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

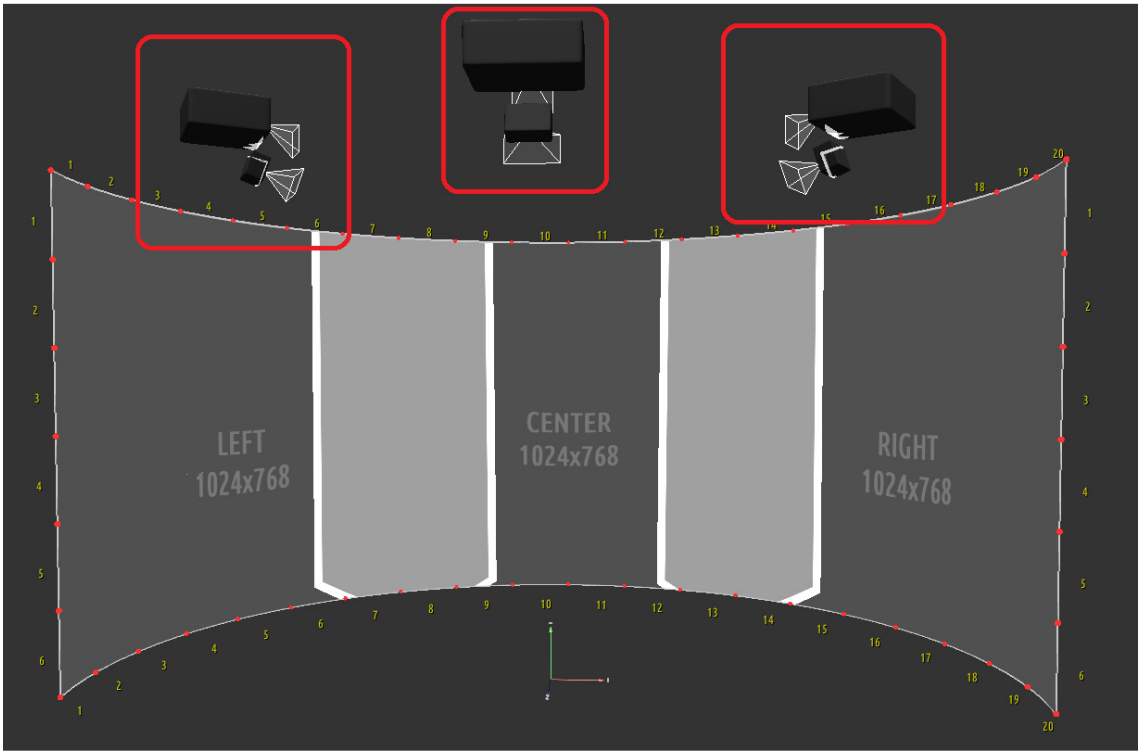
1 Introduction

This is a step-by-step guide for setting-up a seamless immersive projection using 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.
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.

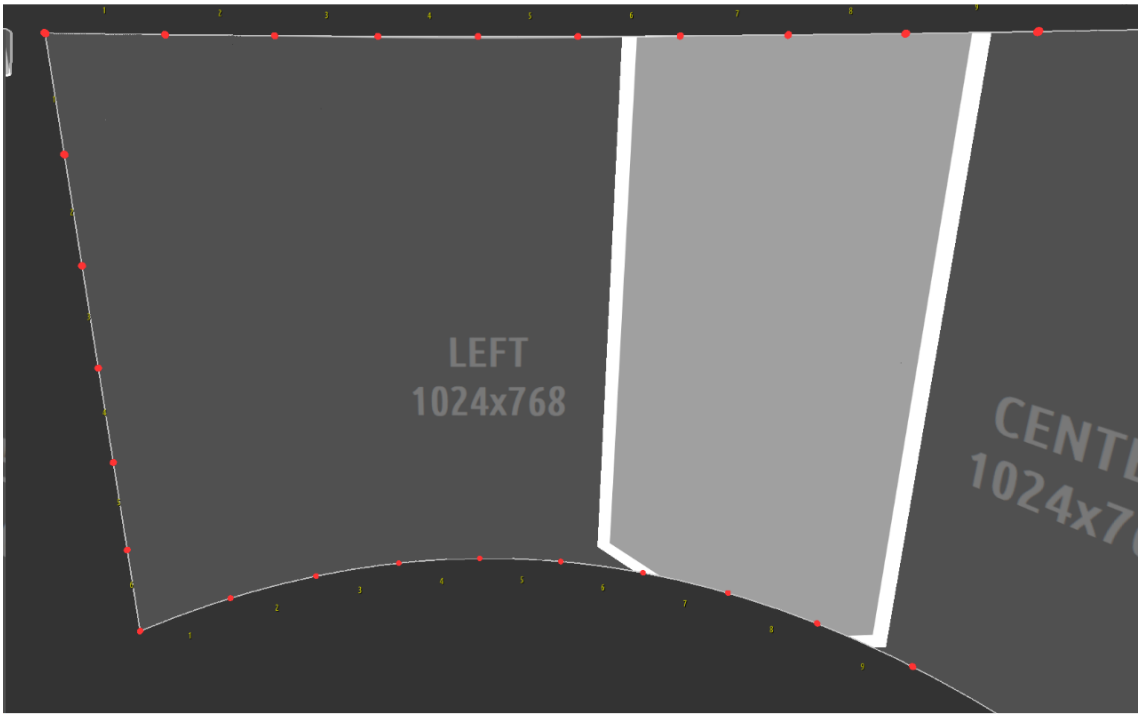
For multi-camera calibration we can use one or more HD webcams to automatically map the projector images to the screen and automatically calculate the needed warping and blending. Either a single camera can be used, or multiple cameras can be used for each view. When a single camera is used the camera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

For this step by step guide we will use 3 Logitech HD Webcam C920 cameras mounted below the projectors to capture part of the screen and projectors images.

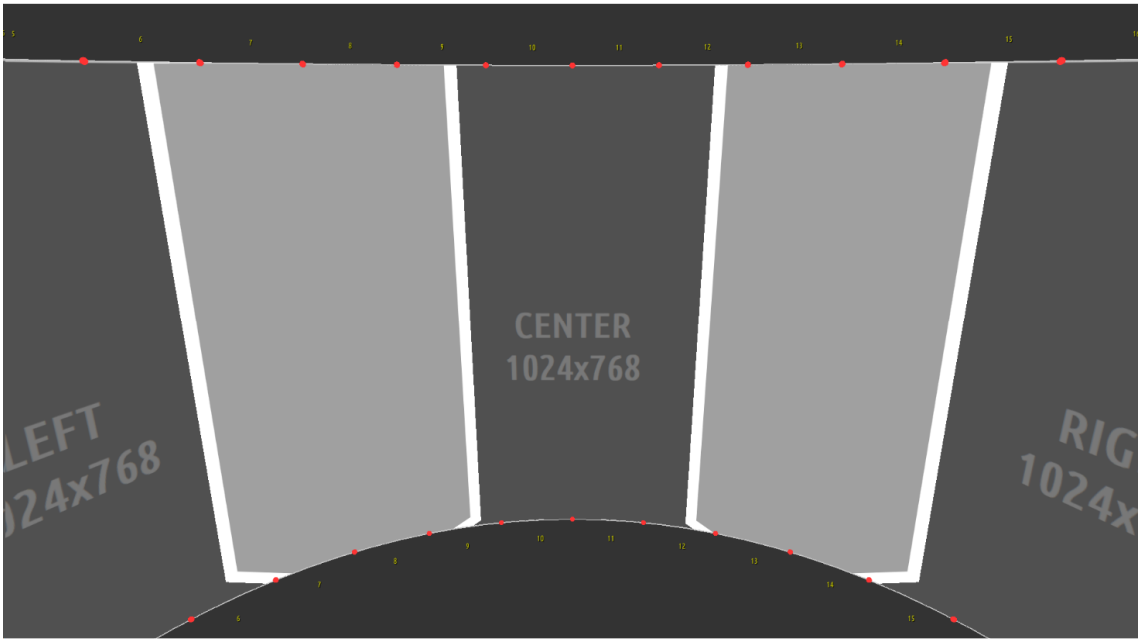
For the purpose of this step-by-step guide we will use a cylindrical projection screen with the following parameters: horizontal angle 200 degrees, height 1.8 meters and radius 1.7 meters (diameter 3.4 meters). The 3 projectors are positioned in such a way that the complete projection screen is covered by a projection images from projectors and that the projector images overlap by about 15%.



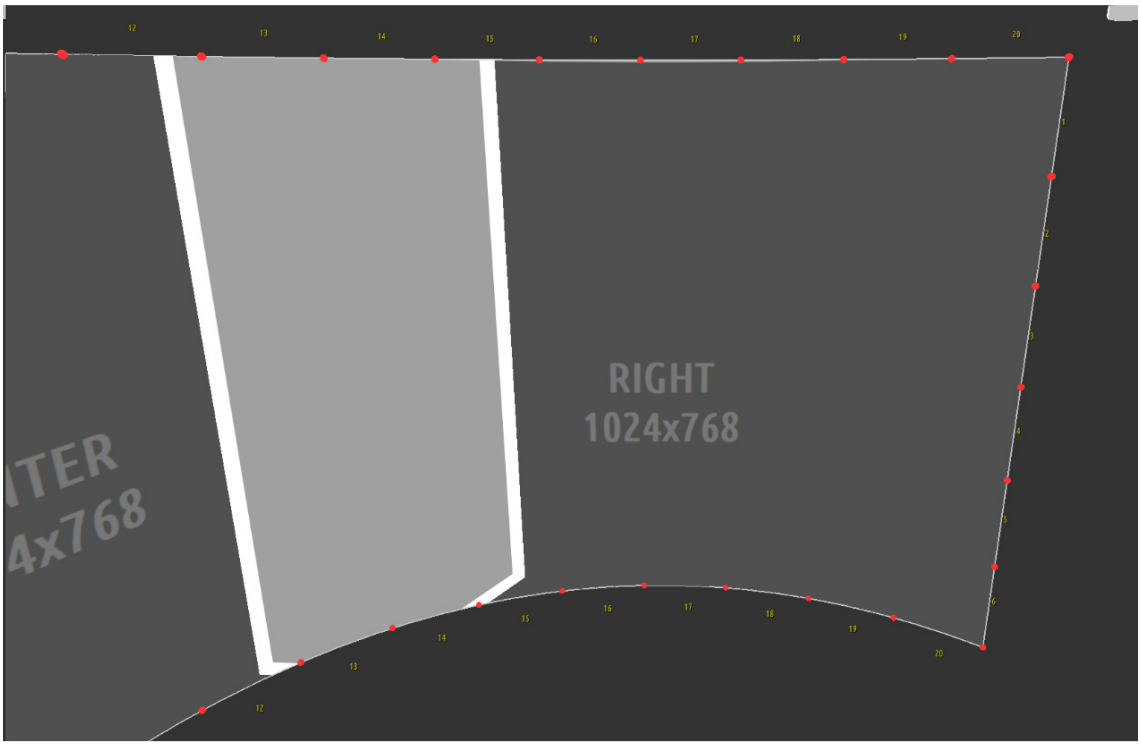
The cameras are positioned just below the projectors to capture part of the projection screen and the full projector image on the screen, as well as the overlap areas from the other projectors.



Camera 1



Camera2



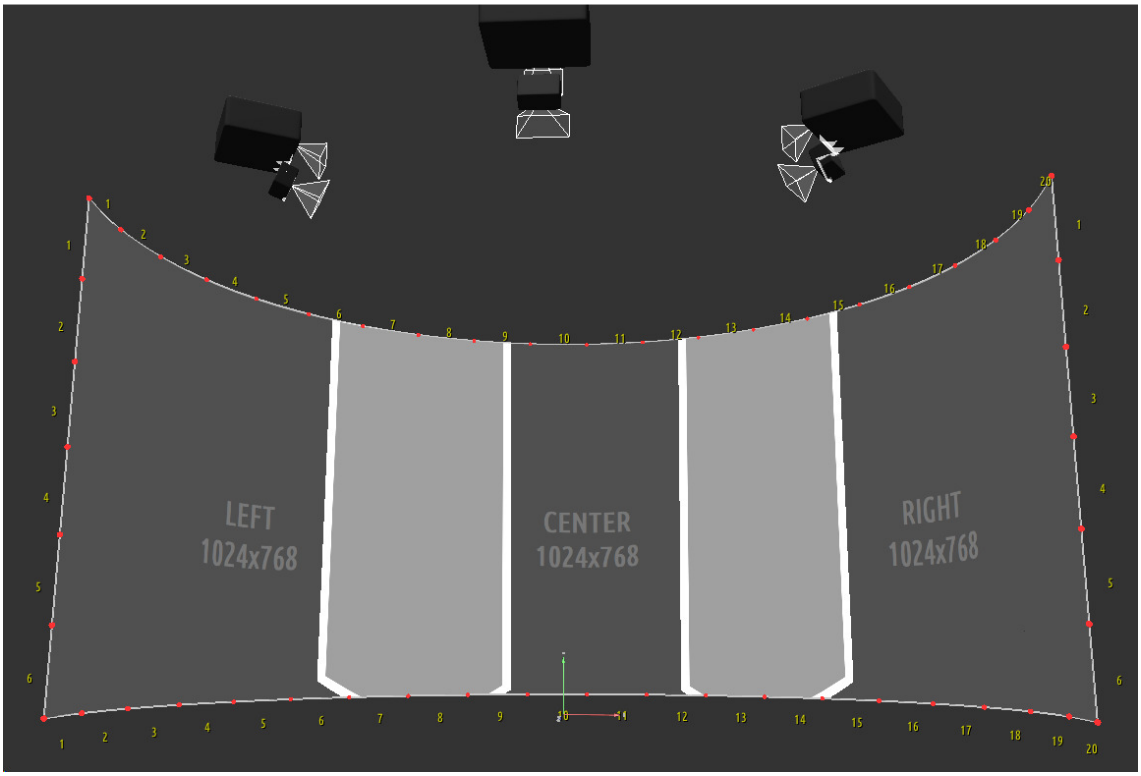
Camera3

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 6 rows and 20 columns. 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 cylindrical screens a number between 20 and 30 columns is enough.

For this screen dimensions we can calculate:
The height of a single row section is:
1.8 m/6 = 0.3m.

The length of a single column section (along the screen edge arc) is:
((200 deg/360 deg) * 2 * PI * 1.7m) / 20 = 0.296m



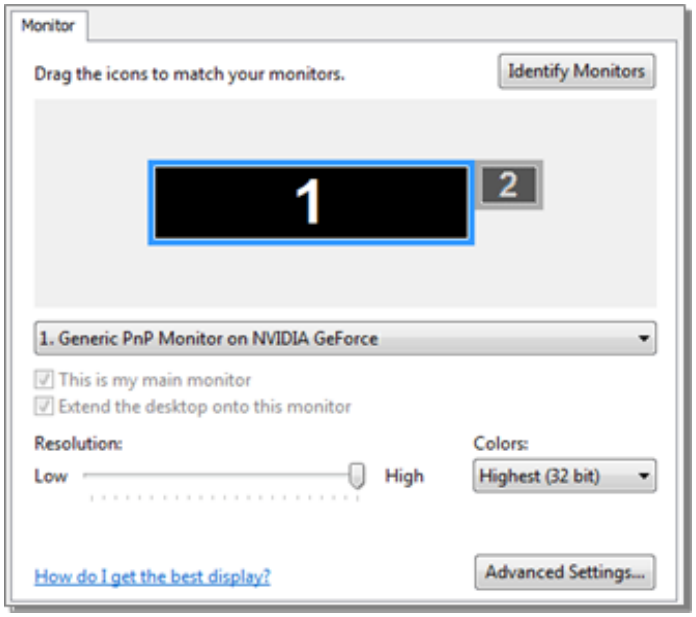
The columns sections are numbered from left to right starting from 1. Rows sections are numbered from top to bottom starting from 1. This numbering is important later when we define the views.

Note that the numbers on the image above are for illustrative purposes. Users

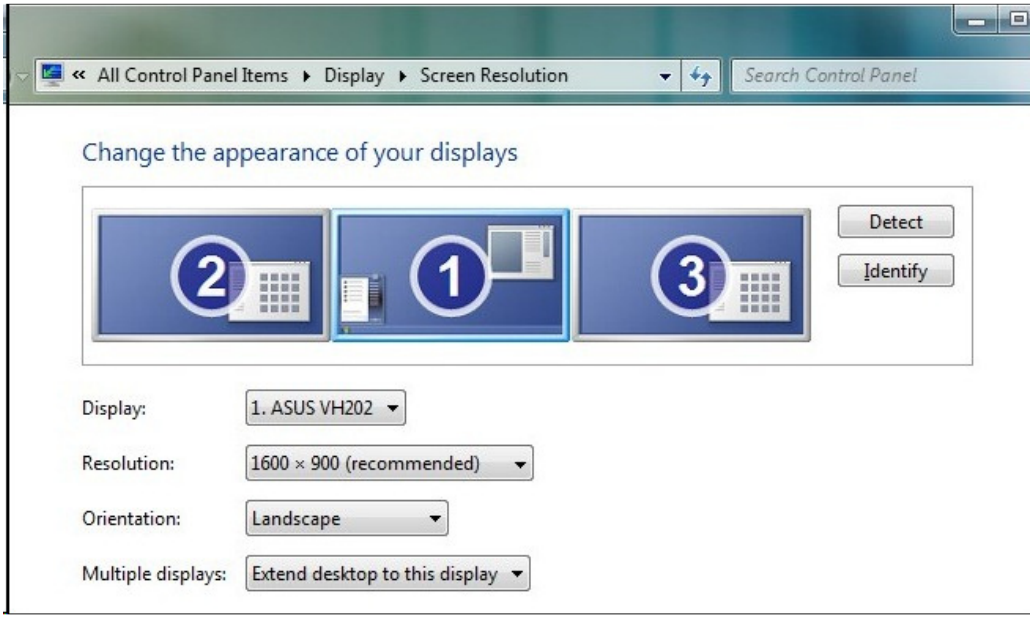
can use different methods to mark the rows and columns, including stickers or other temporary markers.

