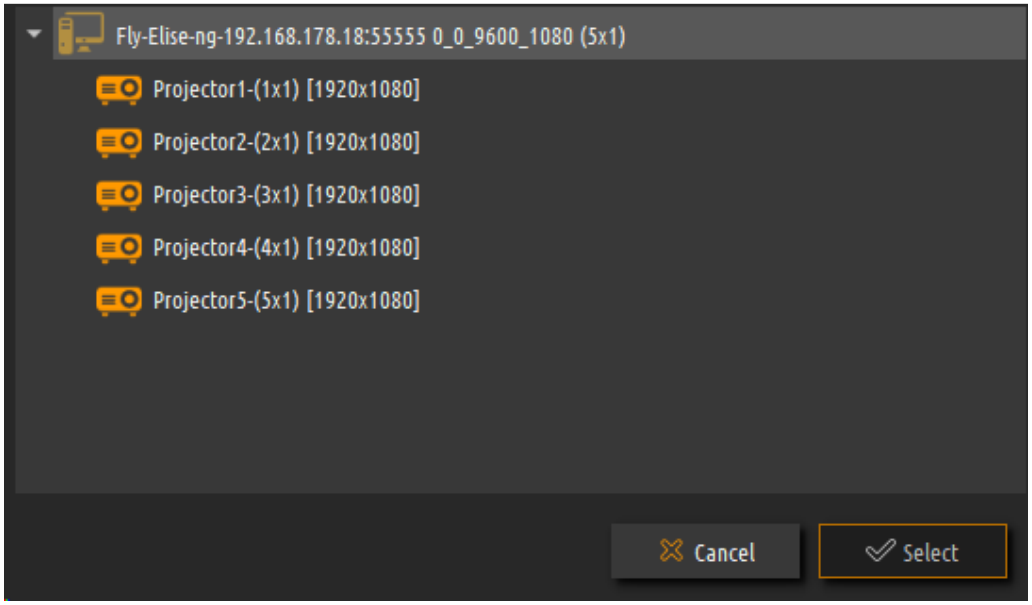
The virtual display is initially not configured. Set the projector configuration to 5x1 and select the individual projector resolution.



A pop window shows a list of standard resolutions per projector. Select the projector resolution from the list of available resolutions or select “Custom resolution” and enter the projector resolution.

The virtual display will be configured with projector configuration 5x1. The individual projectors are not “assigned” and not connected yet to the projectors defined in the “Rendering Client”. The available projectors from the client(s) are shown in the left panel.

Double click on each projector to connect to a projector defined in the “Rendering Client”. If the “Rendering Client” successfully connected to the “Controller Server”, a list of the projectors will be presented. Select a projector from the right list to “assign” the projector. This will assign and connect the virtual display projector to a remote projector.

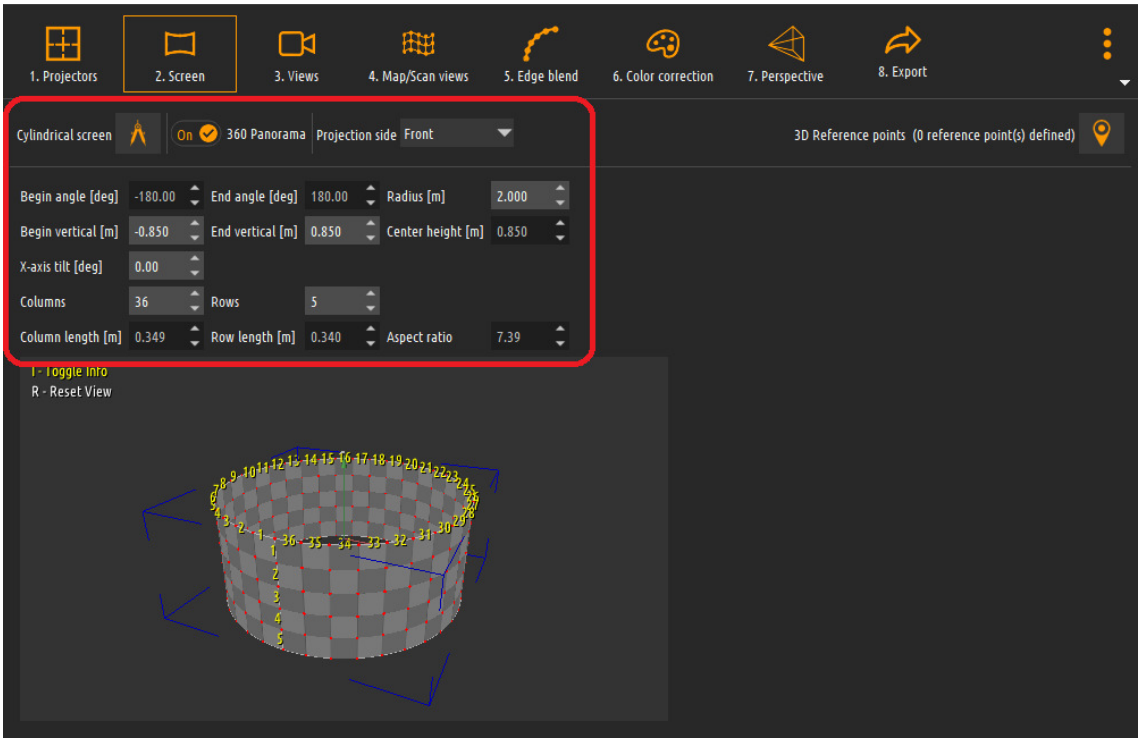


Repeat this step for all projectors. When all projectors are assigned click the "Screen" button to configure the screen.

5 Screen settings

Before we continue with the calibration we have to enter all calibration settings needed for successful calibration. This is one of the very important steps for achieving first-time-right calibration.

In the screen settings window enter the screen dimensions, the angles and the number of rows and columns sections.



Our screen has an angle of 360 deg, height of 1.7 m and radius of 2.0 m. Make sure the 360 Panorama is turned on. As the reference point is in the middle of the screen, and the height axis points to up, we enter the values -180 deg as begin angle and 180 deg as end angle. Similarly, for the height we enter -0.85 m as vertical begin and 0.85 m as vertical end. The radius is 2.0 m.
Because we divided the screen in 20 columns and 5 rows, we enter the Columns and Rows values respectively 36 and 5.
After that click on the “Views” button to configure the Views.

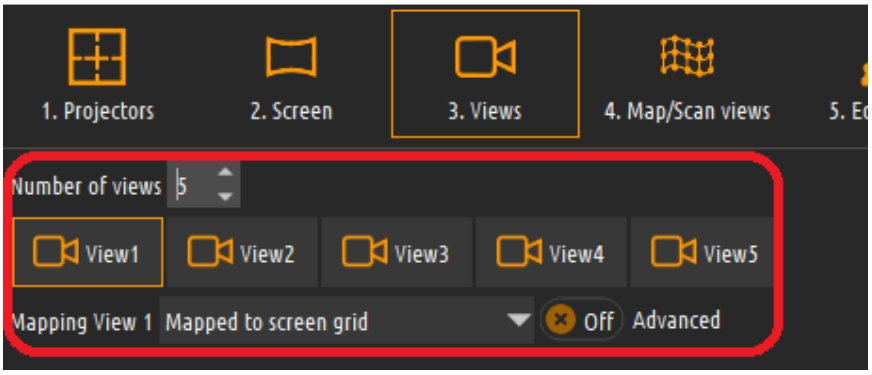
6 Views settings

In the views tab, we will define the number of cameras. For each camera we will have to enter the screen sections (rows and columns) that are visible in this camera view.
In this type of calibration, a view is defined as part of the screen "seen" by one camera. When entering the screen rows and columns for a view, we will count all the rows and columns that are fully visible from this camera.

Note: The red markers on the images below represent the visible or invisible markers put on the screen. The numbers are for illustrative purposes to make it easier to count the columns. Make sure that you put visible markers on the screen to configure the views and map the screen into the cameras views.

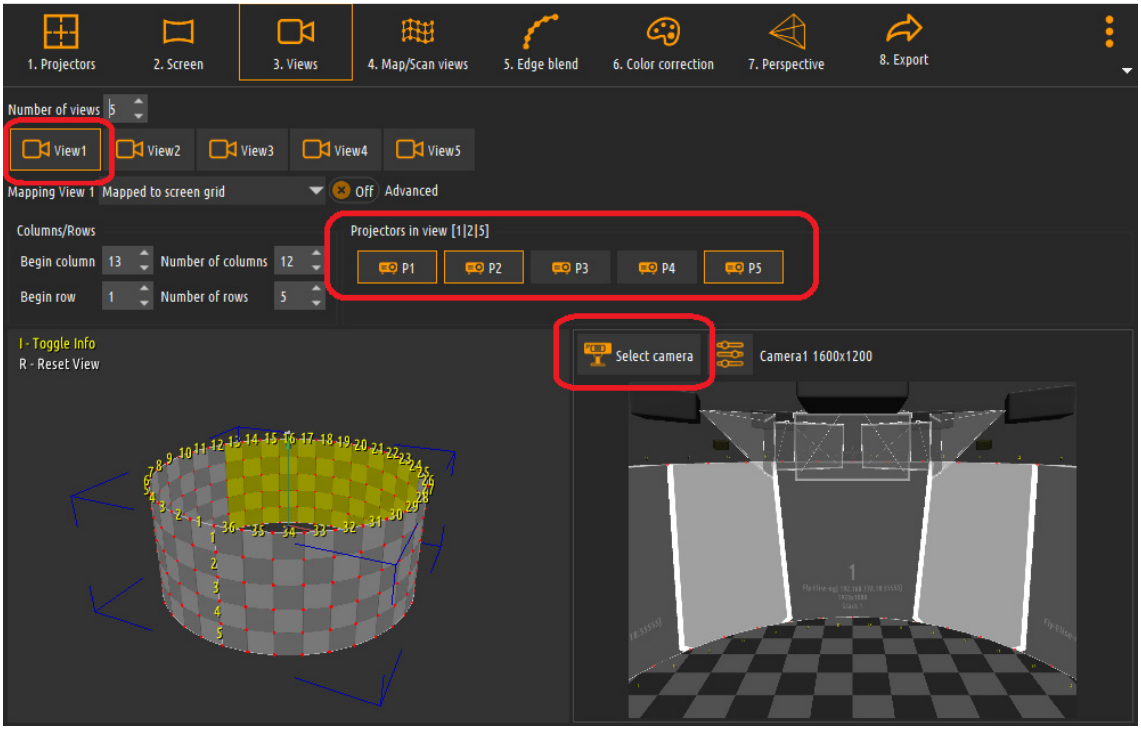
For a successful calibration it is very important that we enter the correct values in the Views page. Automatic calibration will use those to automatically calculate the warping, blending and the frustums info.

Because we use 5 cameras, we will specify that we have 5 views.



The mapping for each view will have to be set to "Mapped to screen grid".

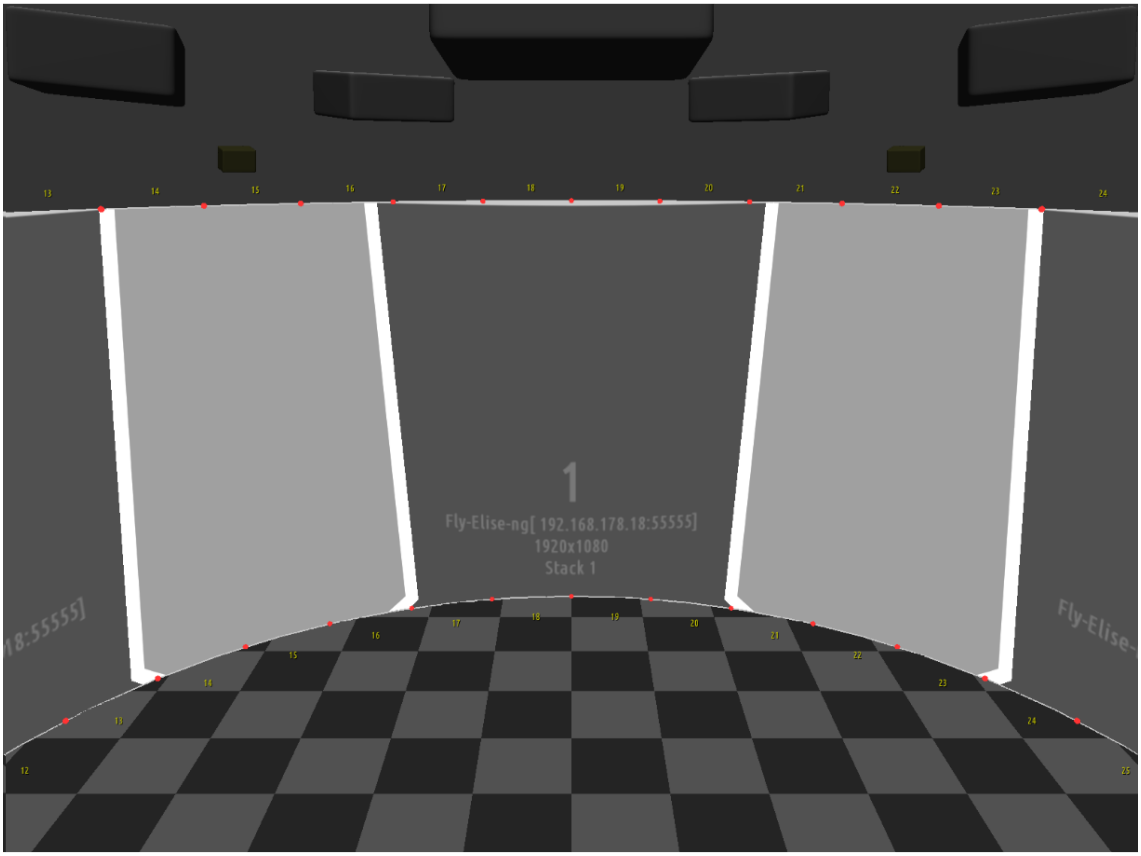
Now, for each view, click the View button (View1, View2, .. View5) and select the corresponding camera for that view.



