The United States Military Academy Flight Laboratory Program: A Hands-On Approach to Engineering Education

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Abstract

Since 1970, the United States Military Academy (USMA) at West Point has used military aircraft to conduct Flight Laboratories as an integral part of the Mechanical Engineering curriculum. Conducting Flight Laboratories with pilots who are also classroom instructors from the Department of Civil & Mechanical Engineering (C&ME) accomplishes several things. First, they provide high quality, hands-on, one-on-one instruction to students in actual aircraft. The laboratories also demonstrate important aerodynamic concepts and the operation of aeronautical systems while validating the theory presented in the classroom. Most importantly, the labs excite students about engineering and inspire in them the desire to continue learning both in and out of the classroom. The USMA Flight Laboratory Program provides a model for a hands-on introduction to Aerospace Engineering. This paper details the experiments conducted in the three fixed-wing Flight Laboratories and the one rotary-wing Flight Laboratory currently conducted as a part of the USMA Aeronautical Subsystems curriculum to include the aircraft specifications, experimental methodology, and sample student results. Also included are samples of student feedback on the Flight Laboratory Program as well as a brief look at other universities with similar programs.

Introduction

Joseph Lowman, in his text titled Mastering the Techniques of Teaching, said "Because science is based on empirical investigations and the application of general principles to real-world examples, science lectures are universally accompanied by laboratory experiences."[i] This spirit has been a guiding principle in undergraduate engineering education at USMA for a long time. Like most engineering departments, the Department of C&ME at West Point utilizes concrete laboratories, wind tunnels, materials laboratories, internal combustion and turbine engines and a host of other equipment to help cadets understand the physical principles underlying the theory they study. The challenge to the department and any Aeronautical or Aerospace Engineering program is to provide students that same level of practical experience in their discipline.

In 1921, General Douglas McArthur, then Superintendent of the United States Military Academy, wrote about the Academy's newly founded Aerodynamics course that the "…instruction is made as practical as possible by using charts, graphs, models, results of wind tunnel tests, lantern slides, films, lectures and actual demonstrations of an airplane."[ii] This focus on practical application remains a hallmark of the Aeronautics curriculum at West Point to this day. Since 1970, the department has used available military aircraft to supplement the curriculum with Flight Laboratories. There are five main goals of the Flight Laboratory Program.

1. To provide students with quality, hands-on instruction one-on-one with their instructor in an actual aircraft.
2. To build technical understanding of the aerodynamics and performance of airplanes and helicopters for both students and instructors.
3. To validate theory presented in the classroom through hands-on application.
4. To reinforce the test and experimentation aspect of engineering.
5. To excite students about aerospace engineering and to inspire in them the desire for continued learning.

In the words of one student, "Much like Physics classes that have labs, or Social Science classes that visit the United Nations, it is very useful to see the actual system that you spend years learning how to model. For me, flight labs helped me to better understand the capabilities of the aircraft, as well as believe what I hear in class." However, the Flight Laboratory Program is not a flight training program and makes no attempt to teach students how to fly. Currently, students enrolled in the Mechanical Engineering, Aeronautical Subsystems major in the Department of C&ME take part in three fixed-wing and one rotary-wing Flight Laboratories in support of three undergraduate academic courses: Introduction to Applied Aerodynamics, Aircraft Performance and Stability, and Helicopter Aeronautics.

Fixed-Wing Flight Labs

The department began conducting Flight Laboratories in 1970 with three T-41 aircraft. In 1989, the U.S. Army replaced the T-41s with a Cessna 182Q and a Cessna 182R. The Cessna 182 is an excellent platform for performing the Flight Laboratories since it has the capacity to carry an instructor and two students and can perform over a large range of airspeeds (with and without flaps extended) and center of gravity positions. A picture of one of the current aircraft appears in Figure 1. The Cessna 182s operated by the Department of C&ME are fully Instrument Flight Rules (IFR) capable and have been modified with additional equipment including three-bladed propellers, four place intercom systems, digital fuel consumption rate indicators, digital engine cylinder temperature monitors, Global Positioning System navigation equipment, and horizontal situation indicators (HSI). Also, the right side of the cockpit where the student sits also has an additional altimeter, airspeed indicator and outside air temperature (OAT) gauge to facilitate student data recording. A picture of the cockpit layout appears in Figure 2.

Figure 1: C-182 Used for Current Flight Labs

Figure 2: Cockpit Layout of C-182 Aircraft

Experimental Procedures

Cadets conduct three flight labs within their two fixed-wing aerodynamic courses. Their first flight lab experience begins in ME387: Introduction to Applied Aerodynamics. Their remaining two labs take place in ME481: Aircraft Performance and Static Stability. Each of the labs has two components: flight demonstrations and data gathering. The data gathering procedures for all three labs are extremely simple, but the complexity of the information derived from the data increases with each successive lab. The data gathering procedures used for each test are outlined in the Jeppesen manual, Introduction to Aircraft Flight Test Engineering.[iii]

With current enrollment in each of the courses with Flight Laboratories at approximately 30 students, each Laboratory requires approximately a month to conduct all of the labs due to weather and scheduling conflicts. Each lab is conducted with two students at a time and lasts for approximately two flight hours.

The first flight lab in ME387 provides an introduction to the flight lab experience and validation of some of the most fundamental aerodynamic theories. The objectives of Flight Lab One are as follows:

1. To familiarize the cadets with fixed-wing aircraft, basic airplane maneuvers, and airborne data-taking procedures.
2. To gather data necessary to create the lift-curve (Lift Coefficient v. Angle of Attack) for the Cessna 182.
3. To compare the flight test data with theoretical solutions.

The flight lab begins with an orientation to the basic components of the aircraft and cockpit. Once airborne, the pilot instructors introduce the cadets to some fundamental aircraft maneuvers including straight-and-level flight, turns, climbs and descents, aircraft stalls, flight at minimum controllable airspeed (slow flight), gliding flight, load factor demonstrations (steep turns and the "zero-g" pushover), and landings. The objective of demonstrating these maneuvers is to demonstrate the various aircraft capabilities, appropriate pilot control techniques and actions, and to the extent possible, how the maneuvers support the classroom instruction. This is by far the most popular aspect of the flight lab program, especially the "zero-g" pushover.

