tem that tracks *slate numbers*. The first setup of the first day of shooting is slate number 1 and the slate number increases with each new camera angle until the end of the production (the slate in Fig. 9-30 indicates slate 108, take 15). Numbers are often written on pieces of tape that can be stored on the back of the slate and quickly stuck on the front as needed (obviously not necessary with tablet or smartphone slates). The assistant should increment the numbers immediately after slating to be ready for the next take.

Today, much of the information on the slate can be logged electronically and included as metadata with the picture or sound files (see p. 242). For more on slates and slateless timecode systems, see Syncing Audio and Picture, p. 465.

Shooting a Take

For staged work, there's a basic protocol for beginning each take. The following assumes that double-system audio and slates are being used.

The assistant director announces the upcoming take and calls "last looks" so everyone finishes their prep. The AD then calls for quiet and says "sound." The audio recorder is started, and the recordist says "speed" when ready to record. The AD then says "camera," and the camera operator calls "speed" or "rolling" when the camera is ready to record. The AC reads aloud the scene and take numbers from the slate, says "mark" or "marker" (to help the editor find the sound) and closes the clap sticks.[7] When ready, the director calls "action." Normally, the camera and recorder are not turned off until the director says "cut."

After the take is over, the director should indicate to the script supervisor or person logging if the take is good (*circle take*) and any notes. With digital postproduction, often all the takes are available in the editing room (unlike traditional film, in which only the best takes are printed), but there should be a record of which takes the director liked best.

When shooting the slate, be sure it's large in the frame and in focus so the numbers are readable. If the slate is in place for the very first frame of the take, it will appear in the clip's thumbnail in editing, which can save time. Even when using a slateless timecode system, a clap stick with manual slates may still be done as a backup in case of timecode problems and for scene/take information.

When possible, do *head slates*, which are done at the beginning of the shot. Head slates speed the process of putting the sound and picture in sync in the editing room. *Tail slates*, done at the end of the shot, are sometimes preferable for unstaged documentary filming since they don't loudly announce to everyone that filming is about to begin; they may also be less disruptive for acted scenes where the mood is delicate. However, tail slates can slow down syncing, since you have to locate the end of the take and work backward. The clapper board is held upside down to indicate a tail slate; the person slating should call out "tail slate" or "end sticks."

If either the camera or the audio recorder misses a slate and you have to do it a second time, announce "second sticks" or "second marker" to alert the editor. In any

7. If the sound files are labeled with the scene and take numbers, reading them aloud may not be necessary. Different productions use variations on the above protocol.

situation, a gentle slate helps put actors or film subjects at ease. Generally actors should not be rushed to begin the action immediately after the slate.

Fig. 9-31. Slating on a DSLR shoot. (Sean Ellis/SmallHD)

Covering the Scene

Be sure to first read Style and Direction starting on p. 332.

When shooting, ask yourself how the shot you're taking might work with the other shots you've gotten or need to get. Do you have enough coverage—that is, have you provided enough options for editing? Do you have an establishing shot? Cutaways? Have you got interesting close-ups?

Both the order of scenes in the original script and the overall length of the movie are often changed substantially in the editing room. Keep this in the back of your mind as you plan your coverage. Don't paint yourself into a corner so that shots and scenes can only be put together *one* way. Filming a continuous master shot of an entire scene can be time-consuming on set to get everything right. Even if you plan to do the scene in a single shot, surprise errors often show up in the editing room and you'll want to cut around them. Shooting a reaction shot or a cutaway as editing insurance can be valuable even if you don't intend to use it. Sometimes a long take is good, but you need to cut the sequence shorter and your beautiful three-minute shot now becomes a burden.

Directors often concentrate on the characters who are talking. Keep in mind that some scenes are more interesting for the reactions of other characters. When filming a close-up of one actor talking to an off-screen actor, it's a good idea to set a microphone for the off-camera actor as well—the performances from these takes can sometimes be better than the on-camera takes. Higher-budget films often shoot with two cameras simultaneously in this situation.

For very wide shots in which a boom mic can't get close to the actors (and you're not using lavaliers) consider recording the dialogue a few times *wild* (sound but no picture) with the mic in close. This may help you in the edit and is a lot cheaper than doing ADR.

Blocking the camera and actors is a kind of choreography. Keep the image as dynamic as possible. Be attentive to the depth of the space you're shooting in, either to show it or to let actors move through it.

How Many Takes?

Directors differ in terms of how many takes they typically shoot. Sidney Lumet, whose background was early television, liked to rehearse actors prior to the shoot and only film a few takes because the first ones have the freshest performances. Stanley Kubrick, with a background in photography, would often shoot numerous takes in order to groom each shot to perfection. One saying has it that the best takes are the first and the tenth (the advantages of spontaneity versus practice), but the budget may not permit ten takes.

Inexperienced directors tend to shoot more takes and choose more of them as preferred (circle takes). At minimum, always shoot at least two keepers of any shot to have a *safety* in case one gets damaged or has unnoticed technical problems. Even if a take is good, it can be productive to try it again faster or slower or to vary something in the reading or action. Often in the editing room, you wish you had more options to choose from, not just more versions of the same reading and blocking.

When something goes wrong in the middle of a take (*busted take*) try to reset quickly ("back to one") without a lot of chatter and keep the momentum and concentration going. Some directors like to go immediately into a second or third take without stopping to reslate. This can be helpful to actors but may create some confusion in the editing room.

For more, see The Shooting Ratio, p. 360.

Reviewing the Footage

Some directors like to play back each good take on video after shooting it; this can slow production down a lot. However, it's generally a good idea to check the best takes before breaking down a camera- or lighting setup and moving on to the next one.

Looking at dailies is a good way for the director, cinematographer, and others to evaluate the footage as it gets shot, preferably on a relatively large screen. Some directors invite actors to attend dailies screenings; others prefer that actors not see themselves and get self-conscious. Uncut dailies don't look like polished movies—they're repetitive, rough, and often messy. It takes experience to see the potential in the raw footage. On larger productions, dailies are often uploaded to the cloud so that executives and members of the production team can monitor progress wherever they are on a tablet or computer (see p. 94).

On some productions, the editor cuts scenes as they're shot, which can be a good feedback mechanism for the director. You'll either know things are working or you'll see where adjustments need to be made (or even when scenes need to be reshot).

Errors discovered while viewing rushes or during editing often necessitate pickup shooting, which entails going back to get additional shots to fill in a sequence. A documentary crew might return to get a cutaway from a car window, or, in a fiction film, there might be a need for a reaction shot of an actor. Take stills of sets, lighting setups, makeup, and costumes to help match shots that may need to be redone. Many DPs (or their assistants) keep detailed notes about lenses, camera angles, and lighting to facilitate reshoots, some of which may be recorded as metadata in camera files or with an app such as MovieSlate (see Fig. 9-30).

Working with Actors

As much as films vary stylistically, directors vary in their style of working with actors and in the tone they set for the talent and the crew. Some like to plan and control every line and gesture. Others, such as Robert Altman, like to create an environment in which actors are encouraged to experiment with their roles. Some like to discuss deep psychological motivation and others are more interested in basic blocking and line readings. Michael Caine once complained to director John Huston that he didn't give him any instructions. Huston replied, "The art of direction, Michael, is casting. If you've casted right, you don't have to say anything."[8]

As noted above, some directors see rehearsal as a chance to work out ideas with the actors; others prefer to go into the shoot with as much spontaneity as possible.

Whatever your style, do what's necessary so actors can deliver their best performance. Actors are often extremely vulnerable to disruptions of mood and should be treated with respect and deference. Only the director should give performance instructions to actors; anyone else wishing to communicate should tell the director. Particularly in intimate or difficult scenes, some actors prefer that crew members not even make eye contact with them while the camera is rolling (in some scenes it may be best to clear the set of unneeded crew). Use your tone of voice even in calling "action" as a way to set the mood for the take.

Rehearsal is done both for the actors and for the crew. The actors' blocking will affect the lighting and the camerawork (and vice versa). You may want the actors to take part in working out the blocking but don't make them stand around while the lighting crew does its work (that's what *stand-ins* are for). Marks for the camera or the actors to hit are "spiked" with a piece of tape on the floor. Keep in mind that once lighting, props, and dolly tracks are set, your flexibility to change things is limited.

Avoid shouting and arguments in front of the actors (or anyone else, for that matter) and don't involve them unnecessarily in your technical business. Make sure they have a comfortable space to go to off the set to relax.

It's very helpful for the director to get a wireless headphone feed from the sound recordist to hear how dialogue sounds as it's actually being recorded. When a dramatic shoot is done with a live video monitor, there's a tendency for some directors to bury themselves in *video village* (the place where monitors and playback equipment are located, sometimes under cover when shooting outside). This can leave actors feeling isolated. When video village is filled with a lot of people kibitzing over the video monitor, you can easily end up with a "too many cooks" problem.

