A picture may be worth a thousand words, but it is rare that we can adequately describe a thousand word set. We often assume that a graph or plot of data will automatically convey our message. However, an inappropriate or poorly designed plot may raise more questions than it answers. Effective graphics must be designed to communicate. I hope to show some of the ways that this communication can be assured.

In this paper I will be discussing:

1. The purpose of graphics.
2. Knowing your capabilities.
3. Typical Chart Errors.
4. Effective Chart Design.
5. Chart junk, data ink, and the lie factor.
6. Steps for creating a plot.

Before continuing, I should mention an excellent reference book on this subject: The Visual Display of Quantitative Information, by Edward R. Tufte, Graphics Press. Several examples and definitions were obtained from this source. In addition examples of typical chart errors were taken from an IBM reference manual "Pointers on Effective Chart Design". Unfortunately I have no other information on this manual.

The Purpose of Graphics

Graphics has been defined as the art of drawing. Recently, the use of computers has changed graphics to a push a button - get a graph simplicity that has compromised the art portion of graphics. While it is easier than ever to display our data visually it is also easier to make mistakes. Much of today's presentation graphics use inappropriate or visually cluttered plots that obscure the message being presented.

Graphics can be used for many ends. Generally it can be thought of as the communication of ideas through visual means. Good graphics should:

- Show the data clearly
- Display your conclusions
- Avoid distorting the truth
- Avoid ornamentation
- Be interesting and aesthetic

A good graph should clearly display data and conclusions. Decoration of the plot will almost always obscure your point.
The other uses of graphics should not be overlooked. In a presentation a variety of graphics may increase interest and retention of the points being made. Use of visually stimulating and well designed graphics will always enhance the communication between the speaker and the audience.

Knowing Your Capabilities

It is important to be familiar with all of the charts and plots available. You may have several plotting packages to choose from and a variety of output devices available. Take the time to familiarize yourself with the types of charts, fonts, patterns, and colors available. Test examples may be run to show you how the output will look. Figure 2 shows a test of various fonts and Figure 3 shows patterns available by pattern number.

Fig. 2

Typical Chart Errors

Typical errors include:
- Letting the software defaults determine the final chart
- Getting carried away with fonts, pattern, color, and 3D effects.
- Forgetting what you want the graph to show.
- Omitting or distorting information
- Using the wrong type of chart.

One of the most common errors made in presentation graphics is the use of an inappropriate chart type when displaying data. Figure 4 shows some typical chart types. Most of us would never consider using a pie chart for time series data, but would readily consider using a tower chart for two dimensional data. Figures 5-8 show the same time series data plotted using different chart types. The line or step chart is probably the clearest representation of the data. The tower chart is interesting looking but fails to show the data clearly and partially distorts the actual increase in value over time. Tower charts should be used when comparing data in two directions and even then the data should be clearly labelled to avoid distorting the truth.

Typical Chart Types

- Line Graph - Useful for time series and showing trends over many timepoints.
- Bar Chart (column chart) - May be used for time series when there are fewer timepoints. Particularly good for showing large changes.
- Horizontal Bar Chart - Used for comparisons.
- Surface Chart - This is a line graph with the area under the line shaded. Generally used for showing volume or quantities.
- Step Chart - This is a column chart with no space between the columns. It is used instead of a column chart when there are many periods.
- Pie Chart - These are used for showing percentages of a total or allocation of resources. "Exploded" section helps to single out a single area.
- Tower Charts - These are three dimensional column charts used for comparing data in two directions.

Fig. 4
Effective Chart Design

The following points are adapted from the IBM manual "Pointers on Effective Chart Design". They cover many of the common graphical errors.

1. Use Well-Designed Charts for all Your Graphics

Often charts used for analysis find their way into a presentation or a report. Poor charts will confuse the audience and reflect poorly on the presenter.

2. Determine What Relationships You Want to Show

Decide what point you want to make before you choose a chart, then design the chart to illustrate your point. You may want to write down a statement of what the data shows and later see if the chart shows that relationship effectively.

3. Make curves thicker than your grids.

4. Label curves if there is room.

5. Write axis labels horizontally.

6. Make axis numbers large enough to read.

7. Use the same scale when comparing trends.

8. Include zero when comparing levels or totals.

9. When you omit zero let your reader know.

10. Use scales that make interpolation easy.

11. Use different line thickness for data - use dashed or dotted lines for projections or extensions.

12. Limit pie charts to five or fewer segments.

13. Make bars or columns wider than the spaces between them.

14. Order shade patterns from darkest to lightest.

15. Place labels in shaded areas of surface chart if possible.

16. Order data in surface charts so irregular layers are on top.

17. Avoid semilog scales for audiences unfamiliar with them.

18. Order shade patterns on maps to facilitate remembering scale ends.

19. Don't allow grid lines to pass through columns or bars.

20. Avoid garish shade patterns.

21. Use a single type font from chart to chart to maintain consistency.

Following these guidelines will result in a clear presentation of the data.
Chart Junk, Data Ink and the Lie Factor

Closely spaced parallel lines used for some fill patterns create an op-art feeling of movement and tend to confuse the eye. The strident colors used in many computer systems tend to create 3D effects. Most graphic artists make use of solid pastels for their graphics.