Measure the edges of the screen and put physical markers on the screen edges to mark the rows and columns. 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 3 outputs connected to the 3 projectors. The simplest configuration is to have one wide display (3x1) created either by using Matrox TripleHead 2 Go or ATI Display Group or NVidia SLI Surround. The graphical program (ex FSX, Prepar3D, X-Plane, etc) will run on this display.



Note: When using the latest version of P3D v3.3+ with ViewGroups.xml, make sure that the displays are not grouped as one single display. P3D v3.3+ with ViewGroups.xml require ungrouped displays in extended desktop mode.

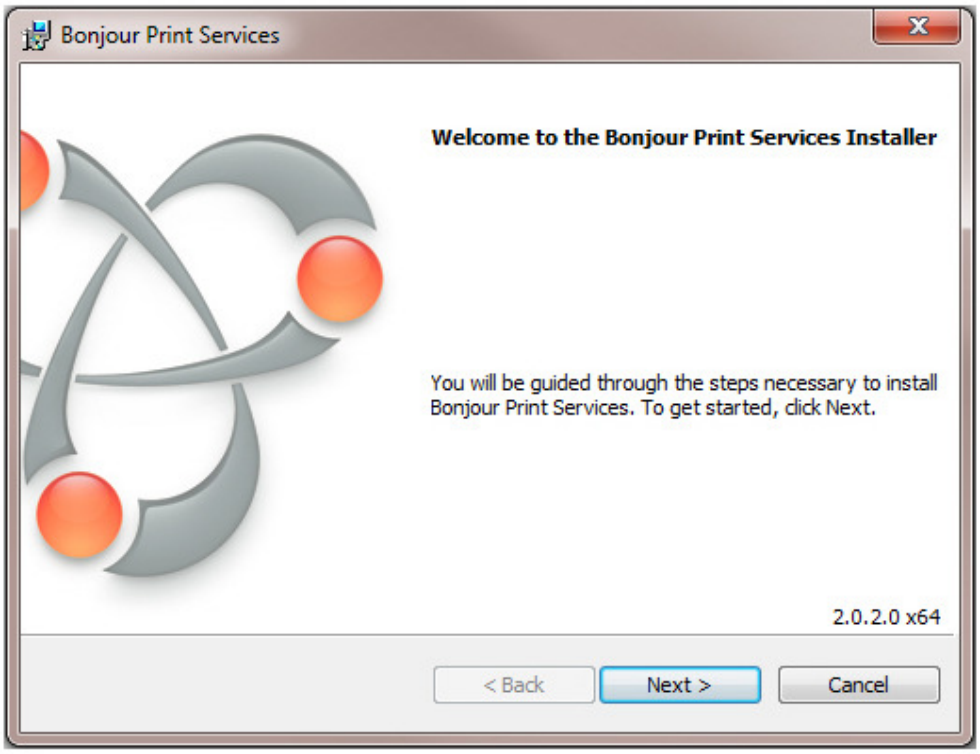


The name of this PC is **WIN7** and will be used as **Rendering Client** during the calibration.

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 WIN7 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

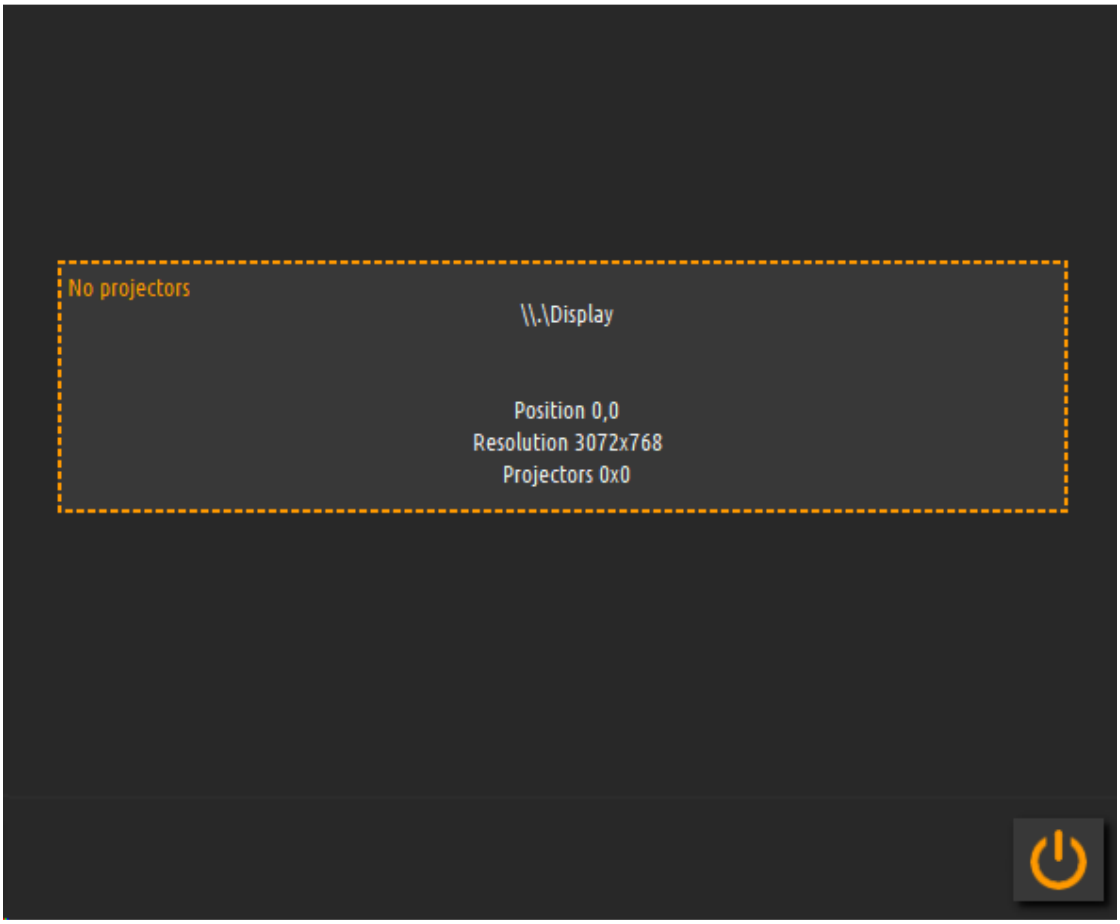
In order to automatically recognize and connect the client and the server PC on the network, a zero-configuration service is used. For this purpose the Bonjour service needs to be installed on both the client and the server PC.
From the Immersive Calibration PRO locate and double click on the INSTALL_FIRST_BONJOUR.bat 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.



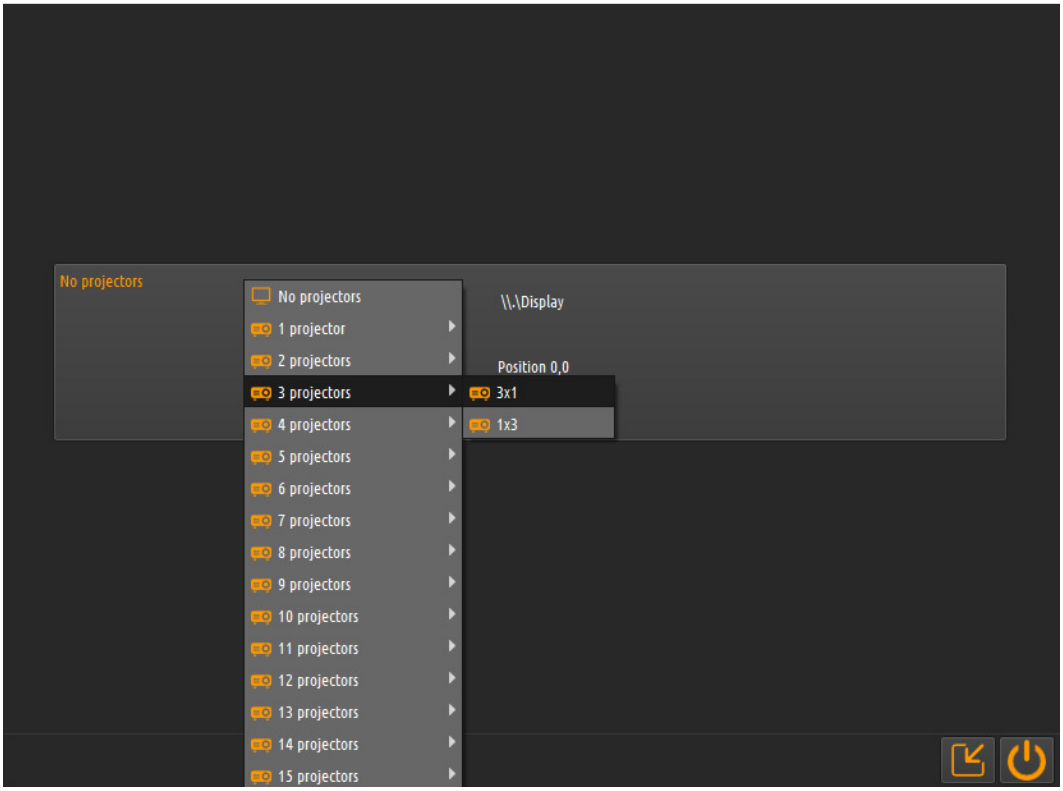
Note: If using firewall, make sure that the firewall is disabled on both the client and the server PC in order to allow the client and the server PC to connect to each other without being blocked by the firewall.

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 3x1 from the popup menu.



The selected display will be configured with projector configuration 3x1 and the rendering client will be prepared to be connected to the server.

Note: When using the latest version of P3D v3.3+ with ViewGroups.xml, there will be 3 separate displays available. Right-click on each display and select projector configuration 1x1 from the popup menu.

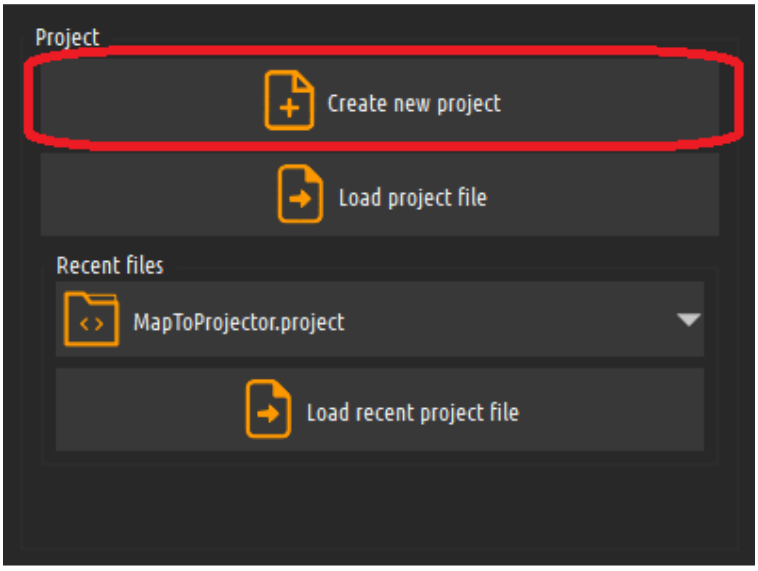
A tray icon will be shown on the system tray to indicate that the client is running.

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 the 3x1 display.

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

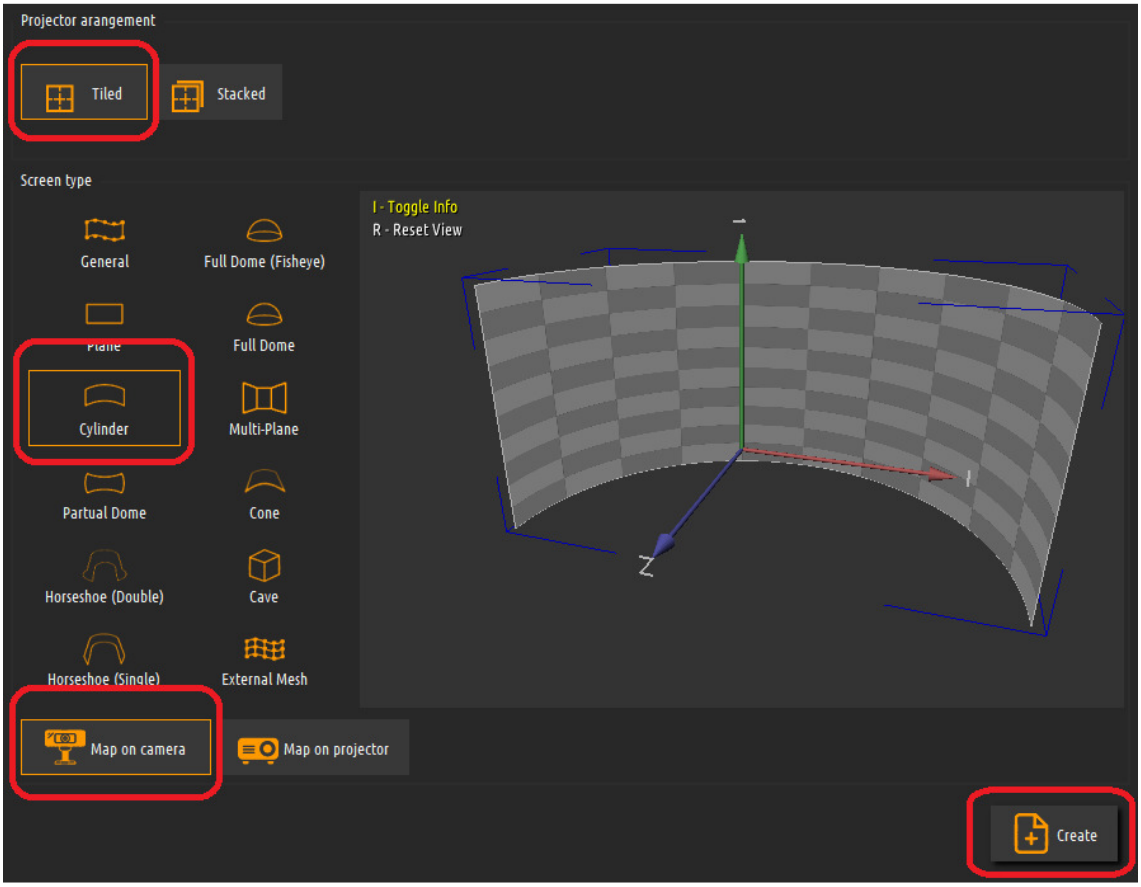
4 Start and configure the Controlling Server

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



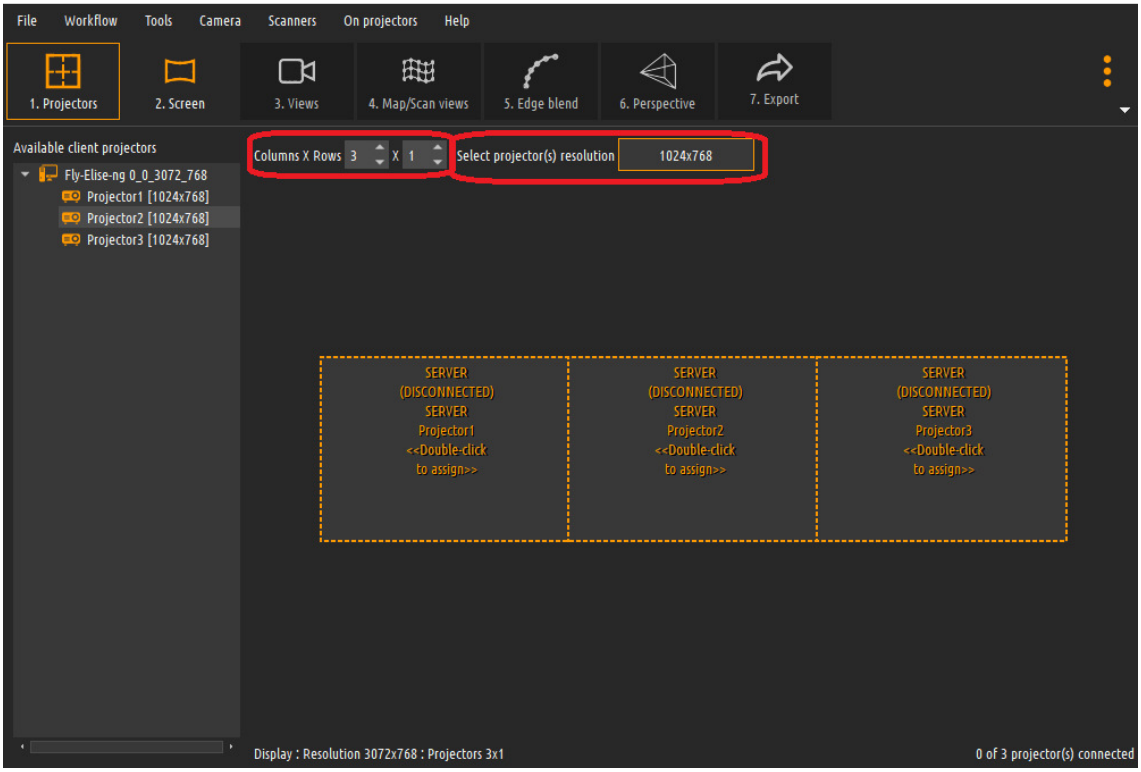
When starting for the first time, select “Create new project”. Once the project is saved, the project can be loaded by selecting “Load project file.

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.

