Comprehensive Guide for Photographing Star Trails

Digital After Dark Blog: www.kadamsphoto.com/nightphotography

Some people consider star trail images to be cliché, but I happen to like well-done clichés. I don't know what it is, but something about those light streaks captures my attention more than most night subjects. But while it's ridiculously simple to make a star-trail photo, it's not so easy to make a *good* one. It takes a lot of planning and execution.

With pinpoint star scenes, we're trying to create an image that replicates what we see in the sky at night. With star trails, on the other hand, the resulting image looks nothing like what we see, but is instead a representation of Earth's rotation. The idea is to set up the camera on a fixed tripod and open the shutter long enough to allow Earth's rotation to cause the stars to record as streaks of light.

Photo 1
Nikon Nikkormat, Nikon 28mm f/2.8 lens, Fujichrome Velvia film, f/4. This is a single 3-hour exposure. You could not do this with a digital camera without recording excessive noise.

If you're having trouble grasping how star trails work, just imagine the stars as fixed points of light in the sky. For all practical purposes they do not move. But Earth does move (rotates), so if you mount a camera on a tripod and shoot a long exposure, the stars record as streaks. It's the same thing as photographing fireworks or any other streak of light, but in reverse. With fireworks, the camera remains still while the light streak moves. With star trails, the light source remains still while the camera moves under it. Both scenarios result in the light recording as streaks.

So the concept is simple. Mount the camera to a tripod, point it at the sky, open the shutter for two or three hours, and you have a star-trail photo. Simple, right? Yep, except for the part about it being simple. Actually, it *is* simple to make a star trail photo. But as I said, making a *good* one requires some work.

The first consideration is that you can't shoot a two- or three-hour exposure. Well, you could, but the resulting image would show nothing but noise. Back in the film days, we could load an ISO (ASA) 100 film in a camera and open the shutter for a few hours, never worrying about how noisy the image would be. Try that with digital and you'll be hitting the delete button when you're finished. If it's very cold outside (heat contributes to noise) and your camera has good noise characteristics, you might be able to get by with a 30-minute or even longer exposure as long as you shoot at a low ISO. But if you want a relatively noise-free image, or one with long star streaks, you're going to have to shoot multiple exposures and stack them. Don't let that scare you; it's really not that difficult.

The Concept of Multiple Exposures

Don't panic! Even if you don't do any post processing of your images, you can do this. Trust me. I'll be going into a lot more detail about stacking layers later on in this article, but for now, I want to explain the basic concept. As stated above, with star trails, it's very hard to shoot a single exposure with digital because of excessive noise. So we shoot a lot of shorter exposures and stack them as layers. This gives us the accumulative effect of the star streaks, while exhibiting only the noise from a single exposure. It's magic!

But there are other advantages as well. One is that we can also shoot multiple exposures for the foreground and stack those in with the star trails. And here's the biggie: We don't have to shoot the foreground in the same exposures with the trails. So we can set up a campsite scene, for instance, and shoot all the exposures we need to get the campfire and tent lighting just right, and then shoot our star trails. Then we stack everything together to create the finished image.

There's a little catch, though. (There had to be, right?) While you can very easily stack your star-trail exposures using free software (more on that later), if you also want to stack foreground layers that you shot separately from the star trails, you'll have to use a software such as Photoshop that has layering capability. And you'll need to learn at least the basics of masking with layers. Fortunately, there is an overwhelming amount of information on the Internet to help you with this.

Lots more to come about layers. For now, just keep in mind that by shooting multiple exposures and stacking them, you have a lot more flexibility with the foreground lighting, regardless of how much post-processing you do.

For those of you who just don't want anything to do with layers and the post-processing side of this, you *can* get by without shooting the foreground separately. You can simply do any light painting desired *during* the same exposures you make for the star trails. The disadvantage of this should be obvious, and that is that you have no margin for error in you light-painting exposures. Whatever you do is going to show up in the finished image.

Gear list

- Camera
- Lens
- Tripod

- Intervalometer
- Lens warmer
- Camera power
- Memory card
- Miscellaneous goodies

Camera. Most cameras work fine for star trails. The camera must allow you to set the aperture, ISO, and shutter speed manually and the shutter must have a "bulb" setting that lets it remain open for as long as you choose. The only other requirement is that it accepts an external programmable shutter release (intervalometer) that plugs into the camera.

Lens. You can use everything from wide-angle to extreme telephoto lenses for star trails, but you'll use wide angles the most. See the section on composition for more about this.

Tripod. Unless you have the ability to handhold a 2-hour exposure rock-steady, you're going to need a tripod. A sturdy tripod. You're going to be leaving the camera set up for hours at a time. Regardless of how calm the wind is when you begin, a sudden gust could topple a flimsy tripod. A strong heavy tripod is also good insurance against accidental bumping from a night photographer's bumbling feet. Don't laugh; you wouldn't believe how many times I've bumped my tripod when shooting at night.

Intervalometer. You need the ability to program the camera for shooting continuous exposures up to several minutes long. Many cameras have programmable timers built into the menu system, but as far as I know, none of them will allow shutter speeds longer than 30 seconds. For Nikon shooters with cameras having a 10-pin port, you want the MC-36A or one of the much cheaper knockoffs. For Canon shooters, it's the TC-80N3. Read the supplemental document "Intervalometers and Shutter Releases" for more information.

Lens warmer. Yes, I said *lens warmer*! If you've shot many star trails or nighttime time lapses, you've undoubtedly experience the problem of dew or frost forming on your lens. It's an unfortunate fact of a night photographer's life. There are several methods for combatting dew, but only two of them really get the job done and only one of them is practical for any shooting scenario. If you're shooting close to the car, you can use battery-powered heater strips that wrap around the lens and keep it warmed above the dew point. In my opinion, the most practical solution is to use hand warmer packs to heat the lens. Read the supplemental document "Dealing with Dew" for more information.

Camera power. For most of us, this is not the issue that as it used to be. When I was shooting star trails with my Nikon D200 and then the D700, I was lucky to get two hours on a single battery charge. I had an electrical engineer friend make a special adapter that allowed me to power the camera using a 12-volt battery so I could go as long as I wanted. Now that I use the Nikon D800, I have no need for external power. On a single D800 battery charge, I can go nearly four hours, which is plenty long enough for star trails.

