CAMERATRACKER

AFTER EFFECTS USER GUIDE

VERSION 1.0v7

CameraTracker User Guide

Software engineering: Ralph McEntagart, Robert Fanner, Ben Woodhall, Mailys Levassort, Jon Starck, Ben Kent, Phil Parsonage, Lucy Wilkes, Jun Liu, and Jack Binks.

Product testing: Dan Allum, Mark Titchener, and Sam Smith.

Writing and layout design: Joel Byrne, Tytti Pohjola, and Eija Närvänen.

Proofreading Eija Närvänen.

Contents

1 INTRODUCTION

Welcome to this User Guide for CameraTracker 1.0 on After Effects.

We hope you enjoy using CameraTracker.

About this User Guide

This User Guide will tell you how to install and use CameraTracker 1.0 on After Effects. This guide assumes you are familiar with After Effects and the machine it is running on.
For the most up to date information, please see the CameraTracker product page and the latest user guide on our web site at http://www.thefoundry.co.uk.

Release Notes

For information on system requirements, new features, improvements, fixed bugs, known bugs and workarounds, see "Appendix A: Release Notes" on page 96.

Example Images

Example images for use with CameraTracker can be downloaded from our web site http://www.thefoundry.co.uk.

Installing CameraTracker 1.0 on After Effects

Please note that installing CameraTracker will effectively overwrite any other versions of CameraTracker that have been installed to the default location.

On Windows

CameraTracker is distributed as a software download from our web site at http://www.thefoundry.co.uk. To install CameraTracker on a computer running Windows follow these instructions:

1. Download the correct installation file from our web site at www.thefoundry.co.uk.

2. Unzip the file and double-click on the EXE file to launch the installer. Follow the on-screen instructions to install CameraTracker.

On Mac

CameraTracker is distributed as a software download from our web site at http://www.thefoundry.co.uk. To install CameraTracker on a Mac, follow these instructions:

1. Download the correct installation file from our web site at www.thefoundry.co.uk.
2. Double-click on the downloaded DMG file.
3. Double-click on the PKG file that is created.
4. Follow the on-screen instructions to install CameraTracker.

Licensing CameraTracker

You can license, or activate, CameraTracker in one of two ways:

- **Licence Key**—a sequence of numbers and letters stored in a plain text file that unlocks CameraTracker.

  Using FLEXlm encryption, licence keys can be created for a particular computer enabling the software to run only on that computer. These are called node locked licences. We also supply floating licences that will unlock CameraTracker on any computer networked to a Foundry Licensing Tools (FLT) server.

  Here is an example node-locked (uncounted) licence that expires on 31 July 2010 for a computer running CameraTracker with a System ID of 00123fdb9e9f. Node-locked licences allow you to run CameraTracker on one machine only.

  ```
  INCREMENT cameratracker_ae_i foundry 1.0 31-jul-2010 uncounted
  \ HOSTID=00123fdb9e9f ISSUED=30-jun-2010 TS_OK SIGN="030A 5EB4
  \ FC11 3D9C B47F 3C03 6AEE 88A5 3338 ADB9 6E00 BE55 FC97 6021 \
  7AAF 82CD D2F3 3833 E5D8 4CED A3CD"

  INCREMENT cameratracker_ae_r foundry 1.0 31-jul-2010 uncounted
  \ HOSTID=00123fdb9e9f ISSUED=30-jun-2010 TS_OK SIGN="00C2 EE6A
  \ 9BBF EE0C FA43 45EB 282C 10B7 47FA 4FE3 8C01 FF47 7A39 F35E \
  8E65 8D65 7C52 3B07 E1A3 F39F 70D5"
  ```

  FLT tools and a user guide to install licence keys, manage floating licences, and diagnose licence problems can be downloaded from our web site, http://www.thefoundry.co.uk/licensing.

- **Activation Key**—a series of numbers and letters emailed to you that activates CameraTracker.

  Here is an example activation key:

  ```
  ctae-0101-3733-eeda-8376-df83-7235
  ```

To authenticate CameraTracker from the After Effects user interface:

1. Click the **Activation** button. See "Basic Controls" on page 16.
2. You are automatically directed to The Foundry web site log in page.

Note *If you're logged in already, skip ahead to step 4.*

3. Log in as normal, or sign up if you do not have a log in ID and password.

   The **Product Activation** page displays.
4. Enter the activation key that was emailed to you in the first field provided.
5. Enter your System ID in the second field.

   It is very important to check the System ID matches your machine before continuing, as CameraTracker will only be licensed to the computer identified with this unique number.

Note *You can display your System ID by clicking on the **About** button of Foundry plug-ins running on After Effects.*

6. Click **Create Licence Key**.

   You will receive an email containing the on-screen information.
7. Follow the on-screen instruction to install the Licence Key.

Other Foundry Products

The Foundry is a leading developer of visual effects and image processing technologies for film and video post production. Its stand-alone products include Nuke, Hiero, Mari, Katana, and Storm. The Foundry also supplies a suite of plug-ins, including Ocula, Furnace and FurnaceCore, Keylight, RollingShutter, Kronos, and CameraTracker for a variety of compositing platforms, including Adobe® After Effects®, Autodesk® Flame®, Avid® DS™, and Apple's Final Cut Pro®. For the full list of products and supported platforms, visit our website at http://www.thefoundry.co.uk.

Nuke is an Academy Award® winning compositor. It has been used to create extraordinary images on scores of feature films, including *Avatar, District 9, The Dark Knight*, *Iron Man*, *Quantum of Solace*, *The Curious Case of Benjamin Button*, *Transformers*, and *Pirates of the Caribbean: At World's End.*

Hiero is a collaborative, scriptable timeline tool that conforms edit decision lists and parcels out VFX shots to artists, allowing progress to be viewed in context, and liberating your finishing systems and artists for more creative tasks.

Mari is a creative texture-painting tool that can handle extremely complex or texture-heavy projects. It was developed at Weta Digital and has been

used on films, such as *District 9*, *The Day the Earth Stood Still*, *The Lovely Bones*, and *Avatar*.

Katana is a look development and lighting tool, replacing the conventional CG pipeline with a flexible recipe-based asset workflow. Its node-based approach allows rapid turnaround of high-complexity shots, while keeping artists in control and reducing in-house development overheads. Extensive APIs mean it integrates with a variety of renderers and your pre-existing shader libraries and workflow tools.

Ocula is a collection of tools that solve common problems with stereoscopic imagery, improve productivity in post production, and ultimately help to deliver a more rewarding 3D-stereo viewing experience.

Furnace and FurnaceCore are collections of film tools. Many of the algorithms utilise motion estimation technology to speed up common compositing tasks. Plug-ins include wire removal, rig removal, steadiness, deflicker, degrain and regrain, retiming, and texture tools.

Keylight is an industry-proven blue/green screen keyer, giving results that look photographed, not composited. The Keylight algorithm was developed by the Computer Film Company who were honoured with a technical achievement award for digital compositing from the Academy of Motion Picture Arts and Sciences.

RollingShutter is a plug-in that tackles image-distortion problems often experienced by users of CMOS cameras. The plug-in will often vastly improve the look of distorted footage, by either minimising or eradicating image distortions. Unlike solutions tied to camera stabilisation, that stretch the image as a whole, the RollingShutter plug-in compensates for local skewing and distortion in the scene, by correcting each object individually.

Kronos is a plug-in that retimes footage using motion vectors to generate additional images between frames. Utilising NVIDIA's CUDA technology, Kronos optimises your workflow by using both the CPU and GPU.

CameraTracker is an After Effects plug-in allowing you to pull 3D motion tracks and matchmoves without having to leave After Effects. It analyses the source sequence and extracts the original camera's lens and motion parameters, allowing you to composite 2D or 3D elements correctly with reference to the camera used to film the shot.

Storm is a product developed in-house at The Foundry to assist RED Digital Cinema camera production workflows from on-set to delivery. It acts as a hub, providing access to both metadata and original RAW image files throughout the production process.

Visit The Foundry's web site at http://www.thefoundry.co.uk for further details.

2 GETTING STARTED

Overview

CameraTracker is designed to provide an integrated camera tracking or matchmoving tool which allows you to create a virtual camera whose movement matches that of your original camera, all without leaving the After Effects environment. This camera can be used for a multitude of tasks including integrating 2.5D objects in to the scene to reduce masking and roto work, projection mapping, and more.

You can automatically track features, solve the position of cameras, and create a scene linked to the solve containing a 3D camera. CameraTracker also enables you to mask out areas of the scene that you don't want tracked, like moving objects for example.

Bear in mind that CameraTracker requires footage from a moving camera with sufficient parallax between features from frame to frame in order to extract enough data to solve the 3D camera—static camera footage does not provide enough information to solve the data correctly.

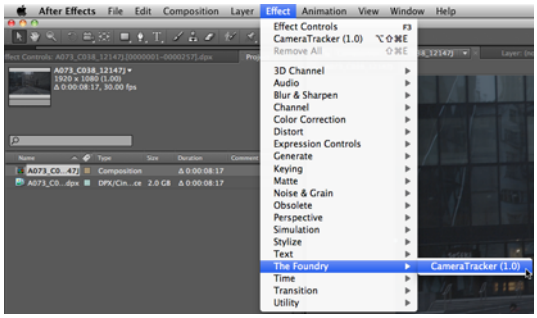
Launching CameraTracker

CameraTracker on After Effects acts like any other effect available on the user interface, and as such, you can access the controls from the **Effect** drop down menu or **Effects & Presets** panel.

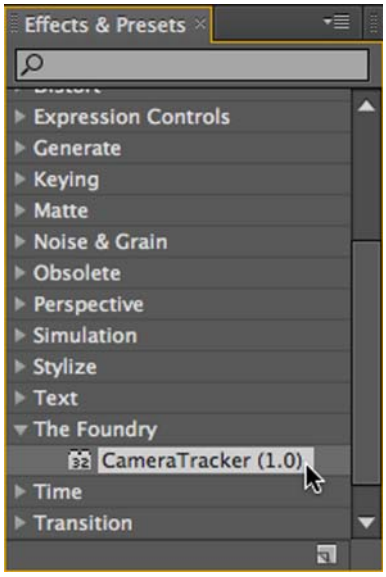
NOTE: In order to get the best results, we recommend that you apply CameraTracker to your original footage rather than footage that has been composited or processed in a fashion not designed to assist in tracking. You should also avoid using CameraTracker on precomposited footage, as doing so may cause the track to fail or result in other problems.

To access CameraTracker from the **Effect** menu, select **Effect** > **The Foundry** > **CameraTracker**.

NOTE: In order to access CameraTracker from the **Effect** menu, a layer must be selected in the **Viewer** or **Timeline**.



To access CameraTracker from the **Effects & Presets** panel, select **The Foundry** and double-click **CameraTracker**, or drag and drop the effect on to the required layer in your composition.



Quick Start CameraTracker

On the CameraTracker panel you can see the default settings shown below.

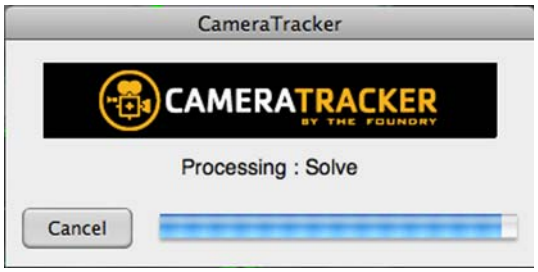
CameraTracker can automatically calculate your feature tracks, solve the camera, and create a scene with three button clicks, but the results may not be very useful unless the layer you're tracking is extremely simple.

To use CameraTracker on a simple layer, follow the steps below. Otherwise proceed to Using CameraTracker on page 15.

1. In the CameraTracker Effect Control Window (ECW), click **Track Features**, or navigate to **CameraTracker Menu** > **Actions** > **Track Features** in the Viewer.

NOTE: This step can take a long time depending on the length of your composition.

2. When the track phase completes, click **Solve Camera**, or navigate to **CameraTracker Menu** > **Actions** > **Solve Camera** in the Viewer. A dialog box displays the solve progress.



3. Click **Create Scene**, or navigate to **CameraTracker Menu** > **Actions** > **Create Scene** in the Viewer.

   CameraTracker creates a camera (and a parent null object) within your composition, then you can select feature points in the viewer to create solids or nulls at specific locations.

For very simple tracking problems, these three steps may allow you to create a tracked camera and place 3D objects so that they 'stick' to the required plane in the composition when viewed through the tracked camera.

3 USING CAMERATRACKER

Getting the best results from CameraTracker usually involves more than simply using the automatic tracking, solving, and scene creation tools. The CameraTracker interface incorporates many settings that can improve your final output, and this chapter aims to instruct you on using the tools included in the package.

CameraTracker Workflow

Camera tracking, or matchmoving as it is sometimes known, generally occurs early on in the post-production workflow. A typical workflow using CameraTracker can be broken down in to the following steps:

1. **Tracking Features**—record a layer's feature data using the automatic tracking function. See Tracking Features on page 17.
   - Mask out any areas in your sequence that you don't want to track. See "Using Mattes" on page 17.
   - Enter the tracking range and configuration. See "Setting Tracking Parameters" on page 19.
   - Troubleshoot the feature tracks if necessary. See "Fine Tuning Your Feature Tracks" on page 64.
2. **Solving**—analyse the 2D tracking data and create an internal representation of the scene's feature points and camera. See Solving Your Camera Position on page 27.
   - Set the solve and lens parameters including focal length and lens distortion. See Setting Camera Parameters on page 27 and Setting Lens Distortion Parameters on page 51.
   - Troubleshoot the solve if necessary. See "Troubleshooting Solves" on page 68.
3. **Creating a Scene**—create a 3D scene incorporating the 3D camera position and related solid and null objects associated with the scene. See "Creating a Scene" on page 32.

Successfully completing the CameraTracker workflow above creates a camera, identical to other cameras within After Effects, that can be used in a range of techniques from simple floating text within a 3D environment to

extensive projection mapping and high-end 2D/3D integration.

NOTE: In order to get the best results, we recommend that you apply CameraTracker to your original footage rather than footage that has been composited or processed in a fashion not designed to assist in tracking. You should also avoid using CameraTracker on precomposited footage, as doing so may cause the track to fail or result in other problems.

Basic Controls

CameraTracker's basic controls show effect information, provide an activation function for licensing purposes, and allow you to reset or turn effects on or off without removing them from layers.

Menu Bar

The menu bar at the top of the CameraTracker panel displays the current effect and file names as well as the following buttons.

Icon	Name	Description
	Reveal	Show or hide the current effect panel.
	Effect Toggle	Enable or disable the current effect to quickly view the results.
	3D	Though not strictly a button, this icon tells you that the current effect is a 3D feature.
Reset		Return all CameraTracker settings to their default values.
Activation		Click to open a web page for activation of CameraTracker serial numbers. See "Licensing CameraTracker" on page 7.

Icon	Name	Description
	About...	Displays the About window containing information on CameraTracker.

Tracking Features

Tracking is the first stage of the camera tracking process and obtaining accurate results is crucial as subsequent stages rely on the integrity of the initial tracking data. CameraTracker handles feature track selection for you, including reseeding tracks if they become unusable.

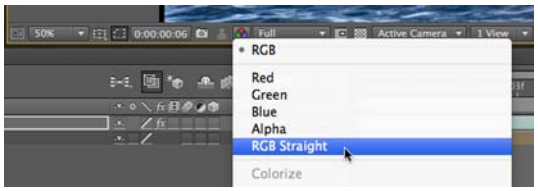
CameraTracker sometimes encounters problems with the automatic tracking of features, for example when objects go off screen or are occluded by moving foreground objects. You can assist CameraTracker by masking moving objects or by removing problem tracks using the delete track functions. See Using Mattes below and Removing Feature Tracks on page 62.

Using Mattes

Mattes can help to reduce processing time and eliminate unusable tracks by covering areas of the layer, allowing CameraTracker to ignore features in certain parts of the scene. These mattes should generally be keyframed to allow them to follow features as they move around the screen.

There are a couple of things to be aware of before you get started with mattes that will hopefully stop you becoming frustrated.

1. The first thing to understand is that After Effects has a number of Channel and Colour Management filters that you can apply to the viewer.



The **RGB** and **RGB Straight** modes display mattes in different ways. While not disastrous, the differences between the two can be extremely confusing.

Figure 3.1: A matte around the background building in **RGB** mode.

Figure 3.2: The same matte when viewed in **RGB Straight**.

The reason for this is that **RGB Straight** uses the bounding box alpha instead of the matte alpha.

2. You **MUST** pre-compose your matte layer before you use it or CameraTracker uses the source layer without any effects that you apply.

To use a matte on a layer:

1. Create a suitable matte and add it as a layer in the project. See your After Effects User Guide for more information on creating and using mattes.

NOTE: Matte layers must be pre-composed using **Layer** > **Pre-Compose** before they can be used by CameraTracker.

2. Select an appropriate **Matte Source** from the drop down menu, depending on the matte you are using.

   The **Matte Source** parameter controls how the pixel values in the matte are used to do the masking.

   - **None**—no matte is applied.
   - **Src Alpha**—use the alpha of the source layer.
   - **Src Inverted Alpha**—use the inverted alpha of the source layer.
   - **Matte Layer Luminance**—use the luminance of the matte layer.
   - **Matte Layer Inverted Luminance**—use the inverted luminance of the matte layer.
   - **Matte Layer Alpha**—use the alpha of the matte layer.
   - **Matte Layer Inverted Alpha**—use the inverted alpha of the matte layer.

3. Select the matte you created from the **Matte Layer** drop down menu.

NOTE: You cannot select a **Matte Layer** without first specifying a **Matte Source**.

4. Select the **Tracking** > **Preview Features** checkbox to preview where features will track with the matte in place.

Setting the Analysis Range

The **Analysis Range** is set to **Source Clip Range** by default, which causes CameraTracker to analyse the entire layer from start to finish. In some cases, however, you may only require tracking data for specific frames.

TIP: Analysis Range is particularly useful for testing your settings on a small frame sample before committing yourself to the potentially lengthy full feature tracking process.

To select a range for tracking:

1. Select **Analysis Range** > **Specified Range** from the drop down menu.
2. Use the slider or enter an **Analysis Start** value to set which frame is the starting point.
3. Use the slider or enter an **Analysis Stop** value to set which frame is the ending point.

   In the below example, Analysis Range is set to start at frame 5 and end at frame 15. The range is inclusive, so both frame 5 and frame 15 will be included in the analysis.

NOTE: The **Analysis Range** refers to the CameraTracker effect layer, not your entire composition, so you can move layers within your composition without invalidating your track data.

Setting Tracking Parameters

Tracking parameters are used to tailor the properties of the data you'll capture when you track features on a layer.

In most cases, the default settings supplied with CameraTracker should do a

good job of tracking features, but you may want to fine tune your settings using the following guidelines.

