Using SAS/GRAPH® Software to Produce High-Resolution Color Images for Publication
Craig Sampson, SAS Institute Inc., Cary, NC
Woody Middleton, SAS Institute Inc., Cary, NC

ABSTRACT
The goal of the Publications Division at SAS Institute is to produce accurate, high-quality product documentation for a reasonable cost and to have that documentation available for shipment with new releases of software. To accomplish this goal, the Publications Division keeps as much of the prepress work in-house as possible. In particular, we sought and found a solution to our need to image accurate, high-quality product documentation for a reasonable cost and to have that documentation available for shipment with new releases of software. To accomplish this goal, the Publications Division keeps as much of the prepress work in-house as possible. SAS/GRAPH® output for our documentation. This paper analyzes the imaging problems and then describes how a team of programmers from the Publications Division and the SAS/GRAPH Computer Graphics Division worked together to modify the SAS/GRAPH PostScript® driver to provide a solution to our color imaging problems.

INTRODUCTION
As the SAS® System has grown so has the need to include more color displays in our documentation. Adding the color images to our manuals has been, and still remains, a balancing act. Color in a document increases the production costs both in-house and at the printer. However, the addition of color can also make a complex document easier to understand and show what the various software products can really do. If we use too much color in a document, it must be priced above what we consider reasonable in order to recover the increased production, prepress, and printing costs. By controlling the amount of color in a document or performing more of the expensive prepress work in-house, we can hold the line on the selling price of the book while increasing its usability.

IDENTIFYING THE PROBLEMS
There are two basic methods used to reproduce color images on a printed page: process color and spot color.

Process-color printing uses subtractive primaries to reproduce the widest range of colors from the fewest inks: cyan, magenta, yellow, and black (CMYK). These colors are called subtractive primaries because each represents two additive primary colors left after one primary has been subtracted from white light. Process-color printing requires that these inks be deposited on the page in rows and columns of dots that form a screen. Each of these different colored screens must then be oriented on the page so that the dots are in the correct alignment with each other. There are several schemes for aligning the screens; we have chosen to use the traditional method, which assigns a different angle for the rows in each of the four screens. These screens of different colored inks combine visually to produce a broad array of colors. The size of the dots in the screen is determined by the frequency of the screen and the color to be reproduced. The frequency of the screen refers to the number of rows of dots imaged per inch. The higher the frequency, the smaller the dot and the better the quality of the reproduced image.

Spot-color printing, sometimes called match color, relies on the mixing of different colors of ink to achieve a specific color. This blended ink is then used on the press to print only the areas or spots that are to be that color. The mixed ink can be printed at 100% (full coverage) or it can be screened to produce a lighter shade. Spot-color inks are not blended with other colors on the printed piece to achieve additional colors as with process color. Spot-color printing has the advantage of accurately reproducing thin lines, which process color cannot. A thin line in process color must be created from dots, which lose a percentage of the line's information. However, 100% of the line can be imaged using spot color.

Spot-Color Problems
Prior to 1990, our imaging equipment did not have enough resolution to produce usable four-color process separations. The resolution of dots per inch (DPI) of an imaging device must be taken into account to determine the makeup of the process color dots. These dots are created from groups of imager dots. The more imager dots available to use per process-color dot the better the reproducible color tonal range. The greater the tonal range, the greater the number of reproducible colors.

We were limited to producing only type and spot-color separations on our typesetter. Since SAS/GRAPH software did not have a driver for our typesetter, spot-color graphics created by SAS/GRAPH procedures were imaged on various black-and-white hardcopy devices on campus. The color graphics were separated to send one color at a time to the output device. We accomplished this by using the GREPLAY procedure with a color map so we could map one color to black while changing the others to white. This allowed us to display the colors individually. We repeated this procedure for every color in a graph until it was fully separated. The single color pages were ejected before the next color was downloaded to the imager. The separated output from these imagers was sent along with the typeset pages to the printer.