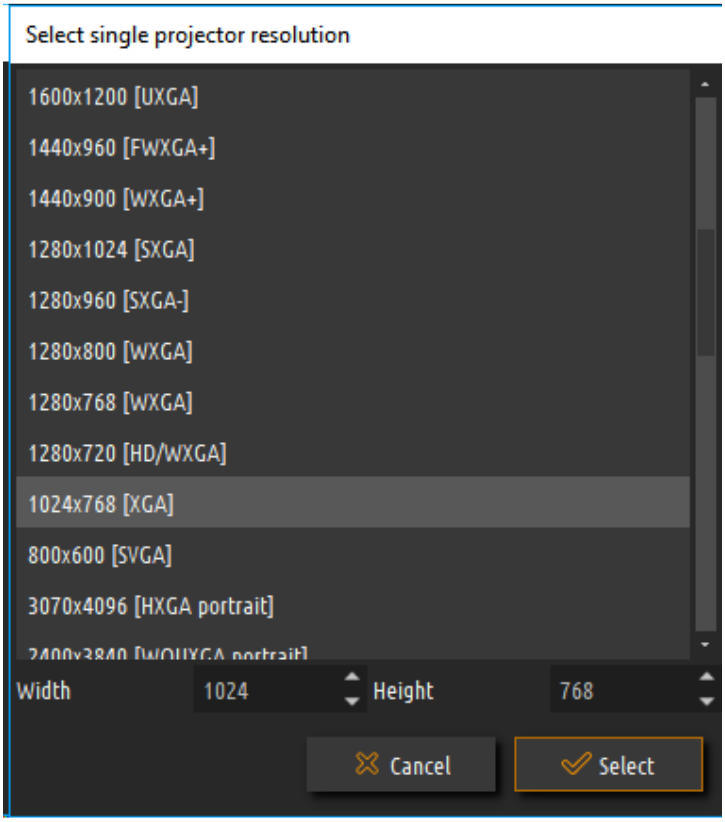


We will enter the size and the divisions of the projection screen later.

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



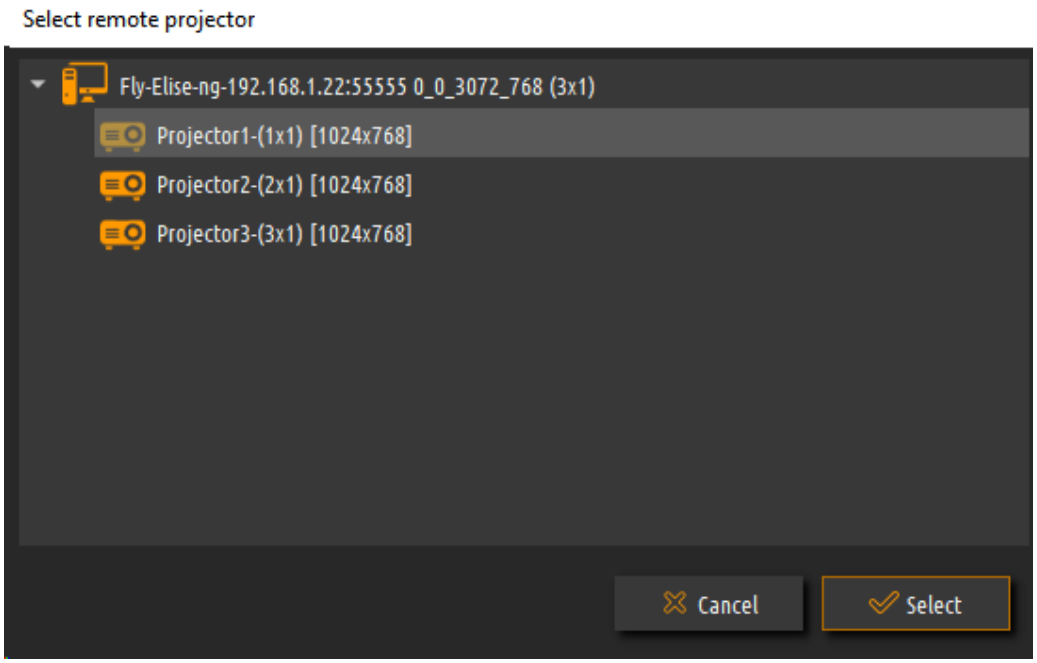
The virtual display is initially not configured. Set the projector configuration to 3x1 and select the individual projector resolution.



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 3x1. 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.

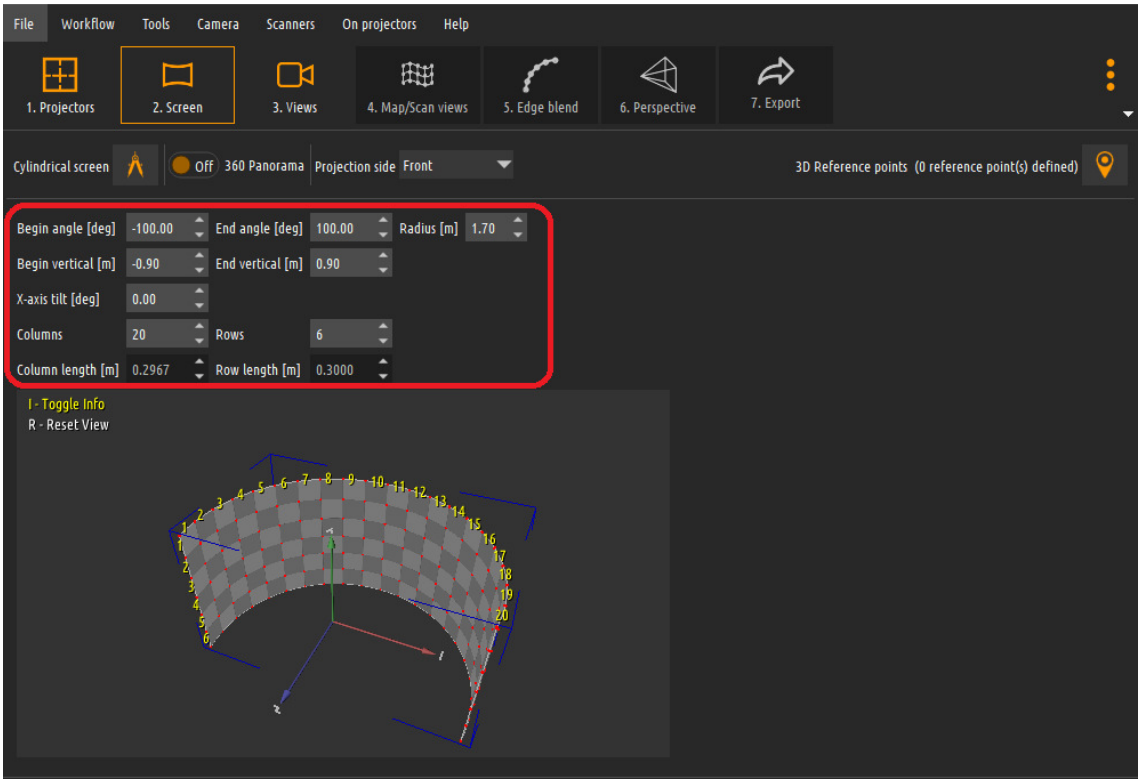


Repeat this step for all projectors. When all projectors are assigned click the "Screen" button to configure the screen.

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 200 deg, height of 1.8 m and radius of 1.7 m. As the reference point is in the middle of the screen, and the height axis points to up, we enter the values -100 deg as begin angle and 100 deg as end angle. Similarly, for the height we enter -0.9 m as vertical begin and 0.9 m as vertical end. The radius is 1.7 m.
Because we divided the screen in 20 columns and 6 rows, we enter the Columns and Rows values respectively 20 and 6.
After that click on the “Views” button to configure the Views.

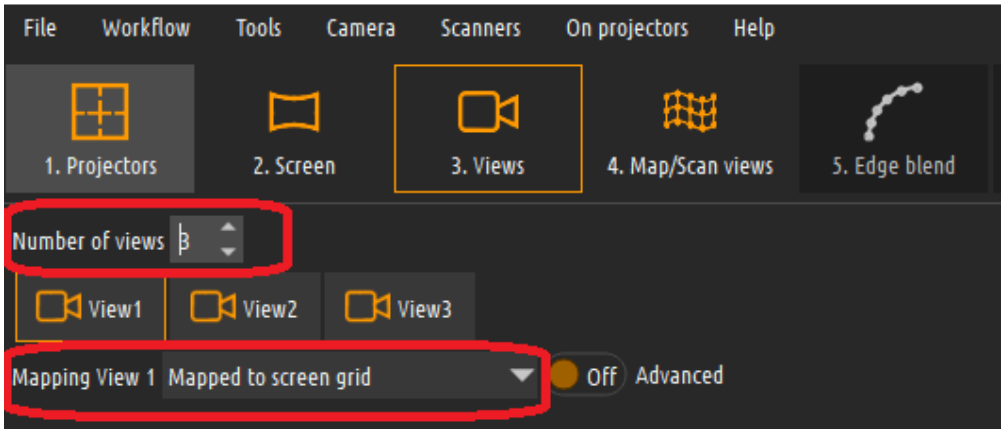
6 Views settings

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.

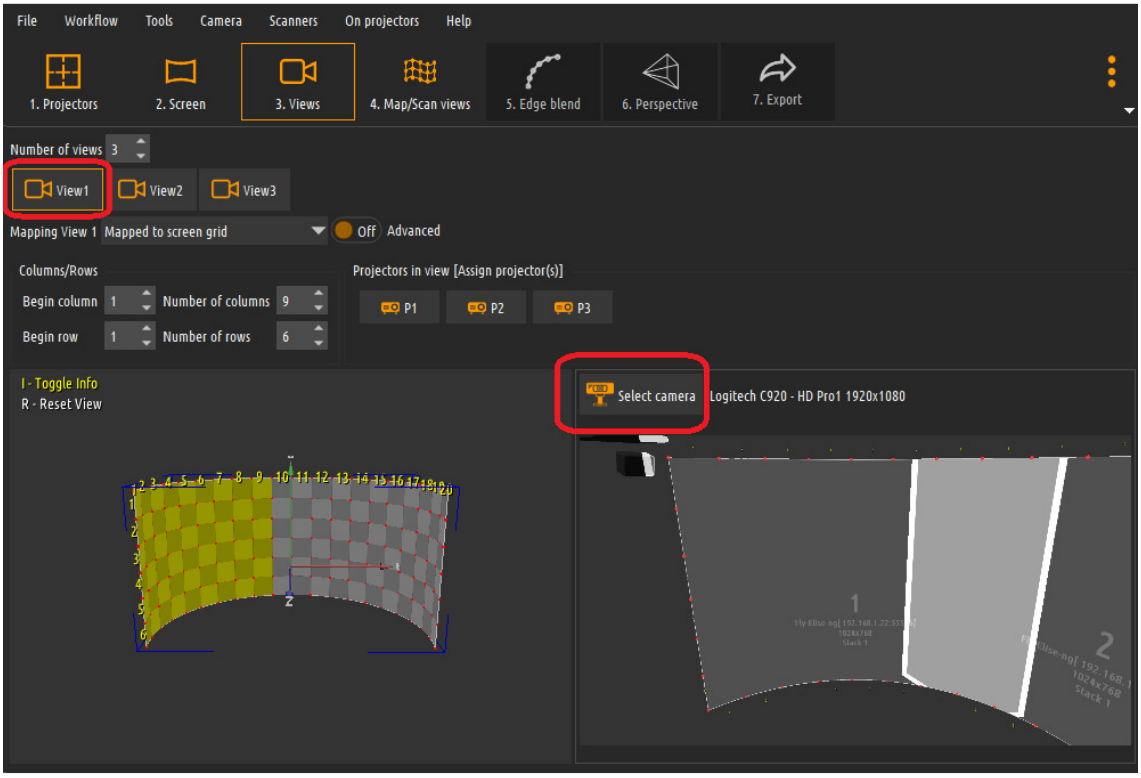
For a successful calibration it is very important that we enter the correct values in the Views page. Automatic calibration will use those to automatically calculate the warping, blending and the frustums info.

Because we use either 3 cameras, we will specify that we have 3 views.



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

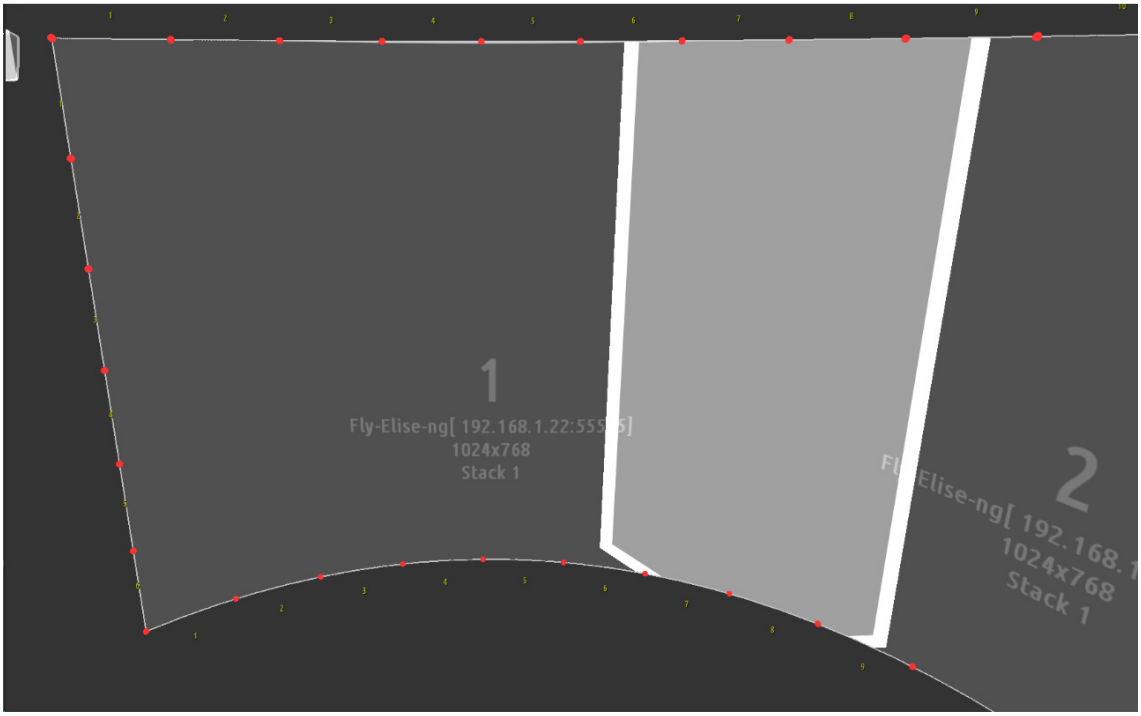
Now, for each view, click the View button (View1, View2 and View3) and select the corresponding camera for that view.



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.

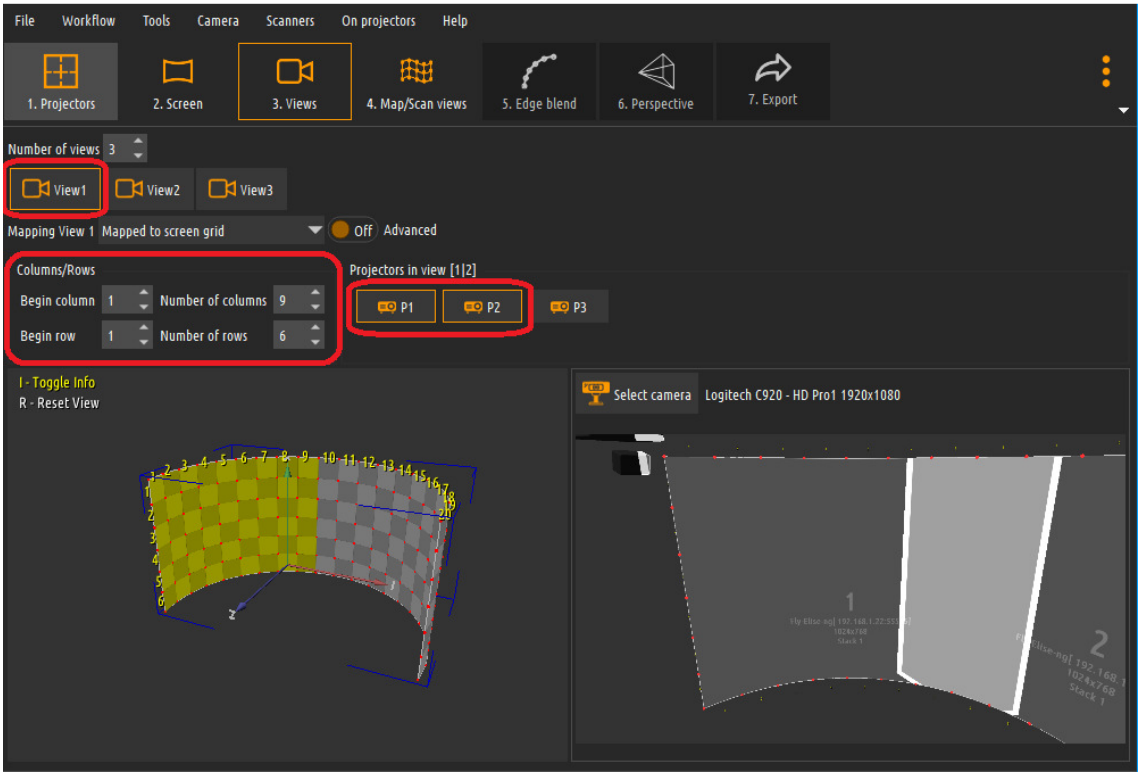
Note: The red markers on the images below represent the visible o invisible markers put on the screen.