Number of Features

As the name suggests, setting this value alters how many features are tracked within the current layer. For extremely simple scenes, a lower number of features may be required for the solve and vice-versa. As a general guideline, you should track no fewer than 100 features for most layers.

NOTE: Bear in mind that although tracking more features can improve your results, the process will take longer.

Figure 3.3 and Figure 3.4 show examples of low and high value feature tracks.

Figure 3.3: Tracking 50 features.

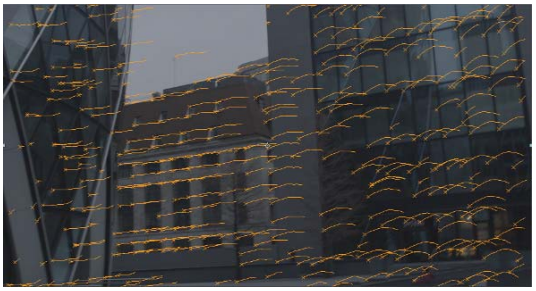


Figure 3.4: Tracking 300 features.

Detection Threshold

Detection Threshold sets the distribution of tracked features over the layer. A low value selects prominent points throughout the layer, whereas a high value selects more localised points in distinct regions.

TIP: Using a low Detection Threshold (Figure 3.5) can produce a more accurate solve when large areas of the layer are relatively featureless.

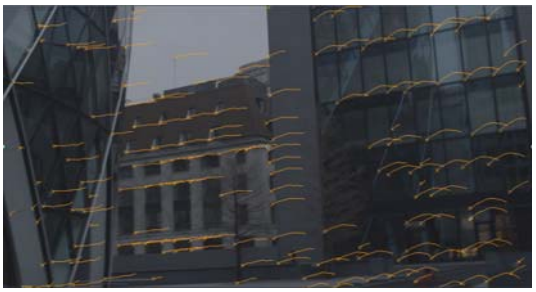


Figure 3.5: A low Detection Threshold value produces a more even feature spread.

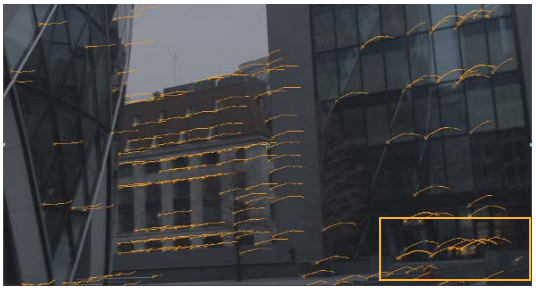


Figure 3.6: A high Detection Threshold value produces more localised grouping.

TIP: You can select the **Preview Features** checkbox to preview your features before tracking.

Feature Separation

Separation determines the distribution of features in relation to each other. To force feature separation and spread features evenly over the image at even distances, enter a high feature separation value.

TIP: You may consider reducing **Feature Separation** when you increase the number of tracked features.

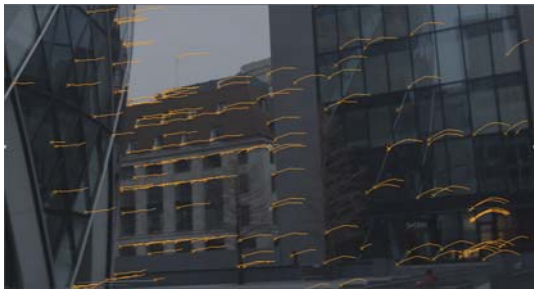


Figure 3.7: Low separation value of 1.

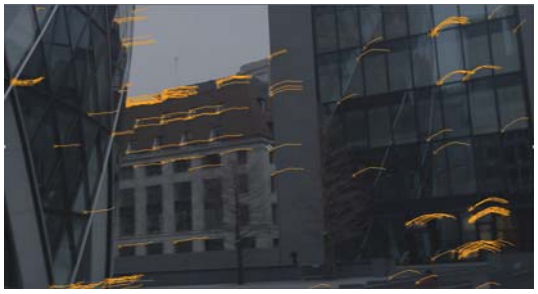


Figure 3.8: High separation value of 100.

Previewing Features

Select the **Preview Features** checkbox to preview the features that will be tracked. Preview comes in handy when you want to tweak the tracking parameters further before tracking.

Tracking Your Features

After testing feature tracks on a small number of frames and previewing, you're ready to track features on your layer.

NOTE: Tracking can take a long time, but you can speed up the process by disabling **Render During Analysis**. Bear in mind, however, that the dynamic tracks in the Viewer are also switched off if rendering is disabled.

In some cases, tracking may be interrupted if the After Effects **Auto Save** feature is turned on. To work around this, you can either:

Turn off **Auto Save** or increase the time between saves in **After Effects** > **Preferences** > **Auto Save**,

OR

Turn off **Render During Analysis** in the CameraTracker Effect Controls Window (ECW) before tracking features.

To start tracking, click the **Track Features** button on the CameraTracker panel shown in Figure 3.9, or navigate to **CameraTracker Menu** > **Actions** > **Track Features** in the Viewer.

Figure 3.9: Automatically track features within a layer.

CameraTracker begins reading the frames in the layer sequentially and tracking the features present. Tracks that encounter persistent errors are automatically reseeded—CameraTracker keeps the number of tracks constant as specified in **Tracking** > **Number of Features**.

When the playhead reaches the end of the layer, it begins a verifying pass by reading the frames sequentially backwards. Any tracks that were reseeded due to error are tracked back past the point where they were

created, if they remain viable.

NOTE: Unlike the initial track, the verifying pass can increase the number of tracks past the **Number of Tracks** you specified.

Once the verification pass is complete, you can view track and point information using the **Display** drop down menu, or point tooltips, as described below.

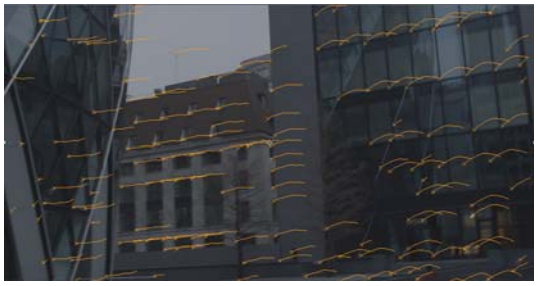
Viewing Tracks and Track Information

Viewing your track information can help you to decide whether to retrack the features in the layer or just delete the problem tracks before solving the scene. See Fine Tuning Your Feature Tracks on page 64 for more information on retracking layers and deleting tracks.

You can view your track quality or point quality using the **Display** drop down menu. You can navigate through the layer using the **Preview** panel to examine the information associated with each frame.

- **Tracks**—the default setting used to view tracks without colour coded quality information. After solving the camera, tracks are colour coded red (for a rejected track), orange (for an unsolved track), and green (for a solved track).

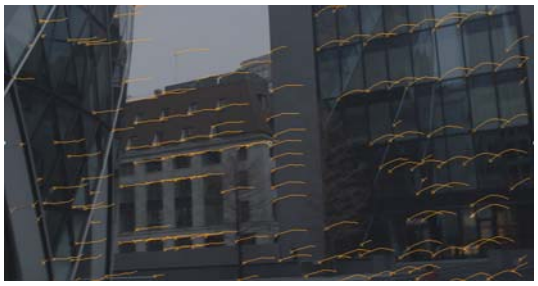
NOTE: All tracks are coloured orange before solving.



- **Track Quality**—view the reliability of your tracks. The tracks are colour coded red (for an unreliable track), yellow (for a potentially unreliable track), and green (for a reliable track).

- **Point Quality**—view the quality of your 3D points. The tracks are colour coded according to their reprojection error figures, red being the worst and green the best.

NOTE: Reprojection error values are not available until you solve the camera.

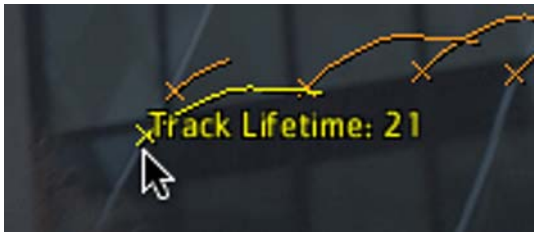


- **View Keyframe Points Only**—select this checkbox to only view the keyframe points used during tracking. CameraTracker creates these keyframe points as it tracks the layer, using the keyframes as reference points to fill in the other tracks.

  Viewing keyframe points can assist you when troubleshooting your track data because all the tracks within a layer reference these points—if you

define the keyframe points more accurately, you'll output a more refined feature track.

You can also display the track lifetime for individual tracks by hovering the mouse pointer over the track to display the tooltip. Track lifetime refers to how persistent the track is within a layer—the higher the track lifetime, the better the track. In the example, the highlighted track was good for 21 frames within the tracked layer.



If you're happy with the tracking results you can proceed to Solving Your Camera Position on page 27, otherwise you can adjust your tracking data by using the fine-tuning parameters described in Troubleshooting Tracks and Solves on page 54.

Solving Your Camera Position

When you're happy with the features that you've tracked, you can proceed to solving the camera. CameraTracker uses the tracking information to internally calculate the camera position and add positional information to the feature points in the Viewer. The first step is to adjust the parameters for your camera solve.

NOTE: The camera solve doesn't place the camera in your composition—the **Create Scene** step takes care of the camera's location within the layer.

Setting Camera Parameters

Camera settings relate to the physical aspects of the camera used on set. Accurate physical camera data produces a better camera solution.

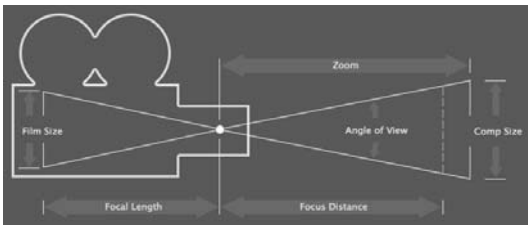


Figure 3.10: Physical camera properties in After Effects.

Focal Length Type

Select the focal length type for the camera from the drop down menu:

- **Known**—select this option if the focal length is available and enter a value in the **Focal Length** panel.
- **Approximate Varying**—select this option if an approximate focal length is available and enter keyframed focal length values in the **Focal Length** panel.
- **Approximate Constant**—select this option if an approximate focal length is available and there is no zoom, and enter a focal length value in the **Focal Length** panel.

NOTE: If you select either of the **Approximate** options, CameraTracker tries to refine the **focal length** during the solve.

- **Unknown Varying**—select this option if the focal length is unknown and changing.
- **Unknown Constant**—this is the default option. Use this option if the focal length is unknown and there is no zoom.

Focal Length

The **Focal Length**, or distance between the film back and the lens, assists CameraTracker to emulate the on set camera. If you don't know the **Focal Length**, select **Unknown Constant** or **Unknown Varying** from the **Focal Length Type** drop down menu.

NOTE: Digital cameras often record the **Focal Length** for you as metadata contained within the output.

Film Back Size

Film Back Size is the physical size of the film used or the size of the imaging sensor used in digital cameras. If you entered a **Focal Length**, the film dimensions are critical for achieving accurate data.

NOTE: You can usually find these values in the Specification pages of the camera used on set, or online at sites such as http://www.dpreview.com/

Select the required units from the **Units** drop down menu and enter the horizontal and vertical film or sensor size in the **Film Back Size X** and **Y** fields.

Camera Motion

You can assist CameraTracker with the solve by selecting the motion type of the on set camera from the **Camera Motion** drop down menu.

- **Rotation Only**—select this option if the camera is static and rotating, for example, if you're using a tripod mounted camera for nodal pans.

  The following images show the difference in solve quality you can achieve by selecting **Free Camera** and **Rotation Only** on the same piece of footage.

  Notice the large amount of rejected tracks if **Free Camera** is selected?

Figure 3.11: Free Camera.

Figure 3.12: Rotation Only.

NOTE: If you select **Rotation Only**, make sure that **Tracking** > **Track Validation** is also set to **Rotating Camera**. See Track Validation on page 66 for more information.

- **Free Camera**—select this option if the camera is both translating and rotating.

Creating a Solve

Once you're happy with the physical camera and lens parameters, you're ready to create a solve using your tracks and camera properties.

To create the solve, click **Solve Camera** in the CameraTracker ECW, or navigate to **CameraTracker Menu** > **Actions** > **Solve Camera** in the Viewer.

The solving process does not take as long as tracking features within a layer, but it is dependent on the number of frames and complexity of the tracks. Once the solve completes successfully, a solve report displays.

In Figure 3.13, CameraTracker reports that reference frame 7 was used, 5 keyframes were used, and the total root mean square (RMS) reprojection error rate was 0.849 pixels.

NOTE: The Reference Frame is the point at which the camera was located at the origin 0, 0 in 2D. This value is significant later on—see Using Null Object Transforms in Compositions on page 47.

TIP: If your solve reports an RMS projection rate higher than 1.0 pixel, you may want to consider fine-tuning your solve or tracking data. See Troubleshooting Tracks and Solves on page 54.

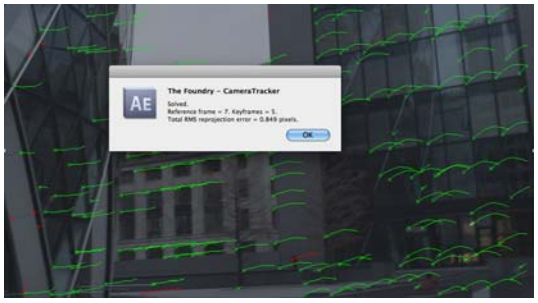


Figure 3.13: Solve camera report.

NOTE: If your tracking phase was relatively lengthy, CameraTracker may need some extra time to create the **Refine** menu statistics.

If this is the case, a second progress bar displays the amount of time remaining:

CameraTracker solves take less time than tracking features and should produce data similar to that shown in Figure 3.14.

Figure 3.14: Typical After Effects solve data.

TIP: Notice the red solve data in the lower half of the solve in Figure 3.14. The data could be unreliable due to the movement of the figure during tracking. This is a good example of when CameraTracker could benefit from masking features as described in Using Mattes on page 17.

You can also display track and solve data for individual tracks by hovering the mouse pointer over the track to display the tooltip, as shown in Figure 3.15 on page 31.

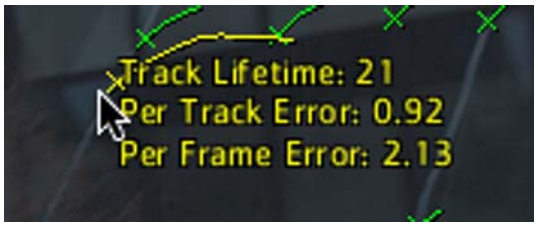


Figure 3.15: Reprojection Error report.

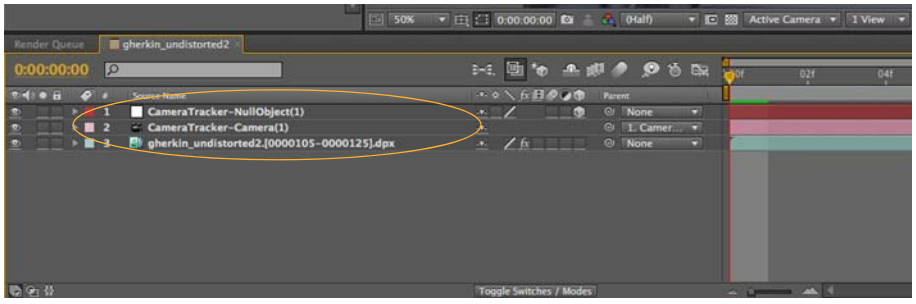
If you're happy with the solve results you can proceed to Creating a Scene on page 32, otherwise you can adjust your solve by using the fine-tuning parameters described in Troubleshooting Tracks and Solves on page 54.

Creating a Scene

After solving the camera, you're ready to create your scene. **Create Scene** produces an After Effects camera, that you can use in conjunction with the integrated 3D object creation functions, to place various solids relative to the camera in 3D space.

In a similar way to the previous steps, you can use CameraTracker to create the scene automatically by clicking **Create Scene**, or navigate to **CameraTracker Menu** > **Actions** > **Create Scene** in the Viewer.

Creating a scene takes very little time—all the hard work was completed in previous steps. There is very little to see in the After Effects Viewer when the camera is ready, but you may notice that new camera and null layers have been added to the Timeline.

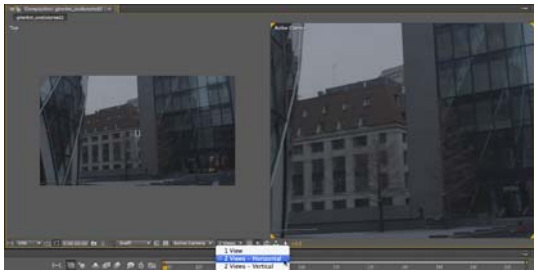


So where is your camera and where is it in the layer?

In order to 'see' the camera within the layer, you'll have to view things slightly differently.

You could create a new camera to view your composition, but the simplest way to view your scene is using Custom Views.

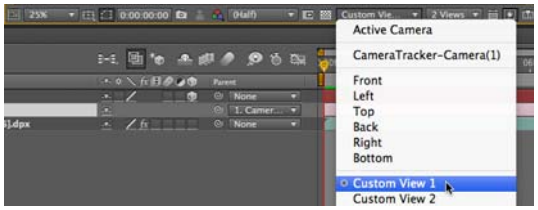
1. In the Viewer, navigate to **Select viewer layout** > **2 Views - Horizontal** to add a second panel to the Viewer.



The default settings display the **Active Camera** on the right and **Top** view on the left.

NOTE: The **Active Camera** is always located in the highest layer of your composition. If you have more than one camera in your composition, select **CameraTracker-Camera(1)** to view your solved camera.

2. Click the left view to highlight it, then navigate to **3D View Popup** > **Custom View 1** to change the camera view from **Top** to a customisable view.



Custom View 1 represents the solved camera CameraTracker camera (1), but it is not fixed in place. You can move the camera around to view your scene from any angle you choose.

The red square at the same XY coordinates as the camera in Figure 3.16 represents the Null Object associated with the camera, and the yellow highlight shows a Point of Interest (POI) marker.

NOTE: If you click **Solve Camera** and **Create Scene** again, CameraTracker will attempt to update the existing scene. If, however, you have renamed the existing camera, CameraTracker creates a new camera and pairs it with the existing null.

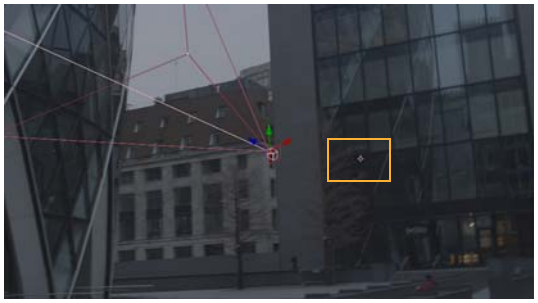


Figure 3.16: The **Null Object** associated with the solved camera and a **Point of Interest** marker.