8. From Michael Caine interview on NPR's *Fresh Air*.

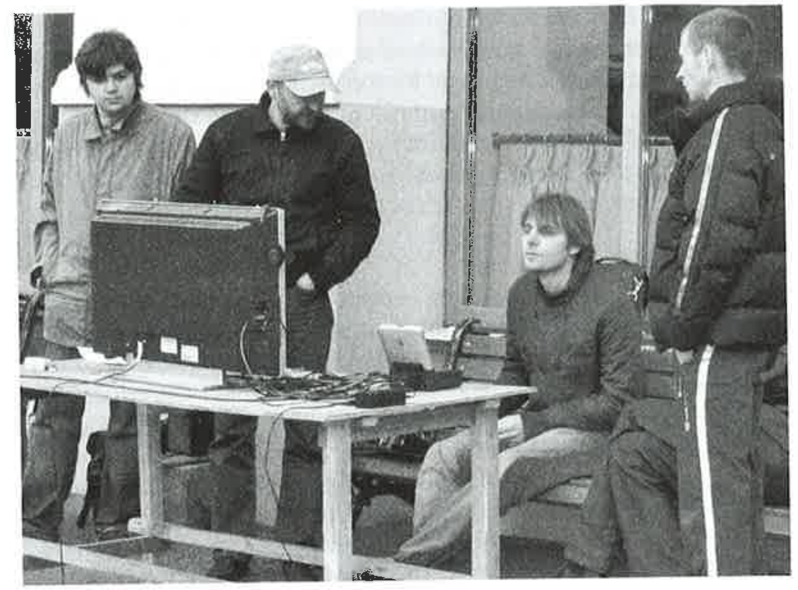


Fig. 9-32. Kibitzing in video village. (Steven Ascher)

Wardrobe, Makeup, and Set

An actor's wardrobe, makeup, and hair can have a huge impact on the look of the movie and on the character's presence on screen. Don't overlook the importance of good makeup and wardrobe as well as art direction. With documentaries, it's often not appropriate to deal with these issues, but in some situations—such as shooting interviews—you can choose the setting, make suggestions for wardrobe, and apply some minimal makeup.

Guidelines for clothing also apply to wall treatments, furniture, and other items on the set.

In general it's a good idea to avoid very bright or very dark clothing. White shirts often burn out (overexpose) when the camera is exposed for proper skin tones, especially in daylight. Pastel or off-white shades work better. Video cameras and particularly DSLRs can react badly to fine patterns like checks and stripes, which can cause moiré patterns (see Fig. 5-18).

Avoid shiny surfaces or jewelry. Washable *dulling spray* or even a little dry soap can be applied to bright items, or lights can be flagged (see Chapter 12) to minimize reflections. When shooting people with glasses, light them from high above or to the side to avoid kicks in the glasses.

Applying makeup is an art and needs to be tailored to individual faces. Facial shine, caused by sweating under hot lights, is a common problem that is easily remedied with a little translucent face powder, which can be brushed on actors or interview subjects and will be totally invisible. Apply the powder first to the brush, not directly to the skin, and touch up faces whenever you see shine. Many cinematographers carry powder in their ditty bag.

Prompters and Cue Cards

Actors may forget their lines. Correspondents or on-camera narrators may be asked to speak long passages directly to the camera. Lines can be written on *cue cards*. When a host or correspondent reads to camera, her eye line must be directed as close to the lens as possible so she won't appear to be reading. A low-budget technique is to cut a hole in the center of the cue card for the lens. A better solution is to use a *teleprompter*, which mounts in front of the lens and displays written copy from a computer (see Fig. 9-33). Larger teleprompters may limit camera mobility and usually require a solid camera support. Smaller teleprompters based on tablet computers and smartphones are lighter and can sometimes attach directly to the lens, permitting use of a handheld camera. Some actors are adept at using an *ear prompter* (also called an *earwig*), which is a miniature receiver that fits in the actor's ear and can be fed wirelessly from a pocket-sized recorder. The actor reads his lines into the prompter prior to the take; then during the take he hears the words played back while he speaks to the camera (this only works for scenes in which no one else talks). It takes practice to talk while listening, so don't let the talent try this for the first time on the shoot.

Fig. 9-33. Teleprompter. (left) In this lightweight ProPrompter model, the person being filmed can look directly into the lens and read, via the partially reflecting mirror, text displayed on an iPad. (right) This bracket holds an iPad displaying text that can be positioned near the camera and controlled from an iPhone. (Bodelin Technologies)

LOGGING

As you move from production to postproduction, it's essential to organize the material that was shot and keep good records of what went on during the shoot. Once you're in the editing room, you'll want to be able to quickly find every bit of picture and sound that was recorded. Several different kinds of logs or reports are used in production.

Basic Log

The simplest kind of log is a record of each take. It's easy enough to create your own log form by making a table with a word processing program. There are also several apps for mobile devices. The log includes information on:

- Date and location.
- Tape number, card number, optical disc, or hard drive. Never have two tapes, optical discs, or film rolls with the same number. Use letters if necessary.
- Scene number and/or description.
- Take number (if any).
- Timecode start for each take. (Usually the starting timecode of the next take tells you the ending timecode of the previous take, but some people note both start and stop codes.)
- Indicate if the take was good; any performance or content notes.

Devices such as ScriptBoy can provide a wireless remote readout of the camera's timecode to aid the person logging (so he or she doesn't have to keep bugging the cameraperson for timecode numbers). When practical, timecode can also be superimposed on a video monitor for the logger. There are various logging apps for mobile phones and tablets that allow you to email the logging file to the rest of the production team. NLEs often provide a way to import logging data as XML text files, which they then map into their own metadata fields.

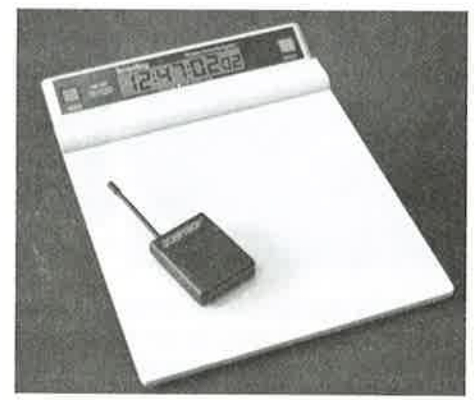


Fig. 9-34. For logging in the field, the ScriptBoy provides a writing surface with built-in timecode display. The transmitter sends timecode wirelessly from the camera. (Vortex Communications, Ltd.)

In unscripted documentary work there tends to be little time for detailed logging. It's important to write down notes whenever you can, at least at the end of every day, indicating what has been shot and which files/tapes/film rolls cover what.

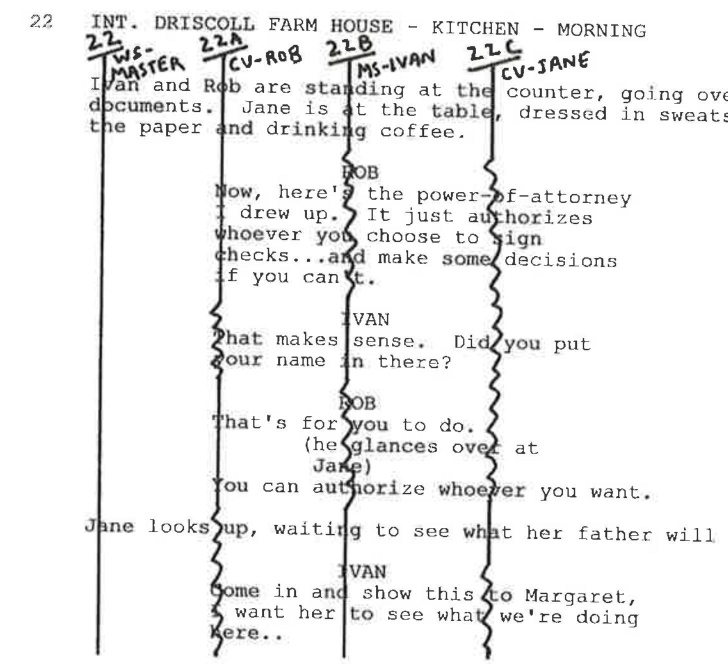
Continuity Script

For feature films and other scripted work, the script supervisor creates a marked script to show what camera angles were used to cover each page. This *continuity*

script serves as a reminder of what coverage has been shot and needs to be gotten, and it tells the editor what shots were filmed during production (see Fig. 9-35). Script supervisors will also create an *editor's daily log* (or similar name), which lists all picture and sound takes in the order they were shot, or at least all the selected takes. The script supervisor will also prepare *script notes*, which include descriptions and comments on each take and may include items about lenses used and continuity issues. Sometimes camera reports include lens settings.

Some systems can upload script information to the telecine shot log to help organize video clips by their content (see Shot Logs, p. 693).

On a feature, a *daily production report* is done every night to track what was filmed that day.



22 INT. DRISCOLL FARM HOUSE - KITCHEN - MORNING

22 WS-MASTER 22A CV-ROB 22B MS-IVAN 22C CV-JANE

Ivan and Rob are standing at the counter, going over documents. Jane is at the table, dressed in sweats, the paper and drinking coffee.

ROB
Now, here's the power-of-attorney I drew up. It just authorizes whoever you choose to sign checks...and make some decisions if you can't.

IVAN
That makes sense. Did you put your name in there?

ROB
That's for you to do.
(he glances over at Jane)
You can authorize whoever you want.