View1



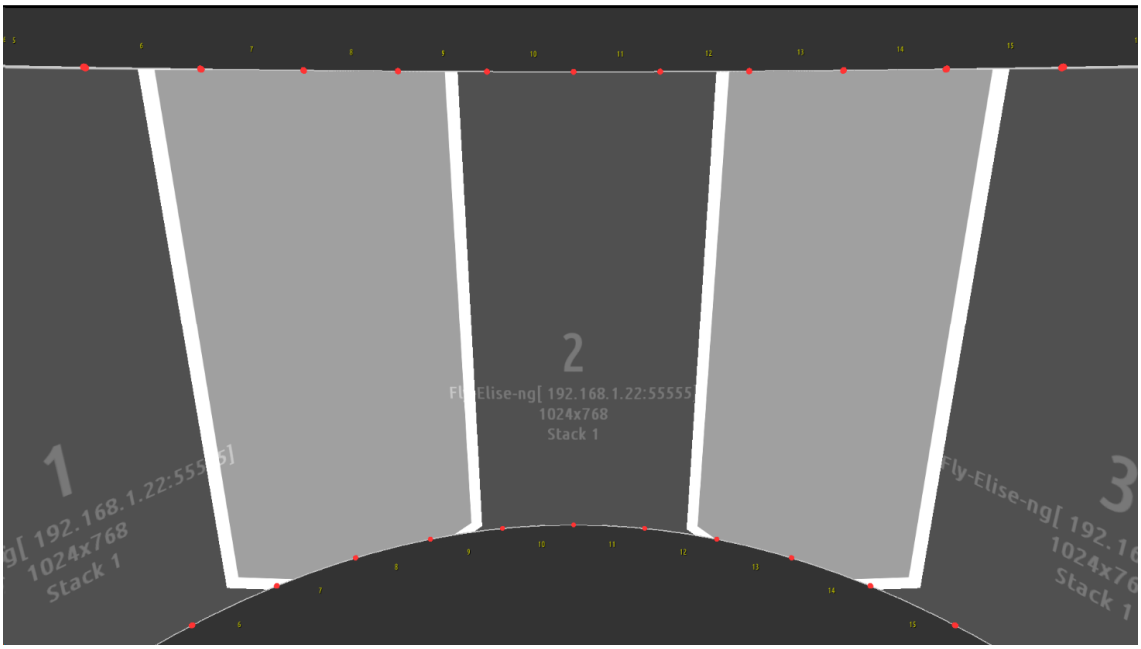
Looking at the camera image we can see that the camera covers row 1 and covers all 6 rows (1, 2, 3, 4, 5 and 6). The camera image captures 9 columns starting from 1 (1, 2, 3, 4, 5, 6, 7, 8 and 9).
So we enter the values for View1 accordingly: Begin column 1, Number of columns 10, Begin row 1 and Number of rows 6.

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

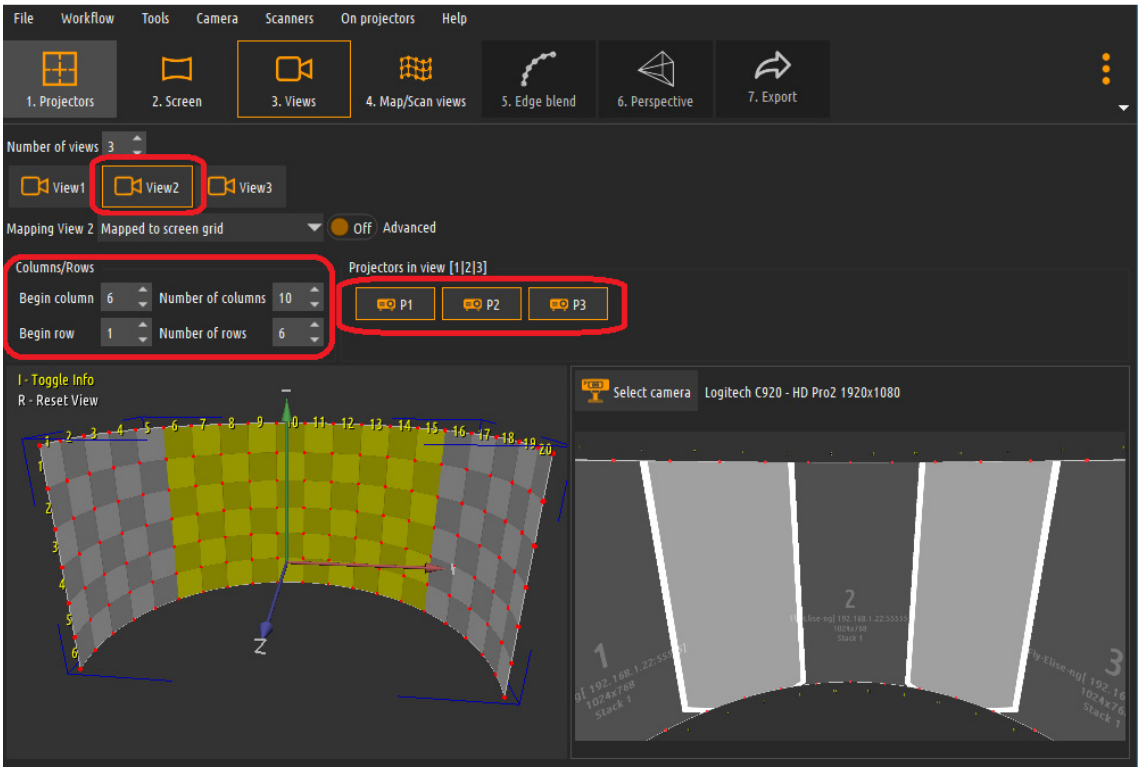


View2

Select View2 and select the camera 2.

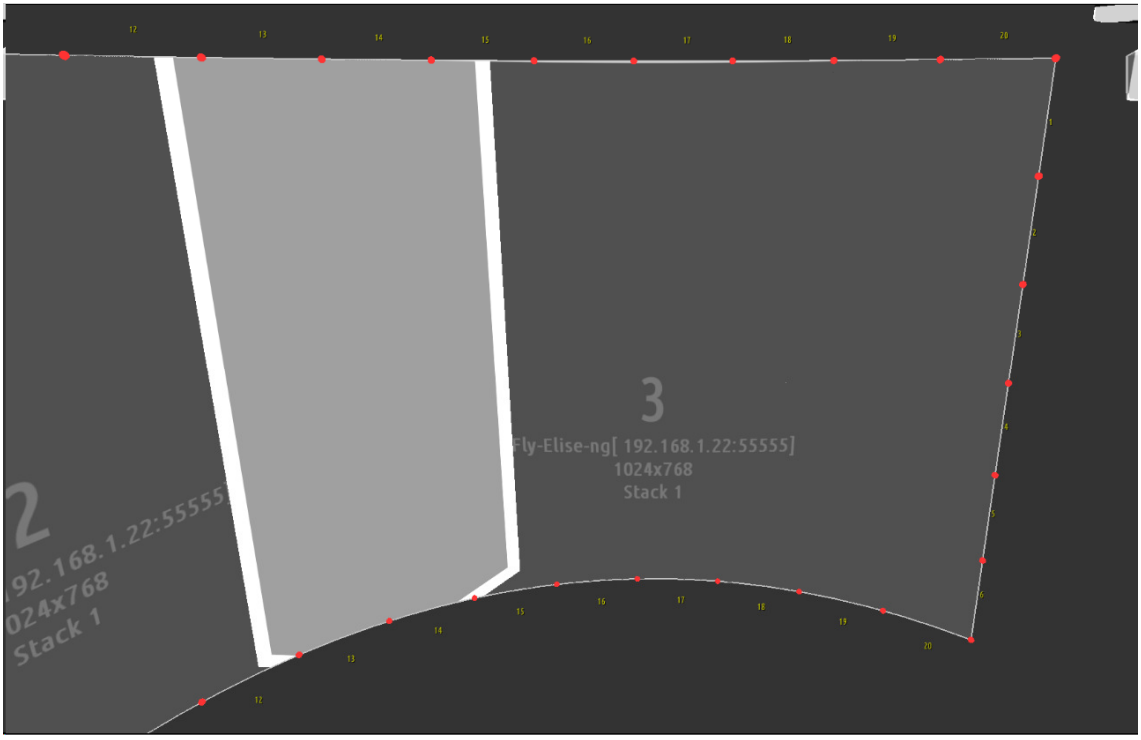


Looking at the camera image we can see that the image covers row 1 and covers all 6 rows (1, 2, 3, 4, 5 and 6). The camera image captures 10 columns starting from 6 (6, 7, 8, 9, 10, 11, 12, 13, 14 and 15).
So we enter the values for View2 accordingly: Begin column 6, Number of columns 10, Begin row 1 and Number of rows 6.
In this camera view Projector2 is fully visible and Projector1 and Projector3 are partially visible.
So we make sure that Projector1, Projector2 and Projector3 are selected.



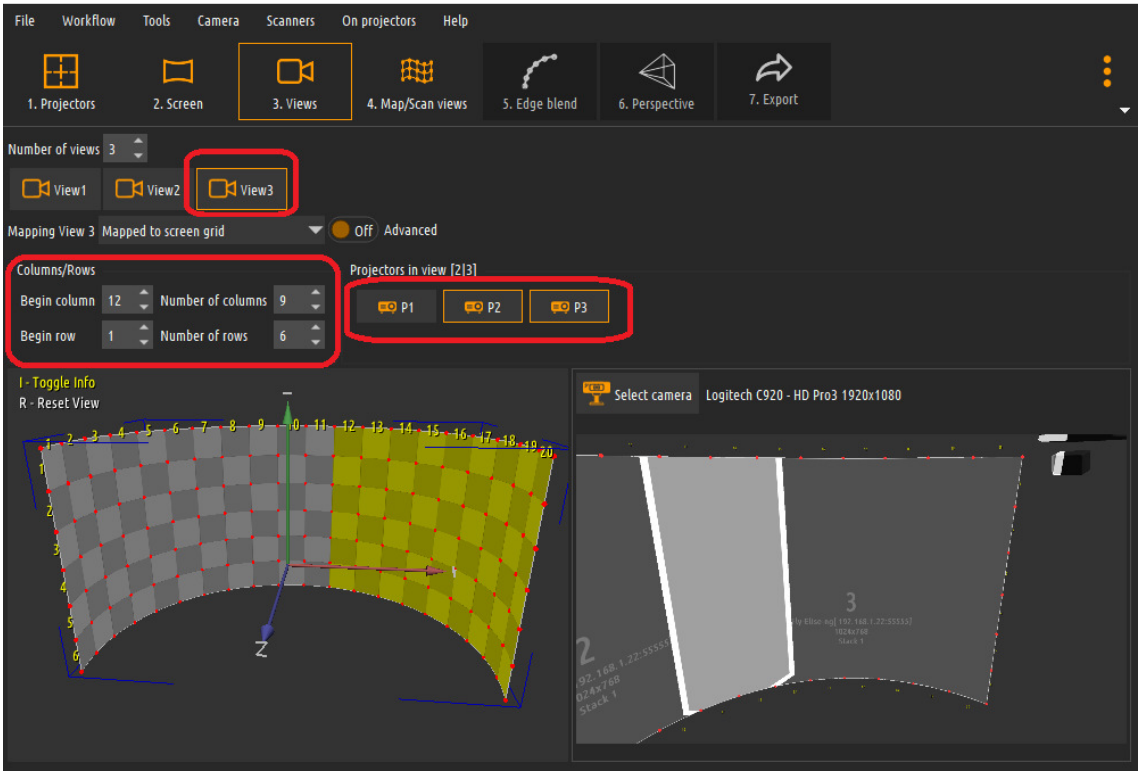
View3

Select View3 and select camera3 for this view.



Looking at the camera image we can see that the image covers row 1 and covers all 6 rows (1, 2, 3, 4, 5 and 6). The camera image captures 9 columns starting from 12 (12, 13, 14, 15, 16, 17, 18, 19 and 20).
So we enter the values for View3 accordingly: Begin column 12, Number of columns 9, Begin row 1 and Number of rows 6.

In this camera view Projector2 is partially visible and Projector3 is fully visible. So we make sure that Projector1 and Projector3 are selected.



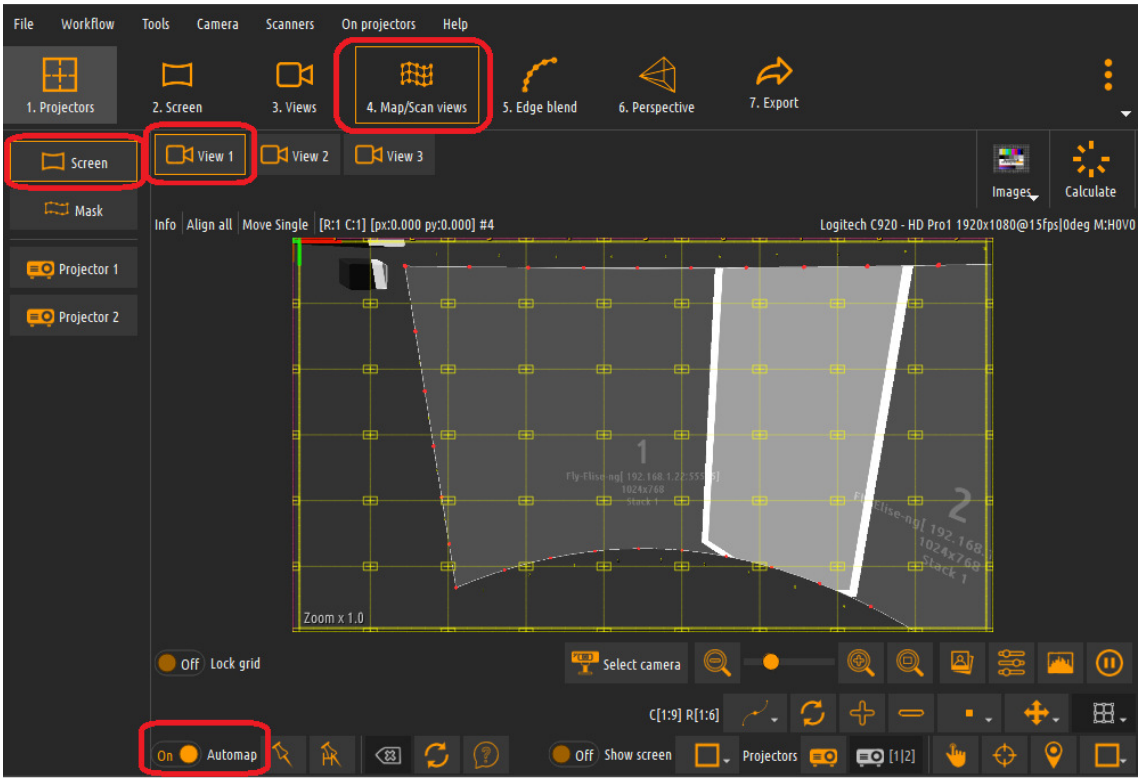
This finishes the configuration of the calibration settings. The next steps will describe the mapping of the screen in the camera views.

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.

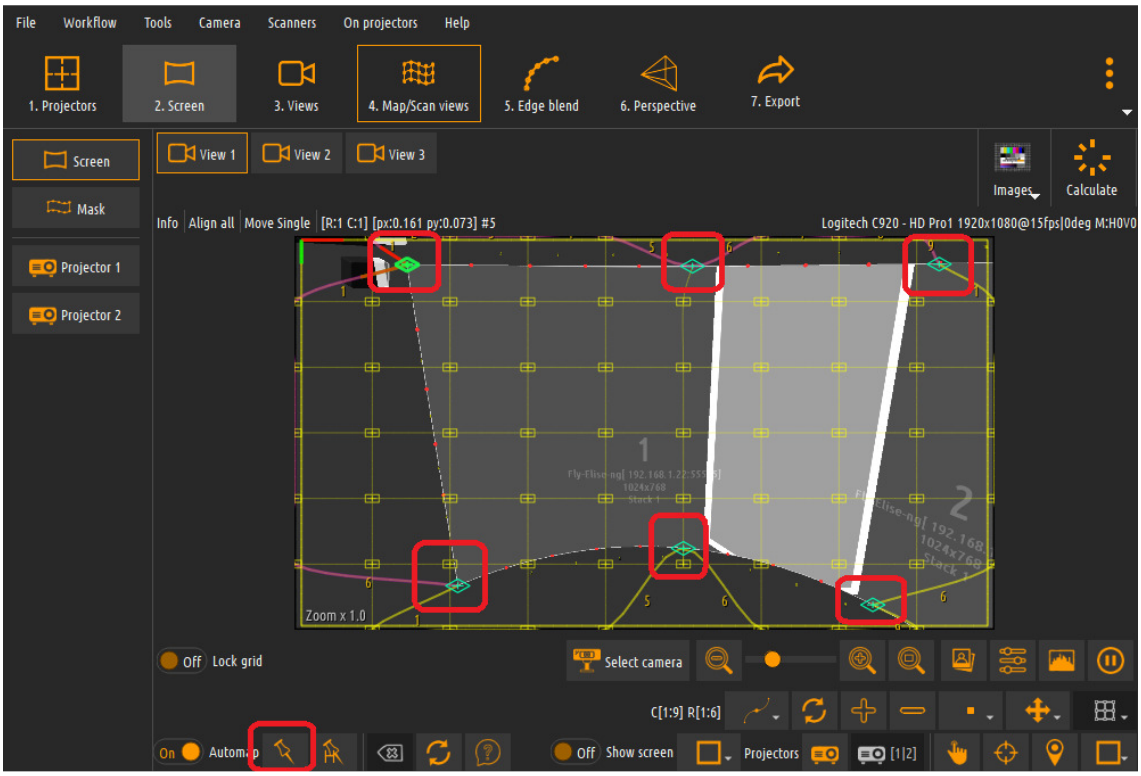
Repeat the steps in this section for each camera view.
For each camera view, part of the projection screen and the projectors visible in that view will be mapped and scanned.