NOTE: CameraTracker creates a one-node camera, so the POI is set to the default location and provides no real benefit.

See your After Effects User Guide for more information on POI.

3. Click the **Unified Camera Tool** icon or press **C** on your keyboard to activate the camera tool.
4. Select the **CameraTracker-Camera(1)** layer in the composition and try moving the camera around the scene to view different angles.

   Switch between 2D and 3D by clicking **Toggle 2D/3D** or pressing **Tab** on your keyboard.

NOTE: The layer itself does not move and this can be confusing at first. No matter where you move the camera view, as with any 2D layer in After Effects, the layer will always remain front and centre.

If for any reason your camera doesn't work, you may have to make some parameter changes and re-solve the camera or in some cases go back to the tracking stage to iron out tracking errors. See "Troubleshooting Tracks and Solves" on page 54.

That takes care of tracking, solving, and creating a scene. From here you can set the ground plane, axes, or origin, add your geometry (that is shapes or text), or use other After Effects features to add layers to your composition.

Alternatively, there are some third party scripts (snippets of code which extend After Effects functionality, but are not supplied by After Effects or CameraTracker) that allow you to export your camera tracks to other software suites like Maya or Cinema 4D, but these are not covered in the scope of this User Guide.

Using the Point Cloud

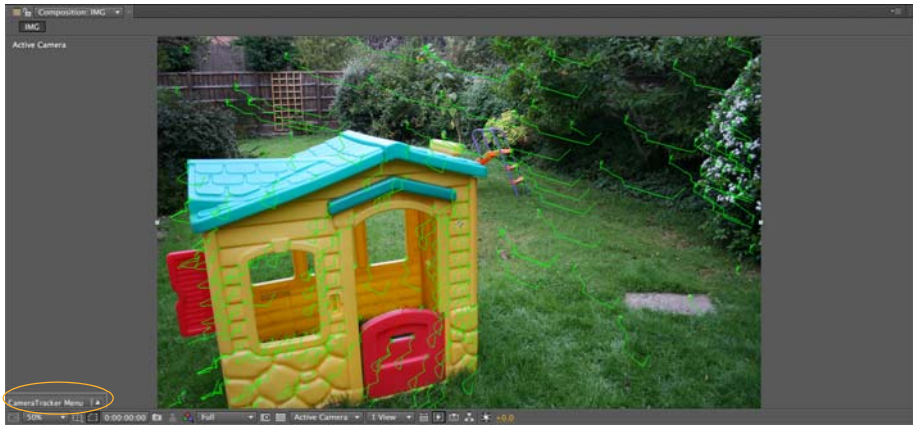
The Point Cloud is a very powerful tool that enables you to view the 2D scene by examining the tracked points in 3D. All the features that were tracked and solved during the CameraTracker workflow can be viewed, each colour coded with the original layer colour.

TIP: You can reduce the Point Cloud size to view more accurate keypoints from the solve by checking **View Keyframe Points Only** on the CameraTracker panel.

In this demonstration we'll use a nice colourful scene as shown below.

Select the image layer in your composition and the CameraTracker effect in the Effect Controls window to access the CameraTracker Menu displayed in the bottom left of the Viewer.

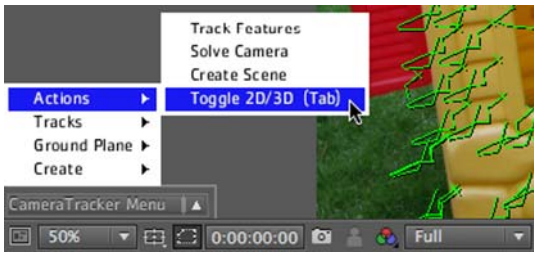
NOTE: The CameraTracker menu is only available when the CameraTracker effect is highlighted in the Effect Controls window.



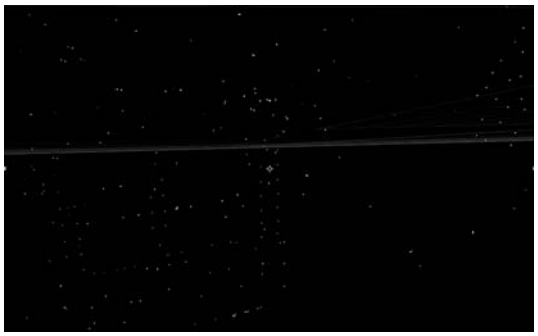
NOTE: You may notice that CameraTracker Menu selections can be slow, especially on **Windows** platforms. To avoid this, try holding down the left mouse button in the menu, locating the option you require and releasing to complete the selection.

To start using the Point Cloud, follow these simple steps:

1. Navigate to **CameraTracker Menu** > **Actions** > **Toggle 2D/3D**,
   OR
   Press **Tab** on your keyboard to toggle between 2D and 3D.

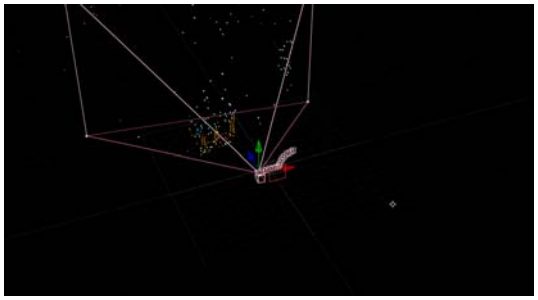


The Point Cloud displays in the Viewer.



From the camera's point of view, the cloud is not very useful. Point Clouds really come in to play when viewed using After Effects custom cameras, so you can really get 'into' the 3D scene.

2. Navigate to **3D View Popup** > **Custom View 1** and select the **CameraTracker-Camera(1)** layer in your composition.



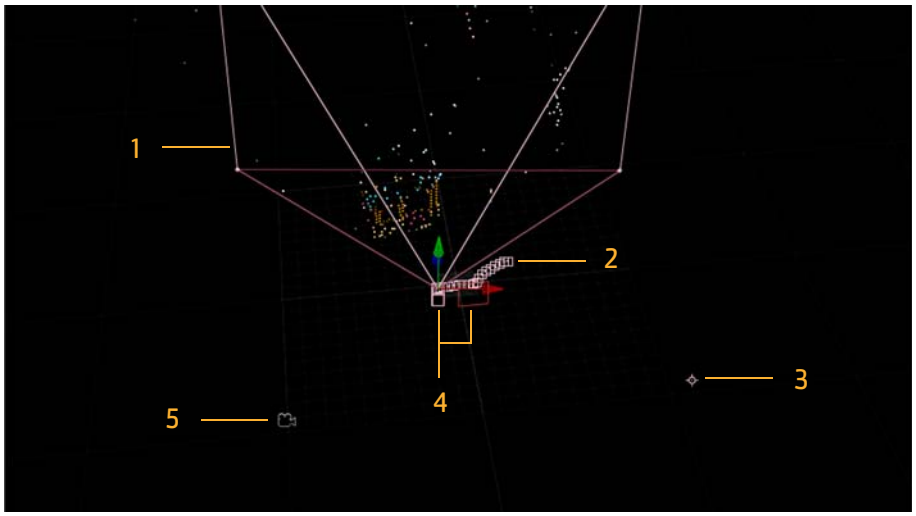
The Point Cloud and custom camera perspective are now displayed on screen.

3. Click the **Unified Camera Tool** on the After Effects interface,

   OR

   Press **C** on your keyboard to activate the camera tool.

4. Click and drag the camera tool around to view the scene.

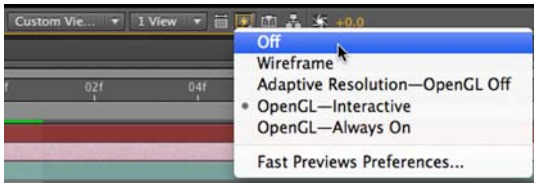


No.	Item	Description
1	View	Shows the camera's current view.
2	Track	The track that the camera follows through the scene. Each square represents one frame in the layer.

No.	Item	Description
3	POI	The scene's Point of Interest.
4	Camera and Null	The camera and associated null.
5	Control	Unified Camera Tool used to control camera movement.

You may notice that the tracked points lose resolution as you drag around the scene. This is due to the **Fast Previews** default setting within After Effects.

If you want to retain resolution during movement, navigate to **Fast Previews** > **Off**.



5. You can select points in 2D by dragging a marquee or holding down **Shift** and clicking individual points then view them in 3D.

   Figure 3.17 shows the same points selected in 2D and 3D. By moving the custom camera around the scene, it's quite easy to see that the points selected are on the same plane.

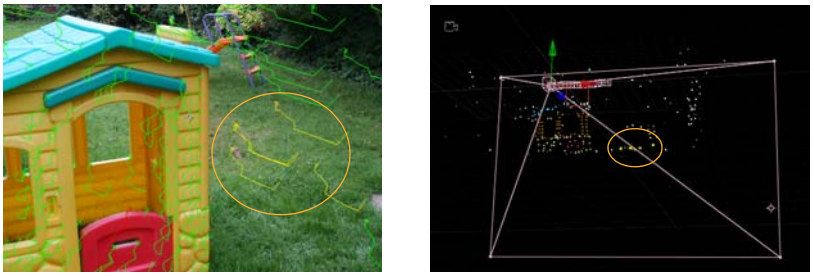


Figure 3.17: 2D and 3D point comparison.

Once you master using the Point Cloud, you'll find the other topics in this chapter, such as Setting the Ground Plane on page 39 and Adding Solids to Your Composition on page 43, relatively simple to achieve.

Setting the Ground Plane

A tracked camera has no notion of where the ground plane is in the layer, and so it, and any associated 3D objects, can be at an unexpected offset and angle relative to where we expect the ground to be in 3D space. Essentially the camera has a different frame of reference to us, which can make working in the 3D environment confusing at first.

Setting the ground plane, origin, or set of axes is designed to provide CameraTracker with a sensible frame of reference. While doing so is not strictly necessary, it can simplify working in the 3D environment.

Before placing the ground plane, scan through your layer to find a frame with good track and solve data in an area that you know to be at ground level. Hover over likely points to display the track and solve data, and use the Point Cloud to guide you when selecting suitable points.

TIP: Bear in mind that setting a ground plane over a number of points in the scene creates a 'best fit' plane and, crucially, translates the camera to make use of the new plane.

If you don't want the camera to move or placing a ground plane is proving tricky, you might consider using an origin and setting individual axes as described later on in this chapter.

1. Drag a marquee over the required points or hold down the **Shift** key and click individual points.

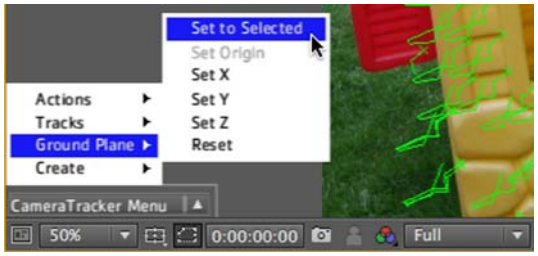
   Figure 3.18 shows a scene with five good ground level points selected.

Figure 3.18: Ground plane points within a layer.

2. Once you've selected your points, navigate to **CameraTracker Menu** > **Ground Plane** > **Set to Selected**.

NOTE: The CameraTracker menu is only available when the CameraTracker effect is highlighted in the Effect Controls window.

You may notice that CameraTracker Menu selections can be slow, especially on **Windows** platforms. To avoid this, try holding down the left mouse button in the menu, locating the option you require and releasing to complete the selection.



CameraTracker uses the points you selected as the 'ground' when adding layers to your composition.

You can also add points to the ground plane calculation from other frames in the layer to help refine the results:

1. Set a ground plane as described previously.
2. Play through the layer to locate points to add to the ground plane.
3. Select the features and navigate to **CameraTracker Menu** > **Ground Plane** > **Set to Selected**.

   The points are added to the ground plane.

Setting the Origin

Defining the origin within a layer can assist you when placing objects in your composition—if you know where 0, 0, 0 is located, you can easily place objects precisely where you want them on any axis.

NOTE: Unlike setting a ground plane over a set of points, defining an origin does not translate the camera position.

1. Select a single track as an origin point from your feature and solve data and navigate to **CameraTracker Menu** > **Ground Plane** > **Set Origin**.

   Figure 3.19 shows a track selected for CameraTracker to use as the X, Y, Z origin.

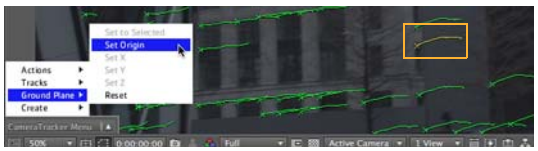
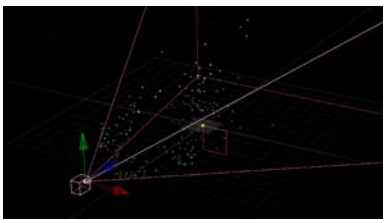


Figure 3.19: Setting the origin.

2. Switch to the Point Cloud and use custom view on the scene. Notice that the CameraTracker Null has moved to the point you selected.



Setting Independent Axes

In some compositions, you may not have a clearly defined ground plane to reference. Using CameraTracker, you can set the X, Y, and Z axes separately instead of grouping them on the ground plane.

NOTE: Unlike setting a ground plane over a set of points, defining an origin and independent axes does not translate the camera position.

1. Set an Origin within the scene as described in Setting the Origin above.
2. Select the Origin and a point that you know to be on the required axis, or use the Point Cloud to assist you.
3. Navigate to **CameraTracker Menu** > **Ground Plane** > **Set X**, **Y**, or **Z** depending on the points selected.

Figure 3.20 shows the Origin and one vertically aligned track selected as reference points for CameraTracker to use for the Y axis.

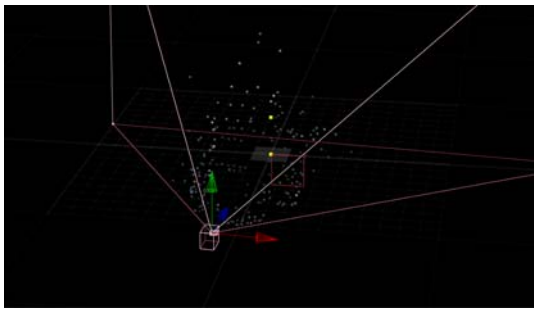


Figure 3.20: The Origin and Y axis reference points.

Resetting Planes, Axes, and Origins

Adding planes, axes, or an origin can greatly improve your 2D/3D integration but, in some cases, you might end up with too many points selected within your composition. You can reset all point and plane data by navigating to **CameraTracker Menu** > **Ground Plane** > **Reset**.

Adding Solids to Your Composition

At this point, you can use the camera you've created, as you would any other After Effects camera, for all manner of applications. However, the CameraTracker Menu can still help you to add solids and nulls to your composition.

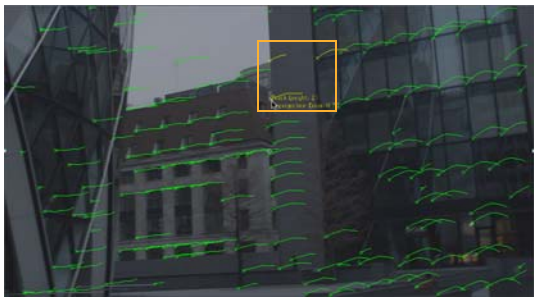
You can add solids manually by right-clicking in the left Timeline panel and selecting **New** > **Solid...** but positioning them inside the camera's field of vision at the desired position can be time consuming. CameraTracker provides an automatic solid creation function to help you achieve the results you need.

1. Select points on the plane that will hold the solid by hovering over likely features to locate suitable points.

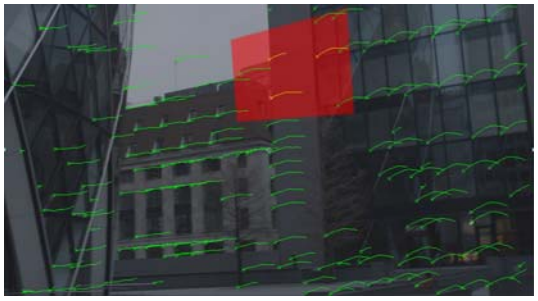
TIP: Using the Point Cloud can really help you locate the best points available on any plane. See Using the Point Cloud on page 35.

2. Drag a marquee over the required points or hold down the **Shift** key and click individual points.

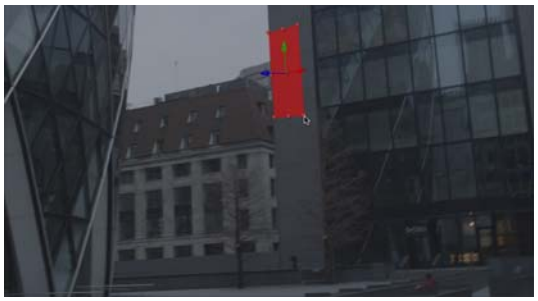
NOTE: The following example uses three points, but you may need to select more depending on the track and solve data.



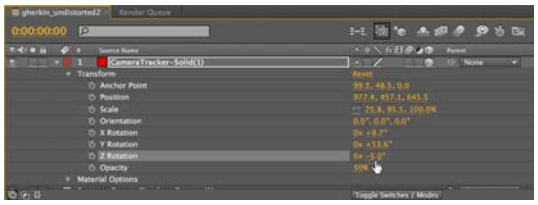
3. Navigate to **CameraTracker Menu** > **Create** > **Solid** (or press **S**) to add a default solid to the composition.
4. CameraTracker default solids are red, have an opacity of 50%, and depending on the points you selected, may be quite large as shown in the example.



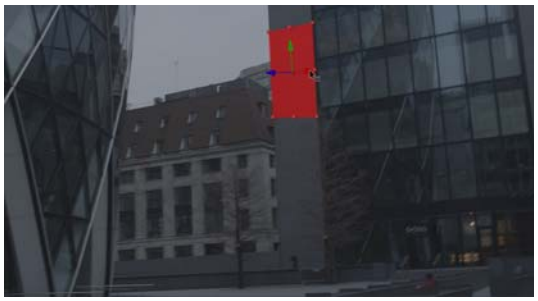
5. Select the solid in the timeline and use the solid handles in the viewer to adjust the size of the solid so that it fits on the plane of the building.



6. You may notice that the solid is slightly skewed on the Z axis in the example. Use the solid's **Transform** > **Z Rotation** to align the solid with the edge of the building.



7. Next, use the solid handles in conjunction with the **Z Rotation** and axis handles to adjust the solid so that it fills the side of the building.



8. Using the dual views described in Creating a Scene on page 32 you can view the solid from any angle using the **Custom View 1** camera. See Figure 3.21 on page 45.