For this maneuver, the pilot establishes straight-and-level flight at 90 knots while having the cadets hold a checklist or pencil in palms of their hands. Without changing the power setting, the pilot pulls back on the yoke, increasing the aircraft's altitude, while decreasing its airspeed. When the airspeed decreases to 60 knots, the pilot abruptly pushes the yoke to force the nose of the aircraft down. Similar to reaching the top of an arc on a roller coaster, the load factor on the aircraft decreases to zero, and the objects in the cadets' hands "float" for approximately two or three seconds.

During the data gathering portion of the lab, the pilot instructor establishes the aircraft in straight-and-level flight at 120 knots. The cadets then record the outside air temperature, pressure altitude, and fuel remaining for that speed. Using an inclinometer placed in one of the aircraft windows, the cadets also record the angle of attack of the aircraft. The pilot then decreases the airspeed to the stall speed in increments of five knots, allowing the cadets to record the same data at each speed. When this procedure is complete, the pilot then deploys the flaps; the cadets then gather the same information for each airspeed interval.

From this basic data set, the cadets can then calculate the aircraft weight (the weight of the aircraft is constantly decreasing as it burns fuel), ambient air density, true airspeed, and finally, the lift coefficient. They can then plot the lift coefficient vs. angle of attack for the two configurations (flaps-up, flaps-down) and compare the two.

Probably the most important objective for the flight lab is to compare the flight test results with the theoretical techniques taught in the classroom. The course teaches three basic aerodynamic theories: Thin Airfoil Theory, Finite Wing Theory, and a numerical solution called the Vortex Lattice Method. The flight test requires that the cadets plot their flight results against these three theories and comment on the results. A sample of cadet results follows in the figure below; the chart clearly illustrates how the relationship between theory and flight test.

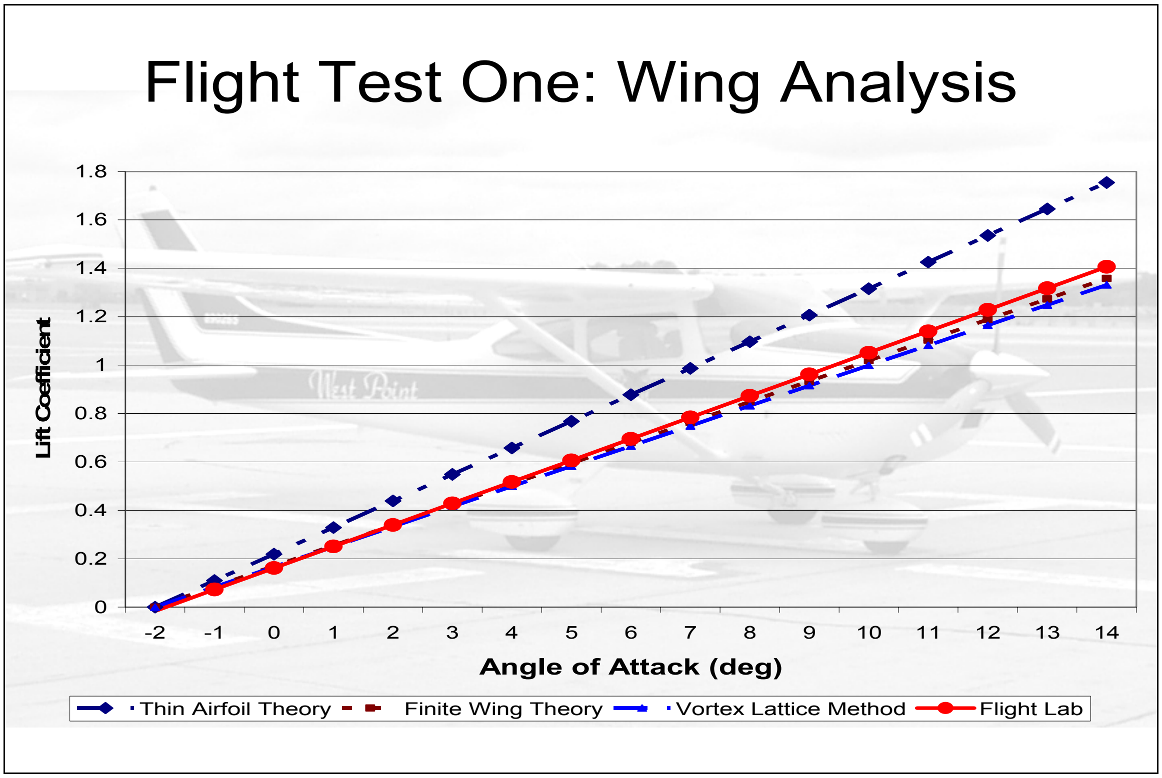


Figure 3: Flight Lab One Results: Lift Coefficient vs. Angle of Attack

The second flight lab allows the cadets to determine some of the performance characteristics of the airplane. The objectives of Flight Lab Two are as follows:

1. To determine the relationship between calibrated and indicated airspeed.
2. To determine the drag polar of the Cessna 182.

3. To construct the basic performance curves of the airplane (lift-drag ratio v. airspeed, power required, and thrust required).

This is the longest flight lab of the three, and consists mainly of data- gathering with little demonstration. In determining the forces acting on an airplane in flight, one must know the true speed of the air flowing over the wing (true airspeed). However, this is different than the speed seen by the pilot on the airspeed indicator (indicated airspeed). The cadets must convert from one to the other. The difference between the two speeds is dependent upon the altitude and density of the air, in addition to the calibration and installation errors distinctive to each aircraft. The indicated airspeed corrected for these errors is the calibration airspeed. Aircraft manufacturers generally provide a table relating the indicated and calibrated airspeeds for different configurations. In this portion of the lab, the cadets use flight testing to establish the relationship between calibrated and indicated airspeed. With that information, they can determine the true airspeed and calculate the aerodynamic forces acting on the airplane.