Jane looks up, waiting to see what her father will s

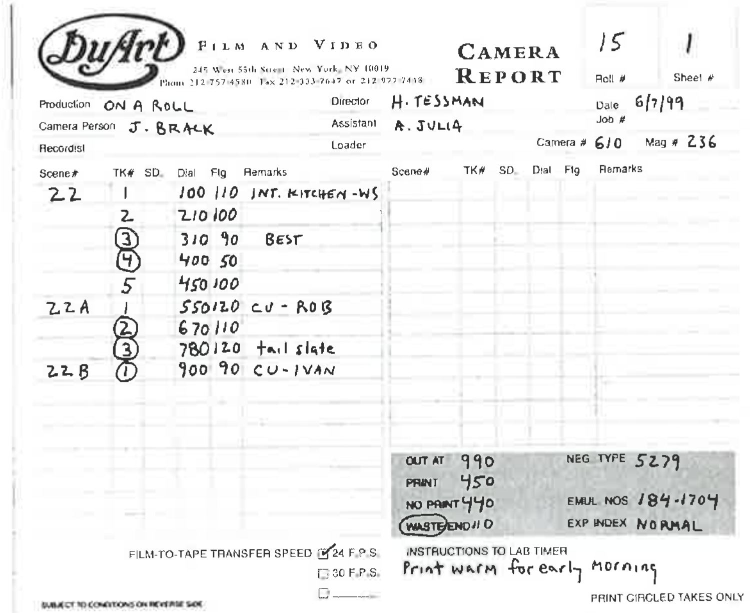
IVAN
Come in and show this to Margaret, I want her to see what we're doing here..

Fig. 9-35. Lined script. Each vertical line indicates a different camera angle or shot that was filmed. Zigzag portions indicate off-camera dialogue or action. The script is normally marked by the script supervisor during the shoot.

Camera and Sound Reports

When shooting film, the camera assistant fills out a *camera report* that indicates every take on a given roll of film, including the length of the shot and any remarks (see Fig. 9-36). Good takes are normally circled when shooting 35mm. This tells the lab which 35mm takes to print and/or transfer to digital. The camera report should also include scene and color information that will help the lab or transfer facility with picture adjustments, such as exterior ("Ext") or interior ("Int"); special instructions ("print slightly red"). Without instructions, the lab may attempt to bring intentionally underexposed scenes (for example, day-for-night shots) or scenes with colored gels (say, at a nightclub) back to normal.

When double-system sound is recorded for film or video shoots, the sound recordist may fill out a *sound report* (see p. 442).



DuArt FILM AND VIDEO
245 West 55th Street New York, NY 10019
Phone 212-757-4580 Fax 212-333-7647 or 212-977-7448

CAMERA REPORT

Roll # 15 Sheet # 1

Production ON A ROLL Director H. TESSMAN Date 6/7/99
Camera Person J. BRACK Assistant A. JULIA Job #
Recordist Loader Camera # 610 Mag # 236

Scene#	TK#	SD.	Dial	Ftg	Remarks
22	1		100	110	INT. KITCHEN - WS
	2		210	100	
	3		310	90	BEST
	4		400	50	
	5		450	100	
22A	1		550	120	CU - ROB
	2		670	110	
	3		780	120	tail slate
22B	1		900	90	CU - IVAN

OUT AT 990 NEG. TYPE 5279
PRINT 450
NO PRINT 440 EMUL. NOS 184-1704
WASTE END 10 EXP INDEX NORMAL

FILM-TO-TAPE TRANSFER SPEED ☑ 24 F.P.S. ☐ 30 F.P.S. ☐

INSTRUCTIONS TO LAB TIMER Print warm for early morning

PRINT CIRCLED TAKES ONLY

SUBJECT TO CONDITIONS ON REVERSE SIDE

Fig. 9-36. The camera report accounts for every take on each camera roll. The best takes are circled. In 35mm, usually only circled takes are printed.

SUPPORTING THE CAMERA

The Tripod

The *tripod* is a three-legged camera support. The camera mounts on the *tripod head*, which sits on the tripod's *legs*. Heads designed for motion picture work are able to *pan* (short for *panorama*), which means to rotate the camera horizontally, or to *tilt*, which is a vertical rotation. *Friction heads* for tripods are the cheapest, but they make it hard to pan smoothly. *Fluid heads* have a built-in hydraulic dampening device to make panning much easier (see Fig. 9-37). Their light weight and ease of operation make them the best for most situations. Large cameras are sometimes used with *geared heads* that use two gear wheels to control movement (see Fig. 9-38). These are heavy and take experience to operate but can produce smooth, repeatable movements.

Heads have an adjustment for the amount of drag or dampening for panning (it's easier to pan smoothly when the head "sticks" a little). Most heads made for video cameras have a balancing mechanism, either a spring affair or a forward/back adjustment. When the camera is properly positioned and balanced, it should not move

when the head is unlocked. Use the lock on the tripod heads to prevent an unintended tilt, since camera and tripod can fall over.

Tripods have aluminum or carbon fiber legs (which are lighter and more expensive). Standard legs will telescope out to around six feet, and *baby legs* raise to around three feet. Dual-stage legs have three sections, allowing them to go lower than single-stage legs while reaching the same height or higher (see Fig. 9-39). The *hi hat*, used for low-angle shots, does not telescope and is often attached to a board. A *table stand* can be useful for small cameras. Tripod legs and heads are rated by the weight they support; don't use a camera heavier than the rating.

Level a tripod so that the horizon line is parallel to the top or bottom of the frame. Unleveled tripods result in canted shots and tilted pans. To level a tripod, extend one of the legs (loosen the leg lock and tighten at the proper length); extend the other two legs but don't tighten them yet; hold the tripod in a vertical position and press down on it until the legs are even, and then tighten all of them. Point the legs so you can stand comfortably next to the camera. With a ball-in-socket head, loosen the ball and move the head until the bubble on the attached spirit level is centered. If the tripod has no level, align a true vertical (like the edge of a building) with the vertical edge of the frame; or align a true horizontal, viewed head-on, with the top or bottom of the frame.

Quick-release mechanisms save an enormous amount of time mounting and releasing the camera from the tripod head without having to screw and unscrew the connection each time. Avoid tripods that lack a quick-release plate. Tripod legs often have a point or spike at each toe that can be secured in dirt or sand. A *spreader* (also called a *spider* or *triangle*) is a three-armed device that spreads from a cen-

Fig. 9-37. Fluid heads are the most versatile and easiest to operate. This Sachtler head has seven-step pan and tilt drag controls and a quick-release plate that attaches to the camera and can be snapped on and off the head. The top surface slides forward and back for balance. (Fletcher Chicago/Sachtler Corp. of America)

Fig. 9-38. Geared head. Arrihead 2 shown with Arriflex 535B 35mm camera. (ARRI, Inc.)

Fig. 9-39. (left) Tripod legs with the spreader mounted midleg can have an advantage when shooting on uneven surfaces. (right) Dual-stage legs (note three sections on each leg) can often go both lower and higher than comparable single-stage legs. This spreader is at ground level and attaches to the tripod feet. (Miller Camera Support)

Fig. 9-40. A tripod that allows the legs to be spread wide permits low-angle shots. An external monitor makes viewing easier when the camera is low or high. (Toby Ralph/SmallHD)

tral point and clamps to each tripod leg; this prevents the legs from sliding out from under the tripod head. A spreader that remains attached to the tripod even when stored for travel saves a lot of setup time. A spreader that attaches midway up the legs instead of at ground level can be helpful when shooting outdoors or on uneven surfaces.

When shipping or transporting a tripod, loosen all locks and drag mechanisms on the fluid head so the head is free to move in its case and is less likely to be damaged by rough handling.

A *rolling spider* or *tripod dolly* (a spreader with wheels) facilitates moving the camera between shots. Don't use it for dolly shots except on the smoothest of surfaces. When no spreader is available, a four-by-four-foot piece of rug can be used. You can tie rope or gaffer's tape around the perimeter of the legs for an improvised spreader.

Some tripods (usually made for still photography) have devices for elevating the center of the tripod. On some tripods this extension may contribute to the unsteadiness of the image; it's usually better to extend the legs. If additional height is needed, mount the tripod on a platform. On larger productions *apple boxes*—strong, shallow boxes of standard sizes—are put together to make low platforms. Apple boxes are available in full, half, and quarter size.

If you'll be shooting with a digital camera for extended periods on a tripod or dolly it's very helpful to have an external monitor or, for a film camera, a viewfinder extension. Remote controls for the lens and camera are available for both video and film cameras. Some mount on the tripod handle; some extend from the lens or camera directly or on cables. When shooting from a tripod or dolly, it can often be difficult to reach the lens or camera switch without them.

Dollies

The *doorway* or *door dolly* is basically a board on rubber wheels with a simple steering mechanism; this is a lightweight, portable, and inexpensive dolly. You can place a tripod on it and anchor it with sandbags. The *western dolly* is a larger version. Though these dollies are steerable, they can't move laterally, as a *crab dolly* can.

A dolly with an integral *boom* provides up-and-down (vertical) movement, which adds enormously to the lexicon of possible shots. A *jib arm* can be used with a tripod and/or a dolly for up-and-down or side-to-side movement. Jib arms are harder to control than built-in booms, but they can provide extended reach for high-angle shots. If the support can reach great heights, it is called a *camera crane*. Industrial "cherry pickers" (like a telephone repair truck) may be used to raise the camera up high for a static

Fig. 9-41. Doorway dolly. Lightweight, affordable, basic dolly. (Matthews Studio Equipment, Inc.)

