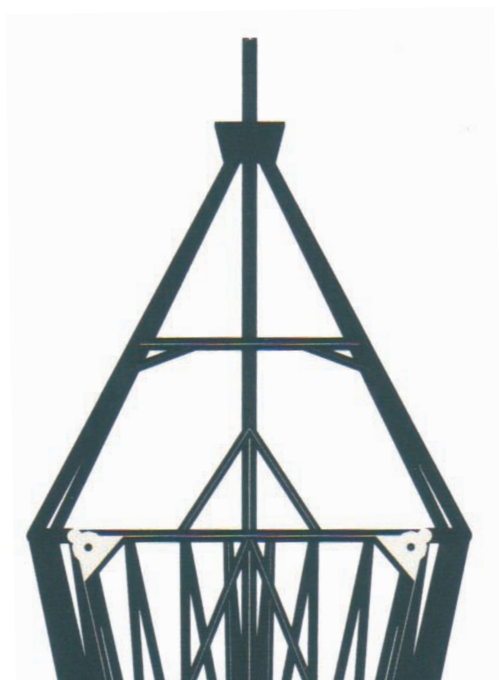
Construction of Tubular Steel Fuselages



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Chapter 1
Welded Fuselage Construction and Design

The principle of the tubular fuselage is similar to the trusses used to build bridges, antennae towers, and other strong, lightweight structures. In the truss, the loads that are applied to it are distributed amongst the various members, allowing a number of small members to be used as opposed to a few large ones. A three dimensional truss is also known as a space frame.

Round tubing is mainly used because it is a continuous medium and utilizes the available material in a member efficiently. It is the most efficient cross-sectional shape under axial compression (compressed at the ends toward the center), as it is equally stable in all directions when the force is applied. This makes it easy to analyze and allows structures to be designed with a minimum of material. The fuselage is designed so that the round members are always under tension or compression (whether a member is under tension or compression depends on the direction of loads that are applied to the whole fuselage).

Note that the members make triangular shapes in their arrangement in the fuselage illustrated in Figure 1-1. Triangular shapes are structurally robust because a load imposed on one corner of the triangle is divided up into the other members. The equilateral triangle (three equal length sides and three equal angles) is the most efficient triangle in this respect.

Almost all high-performance sport aircraft are built by this method. This construction method has the added convenience of being able to easily design and attach all the fittings that an aircraft requires, especially those fittings requiring a great deal of strength.

Terminology for Tubular Steel Fuselages

Some of the terminology is common to other types of aircraft structures. See also Figure 1-1.