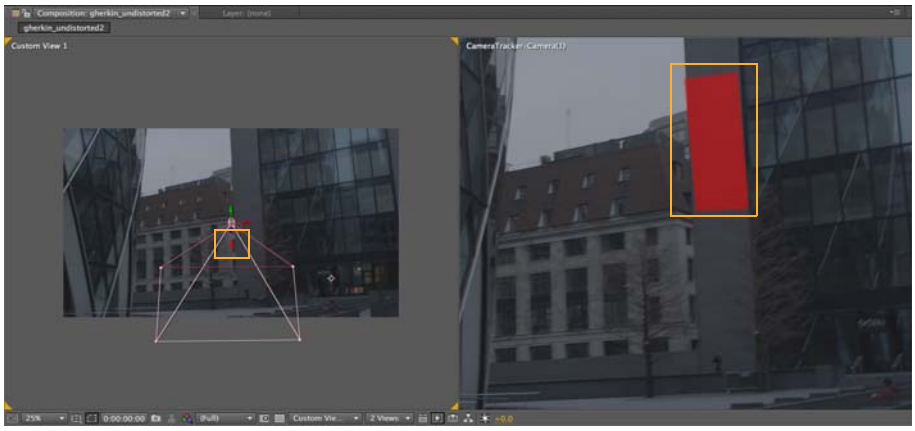
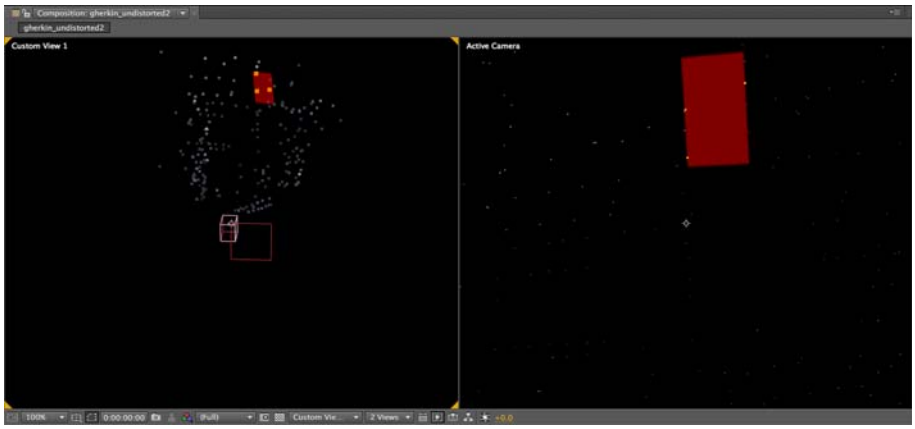


Figure 3.21: The same solid viewed from 2 angles.

As mentioned previously, although the camera moves around the scene, the 2D layer is fixed in place and doesn't relate to the camera movement. In Figure 3.21, the custom camera is 'looking' down on the scene and as a consequence, the solid appears lower in the scene and further away from the camera.

9. Switching to 3D and viewing the solid and Point Cloud together is more informative.



The 3D view can help you determine where your solid really is—hovering in space, or 'stuck' to the wall as desired. You can also select the tracked camera so as to see its field of view and positions in subsequent frames, and play through the sequence and see things change in 3D.

10. The final step is to check that there is no 'slipping' between the scene and the solid. The best way to do this is to play the composition using the **Play** button in the **Preview** panel.

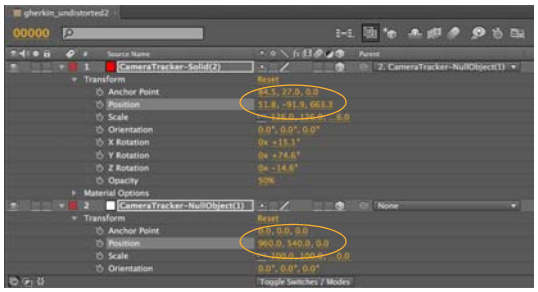
    The only real way to verify your results is to view the solid with the naked eye and make a judgement based on your experience.

Unparenting Solids: Absolute vs. Relative Transforms

Solids and nulls created using the **CameraTracker Menu** > **Create** menu are parented to the **CameraTracker Null** object by default and any translation, rotation, and scale changes applied are relative to this null. These objects can be described as residing in a **relative** coordinate space. This is so that the overall scene scale, orientation, and origin can be set both before and after creating objects, using the **CameraTracker Null**.

If you wanted to copy position transforms from a created object to another object, for example a text layer, solid, or null, you must ensure the source object's position, rotation, and scale parameters are in **absolute** space. To do this, unparent the solid before copying its parameters:

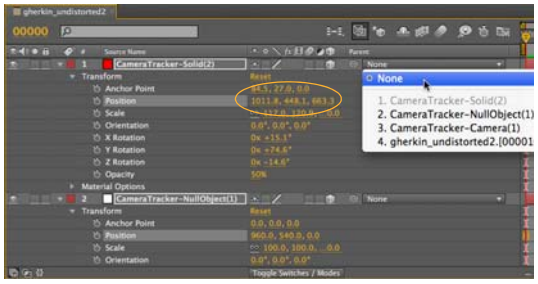
1. Using the solid and null twirlies, reveal both **Position** parameters. If you compare the **xyz** values, you'll notice a considerable difference.



   The null's positional coordinates are **absolute**, rather than **relative** like the solid.

2. Using the solid's **Parent** dropdown menu, select **None**.

   Notice the solid's position values have changed?



Moving the solid around the scene when it is unparented produces an absolute move, rather than a move relative to the null object.

Once the data copy is complete you can reparent the solid and, if necessary, the new object to the **CameraTracker Null** to return them to relative coordinate space. You can then control the overall scene position, rotation and scale changes.

Using Null Object Transforms in Compositions

CameraTracker 3D objects are created relative to the tracked camera, and as a result, any offset, scale, or rotation transform applied to both the camera and objects will have no effect when viewing the composition through the tracked camera—everything will still be in the right place.

When you use the **Create Scene** button, CameraTracker creates a tracked camera and automatically parents it to a null object. Once you've completed the CameraTracker workflow and are happy with your scene, you can use the automatically generated null associated with the camera to control the offset, scale, and rotation of elements added to your composition.

Applying an additional transform using the null can be useful in many contexts. For example:

- You can adjust the scale of the 3D scene to approximately match that of the real world.
- If automatic ground plane setting is problematic, the null can be used tweak the position of the tracked camera relative to the ground plane.
- Sometimes, you may have already created a 3D environment. The null can then be used to reconcile that environment and the camera tracker environment.
- If a CameraTracker scene is added to a pre-existing 3D environment, nulls can be used to reconcile the offset, scale, and rotation of elements between the two scenes.

Creating Multiple Nulls

Creating compositions can be a very time consuming process, and using shortcuts during your workflow can be the difference between success and failure. If you're going to be placing and translating a large number of objects in your scene, you may consider using **Multiple Null Objects**. The only limit on the number of nulls you can create is the number of tracked features in your scene.

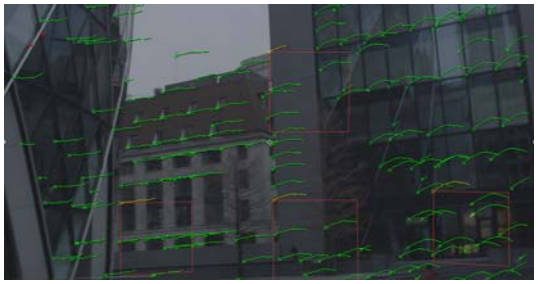
Bear in mind that there is a significant difference between creating multiple and single nulls across points:

- Creating multiple nulls across multiple points attaches a null to each point 'facing' the camera.
- Creating a single null across multiple points averages the coordinates from the points you selected and places the null at 'best fit' coordinates.

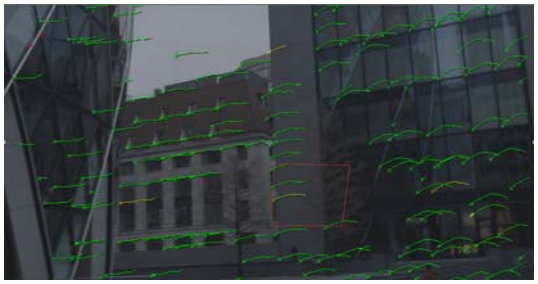
To create multiple nulls on selected tracked features:

1. Select the tracks in your scene that will anchor the nulls and navigate to **CameraTracker Menu** > **Create** > **Multiple Null Objects** (or press **F**).

2. CameraTracker places nulls at each selected track.



NOTE: If you place a single null across the same points, the result would be quite different.



Accounting for Lens Distortion

You can use CameraTracker's lens distortion features to account for lens distortion in your footage. Often, what you want to do is add CG images to your footage and distort those images so that they match the lens distortion in the footage.

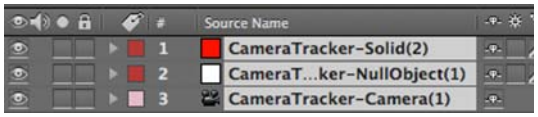
The best practice for doing this is to apply CameraTracker to your footage, add the CG images, and apply lens distortion to the CG images. Do the following:

1. Use **Track Features** to track the features in your footage. See Tracking Features on page 17.
2. Set **Lens Distortion** parameters to automatically estimate or manually adjust the lens distortion of the camera used to shoot your footage. See Setting Lens Distortion Parameters on page 51.

   This allows you to calculate the camera for the undistorted footage.
3. Use **Solve Camera** to create a solve. See Creating a Solve on page 29.
4. Use **Create Scene** to produce an After Effects camera that you can use in conjunction with the integrated 3D object creation functions to place

a solid relative to the camera in 3D space. See Creating a Scene on page 32.

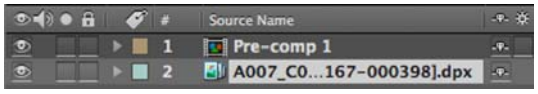
5. Create the solids, text, or CG elements you want to add to your original footage.
6. Select the objects you created in the previous step and the **CameraTracker-NullObject(1)** and **CameraTracker-Camera(1)** layers in the composition.

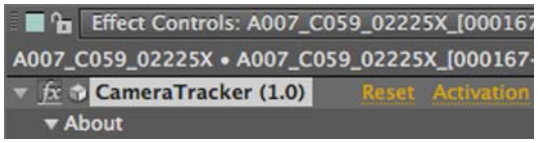


7. Then, navigate to **Layer** > **Pre-compose**. In the **Pre-compose** dialog, select **Move all attributes into the new composition** and click **OK**.

   In the composition, you should now only see the **Pre-comp 1** layer and the original footage you applied CameraTracker to. **The Pre-Comp 1** layer allows you to process both the original footage and the created objects together.

8. Next, you need to copy the CameraTracker effect. You're going to use this copy to apply lens distortion to the objects in your Pre-Comp. To copy the effect, first select the original footage in the composition and the CameraTracker effect in the ECW.





   Navigate to **Edit** > **Copy**. Then, select the **Pre-Comp (1)** layer and navigate to **Edit** > **Paste**.

9. In the ECW, expand the **Lens Distortion** group and check **Redistort**.

That's it! You have now added objects to your tracked footage and distorted them to match the lens distortion in the original footage.

NOTE: If your footage has a very large amount of lens distortion, CameraTracker may not be able to track or solve the footage. If this is the case, set the **Lens Distortion** drop down to **Known Lens** in the ECW and check **Undistort** to flatten the footage. Tweak the **Lens Distortion** parameters by eye to get the correction close. Then, apply another CameraTracker effect and use that to track and solve the flattened footage. You should create your 3D scene, camera and elements using the second, solving CameraTracker. When you're done, precompose your 3D elements, and then copy and paste the first CameraTracker effect onto the precomposed layer, and check **Redistort** to distort it. If your eyeballed correction is close but not quite there, you can also set the second CameraTracker to **Unknown Lens** to get it to estimate the final part of the correction.

NOTE: If CameraTracker is able to track and solve your footage but the lens distortion estimate that it comes up with is poor, set **Lens Distortion** to **Refine Known Lens** in the ECW. Then, adjust the other **Lens Distortion** parameters until your footage looks about right when **Undistort** is checked, and hit **Solve** again.

Setting Lens Distortion Parameters

Lens Distortion

Lens Distortion is used to select the type of lens used on set. Select the lens type from the drop down menu.

- **No Lens Distortion**—disables all lens distortion controls and treats the footage as having no distortion.
- **Known Lens**—allows you to specify the lens distortion manually for the camera solve.
- **Refine Known Lens**—gives you a chance to give an approximate distortion to use but attempts to refine it in the camera solve.
- **Unknown Lens**—calculates the lens distortion automatically from the sequence and then refines the distortion in the camera solve.

If you chose either **Known Lens** or **Refine Known Lens**, enter values for the **Lens Type**, **Radial Distortion**, **Distortion Centre** controls and, if necessary, the **Anamorphic Squeeze** and **Asymmetric Distortion** controls.

Lens Type

You can select the type of lens used on set from the drop down menu allowing CameraTracker to compensate for the selected type. The equations used to account for lens distortion are quite complex, but using these guidelines you should be able to output undistorted layers from distorted layers.

- **Spherical**—compensates for different spherical lenses. This is the simpler of the two lens corrections and uses the following equation:

$$X_u = \frac{X_d}{1 + d_1 r^2 + d_2 r^4}$$

X_u and **X_d** are equal to the same point in an undistorted plate and a distorted plate respectively.

d_1 is equal to Radial Distortion 1

d_2 is equal to Radial Distortion 2

r^2 is equal to the distance of the point from the distortion centre

r^4 is equal to the square of **r^2**

- **Anamorphic**—compensates for anamorphic lenses. Anamorphic correction uses three additional parameters (A_x, A_y, and A_{sq}) and requires two equations because, unlike with spherical lenses, the amount of distortion parallel to the x-axis is not the same as that parallel to the y-axis.

$$x_u = \frac{x_d}{1 + \left(\frac{d_1}{A_{sq}}\right) r^2 + \left(\frac{d_2}{A_{sq}}\right) r^4 + A_x {y_d}^2}$$

$$y_u = \frac{y_d}{1 + d_1 r^2 + d_2 r^4 + A_y {x_d}^2}$$

(x_u, y_u) and **(x_d, y_d)** are equal to the same point in an undistorted plate and a distorted plate respectively.

d_1 is equal to Radial Distortion 1

d_2 is equal to Radial Distortion 2

r^2 is equal to the distance of the point from the distortion centre

r^4 is equal to the square of **r^2**

A_x is equal to Asymmetric Distortion X

A_y is equal to Asymmetric Distortion Y

A_{sq} is equal to Anamorphic Squeeze

Lens Parameters

You can manually enter physical lens characteristics depending on which **Lens Type** you selected.

- **Radial Distortion 1 (d_1)**—defines the first radial distortion term. This is proportional to r^2, where r is the distance from the distortion centre.
- **Radial Distortion 2 (d_2)**—defines the second radial distortion term. This is proportional to r^4, where r is the distance from the distortion centre.
- **Distortion Centre (r^2, r^4)**—defines the values for the centre of the radial distortion on the X and Y axes.
- **Anamorphic Squeeze (A_{sq})**—defines the anamorphic squeeze value. If you select an anamorphic lens, the **Distortion Centre** on the X axis is scaled by this amount.
- **Asymmetric Distortion (A_x, A_y)**—defines distortion for anamorphic lenses. Enter values to define asymmetric distortion to correct for slight misalignments between multiple elements in the lens.
- **Undistort**—check this to view your footage undistorted.

  Redistort—check this to view your footage distorted.

4 Troubleshooting Tracks and Solves

Unless the composition you're working on is extremely simple or ideal for tracking, troubleshooting your tracks and solves is a necessary part of the CameraTracker workflow. Effective troubleshooting can improve your end result immeasurably and can be the difference between a good 3D result and a composition with slipping elements.

Knowing when to refine tracking or solving is also an important concept. If your scene doesn't create successfully, the solve may be faulty and some fine-tuning may be necessary. Bear in mind, though, bad solves are often the result of bad feature tracks—if it seems that no amount of solve fine-tuning is improving your results, try going back to square one and refining and retracking the layer.

Overview

So, you've gone through the camera tracking workflow, but you want to improve the quality of the result you're getting. The first thing to do is to figure out where the problem lies: the tracking, the solving, or the scene creation.

Bear in mind that a problem in one stage of the process can be caused by any of the earlier stages. If you create a solid and get unexpected results, this may be caused by a bad solve or bad feature tracks. If you have a bad solve, this may be caused by bad feature tracks.

The table on the next page attempts to illustrate the troubleshooting process. The recommended workflow is to go to the step where you have a problem and work your way up from there.

Workflow Step	Result	Troubleshooting Methods	Potential Solutions
1. Track Features	2D tracks	• Play through the sequence in the 2D View and look at the tracks in the Viewer. See if any tracks slip, jump, or seem too short. • Have a look at the **Track** statistics under the **Refine** group. See Using the Refine Group on page 56. • Use the **Track Finder** to locate poor tracks. See Using the Track Finder on page 61.	• If only a few of the tracks seem poor, you can delete those tracks, give precedence to tracks that you know are good, set thresholds for the tracks, and click **Solve Camera** again. See Removing Feature Tracks on page 62, Giving Precedence to Good Feature Tracks on page 64, and Track and Solve Thresholds on page 60. • If you have a lot of poor tracks, adjust the Tracking parameters or add a matte, and start again by clicking **Track Features**. See Setting Tracking Parameters on page 19, Using Mattes on page 17, and Retracking Features on page 67.
2. Solve Camera and Create Scene	Camera, null, and point cloud	• Have a look at the **Solve** statistics under the **Refine** group. Using the Refine Group on page 56. • Use the **Track Finder** to evaluate the quality of the solve. See Using the Track Finder on page 61. • Play through the sequence while looking at the Point Cloud in the 3D View. See if any points slip. See Playing through the Sequence on page 70. • Look at the 3D scene from a Custom View, move around the scene, and see if any feature points are offset from the rest. • Create a grid on the ground plane. See Creating a Grid on the Ground Plane on page 68.	• Remove bad tracks, give precedence to tracks that you know are good, adjust the **Solve** parameters (**Keyframe Separation** in particular), and/or set thresholds for the solve, and click **Solve Camera** again. See Removing Feature Tracks on page 62, Giving Precedence to Good Feature Tracks on page 64, Setting Camera Parameters on page 27, Keyframes on page 69, and Track and Solve Thresholds on page 60. • Of course, the problem could also be in the tracking stage of the process. Proceed to troubleshooting tracks.
3. Create Objects	Solids, nulls, text, etc.	• Select some points, create a solid, and see if the solid looks as you'd expect. Creating a Solid on page 71.	• If the solid looks wrong but isn't moving around over the course of time, try troubleshooting the solve. • If the solid is moving around over the course of time, you've probably got a bad track rather than just a bad solve. Try troubleshooting the track.

