
The American Drafter: Why use 1st Angle Projection in a 3rd Angle World?

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Abstract: The concept of graphical representation dates back thousands of years. The drafters of yesteryear and even today have continuously disagreed on what method should be used in the representation of engineering drawings. A preference for first angle projection compared to third angle projection representation depended on one's point of view. Today's technology brings even another methodology into focus in the world of graphical representation, computer-aided-drafting (CAD). CAD has become the linking technology that allows for translation between first angle and third angle projection, thus removing the argument for one method over the other. Tools such as CAD have simplified the method of representation and allowed the draftsman, designer, and engineer to graphically represent their creation in multiple ways.

Keywords: First-Angle Projection; Third-Angle Projection; Orthographic Projection

1. Introduction

The concept of graphical representation of three-dimensional objects onto a two-dimensional medium dates back thousands of years to the time of the first cave paintings. Neolithic hominids attempted to depict and preserve important events in their history through crude images carved or painted on the walls of caves. Early humans used these primitive images to relay important information about hunting successes, dangerous animals, and even to describe simple inventions such as the spear to other members of the clan. In this way information was passed on to others who could use this new information to increase their survival chances in a hostile world.

These early cave dwellers created a means of communication that predated spoken language (Deacon, 1997, pp 268-275) and allowed others to grasp concepts that were not easily expressed in vocal terms. The contribution of these early humans to the knowledge base of our species is exemplified by mankind's continued use of pictographic symbology to represent complex ideas. This symbology has taken many forms throughout history: early Egyptian hieroglyphs, Celtic runic symbols, linear perspective drawings, and so on. Improvements on the theme have touched

every major culture and have increased the ease with which visual images can be used to represent complex ideas and concepts. One of the most important improvements to affect graphical symbology was the use of a branch of mathematics called *descriptive geometry* to improve the development of drawings representing three-dimensional objects on two-dimensional (orthographic) planes.

Descriptive geometry is the basis for all orthographic drawings and involves the placement of specifically oriented views which are defined by projecting points from one view of a three-dimensional object, through a rotation angle of 90° , to create the remaining surface views of the object. The man credited with first using descriptive geometry in the development of orthographic drawings of three-dimensional objects is Gaspard Monge (Rouse-Ball, W.W., 1908).

Monge was an 18th century Frenchman with an interest in drawing and a strong knowledge of descriptive geometry. His use of descriptive geometry to create fortification drawings from observational details, much faster than by traditional drafting methods of the time, eventually led to his work being classified as a French military secret (Rouse-Ball, W.W., 1908). Monge eventually became a professor at the Polytechnic school in Paris, France where, in 1800, he published his book *Géométrie Descriptive*, which contained sections on the theory of perspective, and more importantly to this discussion, the art of representing three-dimensional geometrical objects in two dimensions (Rouse-Ball, W.W., 1908).

This art, described in the above paragraph, has led to the development of two similar but different ways of visualizing three-dimensional objects drawn onto a two-dimensional medium: *first angle projection*, and, *third angle projection*. Both methods reflect the objects visible and hidden surfaces adequately, but they differ in how the orthographic projection views are rendered relative to the static state of the original three-dimensional object being drawn.

2. Defining terms

In order to better understand the subtle differences between these two projection systems, some of the more important terms require definition and explanation.

- *Angle of projection* relates to the four quadrants established by the two-dimensional Cartesian Coordinate System (CCS) in which the first quadrant is defined by the area bounded by the positive X-axis and the positive Y-axis; second quadrant is bounded by the negative X-axis and the positive Y-axis; third quadrant is bounded by the negative X-axis and the negative Y-axis; and the fourth quadrant is bounded by the positive X-axis and the negative Y-axis.
- *Orthographic projection* is a method of representing multiple views of a three-dimensional object from different points of view rotated at 90° increments about the center of the object.
- *Projection planes* are planes that intersect each other at 90° and upon which the individual views of the object are projected in the creation of an orthographic drawing. The names of these projection planes are: horizontal or plan (top view), vertical or elevation (front view), and profile (left and right side views). Generally speaking, three

views (plan, elevation, and profile) are all that are required to fully describe a three-dimensional object orthographically. Other views may be added as needed for clarity.