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.

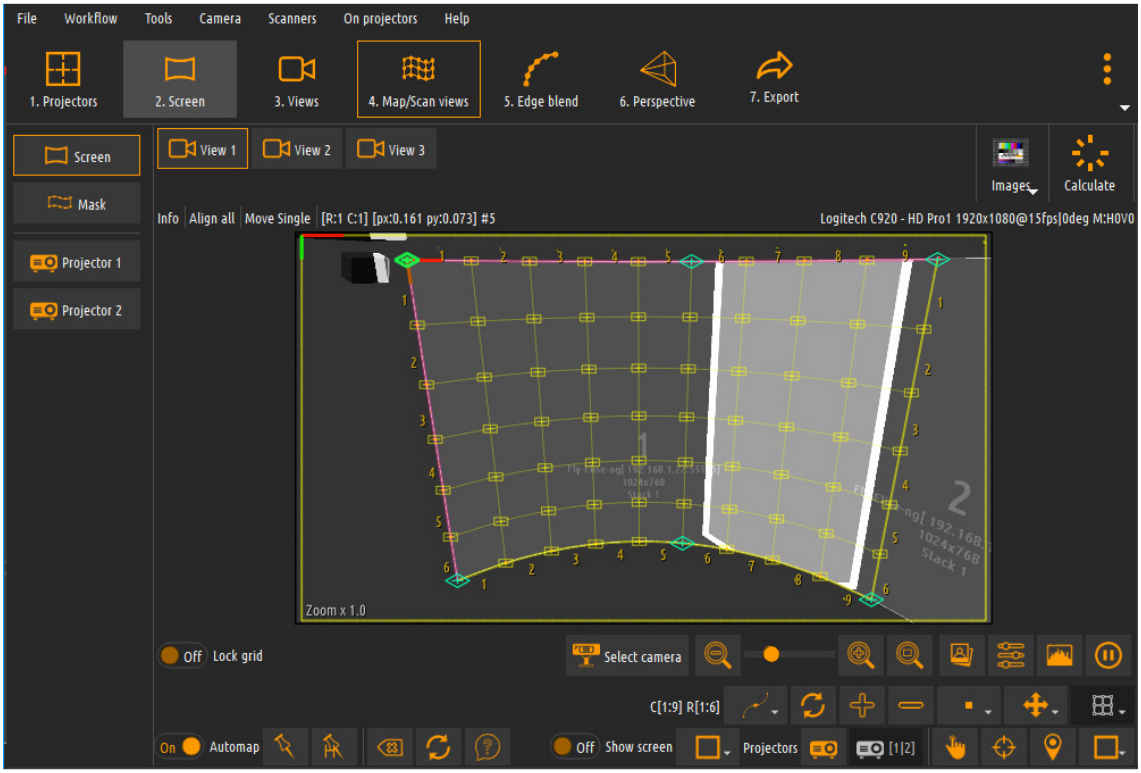
Enable the “Automap” check box on the left corner and move the corresponding grid control points to the marked points on the screen.

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.



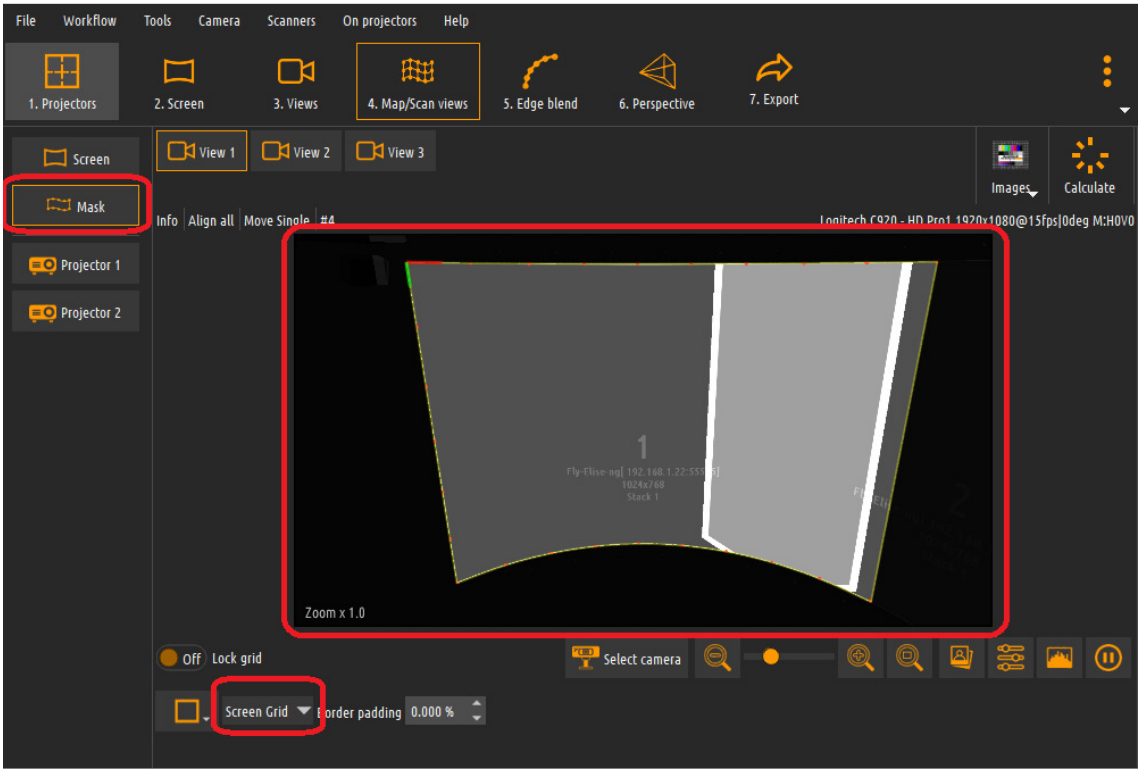
At least 6 points are required to do the auto mapping. However, if more points are used the mapping can be more accurate.
Use the Right mouse button to drag the point with subpixel resolution. Set the points on the screen markers as accurately as possible.

Now press the “Auto map screen 3D” button, to map the rest of the screen grid to the screen automatically.



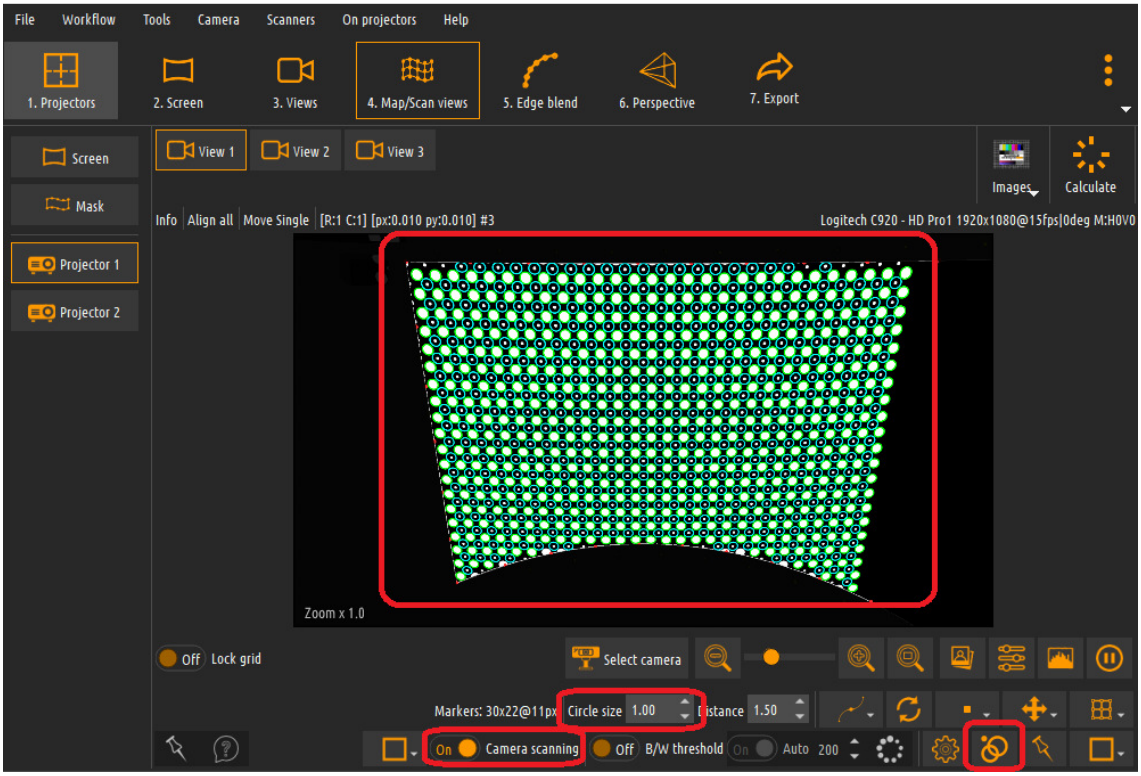
After the screen grid is mapped to the screen, we will proceed with the projectors scanning in this camera view.

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.

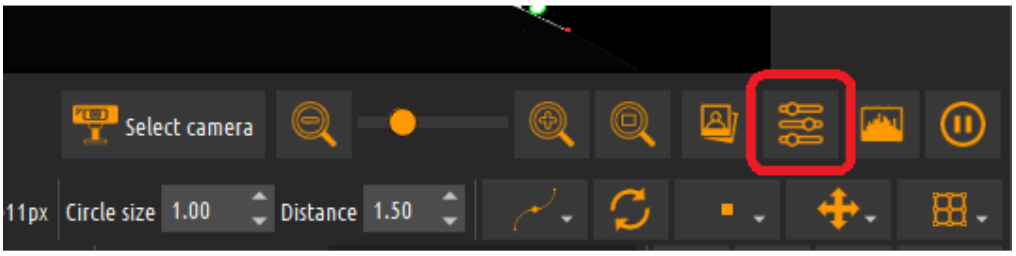
Select the first projector from the list of projectors in this view.
Make sure the “Camera scanning is enabled” and press on “Recognize projector circles” button.
Press the “Recognize projectors circles” button will quickly verify which circles can be successfully recognized and mapped. The recognized 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.

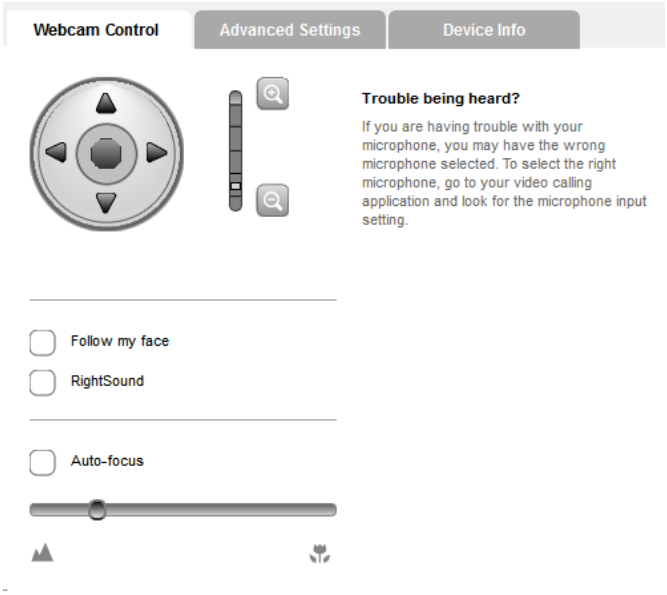


Note: The camera has to be fixes and should not be moved during the rest of the calibration.

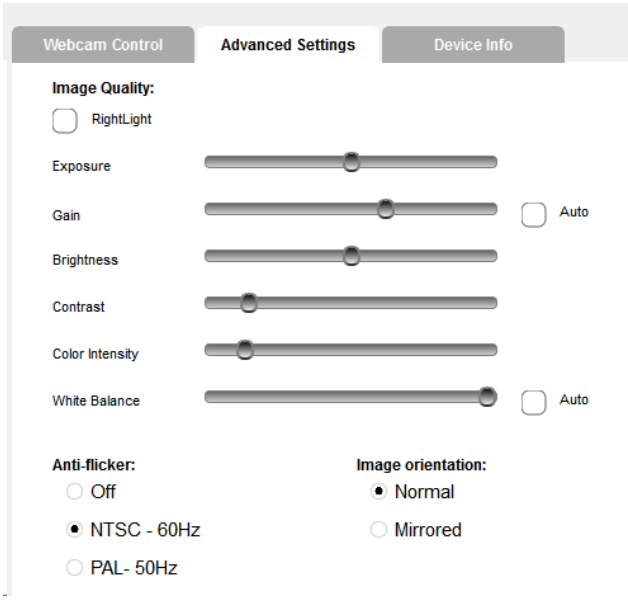
For successful calibration it is important that all automatic camera features (auto-focus, auto-zoom, white balance, etc.) have to be turned off.

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.



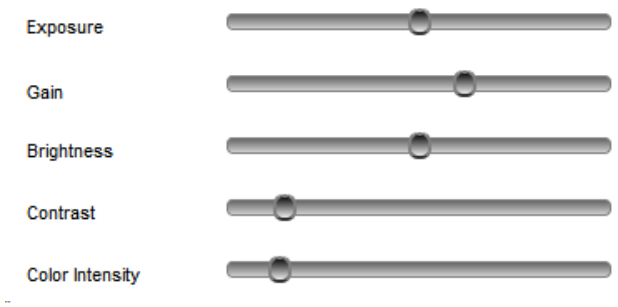


No Auto focus



No Auto Gain and Auto White Balance

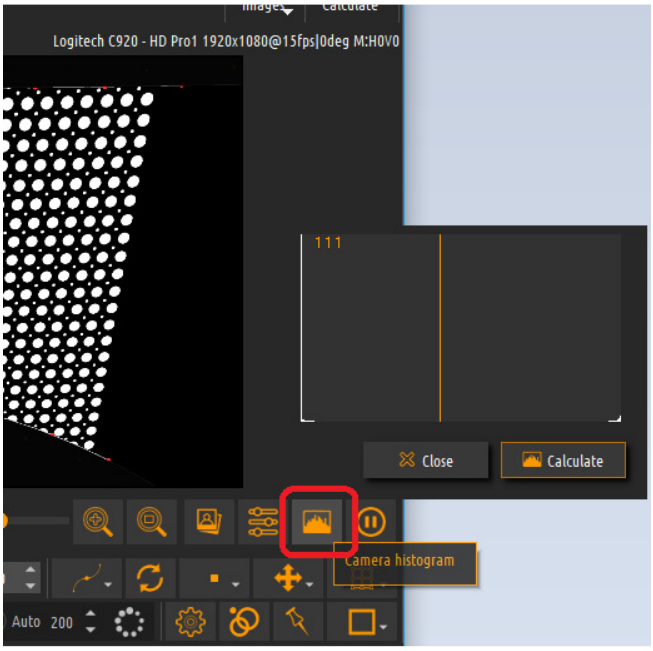
Use the camera controls to adjust the camera image for the best projector scanning and calibration results.



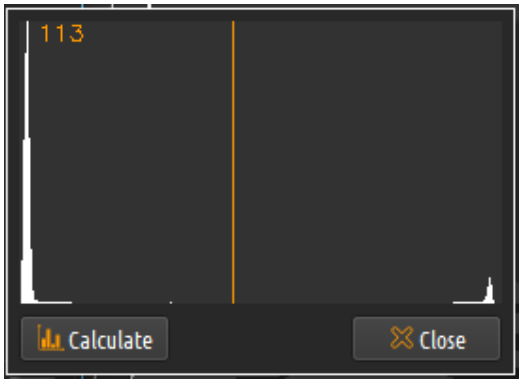
The primary control of the camera image is the “Exposure” control. Use the Exposure to get the most natural looking camera image.
The camera image should look natural and should not be too dark, too bright or saturated. The black and darker colors and the white and brighter colors should utilize the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

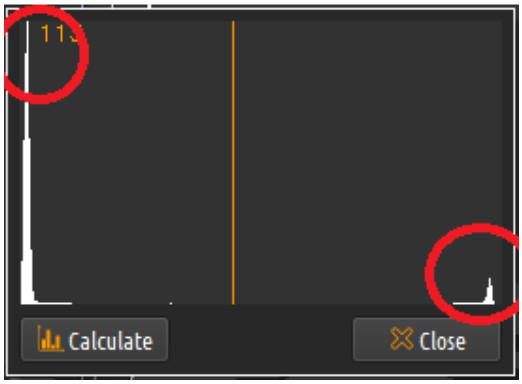
Select the Histogram button and press on the calculate button.



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.