I recommend that you test your battery to see how long it will last for a star-trail sequence. First, make sure it is fully charged. Then set the camera to shoot continuous four-minute exposures, which is a typical shutter speed for star trails. You'll need the programmable timer for this. Make sure you test all of your batteries, as they probably won't all be the same unless they're brand new. And don't do the test by simply opening the shutter on bulb and leaving it open until the battery dies. For the test to be accurate, it must duplicate the operations of a star-trail capture, which involves closing the shutter after each shot, writing to the memory card, and opening the shutter for the next one.

Once you know how long the battery will power the camera, it's a good idea to write the time on the battery using a Sharpie pen. That way, you can pick the strongest battery you have and you'll know just how long it will last for each outing. And since batteries lose capacity over time, you should test them every six months or so.

If your camera battery won't power the camera long enough to give you the length of trails you want, you have two options. Maybe. For some cameras, there may be other power options offered by the manufacturer or third

parties that will give you more juice. The options are so varied that I've stopped trying to keep up with it all. You'll just need to do some research for your camera.

The second option isn't something I recommend, and that is to switch out batteries during the star trail capture. Even if you're really fast, it's going to take at least three or four seconds to turn off the camera and intervalometer, switch batteries, and then turn the camera and intervalometer back on. And you have to turn the camera and intervalometer off before you switch out the batteries or you could screw up their minds. (They are computers, after all.) A three-second gap between star trails is going to show up in the photo and the gap-filling technique I discuss later on won't help.

The supplemental document "Powering the Camera at Night" provides more detail about keeping the camera juiced up.

Memory card. I'm often asked if you need a fast memory card for shooting star trails, so that the camera can write all those exposure to the card quickly enough. Actually, it's even less of an issue than in other types of photography. The camera only needs to write *one* exposure to the card between exposures of at least 30 seconds. If a memory card couldn't handle that, you wouldn't be able to take pictures of anything and there would be no need for a camera to have the ability to shoot multiple frames per second. For star trails and most time lapses, the internal buffer in your camera is more than enough for even the slowest memory card.

Miscellaneous goodies. As with any night photo, there are lots of other types of gear you might utilize in the shoot. Light painting gear, alarm clocks, warm clothing, flashlights for focusing on foregrounds, black cloths for shooting dark frames (more on that later), headlamps or night vision hats for setting your gear in the dark, etc., etc. But the items listed above are the only ones you *have* to have. (Okay, you *could* get by without an interval timer, but with most cameras the longest shutter speed you can shoot is 30 seconds and the maximum number of exposures you can shoot continuously is 100. And you *could* get by without a lens warmer, but if dew forms on the lens, the photo is ruined.)

Composition

The positions of the stars will vary depending on the direction and time of year you shoot, but once they streak into star trails, they pretty much all look the same. A photo that shows nothing but star trails might look cool at first glance, but it will quickly become boring. You need something beside the star trails for the image to be successful. The elements you include in the foreground will determine the image's success more than anything else.

Foregrounds can be a silhouettes or lighted objects, or combinations of both. Graphic objects that project in the sky work well as silhouettes—trees, lighthouse, bridges, interesting rooflines, and towers are good choices. For a lighted foreground, almost anything is a good candidate. I like to use campsite scenes, waterfalls, and old barns and cabins. The radio telescope in **Photo 2** makes an excellent foreground.

The foreground and its lighting determine how much of the sky you include in the composition. If it's a distant mountain range for instance, without anything lighted in the foreground, you'll probably want to compose so that only a narrow line of the mountains are at the bottom, with star trails taking up most of the frame. You don't want a big blob of black nothingness occupying a large portion of the composition. If, on the other hand, you are light painting an object in the foreground, you can include less sky and more foreground.

Star trails make very strong compositional elements, so you don't need to fill the frame with them for a successful image. Compose the scene as you normally would and let the star trails fall as they may. An exception to this is when you want circular trails, as discussed below.

Ideally, you'll want to set up the composition before it gets dark so you can make sure everything is fine-tuned and in focus. If you do this, be sure to pay attention to the elements that you won't be light painting and make sure any black areas will complement the scene rather than detract from it. Remember, a little black can be a good thing. A big blob of black nothingness…not so much.

Photo 2

Nikon D700, Nikon 17-35 mm f/2.8 lens, f/4, ISO 400, 41 3-minute exposures.
Light painted the tower in one of the exposures with a flashlight and light red gel filter.

The Shape of Star Trails

A question I hear often when I show star trail photos is, “Why are the lines going in different directions?” Good question. Star trail lines are not always in the same direction because, in effect, those lines orbit a globe (Earth) and therefore will look differently from different viewing angles.

Back in the 1990s when I was shooting star trails with film, I remember well the first time I pointed the camera to the South and captured both convex and concave star trails in the same photo. What the heck was going on? I asked an astronomy friend about it and he couldn’t answer. In fact, I couldn’t find an answer anywhere. (This was before I had even heard of Alta Vista, much less Google.) So I did what I always do in a case like this. I figured it out for myself.

I started thinking about what the star trails would like from space. Of course, I knew that the stars didn’t actually move. It was the rotation of Earth that caused the effect. A stationary camera on Earth that was exposing the film for more than a minute or so would have to record the star as a streak since the star was still but Earth was moving. (Stars do move, but imperceptively so for us.) So I imagined all of those star streaks circling the globe as viewed from space. It would look like a dense grid of latitude lines. Those at the equator would be longer than those close to the poles, since they have a greater distance to cover. And all of them would be circular, since they are circling a globe.

Next, I imagined what those same lines would look like if I moved from space to the surface of Earth. I kept those lines pictured in my mind as I travelled back to Earth and looked back up to the sky. Now I could see why the lines had to be in different directions depending on the angle of view and latitude. From the North Pole, I’d see circles directly overhead, circling Polaris at the north celestial pole. As I moved away from the pole, I’d see Polaris sinking toward the horizon until at one point it was no longer visible. From the equator, if I looked directly overhead and used a wide angle of view, I’d see convex and concave lines meeting in the center of the frame. If I kept going, I’d then start to see star trails circling the southern celestial pole.

Once you wrap your head around this mental image, it’s easy to determine what the star trails will look like from any point on Earth. And why would you want to do that? Well, I can’t think of a good reason other than to satisfy the curiosity corner of the left side of your brain. The truth is, there is no practical application for this knowledge for the night photographer. You’re not going to start shooting a star trail image and adjust your composition based on what direction the stars are going to streak. You’re going to compose based on foreground elements and open views of the sky.