- *First angle projection* is the projection of the defining points of each view of a three-dimensional object, in the direction of the viewer's gaze, onto the interior walls of an imaginary three-dimensional box surrounding the object as shown in figure 1 (Browne, 2006).

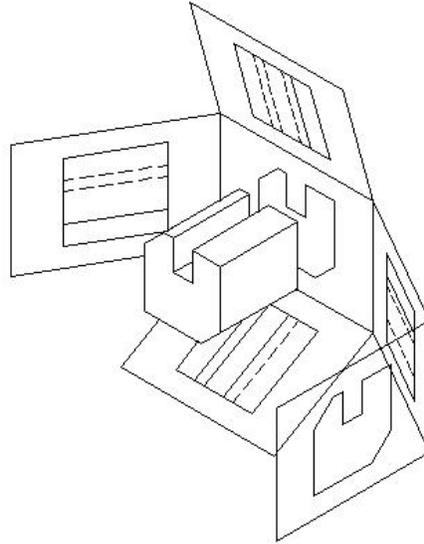


Figure 1: First Angle Projection (Folded Box)

Unfolding the box provides the orthographic projection views shown in figure 1a (Browne, 2006). (Note the location of each of the labeled views of the orthographic projection upon the folded box shown in figure 1).

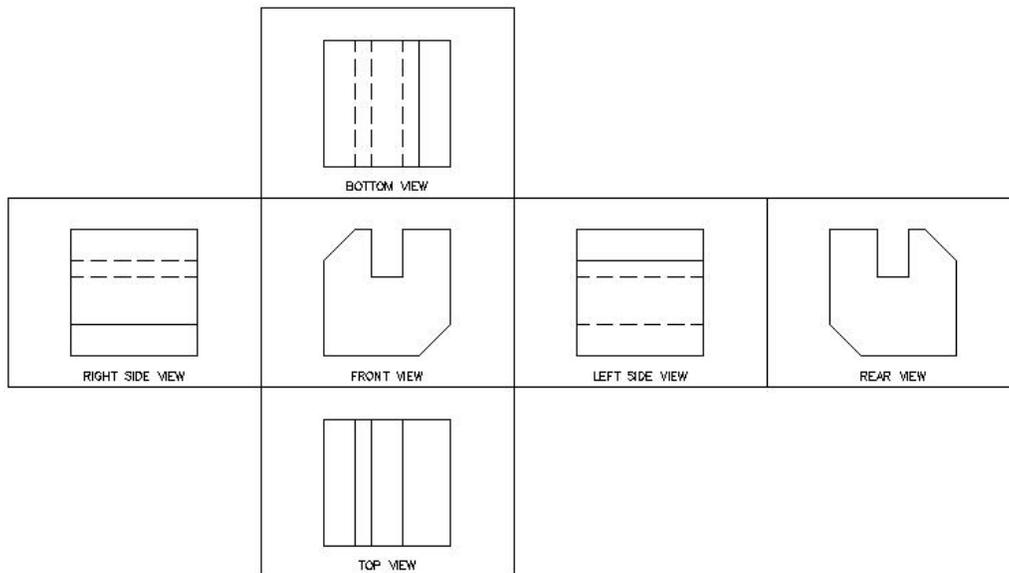


Figure 1A: First Angle Projection (Orthographic)

As can be seen from the illustrations, *first angle projection* requires the drafter to project the image that is viewed onto the opposite inner surface of the imaginary box, thereby resulting in placement of the orthographic views in a less intuitive location relative to the actual object being drawn. For example, the right side view of figure 1a appears to the left of the front view in *first angle projection* orthographic drawings instead of to the right of the front view. Intuitively, one would expect the right side view to appear to the right of the front view; however, the image is projected onto the surface of the box directly ahead of the viewer's gaze. The viewed surface of the object that is drawn is said to be 'projected' through the object onto the view plane. This is the key element that distinguishes *first angle projection* from the other method of producing orthographic views of objects, *third angle projection*.