For each view we need to specify which part of the screen is visible in the view and which projectors are visible (fully or partially) in this view.

Note: The red markers on the images below represent the visible or invisible markers put on the screen.

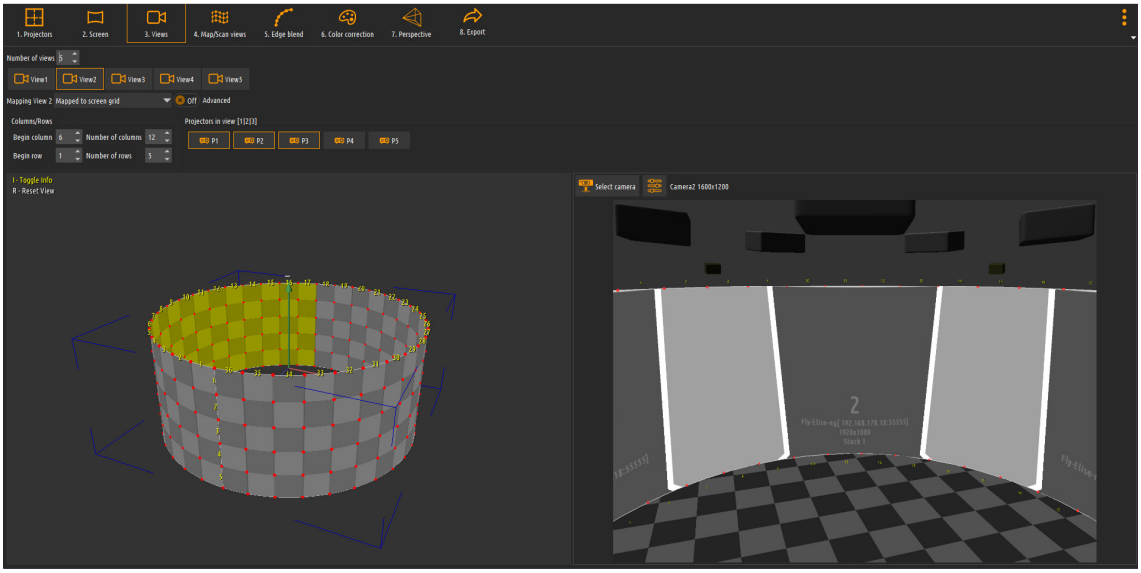
View1

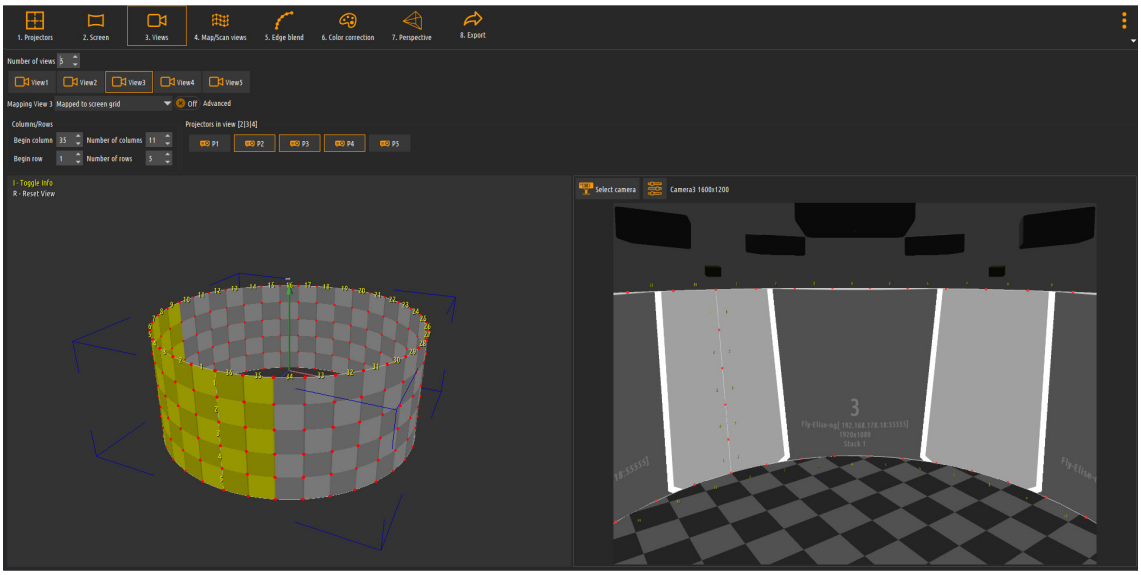


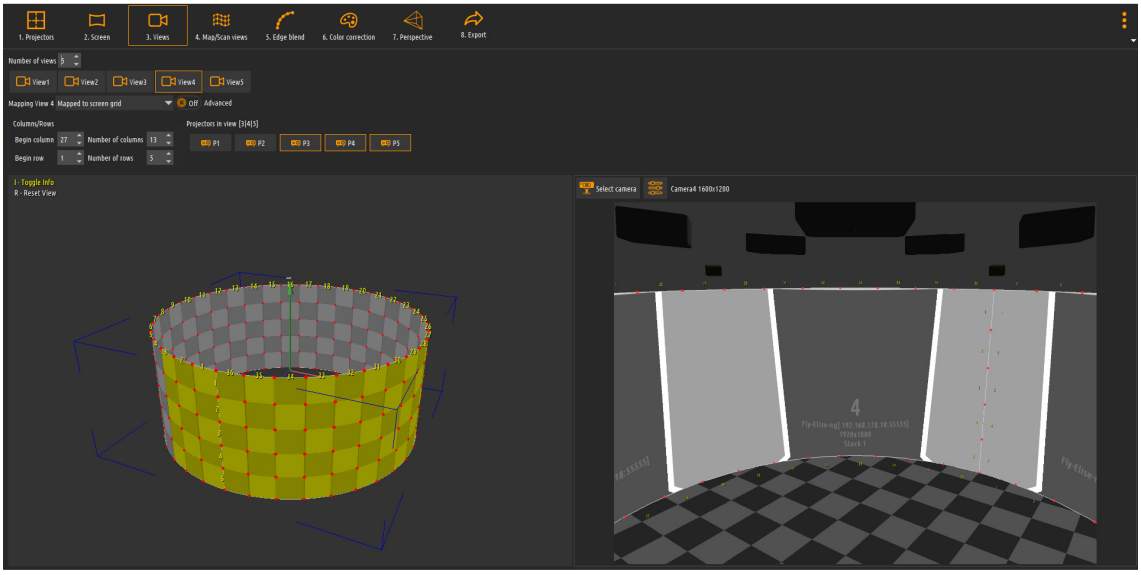
Looking at the camera image we can see that the camera covers row 1 and covers all 5 rows (1, 2, 3, 4, and 5). The camera image captures 12 columns starting from column 13.
So we enter the values for View1 accordingly: Begin column 13, Number of columns 12, Begin row 1 and Number of rows 5.

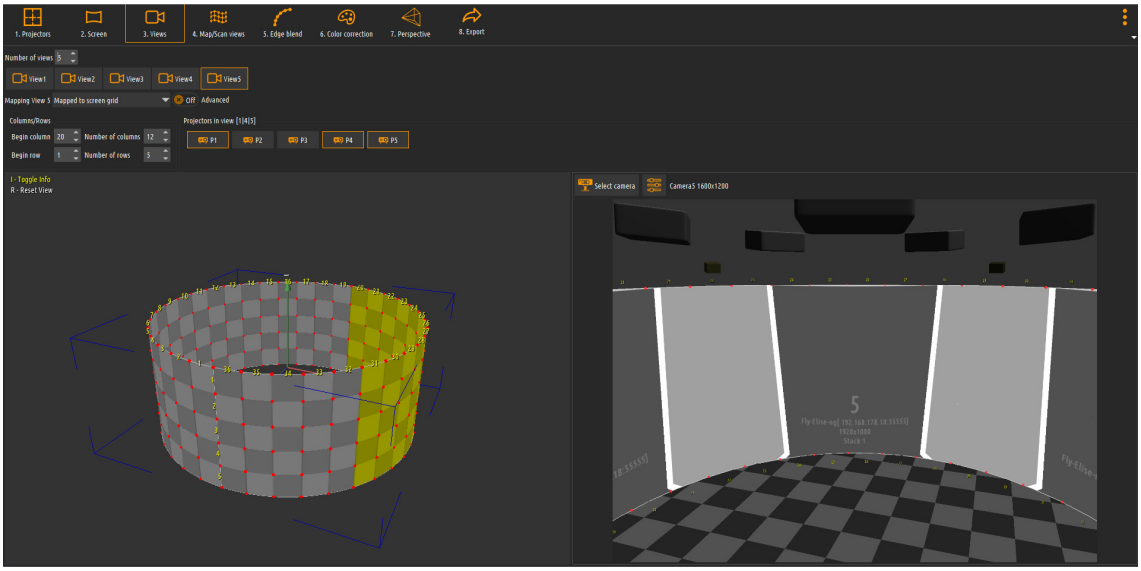
In this camera view projector 1 is fully visible and projector 2 and 5 are partially visible. So we make sure that Projector1, Projector2 and Projector5 are selected.

We repeat the same for all 5 views, by selecting the correct camera per view and using the correct rows and columns per view.


1. Projectors
2. Screen
3. Views
4. Map/Scan views
5. Edge blend
6. Color correction
7. Perspective
8. Export
Number of views 5
View1
View2
View3
View4
View5
Mapping View 2 Mapped to screen grid
Off
Advanced
Columns/Rows
Begin column 6
Number of columns 12
Begin row 1
Number of rows 5
Projectors in view [1][2][3]
P1
P2
P3
P4
P5
I - Toggle Info
R - Reset View
Select camera
Camera2 1600x1200


1. Projectors
2. Screen
3. Views
4. Map/Scan views
5. Edge blend
6. Color correction
7. Perspective
8. Export
Number of views 5
View1
View2
View3
View4
View5
Mapping View 3 Mapped to screen grid
Off
Advanced
Columns/Rows
Begin column 35
Number of columns 11
Begin row 1
Number of rows 5
Projectors in view [2][3][4]
P1
P2
P3
P4
P5
I - Toggle Info
R - Reset View
Select camera
Camera3 1600x1200





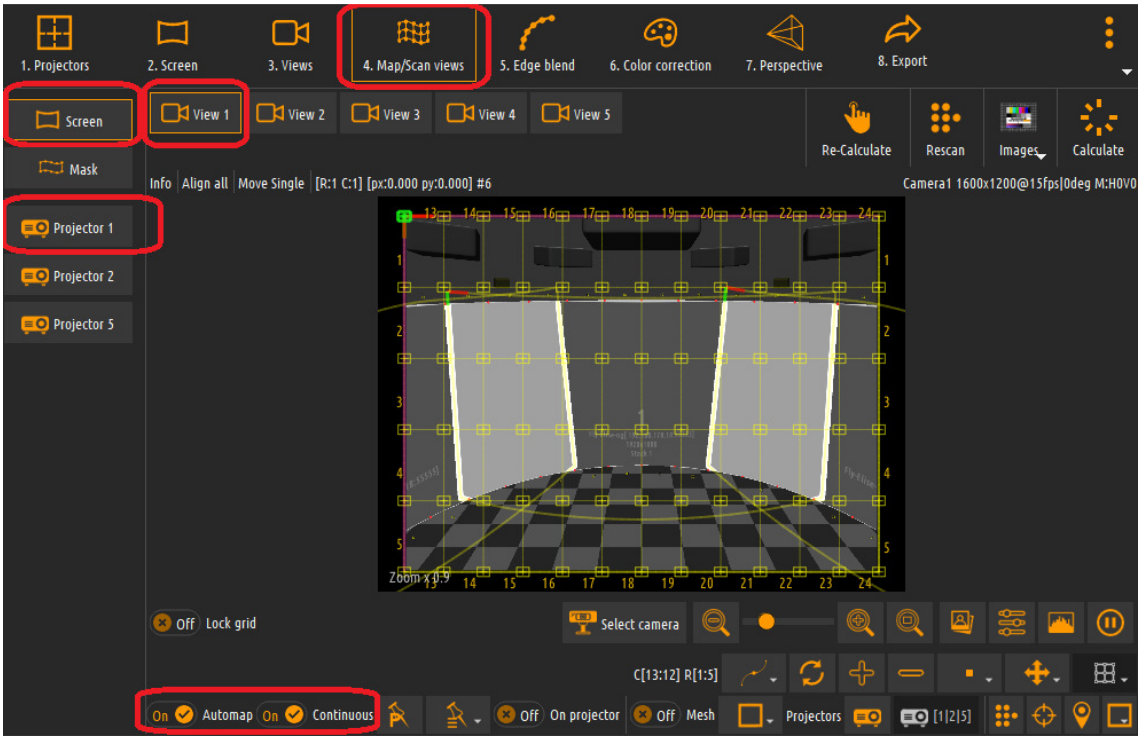
This finishes the configuration of the calibration settings. The next steps will describe the mapping of the screen in the camera views.