The printer would begin two processes with the materials we had sent. First, the camera-ready copy or typeset pages would be photographed with a special camera. This camera holds film that matches the size of the printing plate that will be used on the press. The camera positions the film so that the pages are imaged on the film in the correct positions for making up flats, which are the position negatives from which the printing plates are made. During this process, all of the windows we left in our typeset pages would become holes in which the negatives of the color separated images would later be placed. Second, while the flats were being made the printer would photographically size the separated images so they would fit in the windows we had left for them. Prepress personnel called strippers would then combine the spot-color negatives with the flats to construct the final pages. This process, done by hand, involves cutting holes in the flats and taping the color separated negatives in position. The black separation is assembled with the black text flats. Any other spot colors require an additional flat to be made with the negatives located and taped in so that the final printed piece will register properly. The number of colors used determines the number of flats that must be made.

We limited the number of colors in our spot-color work to four, primarily because a lot of printers doing color work have four-color presses. The number of printers with larger presses capable of producing more than four colors is a smaller percentage of the available vendors, and the cost for printing increases sharply.

While we got the job done, this method was time-consuming and expensive. There was also the possibility that the illustrations could be mixed up at the printer and inserted in the wrong order. To prevent this from happening, our printers supply us with contact prints of every page in a document. These contact prints, called blueprints,
give us one final quality control checkpoint before the printing plates are made and the document is printed. If we find a mistake, such as a graphic in the wrong place, there is a chance to correct it before the plates are made. Finding the mistakes that occurred at the printer is time-consuming, and there remains the possibility that errors will be missed.

Process-Color Problems
When we produced documents such as the SAS/GRAPH User's Guide, Version 5 Edition, which contained process color, we again had to leave windows or empty places on the pages for the illustrations to be inserted by the printer. We would output the illustrations for the document on a high-resolution slide camera supported by SAS/GRAPH software. These 35mm slides would be sent along with the typeset pages to the printer.

The printer would again begin two processes with the materials we had sent. The camera-ready copy would be photographed with a special camera to create the flats. While the typeset pages were being photographed, the 35mm slides would be going through the separation process. The printer would use a color separation scanner to break the images down into four process colors: cyan, magenta, yellow, and black; these could then be used to re-create the image on press. The scanning process would produce four black-and-white negatives per slide, one negative per process color, that were sized to fit the windows we left in our typeset pages. The printer would then strip the negatives into the flats.

This process produces four flats for every press sheet that contains process color. Blue-line proofs are made from the flats at this point and returned to us for approval. Once approved, the flats are then used to make the printing plates. When the plates are finished, they are mounted on the press and the actual printing of the book begins.

Since there are four plates involved with reproducing the color images, a press with at least four printing heads is required. Each printing head must be supplied with the correct color ink, and the plates mounted on the heads must be perfectly aligned with the other three plates. When everything is ready and aligned, paper moving through the press is printed with each color before exiting the press and being stacked up awaiting the next procedure.

This method worked, but extra time was required in-house preparing the slides and at the printer due to the color separation required. Color separation performed by the printer is available in a range of qualities, beginning with pleasing color and ending up with fully enhanced, magazine-quality separations. The cost for this service runs from expensive to unbelievable. For our standard book work, we specify ganged separations to the pleasing color level of quality. Ganged separations help us to reduce costs because the printer mounts and scans several slides at one time. This procedure is limited to scanning images of similar color composition at one time so that the overall color balance is not adversely affected but results in producing several separations for the price of one.

To compound the problem, the expected time and expense required to produce a book grew due to the slide camera's inability to produce consistent color images through the run of a book. This forced us to run and rerun batches of slides until a single set of slides could be assembled that contained uniform color and density.

FINDING A SOLUTION
Wanting to go first class, we chose a course of action that would draw from the Publications Division's knowledge and experience of document development, production, and printing. To this we would add the graphics manipulation and imaging capabilities of the SAS System. This combination of abilities would enable us to increase the amount of color in our books while holding the line on costs.

New Hardware
Late in 1989, the Institute purchased a new high-resolution imager that could image usable four-color process separations. This device was also able to accept PostScript input. SAS/GRAPH software already had a PostScript driver, so work was begun to solve the process- and spot-color limitations by creating SAS/GRAPH drivers to do the color separations for us.

Process Color
Our first goal was to use a PostScript driver to create a four-color process separation of the graphs we needed. The PostScript driver would receive the color specification in red, green, blue (RGB) video format, convert it to CMYK format, then produce a separate page of output for each of the four colors. Also, the driver would communicate to the PostScript interpreter within the typesetter which screen angle to use for the dots on the page, the number of lines per inch, and the pattern of the display dots. Since the new typesetter has a resolution of 1016 dots per inch (DPI), we could achieve the necessary addressability to create in-house images in process-color format. The resolution not only allowed us to achieve the number of colors we wanted to print, but also provided a crisp, clean image for the manual.