- *Third angle projection* represents a method of producing orthographic views of three-dimensional objects by projecting the defining points of each view of the object onto the exterior face of the imaginary three-dimensional box as the viewpoint is changed by rotation through 90° increments about the center of the object as shown in figure 1 (Browne, 2006).

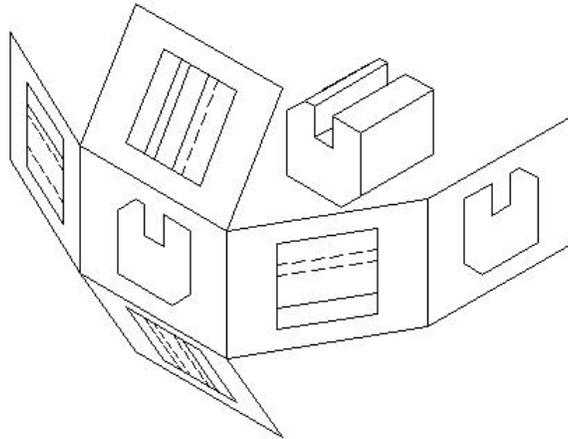


Figure 2: Third Angle Projection (Folded Box)

Unfolding the box provides the orthographic projection views shown in figure 2a (Browne, 2006). (Note the location of each of the labeled views of the orthographic projection upon the folded box shown in Fig. 2).

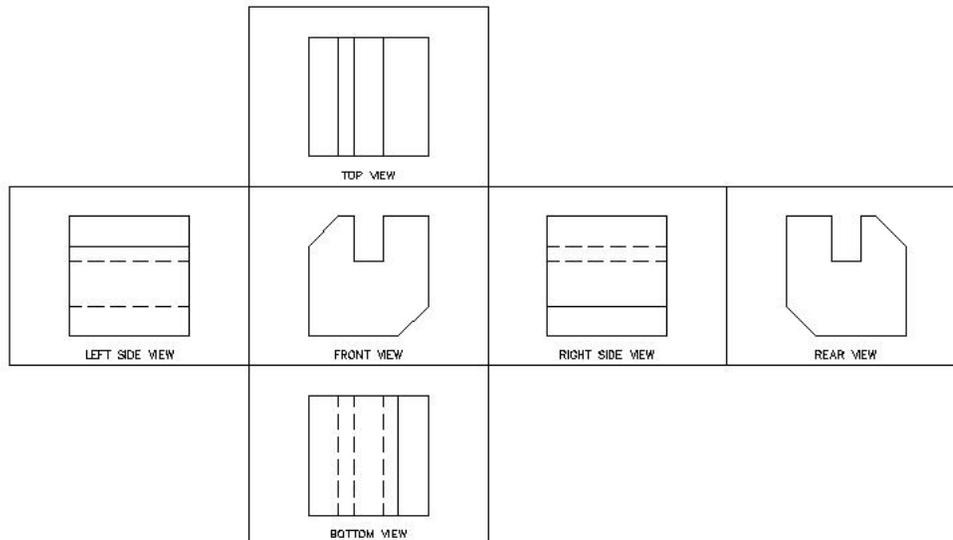


Figure 2A: Third Angle Projection (Orthographic)

As can be seen from the illustrations, *third angle projection* presents each of the projected views in their logical positions relative to the position of the original object being drawn. For example, in figure 2a, the top view is positioned directly above the front view, the bottom view directly below the front view, and the left and right side views are, respectively, placed to the left and right sides of the front view (Schumann, C. H., 1940).