Use the File/Save menu to save the calibration project.

7 Map & Scan Views

Press the “Map & Scan View” button to enter the map & scan configuration screen.

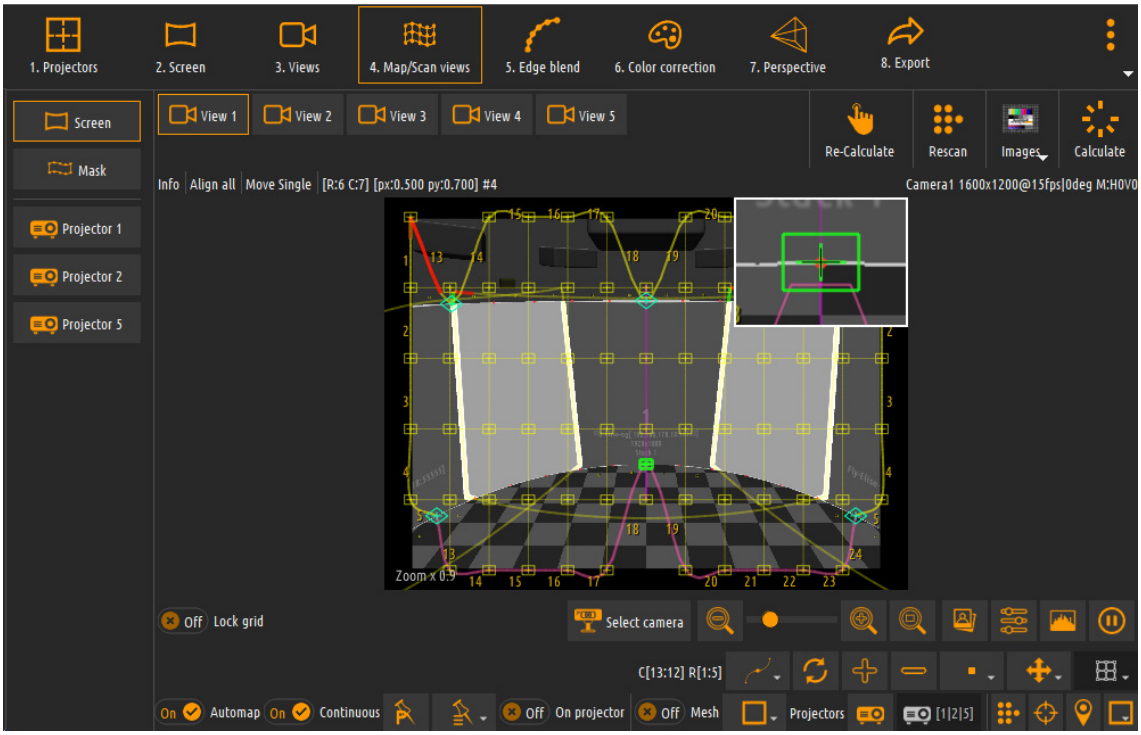
Repeat the steps in this section for each camera view.
For each camera view, part of the projection screen and the projectors visible in that view will be mapped and scanned.



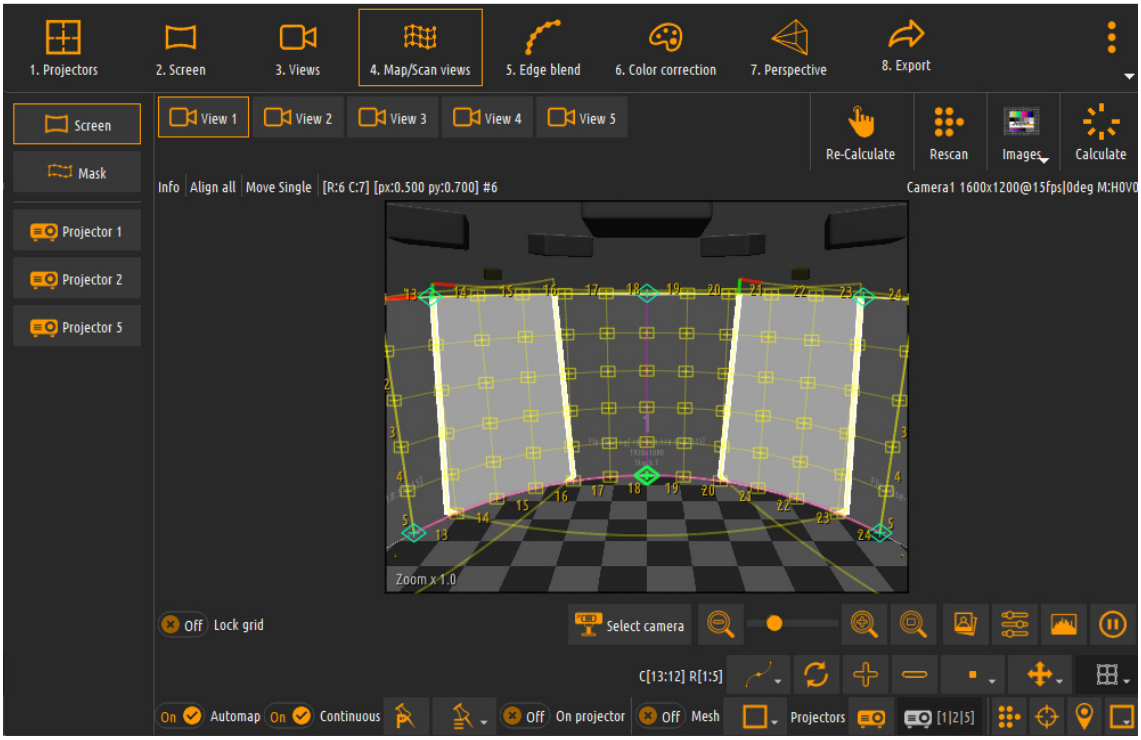
For this mapping we will use the Automap functionality that will automatically map the screen grid in the camera view to the screen edges. For Automap we will need at least 6 grid points to be mapped to the screen edges.
For the best mapping results the points have to be selected to cover the most part of the camera image.
For this guide we will use the most outer points of the screen top and bottom edge visible in the view as well as two points in the middle of the image.

Enable the Automap and Continuous check boxes on the left corner and move the corresponding grid control points to the marked points on the screen.

Optionally press the “Z” button to enable the zoom preview for more accurate positioning.
After the grid point is positioned on the screen point press the CTRL + Left mouse button or “Space” to mark this point as mapped. The grid points will change the shape to a rotated rectangle and will change the color. This point will be used to Automap the rest of the grid points.

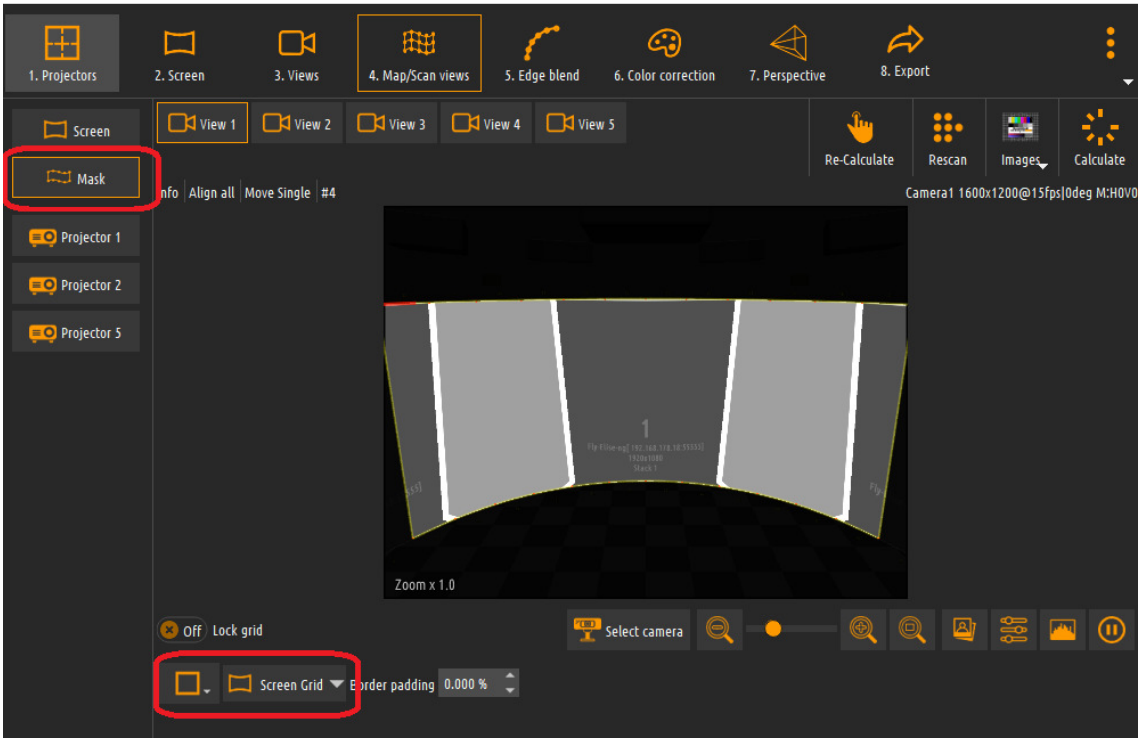


At least 6 points are required to do the auto mapping. However, if more points are used the mapping can be more accurate.
Use the Right mouse button to drag the point with subpixel resolution. Set the points on the screen markers as accurately as possible.
The Automap feature will automatically map all other points in the camera image.



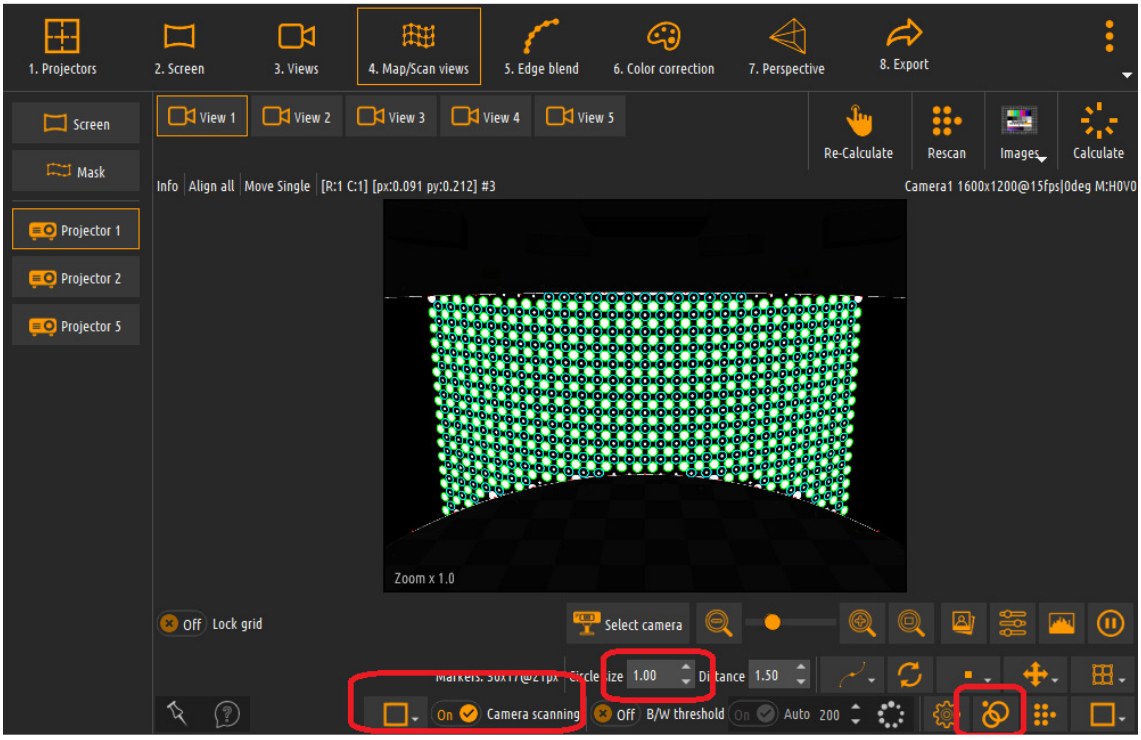
After the screen grid is mapped to the screen, we will proceed with the projectors scanning in this camera view.