The airspeed portion of the lab consists of the pilot flying a known-distance across the ground and the cadets recording the time it takes to traverse the distance at a given speed (ground speed). The pilot then flies the track in reverse to negate the effects of the wind. The average of these two speeds results in the true airspeed of the aircraft. The cadets then record this data at 10 knot intervals from 120 knots to 60 knots. They also record the pressure altitude and air temperature for each "lap." With the true airspeed and the ambient air conditions, the cadets can calculate the calibrated airspeed. The cadets then plot that information versus the indicated airspeed and perform a regression of the data points to establish a relationship between the two. They then use this relationship in the successive analysis.

The second portion of the flight lab involves the execution of several "power-off" (gliding) descents that will enable the cadets to determine the drag properties of the airplane. Starting at 120 knots and decreasing incrementally to 60 knots, the pilot pulls the throttle to idle and establishes a power-off descent. The cadets record the time it takes for the aircraft to descend through 1,000 feet. Additionally, for each airspeed, they record the pressure altitude, air temperature, and fuel remaining. From these measurements, the cadets can determine the drag acting on the airplane, the power required to overcome that drag, and the thrust required for each airspeed. They can also calculate the lift-drag ratio at each airspeed. Plotting these data points provides the most basic performance charts for the Cessna 182, and the cadets can compare that with the material taught in the classroom.

The two curves below show cadet results of Flight Lab Two. The data below represents one-half of the cadets enrolled in the ME481 course for one semester. When the data is combined in this way, the trends in the performance curves become very evident. The drag polar in Figure 4 confirms that the flight lab data closely matches the aircraft's theoretical prediction. Additionally, Figure 5 demonstrates that the maximum lift-to-drag ratio occurs where the parasite power and induced power are equal, which corresponds to the tangent point on the power required curve. This occurs at a true airspeed of approximately 78 knots (approximately 76 knots indicated airspeed at sea level), which is the best glide airspeed of the Cessna 182. By way of comparison, the manufacturer lists the best glide indicated airspeed as 75 knots.[iv]