3. The Need for Standardization of Engineering Drawings

“This question of which way to project cannot in the nature of things be of such very great importance in itself, like theology, or so many good people would not differ regarding it. Let us then all strive to come to a common practice in the matter and meet upon common ground of direct revolution if we can, or indirect if we must. Let us all remember, however, that America is all the time becoming less provincial and that this common ground should be international, rather than merely occidental.” – Oberlin Smith, *American Machinist*, Volume 18, No. 20, July 18, 1895.

The above quoted passage goes to the heart of the matter regarding the need for commonality and standardization of engineering views representing three-dimensional objects. Its author identified that the matter of how drawing views are projected is not as important as the establishing of a common, international set of rules, all of which follow a singular method of projection. Although this was written in the United States during the latter part of the 19th century, the author, who favored first angle over third angle projection, put forth the notion of a global standard, refraining from the limitations of an ‘American-only’ standard.

During the time prior to World War I, the lack of standardization of engineering drawing conventions was not considered a problem of great importance. Engineering drawings representing three-dimensional objects were used primarily by engineers and managers, or by machinists familiar with the product being made. Strict placement of the various views of the object within the drawing was not considered essential to the production process, as long as the machinist or senior craftsman could understand how to fabricate the necessary components to make them work properly.

However, during World War I, it became increasingly necessary to provide detailed working drawings to machinists and production workers in both the United States and Europe. This exchange of ideas via engineering drawings was hampered somewhat by the differences in drafting conventions between Europe and the United States, particularly with regard to representative view placement. Europe had used the method of *first angle projection* in creating orthographic views of three-dimensional parts for manufacturing for many decades, while in the U.S., engineers had settled on using *third angle projection* with its more logical placement of views.

As a consequence of exchanging drawings with differing visualization conventions, problems of interpretation arose, possibly slowing production (Booker, P. J., 1963). The need for an agreed-upon international standard for representing orthographic views was obvious. But which of the two standards should be used: *first angle*, or *third angle* projection?

4. Taking Sides

The early adoption of *third angle projection* in the United States was due, in part, to the educators of the time whose jobs were to train draftsmen in the methods of graphic representation. As early as 1816, texts on descriptive geometry had made their way to America and were being taught to draftsmen at the U.S. Military Academy at West Point (Booker, P. J., 1963). Colonel Claude Crozet credited with being the *Father of Descriptive Geometry in the United States* taught descriptive geometry and engineering to the cadets. Crozet's *A Treatise on Descriptive Geometry*, published in 1821, is probably the first English language version on the subject of descriptive geometry (Booker, P. J., 1963).

Textbooks on technical drawing published in the U.S. in later years included not only the necessary introduction to descriptive geometry, but also adaptations of drawing practices indigenous to the American draftsman, including the use of third-angle projection. Author Carl Lars Svensen (*Essentials of Drafting*) and others, began using new expressions such as *engineering drawing*, and, *graphic language* in their textbooks to replace outmoded terms such as *mechanical drawing*, *machine drawing*, and *tool drawing* (Booker, P. J., 1963).

This shift from earlier ideas about the nature of engineering drawings represented an avant-garde philosophy about the importance of visual representation in production drawing. This philosophy refocused the attention of engineers, who had thought of drawings in terms of the methods and machines used to create them, into the concepts of how engineering drawings should be represented and prepared. By the time of World War I (1914 – 1917), engineers in the United States had adopted *third angle projection* in engineering drawing as a general practice.

Engineers in Britain and her allies in Europe had long before adopted *first angle projection*, based on the style of Monge's descriptive geometry, as the standard for orthographic representation. There was a consensus among European nations that orthographic views be created by projecting the visible surface of an object onto the opposite projection plane, (front view on the back projection plane, right-side view on the left projection plane, etc.). Having used this system of orthographic representation for more than a century, Britain, and the rest of Europe, at the time of World War I, was not inclined to quickly change to the newer American system of *third angle projection*. European engineers and draftsmen considered the third angle method confusing and not in keeping with the concepts of Monge's descriptive geometry.