Press the “Mask” button, and select “Screen grid”. This will make sure that the scanning of the projector circles will be limited to the area marked by the screen gird. Any projector image coverage outside of the screen will be ignored.



Automatic projectors mapping is a process to accurately map the projector images on the screen in order to automatically calculate the needed geometrical correction and soft-edge blending.
Camera images will be used to automatically map the projectors. This is the same for all projectors.

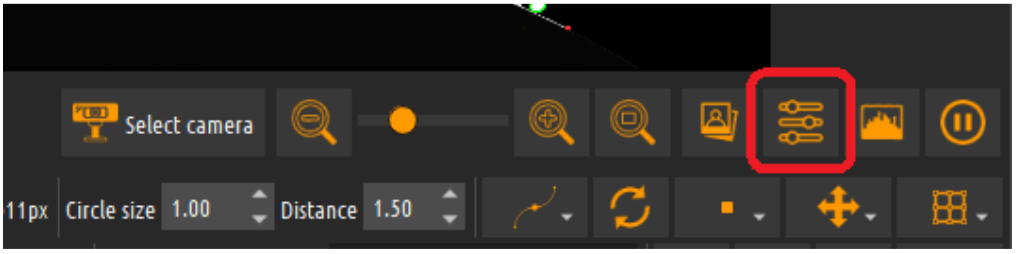
Select the first projector from the list of projectors in this view.
Make sure the “Camera scanning is enabled” and press on “Recognize projector circles” button.
Press the “Recognize projectors circles” button will quickly verify which circles can be successfully recognized and mapped. The recognized circles will be shown in green color. Not all circles need to be successfully recognized for a successful calibration. The not recognized circles will be automatically estimated by the software. If needed, adjust the camera settings and increate the circle size to be able to recognize as much circles as possible.

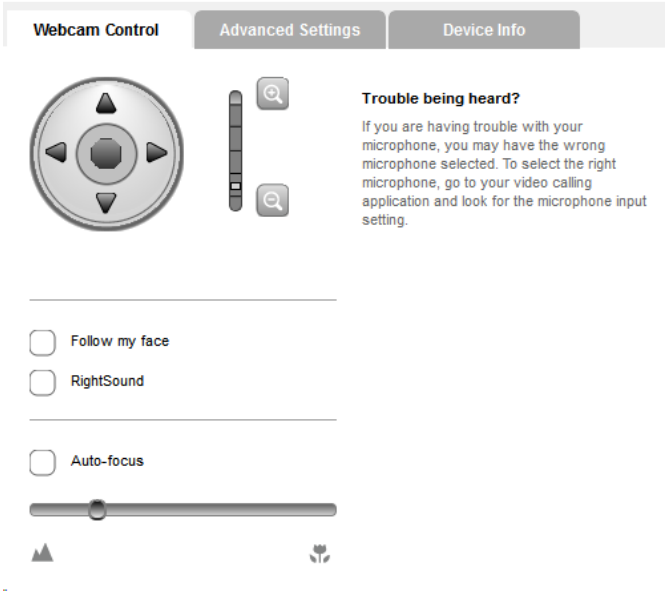


Note: The camera has to be fixes and should not be moved during the rest of the calibration.

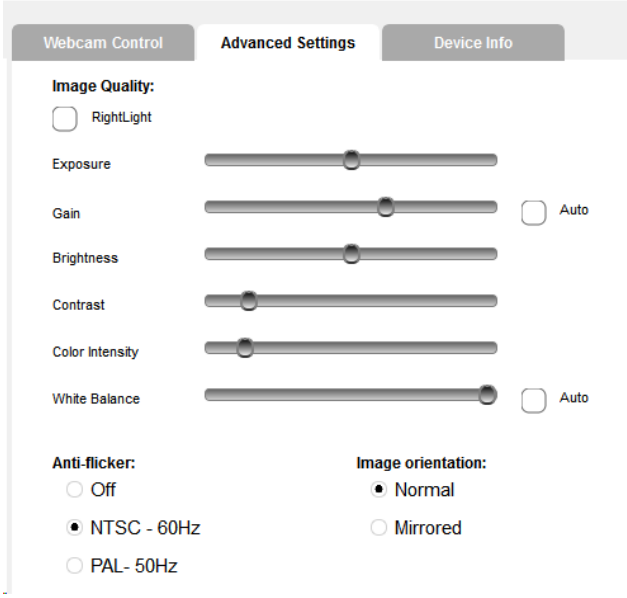
For successful calibration it is important that all automatic camera features (auto-focus, auto-zoom, white balance, etc.) have to be turned off.

Press the camera properties button to open the camera properties widow. This window is provided by the camera drivers and can look differently for different cameras.



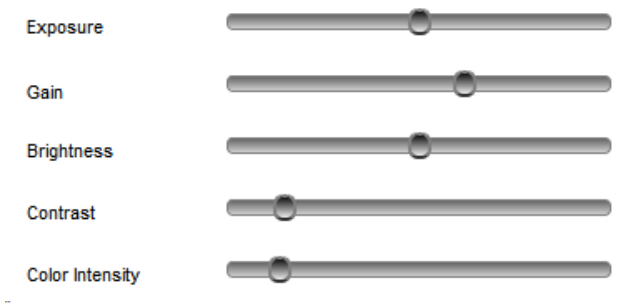


No Auto focus



No Auto Gain and Auto White Balance

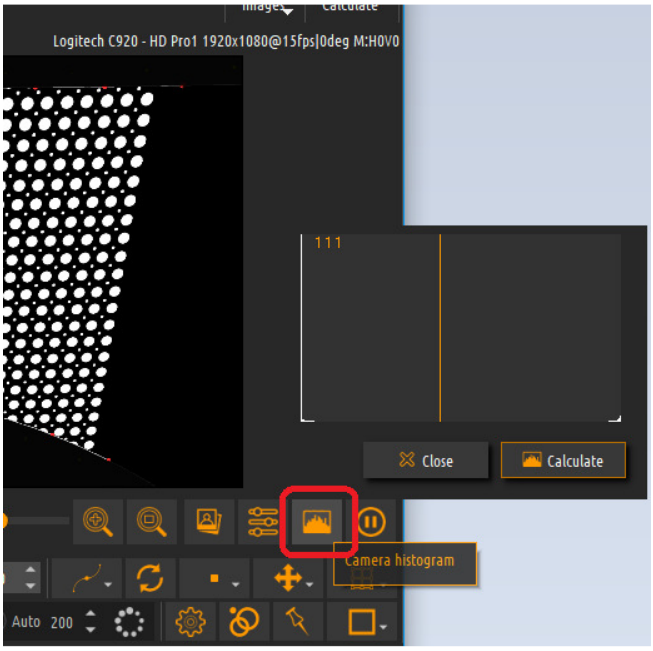
Use the camera controls to adjust the camera image for the best projector scanning and calibration results.



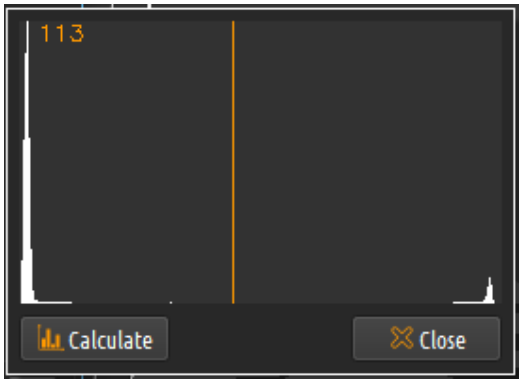
The primary control of the camera image is the “Exposure” control. Use the Exposure to get the most natural looking camera image.
The camera image should look natural and should not be too dark, too bright or saturated. The black and darker colors and the white and brighter colors should utilize the complete camera colors range.

In order to help and facilitate the adjustments of the camera properties, the software comes with a tool called Histogram to evaluate and calculate the used camera dynamic range.

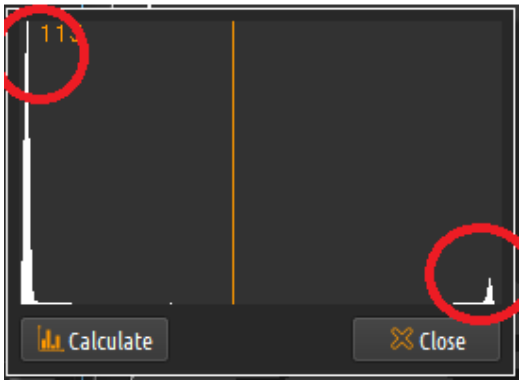
Select the Histogram button and press on the calculate button.



The software will project a number of patterns on the projection screen and will calculate the range between the dark colors and the bright colors as well as the middle distance.



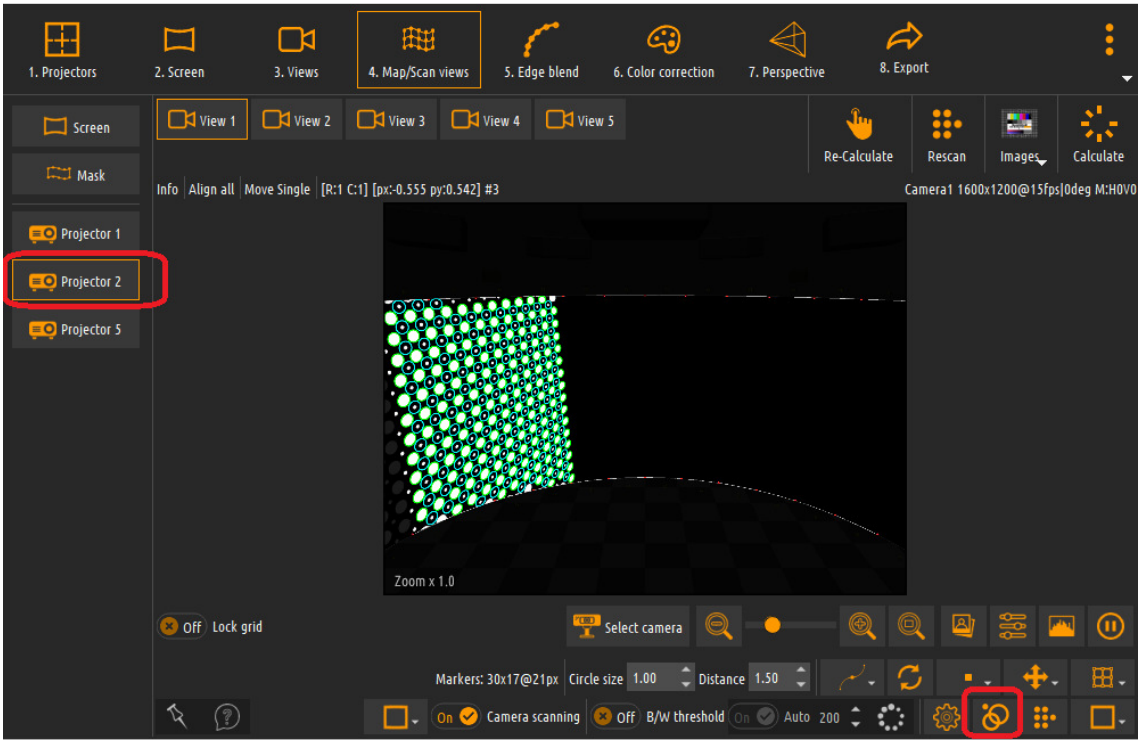
The camera histogram shows two peeks. The left peek is for the dark colors and the right peek is for the bright colors.



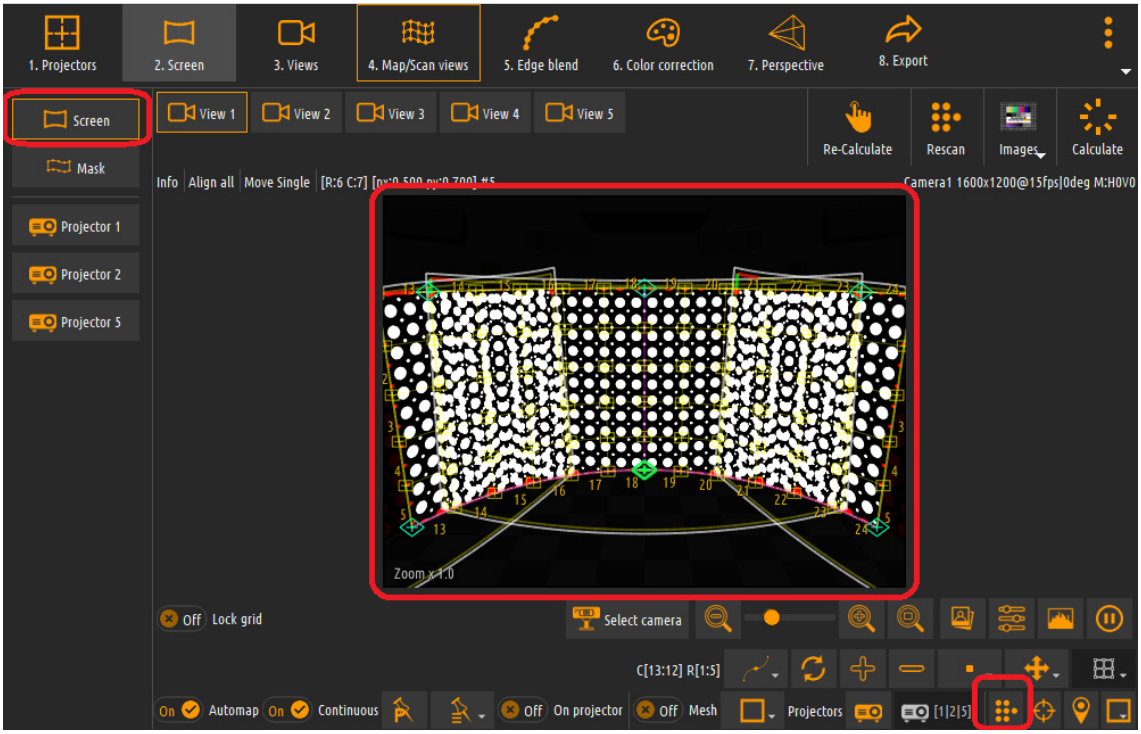
Camera histogram peeks

Use the camera properties (primarily the Exposure) to change the camera properties in such a way that the two peeks are as far as possible and that there orange line lies in the middle between those peeks.
Note: Make sure that you recalculate the Histogram each time the camera parameters have been changed.