Fig. 9-42. Dolly with boom permits vertical as well as horizontal movements. (J. L. Fisher, Inc.)

shot, but they don't have the proper dampening for a moving shot that ends with the camera motionless.

Most dollies can be run on plywood sheets or smooth floors. Use air-filled tires when running on pavement. Large tires, especially when underinflated, give smoother motion on rougher surfaces. For the smoothest, most repeatable movements, use a dolly that runs on tracks. Track comes in straight and curved sections of various lengths that can be combined as needed. Track can be used indoors or out, but it needs to be carefully positioned and leveled with *wedges* to produce bump-free, quiet movements. A little lubricant helps stop squeaks. Some dollies with flat wheels can be switched to or mounted on *bogey wheels* or skateboard wheels for track.

There are substitutes for professional dollies—wheelchairs, shopping carts, a pushed automobile, a blanket pulled along the floor or a table. Don't secure the camera rigidly to most of these improvised dollies. Hand-holding or using a Steadicam insulates the camera from vibrations.

The person pushing the dolly (the *dolly grip*) becomes an extension of the camera operator and needs just as much practice and finesse to get the shot right. Keep this in mind when hiring your dolly grip. Even if you don't plan to do moving shots, having the camera on a dolly with a boom can save a great deal of time on the set, allowing you to quickly put the camera in positions that would be slower or impossible to do with a tripod.

Fig. 9-43. Compact jib arms can be used for location and studio work, and can be mounted on a tripod or a dolly. (Miller Camera Support)

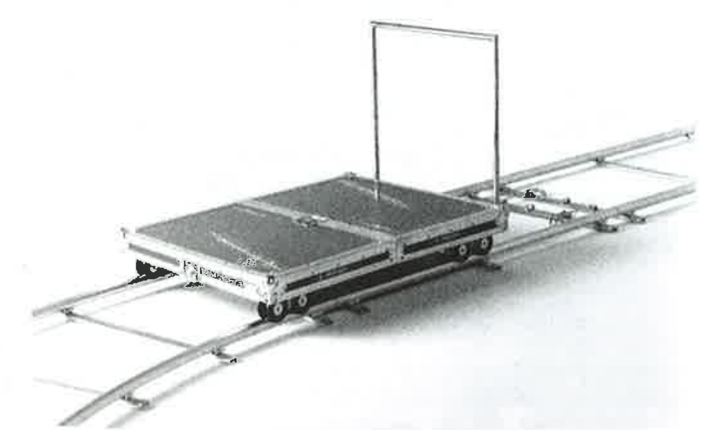


Fig. 9-44. Briefcase dolly. Can be used with straight or curved track or on bare floor. The dolly platform folds up, becoming a thin carrying case for travel. (Fletcher Chicago/Egripment USA)

Fig. 9-45. The dolly grip (left) plays a crucial role in executing a well-timed dolly shot.

Fig. 9-46. Cinevate slider permits lateral or vertical moves. Can be mounted on a tripod or on the ground. When doing any kind of camera move, placing the subject or objects in the near foreground helps accentuate the sense of movement. See also Fig. 1-19. (Cinevate)

Short camera moves can be done with *sliders*, which are compact rail systems often small enough to fit on a single tripod. Different lengths are popular, from a mere two feet to six feet and longer. Some are ultralight, designed for the DSLR weight class; others are sturdy enough for the largest 35mm film cameras (and require more support than a single tripod). With even a two-foot slider, the use of a wide-angle lens to emphasize movement through space and a slow, deliberate forward glide or lateral move of six seconds or more can add welcome production value to documentary and dramatic sequences alike. The movement will be most visible on screen if the camera moves past objects in the foreground.

Shooting in a Moving Vehicle

When you need a tracking shot that's faster than what you can get from a dolly, use a motorized vehicle. A vehicle, especially if it is equipped with a shooting platform, is extremely versatile. In general, the larger the car, the smoother the ride. Automatic transmission is preferable, since manual shifting may create a jerky movement. Keep tire pressure low to smooth out the ride. If you're not using a professional camera vehicle, it's usually best to hand-hold the camera to absorb automobile vibrations. It's easiest to achieve smooth camera movement if the car's speed remains constant, and most difficult if the vehicle goes from a stop into motion.

Shooting in the same direction as the moving vehicle results in the motion appearing normal on the screen. Shooting at right angles to the direction of the vehicle makes the car appear to be going roughly twice as fast as it is. At intermediate angles, the speed is between these extremes. Wide-angle lenses increase apparent speed and long focal length lenses can decrease apparent speed (see Perspective Effects, p. 385). By shooting at a higher frame rate you can smooth out unevenness in the ride (similarly, you can slow down normally shot footage, but this won't look as natural).

When shooting action that takes place in a car, you may be able to get the shots you need by shooting from inside the car, which might involve shooting handheld

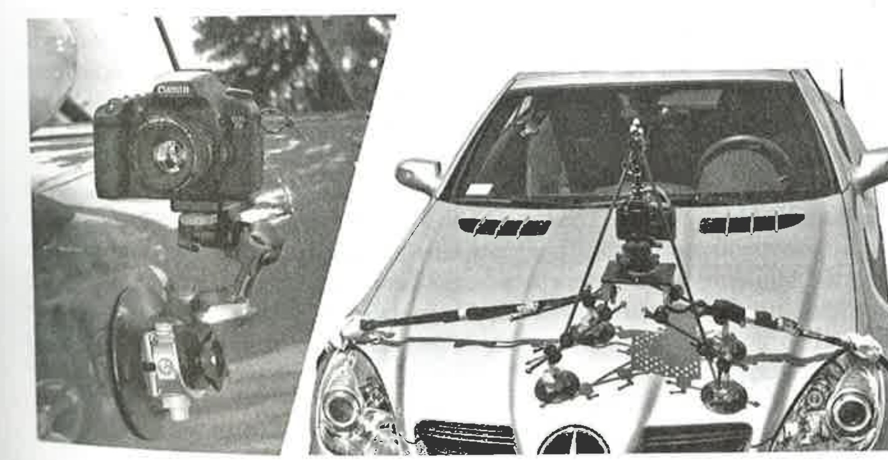


Fig. 9-47. Suction mounts can be attached to cars, windows, and nonporous surfaces. Car mounts should be set up by experienced persons using safety lines when possible. (Filmtools)

from a passenger seat or mounting a camera inside the car or out. Heavy-duty suction mounts and clamps allow you to attach cameras to the hood or side of the car. The surface must be smooth, clean, and dry to use suction mounts. If the camera is mounted on a moving vehicle or in a precarious spot, be sure to tie it down with safety lines.

For better control and lighting, as well as a wider range of camera angles and moves, larger productions use a camera vehicle to tow the car that the actors are in (which is called the *picture car* or *picture vehicle*) either on a hitch or on a trailer. A trailer facilitates doing shots through the side windows, including dolly moves. Towing the picture car frees actors from having to concentrate on driving while doing their scenes and is safer.

The Handheld Camera

The handheld camera was first experimented with during the silent era, especially in the films of Dreyer, Clair, Vigo, and Vertov. Cameras then were hand-cranked or spring-wound, or they used heavy motors, and sound, if possible, was nonsynchronous. Not until the early 1960s, when lightweight 35mm and sync-sound 16mm cameras arrived—launching New Wave fiction filmmaking and cinema verité documentary filmmaking—was the potential of the handheld camera realized. Not only could the camera now capture new subject matter in new locations, but handheld shooting, at its best, imparted a new electricity to the image. The extreme mobility of a handheld camera permits following every action, achieving a feeling of intimacy and spontaneity impossible when using a tripod- or dolly-mounted camera, which is why handheld shooting is often best in unscripted situations—whether a documentary or with improvised acting.

Sometimes a handheld camera is used specifically to bring a "documentary" feel to the footage, in which case a little bit of shakiness may be desired. On the other hand, a skilled cameraperson can hand-hold with real steadiness, maintaining mobility but keeping the image very stable. Cameras that ergonomically lend themselves to comfortable, balanced hand-holding are often used to squeeze off shots that would take too long to set up otherwise. It is not uncommon these days to see an occasional handheld shot mixed in with mostly tripod and dolly shots. Audiences, whether they know it or not, have grown used to seeing this mix of mounted and handheld shots in both movies and particularly television dramas that are limited to tighter budgets.

TIPS FOR HANDHELD SHOOTING. Shoulder-mounted cameras are the steadiest, because the operator's body braces the camera and dampens vibrations (see Fig. 2-16). Cameras that are held in front of the eye, like small digital camcorders, are harder to hold steady and can feel heavy after a few hours of shooting, especially when you add items like a matte box, focus control, onboard monitor, wireless receiver, portable recorder, and/or light. A single lightweight item can often be mounted to the camera's shoe; others can be attached to rods or a "cage" (see Fig. 10-15). Heavier items, like a wireless receiver, can be mounted on your belt or put in a small shoulder bag with wires to the camera (see Fig. 11-1).