Monge's method of projection required creating lines of projection from one view to the next in similar fashion to that of the third angle method, with the exception that the projection lines must cross the object from which they originate before being represented on the projection plane. As can be seen in figure 3 (Browne, 2006), as each feature of the front view is projected onto the projection planes, its projection lines crisscross the object. In complex drawings, this becomes quite cumbersome and difficult to follow.

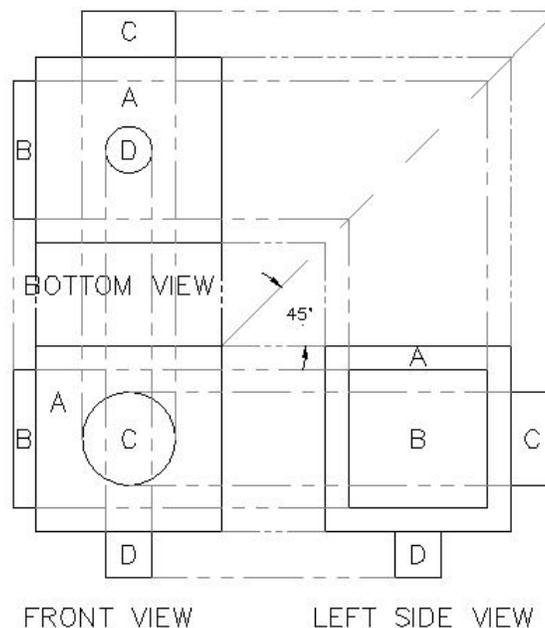


Figure 3: Monge's First Angle Projection

Although the third angle method also uses projection lines to create its views, the lengths of the projection lines are shortened and there is less clutter due to the more logical placement of the views (See figure 4, Browne, 2006).

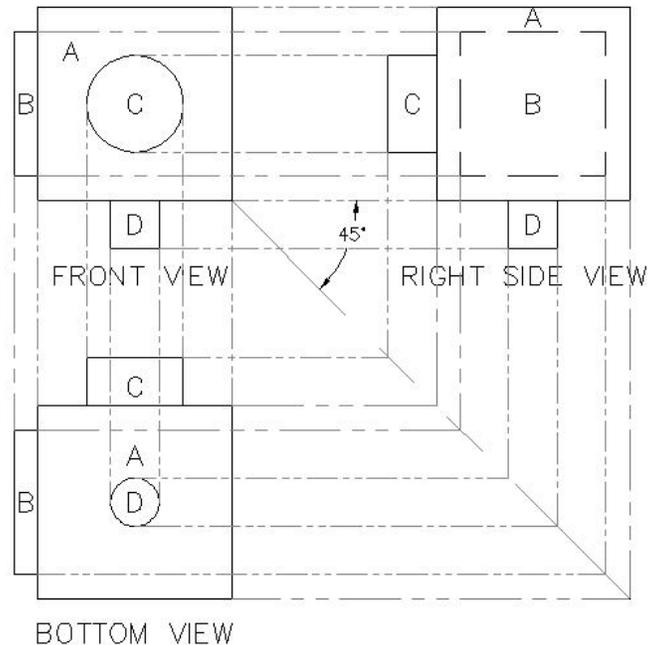


Figure 4: American Third Angle Projection

Throughout both World Wars I and II, it was clear to American and European engineers that a common method of representing orthographic views was needed. However, there was no consensus between the two sides as to which method should be adopted as an international standard. Neither side was willing to concede that the other side had the better method. And so, an international drawing standard that defined orthographic view development as either first or third angle projection was not adopted.

5. New Technologies and Projection Angles

The advent and rise of computer-aided drafting, or CAD, in the latter part of the twentieth century brought changes to the ways in which drafting was done. With the introduction of software designed specifically to increase the ease of drawing and reduce the time required to produce drawings, the need for drafters to develop the skills required by their predecessors was minimized. As more powerful graphics programs were developed, drafters came to rely less on the skills of the past to create the necessary views of parts, and to rely more on the technology of computers to provide structure to their drawings. Although orthographic projection was still the mainstay of two-dimensional drafting, new types of software that allowed virtual models to be constructed in three dimensions were finding increasingly more applications in the engineering world.