Repeat the same steps for all projectors in the camera view, to make sure all projectors will be scanned successfully.



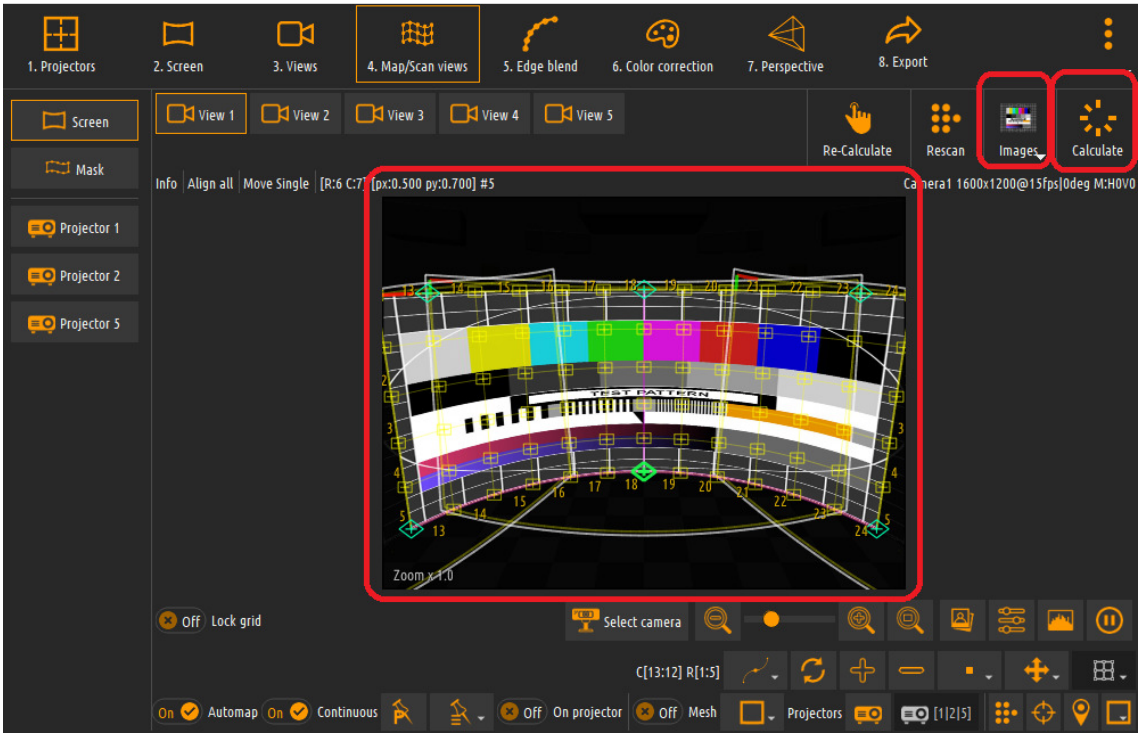
Once the pre scanning is completed and verified, we can proceed with completely scanning all projectors in the camera view.
Click on the screen button and click on “Scan projectors in view” button. This will scan all the projector in this view.



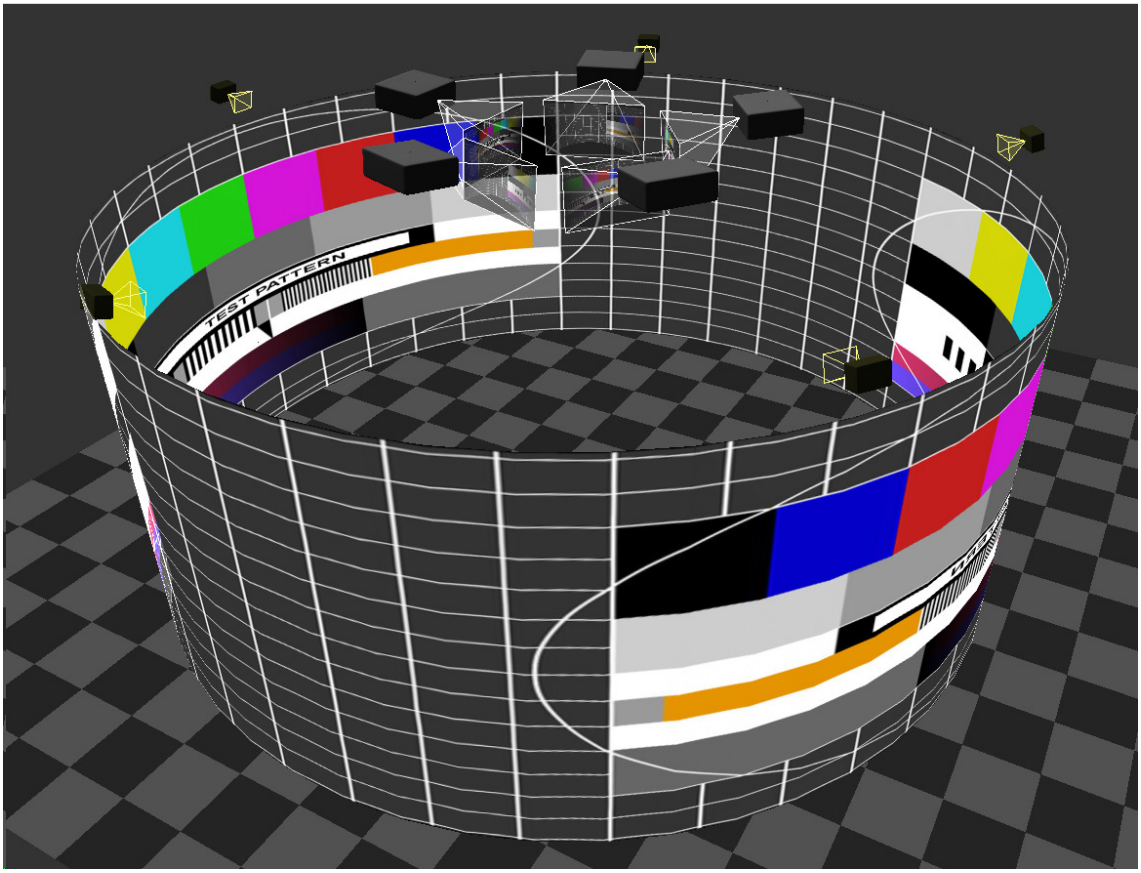
After the scan is completed, the projectors will show the recognized while circles on the screen for this view.

Go to the beginning of this section and repeat the same step for View2, View3 View4 and View5.

When projecting static images, video, of games that do not support multiple perspective views, Immersive Display PRO will calculate the warping and blending to map this single virtual camera view to the projection screen. The actual (real) field of view will be determined by the field of view of this single virtual camera.
Press the “Calculate” button to calculate the geometrical correction, auto-alignment and edge blending.

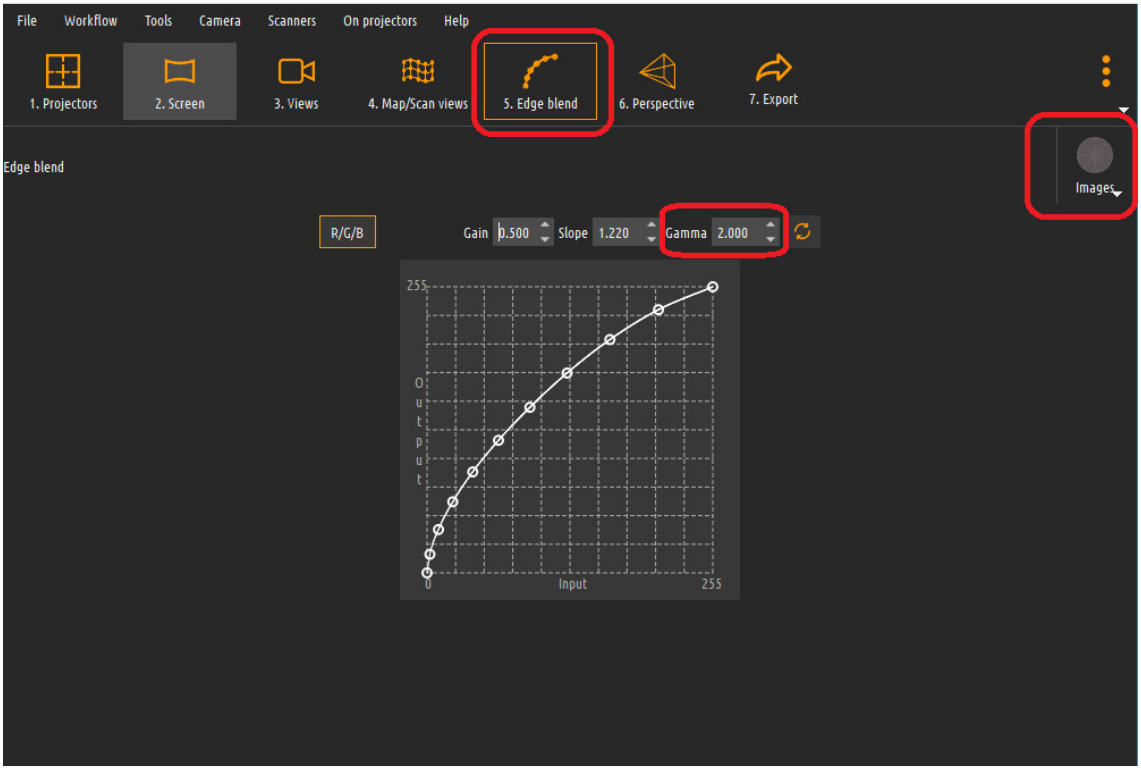


After calibration finished, the geometrical correction and the soft-edge blending will be calculated and send to the Rendering Client PC. A test image will be projected on the screen from multiple projectors.
Optionally, change the images to preview the alignment.



8 Edge - blend

Click the edge-blend button to fine tune the edge blend if needed. The default settings give the best results for most of the projectors. If the projectors have different gamma profile, do a slight change to the gamma value to achieve the best edge blend. Use different images to verify the blending.

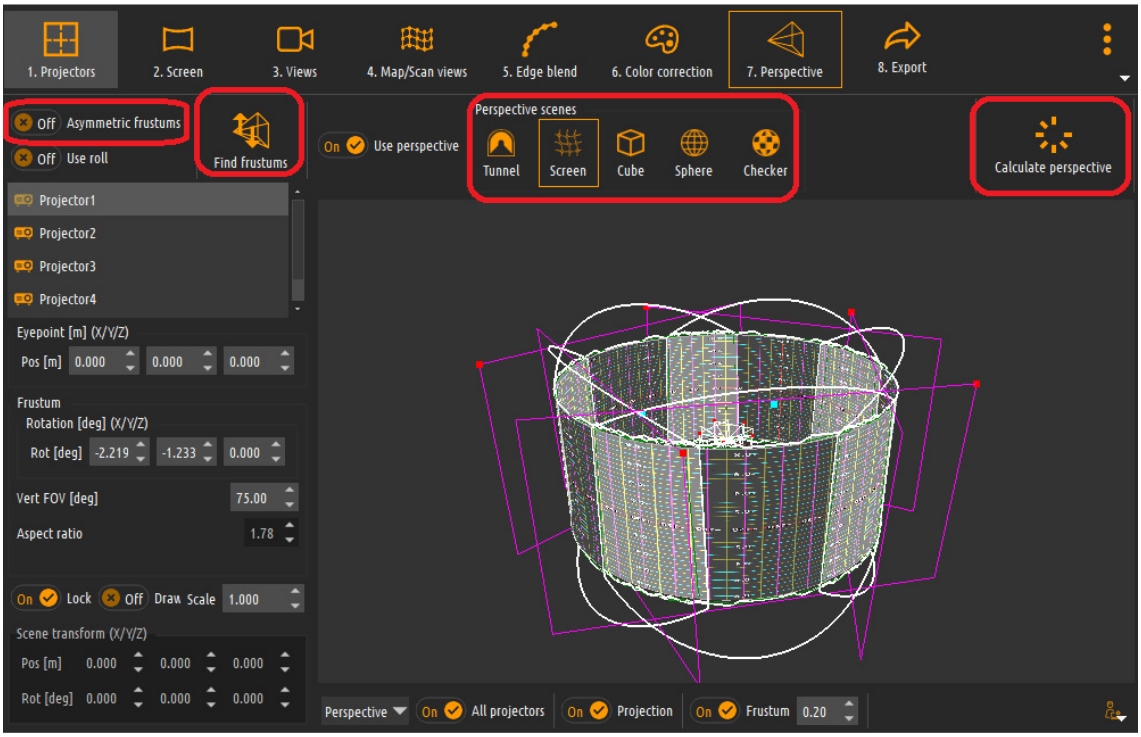


When the result is satisfactory Save the selected settings in a ".project" file using the File/Save menu.

