# Unlocking the Mysteries of Flight: From the Top Down

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## Abstract

Traditionally, principles of flight are taught from the bottom-up. That is, we start by examining underlying causes (properties of air) and later move up to top consequences (aircraft performance) of aerodynamic processes. This traditional approach is analogous to that used by airplane designers and is most obvious in theory of flight textbooks for pilots. The problem with a bottom-up approach is that it introduces basic concepts as isolated "parts" without providing a "big picture" context. This can lead to poor understanding among student pilots. This paper suggests an opposite approach. Rather than starting with the underlying causes of flight, we unravel basic principles by starting with top aerodynamic consequences. This top-down approach is analogous to that used by physiologists who start by taking energy measurements of animals (or humans) moving at different speeds. By first exposing students to the "whole" rather than the isolated "parts", a top-down energy-centered approach can lead to a better understanding of how the airplane works.

## Introduction

A good understanding of the theory of flight should allow students to: 1) develop an accurate mental model of how the airplane works; and 2) transfer concepts learned in the classroom to real situations in the airplane. Unfortunately, this is not the usual outcome. In fact, most student pilots have a hard time grasping aerodynamics. According to Wolfgang Langewiesche, author of *Stick and Rudder* (Langewiesche, 1944), what is wrong with teaching "Theory of Flight" to pilots is not the theory itself but how we teach it. The traditional approach seems to be more about how to "build" an airplane rather than how to "fly" it (Langewiesche, 1944). Today, not much has changed—judging from current books on "theory of flight" for pilots and the way instructors teach principles of flight in the classroom (Merkt, 2013).

This paper, adapted from a more detailed account of flight energy management training (Merkt, 2013), contrasts the traditional approach of studying flight with a top-down, energy-centered approach. The traditional approach is analogous to that of early aeronautical engineers designing airplanes, while the alternate approach is analogous to that used by physiologists studying animal locomotion (Merkt, 2013).

## Traditional Bottom-Up Approach

Engineers begin by examining the underlying causes (air properties and airflow), as opposed to top consequences (power curves), of aerodynamic phenomena in order to understand principles they can apply to design airplanes (Warner, 1936). In other words, design engineers use a bottom-up approach (Figure 1). This approach is evident in traditional textbooks for aeronautical engineers (e.g., von Mises, 1945) as well as those dealing with principles of flight for pilots (e.g. Dole, 1989; Hurt, 1965). Merkt (2013) named this traditional method of teaching basic principles the *designer* approach.

The problem with this traditional approach is that it introduces basic concepts as isolated "parts" (Hadjilogiou, 2001; Merkt, 2013). Without the proper ''big picture'' context and a solid background in physics and mathematics, it may be difficult for student pilots to understand abstract concepts such as ''lift'' or ''angle of attack,'' which they cannot ''see'' or ''feel'' during training flights (Merkt, 2013). Needless to say, this approach is not very conductive to learning.

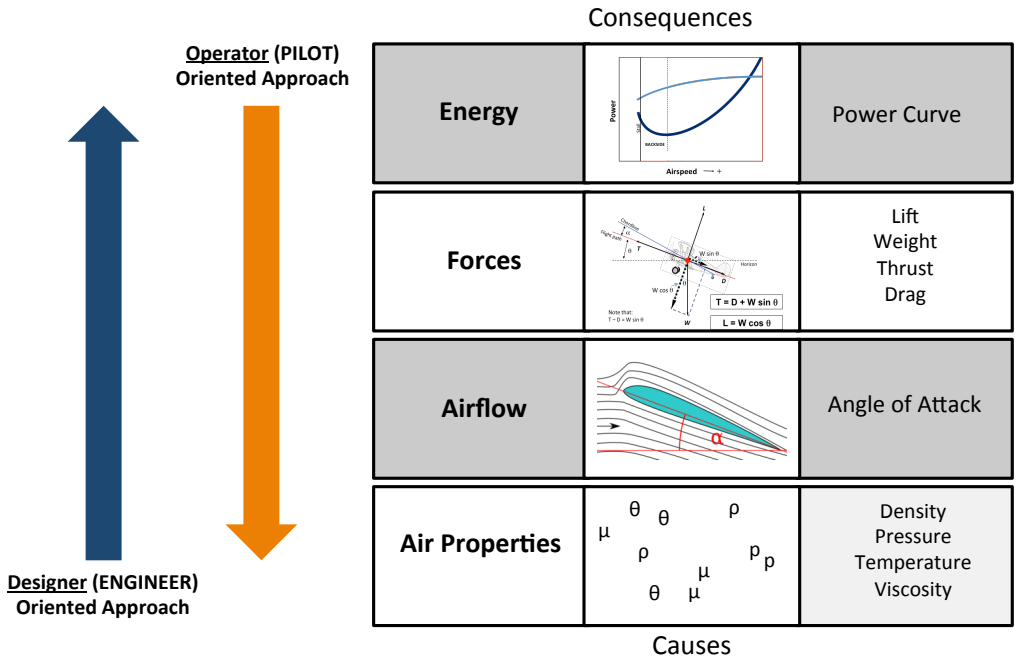


Figure 1. Two opposite approaches to the study and practice of flight (adapted from Merkt, 2013). The designer (engineer) oriented approach starts by studying the causes of aerodynamic phenomena (e.g. air properties) and proceeds up to higher-level consequences (e.g. aircraft performance). The operator (pilot) oriented approach starts with the highest consequences of aerodynamic processes and proceeds downward to unravel underlying principles.

## Top-down Approach

A "top-down" approach, on the other hand, starts by showing students the "big picture" (Merkt, 2013). Rather than beginning with underlying causes, one can unravel basic principles of flight by starting with top consequences such as aircraft performance. This approach is analogous to that of physiologists studying animal locomotion. Physiologists start by measuring performance power curves of animals running on treadmills or flying in wind tunnels at different steady speeds (Schmidt-Nielsen, 1972). The physiologist's top-down approach is thus exactly opposite to that of design engineers. After all, physiologists begin their studies with a "finished product," namely a live, performing animal. They start at the "top" energy level and work their way "down" to elucidate how animals move (Merkt, 2013).

Similarly, one can use power-required and power-available curves to start unlocking the mysteries of mechanical flight (Merkt, 2013). Like physiologists, pilots have to deal with a "finished product"—a functioning airplane. Merkt (2013) named this top-down method of teaching basic principles the *operator* approach (Figure 1). The bottom-up approach has been useful in teaching the theory of flight to engineering students, but the opposite approach may be better suited for teaching the same principles to student pilots (Merkt, 2013).

By focusing first on top-level energy concepts, students can learn a great deal about flight without having to dig down too deeply into complex underlying mechanisms (Feynman, 1942, p. 12). Should there be a need to dig down, the top-down approach guides students through distinct explanation "levels" (Figure 1)—each containing the underlying elements that explain the next level up. By starting at the top, students only need to focus on the level immediately below to begin their search for explanations. These underlying principles, however, only emerge in the context of the big picture. Students view relevant components within a meaningful context and begin to appreciate how these concepts apply to real flight situations, such as slow flight, which they can then practice with an instructor during flight (Merkt, 2013).

## Conclusion

Compared to the traditional approach, an operator, top-down approach may be a more effective way of teaching the fundamentals of flight in the classroom. The top-down approach can serve not only as a practical guiding tool in course design, organization, and delivery, but also as a powerful learning tool to help pilots develop a correct mental model of how the airplane works right from the start (Merkt, 2013).

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