Most small camcorders feature some type of internal image stabilization, which can be very effective. Cameras that don't balance on the shoulder can be used with a brace. Some braces increase stability but still require you to support the front of the camera (see Fig. 3-15). A larger body brace can take more weight off your arms and allow steadier shots, but some cinematographers feel it imparts a mechanical feel to the shooting and makes it harder to respond to unpredictable events or to shoot in small spaces, like a car.

With each different make or model of camera or camcorder you must memorize which way to turn the lens controls for focus, aperture, and zoom. Make up your own memory aid, such as "pull to bring infinity close and bright," which means (assuming the lens is operated with the left hand) pull counterclockwise for farther distances (infinity), to open up the aperture (bright), and to zoom in closer. The controls on your lens or camera may be completely different, so you may need to make up another memory aid for your rig.

To shoot a handheld camera over extended periods of time, it helps if you're in good physical shape. Find a comfortable position for shooting by practicing before you begin. Some people shoot with one foot in front of the other, others with their feet shoulder-width apart. Don't lock your knees; keep them slightly bent. Stand so you can smoothly pan in either direction and move forward or backward. For filming while walking, walk Groucho Marx–style, with your knees bent and shuffling so that the camera doesn't bob up and down.

When you film without a script, avoid excessive zooming and panning, which could produce results that are unwatchable and uncuttable. To get in the rhythm, students should try counting slowly to six without making any camera movements.

When you shoot while walking backward, have someone (say, the sound recordist on a small crew) put his hand on your shoulder and direct you. Try cradling the camera in your arms while walking and shooting; use a fairly wide-angle lens, positioned close to the subject, and keep in stride. Put the camera on your knee when shooting the driver in the front seat of a cramped car.

To steady a static shot, lean against a person or a support, such as a car or building. When shooting landscapes or scenes with strong architectural elements, any jiggles become obvious due to the stillness of the subject. Consider using a tripod or putting the camera on a surface for these shots. The *Steadybag* is like a small beanbag and allows you to perch a camera quickly on a flat or uneven surface for a steady shot.

Documentary filmmaking creates some of the most difficult follow-focus situations, as the camera-to-subject distance constantly changes in unpredictable ways. This is especially problematic with large-sensor cameras that have shallow depth of field. When careful focusing is not possible, zoom to a wider angle to increase depth of field and move the distance ring to the approximate position. As your skill increases, it will become easier to pull something directly into focus by looking through the viewfinder. As previously said, remember that the wider the angle of the lens, the less annoying any camera jiggle will be in the image (see Chapter 4).

Image Stabilization Devices

Image stabilization methods can be used to lessen unwanted camera vibrations and jiggles. These range from common *optical image stabilization* (*OIS*) systems built into small camcorders and DSLR lenses to built-in systems for B4- and PLmount lenses (by Canon) to lens peripherals (also Canon) to handheld or body-mounted devices, including helicopter and other vehicle mounts. In post, there are numerous software applications to remove unwanted camera shake, notably Adobe After Effects. Most professional editing systems now offer this function; Apple Final Cut Pro X, for example, can automatically stabilize when you import the footage (see p. 593).

INTERNAL IMAGE STABILIZERS. *Electronic image stabilization* (*EIS*) requires a sensor larger than the actual image itself (or first must slightly enlarge the image) to digitally reposition the image while you're shooting to reduce image shake, which may noticeably affect image quality. For this reason it is found mostly in cheaper consumer camcorders. As mentioned above, internal optical image stabilization is used in DSLR lenses and camcorders favored by professionals to dampen vibration and shake. Experiment to see whether you like the effect of optical image stabilization. Some OIS systems add a slight lag to certain camera movements, giving an unwanted floating effect. Some newer camcorders offer a choice of different levels and types of OIS.

THE STEADICAM. The Steadicam, Glidecam, and similar devices allow the camera to be mounted on a gimbaled arm attached to a harness worn by the camera operator that isolates the camera from body shake, enabling smooth movements (see Fig. 9-48). This enables camera movements similar to those from a dolly, but with much faster setups, shooting in tighter quarters, and significantly increased mobility. Any vehicle—automobile, boat, helicopter—can serve as a platform for dolly-smooth movements. Pans, tilts, running shots, and shots going up stairs can be made with the subtlety of the moves of the human body without any handheld jiggles.

Since the mid-1970s, camera stabilizing systems—first and famously Steadicam—have enabled new camera moves that blend the freedom of hand-holding with the controllability of a dolly or crane. In fact, the very first Steadicam shot ever seen in a movie, from *Bound for Glory* (1976), was produced by Steadicam inventor Garrett Brown riding a tall crane shot all the way to the ground, then hopping off and floating the camera through the movie's set. Prior to Steadicam, this would have been an impossible shot. Alexander Sokurov's *Russian Ark* (2002), a costume-drama romp through the history and galleries of the State Hermitage Museum in Saint Petersburg, is nothing but a single ninety-six-minute Steadicam take—and a virtual encyclopedia of Steadicam timing, technique, and moves.

The impact of a device like this on the language of film shot-flow has been monumental. Not only does it expand the basic repertoire of dollylike shots, but, more important, it creates new relationships between filmmaker and location and between filmmaker and actors. Quick, inexpensive setups relieve the pressure on actors and crew. In documentary, the use of image stabilization devices can be effective for tracking or establishing shots. For filming people in more intimate settings, however, the equipment may be too intrusive.

Although you can respond to unplanned subject movement (unlike a dolly, for which each shot must be blocked), response is slower than that of a shoulder-mounted camera. Steadicam or Glidecam shots have a floating quality that some

people find less exciting than well-done handheld shots. And at the end of a move, it is sometimes a challenge to maintain a perfectly stable horizon line without some bobbing.

A Steadicam-type system must be set up specifically for each size, weight, and balance of camera and requires that film cameras be equipped with a video tap for monitoring. Film cameras with vertically mounted magazines or coaxial magazines (see p. 262) work best, since the camera's center of balance remains more stable during a take. The operator needs special training and plenty of practice. Often wide-angle lenses work best when tracking action.

There are various smaller devices designed to smooth out camera movement for small digital cameras exemplified by the Steadicam Merlin (see Fig. 1-15). These are handheld, with no body brace or monitor. With practice, these can provide smooth moves in some shooting situations.

Fig. 9-48. Steadicam. The camera floats smoothly, isolated from shocks or jarring with springs in the support arm. The operator wears a harness and watches a small monitor mounted on the Steadicam. Steadicam and Glidecam also make smaller, handheld systems for small cameras (see Fig. 1-15). (The Tiffen Company)

CAMERA MOUNTS. To stabilize large movements (for example, when shooting from a boat) a *gyroscopic stabilizer* can be mounted on a tripod to compensate for motion in the camera platform. When shooting from a helicopter, a Tyler mount or Wescam system can be used to stabilize the camera.

SOFTWARE STABILIZATION. Many software applications allow you to stabilize a shot in postproduction. Some are astonishingly sophisticated and can make a bouncy, handheld shot look dolly smooth. For more, see p. 593.

SLOW MOTION, FAST MOTION, AND JUDDER

SLOW MOTION

Slow motion can be used to analyze motion or to call attention to motion itself. In Leni Riefenstahl's *Olympia*, a film of the 1936 Olympics in Berlin, the movements of the athletes are broken down and extended in time with slow motion, letting the viewer see things unobservable in real time. Televised sports events often show re-plays in slow motion ("slo-mo") to analyze the action. Slow motion extends real time, sometimes giving an event more psychological weight. A character's death may occur in an instant, yet be the most important moment in a film. Starting with *Bonnie and Clyde*, countless films have shown the protagonist's death in slow motion, extending the time of death to give it greater emotional emphasis. Today filmmakers often use slow motion to add feeling to otherwise mundane shots.

Slow-motion effects can be achieved in two ways: by running the camera at higher than regular frame rate; and by shooting at normal speed and then slowing the footage down later during postproduction. There can be a noticeable difference between the two methods.

When the camera runs fast, you are capturing many continuous frames in a given period of time (say, 80 frames in a second). This makes the slowed action seem smooth and continuous on playback or projection. This technique is also called *overcranking*.

However, when a film or video camera is shooting at normal speed (say, 24 or 30 frames a second), and you then slow the footage down in post, motion may appear discontinuous and jerky. The slow-motion effect is achieved in post by repeating each frame two or more times, then moving to the next frame. There will be a slight jump when you move to each new frame. Also, the normal motion blur that takes place with any camera and/or subject movement—which is invisible at normal playback speeds—will be more pronounced when normal footage is slowed down (see Figs. 2-14 and 2-15). This effect may be desired, or at times it may just look inferior to true slow-motion shot with a camera running at a higher frame rate.

Software apps like Twixtor and the time warp effect in After Effects can create better slow motion during postproduction by interpolating (essentially creating a new frame that bridges the gap from one frame to the next). If you plan for this, shoot with a fast shutter speed (less than 1/2000 second) to reduce motion blur.

The effect of overcranking depends in part on the base frame rate of your project. For example, if the rest of the movie is being shot at 30 fps, then shooting at 60

Fig. 9-49. Phantom Flex high-speed digital camera can shoot 5 to 2,570 fps at 1920 x 1080 HD resolution. (Vision Research)

fps will slow motion by half. High frame rates also result in shorter exposure times, which require more light.