The one exception to this is when you want to capture those circular star trails around Polaris (or Sigma Octantis in the Southern Hemisphere). You’ll need to identity Polaris and compose it in the scene for the effect you're after. A good compositional approach is to center a strong foreground object, such as a tree, lighthouse, cactus, or tent, and place Polaris directly above or behind the object.

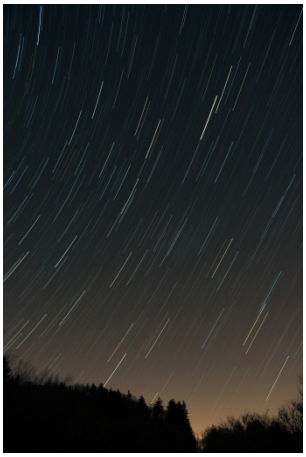

Photo 3
Due East

Photo 4
Due West

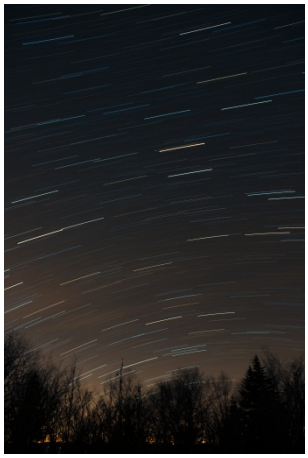

Photo 5
Due South

Photo 6

Nikon D800, Nikon 14-24mm f/2.8 lens, f/4, ISO 320, about 35 4-minute exposures. The last exposure extended into dawn twilight, which caused the blue color in the sky. The direction of view is due north in the Northern Hemisphere, which causes the circular star trails. Photos 3-5 show what the trails look like when shooting in other directions.

The Length of Star Trails

Some people are surprised when I tell them that the length of a star trail varies according the direction in which you point your camera. A person I told this to recently said she was certain that I was just trying to pull her leg. I have no clue why someone would think I would do something like that (insert sound of throat clearing here), but I assured her that I was telling the truth.

To understand this phenomenon, go back and imagine those lines (star trails) encircling Earth that I talked about above. In effect, they are just like imaginary lines of latitude that are suspended in space above Earth. A line directly above the equator is going to be much longer than one near the poles since it has to travel all the way around the widest part of Earth.

If you were standing on the equator, pointed your camera at a star directly overhead at the zenith, and shot a one-hour shutter speed, the light streak would occupy 1/24th of the star's imaginary line in the example above. If you were standing close to the North Pole and did the same thing, the star streak would still occupy 1/24th of the imaginary line, but the streak would be shorter since Earth rotates a shorter distance at the poles than it does at the equator.

Here's another and perhaps easier way to visualize what's going on. When we shoot star trails, we don't capture the full circle of trails unless we shoot from a location that is in darkness for the full 24-hour period and we point the camera toward the celestial pole. We only capture a slice out of the star's apparent 24-hour rotation around the pole. Look at a star trail photo that shows star streaks circling Polaris and you can see this plainly. You'll see that Polaris shows almost no streaking, since it's nearly at the exact celestial pole, but the star streaks get longer the farther away from Polaris you go. Streaks that are closer to the poles will be shorter because they have a shorter distance to cover in their rotation around the pole.

How different the streaks are depends on the direction you're shooting and the field of view. A wide-angle lens is going to cover a broader range of the differing star-trail circumferences than a telephoto will, so you'll get a wider range of streak lengths. The farther away from the north or south celestial pole you go, the longer the streaks will be.

At this point, you might be asking what difference it makes whether or not the length of a star trail varies. Well, it doesn't really matter how long the streak is as long as it's a least enough to look good. Sure, you can shoot a shutter speed of only a couple minutes and record a star trail, but it's probably going to look more like a mistake than a good star-trail image. "Why is that star streaked?" is probably the response you'll get more than, "Wow, look at those star trails!"

How long the trails need to be to look good is purely subjective. Personally, I like to go with a minimum of 30 minutes for the shutter speed and preferably two or three hours. Interestingly, and in apparent opposition to everything I said above, it doesn't make a lot of difference where in the sky you shoot for any given shutter speed. That's because with a wide-angle lens, you're going to be covering a wide enough range to capture some longer trails even if you point to Polaris, and with a telephoto lens, you'll be covering a narrower field of view, which will make the star trails occupy more of the frame and appear longer. By the way, that's at least 30 minutes of *accumulative* time. I probably wouldn't shoot a 30-minute exposure for star trails, but would shoot six 5-minute exposures instead. When I can, I load a fresh battery and shoot as many exposures as it will take, which is nearly four hours' worth in my D800.

Color, Intensity, and Exposure of Star Trails

Why are my star trails different colors? It's a good question. I mean, shouldn't the stars all be white, just as we see them with our eyes?

Ah, but we don't see them as all white. Next time you're out under a dark sky, wait at least 20 minutes for your eyes to adapt to the darkness and then study the sky. If you look with this in mind, you'll see that the stars are many different colors, ranging from reddish to bluish. And since your camera can reveal those stars much

better than you can see them with your naked eye, star photos reveal a lot more of the color. So the reason the star trails have different colors is because the stars have different colors.

Simple, eh? But you want to know *why* they have different colors, don't you?

The color of stars comes from temperature. Cooler stars, such as Betelgeuse, appear reddish, while very hot stars, such as Rigel, are blue. The Sun is a medium-temperature star and appears yellow. At first, this might not make sense. A hot star should be red, right? Red means hot, right? But think about what happens with heat sources on Earth. Low temperature flames, such as those from candles or matches, are yellow, while very hot flames, such as from a welder's torch, are white or blue.

That's all there is to it. Cooler stars appear in warmer tones, while hotter stars appear in cooler tones. Except for night photographers, that's not all there is to it. We want to be able to record those colors as much as possible. Unfortunately, it's not a simple matter of taking the picture and getting a sky full of nice colorful stars. There are so many things in both capture and post processing that can wipe out the color of stars and make them all appear white. In fact, that's a big reason why people are often surprised when they see a photo with colorful stars. So many of the night-sky photos they see are full of only white stars.