Examining Your Feature Tracks

In addition to looking for bad tracks in the 2D View, the following tools can assist you when you're troubleshooting tracks:

- The **Refine** group, in conjunction with the Graph Editor, provides detailed statistics on track and solve data across the entire composition, helping you to locate problematic frames within the scene.

  The **Refine** group also lets you set minimum and maximum thresholds for the tracks and the solve. Any tracks that fall outside these thresholds are automatically rejected.
- The **Track Finder** examines individual frames that you have identified using the **Refine** group and Graph Editor. After locating the problem features, you can remove them and begin reprocessing your data.

Using the Refine Group

The **Refine** group in the ECW contains animated parameters calculated after tracking and after solving. These parameters allow you to view various quality measures from the tracking and the solving phase, enabling you to troubleshoot and refine the resultant camera. You can also view the animated parameters using the Graph Editor in After Effects.

The parameters are divided in to two groups: **Track** statistics and **Solve** statistics. As the names suggest, each group is used during a particular phase.

Bear in mind that the Track and Solve statistics are only meant for viewing information on track and solve data in the composition. The values here are not meant to be edited – indeed, doing so has no effect on the final result and will just confuse matters.

If you want to affect the values, you can use the **Threshold** controls under **Refine** to set minimum and maximum thresholds for the tracks. Any tracks that fall outside these thresholds are rejected and displayed in red. You can then click the **Delete Rejected** button at the bottom of the **Refine** group to delete all such tracks in one go.

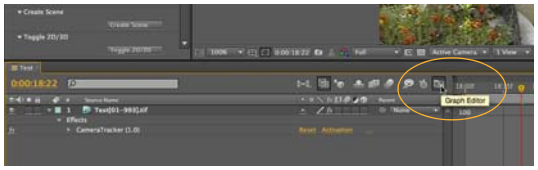
If you want to delete all unsolved feature tracks (that is, tracks that don't have a valid 3D point after solving), you can also click the **Delete Unsolved** button in the bottom of the **Refine** group.

If necessary, you can refresh the statistics by navigating to **CameraTracker Menu** > **Tracks** > **Refresh Stats** (or by pressing **R**). This updates everything under **Refine** (including the thresholds, which by default are set to the minimum and maximum values that exist in your track and solve data).

Track Statistics

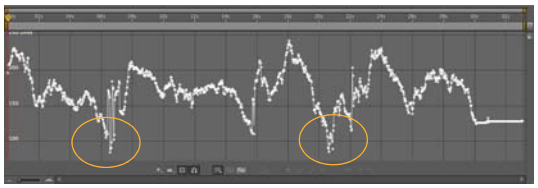
Track statistics can only be used after you have tracked your initial composition. To access statistics in the Graph Editor:

1. Click the Graph Editor toggle in After Effects.

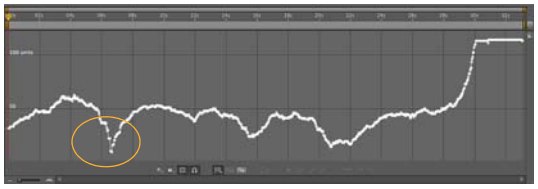


2. Select your composition and press the After Effects hotkey **U** to display the currently animated parameters associated with that layer. Often this just displays the animated statistics, as there may not be any other animated parameters.

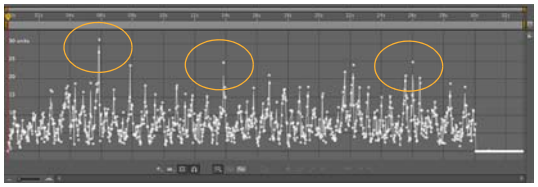
- **Track-Points** displays the total count of feature points over the track phase. Large variations from the number set in the tracking parameters allows you to see possible tracking issues.



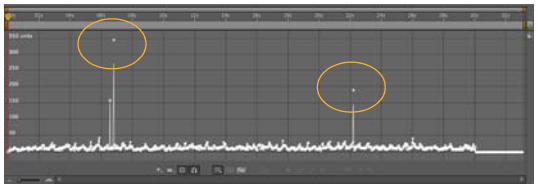
- **Track-Lifetime-Min** displays the shortest lifetime, in frames, of any track point on the current frame. Very short tracks are likely to be poor quality and are good candidates for removal.
- **Track-Lifetime-Avg** displays the lifetime of all track points, in frames, present on the current frame, averaged together. Look out for significant drops in this value which can indicate a significant number of track points being reseeded. You could try matting on the frame to remove potentially troublesome regions, and then retracking.



- **Track-Distance-Avg** displays the total distance the track points have moved from the previous frame to the current frame, averaged together. Large variations in the average distance could indicate tracking problems.



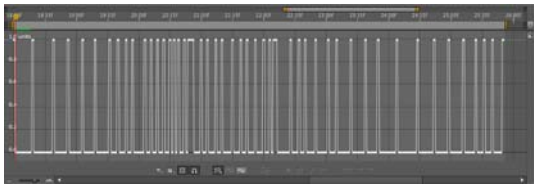
- **Track-Distance-Max** displays the maximum distance a track point has moved from the previous frame to the current frame. Used in conjunction with **Track Distance-Avg**, this graph can be used to look out for track points being influenced by nearby features. Look out for a spike in the maximum distance measurement, while the average stays fairly constant.



Solve Statistics

Solve statistics can only be used after you have solved your camera, but they can be accessed in the same way as Track statistics.

- **Solve-Keyframe** displays frames used as a keyframe by the solve process: 1 for keyframes, 0 for those not used as a keyframe.

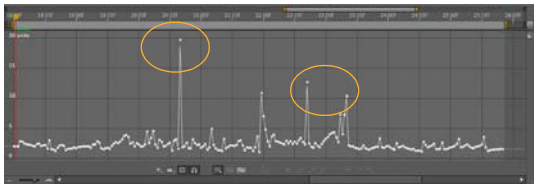


NOTE: The Keyframe statistics only show you whether or not a frame is a Keyframe. The number of Keyframes can increase or decrease depending on the **Keyframe Separation** setting.

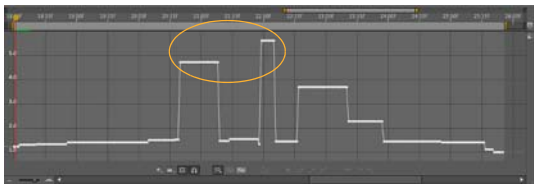
- **Solve-Overall Error** displays the total solve error, as reported in the post solve dialog box. The value is recorded here for reference.
- **Solve-Margin of Error** indicates frames where outlying points may have caused possible solve errors. Higher values represent a greater margin of error.

- **Solve-Per Frame Error-Avg** represents the general quality measure of the solve over time. It's calculated as the average of all the solve errors for the points present on the current frame (the error measure on the tracks is a snapshot, rather than constant average over the lifetime of the track point).

- **Solve-Per Frame Error-Max** displays the maximum value of all the solve errors for the points present on the current frame (again, a snapshot not an average). Look out for a spike in the maximum distance measurement, while the average per frame stays fairly constant. This could indicate possible outliers which need cleaning up.



- **Solve-Per Track Error-Max** displays the maximum value of all the solve errors for the points present on the current frame, averaged over the course of the track lifetimes. High values could indicate feature points which are generally bad over their lifetime (as opposed to those which spike in the **Per Frame Error-Max** graph).



Once you've located the possible problem areas, you can use the Track Finder to locate the offending tracks in individual frames, or set minimum and maximum thresholds for the tracks and delete any tracks that fall outside these thresholds.

NOTE: If you track and solve your footage, then re-track the footage, and refresh the statistics by selecting **CameraTracker Menu** > **Tracks** > **Refresh Statistics**, the solve statistics get reset to 0. This is to avoid displaying outdated solve statistics.

Track and Solve Thresholds

In addition to viewing the statistics as described above, you can use the following controls to set minimum and maximum thresholds for the tracks and the solve. Any tracks that fall outside these thresholds are automatically rejected and displayed in red. You can easily delete them by clicking **Delete Rejected**.

- **Threshold-Track-Lifetime-Min** sets the shortest acceptable lifetime of track points. This is measured in frames. For example, if you set the threshold to 3, any tracks that only exist for one or two frames are automatically rejected. This allows you to easily reject any very short tracks, which are likely to be of poor quality.
- **Threshold-Track-Distance-Max** sets the maximum distance a track point can move from one frame to the next without being rejected. This is measured in pixels. For example, if you set this to 80, CameraTracker

rejects any tracks where the track point moves 81 pixels or more between two adjacent frames.

- **Threshold-Solve-Frame Error-Max** sets the maximum acceptable value of all the solve errors for the points present on any one frame (the error measure on the tracks is a snapshot, rather than constant average over the lifetime of the track point). This allows you to reject tracks that may not be generally bad over their lifetime but do go wrong at some point in time.
- **Threshold-Solve-Track Error-Max** sets the maximum acceptable value of all the solve errors for the points present on any one frame, averaged over the course of the track lifetimes. This allows you to reject tracks that are generally bad over their lifetime.

NOTE: By default, the thresholds are set to the minimum and maximum values in your track and solve data. If you use **CameraTracker Menu** > **Tracks** > **Refresh Stats** (or press **R**) to refresh the statistics, the thresholds are also refreshed.

Using the Track Finder

CameraTracker is supplied with track finding tools to help you locate good and bad feature tracks after tracking and after solving. Features which don't have a valid 3D point after solving (the tracks highlighted in red) are automatically deselected by the track finder.

NOTE: All **Track Finders** can be accessed from **CameraTracker Menu** > **Track**, or by using their hotkeys.

Pre-Solve Finder:

- **Cycle Track Distance Selection**—navigate to **CameraTracker Menu** > **Track**, or press **E** on your keyboard to select the feature point on the current frame with the greatest difference in track distance between this frame and the last. Subsequent presses cycle down through the track distances on points in the current frame.

  This allows you to easily select the points which have mistracked (judged using the statistics report and Graph Editor) and delete them. This is only available once you've tracked.

NOTE: On the first frame, all the tracks have a distance of 0. This is because there is no previous frame to compare to.

Post Solve Finder:

- **Cycle Per Track Error Selection**—navigate to **CameraTracker Menu** > **Track**, or press **Q** on your keyboard to select the feature point on the current frame with the greatest per track error. Subsequent presses cycle down through the per track errors on points on the current frame.

  This allows you to easily select the points with the greatest solve error over their track lifetime (on frames judged using the statistics report and Graph Editor) and delete them.
- **Cycle Per Frame Error Selection**—navigate to **CameraTracker Menu** > **Track**, or press **W** on your keyboard to select the feature point on the current frame with the greatest per frame error.

  Subsequent presses cycle down through the per frame errors on points on the current frame. This allows you to easily select the points with the greatest snapshot solve error (on frames judged using the statistics report and Graph Editor) and delete them.

TIP: You can deselect all the tracks you have currently selected by pressing **esc** on your keyboard.

Removing Feature Tracks

CameraTracker allows you remove tracks completely if they're causing problems for the solve. You can:

- Select and remove tracks manually. See Removing Tracks Manually on page 62.
- Delete all unsolved tracks in one go. See Removing All Unsolved Tracks on page 63.
- Set thresholds for acceptable tracks and delete any tracks that fall outside these thresholds. See Removing Tracks that Fall outside Set Thresholds on page 63.
- Create a matte to prevent entire areas from being tracked. See Using Mattes on page 17.

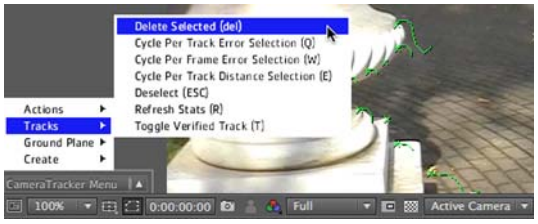
Removing Tracks Manually

To remove feature tracks manually:

1. Drag a marquee over the required points in the Viewer or hold down the **Shift** key and click individual points. If you find it difficult to select individual tracks by clicking on the track point **x**, you can enable **Allow Line Selection** in the ECW.
2. Press **Delete** on your keyboard to remove your selections,

   OR

Navigate to **CameraTracker Menu** > **Tracks** > **Delete Selected** to remove your selections.



TIP: You can also change the **Display** mode so that the Viewer displays **Track Quality** to locate the worst per track error points before deciding which tracks to delete. See Viewing Tracks and Track Information on page 24.

NOTE: The CameraTracker menu is only available when the CameraTracker effect is highlighted in the Effect Controls window.

You may notice that CameraTracker Menu selections can be slow, especially on **Windows** platforms. To avoid this, try holding down the left mouse button in the menu, locating the option you require, and releasing to complete the selection (rather than clicking to bring the menu up and then clicking to select).

NOTE: Instead of deleting selected tracks from the Viewer, consider using a keyframed matte to prevent entire regions from being tracked. This is often better than deleting tracks from the Viewer because a poor track in one area can cause CameraTracker to incorrectly estimate the motion in the footage and produce more poor tracks in the neighbouring areas. For more information on creating and using mattes, see Using Mattes on page 17.

Removing All Unsolved Tracks

To remove all unsolved feature tracks, click the **Delete Unsolved** button in the CameraTracker controls. This removes all tracks that don't have a valid 3D point after solving.

Removing Tracks that Fall outside Set Thresholds

You can use the **Refine** group in the CameraTracker controls to set thresholds for acceptable tracks and then click the **Delete Rejected** button

to remove all tracks that fall outside these thresholds. This is described in more detail under Track and Solve Thresholds on page 60.

Giving Precedence to Good Feature Tracks

In addition to removing poor feature tracks, you can select a track and navigate to **CameraTracker Menu** > **Tracks** > **Toggle Verified Track** (or press **T**) to toggle whether it is a verified track. A verified track is marked with a yellow circle. It is treated differently in the solve phase, and given precedence over non-verified tracks when building the camera model and path. This allows you to clean up tracks by selecting a number of points you can actively see are good and not slipping, and toggling on their verified state.

Fine Tuning Your Feature Tracks

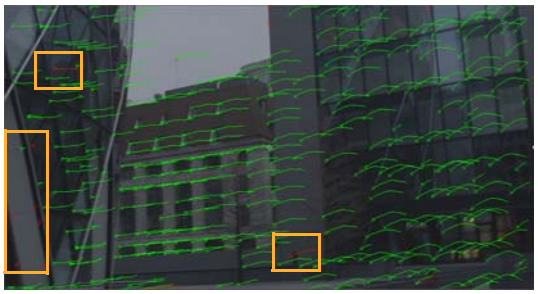
Inevitably some layers that you track will produce results that contain too many errors to be used for a solve. The following parameters are designed to fine tune your tracks if the automatic track data is inadequate.

You can use these settings to fine tune your tracks then re-examine them using the **Refine** group and **Track Finder** to really get the best results from CameraTracker.

Track Threshold

CameraTracker's tolerance to change along the track is determined by the **Track Threshold** parameter. Reducing this threshold makes tracking more tolerant to image changes, potentially producing longer tracks. When used in conjunction with **Preview Features** you can adjust this value to test whether a track is reliable over time.

Tracks marked in red suggest that the current settings may need some fine tuning.



Track Smoothness

Track Smoothness can be useful in preventing poor tracks in complex sequences. Increase the smoothness value to remove tracks that error over time. In Figure 4.1 and Figure 4.2, you can see that the higher value removes some tracks in the lower left of the layer and a number of tracks are shorter as a result of smoothing.

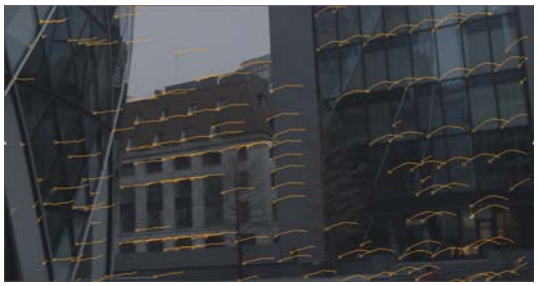


Figure 4.1: A low smoothness value.

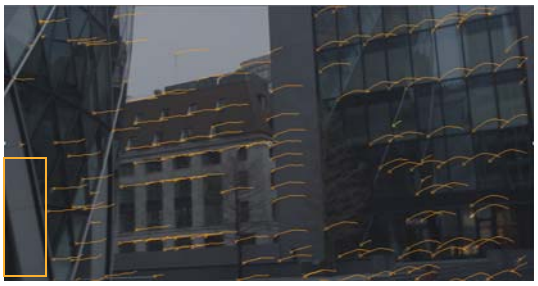


Figure 4.2: A high smoothness value.

TIP: You can select the **Preview Features** checkbox to preview your features before tracking.

Track Consistency

The consistency value defines how inconsistent a feature track can be before CameraTracker discards it and reseeds in a different location. Higher values allow for less inconsistency.

Figure 4.3 and Figure 4.4 show examples of low and high consistency values. Notice that the higher value loses some tracks in the highlighted area.

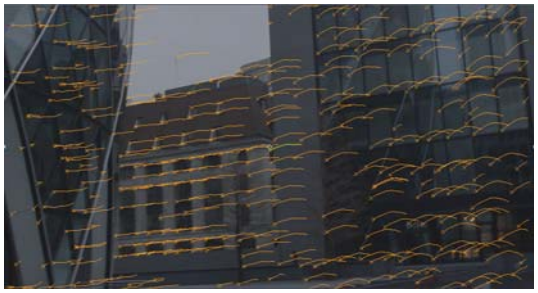


Figure 4.3: Low consistency value of 0.1.

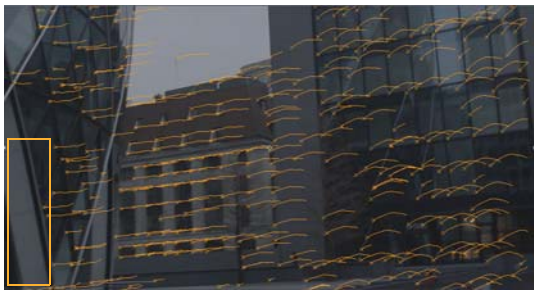


Figure 4.4: High consistency value of 1.

Track Validation

Validation determines what type of camera movement CameraTracker should compensate for while tracking features. Use the **Free Camera** and **Rotating Camera** options to test tracks against the expected motion of the camera.

- **Free Camera**—compensates for a freely moving camera that is rotating and translating. This is the default validation setting.
- **Rotating Camera**—compensates for a static camera that is rotating only, for example nodal pan shots.

  If your tracking results appear as shown in Figure 4.5, with no Y axis translation, you may want to select **Rotating Camera** and retrack.