Chart Junk can be defined as any non-data ink or redundant data ink. A certain amount of any chart is non-data ink. Axis lines and labels, titles, headings, and chart notes are often essential to proper presentation of data. Excessive non data ink should be avoided as it draws the eye away from the data being presented. Patterns, ornate fonts and grids as well as excessive or redundant labels should be avoided.

Figure 9 shows an example of a chart making many of the mistakes mentioned in the last section. Figure 10 and 11 show the plots as they should look. Notice that if you label the bars you don't need to label the y-axis. Grid lines should be unobtrusive and only used if the data values must be read of the axis.

The Lie Factor - In many newspapers and magazines, graphics are used to intentionally distort the data. A measure of the amount of distortion produced is provided by the lie factor which is defined as follows:

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\text{Lie Factor} = \frac{\text{Size of Effect shown in graphic}}{\text{Size of Effect shown in data}}
\]

Figure 12 shows a typical example - if we calculate the lie factor for this picture we see that the increase 18 to 27.5 mpg is represented by an increase on the graph from 0.6 inches to 5.5 inches thus a 93% increase in data is represented by a 783% increase in size of the graphics. The lie factor is 783/93 or 8.5. Any value outside of 0.95 to 1.05 represents a significant distortion of the original data.

Some good rules for graphical integrity -

- The graph should represent proportional to the changes in the data represented.
- The graph should be clearly labeled.
- Show data variation, not design variation.
- Use deflated or standardized units for money when shown in a time series plot.
- Data should not be shown out of context.
- The number of information carrying dimensions should not exceed the number of dimensions in the graph.

The last point is one of my favorites. Three dimensional presentation (i.e. tower charts, 3D pie charts) are generally not needed for two dimensional data. Although they may appear to have a strong impact, they must be carefully designed to avoid distortion of the data. The term dimensions may be applied to patterns and colors also. Avoid using 5 colors to display three pieces of data.
Steps for Creating a Plot

The following ten point checklist has been quite useful to me for preparing graphics for presentation:

1) Know your audience
2) Decide what you want to show
3) Make a sketch
4) Start simple
5) Add titles and symbols
6) Check colors and shading for impact
7) Does the plot show what you want
8) Check for chart junk
9) Refine and simplify if possible
10) Try the plot out on someone

Know your audience - Effective graphics for one audience may be confusing to another group. Tailor your presentation to match the level of your audience.

Decide what you want to show - For graphics to be a form of communication you need to know what you want to say. Make sure your data supports what you want to say.

Make a sketch - Quick sketches can help to visualize the data and determine the proper chart type.

Start simple - When you first plot the data don't bother with triplex fonts, headings, labels, patterns, etc. This will save time and money. Plot to the screen instead of the plotter as you start if possible.

Add titles and symbols - Titles should be sized and positioned for legibility and appropriate balance and use of space. Type fonts should be simple but bold enough to stand out. Symbols should be used to mark the data if necessary, and should be sized to allow differentiation between different data. Avoid large symbols if possible.

Check colors and shading for impact - Impact means an aesthetic chart with the data presented clearly. Impact does not mean multicolored op-art masquerading as a plot.

Does the plot show what you want - This is the reality check of any plot. Does the plot demonstrate your conclusion without distorting the data.

Check for Chartjunk - Is all the ink necessary and useful.

Refine and simplify if possible - Remove any chartjunk or patterns that don't help the plot.

Try the plot out on someone - Does another person see what you are trying to show.

As a final tip don't be afraid of drawing or typing on your plots. You may want to add labels, reference lines, or other information. Color, patterns, shading, or pictures may be added manually to increase the impact of the graphics and allow you to create effects not possible or convenient with your computer system. Combine media for more interesting presentations. Use of a slide bureau or graphic arts department may be necessary for certain types of graphics and are resources that should not be overlooked.

In summary I recommend the following:

- Use the right type of chart
- Design your plots and charts
- Avoid the common graphic errors
- Use colors and patterns carefully
- Avoid chartjunk and the lie factor
- Maintain graphic integrity
- Make the chart communicate effectively
- Use graphics that are interesting and aesthetic

You should always be proud of your graphics.