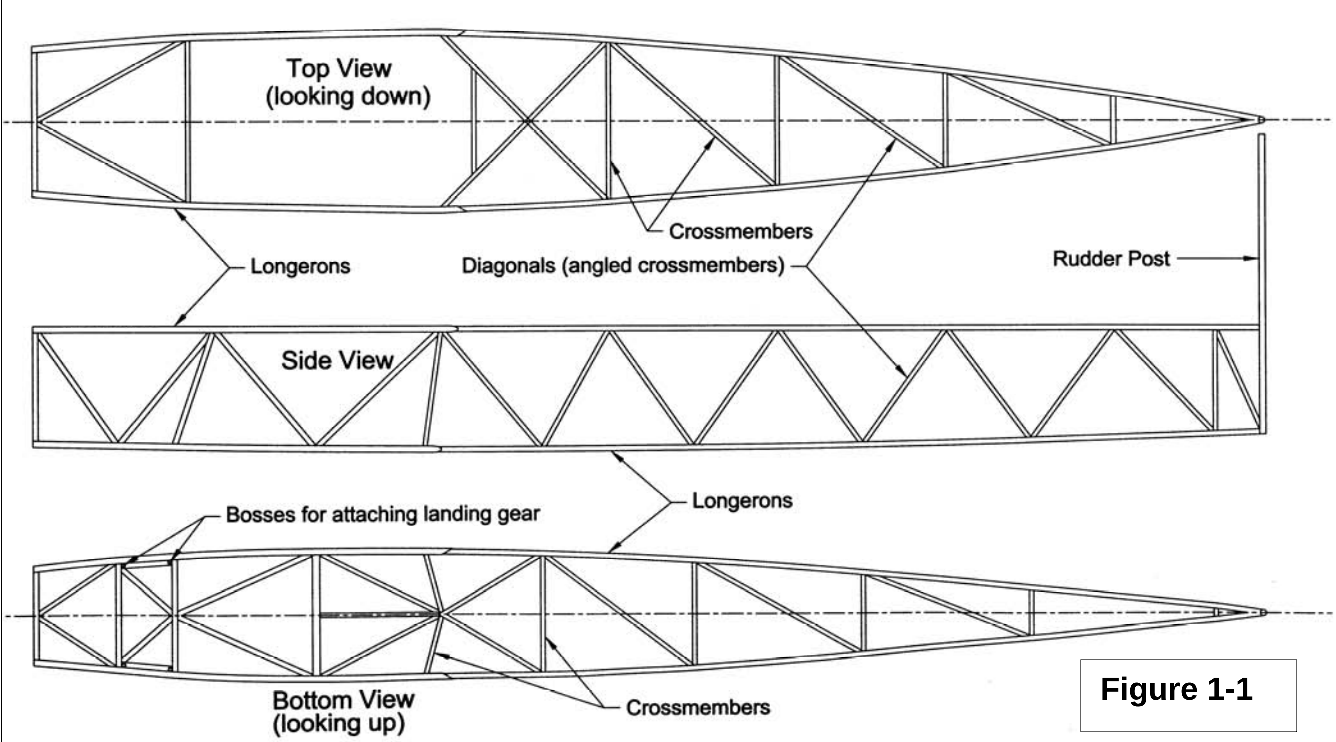

Figure 1-1

Longerons

A longeron is a structural member (tube) oriented along the longitudinal axis of the aircraft (oriented fore and aft). In tubular steel fuselages, there are typically four longerons extending from the firewall to the rudder. Each longeron is usually made from two tubes welded together, the smaller diameter tube being the aft section.

Member

Any piece of tubing used to make up a part of the structure.

Crossmembers

Crossmembers are the short pieces of tubing that connect the longerons together and are typically oriented perpendicular to, or at an angle to, the longitudinal axis of the aircraft. Crossmembers that are at an angle to the longitudinal axis are often referred to as diagonals. Crossmembers that are oriented mainly up and down (as on the fuselage sides) are often called uprights.

Cluster

The point of intersection of two or more tubes, or, the welded area of the intersection of two or more tubes.

Tail Post

Also known as the rudder post, it is at the aft end of the fuselage and typically all longerons will be welded to it there. It serves as one of the spars for the vertical stabilizer and the hinge point for the rudder.

Attach-Point or Boss

A mounting point for something, typically a piece welded on the basic structure that may have hole(s) in it to attach other things.

Gusset

A corner reinforcement, see Gussets in Chapter 2.

Bay

A fuselage station identified by crossmembers intersecting the longerons, or, the space between two fuselage stations (see Figure 1-4, Section A is a bay of the first type).

Axes

Reference is frequently made to a particular aircraft axis in describing geometric relationships for the purposes of jigging and construction (Figure 1-2). It is the same for describing the rotational axes of the aircraft in flight. The flight axes always pass through the center of gravity of the aircraft, but the terms are used more loosely in the context of building to indicate a general direction of some part of the aircraft structure.