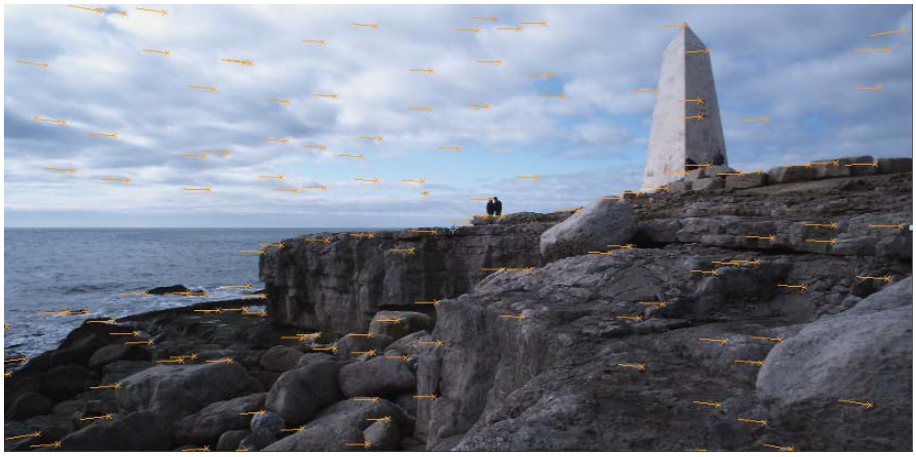


Figure 4.5: A scene shot with no camera motion on the Y axis.

NOTE: If you select **Rotating Camera**, make sure that **Solve** > **Camera Motion** is also set to **Rotation Only**. See Camera Motion on page 28 for more information.

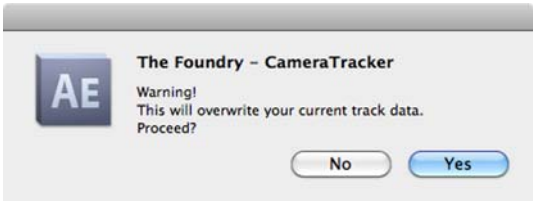
- **None**—do not validate tracks based on any particular camera movement.

TIP: You might want to use the **None** validation option if you need a larger number of tracks and want to keep all tracks in the image.

Retracking Features

Once you've fine tuned your feature tracks and removed any problem tracks, click **Track Features** to retrack your layer.

When you attempt to retrack a layer, After Effects displays a warning to stop you overwriting your previous data.



Click **Yes** to replace your existing tracks or **No** to retain your previous tracking data and cancel retracking.

Troubleshooting Solves

To troubleshoot and improve the solve, you can:

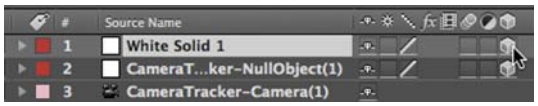
- Use the **Solve Statistics** and **Track Finders** to identify problems. See Using the Refine Group on page 56.
- Create a grid on the ground plane, play through the clip, and see if the ground plane slips. See Creating a Grid on the Ground Plane on page 68.
- Change the keyframe parameters and re-solve. See Keyframes on page 69.

Creating a Grid on the Ground Plane

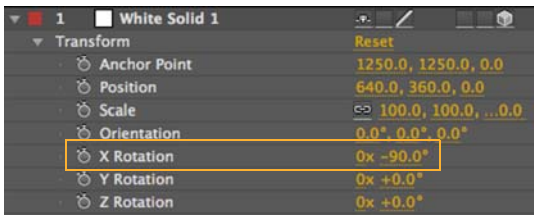
Provided you are able to set a ground plane in your scene, creating a grid on the ground plane can help you judge the quality of the solve. Do the following:

1. Set a ground plane if you haven't already. See Setting the Ground Plane on page 39.
2. Navigate to **Layer** > **New** > **Solid** to create a large solid.

   The solid comes in as a 2D layer.
3. To make the solid a 3D layer, click on the 3D Layer column in the composition.



4. Under **Transform**, set the solid's **X Rotation** to -90.0 degrees. This should put the solid on the ground plane.



5. Select the solid in your composition and navigate to **Effect** > **Generate** > **Grid**. This applies a grid effect to the solid.
6. Adjust the Grid controls as necessary. For example, it may be helpful to set **Size From** to **Width Slider**.
7. Move through the sequence and compare the grid against the plane it's set on (rather than anything above that plane).

Keyframes

During a solve, CameraTracker automatically selects a subset of frames, called keyframes, that describe the camera motion within the layer. Keyframes are usually positioned relatively far apart so that there is sufficient parallax in the images to define 3D points for the tracks. This enables a better definition of the 3D points and makes the solve more accurate.

If you find that the automatic solve isn't acceptable, you can use the **Solve Statistics** and **Track Finders** to troubleshoot and try changing the keyframe parameters and re-solving the camera.

Keyframe Separation

The separation value between keyframes can be tailored to specific layers if the default value of 0.30 is not satisfactory.

- High separation values generate fewer keyframes with a greater spread and are typically used for slower camera motion.
- Low values generate more keyframes with a tighter spread and are typically used for rapid camera motion.

To solve using keyframes:

1. Enter the required **Keyframe Separation**.
2. Enter a **Reference Frame** to use as the first keyframe in the solve.

TIP: You should choose a **Reference Frame** with a large number of tracks and variations in depth distributed throughout the frame.

3. Select the **Set Reference Frame** checkbox to confirm your selections.
4. Select a **Keyframe Accuracy** from the drop down menu.

NOTE: A higher accuracy takes longer to solve but it can improve the result when you're working with a long sequence.

5. Enable **Three Frame Initialization** to force CameraTracker to use 3 initial frames to begin the solve, rather than 2, to help correct distorted solves. Trying different reference frames with this option can be particularly effective to correct complex solves.
6. Click **Solve Camera** to re-solve with the new **Keyframe Separation** value, or navigate to **CameraTracker Menu** > **Actions** > **Solve Camera** in the Viewer.

Bear in mind that a poor solve can also be a result of poor tracking data. If you've fine-tuned your solve and the results are still unsatisfactory, go back and refine your feature tracks to try and improve the results.

Troubleshooting Using the Point Cloud

The CameraTracker Point Cloud displays your track points in 3D space from the point of view of the solved camera and is a very useful tool for troubleshooting. You can use it in at least two ways:

- You can play through the sequence and view the feature points as they would be seen by the solved camera. If any feature points seem to slip between frames, they're most likely producing bad results. For more information, see Playing through the Sequence on page 70.
- You can also select some points, create a solid, and use the **Unified Camera Tool** to move around the scene on one frame. If the solid does not look like you'd expect and you can see that one of the points is way off in the distance relative to other points, it's safe to assume that you've found a bad feature point. For more information, see Creating a Solid on page 71.

TIP: You can reduce the Point Cloud size to view more accurate keypoints from the solve by checking **View Keyframe Points Only** on the CameraTracker panel.

Playing through the Sequence

If your footage has elements that are easy to identify in the Point Cloud, simply looking at the tracked points in the 3D view whist playing through the clip can help you locate bad points.

To try this out, once you've created your scene, click **Toggle 2D/3D** in the CameraTracker controls to switch to the 3D View. Make sure that the active camera is the camera created in the scene: **CameraTracker-Camera(1)**. You should now see the Point Cloud from the point of view of the solved camera.

Next, select **Window** > **Preview** to bring up the After Effects play controls. Go to the first frame in your clip and hit the play button. As the Point Cloud moves through the sequence, try to identify the different elements in your footage and keep an eye out for any points that slip. If you see a point that moves to where it shouldn't be, you've located a bad track point.

NOTE: If your footage doesn't have elements that are easy to identify in the Point Cloud (for example, if all the elements in the footage are pretty much the same colour), it may be difficult to see where the points should be and whether they slip. If this is the case, you can try troubleshooting the Point Cloud by creating a solid and using the Unified Camera Tool to move around the scene, as described below.

TIP: You may also be able to spot poor feature points by looking at individual frames and pressing **Tab** repeatedly to switch between the 2D and 3D Views.

Creating a Solid

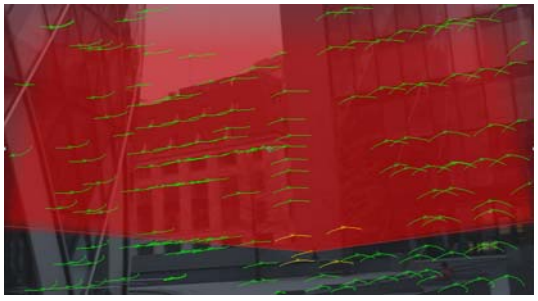
Using **CameraTracker Menu** > **Create** > **Solid** sometimes produces unpredictable results and the Point Cloud is extremely useful to troubleshoot which features are causing the error.

To demonstrate this, let's create an inaccurate solid and use the Point Cloud to fine-tune the result. Bear in mind that the points selected in this example are purposefully inadequate—in reality you wouldn't select these points to create a solid.

Figure 4.6 shows the points selected from the scene created by CameraTracker.

Figure 4.6: Five points selected to produce a bad solid.

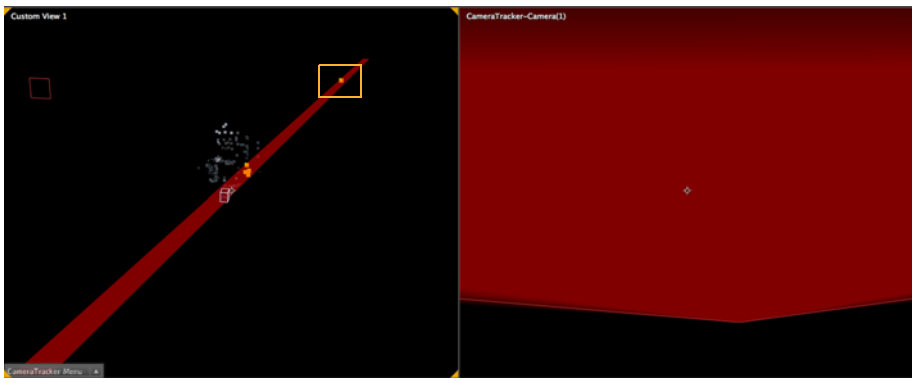
The points in Figure 4.6 produce the following solid in After Effects.



As you can see, the solid is enormous and not what you would expect from good point selection. To troubleshoot the solid using the Point Cloud, do the following:

1. Switch the viewer to **2 Views - Horizontal** and select **Custom View 1** in the left panel (see "Creating a Solve" on page 29 for more information).
2. Navigate to **CameraTracker Menu** > **Switch Mode 2D/3D** or press **Tab** to toggle between 2D and 3D.

   In **Custom View 1**, you can see immediately that one of the points selected is way off in the distance relative to the other 4 points.



3. Use the **Unified Camera Tool** to move around the scene in order to locate the spurious point. The most informative view of the Point Cloud in this example is directly in front and slightly above the scene. See Figure 4.7 on page 73.

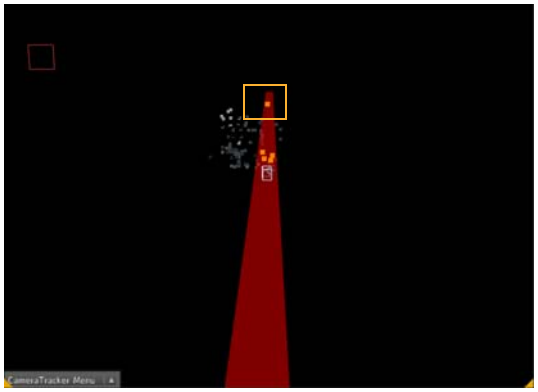
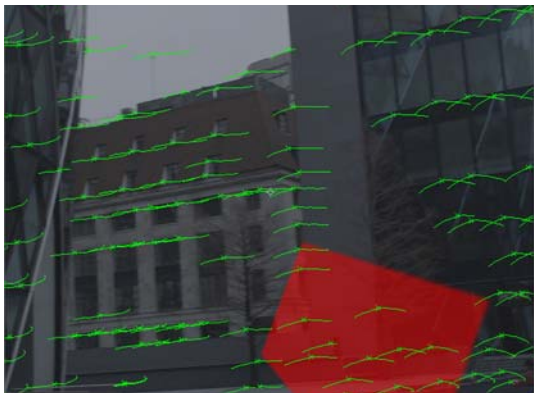


Figure 4.7: Selected points viewed from the solved camera.

In this example, the bad point is clearly the track that follows the moving figure in the centre of the selected points.

4. Deselect the bad point in the 3D View and recreate the solid without that point to improve the solid.



Admittedly, the new solid is still pretty bad—repeat the Point Cloud troubleshooting steps as many times as required to produce a good solid.

NOTE: In the above example, the solid looked wrong but wasn't moving around over the course of time. If you create a solid and see that it's moving around in a way it shouldn't be, you've probably got a bad track rather than just a bad solve or scene. Try troubleshooting the track. If only a few tracks slip, you can delete those tracks and/or use **Toggle Verified Track** to give precedence to tracks that you know are good. Then, solve your footage again. If a lot of tracks slip, you may want to go right back to the beginning, adjust the tracking parameters and/or add a matte, and retrack the footage.

TIP: In addition to creating solids, you can also create null objects to troubleshoot your tracks and solves.

5 TUTORIALS

Introduction

Welcome to CameraTracker Tutorials! If you've reviewed the previous chapters in this guide—which we highly recommend—you already know something about CameraTracker's capabilities. These tutorials show how to pull everything together through a series of practical examples.

NOTE: These tutorials assume that you are reasonably familiar with the After Effects interface and basic compositing theory.

The Projects

- Tutorial 1: Setting a Ground Plane—an example of setting a ground plane badly, then using the Point Cloud to correct the problem.
- Tutorial 2: Adding an Object to a Layer—a basic run through of creating a text banner in the 3D scene.
- Tutorial 3: Correcting a Troublesome Solve—some simple troubleshooting steps designed to help you correct difficult solves.

Example Images

Before you continue, download the tutorial files from The Foundry web site http://www.thefoundry.co.uk and move them to a directory you'll create, called "CameraTracker_Tutorials".

NOTE: You may need to unzip the files before you can use them.

It's up to you where you put the tutorial files, but bear in mind that you'll need them during these tutorials.

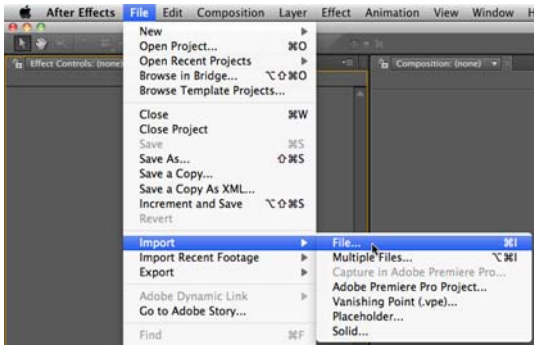
Tutorial 1: Setting a Ground Plane

In this tutorial, we'll select some points in our layer to create a Ground Plane, examine the points using the Point Cloud, and refine the selection to improve the final results.

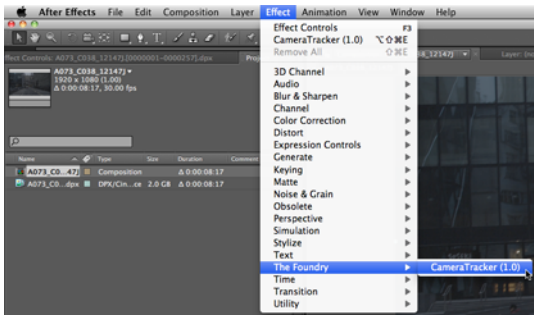
Preparing the Workspace

First, you'll set up the workspace and apply CameraTracker as an effect on a layer:

1. Launch After Effects as normal and navigate to **File** > **Import** > **File**.



2. Navigate to the folder containing the tutorial files and open the **Tutorial1_01.jpg** file (After Effects imports the entire contents of the folder automatically).
3. Drag and drop the content from the **Project** tab to the **Viewer** and click the image to select the layer.
4. Navigate to **Effect** > **The Foundry** > **CameraTracker**.



5. The CameraTracker panel displays in the **Effect Controls** window.

The next step is to track features within the layer, create a solve, and place the solved camera within the layer. For the purpose of these tutorials, we'll use the default settings for tracking, solving, and creating a scene, simply because they work well with the sample images provided.

6. On the CameraTracker panel, click **Track Features**, or navigate to **CameraTracker Menu** > **Actions** > **Track Features** in the Viewer.

NOTE: The layer used in this tutorial should track quickly due to its simplicity.

7. When the track phase completes, click **Solve Camera**, or navigate to **CameraTracker Menu** > **Actions** > **Solve Camera** in the Viewer.
8. Click **Create Scene**, or navigate to **CameraTracker Menu** > **Actions** > **Create Scene** in the Viewer.

Once you've created a virtual 3D camera in your layer, you're ready to select some track points and create a Ground Plane.

The first step when preparing to select Ground Plane points is to get a good feel for the layer that you intend to use. Play through the layer in 2D and 3D using the Point Cloud and try to locate points that:

- appear to be on the correct plane or 'ground' in the layer.
- are as consistent as possible throughout the layer.
- have minimal solve reprojection errors per frame.

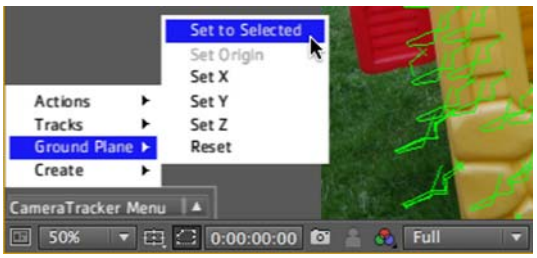
For the purposes of this tutorial, we'll marquee a broad selection to start with, then refine the selection using the Point Cloud.

1. Drag a marquee over some points around the lawn area shown in Figure 5.1. Don't worry if your points are not exactly the same as the ones illustrated—some of these points are purposefully poor.

Figure 5.1: Sample tracking points.

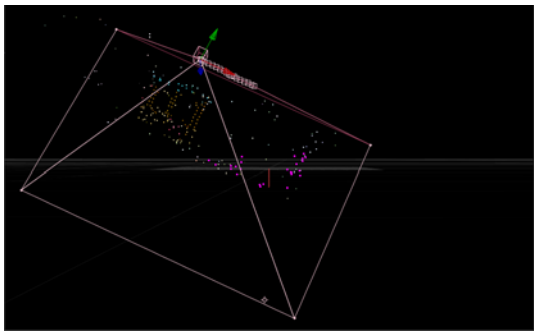
2. Navigate to **CameraTracker Menu** > **Ground Plane** > **Set to Selected**.

NOTE: You may notice that CameraTracker Menu selections can be slow, especially on **Windows** platforms. To avoid this, try holding down the left mouse button in the menu, locating the option you require and releasing to complete the selection.



3. CameraTracker highlights the points that you selected to represent the Ground Plane and shows the new position of the Null associated with the solved camera.

4. Switch to the 3D Point Cloud using **Custom View 1** and activate the Unified Camera Tool by pressing **C** on your keyboard.
5. Select the **CameraTracker-Camera(1)** layer in your composition and move around the scene to view the new Ground Plane. If you align the Null vertically and the grid horizontally, you should see a camera view similar to that shown below.