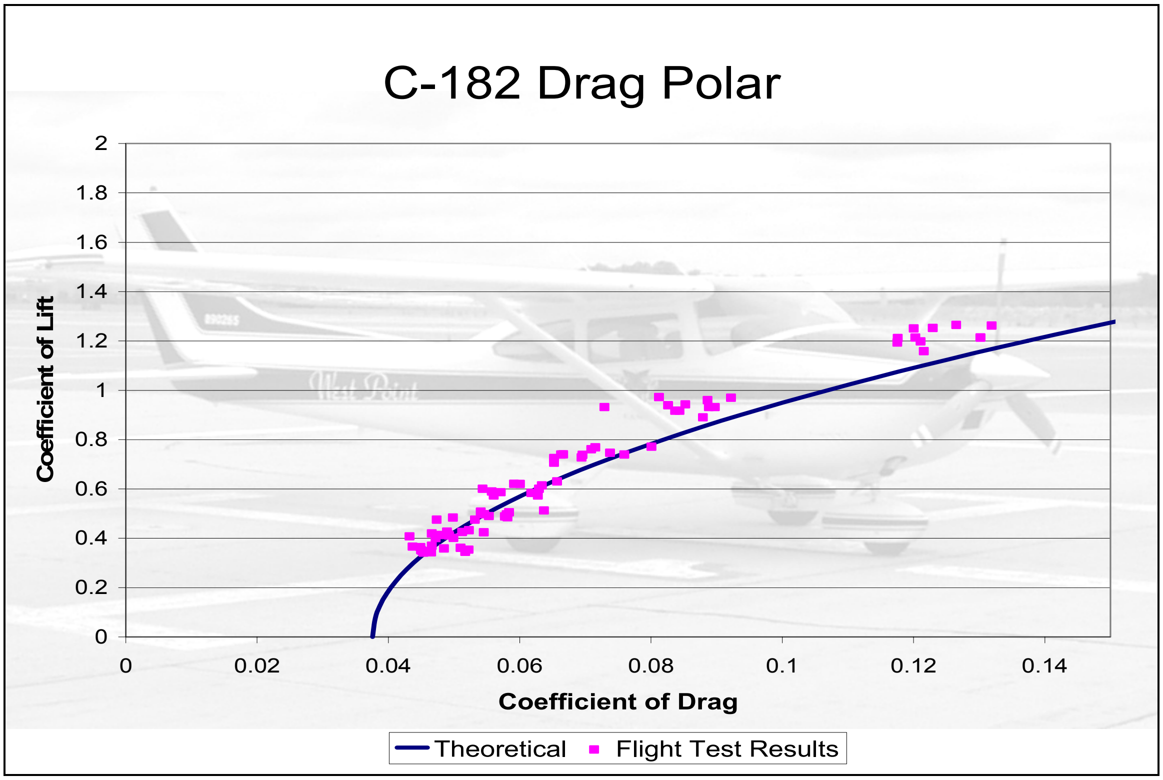


Figure 4: Flight Lab Two Results: Drag Polar

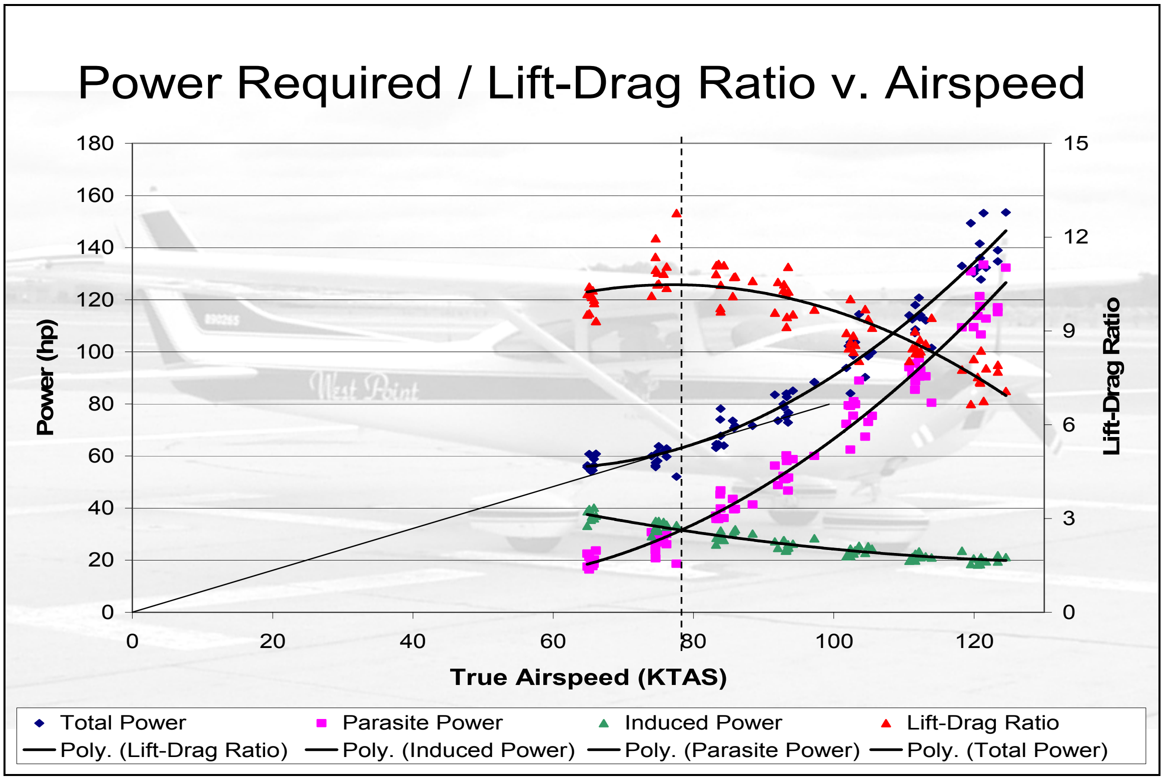


Figure 5: Flight Lab Two Results: Power and L/D vs. Airspeed

The third flight lab focuses on the stability characteristics of the airplane. The objectives of Flight Lab Three are:

1. To determine the effect of center of gravity (CG) location on aircraft stability.
2. To predict the neutral point of the aircraft.
3. To determine the aircraft's longitudinal dynamic stability response (phugoid).
4. To demonstrate some of the C-182's static stability characteristics.

The beginning of Flight Lab Three is devoted to demonstrating some of the directional and lateral stability characteristics to include Dutch Roll, Adverse Aileron Yaw, and Proverse Roll. These demonstrations truly showcase the benefit of the flight lab program. All of these maneuvers do not require data to validate. They are fundamental stability characteristics of any fixed-wing aircraft. However, they are very difficult to explain to a student in a classroom. Concepts that are sometimes only vaguely understood with videos or training aids suddenly come alive during the flight lab experience.

The location of the center of gravity is critical to the stability of an aircraft. In this flight lab, the cadets see how a shift in the CG affects its stability by measuring the force applied to the yoke at different airspeeds. The cadets record this data in two different CG configurations. The first CG configuration is the "standard" configuration with two people at the controls and one in the rear seat. The second configuration requires that both cadets be in the rear seat, with just the pilot at the controls. Based upon the weight and balance data of the aircraft, the crew weight, and the amount of fuel in the airplane, the cadets can determine the location of the CG for each configuration.

For this procedure, the pilot "trims" the aircraft for straight-and-level flight at 90 knots. Trimming the aircraft means that the net moment about the CG at that speed equals zero. If the pilot removes his hands from the controls, the airplane will remain in straight-and-level flight. Once trimmed, the pilot will then increase or decrease the speed once again in 10-knot increments up to 120 knots and then down to 60 knots. As the pilot increases or decreases the airspeed, the aircraft is no longer in trim. At any speed other than 90 knots, there is a moment on the aircraft, and the pilot must apply an appropriate force on the yoke (either pushing or pulling) to keep the aircraft level. The pilot measures this force, for each airspeed, using a force gauge held on the yoke. The force required is then plotted versus airspeed for the two CG configurations.

In an airplane, as the CG moves further aft, the static stability of the airplane decreases. This concept is demonstrated by moving both cadets to the back seat of the airplane. In terms of the force applied to the yoke, since the first configuration is more stable, the force required to move the airplane away from its equilibrium position (90 knots) will be greater than the second CG configuration with both cadets in the rear seat.

Additionally, as the pilot is adjusting the speed of the aircraft, the cadets also measure the yoke displacement at each airspeed, using a tape measure attached to the instrument panel. They also record the pressure altitude, fuel remaining, and air temperature to calculate the coefficient of lift at each airspeed for both CG configurations. These results will produce two curves (stick displacement v. lift coefficient) for each configuration, each with a different slope. Plotting the value of these two slopes versus the CG location, the cadets can approximate the neutral point of the aircraft. The neutral point of the aircraft is the aerodynamic center of the entire airplane, where the moment of the aircraft is independent of the angle of attack. It is an important parameter for static stability. One of the criteria for aircraft longitudinal static stability is that the CG be forward of the neutral point. The results of this procedure confirm that the neutral point is behind the CG.

The final procedure involves recording the phugoid of the airplane. The phugoid is the sinusoidal, longitudinal dynamic stability response of the aircraft. The procedure also involves trimming the aircraft for 90 knots. Once trimmed, the pilot pulls the nose of the aircraft up approximately 20°. The aircraft will gain altitude and decrease airspeed. When the airspeed decreases to 60 knots, the pilot releases pressure on the yoke. The cadets record the maximum altitude and begin a stopwatch to record the time. The aircraft below 90 knots experiences a nose-down moment, so the nose of the aircraft will drop, the aircraft will descend, and the airspeed will accelerate. As the airspeed surpasses 90 knots, the aircraft then experiences a nose-up moment: the aircraft will climb and decelerate. The cadets record the minimum altitude of the airplane and the time elapsed. The aircraft will reach another “peak” altitude, for which the cadets record the altitude and the time. Since the aircraft is dynamically stable, the amplitude of the oscillations will begin to dampen out. The cadets continue to record these “peaks and valleys” until the aircraft returns to equilibrium.

