Appendix C. Evaluating the Effective Resolution of Scanners

As noted in Chapter 2, scanner specifications and settings for resolution do not indicate the true resolution that will actually be obtained. The resolution settings are based on the resolution of the light sensor rather than on the combined properties of the light sensor, electronics, optics, mechanical components, and software that together determine the actual resolution of a scanned image. Most scanners do not come close to achieving the high resolutions that are advertized and that are given as options in scanning software.

Measures of the *effective resolution* of a scanner estimate the actual useful resolution that can be obtained. The most common method for measuring effective resolution is the USAF (U.S. Air Force) 1951 resolution test chart. As shown in Figure C.1, this chart consists of various sets of horizontal and vertical lines with specific separations that get smaller and smaller. For a scanner, a USAF 1951 target is scanned and the effective resolution is the smallest separation distance for which the scanner can distinguish separate lines. This is determined by careful visual examination of the image. USAF 1951 targets on film for scanners have recently become available at more reasonable prices than in the past ($70 to $100 from LaserSoft, the maker of SilverFast scanning software).

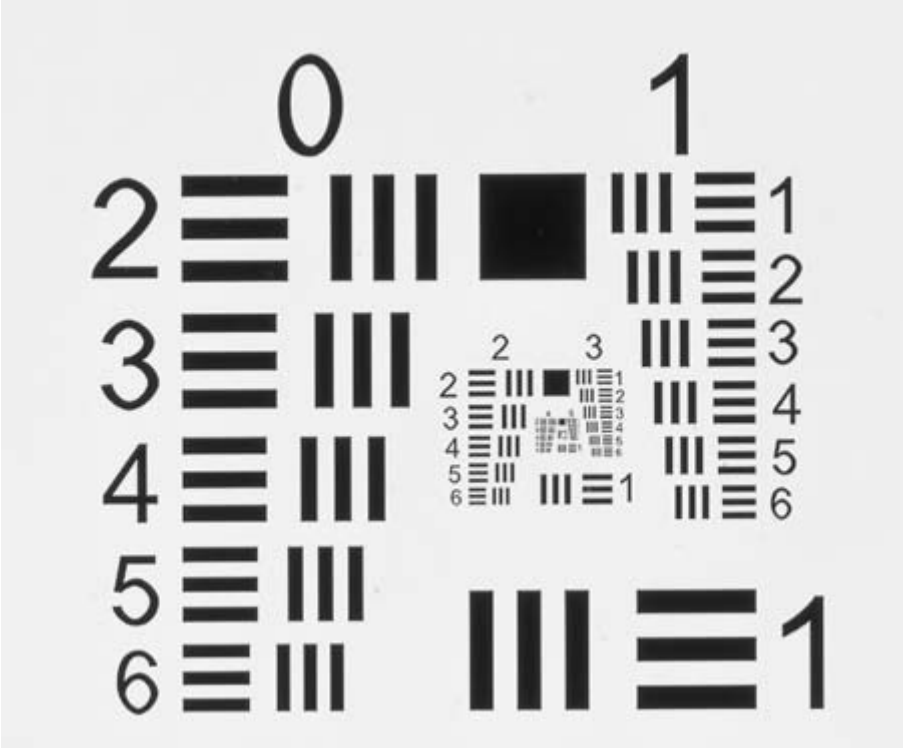

Figure C.1. The USAF 1951 test chart that can be used to estimate the effective resolution of a scanner. A slide with this chart is scanned and the image is carefully examined to determine the smallest set of lines that can be distinguished as distinct lines. Horizontal and vertical lines are provided because the resolution may be different for each dimension.

The use of the USAF 1951 test chart has been criticized for being overly subjective and crude. More expensive and much more complicated alternatives have been developed that are said to be better indicators of the overall sharpness and quality of an image. Information about the more complicated alternatives can be found by internet searches for *spatial frequency response* and *MTF (Modulation Transfer Function)*. However, these methods have been rarely used in practice and reasonably standard criteria for evaluating scanners have apparently not yet been established. My internet search for actual scanner evaluations using MFT found few cases and varying criteria. Studies need to be done that relate the results of these methods to the useful resolution settings for scanners.

Direct comparisons of actual scanner evaluations using MTF and the USAF 1951 chart would be highly valuable, but I have been unable to find such comparisons. Complicated technical methods such as MTF often have pitfalls in practice. Thus far the claimed benefits appear to be based more on theory than on actual practical experience. Likewise, the criticisms I have seen of the USAF 1951 test chart are based more on theory than on reports of practical experience. Given my experience with the USAF 1951 chart, I think it is very possible that the benefits of using the more complicated methods may not be worth the costs.