The first attempt was exciting but not quite what we desired; there was a problem with undesirable patterns or moreso showing up on the test image. These patterns occurred when we used the angles suggested by the vendor of the typesetter we bought. To correct the problem, we adjusted the angle of the dots displayed for the different process colors to values suggested by the printer: cyan, 105 degrees; magenta, 75 degrees; yellow, 90 degrees; and black, 45 degrees. The correct angles for the dot patterns produced reasonable graphs. We needed to produce at least 133 lines per inch to produce the image we wanted to have. Our printer had some problems displaying the graphs, because the PostScript file produced pictures using square instead of round dots. The problem with square dots is that the corners of the square dots overlap other corners, producing an ill-defined color image. Rounding the corners of the square dots yielded satisfactory images. This version of the four-color process color algorithm is available for SAS/GRAPH software, Release 6.06 with the experimental PostScript driver (device name PSCLRSEP).

Spot Color
Even though we had successful pictures, the Publications Services Department wanted to produce images with each color displayed on a separate sheet of paper or film. This format would let them select a set of four to eight colors to display the graphics for the manual. On investigation we discovered that around 90% of all the graphs in our manuals needed fewer than eight colors. The manuals then could be produced using a driver that produces up to eight spot-color separations per image. Each separation could represent either a 100% or 50% saturation of one of the four colors. We could still produce the image within the four process color limit but achieve eight colors.

To use the spot-color separation code, we had to develop a way to allow the driver to draw only one color at a time between page ejects. The simplest model was to make the PostScript device appear to be a plotter. Since SAS/GRAPH software groups all the graph elements using color segments so that each pen mount is optimized, each color could be displayed separately. The graphics driver had to be altered to select black every time a new color was requested. This method worked well, except for one problem: it was possible to have multiple display pages with the same color. This problem occurred because SAS/GRAPH software separates the colors into surfaces, that is, levels of colors. The parts of the graph behind are drawn first, then the successive surfaces are drawn on top. The same color could be used in all the surfaces. The code was
changed to force all the instances of the same color to display in a single surface. Combined with the driver changes to always print in black when this sort of color separation is requested, the result was that we now had a separate page for each of the colors in the picture. The Creative Services Department then used the spot separated images to assign colors for the manual. Using this new driver eliminated the need to create a special SAS job to postprocess a graphic of the complete picture, which was the way we used to provide a spot-color separation.

Merging of Text and Graphics

Our new in-house color separation procedures give us the flexibility of separating SAS/GRAPH images and merging them with our text to produce complete pages. We have chosen not to use this full capability for several reasons.

If we merged all of our color-separated work with the text pages, we would have a dense page for the black separation plus the black type of the document, but we would then be imaging three additional pages that only had the separated pieces of the color image. These three pages would require as much media as the black page, each needing the full page size complete with registration marks and identifying banner. The fact that this format required a full page for each separation wasted both the media and the time it took to image it.

To save time and materials, we chose to output all of the color separated images at one time. All of our images are identified by unique names. These names are imaged in the lower-right corner of the graph when it is output. The same graphic names are used within the place-holding windows we leave in our text, so the printer will be able to match the correct image to the saved location in the document. By producing all the text and then all the graphic images, we make more efficient use of the typesetter and the output media.

The final step to optimize time and materials required a postprocessing program to read the PostScript output files and determine the number of separations per image and the size of the image. This information is then used to pack as many images as possible across the width of the media, saving both the media and the time required to image it.

CONCLUSION

By modifying the SAS/GRAPH PostScript driver and creating a postprocessor to optimize our output, we have been able to save time and money in the production of our documentation. Our solution has enabled us to generate correctly sized, high-resolution, color-separated images on our typesetter. With this new capability we have decreased the time and cost of producing our documentation while increasing the value of our printed product.

SAS and SAS/GRAPH are registered trademarks of SAS Institute Inc., Cary, NC, USA.

PostScript is a registered trademark of Adobe Systems, Inc.