9 Perspective projection

When projecting the content of a 3D application (Games, Simulators, CAD, etc.) that have support for multiple cameras, each projector can project image from a single virtual camera. The total projected image will not be constrained by a single camera field of view but it will match the projection screen field of view.

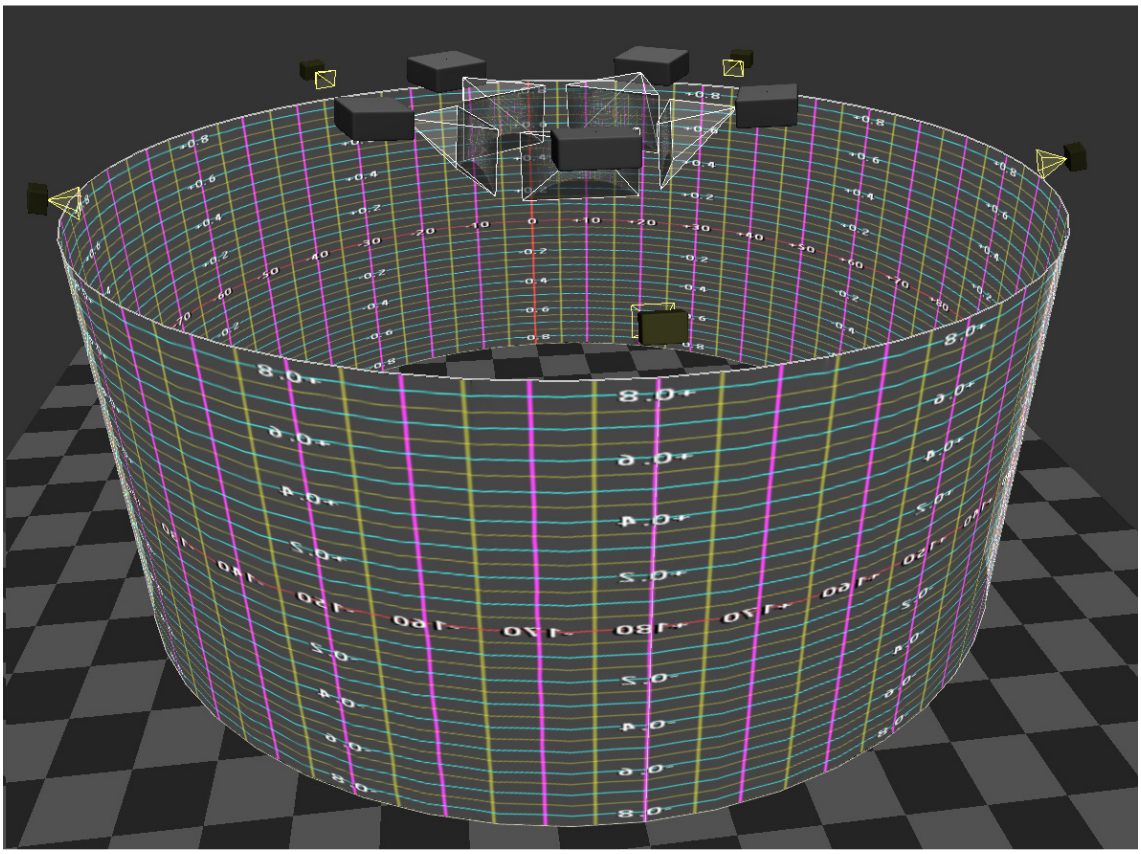
Before calculating the perspective mapping, make sure that the previous steps are performed successfully. Those steps will perform projectors mapping to screen mapping which is a basis for the perspective mapping.
Select the “Perspective” button to enter the perspective configuration screen.
First press the “Find frustums” button. This will find the perspective frustums for all projectors.



Note: Most of the game engines do not support asymmetric frustums so make sure the Asymmetric frustum option is disabled for Unity.

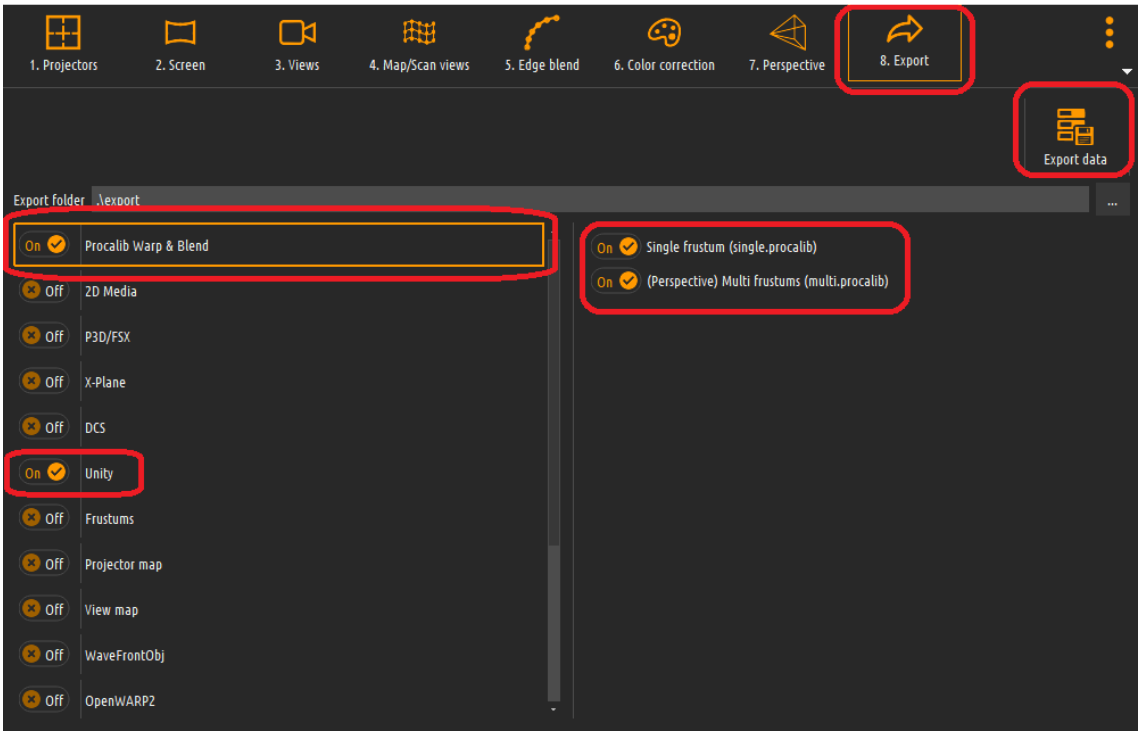
Then press “Calculate perspective” button. This will calculate the perspective correction and the edge blending for each projector.

After calibration finished the results are send to the Rendering Client PC. A test 3D mesh scene or a tunnel scene that corresponds to the screen shape will be projected on the screen from multiple projectors.
Use the available perspective scenes to verify the calculation.



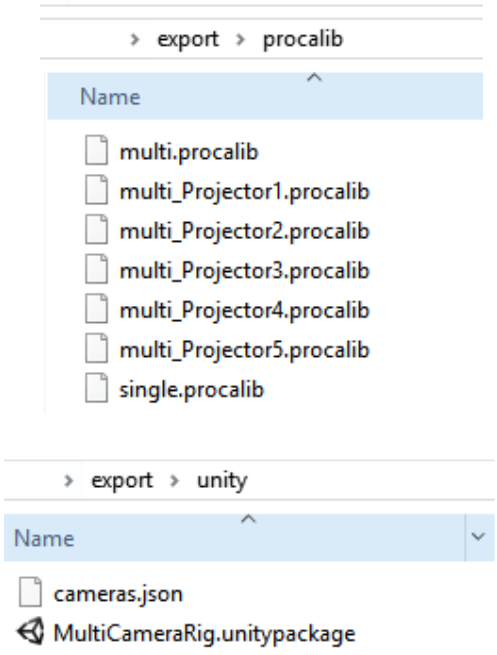
10 Export the calibration result

The calibration can be exported to a file that can be used inside Immersive Display PRO. Also a set of virtual camera parameters (frustums) will be exported that can be used directly or indirectly in to position and orient the cameras in the game or other 3D engine software.
Press the “Export” button to enter the export screen.

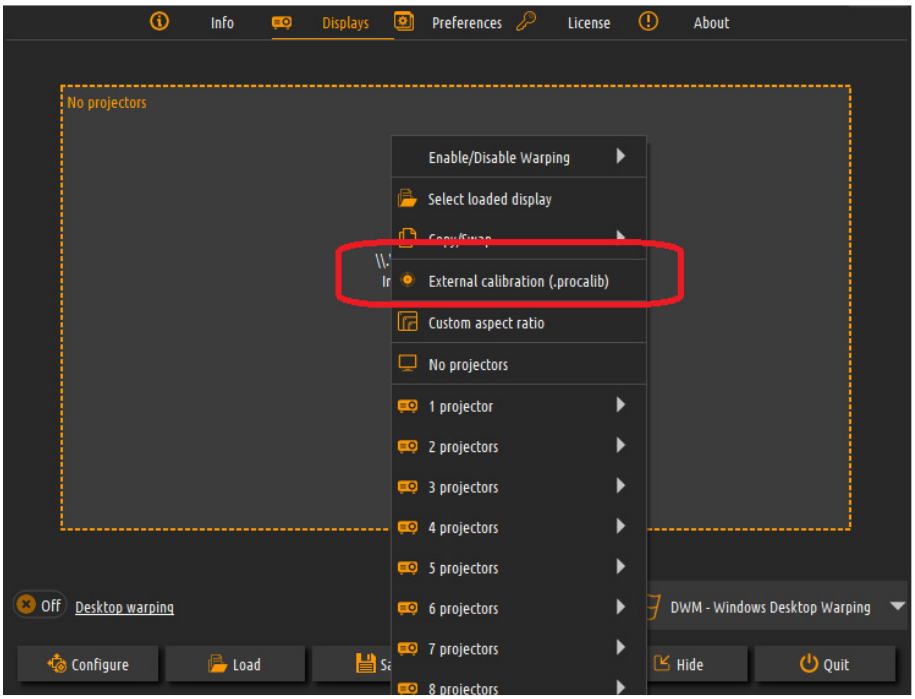


Make sure that the Single and Multi-frustum procailb export is enabled. Also make sure that Unity export is enabled.
Several .procalib files will be exported with the filename selected from the export dialog. The .procalib files can be imported in Immersive Display PRO.
Also the Unity camera rig package will be exported that cab be imported as a camera in any Unity 3D project.

Note: When asymmetric frustums are used, some of the export options are not available because the corresponding software does not support asymmetric frustums. Disable the asymmetric frustum option in the “virtual camera configuration window” to enable those export options.



The _multi.procalib file should be used when projecting multiple virtual cameras content (games, simulators, 3d engines, etc). For Unity we will use the _multi.procaib files.