After exploring the use of the USAF 1951 chart for measuring the effective resolution of scanners, I believe that it can provide very useful information with reasonable cost and effort. However, efforts to verify the validity of the measures and minimize subjective aspects should be incorporated into the methods for using of the chart. Determining when the lines are distinct does have a significant subjective component. The spaces between the lines often become shades of gray rather than white. A person's eyesight and amount of effort as well as the viewing conditions can influence whether the lines are visible against the gray background.

Another limitation of the USAF 1951 chart is that it measures only certain discrete values of resolution. Each step in the chart indicates 12% greater resolution than the previous step. These discrete steps limit the precision of measurements.

C.1 Evaluation Plan

My initial experience with the USAF 1951 target found a variety of situations when I was not sure which set of lines should be considered distinct. Repeating a reading often found inconsistent results. More detailed guidelines were needed, but could only be developed if the target could be applied with known resolutions to determine which choices were best. Using the assumption that an Epson V750 scanner produces accurate resolutions in the range of 600 to 1200 ppi and a Nikon LS5000 ED scanner produces accurate resolutions in the range of 2000 to 2400 ppi, I explored various decision criteria and methods to enhance visibility to obtain more consistent results. The guidelines that were developed for reading the USAF 1951 target images are described in a later section.

After these guidelines were followed, the results became more consistent. The consistent results for the cases that were assumed to be accurate support the use of these methods in situations when the effective resolution for a scanner is uncertain. As noted in the next section, these methods were also found to provide the expected results for certain settings on a different scanner, which provides further evidence for the validity of the measures.

The effective resolutions were evaluated for three different scanners and for five readings at each of several different resolution settings on each scanner. The average of five readings provides more precise results given the discrete nature of the USAF 1951 measures. Also, the five readings can indicate the variability of the readings.

Different resolution settings were evaluated in an effort to determine which resolutions function properly on a scanner. Unfortunately, most reviews of scanners report the disparity between the scanner specifications and the maximum effective resolution but do not report which resolutions, if any, function properly. My main purpose in exploring effective resolution was to determine which resolutions could be used reliably.

The effective resolutions were evaluated at settings of 2300 ppi and 3000 ppi, which are the criteria in Chapter 2 for good and best practices for scanning 35 mm slides. Other resolution settings were also evaluated based on the possible settings for each scanner.

At this point, my working assumption is that an effective resolution that is within 10% of the scanner resolution setting can be considered good, and one that is within 15% will generally be acceptable.

Scanners often have different effective resolutions for length and width. The USAF 1951 target has horizontal and vertical lines that allow resolution to be determined separately for each dimension. Each dimension was evaluated separately and is reported separately in the tables.

C.2 Results for Nikon LS5000 ED Scanner

As reported in Table C.1, the Nikon LS5000 ED scanner produced effective resolutions that were within 10% at both 2300 ppi and 3000 ppi. The effective resolution was also within 10% at the maximum resolution for the scanner (4000 ppi).

Table C.1. Nikon LS5000 ED Scanner
Effective Resolutions for Various Scanner Resolution Settings

Scanner Resolution Setting (ppi)	Effective Resolution for Horizontal Bars[1]			Effective Resolution for Vertical Bars[1]		
	Average of 5 Readings[2] (ppi)	Percent Difference from Setting	Min – Max of the 5 Readings (ppi)	Average of 5 Readings[2] (ppi)	Percent Difference from Setting	Min – Max of the 5 Readings (ppi)
2000	2009	<1%	1825 – 2299	2154	+8%	1825 - 2299
2300	2249	-2%	2048 – 2299	2468	+7%	2299 – 2580
3000	2841	-5%	2580 – 3251	3038	+1%	2896 - 3251
4000	3838	-4%	3251 – 4096	4007	<1%	3649 - 4096

[1]The horizontal bars on the target slide measure resolution in the vertical direction and the vertical bars measure resolution in the horizontal direction.

[2]The effective resolution was measured 5 time for a given scanner resolution setting. The target slide was removed from the scanner and reinserted for each measurement.

C.3 Results for Epson V750 Scanner

As reported in Table C.2, the Epson V750 scanner produced effective resolutions that were within 10% of the specified resolution up to 1600 ppi. However, above 1600 ppi the effective resolution began declining relative to the resolution setting. At 2300 ppi the effective resolution was within 15% and therefore the scanner could be considered acceptable for scanning 35 mm film with the criteria for good practice specified in Chapter 2. However, the scanner cannot achieve the 3000 ppi needed for best practices with 35 mm slides. It does handle the best practices criteria for medium format film.