High speeds can help minimize the effect of unwanted camera jiggle and vibration. When the camera is handheld or on a moving vehicle, faster camera speeds lengthen the distance between jerky or uneven movements and make the image seem steadier. Of course, any subject movement will also be in slow motion.

High-Speed Cameras

Sometimes very high frame rates are needed for an effect or to capture or analyze fleeting events. If you want to see individual water droplets slowly crashing on the ground or a bullet shattering glass, use a high-speed camera (and sometimes strobe lighting, which is like using a very short shutter speed). High-speed digital cameras, like the Phantom Flex, can shoot 720p HD video at over 6,000 frames per second, and even higher frame rates are possible at lower resolution. As a point of comparison, a camera speed of 250 fps stretches one second of real time into more than ten seconds of 24p film time.

High-speed recording implies very short exposure times, which usually requires a lot of light (and a sensitive chip for a video camera or a fast stock for a film camera). Some cameras can be operated at normal speed and then ramped up to high speed when the key action begins and they'll automatically adjust the exposure.

Fig. 9-50. To achieve shots like this, in which rapidly moving objects appear to move slowly but smoothly and are clear and distinct with no motion blur, you need to shoot at a high frame rate and not merely slow down normally shot footage in post.

FAST MOTION

Most film cameras and many digital cameras can be operated at slower-than-normal frame rate (called *undercranking*). This results in each frame being exposed for a greater length of time. For example, shooting at 12 fps gives one stop more exposure than filming at 24 fps. This can be used to advantage in scenes where the light level is too low for exposure at normal speed and there is no movement in the scene—for example, when filming exteriors at night. Keep in mind that any motion, like car headlights, will seem sped up. If shooting in a dark church interior at 12 fps, you might have actors walk at half speed, or move the camera half as fast as usual so the movement will appear normal in playback. If you take undercranked footage and slow it down in postproduction, you can get an interesting ghostlike effect.

Undercranking produces a slower shutter speed. However, it creates a very different effect than shooting at normal frame rate with an adjustable shutter set to a slower shutter speed (see p. 135 and p. 256).

Chase sequences can be undercranked to make motion appear faster and more dangerous. The sped-up motion of silent film comedy was, supposedly, the result of an unintentionally undercranked camera on a Mack Sennett set. You can get this effect by shooting at about 16 to 20 fps and then playing back or projecting at 24 fps.

Time-Lapse

With significantly slower speeds, time is proportionally sped up. In *time-lapse*, the sun can set, a flower can blossom, or a building can be demolished and another constructed in a few seconds (sometimes called *pixilation*). Nonlinear editing systems can speed up shots to create time-lapse sequences from footage shot at normal speed, but for action that takes place over hours or days, you won't want (or be able to) record that much footage to speed it up later.

For very condensed time, you need a camera that can make single-frame exposures. Some digital and film cameras have this option, which may be called *interval recording*. DSLRs are very effective for shooting time-lapse footage and stop-motion animation. Animated films, such as Tim Burton's *Corpse Bride*, have been shot with DSLRs. Filmmakers can put DSLRs on small, motorized tracks to get very exciting moving-camera time-lapse shots. Some film cameras can be used with an *intervalometer* to control time-lapse exposures. GBTimelapse is an app that can provide versatile control of a DSLR and capture images directly to a computer.

Finding the right frame rate for a time-lapse sequence takes some experimentation. Start by estimating how long you want the finished sequence to run on screen. From this you can figure the total number of frames to expose. Say you want to shoot a sunset that takes two hours (120 minutes) and have the shot run ten seconds in the movie. For this example, let's assume this is a 24p digital or film project. Hence, 10 seconds × 24 fps = 240 frames. This means you need to expose an average of 2 frames per minute during the sunset. It's a good idea to start shooting sometime before and continue after the main action to provide flexibility in editing. Unless you're shooting film, it's often safest to record more frames than you think you need in a period of time, and speed the footage up a bit in post if necessary.

Exposures may be programmed for one or several frames at a given time interval or at varying intervals. The fewer exposures at a time and the farther apart, the more jumpy or staccato the motion will look. Single-frame exposures are often slower than the normal camera shutter speed, which can also help reduce flicker when shooting under fluorescents or other pulsed lights. (Avoid fluorescents when possible; if you can't, software plug-ins may be able to reduce flicker in post.) Very slow

shutter speeds for each exposure will increase motion blur. You can use this effect to turn car lights at night into colored streaks.

Some time-lapse sequences look best without changing the lens iris or exposure time over the sequence. In this case, base the exposure setting on the light reading at the most important part of the sequence. You could also "ride" the exposure, changing it manually or by using programmed features in the camera or intervalometer.

In some situations an auto-iris can extend the usable length of the sequence if the light is changing. In others, it might fight with the effect you're looking for: a sunset might look too silhouetted, for example.

Often, a wide-angle lens produces the best time-lapse effect. A wide shot of traffic at a certain frame rate might produce a shot that looks like a fast-moving river of cars; any single car might be seen moving from one side of the frame to the other. However, if you used a telephoto lens to get a long shot of the same scene at the same frame rate, you might end up with a shot that showed individual cars popping into one frame and disappearing in the next. An interesting effect can be had by walking or dollying the camera, shooting a frame or two every step.

Animation

Animation can be seen as a variant of time-lapse photography. A series of paper drawings or paintings on acetate (*cel animation*) is done, with slight changes between the images. A few frames of one drawing are exposed, then the next one is filmed. On projection, the art seems to "move." This technique can also be used for Claymation and other pixilated shots of real objects that seem to move by themselves.

Today, animation is usually generated digitally, but traditional animation can be done with an animation stand and a DSLR or film camera capable of single exposures. In the past, motion-control animation stands such as the Oxberry were used to program moves across an animated or still image. Today it's more common to scan artwork and do the moves in an editing system (see Animating Stills, p. 596).

JUDDER OR STROBING

All motion pictures are based on the illusion that a series of still images, when shown one after another, will appear to have movement. For the illusion to work and for motion to appear smooth, the changes from one image to the next can't be too great. When you shoot video at 60 frames per second (either progressive or interlace) motion tends to look fairly smooth on screen. However, when you shoot video or film at 24 fps, there are fewer images every second, and the changes between frames when either the camera or the subject moves can be greater (see Fig. 2-15). If something moves too quickly, to the audience it can look as though the object is jumping or skipping from one position to the next rather than moving smoothly and continuously. This irregular movement is sometimes called *judder*, *strobing*, or *skipping*.[9] It can give the viewer eyestrain or a headache. Judder is some-

9. The term "judder" is also used to refer to the irregular, sometimes stuttering motion that can result when 2:3 pulldown is used to convert 24 fps material to 30 fps (see Fig. 14-31).

thing to pay attention to when shooting at slower frame rates (like 24 fps) and sometimes even when shooting at higher frame rates when an adjustable shutter is set to a very fast shutter speed.

Judder is most visible in pans, especially fast moves across strong vertical lines. The higher the image contrast or greater the sharpness, the more likely that judder will occur. To minimize strobing when shooting, there are various guidelines or tricks. A rule of thumb is to allow at least five to seven seconds for an object to move from one side of the screen to the other. This applies both when the camera pans or when the subject moves through a stationary frame. If the camera moves or pans *with* a moving subject, the viewer concentrates on the person and is less likely to notice judder in the background. In this situation, use shallow depth of field if possible and focus on the subject, letting the background go soft. Avoid panning across high-contrast scenes that have strong vertical lines. Fast swish pans are usually not a problem. You can get charts of safe panning speeds for different camera and lens settings.

Footage shot with cameras that have relatively small sensors (including SD video cameras, some HD cameras, and 16mm film cameras) may appear to judder more than footage shot with 35mm film cameras or large-sensor HD cameras, in part because shots with large-sensor cameras typically have shallower depth of field, making it easier to throw the background out of focus. Using a slow shutter on a video camera (for example, ¹⁄₂₄ second) may reduce judder. Judder and flicker often look worse in the camera viewfinder than when the image is seen on a normal monitor or projected on screen (see p. 86). However, when it comes to projection on a big monitor or in a theater, bigger screens can make judder seem more severe than on smaller monitors (the jumps in the image are across a greater physical distance). Video projection, because it's brighter, may look jumpier than film.

A phenomenon related to strobing, and frequently referred to by the same term, is often noticed when the wheels of a moving vehicle on the screen seem to be stopped or to be traveling in reverse. This occurs when exposures happen to catch spokes at the same position in consecutive frames (thus, the wheels seem stopped) or catch them in a position slightly behind so the wheels appear to be spinning in reverse.

SHOOTING TVs AND VIDEO MONITORS

There are many situations in which you may want to shoot a video or computer display with either a video camera or a film camera. You may be shooting a scene in which a character is watching TV or you might be getting shots of a website on a laptop.

In some cases shooting video displays is very straightforward. For example, shooting any flat-panel LCD, plasma, or OLED screen with either a video or a film camera usually produces excellent results regardless of the frame rate or shutter speed, at least in most cases.