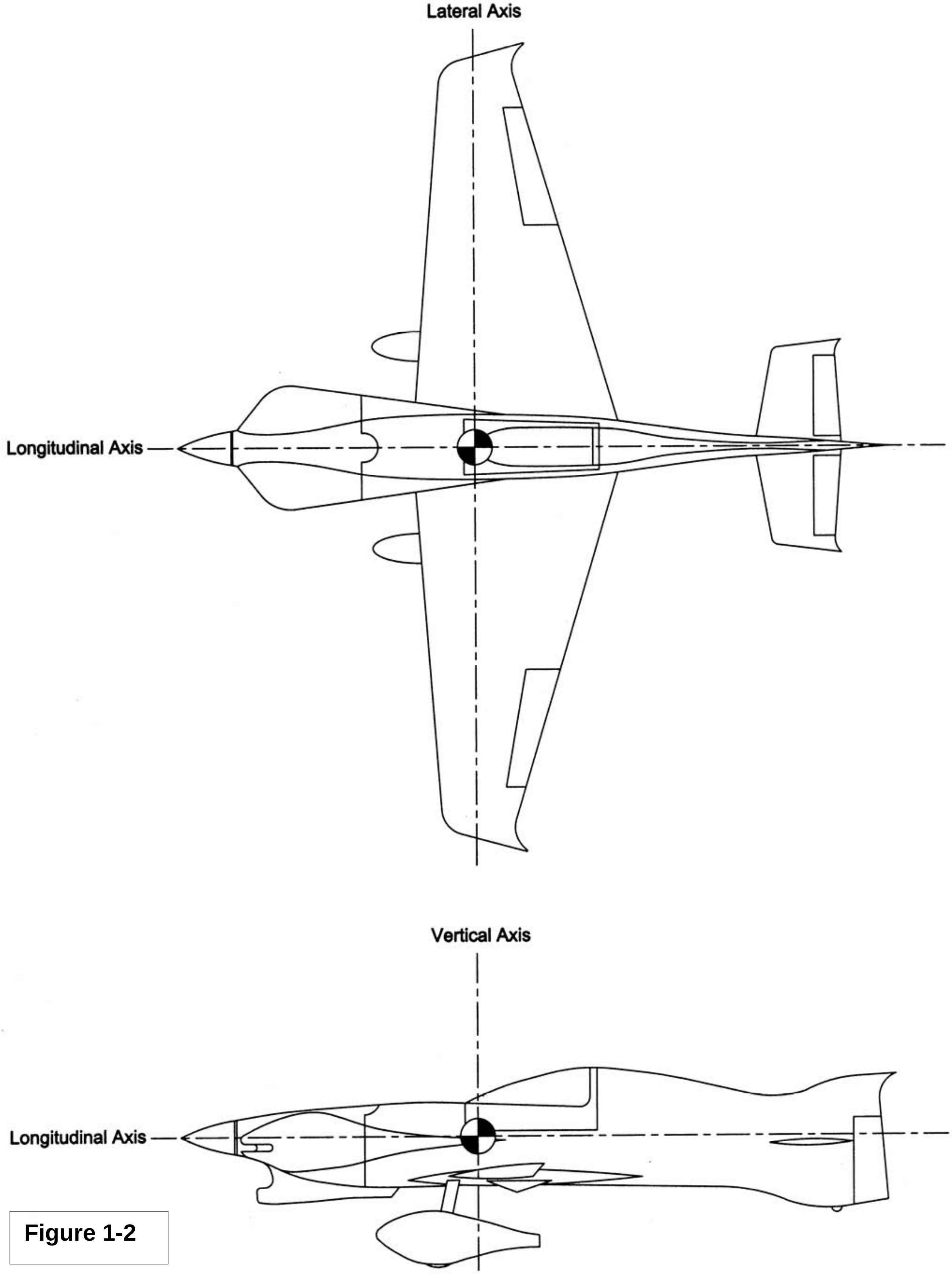
Lateral Axis
Longitudinal Axis
Vertical Axis
Longitudinal Axis