For star trails, the most important consideration when making the photo is ISO. High ISOs tend to wash out the color because they are essentially causing over exposure in the stars. Aperture plays a role, too, but it isn't as important. I shoot all star trails and pinpoint star scenes at mostly wide-open apertures because, as a rule, I'm trying to bring in as much light as possible in the shortest amount of time. But, of course, at a certain point, too much light comes in and washes out the stars. You could adjust this with the aperture, by stopping the lens down, but with all else being equal, it's much better to lower the ISO first because lower ISOs give you better image quality, with less noise.

Think about what happens when you shoot a star trail. Earth is in constant motion, so the instant you open the shutter, the star begins to streak. The shutter speed at which that streaking becomes obvious in the photo is not important here. For now, just remember that the star is constantly moving across the frame. For it to record at all, the aperture and ISO combination must capture enough of its light. If you keep the aperture as a constant, say f/2.8 or f/4—a typical setting for stars—the ISO will determine how much of the star's light will record.

If the star is very bright to begin with, it won't take much for it to record even at low ISOs of 100 or 200. (We old farts used to shoot star trails using Fujichrome Velvia film. That's a film speed of 50!) Two things happen as you crank the ISO higher. One is that the star trail appears brighter. The other is that faint stars—those that might not record with lower ISOs—will show up in the image.

Pondering this, you might wonder why you wouldn't want to crank that ISO on up to 3200 or even 6400 or higher so you can capture as many stars as possible and have them appear as bright as they can. Yes, you'll get lots of stars—bright stars—if you do that, but they won't have much color because they'll be overexposed. Overexpose anything, even a black subject, and the color goes away. With stars, it doesn't take much for that to happen.

Did you catch the upshot of the statement that, if the aperture remains constant, the ISO determines the star exposure? I didn't say anything about the effect of shutter speed, because there isn't any. It's true, shutter speed has no affect whatsoever in the exposure of star trails. Aperture and ISO control the exposure exclusively. Shutter speed only affects how *long* the star trails will be, not how bright they will be. That's because the stars are moving. They never occupy the same pixel space long enough for shutter speed (beyond a certain point) to have an appreciable effect on the exposure. Shutter speed does affect the exposure of the background sky, so you do have to take that into consideration.

There's another consideration with high ISOs and star trails. I said that as you crank up the ISO, faint stars begin to appear. The higher you go, the more stars you'll record. Seems like that would be a good thing as long as you can retain the color in them, right? Well, that's up to you.

Photo 7
Nikon D800, Nikon 14-24mm f/2.8 lens, f/3.5, ISO 200, multiple exposures of 4 minutes.

Photo 8
Nikon D800, Nikon 14-24mm f/2.8 lens, f/3.5, ISO 1600, multiple exposures of 30 seconds.

I shot the individual frames for **Photo 7** at ISO 200 and a shutter speed of 4 minutes. For **Photo 8**, it was ISO 1600 and a shutter speed of 30 seconds. The aperture was f/3.5 for both, so the total accumulative exposure was the same for both. (ISO 1600/30 seconds = ISO 800/60 seconds = ISO 400/120 seconds = ISO 200/ 4 minutes) But look at the difference in the star trails. **Photo 8** recorded tons of star trails filling up the sky.

At ISO 1600, the stars still show some color, so it's really just a matter of personal preference as to which way you want to go. Oh, there is one practical consideration, and for me it's a biggie. In order to get the same length of trails in **Photo 8**, I had to shoot a *lot* more frames. **Photo 7** is a stack of 52 4-minute exposures. **Photo 8** is a stack of 337 30-second exposures! And if you do the math, you'll see that the 337 frames aren't even enough to match the trail length in the first shot. I don't know about you, but I have better things to do with my time than devote hours and hours to post-processing a 337-frame star trail. And besides, I like the look of the ISO 200 shot better, anyway.

Go back and look at **Photo 1**. I shot it years ago using ASA 50 film. Notice how much more colorful the stars are in it? And if you look closely, you'll see that the stars in the ISO 200 shot (**Photo 7**) are more colorful than those in the ISO 1600 image (**Photo 8**).

And now I'm guessing you'd like some sort of formula or chart to help you determine which settings give you the best-looking stars. Sorry, no can do. I'm afraid there are just too many variables, among them the biggie of subjectivity. You're going to have to do some testing with your own gear and use your own mind to figure out what the best settings are. But I can give you a general synopsis.

Low ISO/long shutter speed
With a low ISO (100 to 400), you get the more color in the stars and fewer stars show as trails. You also end up with fewer frames to work with in post processing.

High ISO/short shutter speed
With a high ISO (800 to 1600), you get less color in the stars (but you don't lose all color) and more stars show as trails. You also end up a lot more frames to work with in post processing.

Really high ISO/really short shutter speed
If you go much above ISO 1600, you'll lose a lot (or all) of the color in the stars and you'll have a sky sardine-packed with white star trails. You'll also have to deal with a huge number of frames in post processing.

Regardless of how you make the trails look, you have to choose an exposure that doesn't blow out the sky. Unless you shoot in a very remote region, there is likely to be some amount of light pollution in the sky that will affect the exposure. The point at which this causes over exposure is called "sky-fog limit." I can tell you that as a rule, in a relatively dark site, you can shoot an exposure of 8 minutes at ISO 200 and f/4, or any reciprocal of that. For example, 1 minute at ISO 1600. In a heavily light-polluted region, you might be lucky to get a minute at ISO 100.

At very dark sites, your shutter speed will be limited by noise, rather than the sky exposure. For pro digital cameras, you might get by with 30 minutes or more at a low ISO of 100 or 200, which would allow you to shoot a reasonable star-trail scene in one exposure. But, of course, if you want those long trails, you'll have to shoot multiple exposures and stack them.

You should always make a few test exposures before you start the star-trail sequence to make sure you aren't hitting the sky-fog limit. If you haven't already tested your camera's noise characteristics, you'll want to test that as well. Even if the sky is dark enough for an eight-minute exposure, your camera might not give you good results at an exposure that long. As with any foreground light painting, I always make my tests using a different battery from the one used for the actual star trails. I want that one to be fresh out of the charger.

Speaking of exposure reciprocity, you can use that to your great advantage when making test exposures. Suppose you want to use a low ISO, say 100, so you get nice colorful star trails that don't overwhelm the sky and you don't want to fool with stacking tons of layers. You could spend a lot of time making test exposures of several minutes in length, or you could use reciprocity to shorten the time considerably. Crank the ISO to 6400

to make your tests. Suppose the test showed that an exposure of 8 seconds at ISO 6400 and f/4 is good. Do the math of reciprocity and you'll see that that equates to an exposure of 8 minutes at ISO 100. You can't test the noise this way, though.