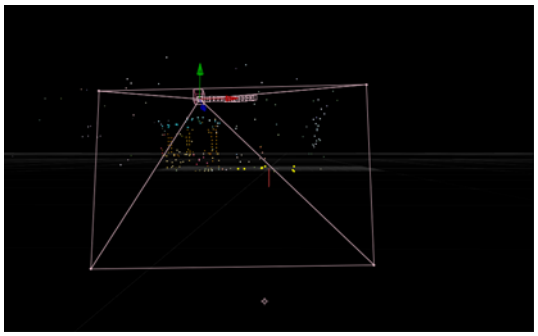
You can tell immediately that the camera view point is severely skewed and the yellow and blue points that represent the Wendy House are positioned at an unnatural angle.

The points producing the skew are most likely those located in the right of the shot, so let's remove those and see if the results improve.

6. Navigate to **CameraTracker Menu** > **Ground Plane** > **Reset**.
7. Reselect your points, excluding those positioned in the bushes, and on the slide, and set the Ground Plane.

8. Switch to the Point Cloud and move around the scene to check your points.

   Again, align the Null vertically and the grid horizontally, you should see a camera view similar to that shown below.



   A great improvement on the original Ground Plane. From here you can experiment by adding and removing points to produce the best results.

Of course, you don't have to use Ground Planes to represent 'the ground' in your scene. If your composition calls for a lot of vertical positioning, why not set your Ground Plane on the side of a building or even the ceiling of a room?

Tutorial 2: Adding an Object to a Layer

In this tutorial, we'll be adding an object to the 3D scene along the path of the camera. The result won't be pretty, that's up to you to refine, but it should give you a feel for working within a 3D scene.

First, you'll set up the workspace as described in Preparing the Workspace on page 76, but in step 2 import the **Tutorial2_01.jpg** files instead.

Once you've created a virtual 3D camera in your layer, you're ready to add objects to the scene.

Creating a Reference Solid

Creating a solid as a reference point in CameraTracker is an excellent starting point before placing other objects within a composition. Solids created in this way are automatically aligned with the tracked features you select.

The first task is to locate likely features to fix the object to in 3D space. The Point Cloud is very useful for checking tracked points within the composition.

1. Play through the composition in 2D and 3D mode a couple of times to get a feel for the tracked features. Try to select points that are consistent throughout the layer.
2. The two points we're going to use to position our solid are shown below in both 2D and 3D space. Select the points by holding **Shift** and clicking each point.

Figure 5.2: Tracked points in 2D space

Figure 5.3: The same 2 points in 3D space using the Point Cloud.

NOTE: The red rectangle in the images represents the Null associated with the solved camera.

3. Navigate to **CameraTracker Menu** > **Create** > **Solid** to produce a default solid using the two points we selected.

NOTE: You may notice that CameraTracker Menu selections can be slow, especially on **Windows** platforms. To avoid this, try holding down the left mouse button in the menu, locating the option you require, and releasing to complete the selection.

4. Adjust the solid so that the edges are aligned with the pillar in the scene.

   You can use the X, Y, and Z handles (the coloured arrows) to determine the correct positioning of the solid.

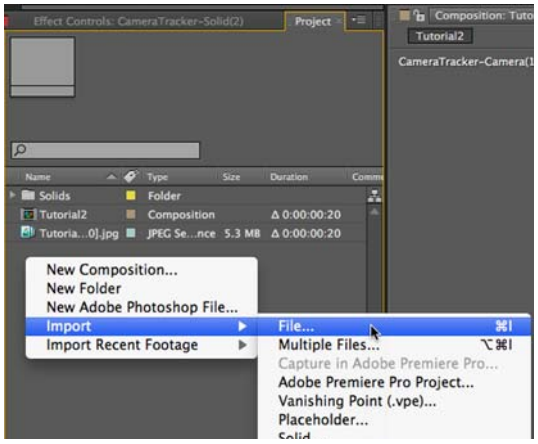
NOTE: Use **Transform** > **Y Rotation** in this case, though in other circumstances you'll probably need the other Transform tools as well.

5. Play through the composition and check that the solid doesn't slip between frames. In this example, the solid is pretty good so you won't need to make any adjustments.

Importing and Placing an Object

Now that you have a solid reference point, we can import and place an object using the solid as a guide.

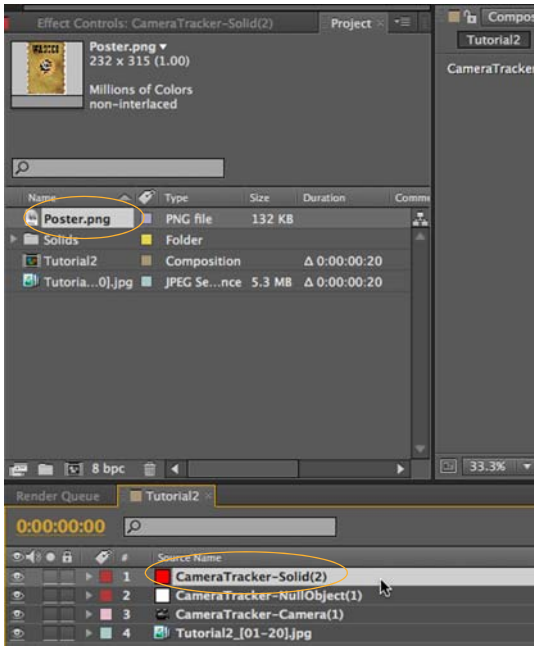
1. Right-click in the **Project** tab and select **Import** > **File**.



2. You can import any file in to your composition, but for the purposes of this tutorial, import the **Poster.png** image supplied with the **Tutorial2** files.

   Next, we'll use a handy After Effects hotkey to swap the imported object for the reference solid.

3. Select the **Poster.png** object and the **CameraTracker-Solid(2)** layer in the composition.



4. Press **cmd** (or **ctrl** on Windows) + **alt /** to swap the object and the solid,

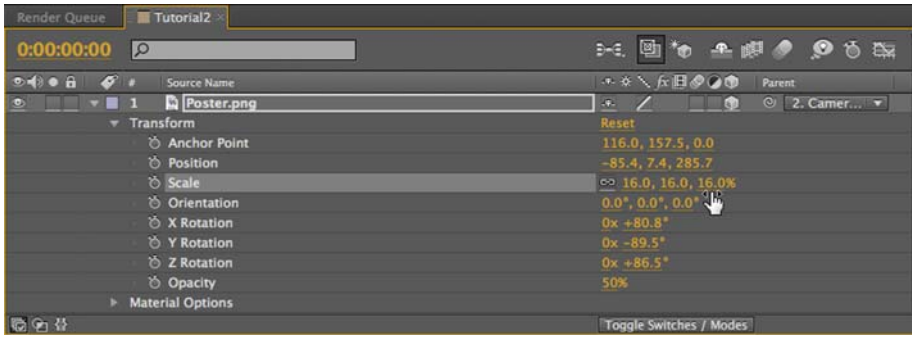
   OR

   Hold **alt** then click and drag **Poster.png** over the **CameraTracker-Solid(2)** layer in the composition.

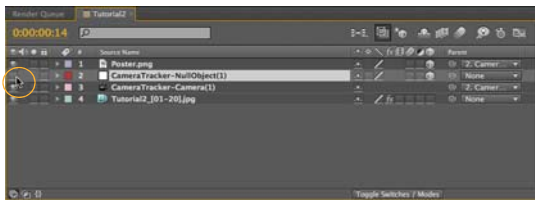
   The object is placed on the plane that the solid occupied, but as you can see, the rotation and scale need some work.

5. Open up the **Poster.png** layer **Transform** controls in the composition.
6. Use the **Scale** and **Rotation** controls to position the object so that it appears on the pillar.

   You should find that settings similar to those shown will position the poster nicely.



7. Finally, click the 'eye' icon to turn off the Null layer to clean up the final result.



Play through the composition to check that your final result produces no slippage, and we're done!

Tutorial 3: Correcting a Troublesome Solve

Tracking and solving a camera isn't always as simple as clicking three CameraTracker buttons. At some stage in your career using CameraTracker, you'll come across a scene that requires some fine-tuning to produce a usable result. In this tutorial, we'll track a layer that won't solve and then run through some steps to correct it.

First, you'll set up the workspace as described in Preparing the Workspace on page 76, but in step 2 import the **Tutorial3_01.jpg** tutorial files instead.

1. The CameraTracker panel displays in the **Effect Controls Window** (ECW).

2. We'll start off with the default **Tracking** and **Solve** parameters—on the CameraTracker panel, click **Track Features**, or navigate to **CameraTracker Menu** > **Actions** > **Track Features** in the Viewer.

   You can tell immediately that there is something strange going on in the scene just by looking at the lengthy diagonal tracks across the Viewer.

3. When the track completes, click **Solve Camera**, or navigate to **CameraTracker Menu** > **Actions** > **Solve Camera** in the Viewer.

The solve cannot complete on this sample footage, probably because there are one or two tracks that are throwing out the other features during the solve.

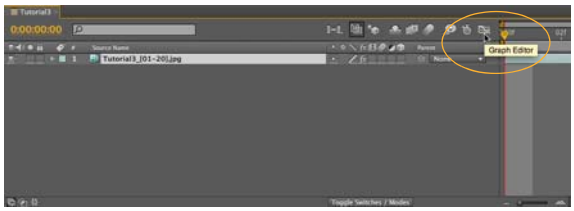
There are a number of ways we can fix the solve and improve the results, the most common being locating and covering the area where the tracks originate with a matte or finding and removing bad tracks. The method you choose will largely depend on the time you have available—searching through track data to locate bad feature points can be time consuming.

Using a Matte to Hide Bad Tracks

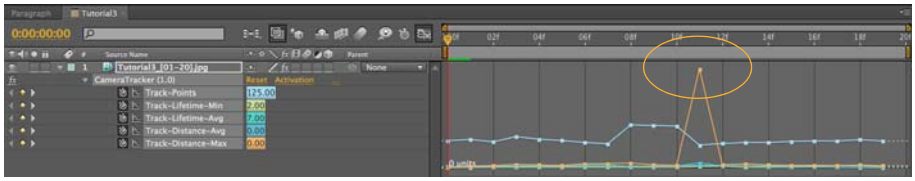
Using a matte to cover areas where you know the track data is bad is a quick fix, but can reduce the accuracy of solve data. You could use this method if you're short of time or patience!

The first thing to do is view the track statistics for the composition:

1. Click the Graph Editor toggle in After Effects.



2. Select your composition and press the After Effects hotkey **U** to display all the statistics associated with that layer.



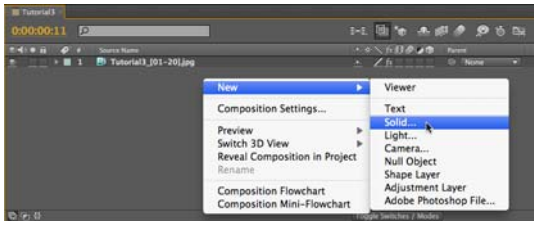
If you examine the results, you should see at frame 11 a large spike in the **Track Distance - Max**.

3. Advance the playhead to frame 11 to view the tracked features.

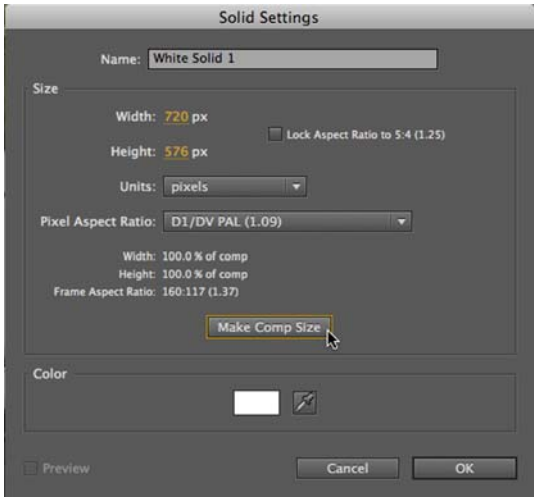
Looking at the top of the composition, in the centre of the frame, you can see a group of three extremely long tracks. These are most likely to blame!

Next, we'll create an animated matte and add it to the composition to cover the area during the tracking phase.

4. Right-click in your composition and select **New** > **Solid** to add a basic shape that we can mould into our matte.



The **Solid Settings** dialog displays.

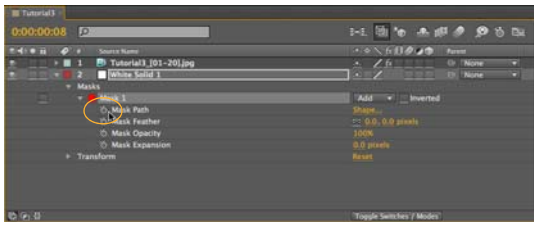


5. Set the colour to white and click **Make Comp Size** so that the solid fills the screen.
6. Click **OK** to add the solid to the composition.
7. By default, the solid is placed at the top layer of the composition, so drag and drop it under the **Tutorial3_01.jpg** layer.
8. Next, select the **Pen Tool** or press **G** on your keyboard.
9. Move the playhead to frame 14 and draw a rough matte shape where you think the faulty tracks are seeded. Something like this should be OK:

NOTE: We've chosen a red outline for ease of illustration—the default After Effects colour is yellow.

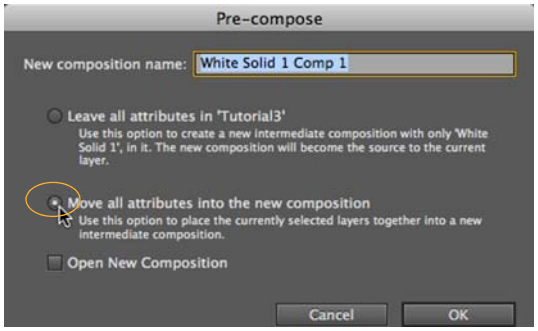
In reality, you would probably not want to matte such a large area throughout the scene because you would lose a lot of good data along with the bad.

10. Drill down through the **White Solid 1** layer to **Mask Path** and click the stopwatch to place a keyframe.



11. Scrub the playhead to frame 10 and adjust the matte so that it still covers the area shown.

12. Select the **White Solid 1** layer and navigate to **Layer** > **Pre-compose**. The **Pre-Compose** dialog displays.



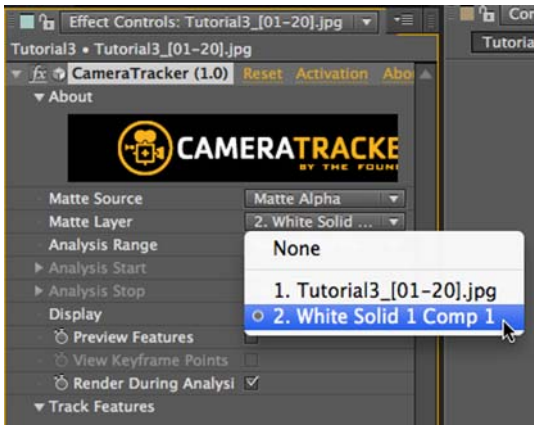
13. Select **Move all attributes into the new composition** and click **OK**.

    Next, we'll tell CameraTracker how to use our matte.

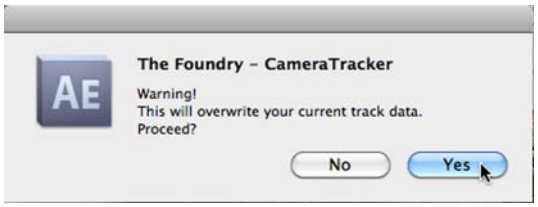
14. Open up the CameraTracker ECW and select **Matte Source** > **Matte Alpha**.

NOTE: We chose Matte Alpha because the matte we created is white. If the matte was black, we would choose Matte Inverted Alpha.

15. Select **Matte Layer** > **White Solid 1 Comp 1**.



16. Click **Track Features** to retrack the layer with the matte in place. Click **Yes** in the warning box.



If you pay close attention, you may be able to see where the matte is stopping tracks from seeding.

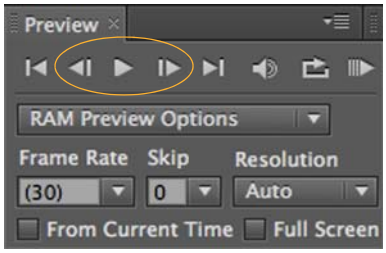
17. When the retrack has completed, check the track statistics again and scrub the playhead to the frame with the highest errors.

    Notice that there are still some long diagonal tracks on frame 11? We should be able to do something about those in the next section.

Locating and Removing Bad Tracks

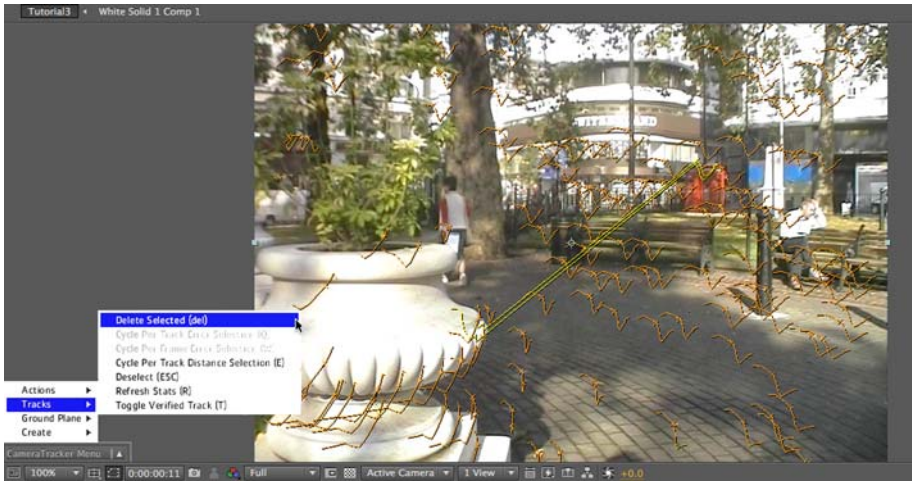
Eliminating bad tracking data is an excellent way to fix a failing solve, if you have the time available. Unlike using mattes, deleting specific tracks doesn't remove good tracks along with the bad.

1. The track statistics did a good job of highlighting frame 11, so we'll start there. Use the **Preview** panel in After Effects to play through the layer frame-by-frame.



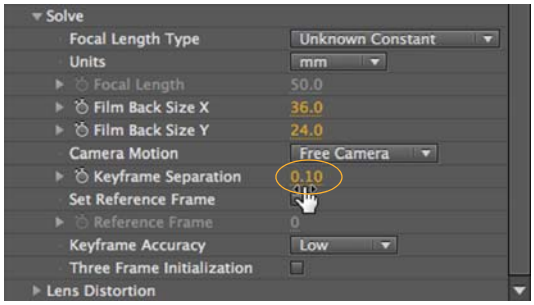
2. Scrub to frame 11 and select the two diagonal tracks as shown. Navigate to **CameraTracker Menu** > **Tracks** > **Delete Selected** or press **delete** on your keyboard.