Figure 1-2

Fuselage Geometry and Construction

Intersections

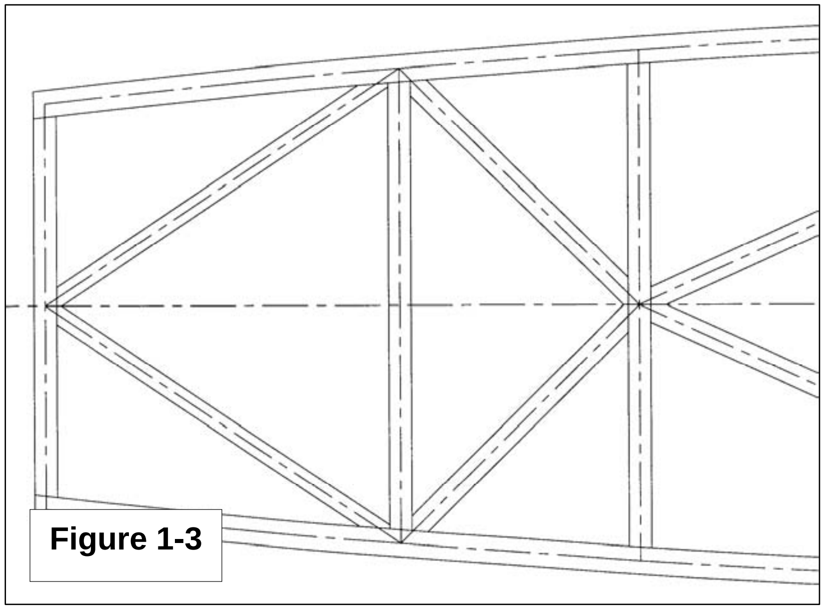

Figure 1-3

The joining of tubular members into a truss type structure requires that where tubing intersects other tubes (a cluster), the centerlines of all the tubes must intersect at the same point (Figure 1-3). It is an imaginary point created by a line going through the center of each tube. Unless it is otherwise specified in the drawings, all tubing clusters or intersections must converge at the imaginary center point that lies inside of the tubes. The structure will not develop its rated strength if the tube centerlines do not intersect. This dictates how the tubing must be cut or *notched* to intersect the other tubes in a cluster. There are simple methods to achieve this in fabrication, even on three dimensional clusters, covered throughout this book.

Flat Pattern Layout

When looking at the drawings of the fuselage, the question might arise as to whether the designer gave the vertical dimensions to the sides of the fuselage from the point of view of looking at them perpendicularly (as in a flat tabletop layout of sides first), or, are these the dimensions that the assembled fuselage should have. When the top of the fuselage is wider than the bottom, the actual length of the vertical crossmembers is longer than the overall height of the fuselage (measured in the vertical plane) because they are at an angle. This is illustrated in the fuselage cross-section in Figure 1-4. It can probably be determined what the case is by looking at the dimensions of fittings, controls, things that go in or on the fuselage, etc., to determine what the designer or draftsmen intended. Drafting practices imply that unless a drawing is specified as the flat pattern layout, the dimensions given are for the finished product. The jigging methods given in this book assume that the drawings contain the finished fuselage dimensions to work from, however, it is still possible to work from flat layout dimensions.

Order of Construction

For the one of a kind aircraft, the typical order of fuselage construction has been to lay out the sides of the fuselage flat on a table, tack weld them, then jig them upright on the table. If the longerons have graceful curves it usually requires putting in a few crossmembers and forcing the sides together with clamps, cables, straps, or whatever else can be employed to force the sides together to create the necessary curves. This can be very frustrating when trying to achieve symmetry, parallelism, and accuracy of various points. Bending a tack welded structure frequently results in breaking of the tacks. Some fuselages are made up of mainly straight line segments when viewed from any angle and are easy to build by any method.