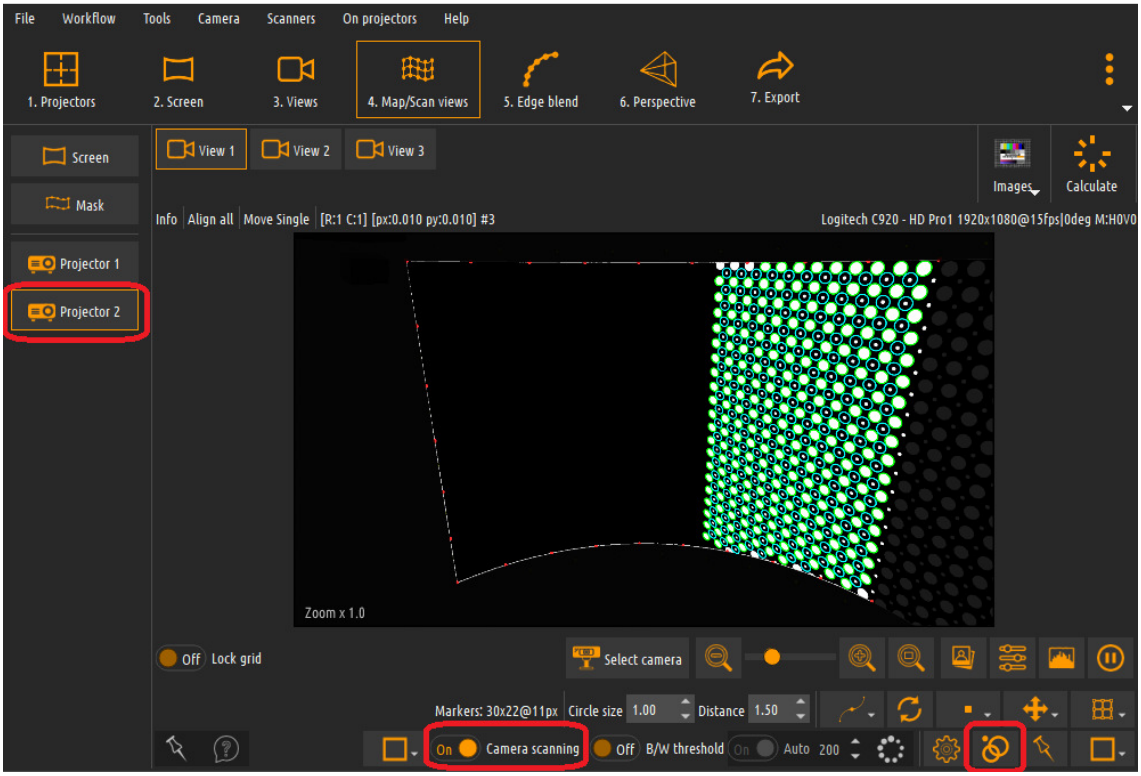
The camera histogram shows two peeks. The left peek is for the dark colors and the right peek is for the bright colors.



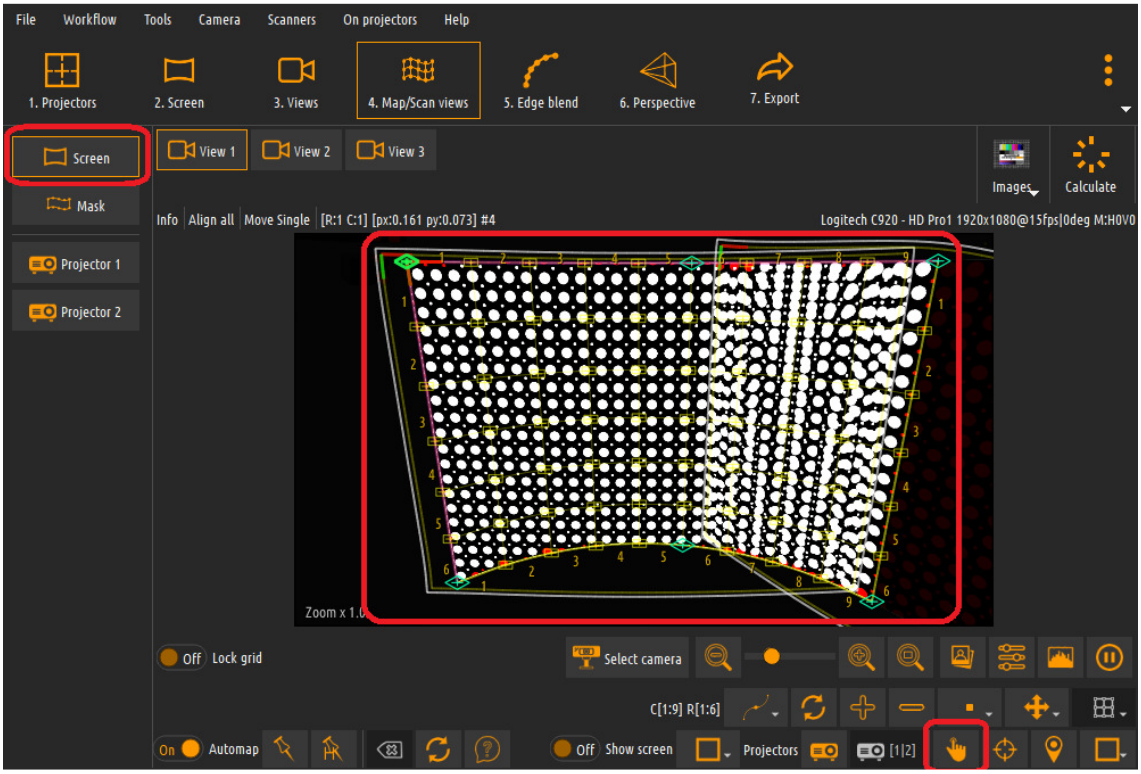
Camera histogram peeks

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.



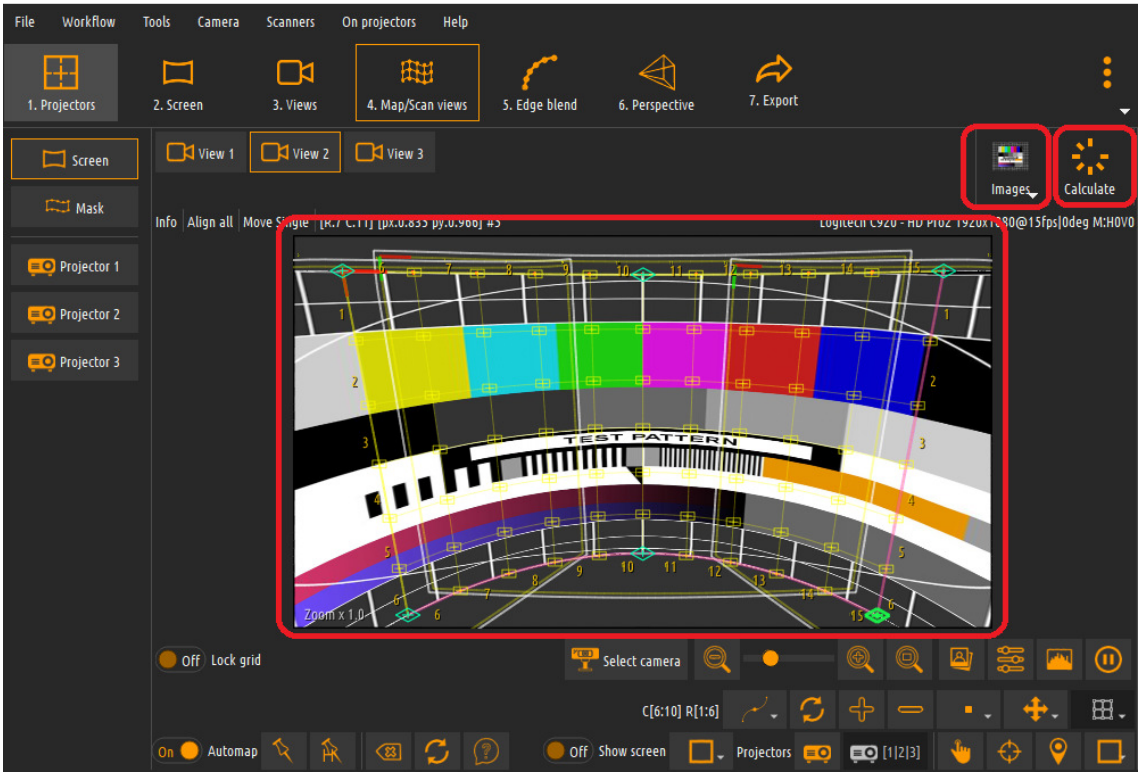
Once the pre scanning is completed and verified, we can proceed with completely scanning all projectors in the camera view.
Click on the screen button and click on “Scan projectors in view” button. This will scan all the projector in this view.



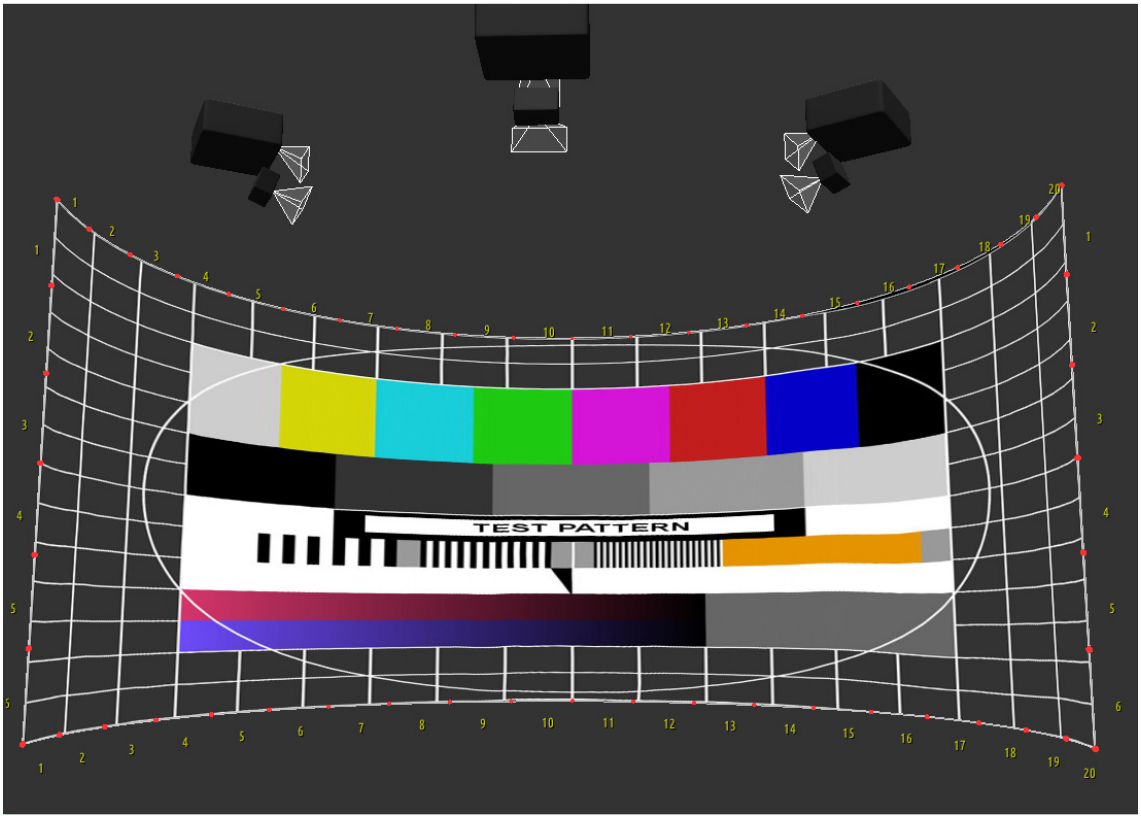
After the scan is completed, the projectors will show the recognized while circles on the screen for this view.

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

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.

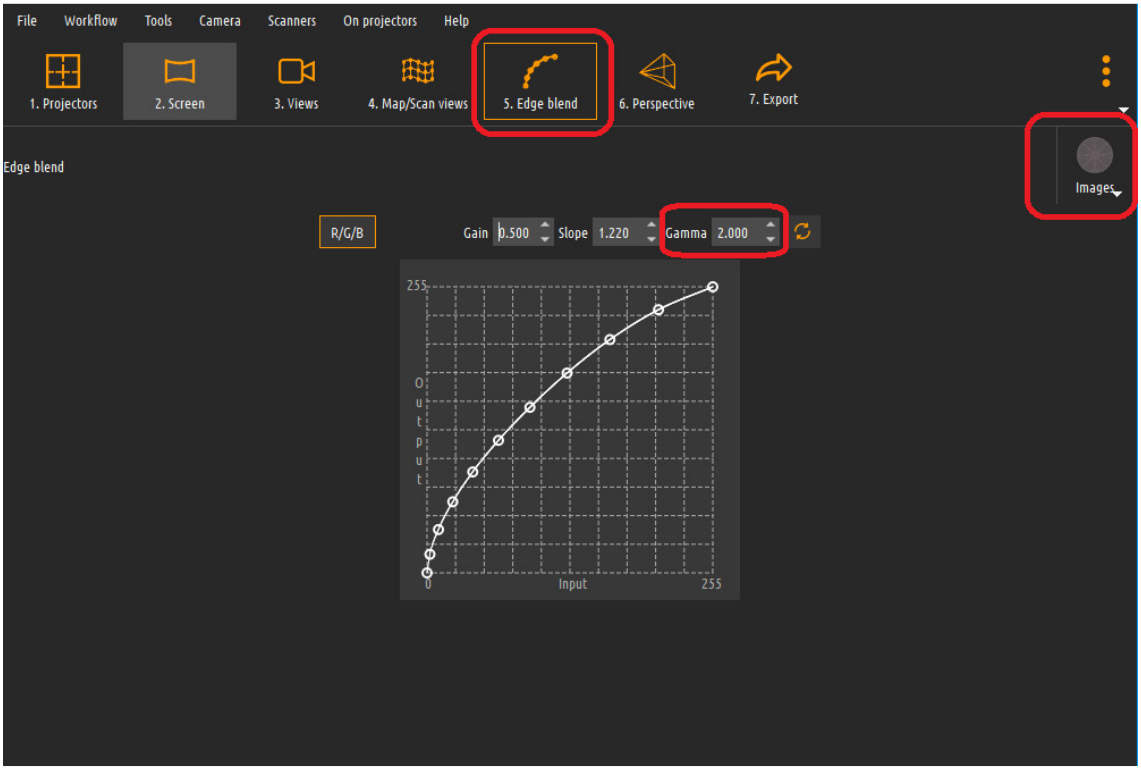


After calibration finished, the geometrical correction and the soft-edge blending will be calculated and send to the Rendering Client PC. A test image will be projected on the screen from multiple projectors.
Optionally, change the images to preview the alignment.



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.

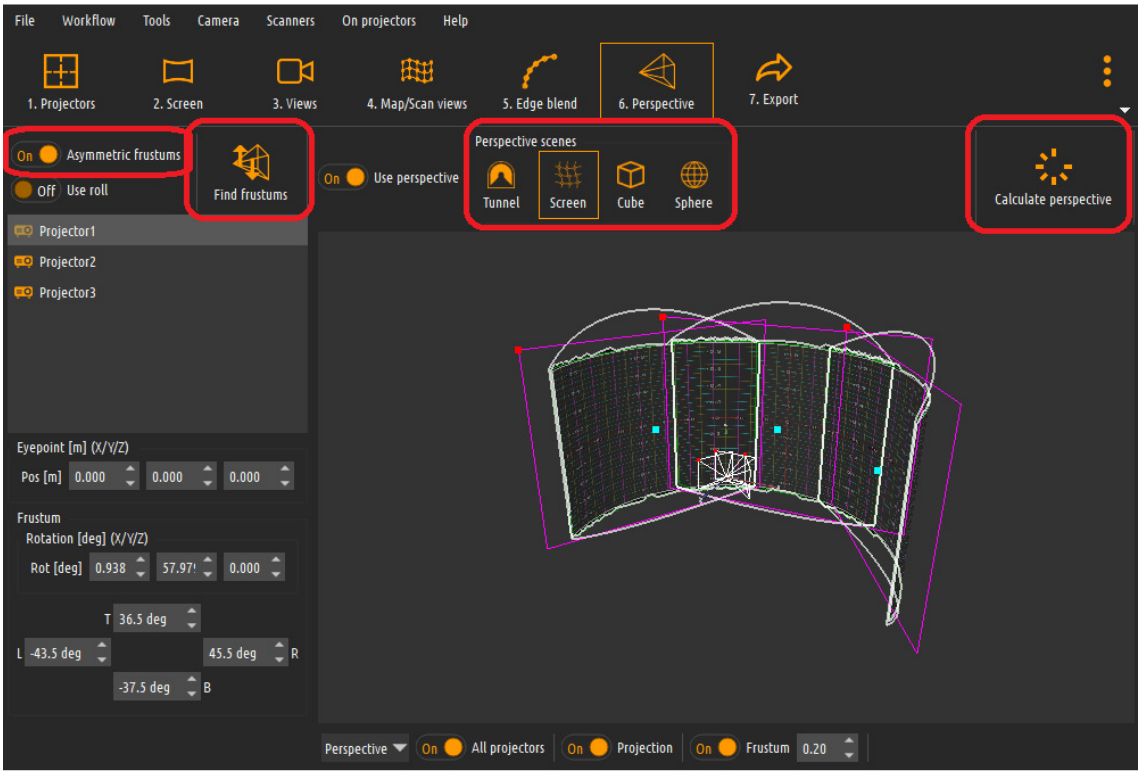


When the result is satisfactory Save the selected settings in a ".project" file using the File/Save menu.