One more thing about the sky exposure. A really cool technique is to begin or end the star trail series during twilight, so you get that nice blue-hour look in the sky. **Photo 6** is an example of this technique. You don't want to include too much of the twilight sky or else it will wash out the other exposures. And if you start exposing too soon at dusk, the twilight shot will be overexposed to begin with. Fortunately, this is easy to control. Simply start the star trails about midway through twilight, or let them continue through twilight in a morning session. Chances are good that you'll capture one good twilight frame before it fades and you can stack this one with the regular star trails frames. You can trash any twilight frames that come before this one (or after, in a morning shoot).

Exposure for the Foreground

The settings you use for the star trails have some roughly fixed parameters and as a result will be pretty much the same with each shot, but not so for the foreground. There are so many variables you're just going to have to figure out this one for yourself. Keep in mind that since the foreground will usually be stacked with the star trails as an entirely separate entity, you can use whatever aperture, ISO, and shutter speed settings you like.

With this in mind, you'll want to choose the settings that give you the best image quality, while still providing adequate exposure. Generally, this means the lowest ISO possible in order to minimize noise, an aperture that gives you adequate depth of field, and a shutter speed that is a short as possible, also to minimize the noise.

Don't forget that you can shoot as many exposures for the foreground as you like. For instance, if you find that you can't do a good job with the light painting without shooting a very long shutter speed, you can break up the painting into several shorter exposures. That's how I do most of my light paintings.

There is a very important consideration regarding light painting a foreground for a night-sky scene. If the object you light paint projects in to the sky, you could have some problems when you stack the exposures. The reason is that before you can stack a light-painted foreground layer, you have to brush out the sky (use a black brush in Photoshop to paint over the stars) so that the stars from that layer don't show up on the finished image. If the exposure you used for the foreground light painting is enough to cause the sky to be very bright, it's going to be very difficult to selectively brush out the sky, particularly if you have something like trees in the images. You want to make sure that the sky in the foreground exposure is *darker* than what the sky will be in the star-trail exposures, so it won't interfere when you stack the layers. If the object you're light painting doesn't project into the sky, you don't have any problems because you can simply brush out everything but the object you painted.

I always use a different battery for the foreground light painting than the one used for the star trails. For the trails, I want a fully charged battery so I can get as many exposures as possible.

Photo 9

Nikon D800, Nikon 14-24mm f/2.8 lens. For the star trails, I shot multiple exposures at f/4, ISO 320, 4 minutes. For the tent lighting, I fired a camera flash with yellow gel filter on a separate exposure of f/8 and ISO 200. This is a self-portrait setup shot in my backyard. I'm controlling the flash with a radio remote trigger. The dark line separating the tent and the sky made it easy to blend the tent exposure with the star trails.

Using the Intervalometer

Most of the programmable intervalometers operate pretty much the same. The Nikon MC-36A and the Canon TC-80N3, as well as all of their aftermarket knockoffs, all use the same basic format. The first setting controls the delay, or how long the timer waits before starting the exposures. It works just like the self-timer in your camera. The next setting controls how long the exposure lasts. Next is the delay between exposures. Next is the total number of exposures desired. Finally, there is a stupid control for whether or not you want to hear an annoying beep every time you make a setting on the timer. Trust me, you *do not* want to enable the beep!

Let's say you want to shoot as many star trails as the camera battery allows with a shutter speed of four minutes, and you want to wait an hour before starting so most of the evening airplanes are gone. First, you need to set the camera shutter to bulb and single or continuous frame advance. Then you will set the intervalometer for 60 minutes for the delay, four minutes for the exposure length, one second for the interval, and either 399 or - - for the total number of exposures. The maximum number of exposures you can program in a Nikon timer is 399. Not sure about Canon. For unlimited exposures, choose - -. I rarely shoot more than 399 exposures, so I choose this instead of - -. Doing so lets me see the exposures count down on the timer.
Note: On the Nikon MC-36A, you have to add the exposure length to the interval time. So in the above example, the interval setting would be four minutes and one second.

With star trails, you obviously want the shortest interval between exposures, but the shortest you can program in the timer is one second. You can put 0 in there, but when you press the set button, it automatically changes to one second. That's okay; with a wide-angle lens, one second is not going to cause a noticeable gap between the trails.

It's not a good idea to let the intervalometer dangle in the wind during the star-trail capture. I glued a little loop on the back of mine so I can hang it from the hook on the bottom of the tripod center post. Another good idea is sticking it to a tripod leg with Velcro.

I like hanging it from the center post so that I can point it the direction I want, which is usually away from the direction I'm shooting. The intervalometer flashes a little red light when it is operating and I don't want that light interfering with the exposures. Admittedly, that's not likely to happen, but there is another reason to have the light aimed behind the camera. After you start the star-trail sequence, you'll undoubtedly walk away from the camera to the car or a resting spot and return after the sequence is finished. Very often, I'll return before the sequence is completely finished, so I can't shine a flashing to light my way. That red flashing light works beautifully to keep me from stumbling into the tripod.

The supplemental document "Intervalometers and Shutter Releases" goes into a lot more detail on this subject.

Dealing With Unwanted Lights in the Sky

You can pretty much count on having an airplane fly across the sky when shooting star trails. Chances are good there will be more than one, and other things like satellites or even fireflies that will interfere. It's impossible to eliminate all of these elements during capture, but you can lessen their potential.

The best approach is to wait until late at night before you begin shooting. You'll see a lot fewer planes after midnight than in the evening hours. The same is true for satellites and, for that matter, fireflies, although I don't mind having a few firefly flashes in the scene. Of course, this also shortens the time you could be shooting, so depending on the location and whether you want to try for some twilight color in the sky, you might want to shoot right through the planes.

Sometimes you can shift the composition slightly and eliminate a lot of the planes. Pay attention as you get everything set up and you'll likely see that most of the planes follow the same flight path. See if it's possible to eliminate this path from the composition without ruining it.

Another issue is having other people or automobiles interfere with the image. If I'm shooting in a location where I think someone could come by and cause problems, I try to wait as late as possible before starting the star

trail sequence. It's not a problem if a car light interferes with a 30-second pinpoint star exposure, but you sure don't want that happening in the middle of three-hour star trail!