Sometimes when the frame rate or scanning rate of a display does not exactly match the frame rate or shutter speed of the camera, the screen image will seem to flicker. Many professional and prosumer video cameras have variable electronic shutters. Some have a specific feature to exactly match the shutter speed of the camera to the display's scanning frequency. Sony's system is called Clear Scan; Panasonic calls its Synchro Scan. These provide for a wide range of scanning frequencies that can be dialed in very precisely. Changing the shutter speed of a video camera affects the exposure time, but the basic frame rate is not affected (see p. 135). Don't forget to go back to your normal shutter speed after shooting the screen.

Another approach when shooting a computer display is to change the scanning (refresh) rate of the monitor, using the computer's control panel (Windows) or settings (Mac).

When shooting any display, be sure to white-balance the camera on the display and set exposure carefully. If you want the display's image to look flat and rectangular, shoot with a long lens from a good distance away. Or you might try getting very close and letting some parts of the screen be sharp in the foreground with other parts softer in the background. Sometimes when you focus on the screen you see the pixels too clearly or get a moiré pattern. Try throwing the lens *slightly* out of focus to reduce or eliminate this moiré.

Sometimes people mount a piece of green-screen material over the monitor so that video or computer images can be added later with a chroma key. You might do this if the monitor image isn't available when you're shooting. This is much easier to do convincingly if the camera you're shooting with doesn't move.

When shooting a monitor with a film camera, take a reflected light meter reading, not an incident reading. The color temperature of many monitors is close to daylight (6500°K). Use an 85 filter for tungsten film if you have enough exposure. Some monitors offer a choice of color temperatures. You may need a fairly fast film to get enough exposure.

SHOOTING CRTs. Shooting old-fashioned CRT televisions or video monitors—especially with a film camera—is more complicated since you often get a horizontal *shutter bar* or *hum bar* in the image. Filmmakers working in PAL countries can get a clean image simply by shooting a 25 fps PAL video monitor with a video camera or standard crystal-sync film camera with a 180-degree shutter running at 25 fps. Sometimes filmmakers in NTSC countries will adopt a similar strategy and shoot film at 29.97 fps. When film is transferred to video at 29.97 fps, motion will look normal, but if transferred at a standard 24 fps, motion will appear slightly slowed. Therefore, use of this technique hinges on considerations of frame rate and scene content. Be sure to consult with the transfer house in advance about proper speed for the sound recorder to maintain audio sync.

Another approach to filming a CRT in NTSC countries is to use a film camera with a variable shutter. When filming at 24 fps, a shutter opening of 144 degrees can be used (equals ¹⁄₆₀-second shutter speed), at least for short shots. Some cameras provide a precise 23.976 fps frame rate to perfectly match NTSC's 0.1 percent slowdown (from 30 fps to 29.97), which creates a true frame-rate lock. Motion shot at 23.976 will appear normal when projected at 24 fps and the footage can be transferred to video at real time.

SHOOTING IN 3D

The Basic Idea

Unlike the single camera and lens, we have twin eyes and our visual perception is binocular. The two eyes are required for *depth perception*: How near is that lion? How distant is that lake? How deep is that ravine? Can I reach for that fruit?

When the fourth dimension of time is added, depth perception allows us to perceive velocity. Not only how near that lion is, but also how fast he's traveling toward us.

From cave drawings onward, artists have attempted to represent the three dimensions of space—height, width, and depth—in two-dimensional form. Not until the Italian Renaissance and the development of *scientific perspective* did realism in painting succeed, and it took the invention of cinema in the nineteenth century to incorporate the extra dimension of time in depicting realistic motion. Even so, the outcome was limited to a flat, two-dimensional screen lacking the visual cues needed for genuine depth perception.

Stereoscopy, or 3D imaging, arrived with the birth of photography. By 1840, the English inventor Sir Charles Wheatstone—who was first to explain the role of binocular vision in *stereopsis* or depth perception—had invented a stereoscope for displaying still photos in stereo pairs. Handheld stereoscopes exploded in popularity in the second half of the nineteenth century, as evidenced by their easy availability at flea markets today.

Just as depth perception requires two eyes, stereoscopy requires two images, one for each eye. This means two cameras. Creating dual simultaneous images was feasible using the earliest still cameras but impossible with hand-cranked silent motion picture cameras.

By the early 1950s, theatrical movies dubbed "3D"—three-dimensional—became technically possible and enjoyed a brief heyday, with more than sixty 3D films released in 1953 alone. Notable examples are *Creature from the Black Lagoon* (1954) and Alfred Hitchcock's *Dial M for Murder* (1954). But the technical challenges of manipulating enormous twin blimped cameras (for sound films) persisted, as did the challenges of simultaneous projection of two giant reels each containing a 35mm print, one for each eye. As a result, 3D films died out until the early 1980s, when a second spike in popularity occurred, including *Friday the 13th Part 3* (1982) and *Jaws 3-D* (1983).

Fig. 9-51. 3D camcorder. The Panasonic AG-3DA1 has dual lenses and two 1920 x 1080 HD sensors. This kind of one-piece camcorder is easier to operate than 3D rigs that use two separate cameras. (Panasonic Broadcast)

This type of 3D filmmaking, using motion picture film, never achieved mainstream status with production crews, audiences, distributors, or exhibitors. Loading and identically exposing two strands of 35mm motion picture film—also developing and printing them identically, with all the costs doubled—was never a picnic; and those funny glasses, whether Polaroid or anaglyphic (red/cyan), which often induced headaches, failed to endear the complex format to the paying public.

Digital 3D

The popularity and commercial success of today's motion 3D (sometimes called *S3D* for stereoscopic 3D, to distinguish it from 3D computer graphics) is driven by the countless advantages of digital video. Compact, silent HD cameras are easily mounted side by side. Since there's no film to load or process, it's possible to view 3D results in real time or upon playback—perfect for realigning the optics, if necessary, for a better stereo experience free of eyestrain.

Even so, 3D doubles the amount and complexity of camera systems: lenses, optical paths, sensors, DSP, frame rate, even storage. All must be perfectly matched and synchronized. Choosing to produce a project in 3D is not a choice to be taken lightly.

The production, postproduction, distribution, and exhibition of digital motion pictures in 3D is an extensive topic warranting its own bookshelf. Since a full treatment of 3D technology and techniques, including the psychophysics of stereo vision, is beyond the means of this book, below is a brief outline of basic 3D concepts and practice, meant as a starting point only.

Fundamentals of 3D Images

The spacing between our eyes is called the *interocular distance* and can range from 55 to 75 millimeters (65mm, or 2.5 inches, is average for adults). The spacing between the two matched lenses required of any 3D camera system is called the *interaxial* distance, the space between the central axis of each lens.

The distance between our eyes, which of course is fixed, is what determines our sense of scale, the depth and size of objects we experience as near and far. Because the interaxial distance between two cameras in a stereo rig can be adjusted, the appearance of depth in 3D space can be collapsed by merely reducing interaxial distance. Increasing the interaxial distance imparts a sense of greater depth.

Convergence (sometimes called *vergence*) is the degree to which two lenses or cameras in a 3D system are angled toward each other, similar to the way our eyes rotate inward as we view an object approaching our nose. As babies we learn both to converge our eyes on an object of interest and, at the same time, focus our eyes on that object.

It's been said that making 3D is easy, making *good* 3D is hard. Many of the problems created for viewers of 3D movies can be found in the fact that when we view 3D, we focus our eyes on a two-dimensional screen, which of course exists at a fixed distance. Meanwhile, because of the 3D effect we are experiencing, our eyes are converging elsewhere, either in front of or behind the screen—an unnatural dissociation of convergence and focus as far as our eyes and brain are concerned (see

Fig. 9-52). Minimizing uncomfortable *vergence/accommodation conflicts* ("accommodation" is the technical term for refocusing our eyes) is the key to making 3D movies that don't tire the eyes.

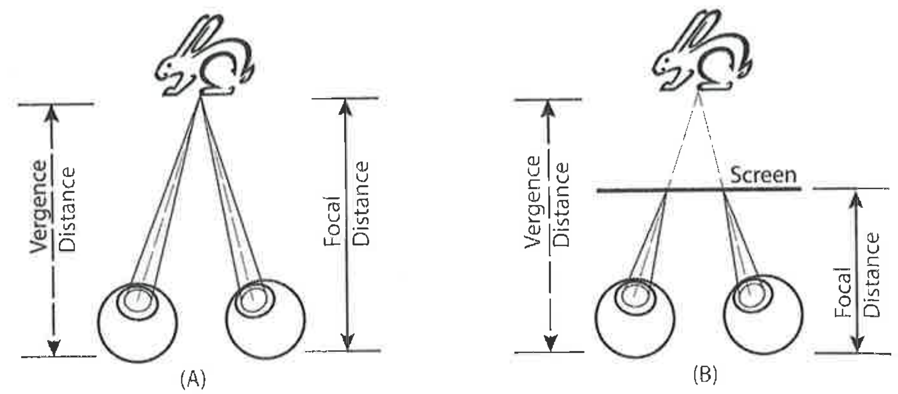


Fig. 9-52. (A) Normally, when we look at an object our eyes converge and focus at the same point. (B) When viewing 3D movies, our eyes focus on the surface of the screen, yet converge at a different point, wherever the object we're looking at is placed.

Angling two 3D cameras to create the illusion of objects behind the screen results in what's called *positive parallax*; placing objects in front of the screen (a spear thrust into the audience, for example) results in *negative parallax*. Consequently, the 3D image area behind the viewing screen is called positive space, while the area in front is called negative space.