9 Perspective projection

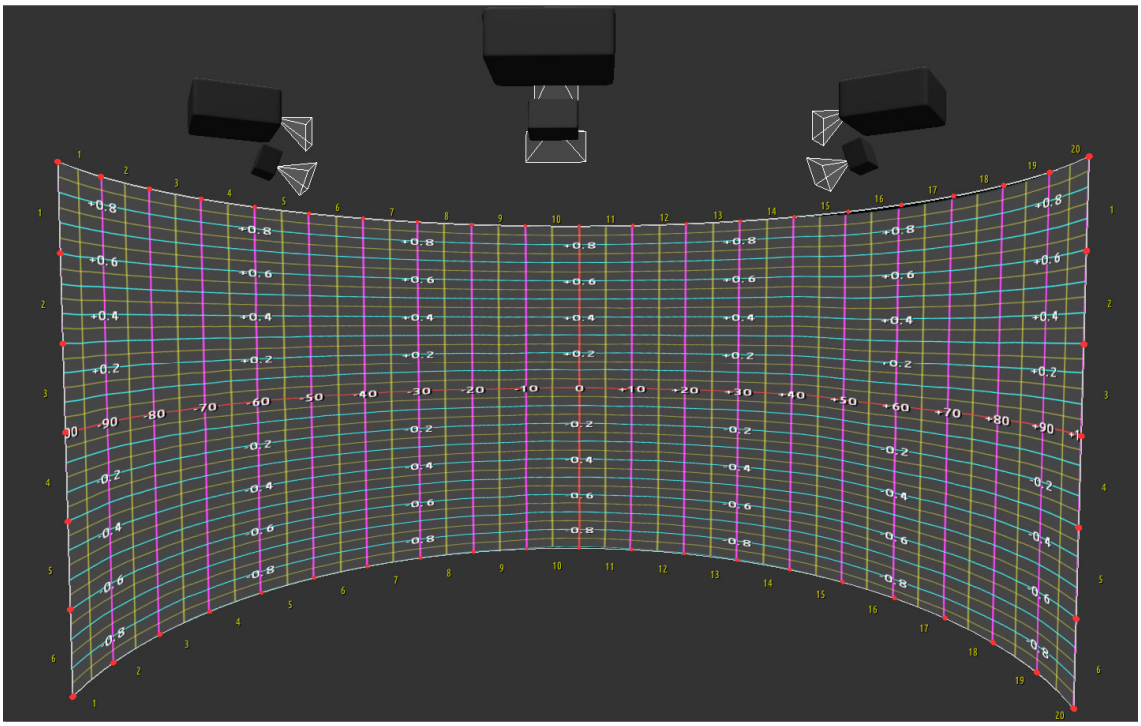
When projecting the content of a 3D application (Games, Simulators, CAD, etc.) that have support for multiple cameras, each projector can project image from a single virtual camera. The total projected image will not be constrained by a single camera field of view but it will match the projection screen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



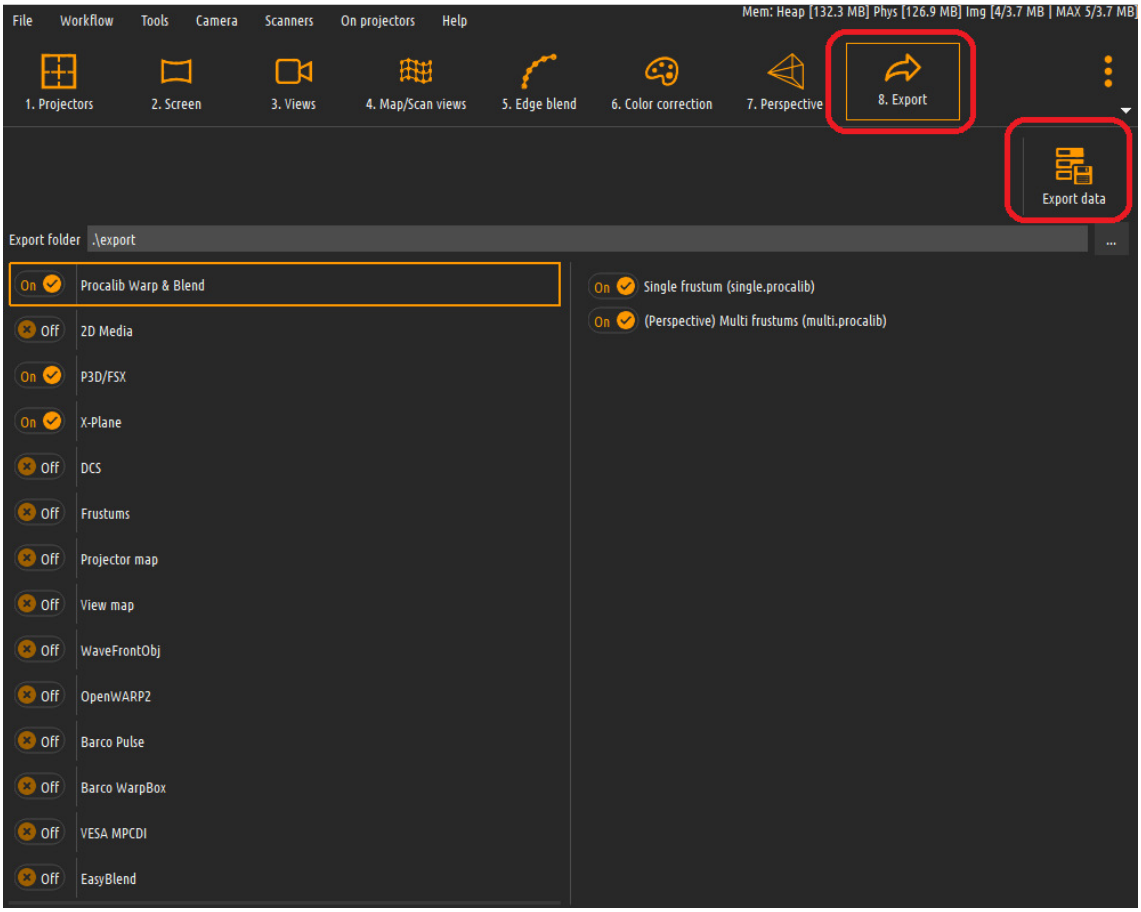
Note: When using the latest version of P3D v3.3+ with ViewGroups.xml, the asymmetric frustums option can be used to calculate the frustums to fit optimally and to maximize the pixel usage.
Most of the game engines do not support asymmetric frustums so make sure the symmetric frustum option is enabled.

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.



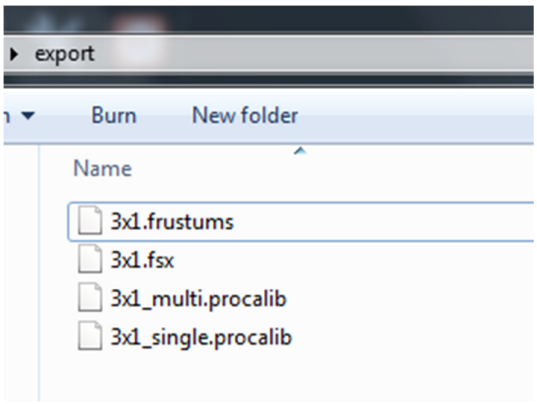
10 Export the calibration result

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.

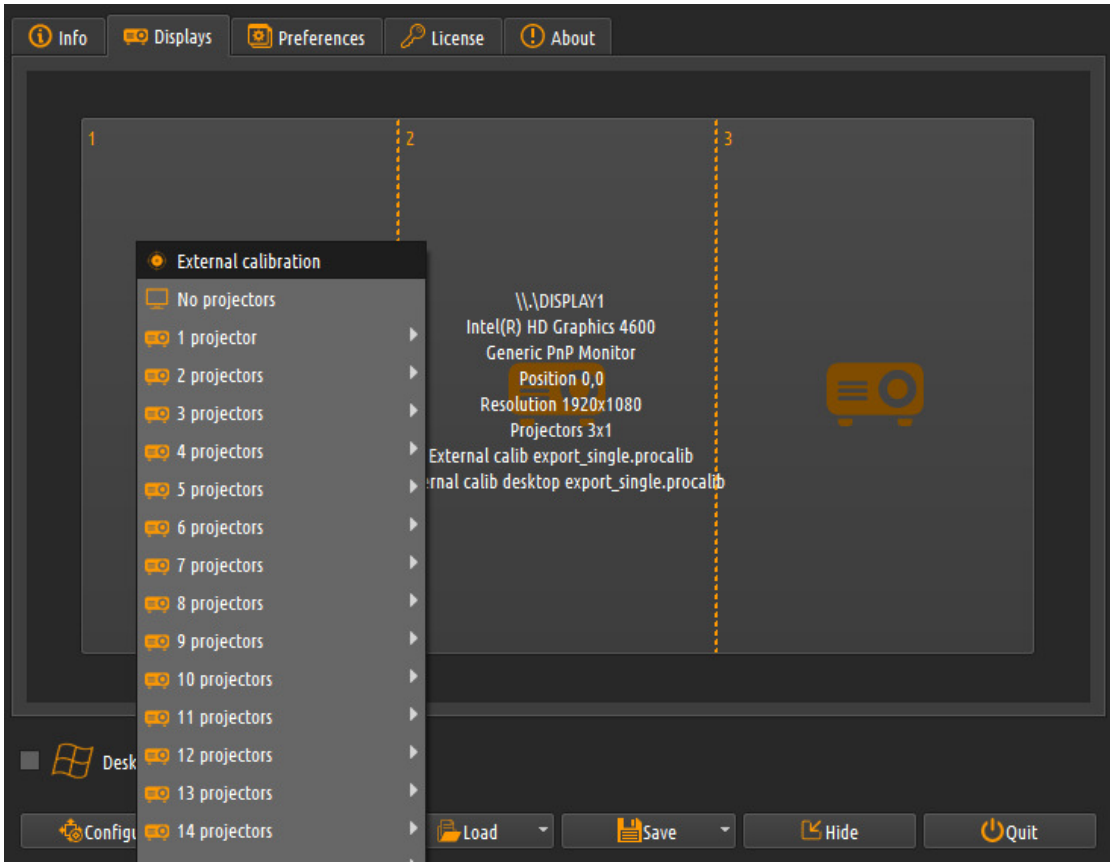


Select the needed additional exports and press the “Export data” button.
Several .procalib files will be exported with the filename selected from the export dialog. The .procalib files can be imported in Immersive Display PRO.

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 _single.procalib file should be used when projecting a single virtual camera content (video, desktop, etc). The _multi.procalib file should be used when projecting multiple virtual cameras content (games, simulators, 3d engines, etc).

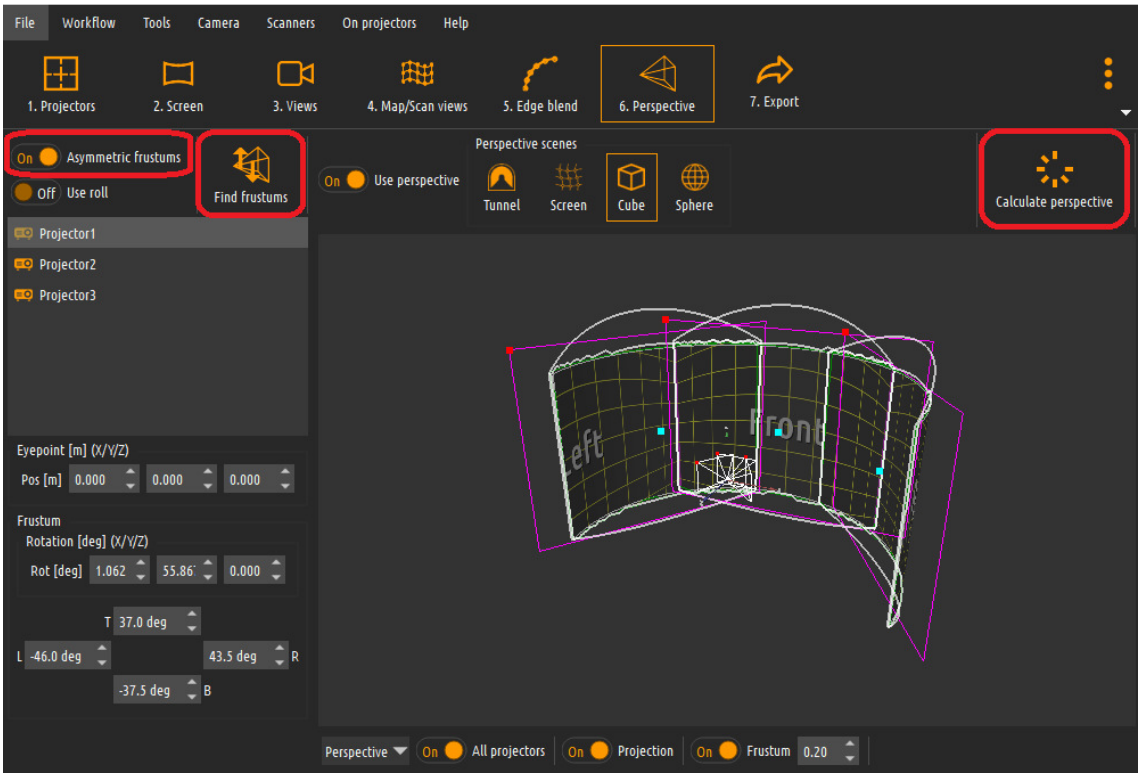


11 Prepar3D v3.3+ camera settings

Prepar3D v3.3 introduced a feature named View Groups. On multi display systems, View Groups can be created to easily configure views across multiple displays using the View Group Management window.

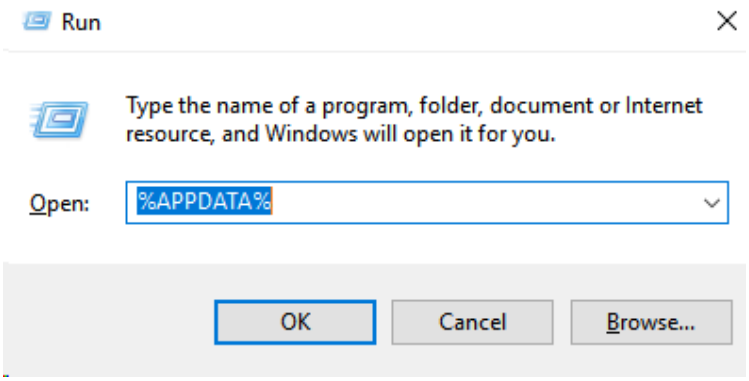
http://www.prepar3d.com/SDKv3/LearningCenter/getting_started/view_system/display_configuration.html

There is no more need for modifying the flight files (fxml files) for creating correct geometry for multi-projection systems.
One important feature of View Groups is the possibility for asymmetric frustums (camera). This allows Immersive Calibration PRO to calculate the best frustum fit and ensure minimum pixel loss and minimum image stretching.
In Immersive Calibration PRO make sure that the option “Asymmetric frustum” is enabled when before pressing “Find frustums”.

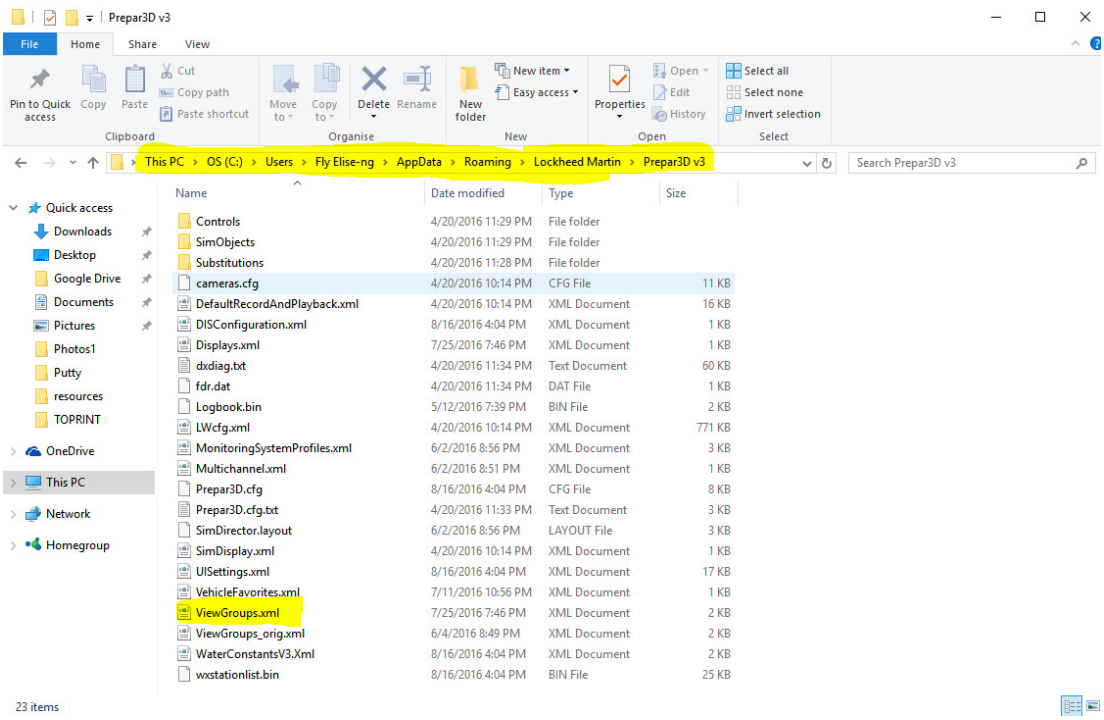


When using asymmetric frustums, the calculation of the frustums will be optimized to minimize the pixel loss and maximize the projector image usage on the screen.

This will export a file ViewGroups.xml that can be copied into the P3D configuration folder.
Open the folder "%APPDATA%\Lockheed Martin\Prepar3D v3". The easiest way is to press WIN + R keys, type %APPDATA% and press enter. This will open the "%APPDATA%\ folder. Open the underlying Lockheed Martin\Prepar3D v3 folder.

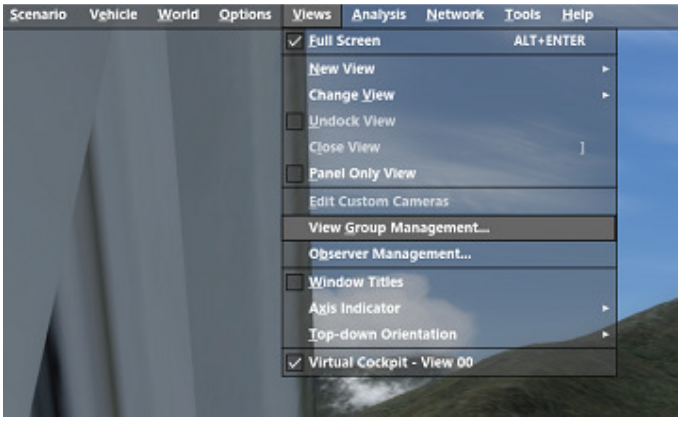


Rename/backup the existing ViewGroups.xml file and copy the exported ViewGroups.xml file in this location.