The results from Flight Lab Three follow below. The results indicate that the neutral point of the aircraft is behind the aft CG limit, meaning that the aircraft will always have positive longitudinal static stability if properly loaded. The phugoid response demonstrates the aircraft’s positive dynamic stability. After an initial nose-up disturbance, the aircraft will return to its equilibrium position over time; in this case, approximately two minutes.

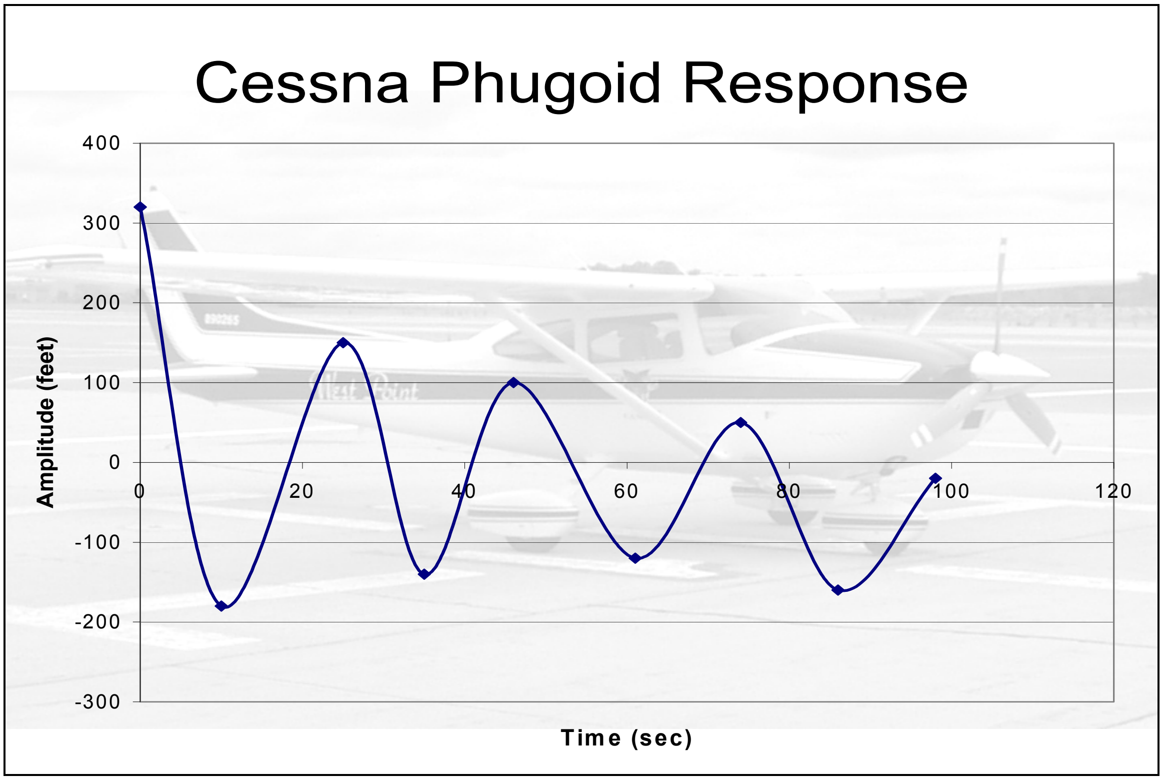


Figure 6: Flight Lab Three Results: Phugoid

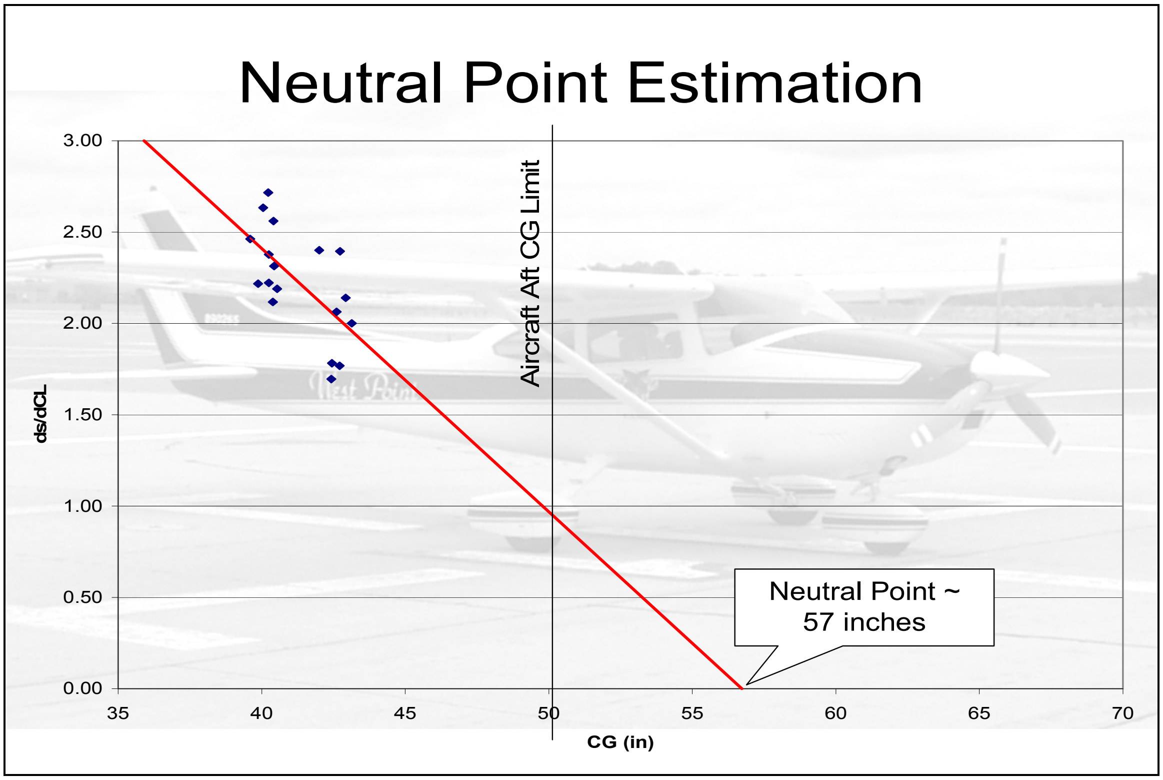


Figure 7: Flight Lab Three Results: Neutral Point Estimation

Rotary-Wing Flight Laboratories

The Department of Civil & Mechanical Engineering also conducts rotary-wing flight laboratories to support its undergraduate course in *Helicopter Aeronautics*. The rotary-wing flight laboratory has three objectives:

1. To allow students to see and put hands on actual helicopter systems.
2. To experimentally verify theoretical predictions of power required versus airspeed.
3. To demonstrate the impact of ground effect on hover power.