Table C.2. Epson V750 Scanner:
Effective Resolutions for Various Scanner Resolution Settings

Scanner Resolution Setting (ppi)	Effective Resolution for Horizontal Bars[1]			Effective Resolution for Vertical Bars[1]		
	Average of 5 Readings[2] (ppi)	Percent Difference from Setting	Min – Max of the 5 Readings (ppi)	Average of 5 Readings[2] (ppi)	Percent Difference from Setting	Min – Max of the 5 Readings (ppi)
600	617	+3%	575 – 645	619	+3%	575 - 724
1200	1234	+3%	1149 – 1290	1262	+5%	1149 – 1290
1600	1590	-1%	1448 – 1626	1710	+7%	1448 - 1825
2300	1959	-15%	1825 – 2048	2249	-2%	2048 - 2299
3000	2148	-28%	2048 – 2299	2255	-25%	2048 - 2580
6400	2148	-66%	2048 – 2299	2643	-59%	2580 - 2896

[1]The horizontal bars on the target slide measure resolution in the vertical direction and the vertical bars measure resolution in the horizontal direction.

[2]The effective resolution was measured 5 times for a given scanner resolution setting. For each measurement, the target slide was placed in a different frame in the slide holder for the scanner.

C.4 Results for Epson V500 Scanner

As reported in Table C.3, the Epson V500 scanner produced effective resolutions that were within 10% of the specified resolution up to 1200 ppi. However, above 1200 ppi the effective resolution began declining relative to the resolution setting. The scanner could not achieve the minimum 2300 ppi needed for 35 mm slides. For medium format film, the scanner would be adequate for the good practices criteria and for the best practices criteria for many sizes of film.

The fact that the measures of effective resolution closely matched the resolution settings for 600 ppi and 1200 ppi for the Epson V500 scanner is further evidence for the validity of using the USAF 1951 target with the guidelines applied here. The Epson V500 scanner was not used in developing the guidelines and these lower resolutions would be expected to be accurate.

Table C.3. Epson V500 Scanner
Effective Resolutions for Various Scanner Resolution Settings

Scanner Resolution Setting (ppi)	Effective Resolution for Horizontal Bars[1]			Effective Resolution for Vertical Bars[1]		
	Average of 5 Readings[2] (ppi)	Percent Difference from Setting	Min – Max of the 5 Readings (ppi)	Average of 5 Readings[2] (ppi)	Percent Difference from Setting	Min – Max of the 5 Readings (ppi)
600	647	+8%	645 – 724	620	+3%	512 - 724
1200	1177	-2%	1149 – 1290	1237	+3%	1024 - 1290
1600	1234	-23%	1149 – 1290	1416	-11%	1290 - 1448
2300	1262	-45%	1149 – 1290	1785	-22%	1626 -1825
3000	1262	-58%	1149 – 1290	1825	-39%	1825 - 1825
6400	1205	-81%	1149 – 1290	1666	-74%	1626 - 1825

[1]The horizontal bars on the target slide measure resolution in the vertical direction and the vertical bars measure resolution in the horizontal direction.

[2]The effective resolution was measured 5 times for a given scanner resolution setting. For each measurement, the target slide was placed in a different frame in the slide holder for the scanner.

C.5 Calculated Resolutions

Some of the resolutions in the tables are native resolutions of the scanner and some require calculations to obtain the resolutions. Using calculated resolutions does not appear to be a significant factor for the effective resolution of a scanner.

C.6 Guidelines for Reading the USAF 1951 Resolution Chart

As noted above these guidelines were developed by exploring different options to obtain reasonably accurate, consistent readings for certain resolutions that were expected to be correct. These guidelines were developed by one person using one computer. The optimal practice would for other people to similarly explore different options for optimizing the results for themselves with their particular computers.

The steps for reading an individual image were:

1. Scan the USAF 1951 target with the specified resolution and 48-bit color. All adjustments on the scanner are turned off.

2. Open the image in an image-editing program such as Photoshop with the image size set to 100% (Ctrl-1 in Photoshop).
3. Place the general area with the smallest differences that can be seen in the middle of the screen.
4. Zoom to enlarge the image until square pixels can be seen. Then reduce the image until square pixels cannot be seen, but not much farther.
5. Apply sharpening to the image. On my system, good results were obtained with Photoshop Smart Sharpen set to Amount: 250%, Radius: 1 pixel, and Remove: Lens Blur. As usual the best practice is to apply the sharpening on a separate layer. Sharpening significantly improved the consistency of results for me.
6. Find and record the values for the vertical and horizontal bars separately. Look for the smallest set of bars where all three bars can be seen and distinguished with relatively similar darkness tones. Slight zooming in or out may be needed to bring a set of bars into focus. Cases are not included if only two bars can be seen or if one of the bars is a different color such as blue. It may be helpful to toggle the layer with sharpening on and off.

Resources

LaserSoft, Inc., no date. “SilverFast Resolution Target (USAF 1951)”. Accessed January 10, 2012 at http://www.silverfast.com/PDF/resolution-target/Resolution-Target_long_en.pdf.