You have to make a choice about any airplanes or other unwanted lights that show up in the finished image. You can leave them there, as some do, or you can spend a lot of tedious time removing them in post processing. Personally, I think airplanes ruin most star trail images, so I do whatever is necessary to remove them.

I've heard other photographers recommend removing airplane lights *before* stacking. The idea being that you can brush out the lights much easier when the star trails from only one exposure are present. You can simply paint a black streak over the airplane lights, since you'll be stacking using the Lighten Blend Mode and the black streak won't show up. This sounds good, but my experience shows that it doesn't work very well. If you brush the streak out with black, it very likely will cause a residual effect in the final image. Even if you brush with the same color and lightness as the sky, I find it hard to prevent some residual effects from showing. So that leaves the only option of using regular image cleanup tools such as the Healing Brush or Clone Stamp. (Content Aware Fill doesn't work well to remove airplane trails in this context. It just can't seem to play nicely with the star trails.)

Since the only good option for removing airplane trails (in my opinion and based on my admitted limited knowledge of Photoshop) is the Spot Healing Brush and/or Clone Stamp tools, I find it much better to wait until all the layers are stacked and then just do all the airplane trails in one go. With these tools, it really doesn't seem to matter how many star trails are around the airplane lights. But there is an even bigger advantage to waiting. With many star-trail photos, the sky in the finished stack is brighter than some of the airplane lights. The stacking process actually causes some of the plane lights to disappear. Less cleanup!

Miscellaneous Camera Settings for Star Trails

White Balance. I bought my first digital camera around 2005 and immediately set the white balance to Auto. I'm on my 5th camera model now, but the white balance is still on Auto. I shoot mostly in RAW, which means I can adjust the white balance to my heart's content when I process the image. If you shoot JPEG, you'll need to learn how to set the white balance. I'm not a good teacher for that.

Image Review. No need to waste battery power by having the image pop up on the LCD after every exposure. It's not like you're going to stand behind the camera and look at every one.

Mirror Lock. This one can bite you if you haven't done some testing before you start the star trail sequence and discovered you have it enabled. With mirror lockup enabled, you can start the exposures and everything appears to work properly, but it's not. I can't tell you for sure about other cameras, but with most Nikons when you have mirror lockup enabled and press the shutter (or press the intervalometer when you're shooting star trails), the mirror goes up but the camera doesn't take the picture until you press the shutter again, which, of course, you won't be doing when you shoot star trails. With Nikons, after 30 seconds the camera does take the picture, but you end up with 30-second gaps between the trails. This is not good, so make sure mirror lockup is turned off.

RAW Versus JPEG. If you aren't shooting multiple shots for the foreground and you don't plan ever to do any serious post processing, you can shoot JPEG and all will be just fine. But if you want the most image data available for making the finished photo look the best it can be, you should shoot RAW. The only time I shoot JPEG is for family events or in situations where I need to show or deliver photos immediately after the shoot. Sometimes I shoot RAW + JPEG. I shoot RAW with *all* night photography.

The comment I sometimes hear about having to process "all those RAW files" is a non-issue with star trails. I batch process the RAWs to change the white balance and convert to TIFF for stacking. That's usually the only processing that's done before stacking and flattened the file (except for dark-frame subtraction, discussed later), and since I do it in a batch process, it takes very little time.

There is another reason why I wouldn't shoot JPEG for star trails, although I can't say for sure if it is a valid one. I would be afraid that the processing performed by the camera software might cause problems with the star trails aligning perfectly. Again, I have no idea if this could happen, but I am suspicious.

Shutter. Set the shutter to bulb and the frame advance to single or continuous. The external timer will control the shutter speed and frame advance.

Long Exposure Noise Reduction (LENR). The supplemental document "Dealing with Noise" covers the subject of noise in detail, including all methods for combatting it. For star trails, you can't use LENR because it doubles the exposure time—a four-minute star-trail exposure becomes an eight-minute one. So you end up with half of the exposures you wanted and a gap between them that equals your exposure time. Some cameras have this enabled by default, so be careful.

High ISO Noise Reduction is different. I can't say for certain about other cameras, but I know that it doesn't affect RAW files in the Nikon D700 and D800, and I assume other Nikons as well. It writes a tag to the file. Nikon's Capture NX reads this tag and applies the noise reduction algorithm to the RAW file when it is converted. Adobe Camera RAW cannot read the tag, and I assume no other software besides Nikon's can either. So, if you shoot RAW, HIGH ISO NR will have no effect on the photo. It only affects JPEGs and the LCD preview image on the camera.

Stacking The Layers And Post Processing

Stacking all the exposures can be as simple as you want it to be. For the simplest method, download the free StarStaX software and point it at the folder of exposures. It will do all the work for you. You can get a little more involved with it by setting up the preferences to your liking or just leave everything on default as many people do. Done!

So if that's all there is to it, why the fuss, and what's all this about Photoshop and other stuff? Because that's not really all there is to it. (You were afraid I was going to say that, weren't you?) Yes, StarStaX will assemble your star trail image for you, but it only works with the star-trail exposures. It won't stack the foreground exposure as well. Well, it *will* stack them, but it won't allow you to do any individual adjustments to them before or after they are stacked, which is the beauty of working with layers in Photoshop.

For the foreground images, you need to stack them first and do any desired adjustments before stacking them with the star trails. The adjustments you make are up to you—contrast, saturation, exposure, color balance, or whatever else you want to do. However, in nearly every case, one of those adjustments is going to have to be brushing out the sky from the foreground image. Otherwise, the stars in the sky of the foreground image will show up in the star-trail layer.

So you're looking at getting into Photoshop anyway for all but the most basic star-trail image. Yes, I did mention the option of doing the light painting in the same exposures as the star trails and then simply letting StarStaX do everything. This is certainly a viable option for those who don't have Photoshop and don't want to get it. You just need to understand that it will be just as difficult to get your light painting perfect during your star-trail exposures as it will be to figure out how to work with layers in Photoshop. Don't have PS and don't want to get it? I understand. But if you do have it, do yourself a favor and learn the basics of layers and layer masks. And, by the way, Lightroom does not have layering capability.