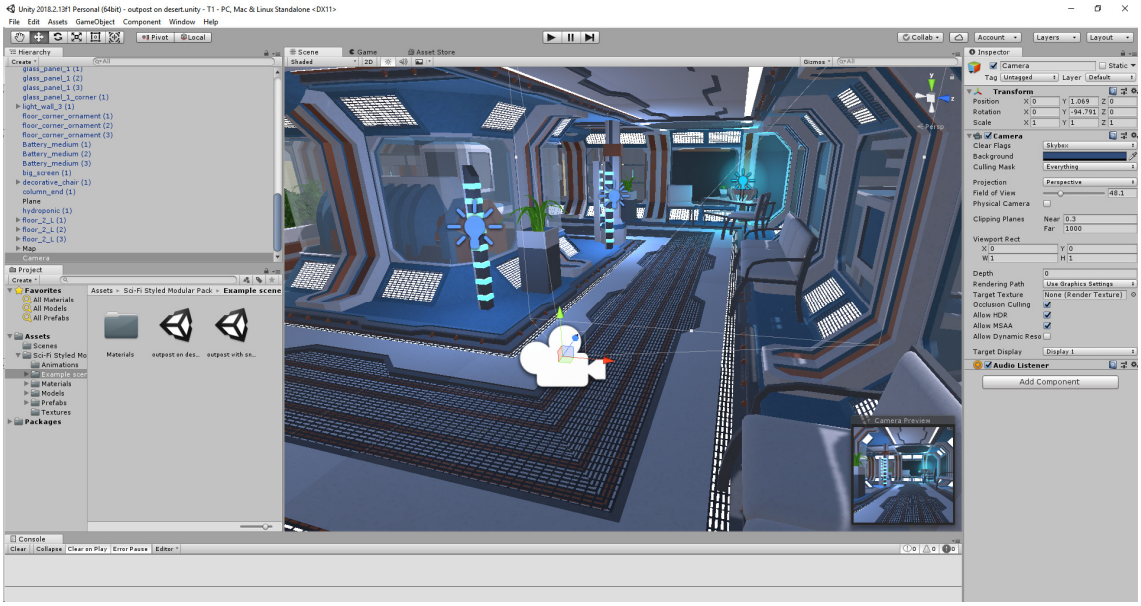
11 Unity camera settings

Unity is a cross-platform game engine developed by Unity Technologies.
The engine can be used to create 3D, virtual reality, and augmented reality games, as well as simulations and other experiences. Unity engine has been adopted by industries outside video gaming, such as film, automotive, architecture, engineering and construction.
Unity gives users the ability to create games and experiences in both 2D and 3D, and the engine offers a primary scripting API in C#, for both the Unity editor in the form of plugins, and games themselves, as well as drag and drop functionality.
For this step by step manual, Unity 2018.2 Personal version has been used.

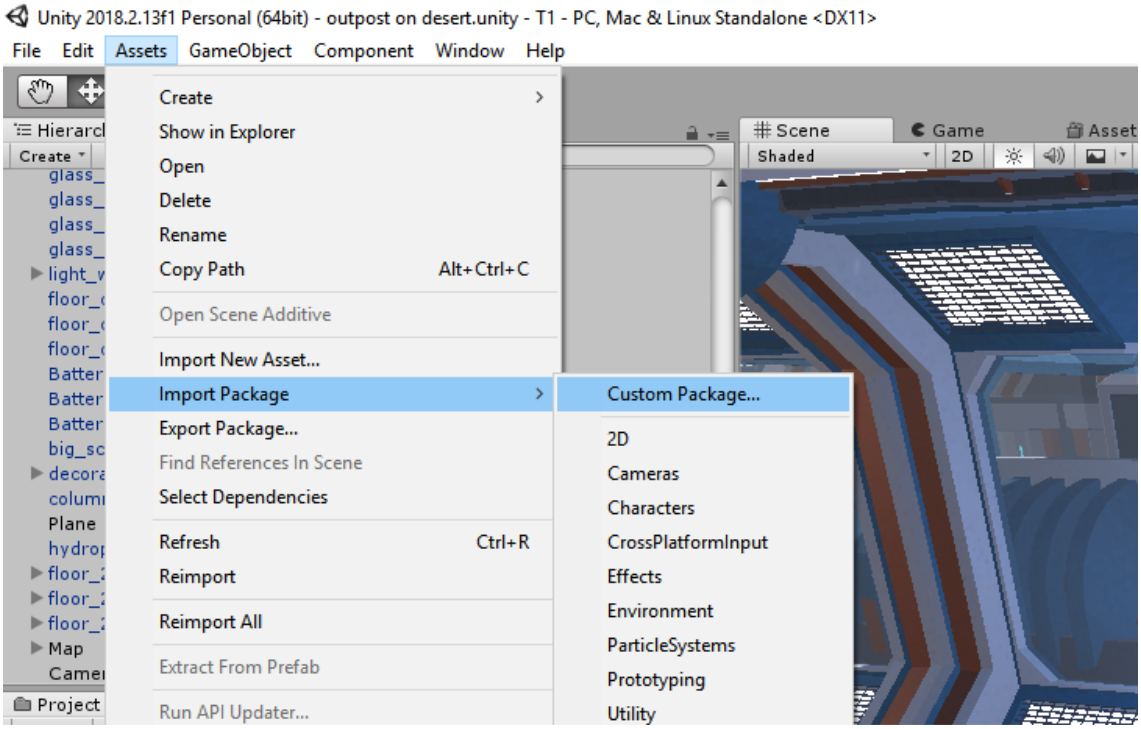
Unity supports multi-display, that allows you to display up to 8 different camera views of your application on up to 8 different monitors/projectors at the same time.
Immersive Calibration Pro exports a unity camera rig that automatically renders and displays the correct camera view on the correct projector. This camera rig will replace the existing Unity single view camera.
The MultiCameraRig is a Unity package that can be imported in any unity project. The corresponding camera.json file contains a definition of each camera view and the target display to be used to render the view.

```
{
    "items":
    [
        {
            "name" : "C1",
            "display" : "1",
            "fov" : "75",
            "rx" : "2.21856",
            "ry" : "1.23262",
            "rz" : "0"
        }
        ,
        {
            "name" : "C2",
            "display" : "2",
            "fov" : "75",
            "rx" : "2.19132",
            "ry" : "-73.1991",
            "rz" : "0"
        }
        ,
        {
            "name" : "C3",
            "display" : "3",
            "fov" : "75",
            "rx" : "2.24524",
            "ry" : "-145.204",
            "rz" : "0"
        }
        ,
        {
            "name" : "C4",
            "display" : "4",
            "fov" : "75",
            "rx" : "2.27741",
            "ry" : "142.726",
            "rz" : "0"
        }
        ,
        {
            "name" : "C5",
            "display" : "5",
            "fov" : "75",
            "rx" : "2.24799",
            "ry" : "70.6938",
            "rz" : "0"
        }
    ]
}
```

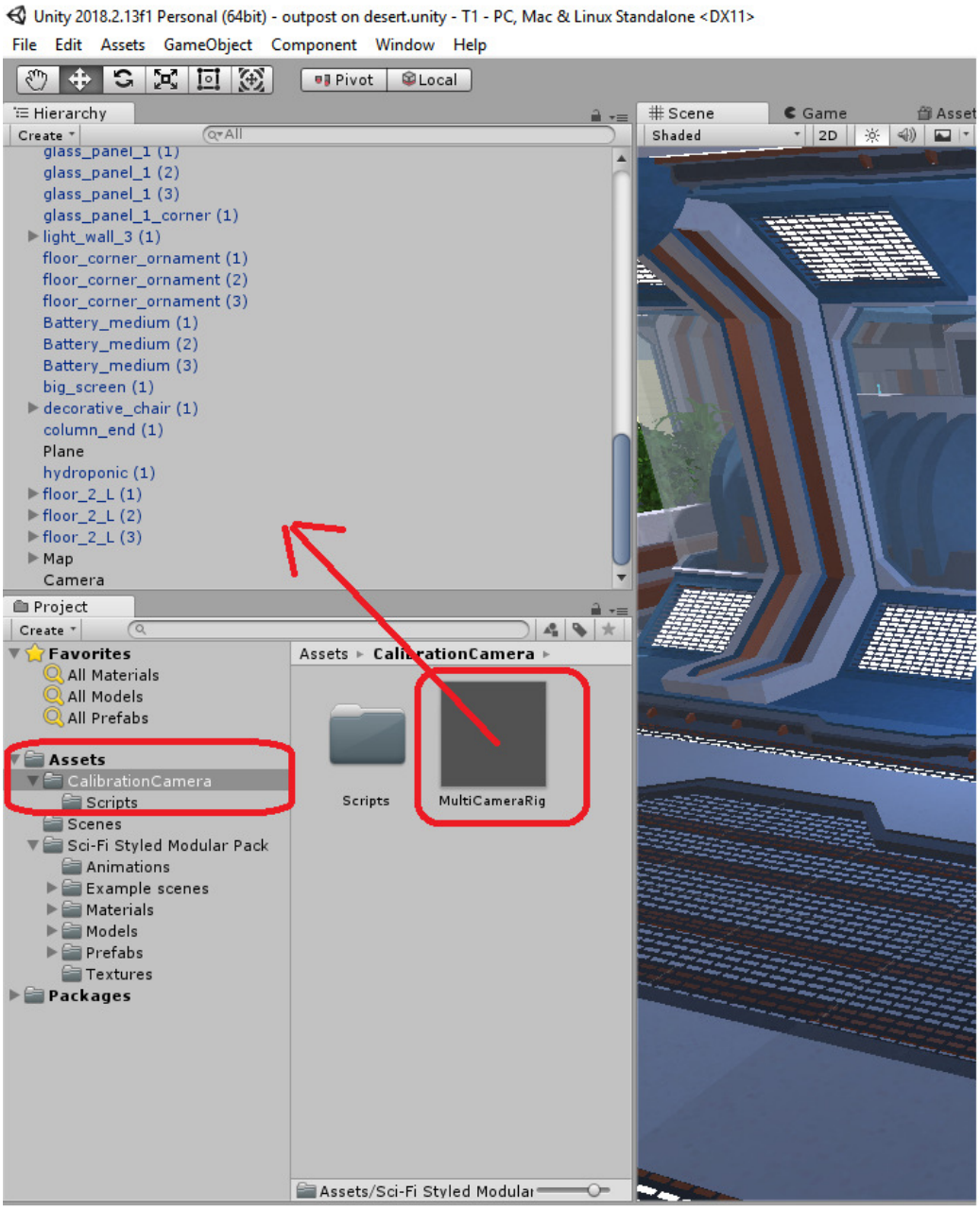
For this manual we will use a free unity 3D scene Sci-Fi Styled Modular with a default camera.



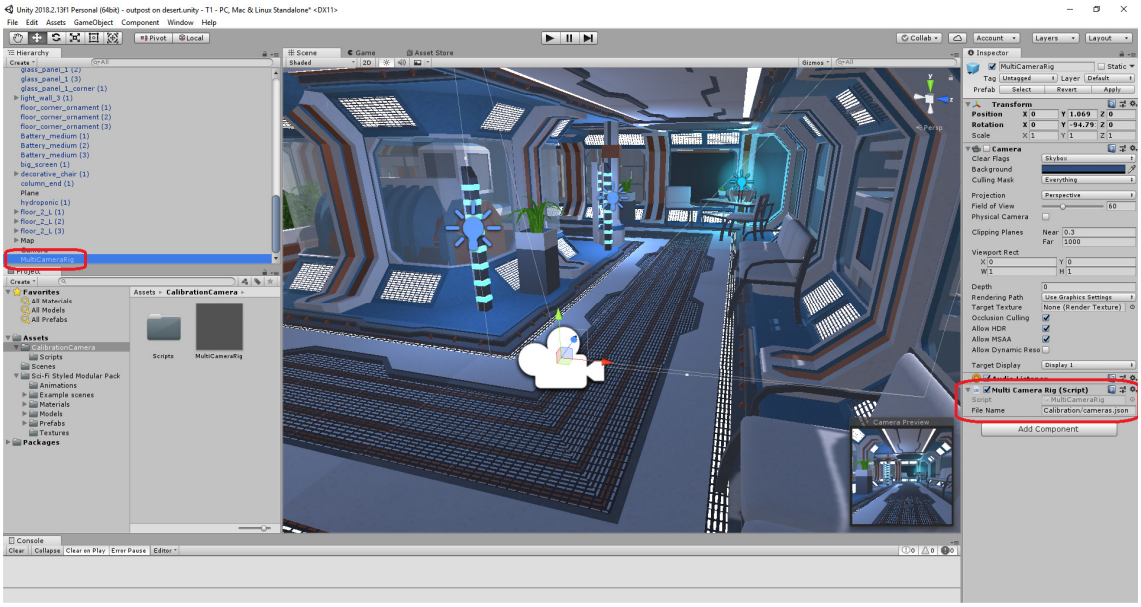
Import the MultiCameraRig Unity package from the exported Immersive Calibration PRO / Unity folder.