The Instructor for *Helicopter Aeronautics* is always a U.S. Army helicopter pilot who in some cases serves as one of the pilots for the flight laboratory and in other cases rides in the back with the students. In either case, the instructor assists the students in taking data and highlights important phenomena, relating them back to concepts students have seen in the classroom.

Aircraft

The aircraft used are U.S. Army UH-1H helicopters operated by the 2nd Aviation Detachment at Stewart International Airport. The 2nd Aviation Detachment operates helicopters to perform utility missions in support of the United States Military Academy (USMA) ranging from VIP transportation to support of the USMA parachute team. The UH-1H is powered by a single 1,400 horsepower Lycoming gas turbine engine and has a 2 bladed, teetering main rotor configuration. A picture of the aircraft used for the rotary-wing flight labs appears below in Figure 8.

Figure 8: UH-1 Used for Rotary-Wing Flight Labs

Experimental Procedures

The rotary-wing flight laboratory is typically accomplished over two days by flying the students in groups of 4 at a time. Each group requires approximately two hours to complete the laboratory. Due to military regulations, students can not sit at the controls of the aircraft as they do in the fixed-wing laboratories. However, all of the students are seated in a position to view the instruments on the control panel.

With the aircraft shut down, the laboratory begins with a safety briefing and an Instructor-guided, hands-on look at the main and tail rotor systems, to include a demonstration of collective, cyclic and pedal control. Students also get a chance to see and ask questions about the other systems of the aircraft to include the engine and fuel control, horizontal and vertical stabilizers, and the tail rotor drive shaft.

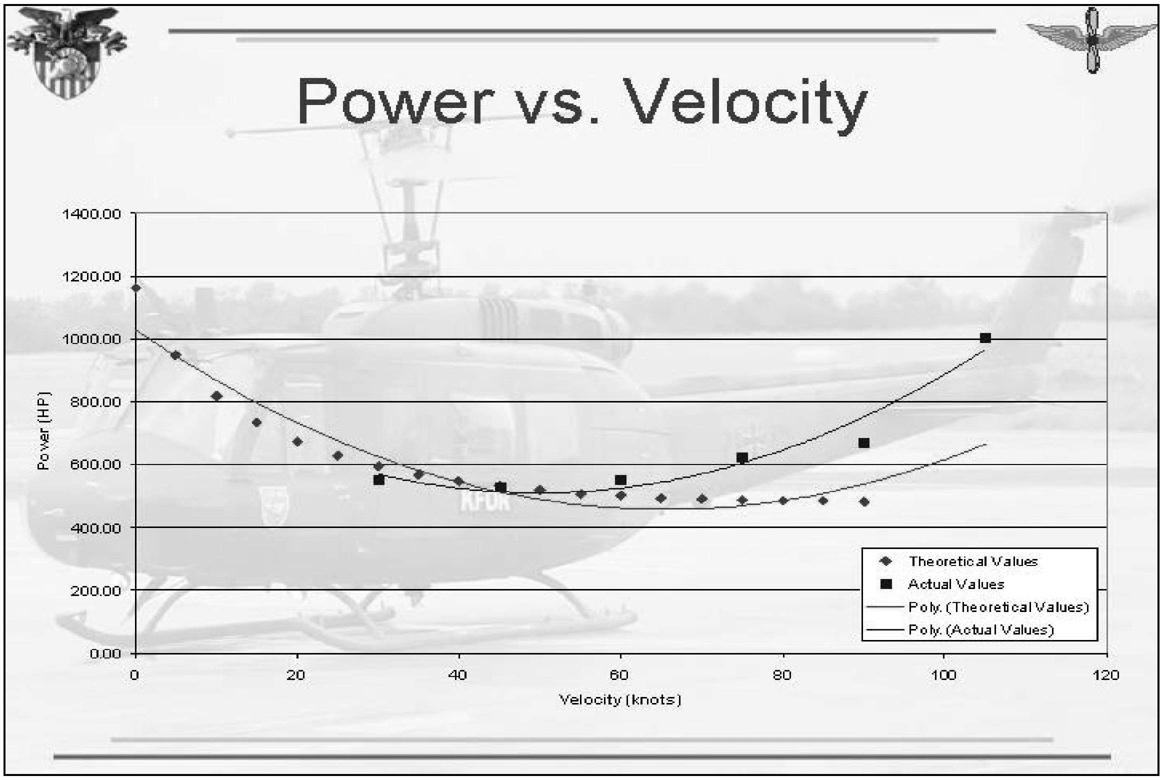
The first maneuver performed is a normal, constant-power takeoff in order to demonstrate effective translational lift as well as pedal control. The second maneuver is a speed-power test. For the speed-power test the pilots fly the aircraft straight and level at airspeeds ranging from 105 knots to 0 knots in 15 knot increments. At each airspeed, students record the pressure altitude, the outside air temperature, the fuel quantity on board, the indicated airspeed and the indicated torque from the instruments on the control panel.

Using the pressure altitude and the outside air temperature, the students can determine the actual air density during the test. Using the weight and balance data for the aircraft, the fuel weight, and the weights of each of the students and the crew, the students can determine the exact weight of the aircraft at each airspeed. Using the density, the weight, and the indicated airspeed the students can predict the power required using a combination of Momentum Theory and Blade Element Theory. The theoretical model used is from Principles of Helicopter Aerodynamics by Leishman[v], and requires some reasonable assumptions about the induced power correction factor, the profile power correction factor, the control axis tilt angle and the induced velocity. The students can compute the actual power output by using the cockpit indicated torque reading and the equations published in the aircraft's operating manual to convert indicated torque into power. A plot of the theoretical prediction versus the experimental data shows that both curves follow the same trend and clearly have a "bucket" shape. Both curves allow the cadets to determine an airspeed for minimum power required. Students can then determine the airspeeds for maximum rate of climb, maximum range and minimum rate of descent.