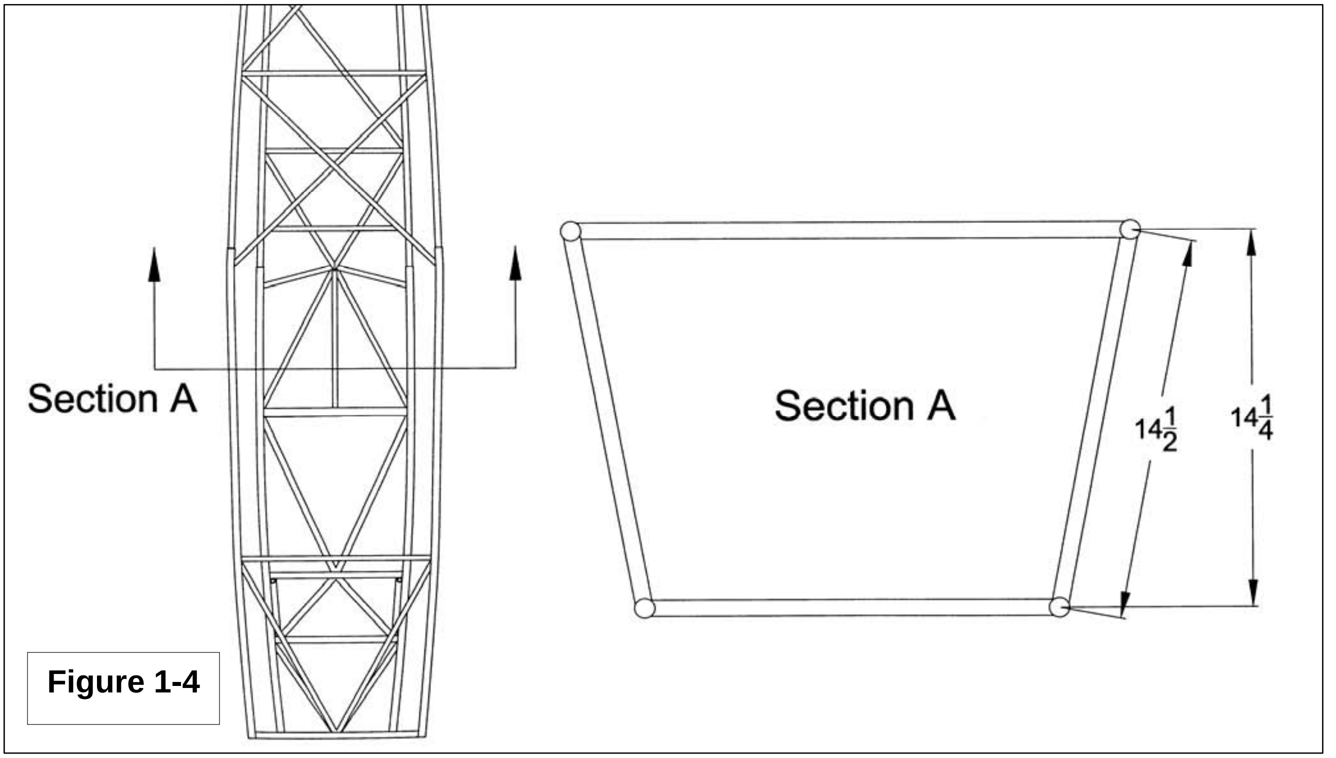

Figure 1-4

The methods given in this book differ from that above (sides first construction), in that the top and bottom are constructed (tack welded) first, then arranged to allow the vertical members to be inserted. For the fuselage with curves, the end result is more accurate and less frustrating to the builder. For other fuselage shapes, this method provides an easy method to jig and assemble the fuselage with very accurate results. It is easy to achieve deviations in parallelism, symmetry, and accuracy of less than .010 inches (comparisons made twelve feet apart) by using this method. It does require some extra jigging and a few extra steps but it is believed that the time spent building the fuselage is about the same as the traditional method. Although some bending may be required on the bottom if it is curved, it is usually minor and easily done with accuracy.

The intent of the procedures used in this book for jigging and aligning the members is to achieve accuracy and symmetry. The methods here also minimize distortion from welding, and cause distortion to occur perfectly symmetrically where it does happen (see Expansion and Contraction in Chapter 2). Although the example used in this manual uses top and bottom construction first, with a particular geometry of fuselage, the same principles are adaptable to ‘sides first’ construction and other fuselage shapes.

NOTE

The order of top and bottom first construction is not new, it just isn’t commonly used because of the requirement for some extra jigging. The idea came from a Cassutt newsletter done by the “Miami Project” where a number of fuselages were constructed in this manner and it was found to be easier and more accurate.