In practice, engineers and drafters found that they could easily manipulate three-dimensional virtual models to provide any view necessary to describe an object, regardless of its orientation. The models, drawn in three-dimensional space within the framework of the computer program, could easily be used to automatically generate the necessary orthographic projection views in *first angle*, *third angle*, or any projection angle desired. This functionality of the computer-

aided-drawing, especially with regard to the use of three-dimensional models, would seem to negate the need to establish a drawing standard based on projection angles. This is true only within the boundary of the virtual space in which the 3-D model is constructed. As viewed on the computer monitor, and within the CAD program that created the model, any projection angle can be represented, be it first angle projection (Europe) or third angle (U.S. & Canada). Within the virtual space of the CAD program, first and third angle views can be interchanged at will to aid the engineer or drafter in accurately representing the object.

Presentation of strict orthographic projection views onto paper has given way to the new pictographic representation of three-dimensional model views of objects via rendering software and more powerful parametric design CAD programs. In addition, high-speed manufacturing, through the use of computers, requires true 3-D modeling rather than orthographic views to establish manufacturing parameters for machining parts to more critical tolerances than ever before. From concept to design to prototyping to manufacturing, the use of three-dimensional models and computer-aided-manufacturing (CAM) has diminished the need for drawings based on projection-angle development in the modern manufacturing environment. With less human interaction with drawings at the manufacturing level, the need for strict standardization of projection angles becomes less important.

6. Summary

Drawing has always been humanity's first means of communicating ideas and innovations to each other: first for basic survival, then later, as a means of progress. As we progressed in our attempts to harness our environment to better serve our needs, we relied on drawings to express more complex systems of ideas and render them into machines, structures, and works of art. Regardless of our cultural differences, civilizations have always had the drawing as a way to communicate and share critical information and concepts.

From the Renaissance and Da Vinci we learned how to shape our ideas into machines on paper using crude instruments of the times. We marveled at our ingenuity to create inventions and to express those ideas in a way that others could see and reproduce. The drawing became the work of scholars and scientists; engineers and craftsmen, upon whose ideas and creations our civilizations expanded.

As we progressed we developed new ways of representing our ideas in drawings. Monge's *Géométrie Descriptive* gave us the concept of plane angles upon which we could depict the various facets of a three-dimensional object. Our insights developed two different methods of representing drawn objects within the planes of descriptive geometry: direct projection, first angle projection, and later indirect projection, third angle projection. Britain and her allies in Europe found first angle projection to be the mainstay of their method of creating orthographic views to represent machine parts, based on the concepts of Monge's descriptive geometry. Although beginning with the use of first angle projection, the United States gradually turned to

third angle projection as its method of creating orthographic views, primarily for its ease of drafting and for economic reasons as well.

The requirements for cooperation among the United States and its allies in Europe during World Wars I and II identified the need for an international standardization of orthographic projection views to eliminate the problems associated with using two different projection methods when sharing manufacturing drawings. This problem led to the general controversy over which projection method should be chosen as the standard. Unable to agree on which method to use, the U.S. and Europe continue to use different methods even today, though there is some compromise among businesses on both continents where necessary.

Today, new technologies such as computer-aided-drafting (CAD), computer-aided-manufacturing (CAM), and 3-D modeling, have somewhat lessened the need for an international standard for projection angle in orthographic views. Integration of computers into the manufacturing process allows 3-D models to be imported directly into the production line equipment, reducing human interaction with the drawings and reducing misinterpretation. Continued improvements in parametric design and modeling will for all practical purposes, eliminate the need for choosing one projection method or another in years to come, thus ending a graphic controversy that has plagued the engineering community for so long. Finally, orthographic projection is and will remain important for sketching preliminary design concepts and for manual machinists, neither of which will become extinct in the near future

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