The so-called *View-Master effect*, in which objects look like cardboard cutouts, can be avoided by not using long focal length lenses, which flatten object space to begin with.

Production in Digital 3D

Creating a digital 3D movie can be a production process or a postproduction process or a combination of both. A live sporting event on TV is an example of digital 3D that must be captured in production. In contrast, virtually all Hollywood digital 3D movies released before 2010 were shot in 2D, then painstakingly and expensively converted to 3D in post. (The 3D conversion of earlier movies, like *Star Wars*, is sometimes called *dimensionalization*.) However, since 2010, shooting 3D on the set has become the norm due to the arrival of compact digital cinema cameras like RED's Epic and ARRI's Alexa M, which make two-camera 3D rigs more manageable in size and weight. (Think Steadicam.) Additional factors are the growing familiarity of experienced crews with the demands of 3D production and a realization on the part of producers that shooting digital 3D takes about the same time as 2D.

Digital 3D camera rigs take many forms. Countless independent producers have created 3D by placing two identical cameras side by side. Typically, very compact cameras are used for this approach, to get as close to a 2.5-inch interaxial distance as possible. To avoid 3D problems, there must be perfect agreement between the two lenses used for left and right images: identical *f*-stops, no vertical displacement

(like our eyes, both lenses must exist on the same horizontal plane), matched geometry for left and right images, and if zooms are used, perfect synchrony in focal length (image magnification), with no center drift in either lens during zooming. It's a tall order, but any deviations will cause eyestrain and entail costly or time-consuming correction in post.

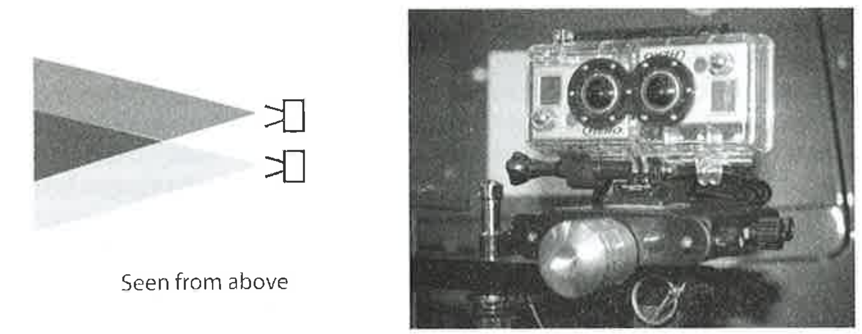


Fig. 9-53. Side-by-side 3D rig. This one uses two GoPro Hero HD cameras (see Fig. 2-8). (Photo by David Leitner)

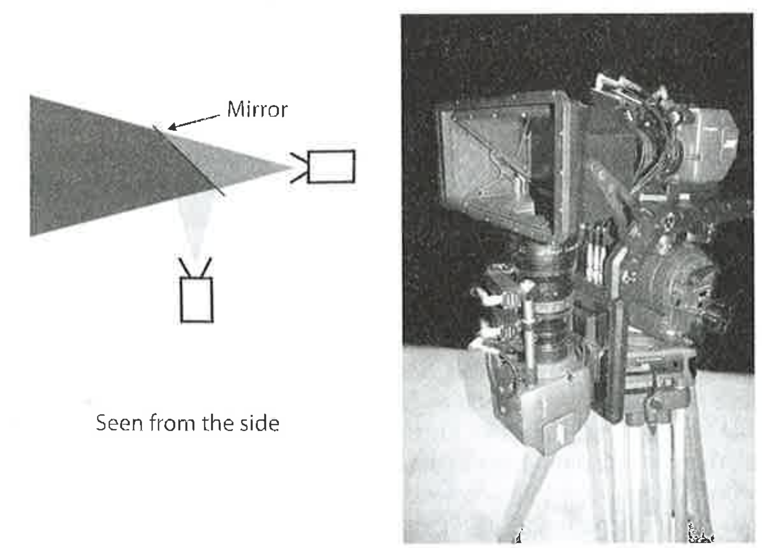


Fig. 9-54. Mirror 3D rig in which the two cameras (ARRI Alexas) shoot through a partially reflecting mirror. (Photo by David Leitner)

Professional 3D camera rigs come in two basic configurations: side by side and a vertical arrangement featuring a beam-splitting mirror. (See Figs. 9-53 and 9-54.) Achieving a tight interaxial distance is always a problem for a side-by-side rig, limited by the width of the cameras involved. The over/under mirror configuration overcomes this easily, since both cameras can share the same optical axis if they want to. For example, during the production of *The Amazing Spider-Man* (2012), an interaxial distance between 0.25 and 0.75 inch was used throughout. An interaxial distance of 2.5 inches was found to be too wide for shooting objects closer than ten feet without inducing a feel of miniaturization in the scene.

Lastly, a number of consumer and professional all-in-one 3D camcorders have been introduced by Panasonic, Sony, JVC, and others. What they have in common are two side-by-side lenses and two sensor systems bundled into one device. Small CMOS sensors are used, from ¼ inch to ½ inch in size, either arranged as dual single sensors or as dual three-chip blocks. Interaxial distance is fixed by each camcorder's size and design, while adjustment of convergence is achieved by an internal optical element shifted manually by dial or automatically in some cases. Dual image streams are recorded onto file-based flash media in popular compression formats like AVCHD. Onboard viewing is achieved using either 2D viewfinders offering overlays to depict proper convergence or by "glasses-free" *autostereoscopic* LCDs, which flip out from the camcorder in normal fashion. Autostereoscopic displays use *lenticular* screens, which, when held at a close distance from the face, offer each eye a difference image. You're familiar with lenticular screens from postcards that produce animated effects when rotated back and forth. The fine vertical ribs you feel when you touch the front surface of these cards are lenses that magnify different images from different angles, just like an autostereoscopic LCD.

This leads to the issue of how you view or monitor digital 3D during production. Autostereoscopic displays are limited to one viewer at a time. They must be small in size and positioned straight in front of your eyes at a short, fixed distance. Note that this describes the viewing conditions of a cell phone, gaming device, tablet computer held at arm's length, or laptop screen—which is why autostereoscopic displays are beginning to arrive on these devices. Anything larger requires either *passive* glasses, with circular-polarized filters, or *active* glasses, with electronic LCD shutters synchronized to the 3D display (more on this below). For this reason, some choose to monitor 3D shoots in standard 2D, placing emphasis on performance and shot flow, and only later view the results in 3D. Adopting this scenario, peace of mind dictates placing an experienced *stereographer* at the center of the production team.

Editing 3D is an evolving craft. Some edit partway in 2D using either the left- or right-eye recording, then switch to full 3D. Plug-ins to facilitate editing of 3D are available for popular NLEs like Final Cut Pro and EFX programs like Adobe After Effects; there are also plug-ins to detect and correct parallax and alignment errors. Dashwood Cinema Solutions (www.dashwood3d.com) is particularly well regarded for both the information at its website and its plug-ins and software tools for 3D production.

Exhibition and Distribution of Digital 3D

Most commercial theaters exhibiting 3D in the U.S. today use a single-projector system from RealD that alternates left circular-polarized and right circular-polarized images 144 times a second. That equals 72 flashes a second to each eye, or 3 flashes per frame at 24 fps. To preserve polarization, a silver screen is required. (A white matte screen won't work, which is how you can always tell it's RealD.) The viewer wears inexpensive *passive* circular-polarized glasses (thin gray filters), which can be thrown away.

If a theater doesn't wish to replace its perfectly good screen with a costly silver screen, it can use the Dolby system, in which a spinning wheel in front of the digital projector alternates two sets of narrow-band RGB filters. The audience, in turn, wears relatively expensive *passive* dichroic glasses (they reflect colors), which permit one set of narrow-band RGB images to enter the left eye, and the other set, the right eye. These glasses the theater owner does not want you to toss or walk out with.

As an alternative, the theater could install a projection system based on *active-shutter* glasses, in which an alternating LCD filter over each eye is wirelessly synchronized to the projector's output. IMAX has used this technology, but it's the most costly of all.

Flat-screen 3D TVs for home viewing use either circular polarization, which favors cheap glasses, or a system of actively switching left- and right-eye images, which active-shutter glasses are wirelessly synced to. The argument against 3D TVs using circular polarization is that they split odd and even scan lines, so that each eye receives only half of 1080 lines, or 540 lines—half the vertical resolution. This can cause the edges of horizontal action to appear serrated as they did in the days of interlaced CRTs. On the other hand, active-shutter glasses require batteries or charging and are expensive. What parent wants to buy replacements when their kids break, lose, or repeatedly decimate them? And what kid wants to hold his or her head perfectly upright for the proper 3D effect? (You can view a 3D TV with passive glasses lying down or standing on your head, if you wish.) The jury is out on which of these 3D TV technologies will dominate the market, with both types being built and marketed by major TV manufacturers.

Signal standards for 3D TV are in place for cable distribution and several 3D channels are testing the waters. With 3D production costs dropping constantly, with a swelling catalog of 3D box office hits available on Blu-ray, and with growing 3D channels on YouTube and Vimeo, digital 3D appears not to be a passing fad.