Upsweep

Upsweep occurs using the traditional methods of fuselage construction (sides first), on fuselages that are wider at the top than the bottom. Upsweep is the change in fuselage shape caused by the previously flat fuselage sides when they are pulled together at the ends, and, the top of the fuselage is designed to be wider than the bottom (see the example fuselage in Figure 1-1). Then upsweep can be seen from the side, where the top longerons (which maybe were straight when the sides were assembled on the table) now curve upward somewhat with the high points being at the front and back. Also the lower longerons, which maybe were curved on the flat layout, become curved even more. Note the change in geometry in Figure 1-5. The lower fuselage illustration was the flat layout of the fuselage side. When the fuselage was assembled, it took on the form of the fuselage in the upper part of the illustration.

NOTE

The change in geometry described above will not occur when using the methods given in this manual for top and bottom first construction.

Upsweep is neither a negative or positive aspect of construction, although it is easier to have a straight line somewhere (the top longerons) from which to reference dimensions and rig the flying surfaces. Some designers and draftsmen have designed and accounted for upsweep in the prints and others haven't. It can create some strange geometry in the finished product if it wasn't accounted for and is often the reason for peculiar discrepancies in dimensions.

On a more positive note, upsweep on many small fuselages amounts to a negligible quantity, and its' effect may be ignored.

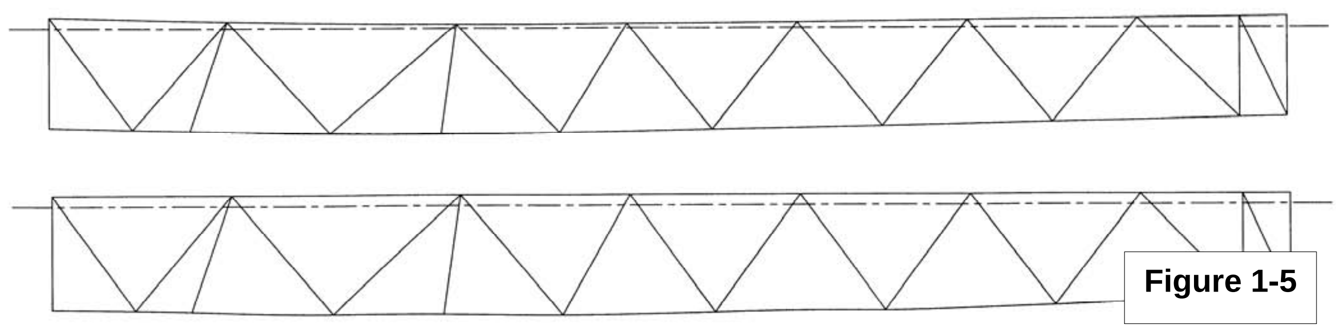

Figure 1-5

Drawing Conventions

There are certain conventions to interpreting engineering drawings and some things are specific to a tubular steel fuselage. Formal standards have been developed and written into specifications, which define how drawings should be drawn, with what symbols, and how they are to be interpreted. Drawings do not always conform to these standards and they have evolved over time, but an understanding is helpful. The following information only illustrates the most common items found on the plans for an experimental aircraft. There are hundreds of other symbols and notation used on engineering drawings.

Airframe Coordinates

Any point on an aircraft airframe can be identified by three coordinates. The coordinates are generally given in inches in relation to a fixed reference point. Aircraft drawings use particular terminology to identify these points. One may encounter some or all of the following terms in looking at the plans for the aircraft. The exact wording and abbreviations have not always been strictly standardized, so it is likely the builder will encounter some variation of what is discussed here. Refer to Figure 1-6 for the following discussion.