More About the Choice of Light Painting and Using Photoshop

I know some photographers who simply will not consider using Photoshop and I know some who do not care to do any type of light painting. But they do like star trails. If you're one of them, guess what? That's okay! They're your photos; you can shoot and process them however you like.

If you don't light paint the foreground, or, more specifically, you don't paint it in multiple exposures that need to be blended and processed before stacking with the star-trail layers, and you don't want to use Photoshop, you

can simply take all of your exposures and let StarStaX do *everything* for you. And if you plan your shots carefully, it is definitely possible to create some great star-trail images this way.

Stacking In Photoshop

Stacking the images is crazy easy. From Bridge, simply select them, then go to Tools>Photoshop>Load Files into Photoshop Layers. Then, depending on how many images you have and how fast your computer is, you will have enough time for only a sip of wine or you'll have time to go out and grow the grapes, crush them, and let the juice ferment before the layer stack magically appears. You don't even have to have Photoshop open, as Bridge will open it for you. That was easy!

So is this. Once all the layers are piled up in the Layers Palate, you need to change the Blend Mode to Lighten in order for all the star trails to show up. In CS6 and newer, you can select all of the layers at once (just as you would select multiple photos in a folder) and change the Blend Mode for all. In earlier versions, you have to select each layer separately. Once the Blend Mode is set to Lighten for all layers, you Flatten the file (Layer>Flatten Image) to create a single image file.

The result you see on the screen will be pretty much the same as what you'd see if you let StarStaX do the work for you. Then what's the advantage of using Photoshop? Hey, we're just getting started here. Patience!

For the star trails, there is really only one advantage of using Photoshop for the stacking and that is to eliminate the gaps that appear between each trail. More on that later. But for the foreground, there is the huge advantage of being able to work on each layer individually. By using masks, you can erase parts from each layer and make selective adjustments on them. You can even change the opacities of the layers individually. Got a little hot with the light painting on the trunk of that tree? No problem. Just brush out that part of the light painting from that layer.

My Star Trails Need Braces!

The problem with using StarStaX or Photoshop (or any other software) to stack your star trails is that it leaves tiny little gaps between the trails. This is not caused by the one-second interval between exposures that the timer requires. One second is not enough to be noticeable in a wide-angle view. It's caused by the way the software stacks the layers, but that's the extent of my knowledge on the subject. All I know is that they are there and I don't like them.

If all you ever do is post your photos on Facebook or a blog, you can get by with leaving the gaps there. But if you want to make a decent-sized print, or if you're like me and just can't stand the thought of your star trails needing braces, you gotta get rid of those gaps. I've read of several methods for removing them, such as using the Clone Stamp tool or making a duplicate layer and slightly shifting one layer onto the other. Trying to clone in the gaps on a star trail image could literally take days (weeks for high-ISO shots) and would be extremely difficult to make them look just right. Making a duplicate layer and shifting it simply won't work, at least not for any star trail I shoot. The only way I can see it working is if you use a telephoto lens for the shot. With a wide angle, there is going to be too much distortion in the lines and too much variation in their curvatures.

StarStaX features a gap-filling option, but I haven't used it. I did read the instructions and once I learned the process it uses to fill the gaps, I realized that it doesn't provide a good, fill-all-the-gaps-all-the-time solution. Even the example photo shown in the tutorial still has gaps in some of the trails after going through the process.

So what does that leave? Thank goodness for smart people! One of them is an exceptionally talented photographer named Floris van Breugal. Floris figured out how to remove the gaps using a special blending mode technique in Photoshop. I started using the technique immediately after reading about it and I can report that it works beautifully. The only problem is that it is very time consuming and consumes a lot of processing power. When I have a large batch of star trails to assemble, I have to break them down into batches of around 30 or else it crashes my computer.

Actually, I don't have that problem any longer because Floris created a script that will do the stacking and gap filling automatically. And if that's not enough, he offers the script free! Floris, you are my hero!

You can read his tutorial on filling the gaps manually and download his free script here. While you're on his site, spend some time browsing his images and reading his articles. This is one talented individual!