NOTE: You may find selecting the points easier if you enable **Allow Line Selection** on the ECW.



Scrub through the layer and make sure there are no more obviously bad tracks.

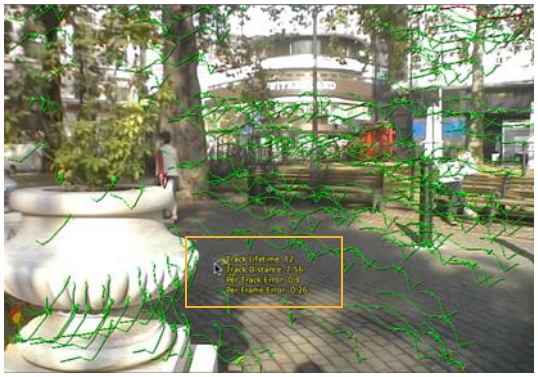
3. Refresh the track statistics by navigating to **CameraTracker Menu** > **Tracks** > **Refresh Stats**. Notice that the error peak at frame 11 has been smoothed out?
4. As a final precaution, we'll reduce the **Keyframe Separation** to 0.10 as shown.



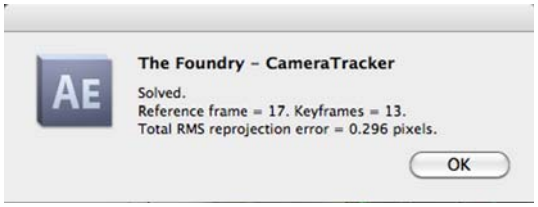
5. Click **Solve Camera** to attempt the solve again.

   The solve should complete with a similar reprojection error to that shown below.

6. Click **OK** to view the solved tracks. You can use the track finder to examine the reprojection errors of individual tracks. See Examining Your Feature Tracks on page 56 for more information.



NOTE: You may notice that CameraTracker has rejected a couple of tracks. When this occurs, you cannot view reprojection errors for these tracks.



A total RMS reprojection error of 0.296 is pretty respectable, but feel free to play around with the track and solve settings as much as you like!

The real test of accuracy for any solve and scene is to add objects to your composition and verify that they don't slip from frame to frame. Try adding the poster from Tutorial 2 to this scene to really show how the refined solve

works.

APPENDIX A: RELEASE NOTES

Release Notes for CameraTracker

This appendix describes the requirements, new features, improvements over previous versions, fixed bugs, and known bugs and workarounds in CameraTracker.

1.0v7

Requirements

1. Either:
   - After Effects CS6 on Mac OS X 10.6.8, 10.7, or 10.8 64-bit, or
   - After Effects CS6 on Windows 7 64-bit, or
   - After Effects CS5 or CS5.5 on Mac OS X 10.5.8 or 10.6 64-bit, or
   - After Effects CS5 or CS5.5 on Windows 7 64-bit.
2. Foundry Licensing Tools (FLT 7.0v1 or later) for floating licences.

Release Date

April 2013

New Features

There are no new features in this release.

Feature Enhancements

CameraTracker for After Effects is now supported on Mac OS X 10.8 (Mountain Lion).

Fixed Bugs

BUG ID 35285 – Playing through a sequence in 3D mode caused CameraTracker to crash on the second play through if the tracked sequence was shorter than the total length of the composition.

Known Issues and Workarounds

- Tracking with **Render During Analysis** enabled may be interrupted by After Effects events such as **Autosave**, and when switching away to another application and back again. If you are tracking a long layer, or are planning on switching away during the track, disable **Render During Analysis**.

- Differences between the frame rate of the composition and imported footage can produce unreliable feature track data.

  To avoid this issue, ensure that the overall frame rate of your composition is identical to the layer containing the footage you intend to track.
- BUG ID 11088 - Menus can't be tied to right click events in the Viewer.

  Use the **CameraTracker Menu** in the viewer or **cmd/ctrl** click to access the menu.
- BUG ID 12298 - Pressing the **Cancel** button during the **Solve Camera** or **Create Scene** phases does not halt the process.
- BUG ID 12975 - Transforming the Null Object parent associated with the CameraTracker camera doesn't automatically update the Point Cloud if you're using an After Effects **Custom View**.

  To force the Null to update, manipulate the camera in the Viewer using the **Unified Camera Tool**.
- BUG ID 12302 - Overlay handles are drawn offset from subset masks.

  To avoid this, precomp your mask in a composition of the same resolution as the current one.
- BUG ID 13979 - Viewing the Point Cloud using the After Effects preset views (Top, Left, Right, etc.) does not produce the correct interpretation of points.

  To avoid this, use the Custom View options and pan the camera around the scene using the Unified Camera Tool.
- BUG ID 33236 - On Mac OS X 10.6 (Snow Leopard), with a dual monitor setup and **mirror displays** enabled, the CameraTracker **About** dialog causes After Effects to become unresponsive.

1.0v6

Requirements

1. Either:
   - After Effects CS6 on Mac OS X 10.6.8 or 10.7 64-bit, or
   - After Effects CS6 on Windows 7 64-bit, or
   - After Effects CS5 or CS5.5 on Mac OS X 10.5.8 or 10.6 64-bit, or
   - After Effects CS5 or CS5.5 on Windows 7 64-bit.
2. Foundry Licensing Tools (FLT 7.0v1 or later) for floating licences.

Release Date

January 2013

New Features

There are no new features in this release.

Feature Enhancements

There are no enhancements to existing features in this release.

Fixed Bugs

BUG ID 33080 – On Mac OS X 10.6 (Snow Leopard), clicking the CameraTracker **About** button crashed After Effects.

1.0v5

Requirements

1. Either:
   - After Effects CS6 on Mac OS X 10.6.8 or 10.7 64-bit, or
   - After Effects CS6 on Windows 7 64-bit, or
   - After Effects CS5 or CS5.5 on Mac OS X 10.5.8 or 10.6 64-bit, or
   - After Effects CS5 or CS5.5 on Windows 7 64-bit.
2. Foundry Licensing Tools (FLT 7.0v1 or later) for floating licences.

Release Date

December 2012

New Features

There are no new features in this release.

Feature Enhancements

There are no enhancements to existing features in this release.

Fixed Bugs

BUG ID 31947 – On After Effects CS6, point cloud data disappeared in custom views. To get this working correctly, you need to install both CameraTracker 1.0v5 and the latest update (11.0.2) to After Effects CS6.

Known Issues and Workarounds

- Tracking with **Render During Analysis** enabled may be interrupted by After Effects events such as **Autosave**, and when switching away to another application and back again. If you are tracking a long layer, or are planning on switching away during the track, disable **Render During Analysis**.
- Differences between the frame rate of the composition and imported footage can produce unreliable feature track data.

  To avoid this issue, ensure that the overall frame rate of your composition is identical to the layer containing the footage you intend to track.
- BUG ID 11088 – Menus can't be tied to right click events in the Viewer.

  Use the **CameraTracker Menu** in the viewer or **cmd/ctrl** click to access the menu.
- BUG ID 12298 – Pressing the **Cancel** button during the **Solve Camera** or **Create Scene** phases does not halt the process.
- BUG ID 12975 – Transforming the Null Object parent associated with the CameraTracker camera doesn't automatically update the Point Cloud if you're using an After Effects **Custom View**.

To force the Null to update, manipulate the camera in the Viewer using the **Unified Camera Tool**.

- BUG ID 12302 - Overlay handles are drawn offset from subset masks.
  To avoid this, precomp your mask in a composition of the same resolution as the current one.
- BUG ID 13979 - Viewing the Point Cloud using the After Effects preset views (Top, Left, Right, etc.) does not produce the correct interpretation of points.
  To avoid this, use the Custom View options and pan the camera around the scene using the Unified Camera Tool.

1.0v4

Requirements

1. Either:
   - After Effects CS6 on Mac OS X 10.6.8 or 10.7 64-bit, or
   - After Effects CS6 on Windows 7 64-bit, or
   - After Effects CS5 or CS5.5 on Mac OS X 10.5.8 or 10.6 64-bit, or
   - After Effects CS5 or CS5.5 on Windows 7 64-bit.
2. Foundry Licensing Tools (FLT 7.0v1 or later) for floating licences.

Release Date

July 2012

New Features

There are no new features in this release.

Feature Enhancements

Added support for After Effects CS6.

Fixed Bugs

BUG ID 14901 – Clicking **Track Feature** caused After Effects to crash if **Render During Analysis** was disabled or **Fast Previews** was set to **OpenGL – Always On**.

Known Issues and Workarounds

- Tracking with **Render During Analysis** enabled may be interrupted by After Effects events such as **Autosave**, and when switching away to another application and back again. If you are tracking a long layer, or are planning on switching away during the track, disable **Render During Analysis**.
- Differences between the frame rate of the composition and imported footage can produce unreliable feature track data.

  To avoid this issue, ensure that the overall frame rate of your composition is identical to the layer containing the footage you intend to track.
- BUG ID 11088 – Menus can't be tied to right click events in the Viewer.

  Use the **CameraTracker Menu** in the viewer or **cmd/ctrl** click to access the menu.
- BUG ID 12298 – Pressing the **Cancel** button during the **Solve Camera** or **Create Scene** phases does not halt the process.
- BUG ID 12975 – Transforming the Null Object parent associated with the CameraTracker camera doesn't automatically update the Point Cloud if you're using an After Effects **Custom View**.

To force the Null to update, manipulate the camera in the Viewer using the **Unified Camera Tool**.

- BUG ID 12302 - Overlay handles are drawn offset from subset masks.

  To avoid this, precomp your mask in a composition of the same resolution as the current one.
- BUG ID 13979 - Viewing the Point Cloud using the After Effects preset views (Top, Left, Right, etc.) does not produce the correct interpretation of points.

  To avoid this, use the Custom View options and pan the camera around the scene using the Unified Camera Tool.

1.0v3

Requirements

1. Either:
   - After Effects CS5 or CS5.5 on Mac OS X 10.5.8 (or later) 64-bit, or
   - After Effects CS5 or CS5.5 on Windows 7 64-bit, or
   - After Effects CS4 on Mac OS X 10.5.8 (or later) 32-bit, or
   - After Effects CS4 on Windows XP 32-bit.
2. Foundry FLEXlm Tools (FFT 5.0v1 or later) for floating licences.

Release Date

May 2011

New Features

There are no new features in this release.

Feature Enhancements

Added support for After Effects CS5.5.

Fixed Bugs

There are no bug fixes in this release.

Known Issues and Workarounds

- Tracking with **Render During Analysis** enabled may be interrupted by After Effects events such as **Autosave**, and when switching away to another application and back again. If you are tracking a long layer, or are planning on switching away during the track, disable **Render During Analysis**.
- Differences between the frame rate of the composition and imported footage can produce unreliable feature track data.

  To avoid this issue, ensure that the overall frame rate of your composition is identical to the layer containing the footage you intend to track.
- BUG ID 11088 – Menus can't be tied to right click events in the Viewer.

  Use the **CameraTracker Menu** in the viewer or **cmd/ctrl** click to access the menu.
- BUG ID 12298 – Pressing the **Cancel** button during the **Solve Camera** or **Create Scene** phases does not halt the process.
- BUG ID 12975 – Transforming the Null Object parent associated with the CameraTracker camera doesn't automatically update the Point Cloud if you're using an After Effects **Custom View**.

To force the Null to update, manipulate the camera in the Viewer using the **Unified Camera Tool**.

- BUG ID 12302 - Overlay handles are drawn offset from subset masks.

  To avoid this, precomp your mask in a composition of the same resolution as the current one.
- BUG ID 13979 - Viewing the Point Cloud using the After Effects preset views (Top, Left, Right, etc.) does not produce the correct interpretation of points.

  To avoid this, use the Custom View options and pan the camera around the scene using the Unified Camera Tool.

1.0v2

Requirements

1. Either:
   - After Effects CS5 on Mac OS X 10.5.8 (or later) 64-bit, or
   - After Effects CS5 on Windows 7 64-bit, or
   - After Effects CS4 on Mac OS X 10.5.8 (or later) 32-bit, or
   - After Effects CS4 on Windows XP 32-bit.
2. Foundry FLEXlm Tools (FFT 5.0v1 or later) for floating licences.

Release Date

October 2010

New Features

CameraTracker is now available on After Effects CS4 for Mac OS X 10.5 32-bit.

Feature Enhancements

- BUG ID 13270 - The generation of post solving statistics now has a progress bar because the creation of **Refine** statistics after long tracking functions seemed to cause After Effects to hang.

Fixed Bugs

- BUG ID 13008 - Creating a Ground Plane using the **Set to Selected** shortcut (**A**) caused After Effects to crash intermittently due to an underlying issue with setting After Effects cameras during certain events.

  Unfortunately, we have had to remove this hotkey to prevent crashes.
- BUG ID 13045 - Copy/Pasting layers between compositions was causing an After Effects error message to display, even though the function was completed.
- BUG ID 13137 - Tracking statistics in the **Refine** menu were not being reset when a new work area was created.
- BUG ID 13138 - Using **Delete unsolved** in the **Refine** settings deleted all points if you hadn't solved the camera.
- BUG ID 13202 - It was not possible to select/deselect points in the 3D Point Cloud on footage with non-square pixel aspect ratios.
- BUG ID 13203 - Solid and null creation on 3D points was being offset on footage with non-square pixel aspect ratios.
- BUG ID 13212 - Saving a project between the **Solve Camera** and **Create Scene** phases caused any input **Lens Distortion** values to reset to default.

- BUG ID 13213 - Transferring projects between OS X and Windows, and vice-versa, was occasionally causing parameters to reset or read incorrectly.
- BUG ID 13304 - Selecting **Known Lens** in the **Lens Distortion** settings caused failing solves to produce a blank error message.
- BUG ID 13964 - When the frame rate of a clip was set to a non-integer value (for example 29.97), features occasionally tracked on the wrong frame range.

Known Issues and Workarounds

- Tracking with **Render During Analysis** enabled may be interrupted by After Effects events such as **Autosave**, and when switching away to another application and back again. If you are tracking a long layer, or are planning on switching away during the track, disable **Render During Analysis**.
- Differences between the frame rate of the composition and imported footage can produce unreliable feature track data.

  To avoid this issue, ensure that the overall frame rate of your composition is identical to the layer containing the footage you intend to track.
- BUG ID 11088 - Menus can't be tied to right click events in the Viewer.

  Use the **CameraTracker Menu** in the viewer or **cmd/ctrl** click to access the menu.
- BUG ID 12298 - Pressing the **Cancel** button during the **Solve Camera** or **Create Scene** phases does not halt the process.
- BUG ID 12975 - Transforming the Null Object parent associated with the CameraTracker camera doesn't automatically update the Point Cloud if you're using an After Effects **Custom View**.

  To force the Null to update, manipulate the camera in the Viewer using the **Unified Camera Tool**.
- BUG ID 12302 - Overlay handles are drawn offset from subset masks.

  To avoid this, precomp your mask in a composition of the same resolution as the current one.
- BUG ID 13979 - Viewing the Point Cloud using the After Effects preset views (Top, Left, Right, etc.) does not produce the correct interpretation of points.

  To avoid this, use the **Custom View** options and pan the camera around the scene using the Unified Camera Tool.

1.0v1

This is the first release for CameraTracker on After Effects.

Requirements

1. Either:
   - After Effects CS5 on Windows 7 64-bit or,
   - After Effects CS5 on Mac OS X 10.5.8 (or later) 64-bit.
2. Foundry FLEXlm Tools (FFT 5.0v1 or later) for floating licences.

Release Date

10 August 2010

New Features

This section will describe new features in later releases.

Feature Improvements

This section will describe feature improvements in later releases.

Fixed Bugs

This section will describe fixed bugs in later releases.

APPENDIX B: THIRD-PARTY LICENCES

Third-Party Licences

This appendix lists third party libraries used in CameraTracker, along with their licences.

Library	Description	Licence
Boost	Source code function / template library	Boost Software Licence - Version 1.0 - August 17th, 2003 Permission is hereby granted, free of charge, to any person or organisation obtaining a copy of the software and accompanying documentation covered by this licence (the "Software") to use, reproduce, display, distribute, execute, and transmit the Software, and to prepare derivative works of the Software, and to permit third-parties to whom the Software is furnished to do so, all subject to the following: The copyright notices in the Software and this entire statement, including the above licence grant, this restriction and the following disclaimer, must be included in all copies of the Software, in whole or in part, and all derivative works of the Software, unless such copies or derivative works are solely in the form of machine-executable object code generated by a source language processor. THE SOFTWARE IS PROVIDED "AS IS", WITHOUT WARRANTY OF ANY KIND, EXPRESS OR IMPLIED, INCLUDING BUT NOT LIMITED TO THE WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE, TITLE AND NON-INFRINGEMENT. IN NO EVENT SHALL THE COPYRIGHT HOLDERS OR ANYONE DISTRIBUTING THE SOFTWARE BE LIABLE FOR ANY DAMAGES OR OTHER LIABILITY, WHETHER IN CONTRACT, TORT OR OTHERWISE, ARISING FROM, OUT OF OR IN CONNECTION WITH THE SOFTWARE OR THE USE OR OTHER DEALINGS IN THE SOFTWARE.
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Library	Description	Licence
FreeType	Font support	Portions of this software are copyright © 2008 The FreeType Project (www.freetype.org). All rights reserved.
FTGL	OpenGL support	FTGL - OpenGL font library Copyright © 2001-2004 Henry Maddocks ftgl@opengl.geek.nz Copyright © 2008 Sam Hocevar sam@zoy.org Copyright © 2008 Sean Morrison learner@brlcad.org Permission is hereby granted, free of charge, to any person obtaining a copy of this software and associated documentation files (the "Software"), to deal in the Software without restriction, including without limitation the rights to use, copy, modify, merge, publish, distribute, sublicence, and/or sell copies of the Software, and to permit persons to whom the Software is furnished to do so, subject to the following conditions The above copyright notice and this permission notice shall be included in all copies or substantial portions of the Software. THE SOFTWARE IS PROVIDED "AS IS", WITHOUT WARRANTY OF ANY KIND, EXPRESS OR IMPLIED, INCLUDING BUT NOT LIMITED TO THE WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE AND NONINFRINGEMENT. IN NO EVENT SHALL THE AUTHORS OR COPYRIGHT HOLDERS BE LIABLE FOR ANY CLAIM, DAMAGES OR OTHER LIABILITY, WHETHER IN AN ACTION OF CONTRACT, TORT OR OTHERWISE, ARISING FROM, OUT OF OR IN CONNECTION WITH THE SOFTWARE OR THE USE OR OTHER DEALINGS IN THE SOFTWARE.
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