The presence of an optimal airspeed for minimum power required is further reinforced by a series of simulated autorotations. Simulated autorotations are performed at airspeeds of 40, 60, 80 and 100 knots. For each descent, the students record the rate of descent from the vertical speed indicator (VSI) on the control panel, the starting altitude and the ending altitude from the control panel altimeter, and the elapsed time. Therefore, the students can compute the descent rate for each iteration from both the VSI measurement and by using the distance and the elapsed time. The autorotation results further demonstrate the presence of an airspeed for minimum power required and therefore minimum rate of descent.

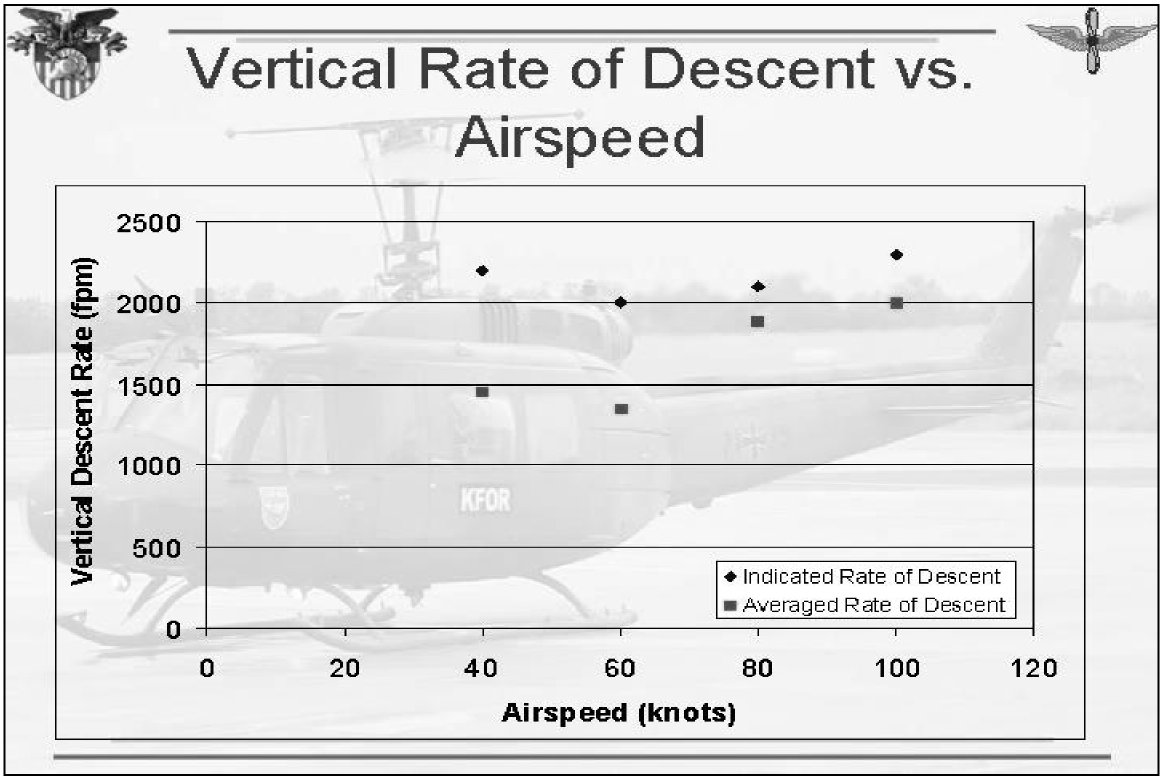
The final experiment is a hover power test. The pilots hover the aircraft with skid heights of 5, 10, 25, 50 and 100 feet above the ground using a radar altimeter. The students record the pressure altitude, temperature, fuel weight and indicated torque for each height and translate their data into a plot of actual power required versus skid height. The plot clearly shows a significant increase in power as the aircraft leaves ground effect. Students are also able to compare the experimentally measured ground effect with theoretical predictions of the ground effect as presented by Leishman[vi].

Original, uncorrected student plots of power required versus airspeed and vertical rate of descent versus airspeed are shown in Figure 9 and Figure 10 below. Despite the uncertainty in the data measurements and minor technical errors by the students, the plots clearly show the trends indicated by the theoretical predictions and serve to reinforce the concepts learned in the classroom.



Power vs. Velocity

Figure 9: Rotary-Wing Lab Results: Power Required vs. Velocity



Vertical Rate of Descent vs. Airspeed

Figure 10: Rotary-Wing Lab Results: Rate of Descent vs. Airspeed

Student Feedback

The comments listed below are actual comments made anonymously by students on course end student surveys for the courses with flight laboratories. The comments demonstrate the effectiveness of the flight laboratory program in providing students with quality, hands-on instruction one-on-one with their instructor, building technical understanding of aerodynamics and aircraft performance, validating theory presented in the classroom, and exciting students about Aeronautics.

> Sitting there having it explained while the aircraft is in flight allowed me to finally understand the more esoteric concepts covered in class. It was like a light bulb would come on and I couldn't help smiling at finally understanding what the instructor was saying. Making the flight lab a session where the pilot basically teaches a lesson while the cadets are engaged in a hands-on flight experience is by far the best way to learn anything.
>
> I have a good friend that is an Aerospace major at SCHOOL NAME REMOVED. His aero classes are 100 people in an auditorium, being lectured at twice a week. These flight labs here provide ME387, ME481, and ME388 students with an advantage and privilege that few other students across the country will get – genuine practical application one on one with my professor.
>
> Flight labs give us the opportunity to do what we came here to do: analyze real airplanes so we can design them.