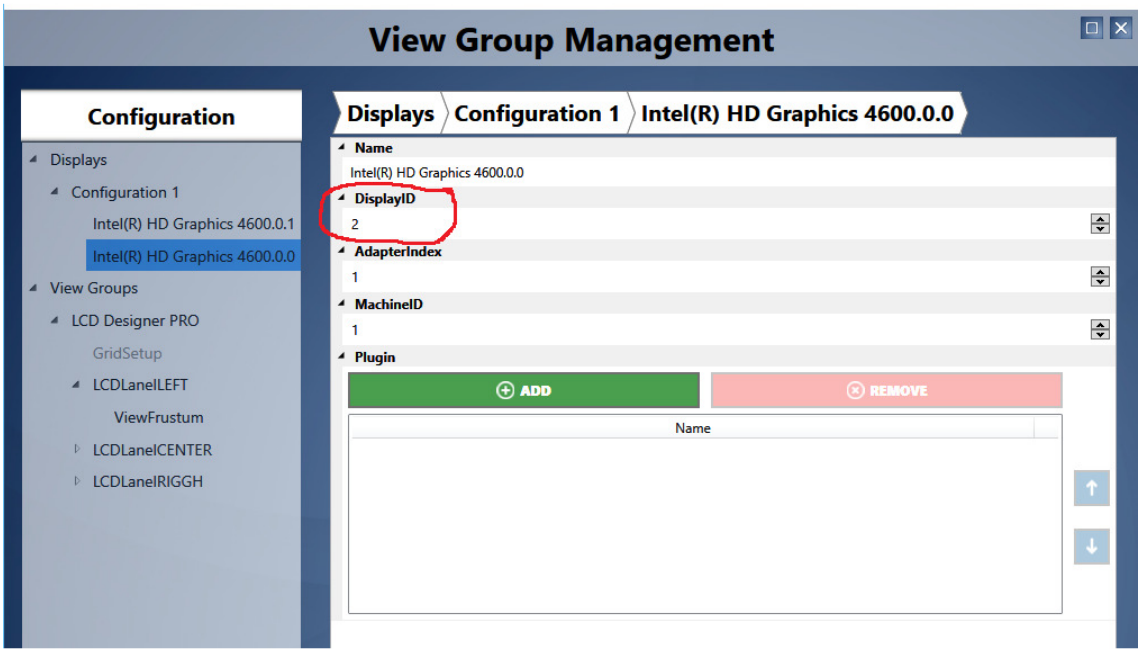


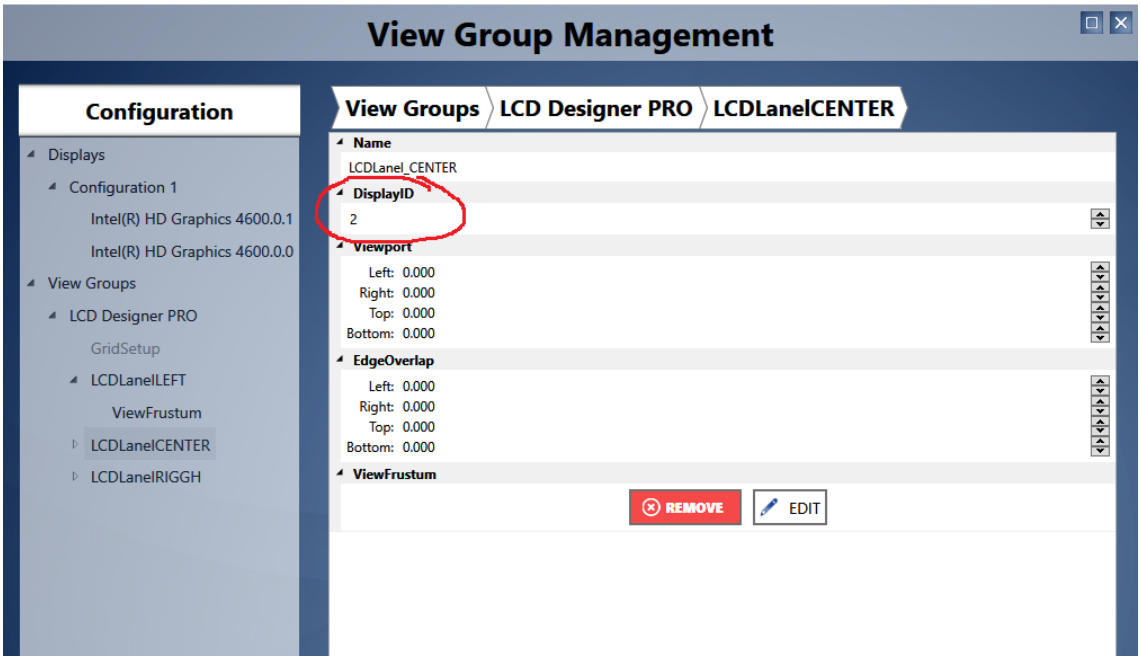
When P3D is restarted it will load the exported ViewGroups.xml.
Open the P3D View menus and select View Group Management.

Note: The latest versions of P3D v3 moved the configuration data to the global location C:\ProgramData\ Lockheed Martin\Prepar3D v3. If this folder exists, copy the exported ViewGroups.xml file in this location.
Note: The latest versions of P3D v4 moved the configuration data to the global location C:\ProgramsData\ Lockheed Martin\Prepar3D v4. If this folder exists, copy the exported ViewGroups.xml file in this location.



Just make sure that the enumerated displays and graphics cards on your system match the DisplayID exported in the ViewGroups.xml file. If they do not match, assign them the correct DisplayID using the View Group Management window.



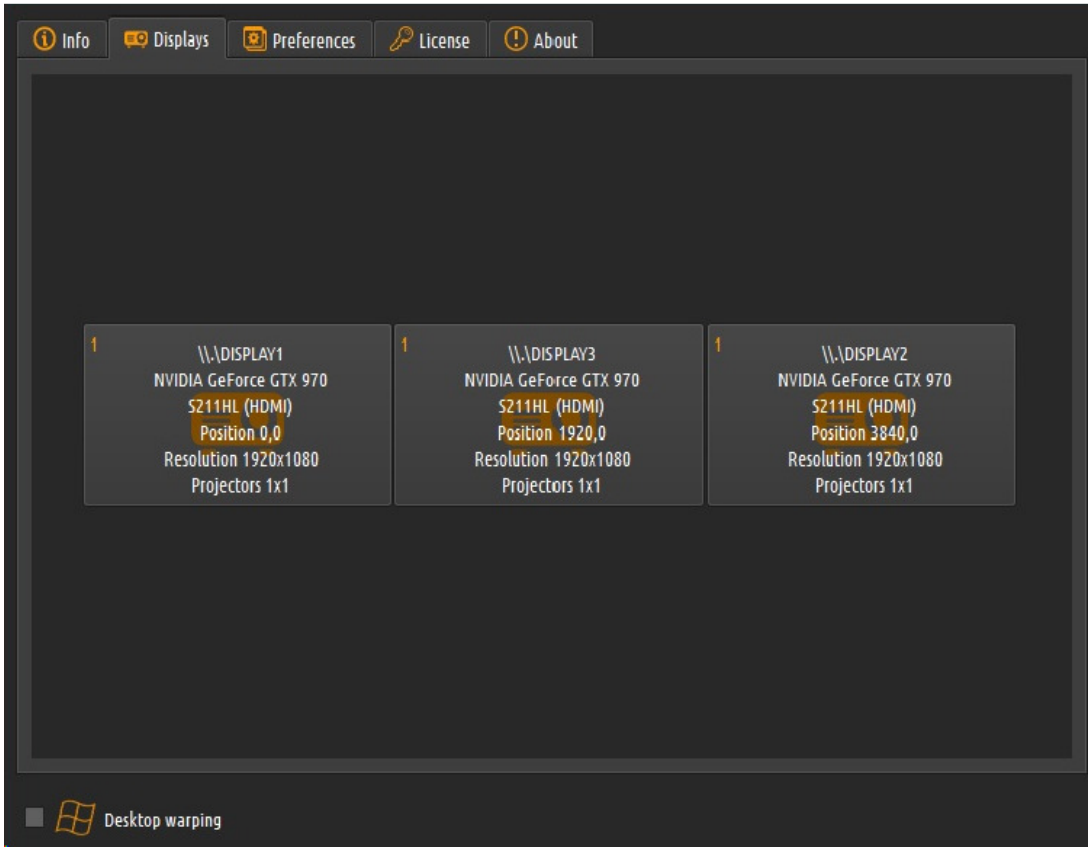


Now you can start any flight in cockpit mode or virtual cockpit mode.

Use the right button and click on the current view (not the View Menu) and select View Groups, then click on Immersive Calibration PRO. This will create the position the views on the corresponding projectors.

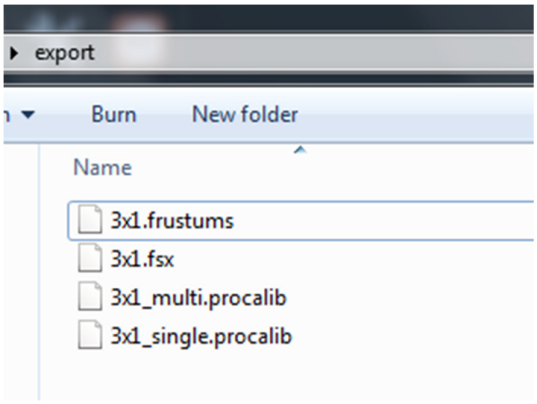
Note: When using the ViewGroups.xml file, there is no need to update the flight fxml files. The ViewGroups.xml file will make sure that the view are positioned on the correct projector.

Start Immersive Display PRO. For each ungrouped display, click on the display, select external calibration and chose the exported _multi.procalib file. Now restart P3D and select the View Groups/Immersive Calibration PRO.


Info
Displays
Preferences
License
About
1
\\.\DISPLAY1
NVIDIA GeForce GTX 970
S211HL (HDMI)
Position 0,0
Resolution 1920x1080
Projectors 1x1
1
\\.\DISPLAY3
NVIDIA GeForce GTX 970
S211HL (HDMI)
Position 1920,0
Resolution 1920x1080
Projectors 1x1
1
\\.\DISPLAY2
NVIDIA GeForce GTX 970
S211HL (HDMI)
Position 3840,0
Resolution 1920x1080
Projectors 1x1
Desktop warping

12 FSX/Prepar3Dv2 configuration

FSX and Prepar3D provide a mechanism to create one or more windows inside the simulator and define the camera parameters (position, rotation and zoom) per window.
Next to the .procalib file Immersive Calibration PRO will export also a .fsx file. This file contains the windows and camera configuration files that can be copied in the FSX/Prepar3D .flt file.



Open the FSX/Prepar3D .flt file and delete all [Window.x] and [Camera.x.x] sections. Copy the content of the .fsx file inside the .flt file at the same place as the original [Window.x] and [Camera.x.x] sections.

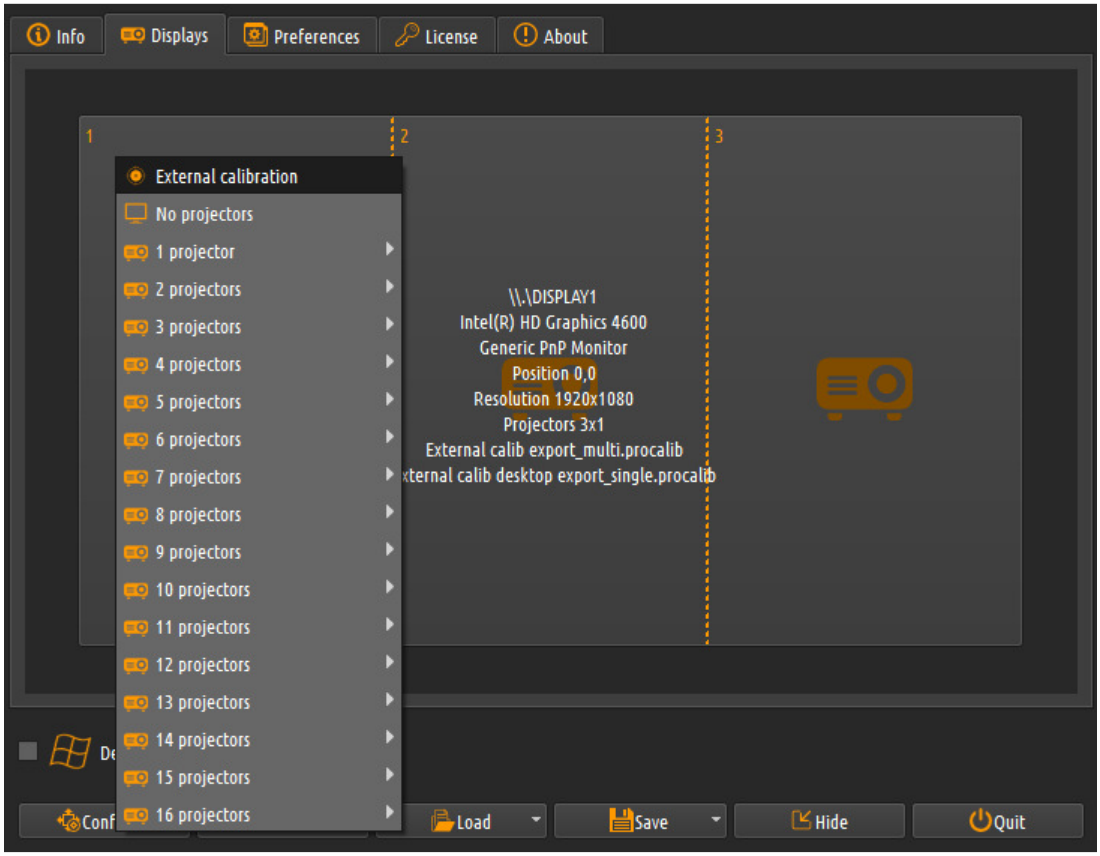
Make Note: Make sure that the file %APPDATA%\Microsoft\FSX\fsx.cfg contains the following entry:
WideViewAspect=True

Also make sure that the model.cfg file of the aircraft that is used does not contain the interior. Comment out the interior part by putting // before the interior section in the file.

```
[Window.1]
Order=0
Active=True
Undocked=False
Maximized=False
ScreenUniCoords=4, 4, 1, 1
CurrentCamera={B1386D92-4782-4682-A137-738E25D1BAB5}

[Camera.1.1]
Guid={B1386D92-4782-4682-A137-738E25D1BAB5}
Zoom=255
Translation=0, 0, 0
Rotation=-90, 0, 0

[Window.2]
Order=2
Active=False
Undocked=False
Maximized=False
ScreenUniCoords=0, 0, 2731, 6144
CurrentCamera={B1386D92-4782-4682-A137-738E25D1BAB5}

[Camera.2.1]
Guid={B1386D92-4782-4682-A137-738E25D1BAB5}
```

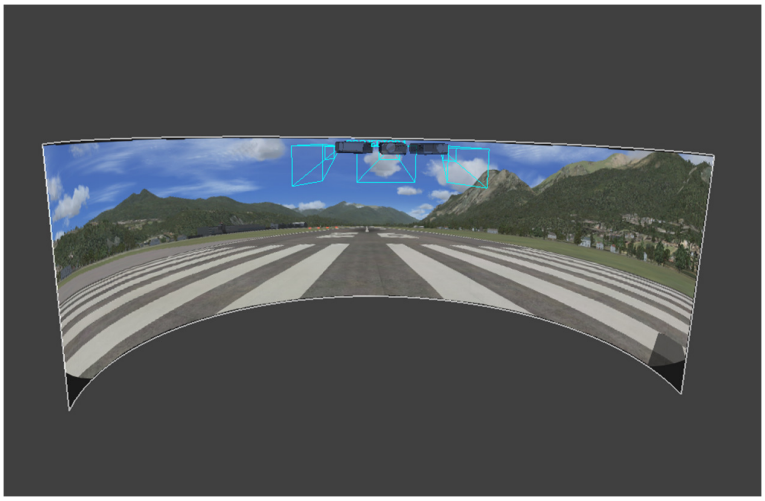
Note: Prepar3D v2 uses a fxml file instead of .flt file. The exported .fxml file can be integrated in the Prepar3D v2 in the similar way.

Start Immersive Display PRO select external calibration and chose the exported _multi.procalib file.



Start FSX in full screen mode. FSX will open 3 internal windows and each window will show part of the scene.

Projection screen will show perfectly aligned and soft-edge blended image.



13 Other 3D game engines configurations

We also offer a plug-in for X-Plane 9 and X-Plane 10 to enable the MultiView settings in X-Plane. By checking the X-Plane (.settings) file in the export dialog, a multiview.settings file will be exported that can be directly copied in X-Plane plugins folder.

For all other 3D game engines we also export a generic .frustums file that can be used to configure the games virtual cameras.
The .frustums file contains 3 sections per virtual camera (FieldOfView, Lens/Frustum and Offset.) Those can be used directly in OpenGL or DirectX programming code.
The general frustums configurations is also exported in an xml file and contains information for left hand and right hand based graphics coordinate systems

export.frustums

```
Camera Row 1 Column 1
{
   FieldOfView
   {
      AspectRatio 1.25;
      VerticalFOV 71.5863;
      HorizontalFOV 84.0568;
   }
   Lens
   {
      Frustum -0.00901301 0.00901301 -0.00721041 0.00721041 0.01 100;
   }
   Offset
   {
      RotateX(Pitch) -0.0092392; // Positive pitch Up
      RotateY(Yaw) 67.5016; // Positive rotation Left
      RotateZ(Bank) 0; // Positive bank Left
      Position 0 0 0;
   }
}
```