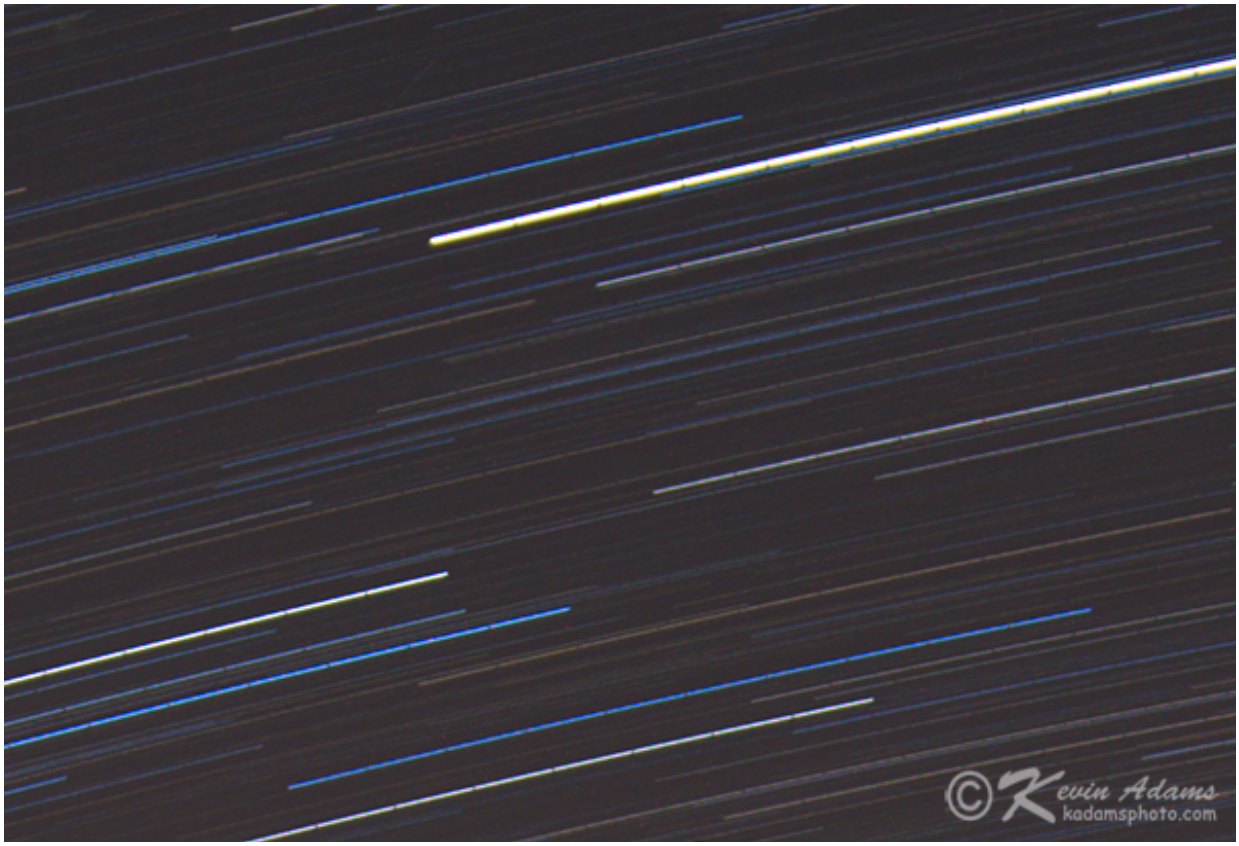

Photo 10
This is what star trails look like if you don't fill the gaps between the trails.
It is much more obvious at higher magnifications.

You're Not Done Yet

After you get the star trails stacked, you still have some work to do if you want the image to look its best. As discussed above, you may need to do some noise reduction and you certainly will need to do at least a little image cleanup to get rid of dust specs, hot pixels, airplane trails, and the like.

Most wide-angle lenses suffer from chromatic aberration, which means that red, green, and blue light is not focused at precisely the same point. Magnify the image to 100, or better yet 200 percent, and examine the image. If chromatic aberration is present, it will show as a colored fringe along the edges of the star trails. There is no way I know of to prevent it from happening while shooting, but it is very easy to correct in post processing. In Photoshop, go to Filter and then Lens Correction. The automatic setting works very well most of the time, but you can adjust it manually if needed.

Of course, there are lots of other adjustments you can and may wish to do with the image. Contrast, color balance, saturation, and sharpening are a few of the ones I consider. For nearly every image, I perform at least a slight Curves adjustment to boost contrast and apply an Unsharp Mask to sharpen the image. You should do whatever you like with your own images.

Checklist for Capturing And Processing Star Trail Images

I realize I've taken you on quite a ride and it may be a little hard to figure out how to proceed. Hopefully, these checklists will help organize your thoughts.

CAPTURING STAR TRAILS

1. Plan the shot ahead as much as you can.
2. Arrive before it gets dark if possible.
3. Choose the general composition, taking into consideration how much of the scene will appear black if you set up before it gets dark.
4. Set up tripod as sturdy as you can. Make sure the feet are firmly seated in the ground. Do not extend the legs any farther than absolutely necessary. DO NOT extend the center post.
5. Make sure front element of lens is clean.
6. Turn off image stabilization.
7. Mount camera on tripod and lock in the composition. (Assuming your tripod head has a quick-release clamp so that you can remove and remount the camera without affecting the composition.)
8. If setting up after dark, make a test photo at very high ISO and perhaps throwing in some light with a flashlight. This test is to make sure the composition is right. The exposure test comes later.
9. Tape the lens focus barrel unless you are focusing manually, in which case you will tape it after acquiring focus.
10. Focus the camera. It is perfectly acceptable (even desirable in most cases) to remove the camera from the tripod and point it where you need it to get the focus set. Remount camera on tripod after focus is set.
11. Turn autofocus off.
12. If there is a possibly for dew to form, attach dew heater strips or LensMuff™ to the lens.
13. Secure camera strap so it doesn't blow in the wind.
14. Acquire foreground shots if you are shooting them separately. Choose camera settings that work best for foreground, not sky.
15. Make test exposures to determine proper exposure settings for the star trails.
16. Attach intervalometer to the camera and program it as desired.
17. Check all settings on camera. Long Exposure Noise Reduction off, Auto Bracketing off, Mirror Lockup off, frame advance to Single, shutter on Bulb, Aperture and ISO as desired, Image Review off, image quality RAW, White Balance Auto (unless capturing in JPEG).
18. Make sure memory card has enough capacity for all the exposures.
19. Acquire one dark frame if desired. (See supplemental document "Dealing with Noise.)
20. Install fresh battery.
21. Start intervalometer. For extra assurance, I always wait for one exposure to complete to make sure the timer is working properly. I hold my ear close to the camera so I can hear it advance to the next frame.
22. After you finish capturing star trails, acquire more dark frames if desired.

PROCESSING STAR TRAILS

Really Simple Method

1. Point StarStaX at a folder of captures and let it do all the work. Will not work if you captured foreground images separately from the star-trail captures.

Simple Method

1. Point StarStaX at a folder of captures and let it do all the work. Take finished image from StarStaX and open it software of choice for image cleanup and tweaking. Will not work if you captured foreground images separately from the star-trail captures.

Somewhat Simple Method

1. Open foreground capture(s) in Photoshop or software of choice and process them as desired. Brush out the sky so the stars or any airplane trails don't interfere with the star trails. If you have multiple foreground shots, flattened the file before brushing sky.
2. Load processed foreground image in folder with star trails.
3. Point StarStaX at folder and let it stack everything.
4. Take finished image from StarStaX and open it in software of choice for further image cleanup and tweaking.

Time Consuming and Tedious Gap Filling Method

1. Open foreground capture(s) in Photoshop or software of choice and process them as desired. Brush out the sky so the stars or any airplane trails don't interfere with the star trails. If you have multiple foreground shots, flattened the file before brushing sky.
2. Load star-trail captures as layers in Photoshop.
3. Follow instructions in Floris van Breugal tutorial for filling gaps.
4. Flatten file and make any adjustments and image cleanup desired.
5. Stack foreground image with star trail layer in Photoshop.

Kevin Adams Method

1. Open foreground capture(s) in Photoshop and process as desired. Brush out the sky so the stars or any airplane trails don't interfere with the star trails. If you have multiple foreground shots, flattened the file before brushing sky.
2. Use script from Floris van Breugal to stack star-trail captures and fill gaps. Allow script to flatten file automatically when finished.
3. Using Photoshop, make any adjustments and image cleanup desired to the star-trail image.
4. Stack foreground image with star-trail layer in Photoshop.
5. Perform any tweaking as desired in Photoshop.