Undergraduate Flight Lab Programs throughout the Country

In an effort to gain more information about conducting flight laboratories, the authors tried to determine if any other schools in the country conducted a similar program for undergraduate purposes. While the search was not all-inclusive, most of the flight-related programs in the country fell into one of three categories.

Several schools owned or leased aircraft for the sole purpose of training their students to fly. Program such as Embry-Riddle, University of North Dakota and Colorado Northwestern Community College fell into this category. However, the aircraft were not utilized to augment the theory of aeronautics or conduct data-related experiments.

A few other schools contacted had some form of flight laboratory program in the past. In almost every case, budget constraints or insurance concerns forced the programs to be canceled. Pennsylvania State University and Cal Poly San Luis Obispo both indicated that flight lab programs existed in the past but were no longer offered for undergraduate students.

Two schools in the country that have a continuing flight laboratory program are the United States Air Force Academy (USAFA) and the University of Kansas (KU). The USAFA program is incorporated into their AeroEngr 456 course, Flight Test Techniques. It is a robust program consisting of four flights in T41D aircraft and one in a T-38A jet trainers. The basic program is designed around the Air Force experimental test pilot curriculum at Edwards Air Force base and reinforces the theory of fixed-wing aeronautics as well as the practical experience of conducting test flight procedures.[vii]

Similarly, the KU Engineering School's Aerospace Engineering Department owns two aircraft, a standard Cessna 172 and the prototype Cessna TR182RG. Students interested in flight testing enroll in AE 732, Introduction to Flight Test Engineering. As a stand-alone course, the focus is not on simply conducting laboratories to verify theory, but on the formulation of the entire flight test. This includes the identification the key performance parameters to be measured, an understanding of the instrumentation available to accomplish the measurements, an understanding of the capabilities and limitations of the sensors, integrating the selected sensors into an instrumentation package that is suitable for use or integration on the aircraft, formulation of the flight testing procedures, assessment of the test results, and reduction of the risk factors involved in the flight test. Only after these processes are completed is the flight test briefed to the test pilot, conducted and then debriefed. Again, the focus of the course is not solely on conducting the flight test, but on designing and developing the flight test.[viii]

Conclusions

After conducting a review of the USMA Flight Laboratory program one can draw several conclusions. First, it is clear from the results of the laboratories that the theories taught in the classroom closely match experimental results. This is important because it reinforces all of the time that students spend in the classroom and reading their text. In order to obtain reliable data, the experimental procedures must be sound, and adhered to by the department pilots. A strong training program and years of experience flying the laboratories makes them a worthwhile supplement to classroom instruction.

Second, based on formal and informal feedback from cadets, the demonstrations conducted during the flight lab serve as a critical component of Aeronautics instruction. Without a doubt, the topics presented in Aeronautics are complex. This is the first time that many students are presented with a six degree of freedom system. The coupling that takes place between axes, the fluids mechanics and physics involved with an aircraft in flight are difficult to understand. Using videos or training devices are two ways to help students understand these ideas. However, demonstrating the concept in flight is clearly the most effective way to teach the material.

It is also evident that a flight laboratory program is not possible for every school with a similar curriculum. The administration, logistics, training, time and costs associated with utilizing aircraft is too much for many programs. The Military Academy is fortunate to have pilots readily available within the ranks of the faculty. Also, because the military routinely operates aircraft, the department can limit the costs of liability insurance and logistics by utilizing existing hangar facilities. However, the idea of demonstrating Aeronautical principles and obtaining in-flight data is still a valid one. There are other opportunities to incorporate some of the procedures outlined above. For example, schools could contract a plane and fly the procedures once. Data can be recorded for future use and the entire process taped for viewing by subsequent students. In addition, simulators can facilitate some of the demonstrations when the software can closely approximate actual physical phenomena. However, the faculty at USMA believes it is critical to continue the practice of conducting laboratories on actual flights to provide Aeronautics students with an extremely high-quality learning experience.

Whenever possible, educators seek new and exciting ways to convey their material. In engineering and physical sciences, any hands-on application that can augment classroom instruction is desirable. In Aerospace Engineering and Aeronautics this is a particularly daunting challenge because of the complexity, danger and expenses of operating actual aircraft. The United States Military Academy's Department of Civil and Mechanical Engineering has both rated pilots on the faculty and aircraft available to conduct this rare and extremely enriching experience. The program serves as just another example of going to the limits to teach engineering to bright, eager undergraduate engineering students.

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Biographical Information

Major Steven Braddom graduated from West Point in 1993 with a B.S. in Mechanical Engineering. He earned an M.S. Degree in Aeronautics & Astronautics from MIT in 2002. He served as an Assistant Professor in the Department of Civil & Mechanical Engineering at West Point. As a pilot, MAJ Braddom holds FAA ratings in helicopters, single-engine fixed wing aircraft as well as military ratings in the UH-1, UH-60, and the C-12.

Major David Stringer graduated from West Point in 1993 with a B.S. in Mechanical Engineering. He earned an M.S. Degree in Aerospace Engineering from Georgia Tech in 2003. He serves as an Instructor in the Department of Civil & Mechanical Engineering at West Point. As a pilot, MAJ Stringer holds FAA ratings in single-engine fixed wing aircraft as well as military ratings in the UH-1, CH-47, and the C-12.

Captain Richard Melnyk graduated from West Point in 1995 with a BS in Mechanical Engineering. He earned an MS Degree in Aerospace Engineering from Georgia Tech in 2003. He serves as an Instructor in the Department of Civil & Mechanical Engineering at West Point. As a pilot, CPT Melnyk holds FAA ratings in helicopters, single and multi-engine fixed wing aircraft as well as military ratings in the OH-58C, AH-64A, and the C-12.

Lieutenant Colonel Bobby G. Crawford graduated with a B.S. in Mechanical Engineering from West Point in 1985, an M.S. in Aerospace Engineering from the Georgia Institute of Technology in 1994, and a Ph.D. in Aerospace Engineering from the University of Kansas in 2004. He is a licensed Professional Engineer in the state of Virginia and holds FAA ratings in fixed and rotary winged aircraft and military ratings in the UH-1, OH-58A/C/D, and U-21.