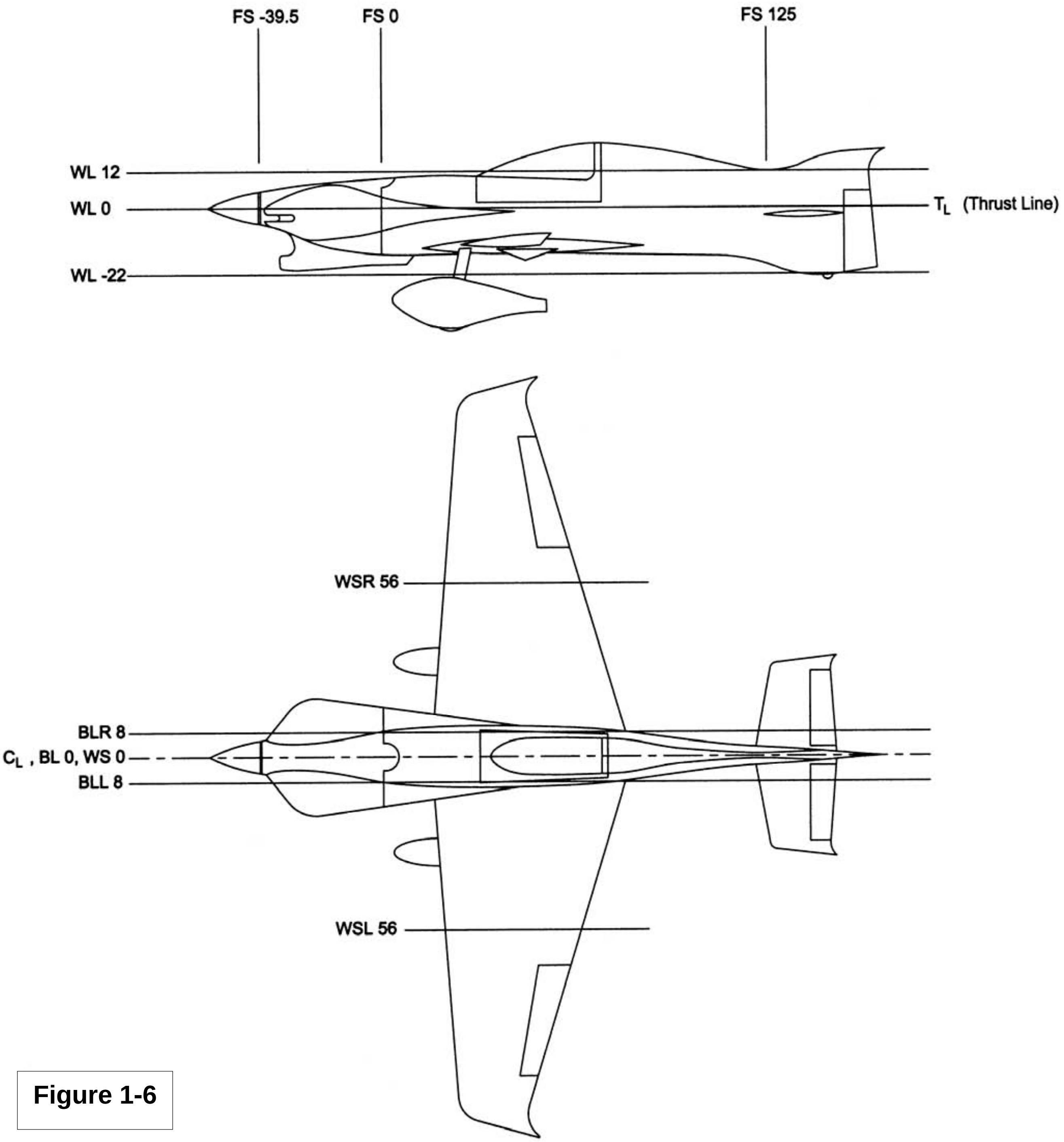

Figure 1-6

Center Line

The centerline, C_L, divides the aircraft into two symmetrical halves. It is at the same location as Buttock Line 0 (see Buttock Lines in the section).

Thrust Line

The thrust line, T_L, indicates the line of action of the thrust. For the purposes of construction of a propeller driven aircraft, it originates at the center of the propeller (prop hub) and is perpendicular to the propeller (sometimes it's not in flight). The thrust line is not always parallel to the longitudinal axis. Depending on the aircraft it may be set at an angle to compensate for asymmetrical thrust (usually by making the engine mount a little off). It may or may not coincide with Water Line 0 (see Water Lines in the section).