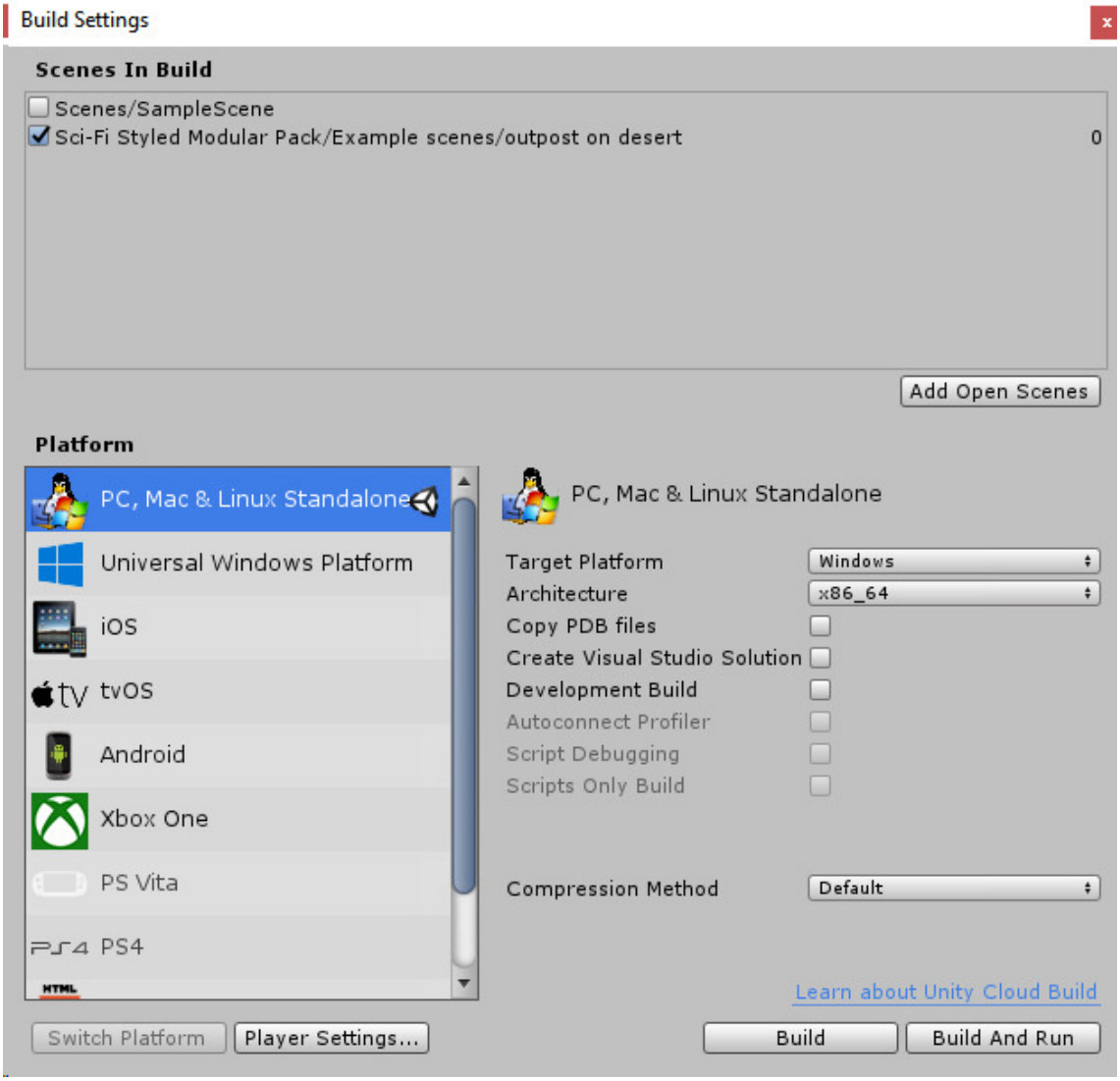
This will add the Immersive Calibration PRO camera rig to the Unity project assets. First remove or disable the default camera. Drag dag the MultiCameraRig into the scene hierarchy.



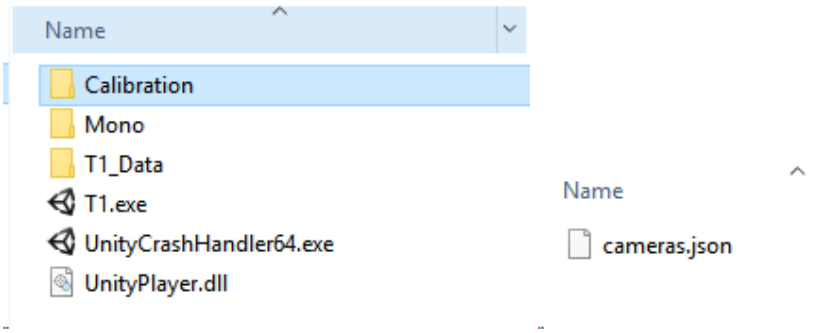
This will create a new multi-view camera. The MultiCamera rig camera will use the cameras.json file to configure and render the multiple camera views.



Configure and build the Unity project. This will produce a standalone executable with all dependent assets.

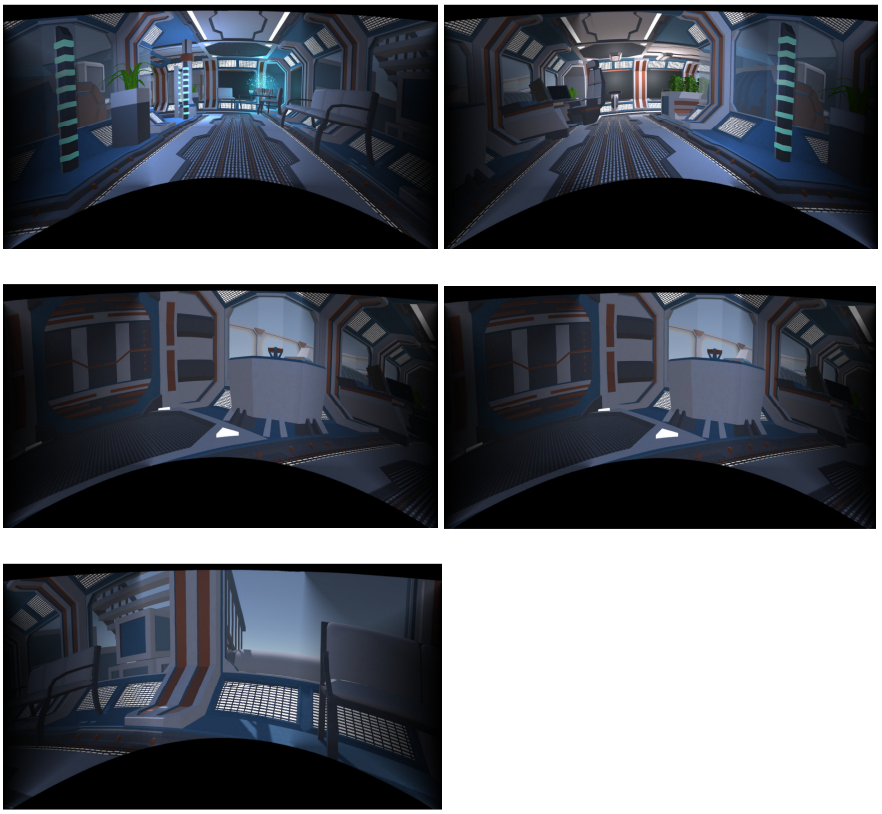


Create a folder Calibration inside the executable root directory, and copy the cameras.json file in this folder. The MultCameraRig will need this file in runtime to configure the camera views on each PC display.

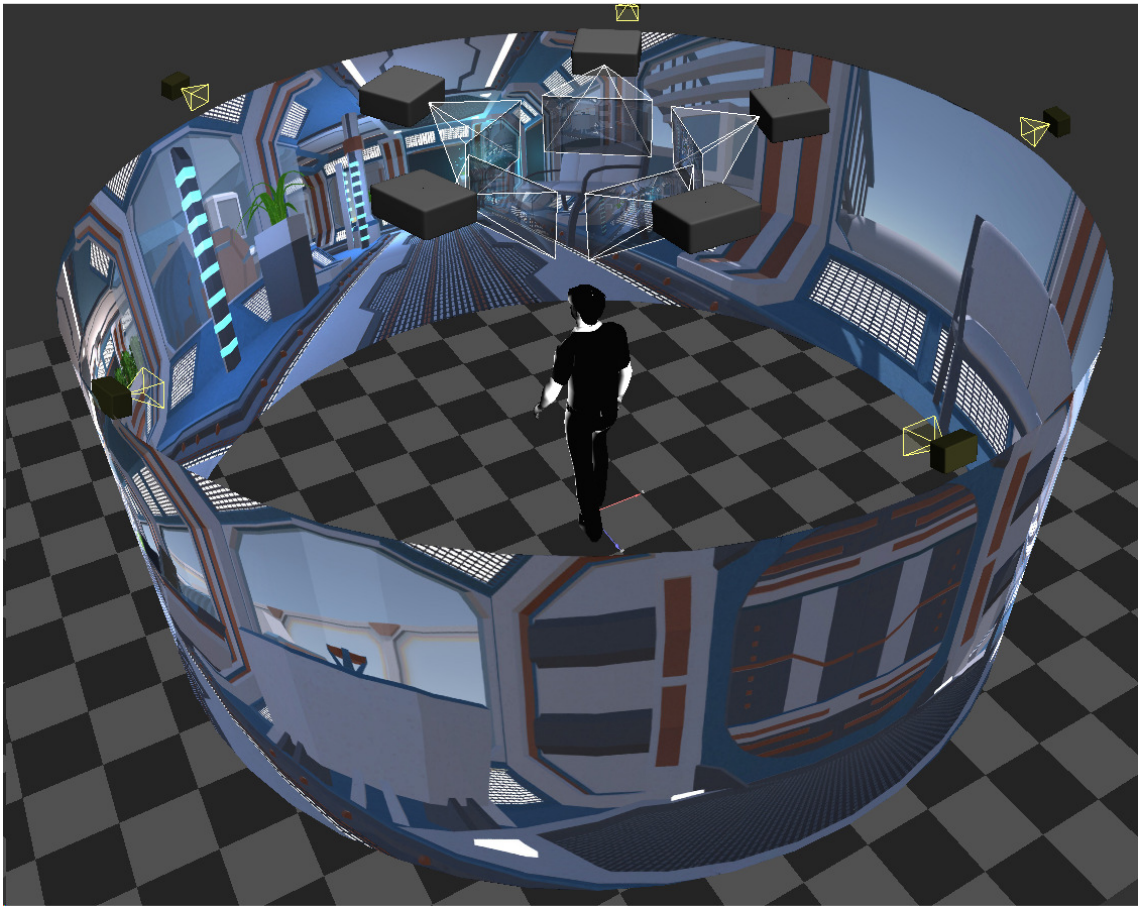


That is all. Start the executable in full screen mode and the software will render the correct views on each display.
Make sure that the display number in the cameras.json file matched the display in unity. If this is not the case, modify the display values in the cameras.json file.

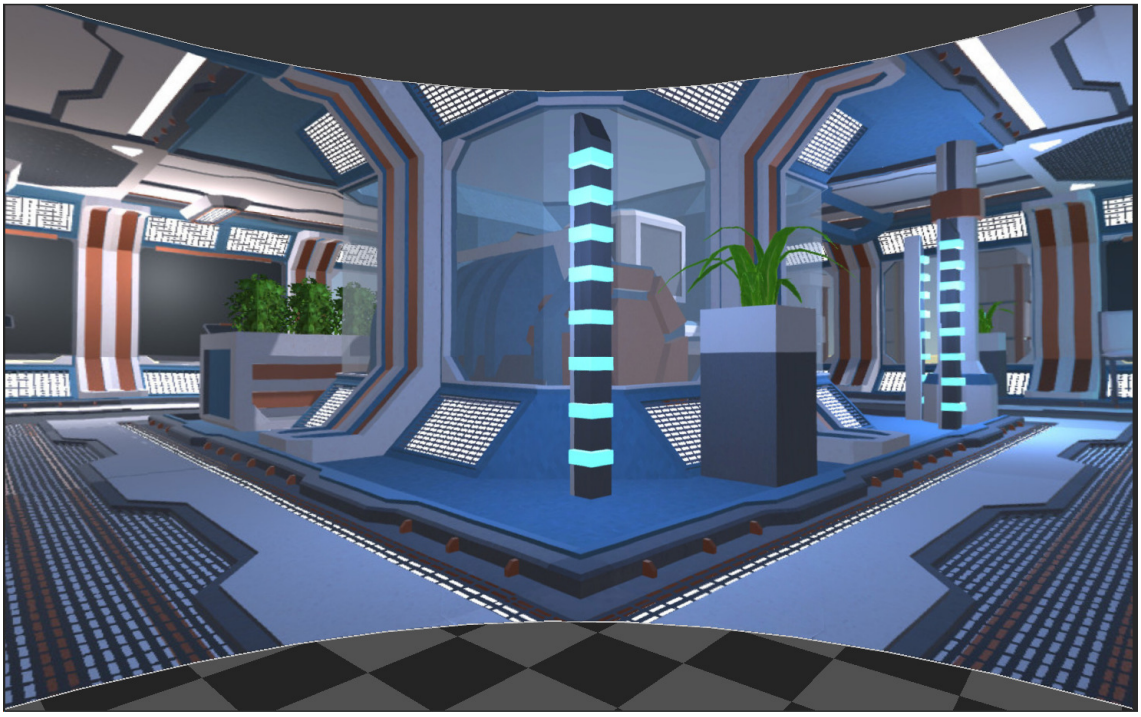
Now make sure Immersive Display PRO is started and runs in the background. Start the executable in full screen mode.



All 5 displays and projector will be perfectly geometrically corrected and aligned.



The view from the observer eyepoint is perfect in all directions.



This is a perfect setup for creating try immersive environments with the unlimited simulation and visualization possibilities of Unity 3D engine and the perfect auto-augment, geometrical correction and edge blending from Fly Elise-ng software.

Now go and create your own immersive visual setups.